# Natural Insecticides

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Washington State University • Oregon State University • University of Idaho

# Natural Insecticides

Natural insecticides can be chemical, mineral, or biological. The common goal of all three is to kill, repel, or otherwise interfere with the damaging behavior of insect pests. Because this purpose corresponds with the legal definition of a pesticide, all natural insecticide products must comply with federal and state regulations for registration, sales, transport, use, storage, and disposal. Some natural insecticides are allowed for use in certified organic systems if additional organic federal standards are met.

This publication provides general information on the categories of natural insecticides that are effective for home gardening in the Pacific Northwest. Also included are more detailed descriptions of the most commonly used natural insecticide products. However, you will still need to read the label of each product for specific application instructions. Many of the products described here may also be used in commercial crop production, but do not represent the entire list available to commercial growers.

As with any pesticide, it is important to choose a natural insecticide that fits the situation in which you will use it. These products vary in their toxicity to nontarget organisms such as fish and bees, as well as their effectiveness at controlling specific insect pests. If used improperly, organic insecticides can harm people and the environment, so do not make the mistake of thinking that products labeled as "natural" are nontoxic.

**FOLLOW THE LABEL**

Always follow the label directions when you use a pesticide, including storage requirements, which insect pest(s) the product is designed to control, how often it can be applied, under what conditions, at what rate, and the personal protective equipment that must be worn during applications. For additional information on reading pesticide labels and maintaining pesticide safety, refer to your state's resources, which are provided at the end of this publication.

Another critical consideration when using pesticides is the potential for target organisms to develop resistance. Resistance results when an insecticide does not kill 100 percent of the pest population and surviving pests are able to tolerate the insecticide. After regular use on multiple generations of the pest insect, the pest population will be dominated by these insecticide-tolerant individuals. To avoid pest resistance, regularly interchange and alternate insecticides that act differently on the target pest's physiology. Because there are fewer natural and organic insecticides available to gardeners and farmers than conventional pesticides, these alternative products are more susceptible to becoming ineffective from overuse.

## Understanding the Terms "Natural" and "Organic"

Many people have questions about the definition of "natural" versus "organic," or misunderstand the terms based on conflicting, misleading, and inaccurate information. The term "natural" conveys a sense of wholesomeness or safety. However, arsenic, strychnine, lead, mercury, nicotine, and other similar compounds used historically as pesticides technically qualify as natural. Today no one considers these compounds wholesome or safe, and they are no longer registered as pesticides.

There are no legal definitions, regulatory oversight, or production standards for products advertised as natural. Although natural products can generally be described as chemical compounds or substances produced by living organisms, the ingredients in many commercially available natural products are made in a laboratory. More importantly, natural insecticides are not more or less dangerous in any way than conventional pesticides. It should therefore not surprise you that the term "natural" is not synonymous with "organic," and not all natural insecticide products are allowed in organic production.

## National Organic Standards

The term "organic" has a specific legal definition when it is used to refer to pesticides, food, animal feed, or fiber crops. The legal definition is drawn from the Organic Food Production Act of 1990, which established national standards for use of the term. An organic pesticide must be produced from materials on the National List of Allowed Synthetic Substances, or come from all-natural substances that are not prohibited. The National Organic Program is administered by the United States Department of Agriculture (USDA) and includes a set of national organic standards, a list of allowed and prohibited substances, and a regulatory oversight structure. More information is available on their website at http://www.ams.usda.gov/AMSv1.0/nop.

Various businesses and organizations review commercial products claiming to be organic and certify that the makers have followed USDA organic standards. One example is the Organic Materials Review Institute (OMRI). The OMRI website includes a free, searchable list of products that have been approved for organic production. The Washington State Department of Agriculture (WSDA) also has an approved organic product list on their website, as well as a brand name material list. Contact your state department of agriculture or the Environmental Protection Agency (EPA) for more information about these lists. Consult your local Extension office for current organic recommendations that are effective in your area.

## Natural Insecticide Categories and Products

The remainder of this publication details the most common types of natural insecticides used in Pacific Northwest home landscapes, gardens, and crop production, followed by related product examples.

### *Biological*

Living organisms that are used to manage pests are called biological controls or biological agents (DeBach and Rosen 1991). When a microorganism is packaged and sold to control a pest, it is legally considered a biopesticide and is regulated as such (EPA 2013). Multicellular organisms such as beneficial nematodes are an exception; although considered biological controls and packaged and applied similarly to other biological insecticides, they are not regulated as pesticides. When using biological insecticides, carefully follow the instructions on the label to avoid killing the organisms in the product, which would make it ineffective. The advantage to using biological products is that they are less likely to negatively impact nontarget organisms, including people (Lacey et al. 2001).

***Bacillus thuringiensis***. *Bacillus thuringiensis* (Bt) is a naturally-occurring bacterium that feeds on the larval stages of insect pests such as mosquitoes, Colorado potato beetles, and cabbage loopers. *Bt.* var. *kurstaki* feeds on Lepidopteran larvae, known as caterpillars, commonly found on vegetables and fruit. Under natural conditions when a caterpillar ingests Bt, the bacterium releases a toxin within the insect's gut, and the toxin degrades the stomach lining, causing the insect to die. While this process can take several days, feeding ceases within a few hours. If the bacteria are successful in reproducing within soft-bodied insects like caterpillars, the pests often become limp. Infected caterpillars can ooze Bt onto plant parts where other caterpillars can ingest the insecticide, continuing the cycle.

Commercial Bt products are formulations of the bacterial toxin and are nonliving. Bt can be sensitive to ultraviolet light (sunlight) and is most effective when applied in overcast conditions or late in the day. Most Bt products degrade within 24 hours regardless of sunlight conditions or temperature, giving them a very short period of effectiveness once they have been applied. Small and young caterpillars are most susceptible to Bt, so monitor caterpillar development regularly in order to time the application to coincide with newly hatched caterpillars. Be sure that the immature insects are feeding, as Bt is only effective when ingested. If temperatures are too cool or too hot, insects may stop feeding. Multiple applications are often needed for adequate management of the pest.

Different strains of Bt are effective against specific pests, so take care to choose the Bt product that targets the pest you need to control. For example, *Bt.* var. *kurstaki* kills caterpillars, while *Bt.* var. *israelensis* is for mosquitoes and other fly larvae (Jurat-Fuentes and Jackson 2012).

Similarly, the various *Bacillus* products available for purchase online and in garden stores should be checked for suitability in your area. For example, *B. popilliae*, marketed as Milky Spore Powder, is only useful for managing Japanese beetles, a pest that is not present in the Pacific Northwest.

***Beauveria bassiana***. *Beauveria bassiana* is a soilborne fungus that feeds on insects and can be used effectively to control thrips, aphids, whitefly, caterpillars, beetles, and subterranean insects like ants and termites. *B. bassiana* is applied to the target pest as a spore, which is the reproductive and dispersal structure of the fungus. Once the spores have contact with the insect exoskeleton, they grow hyphae (long, branching vegetative appendages) that secrete enzymes, which in turn dissolve the cuticle (outermost layer of the skeleton). These fungal hyphae then grow into the insect, feed on its body tissue, produce toxins, and reproduce. It takes up to seven days for the insect to die. If moist conditions (92 percent humidity or greater) are present during this time, *B. bassiana* will "bloom" and release more spores into the environment to repeat the cycle on other pest insects (Figure 1).

*B. bassiana* can be sensitive to sunlight, so it may be best to apply at the end of the day (Vega et al. 2012). The biggest disadvantage of this insecticide is that its spores will infect many nontarget beneficial insects too. However, the strain used and sold commercially does not affect honey bees (EPA 2006).

**Nematodes**. Nematodes are multicellular organisms commonly referred to as microscopic worms. Certain nematode species are considered beneficial, as they are

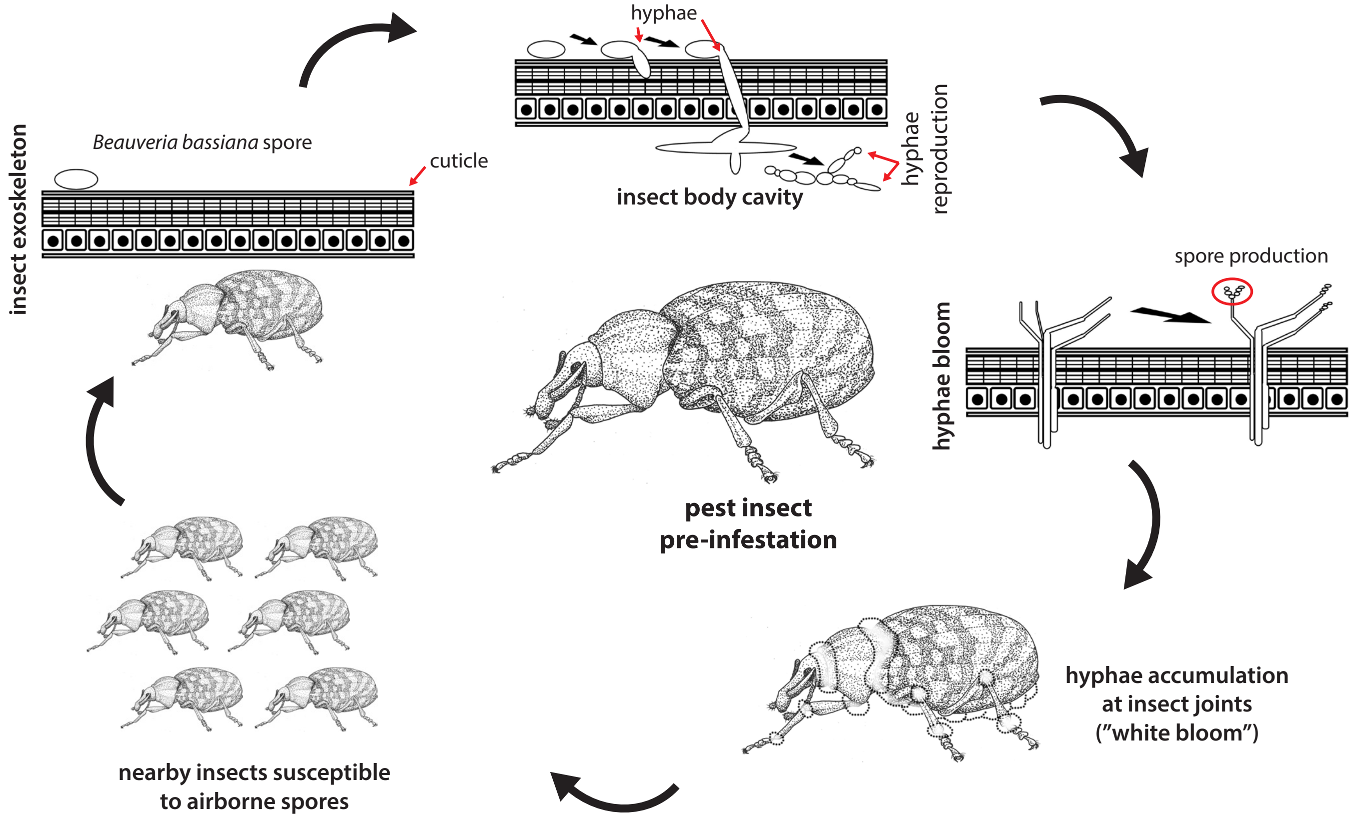


*Figure 1.* Beauveria bassiana *insecticide process. Illustration by T. Murray.*

very effective at managing soil-dwelling insect pests such as root weevils and cutworms, and can also control pests that pupate or hibernate in the soil such as codling moth larvae (Miles et al. 2012, Lacey et al. 2001).

The two different types of nematodes used for insect control are cruisers and ambushers. Cruisers seek out their insect prey, while ambushers wait for insects to pass by. *Steinernema carpocapsae* and *S. scapterisici* are ambushing nematodes effective for managing mobile insects like crane fly larvae, fleas, and cutworms. *Heterorhabditis bacteriophora* and *S. glaseri* are cruisers used to manage slower-moving insects like root weevil and scarab beetle larvae. *S. riobrave* and *S. feltiae* nematodes do both ambushing and cruising. These species are effective at managing codling moth and fruit tree borers.

For both types of nematodes, the infectious juvenile stage attacks susceptible hosts by entering the insect body through openings such as respiratory spiracles. Once inside the body, the nematodes release bacteria that liquefy the innards of the insect, which thereby becomes food for the nematodes and enables them to multiply. A single or small number of nematodes can produce thousands more of their own kind in 2–3 generations. Once the nematodes have consumed the host insect, they disperse to infect other insects.

In commercial insecticide products, beneficial nematodes are often in the form of infective juveniles and housed on a sponge or encased in clay. They must be cared for, stored, and applied properly to be effective. While beneficial nematodes are commonly packaged similarly to other insecticides, they are not regulated by the EPA in the same way. See *Using Beneficial Nematodes for Crop Insect Pest Control* (Miles et al. 2012) for more information on beneficial nematodes.

***Nosema.*** *Nosema* are protozoans (a diverse group of single-cell organisms which can be highly mobile), that have proven to be effective control agents for some insect pests. For example, *Nosema locustae* is used to manage grasshoppers. *Nosema* spores are added to bait (also called an attractant) which the grasshopper eats. The spores germinate and the protozoans feed within the insect's body cavity. As the protozoans reproduce, the insect's health declines. *N. locustae* is active only against young grasshoppers and can take 3–4 weeks to cause mortality (Cranshaw and Hammon 2013). Infected grasshoppers generally feed less and produce fewer eggs. *Nosema* works most effectively in large-scale grasshopper management programs in contrast to home gardens where only small areas are treated, as grasshoppers can easily move into the target space (Roe 2000).

### Botanical

People have extracted compounds from plants to use as botanical insecticides for thousands of years. There is evidence dating back to 400 B.C. that compounds harvested from chrysanthemum species were used to manage insect pests (Silva-Aguayo 2009). Botanical insecticides are usually harvested by macerating (soaking and separating) plant tissues high in the active ingredient and distilling (evaporating and condensing) the specific active compounds. Botanicals may be considered organically-approved products depending on the extraction method and formulation (other ingredients included in the product). The advantage of using botanical insecticides is their short persistence in the environment due to rapid degradation. However, this short persistence can also be deemed a disadvantage since multiple applications may be needed to achieve adequate pest suppression.

Some botanical extracts, such as nicotine and rotenone, are no longer used because they have proven to be very toxic to nontarget organisms, including humans. Nicotine, a commonly used insecticide many years ago, was no longer registered in Washington State after 2008 due to its high mammalian and aquatic vertebrate toxicity. Due to its toxicity to fish, rotenone has not been registered for agricultural use in Washington since 2009 and Oregon since 2010. Currently, there are only three rotenone products registered for use in the Pacific Northwest, and these are all fish toxicants.

### Botanicals: Garlic, Pepper, Cinnamon, and other Plant-Essential Oil Products

Commercial products that contain various plant extracts such as garlic, hot pepper wax, and cinnamon are available and registered for use on some crops and ornamentals. However, there is very little scientific research that demonstrates the effectiveness of these products, and their modes of action are not understood. Studies are needed to show direct mortality or measurable negative effects from specific botanicals on specific insect pests to make sound pest management decisions (Cloyd et al. 2009). If you are interested in experimenting with essential oil products, contact your county Extension office for guidance.

**Neem**. In addition to its categorization as a botanical, neem is also a plant-derived horticultural oil (see p. 5). The neem tree is native to India and is the source of hundreds of products, including insecticides made from the extracts of the seeds and bark. The primary insecticidal extract is azadirachtin. When azadirachtin is used for pest management, it can act as an insect repellant, an anti-feedant (interferes with feeding), and growth regulator (interferes with molting and growth) (Schmutterer 1990). When neem oil or neem soap is used, it poisons upon contact much like other soaps and oils. In some cases, neem can also be a systemic insecticide (when applied to the soil, the active ingredients are absorbed into the plant and transported to the growing tips and leaves).

Neem insecticides are effective against many caterpillars, flies, whitefly, and scales, and are somewhat effective against aphids. Neem may not show signs of efficacy for 3–7 days, and it can degrade within 3–4 days. Multiple applications are generally needed to obtain good management of the targeted pests. Neem is regarded as nontoxic to vertebrate animals and has been shown to minimally affect many beneficial insects such as bees, spiders, and ladybugs.

**Pyrethrum.** Pyrethrum, also known as pyrethrins, is extracted from the seed of *Chrysanthemum cinerariaefolium* and has been used as an insecticide for over 100 years. Today these plants are grown primarily in Kenya. Pyrethrum is effective against a wide range of soft-bodied garden pests such as scales, whitefly, mealybugs, and thrips, but will not control mites. Pyrethrins are neurotoxins that attack an insect's nervous system and cause repeated and extended nerve firings. They may also have a repellant effect.

Pyrethrins are easily broken down by stomach acids in mammals, so toxicity to humans and pets is very low. However, toxicity can occur when significantly more product is applied than specified on the label. Do not spray pyrethrins around ponds or other bodies of water, as they can kill fish. Pyrethrum is a broad-spectrum insecticide that is toxic to beneficial insects. Pyrethrum can paralyze susceptible insects upon exposure, but also degrades in sunlight within hours (ExToxNet n.d.). To get adequate management of some pests, repeated applications are needed. Pyrethrum products frequently contain a low hazard activator or synergist such as piperonyl butoxide or piperonyl cyclonene that substantially increases the effectiveness of the pyrethrum and reduces its cost (Pedigo and Rice 2008). Depending on the way these synergists have been manufactured, some pyrethrum products containing synergists may be allowed for use in organic agriculture.

### *Fermented*

Some microbes can be fermented to produce an insecticide such as abermectins, a fermented product of *Streptomyces avermitilis* (Dybas 1989) used in baits for household insect pests. The best known home gardening product of this type is spinosad. Metabolites of *Saccharopolyspora spinosa,* a soil-inhabiting bacteria that is fermented, are the basis for this new class of insecticide. The fermentation process has been industrialized to produce commercial insecticides.

**Spinosad**. Spinosad is composed of spinosyns A and D. The fermented product is very toxic to caterpillar pests such as cabbageworm, cabbage looper, diamondback moth, armyworm, and cutworm, as well as fruit flies such as spotted wing drosophila. Spinosad can act on a susceptible insect's stomach and nervous system. It is primarily ingested by feeding insects but can have some efficacy when sprayed directly on insects. Affected pests cease feeding and undergo partial paralysis within minutes upon exposure to spinosad, but it may take up to two days for the insects to die (Salgado et al. 1998). Spinosad is systemic in some plants.

Depending on the fermentation process and formulation, some spinosad insecticides are considered organic. Spinosad has low toxicity to many beneficial insects that prey on pests, and is nontoxic to mammals and other vertebrates, with the exception of some fish (e.g., slightly toxic to trout). Spinosad is toxic to bees for three hours after application, so do not apply to blooming plants during the day. Because it is selectively toxic for many pest species and relatively safe to nontarget species, spinosad has become highly desirable as an organic insecticide. However, its popularity raises concerns about the development of pest resistance. Therefore, alternate the use of spinosad with other products.

### *Horticultural Oil*

Horticultural oils were used for insect control as early as 1763 (Olkowski et al. 1993) and are still popular today. Such control agents are often petroleum-based; however, plant-based oils considered acceptable in organic farming are also available. Horticultural oils work by disrupting insect feeding and egg laying when the pest is entirely coated. Eggs covered with oils are prevented from gas exchange, which suffocates the developing pest.

Horticultural oils have minimal phytotoxic (poisonous) effects on plants when used properly. Application timing, plant species, temperature, and oil type all contribute to the level of effectiveness and risk of phytotoxicity. Phytotoxic effects are easily noticed by the browning or "burning" of the leaves or new growth on the stems.

**Dormant and Summer Oils**. Dormant and summer horticultural oils can control egg, nymph, larva, and adult stages of overwintering leafrollers, aphids, mites, and scales (Nielsen 1990). Dormant oils are effective at controlling overwintering eggs and soft-bodied insects and can be used in the early spring before active plant growth begins. Only use dormant oils on woody trees and shrubs in dormant or delayed-dormant stages to avoid severely burning the foliage. Do not apply either type of oil during freezing weather because it will reduce the effectiveness of the oil properties and coverage of the application.

Summer oils can be applied to some woody plants (see the label for specific plants) during the growing season (Figure 2). Some horticultural oils can be applied in either summer or winter; however, the concentration used in summer is far lower than in the winter. To use summer or dormant oils, first dilute with water. (Commercial oil products contain emulsifying agents that allow them to mix easily with water.) Pests rarely develop resistance to oil sprays, and the products cause little or no harm to most beneficial insects (Raupp et al. 1992). When oils are used correctly (as directed on the label), they are not hazardous to human health.

*Figure 2. Summer oil sprayed on fruiting apple trees.*

### *Mineral*

Insecticides developed from elemental (mineral) sources mined from the earth are classified as natural products and often cost less than other processed or harvested insecticides. The toxicity of mineral-based insecticides depends on the chemical properties of the mined elements. Some mineral insecticides such as sulfur are registered for organic use and have relatively low toxic effects on people and nontarget organisms. In contrast, lead arsenate is a natural mineral product that was cancelled as a pesticide in 1988 due to its toxicity and persistence in the environment.

**Diatomaceous Earth**. Diatomaceous earth is a fine particle dust comprised of fossilized diatoms that is effective against slugs and soil-dwelling insects. Diatoms are small, usually single-celled phytoplankton commonly found in aquatic or moist environments. Diatoms are encased inside a cell wall made of silica, the same compound used to make glass. Diatomaceous earth works as a fine abrasive that disrupts the exoskeleton cuticle of a slug or insect and causes it to desiccate (dry out). Use diatomaceous earth only in landscape areas that do not contain edible plants (e.g., ornamental gardens) (Figure 3). To create an effective barrier for slugs, apply diatomaceous earth in a 3-inch wide, 1-inch thick band around the habitats that slugs use. Repeat applications after periods of rain. Note, however, that diatomaceous earth can also be toxic to beneficial insects such as predatory ground beetles and is highly toxic to bees if applied to blooms.

*Figure 3. Diatomaceous earth used on nonedible* Primula *(primrose).*

**Elemental Sulfur.** Elemental sulfur is a finely ground powder that can be applied either as a dust or a spray. This mineral is one of the oldest pesticides known, and reported pest resistance is rare. Sulfur acts as a metabolic disruptor (interferes with a chemical reaction, digestion, or the transport of substances into or between cells) to insects such as aphids, thrips, and spider mites. Most sulfur formulations have low toxicity to people but can be an eye and skin irritant. Sulfur is highly toxic to fish, so it is important to keep it away from water (ExToxNet n.d.).

Do not use sulfur on a crop just before harvest if you plan to preserve it; sulfur can produce off-flavors in canned products, and sulfur dioxide can form, which may cause containers to explode. In addition, sulfur is phytotoxic to most crops if applied two weeks before or after the application of a horticultural oil.

**Iron Phosphate.** Iron phosphate is very effective at managing slugs and snails when combined with bait. Baited iron phosphate usually comes in pellet form. Scatter the product around the crop in need of protection (Figure 4) and areas where slugs seek refuge, such as garden bed borders and rocks. Liquid formulations are also available. Follow label suggestions for subsequent applications.

*Figure 4. Slug bait pellets containing iron phosphate applied to onions.*

Slugs that feed on iron phosphate will stop eating, usually seek a hiding place, and then die of starvation. Iron phosphate is considered relatively nontoxic and does not affect insects, birds, or mammals when applied in the recommended amount. Avoid over-application, as there is some evidence that iron phosphate baits can negatively affect earthworms (Edwards et al. 2009). Because iron phosphate is nontoxic only in the labeled application amounts, be sure to store it in a safe place away from pets and children. Most brands of iron phosphate are approved for organic production by the National Organic Program.

**Kaolin.** Kaolin is a fine clay that is sprayed on plant foliage or fruit to deter feeding and egg laying of insect pests such as apple maggot, codling moth, and leafhoppers. It can also have some repellant properties that cause irritation to insects upon contact (Stanley 1998). The effectiveness only lasts as long as the clay film covers the fruit or foliage to mask its chemical, visual, and tactile cues. Reapplication is necessary if rain washes the product off. Kaolin's toxicity to pests is additionally dependent on the insect being on the fruit or foliage during the entire time of pest susceptibility. You will need to monitor insect activity to be sure that plants are protected during the required times. Kaolin is an organically-approved material.

### *Soap*

Natural soaps are derived from plants (coconut, olive, palm, cotton) or animal fat (whale oil, fish oil, or lard) and have been used since the 1700s to control certain soft-bodied insects such as aphids (Olkowski et al. 1993). Soaps are fatty acids that can degrade or dissolve the protective layers of the insect cuticle, causing the insect to desiccate. Insecticidal soaps are considered nontoxic to humans and many beneficial insects, but selectively kill certain pest insects. Some soaps are approved for use in organic agriculture.

**Insecticidal Soaps.** Insecticidal soaps are very effective for managing soft-bodied insects like aphids, scales, whitefly, mealybugs, thrips, and spider mites. The soap must contact the insect's outer skeleton to be effective. Leaf-feeding insects are often found on the undersides of leaves, so be sure to fully cover plant foliage. Results from the application of soap are usually seen in 1–3 days. Multiple applications are often needed to be effective. Insecticidal soaps are usually diluted with water before applying.

Do not use household soaps as insecticides. Household soaps vary tremendously in composition, purity, and effectiveness, and thus have the potential to harm crops.

For example, household soaps can be phytotoxic to some plants, resulting in leaf burn. Only use soaps that are specifically registered and sold for use as insecticides. Be sure to read the product label for known phytotoxic effects and always test the product on a small portion of the plant to see if leaf burn occurs. Leaf burn symptoms usually develop within two days.

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## General Gardening Resources

**Washington State University**
http://gardening.wsu.edu

**Oregon State University**
http://extension.oregonstate.edu/gardening/

**University of Idaho**
http://www.extension.uidaho.edu/homegard.asp

**Washington State Department of Agriculture Organic Food Program**
PO Box 42560, Olympia, WA 98504-2560
Phone: (360) 902-1805 Fax: (360) 902-2087
Email: organic@agr.wa.gov
http://agr.wa.gov/foodanimal/organic/

**Oregon Department of Agriculture Food Safety Program**
635 Capitol Street NE, Salem, OR 97301-2532
Phone: (503) 986-4720 Fax: (503) 986-4729
Email: fsd-expert@oda.state.or.us
http://www.oregon.gov/ODA/FSD/Pages/index.aspx

**Idaho State Department of Agriculture Organics Program**
PO Box 790, Boise, ID 83701-0790
Phone: (208) 332-8675 Fax: (208) 334-2170
Email: info@agri.idaho.gov
http://www.agri.idaho.gov/Categories/PlantsInsects/Organic/indexOrganicHome.php

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All photos by **Carol Miles** unless otherwise noted.

Use pesticides with care. Apply them only to plants, animals, or sites as listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

Pacific Northwest Extension publications are produced cooperatively by the three Pacific Northwest land-grant universities: Washington State University, Oregon State University, and the University of Idaho. Similar crops, climate, and topography create a natural geographic unit that crosses state lines. Since 1949, the PNW program has published more than 600 titles, preventing duplication of effort, broadening the availability of faculty specialists, and substantially reducing costs for the participating states.



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