ORGANIC GARDENING

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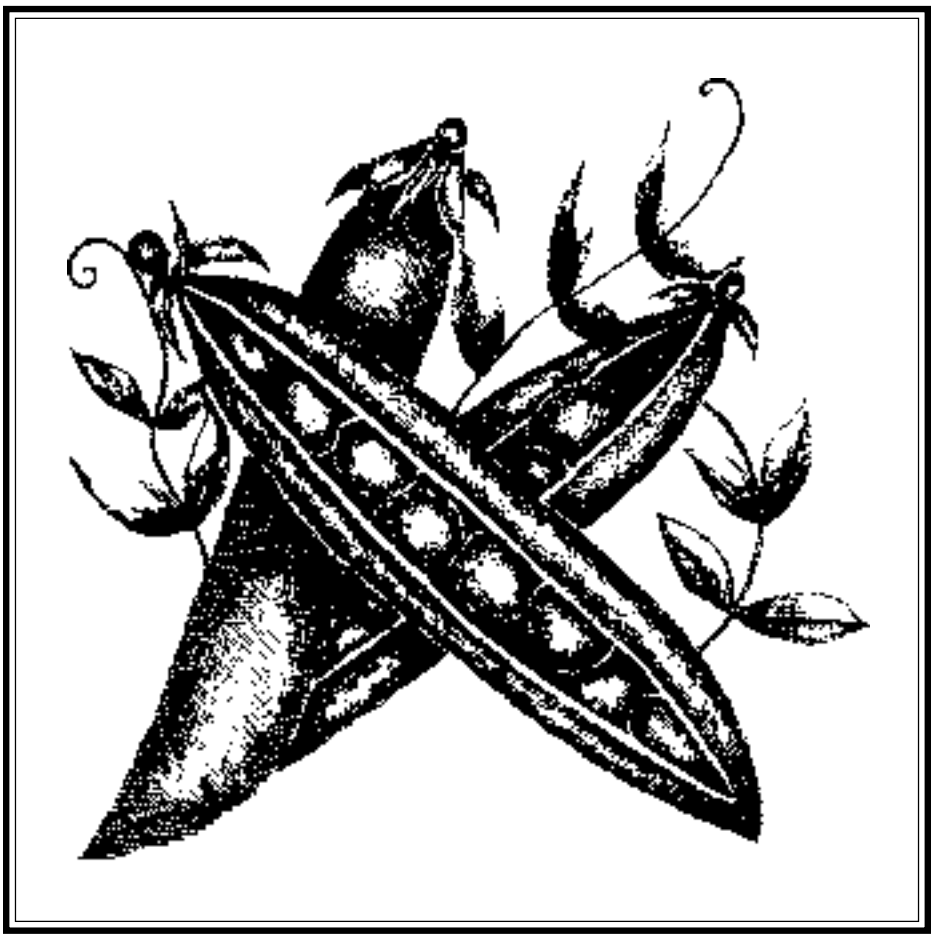

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Organic Gardening

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Organic gardening relies on ecological principles and natural processes to grow and manage garden crops. Although organic gardeners avoid the use of synthetic pesticides and fertilizers, organic gardening is not a list of substitutes for synthetic products or a set of home remedies to kill pests. Organic gardening is a holistic approach that involves understanding soil management, integrated pest management, and the life cycles of plants, pests, and the pests' natural enemies. When properly done, organic gardening can produce high quality food and landscapes, enhance the garden environment, protect water quality, and conserve natural resources.

The basic soil management and pest management approaches of organic gardening make sense for all gardeners, whether you avoid all synthetic fertilizers and pesticides or not. Using these approaches will reduce the amount of fertilizers and pesticides you need, and can improve the quality of your garden.

Other benefits of organic gardening include increasing the number and diversity of beneficial organisms and turning waste materials into valuable composts and fertilizers for the garden.

Organic gardening means actively working with nature in your garden. Organic gardeners need to be smart gardeners—knowing the garden environment, observing plants and pests, knowing choices for management, and acting at the appropriate times.

Overview of Soil Management

A good garden soil allows water to enter, and excess water to drain from the root zone. It has the capacity to hold water, air, and nutrients available for plants and microorganisms. It has a stable structure that is easy to dig and resists erosion.

Improving and maintaining a garden soil involves:

- Proper use of soil amendments to provide organic matter and plant nutrients
- Tillage at appropriate times
- Prevention of runoff and erosion

Adding Organic Matter

Organic matter builds and stabilizes soil structure, improving the porosity, infiltration, and drainage of the soil, and reducing erosion. It holds water and nutrients for plants. Organic matter also is a long-term, slow-release storehouse of nitrogen, phosphorus, and sulfur. Soil microorganisms continually break down organic matter. Gardeners use composts, plant residues, and mulches to replenish soil organic matter. These materials are relatively low in available nutrients, and can be added to the soil in large amounts.

Composts

Composts provide an excellent source of organic matter for garden soils. Composting also closes the recycling loop by turning waste materials into a soil amendment. You can make compost at home or buy commercially prepared compost, often made from yard or food waste.

Making Compost

The key to composting is to supply a balance of air, water, energy materials (grass clippings, green garden trimmings, or fresh manure), and bulking agent (corn stalks, straw, and woody materials). You don't need to buy additives to stimulate your compost pile. You just need to provide conditions favorable for natural composting organisms.

Home composting can be done in hot or cold piles, in worm bins, or in soil trenches.

- Hot (or fast) composting produces a high-quality, finished compost in 6 to 8 weeks. To maintain a hot compost pile, balance and mix energy materials and bulking agents, keep the pile moist, and turn the pile frequently to keep it aerated.
- Cold (or slow) composting requires less work than hot composting. Build the pile, and leave it for months or longer to decompose. Cold composting does not kill weed seeds. Some gardeners have problems with rats and other pests attracted to edible wastes in compost piles.
- You can compost fruit and vegetable scraps in a worm bin. This is a good method for urban gardeners who have small amounts of space.
- You also can bury fruit and vegetable scraps and allow them to decompose directly in the soil.

The WSU Cooperative Extension bulletin, *Backyard Composting,* EB1784, gives more detailed information on making and using home compost.

Using Compost

You can till or dig composts directly into the garden, or use them as a mulch over the winter or summer before turning them into the soil. One cubic yard of compost covers about 300 square feet of garden one inch deep. Adding 1 to 2 inches of compost each year helps build a productive garden soil.

In the first year after application, composts that are woody and not fully decomposed will tie up part of the soil nitrogen, resulting in nitrogen deficiency for the plants. If plants show signs of nitrogen deficiency, add extra nitrogen (manure, blood meal, cottonseed meal, biosolids). In following years, most composts will contribute small amounts of available nitrogen to the soil.

Green Manure

Green manures are cover crops grown specifically to be tilled or dug into the soil. Planting green manure is a way to grow your own organic matter. The value of cover crops goes beyond their contribution of organic matter. Cover crops also can do the following:

- Capture and recycle nutrients that otherwise would be lost by leaching during the winter
- Protect the soil surface from rainfall impact during the winter
- Reduce runoff and erosion
- Help suppress weeds
- Supply nitrogen (if legumes are grown)

No one cover crop provides all of these benefits. Deciding which cover crop or crop combination to grow depends on which benefits are most important to you, and which cover crops fit best into your garden plan. You can grow cover crops over the winter or in summer.

Gardeners usually plant cover crops in the fall and till them as green manure in the spring before planting. The earlier cover crops are planted, the more benefits they will provide. Research in western Washington showed that cereal rye planted in Septem-

ber captured three times the amount of nitrogen as an October planting. Legumes, such as vetch and crimson clover, need an early start to cover the soil before cold weather arrives.

Because gardeners often grow crops into November or December, it is not possible to plant early cover crops throughout the garden. In this case, plant cover crops in areas that you harvest early, and use mulches on parts of the garden you harvest later. For example, plant a cover crop in a sweet corn bed immediately following harvest in September. You also can start cover crops around and among late crops where space allows.

Table 1. Examples of cover crops grown in Washington

Cereal Rye	Very hardy, grows quickly, matures rapidly in spring
Winter Wheat	Leafy, covers soil well, matures slowly
Hairy Vetch	Legume, fixes nitrogen, starts slowly, grows quickly in spring, good companion crop for cereal rye
Crimson Clover	Legume, fixes nitrogen, slower growth than vetch
Buckwheat	Fast growing, frost-sensitive, summer cover, ready to till in 30 days

Till or dig cover crops into the soil before they flower. After flowering, the plants become woody and decline in quality. Also, digging the crop into the soil becomes quite difficult if the plants grow too large. If you cannot till a cover crop in time, cut it off and compost it for later addition to the soil. You will still get the short-term benefit of organic matter from the crown and roots when you till your garden.

The fresh organic matter from cover crops stimulates biological activity in the soil and improves soil structure. A good stand of vetch or clover can supply about half of the nitrogen needed by the next garden crop. Because cover crop residues decompose quickly in the soil, these benefits last only about a year. Make cover crops an annual part of your garden rotation to gain their benefits each year. If cover crops do not fit into your gardening plan, use winter mulches as a substitute. WSU Extension Bulletin EB 1824, *Cover Crops for Home Gardens in Western Washington and Oregon,* gives details on choosing and managing cover crops. For more detail on individual cover crops refer to EM 8704, *Using Cover Crops in Oregon,* available from the Oregon State University Extension Service.

Mulches

During the summer, mulches control weeds and conserve moisture. Winter mulches also protect the soil from raindrop impact and runoff. Organic mulches mixed into the soil at the end of the season will decompose and add to the soil organic matter.

Mulches are categorized into two groups:

1. Organic mulches include materials such as straw, leaves, compost, grass clippings, and sawdust. Till these materials into the soil at the end of the season or leave them on the surface. Use bark mulches or wood chips around perennial plantings and on paths. Do not till them into the soil.
2. Synthetic mulches include black plastic and weed-blocking geotextiles. Remove and discard these materials when they are no longer useful as mulches. Some people use old newspapers or cardboard as a synthetic mulch that will decompose in the soil. Cover newspapers and cardboard with organic mulches to improve the appearance of the garden.

These two types of mulches provide somewhat different benefits, described below. Many organic gardeners avoid plastic mulches because they cannot mix them into the soil or recycle them.

Weed Control

Mulches control weeds by blocking light. Black plastic, geotextile, and cardboard mulches also provide a physical barrier to weed growth. Mulches alone will not control weeds, but they can be a key part of garden weed management. Mulches have limited effectiveness against perennial weeds such as horsetail, quackgrass, and morninglory that can send rhizomes or roots considerable distances.

To control weeds, remove weed seedlings from the area and apply 1 to 2 inches of organic mulches when desirable plants are 2 to 3 inches tall. Be careful not to cover the plants themselves. You may need as much as 6 inches of straw mulch. Although weed seeds can germinate in a mulch, it is easier to pull young weeds from mulch than from soil.

Soil Moisture and Temperature

Organic mulches help maintain soil moisture by improving movement of water into the soil, and by reducing evaporation from the soil surface. Plastic mulches reduce both evaporation and infiltration. We do not recommend plastic mulches in perennial plantings because the mulches make water management more difficult. Soils remain wet later in the spring beneath plastic mulches, creating soil conditions that encourage root rots. In the summer, plastic mulches reduce the effectiveness of overhead irrigation.

Mulches can either increase or decrease soil temperature, depending on the type of mulch. Loose organic mulches insulate the soil. This is a disadvantage in the spring when warm soil temperatures are needed to speed germination and growth. In the heat of summer, organic mulches can be a benefit, keeping soils cooler. Black plastic absorbs heat, and warms the soil in the spring, creating a better environment for warm season crops like melons.

Tilling Mulches into the Soil

You can turn organic mulches into the soil in the fall or spring, depending on your garden plan. Digging or tilling mulches is usually easier than tilling cover crops. Some mulches—sawdust and straw—contain little nitrogen. Once turned into the soil, they will tie up a large amount of nitrogen. To prevent nitrogen deficiency in the next crop, add fertilizer—blood meal, cottonseed meal, or manure.

Nutrients and Fertilizers

Soil is the source of most plant nutrients. Carbon, hydrogen, and oxygen come from air and water. The soil supplies the remaining 13 essential nutrients. We add fertilizers to supplement native soil nutrients. This promotes plant growth and replaces nutrients removed when plants are harvested.

Comparing Organic and Synthetic Fertilizers

Organic fertilizers are natural materials that have had little or no processing. They include both biological (plant and animal) and mineral materials (Table 2). Organic fertilizers release nutrients through natural processes in the soil, including chemical weathering of mineral materials, and biological breakdown of organic matter. The released nutrients are available to plants in a water-soluble form. These soluble forms of nutrients are the same as those supplied by synthetic fertilizers.

When compared with synthetic fertilizers, organic fertilizers usually are less concentrated in nutrients, and release nutrients more slowly. Larger amounts of organic fertilizers are needed, but their effects last

longer. Organic fertilizers contain a variety of nutrients, but the amounts are not always balanced according to plant needs.

Using organic fertilizers recycles materials that otherwise would be discarded as wastes. Production of synthetic fertilizers, on the other hand, can create wastes and use substantial amounts of energy.

Slow Release of Nutrients

Organic fertilizers slowly release nutrients to plants over the course of the growing season. The rate of release of nutrients from organic materials depends on soil microorganism activity, which in turn depends on soil temperature and moisture. Temperature and moisture conditions that favor plant growth also favor the release of nutrients from organic matter.

Nutrients in most synthetic fertilizers are available immediately. They can furnish nutrients to plants in the spring before the soil is warm. However, nitrogen in these fertilizers is vulnerable to leaching loss from heavy rainfall or irrigation. Note: Once nitrogen moves below the root zone, plants can no longer use it, and it may leach into groundwater.

Some organic fertilizers contain immediately available and slow-release nutrients, nourishing plants both early in the season and later. Fresh manure, biosolids, and fish emulsions are examples of organic fertilizers containing available nutrients. As manure ages, the most readily available fraction is lost into the air or leached into the soil, leaving slow-release material in the aged manure.

Some material in organic fertilizers breaks down so slowly that it does not become available the first season after application. Repeated application of organic fertilizers builds a pool of material that releases nutrients very slowly. In the long run, the pool will decrease the need for supplemental fertilizer.

Types of Organic Fertilizers

Animal Manure

Animal manures vary widely in nutrient content and nutrient availability, depending on the type of animal that produced the manure, and the age and handling of the manure. Mixing with bedding dilutes manure. Exposure to rain leaches nutrients. Composting under cover retains more nutrients, but reduces nutrient availability.

Table 2. Comparing organic and synthetic fertilizers

	Organic fertilizers	Synthetic fertilizers
Source	Natural materials; little or no processing	Manufactured or extracted from natural materials, often undergoing extensive processing
Examples	Manure, cottonseed meal, rock phosphate, fish by-products, ground limestone	Diammonium phosphate, synthetic urea, potassium chloride
Nutrient Availability	Usually slow-release; nutrients are released by biological and chemical processes in soil	Nutrients usually are immediately available to plants
Nutrient Concentration	Usually low concentration	Usually high concentration

Table 3 compares typical nutrient values of different manures. The nutrient content of manure could differ substantially from the amounts in this table, depending on how the manure was stored and handled.

Applying farmyard manures. It doesn't take much of a nutrient-rich manure, such as poultry manure, to fertilize a garden. A 5-gallon bucket of poultry manure contains enough nutrients to fertilize 100 to 150 square feet of garden. If more is applied, you risk over-fertilizing, harming crops, and leaching nitrogen into groundwater.

Dilute manures, such as separated dairy solids and horse manure with bedding, contain far fewer available nutrients and can be applied in larger amounts. You can use as much as an inch of these materials in the garden every year. Use these manures mainly as a source of organic matter.

Experiment with the amount you apply and observe the performance of your crops to fine-tune your application rate. It is better to be conservative and add more manure if the crops appear deficient.

Table 3. Typical nutrient content of uncomposted animal manures at the time of application.[1]

Type	N	P_2O_5[2]	K_2O
	lb per cu yard as-is[3]		
Broiler with litter	33	29	30
Laying hen	26	40	33
Sheep	13	6	24
Rabbit	11	7	10
Beef	8	4	12
Dry stack dairy	6	3	13
Separated dairy solids	3	1	2
Horse	6	4	11

[1]Divide these numbers by 40 to estimate the nutrients in a 5-gallon bucket of fresh manure.
[2]Phosphorus and potassium in this table are shown in units of P_2O_5 and K_2O. These are the units typically used on fertilizer labels. To convert from P to P_2O_5, multiply P by 2.3. To convert from K to K_2O, multiply K by 1.2.
[3]*As-is* is typical for manure stored under cover.

Commercial manure composts. Composted chicken and steer manures with known nutrient contents are commercially available as bagged products. Table 4 shows typical analyses of these materials. Nutrient levels and availability in steer manure compost are so low that you should use steer compost as a source of organic matter only. Recommended application rates on packages of these products are good guidelines for their use.

Table 4. Nutrient content of commercial manure composts

Animal	N	P_2O_5	K_2O
	— — — — % — — — —		
Chicken	1-3	0.5	1-2
Steer	0.5	1-2	0.5

Using manure safely. Fresh manure sometimes contains pathogens that can cause diseases in humans. These pathogens are not taken up into plant tissue, but they can adhere to soil on plant roots, or on the leaves or fruit of low-growing crops. Cooking destroys pathogens, but raw food carries a risk of pathogen exposure. Washing and peeling raw produce removes most pathogens, but some may remain. The risk from pathogens is greatest for root crops (e.g. carrots and radishes) or leaf crops (e.g. lettuce or spinach), where the edible part touches the soil. The risk is negligible for crops such as sweet corn, which do not come in contact with the soil, or for any crop that is thoroughly cooked.

Consider raw manure to be a potential source of pathogens, and avoid using fresh manure where you grow high-risk crops. Bacterial pathogens die off naturally during composting, extended storage, or after field application. Complete die-off of bacterial pathogens occurs in days to months depending on the pathogen and environmental conditions.

Keep dog, cat, and pig manure out of your home compost and garden. Some of the para-

sites found in these manures are very persistent, and may survive in both compost and soil.

The best time to apply manure is in the spring before planting. You also can apply manure in the fall, but some of the nutrients may be lost over the winter. Environmental risks of leaching and runoff also increase. If you do apply manure in the fall, apply it early, and plant a cover crop to help capture nutrients and prevent runoff.

Don't overapply fresh manure. Because fresh manure contains available nutrients as well as slow-release nutrients, overapplication can harm your crops.

A safe way to use fresh manure is to mix it into your compost pile and then use the finished compost in your garden. The microorganisms breaking down the other materials in your compost will absorb the available nutrients, reducing the risk of nutrient overapplication and leaching.

Because it is hard to maintain the high temperatures needed to kill pathogens quickly in a backyard compost pile, allow your manure compost to age for six months or more before using it in your garden. An alternative is to buy commercially composted manure.

Biosolids

Biosolids are a by-product of municipal wastewater treatment. Federal standards for organic farming do not include biosolids as an organic fertilizer. However, biosolids do have two important characteristics of organic fertilizers: 1) their nutrients are released slowly from the organic form by natural processes in the soil, and 2) they are a product of the waste stream that can benefit crop growth.

Most of the biosolids produced in Washington are used to fertilize agricultural and forest crops. The material used on farms is rich in nutrients and acts similarly to poultry manure.

Some communities in Washington produce a special class of biosolids and market them to gardeners. These are called Class A biosolids: they have been treated using heat or composting to reduce pathogens to background levels, making them safe for all garden uses. Three types of Class A biosolids are available in Washington: composts, blends, and heat-dried pellets. Biosolids composts are made from biosolids and yard debris or woody materials, and can be used similarly to other composts. Biosolids blends are formulated for different uses, including turf topdressing, mulches, and soil amendments. Heat-dried pellets are rich in nutrients and are used similarly to commercial organic fertilizers. Check with your local wastewater treatment plant to see if they have Class A biosolids available for home use.

Commercial Organic Fertilizers

Many organic by-products and some unprocessed minerals are sold as commercial organic fertilizers. Table 5 shows approximate nutrient content of some of these materials. Figures represent total nutrient contents; because most are slow-release fertilizers, not all of the nutrients will be available the same year they are applied. The table shows that each fertilizer contains one main nutrient. The other nutrients are present in smaller amounts. Several companies produce balanced organic fertilizers, blended into a single product that provides all of the primary nutrients.

Commercial organic fertilizers tend to be more expensive per pound of nutrients than either synthetic fertilizers or manures. Sometimes the difference in price can be substantial.

Choosing organic fertilizers involves tradeoffs in cost and convenience. Farmyard manure is usually inexpensive or free, but is less convenient than packaged, commercial materials. If you or your neighbors have livestock it makes both environmental and economic sense to recycle the manure produced by the livestock.

Packaged organic fertilizers can be expensive, but gardeners may choose them where convenience or quick availability of nutrients is important, or for small gardens

where little fertilizer is needed. The cost per pound of nutrients in organic fertilizers varies widely, depending on the type of material, the concentration of nutrients, and the size of the package. Compare costs and nutrient availability when shopping for organic fertilizers.

Table 5. Total nitrogen, phosphate and potash content typical of some organic fertilizers.

Material	N	P_2O_5	K_2O
	— — — — % — — — —		
Cottonseed Meal	6-7	2	1
Blood Meal[1]	12-15	1	1
Alfalfa	2	0.5	2
Bat Guano[1]	10	3	1
Fish Meal[1]	10	4	0
Fish Emulsions[1]	3-5	1	1
Bone Meal	1-4	12-24	0
Rock Phosphate[2]	0	25-30 (only 2-3% available)	0
Greensand	0	0	3-7
Kelp Meal	1	0.1	2-5

[1]These materials contain a substantial amount of quickly available nitrogen that plants can use early in the season.
[2]Very low availability. Useful only in acid soils.

Lime, Gypsum, and Wood Ashes

Lime, gypsum, and wood ashes are all mineral materials used as organic soil amendments. Lime and gypsum are commercial products, while wood ashes are produced from home woodstoves and fireplaces.

Lime and pH. Lime is ground limestone, a rock containing calcium carbonate. Lime raises the pH of acid soils, and supplies the essential nutrient, calcium. Dolomitic lime contains magnesium as well as calcium, and is a good choice for organic gardeners in western Washington, where garden soils often are deficient in magnesium.

In strongly acid (low pH) soils, many nutrients are less available to plants, and some toxic metals are more available to plants. This can be corrected by the proper application of lime. Soils are naturally acidic in humid areas—most of western Washington—and are neutral to alkaline in drier areas—most of eastern Washington. Fertilizers tend to increase soil acidity over time; some eastern Washington topsoils have become acidic from fertilization.

The best way to determine if your soil needs lime is to have your soil tested. In the absence of a soil test, western Washington gardeners can add about 50 pounds of dolomitic lime per 1000 square feet of garden per year. Do not lime areas where you grow acid-loving plants, because they are adapted to acid soils. Lime is a slow-release material. Fall application will benefit a spring crop.

Gypsum (calcium sulfate) is not a substitute for lime. It provides calcium and sulfur to soils, but has little effect on soil pH. Gypsum has been promoted as a soil amendment to improve soil structure. In the vast majority of cases it will not work. Gypsum improves structure only when the problem results from excess sodium in the soil, a rare condition in Washington. Use organic amendments to improve soil structure, as described earlier.

Wood ashes are a readily available source of potassium, calcium, and magnesium. They also act like lime, raising the pH of the soil. High rates of wood ashes may cause short-term salt injury, so keep applications to less than 15-25 pounds per 1000 square feet of garden. We do not recommend using wood ashes in alkaline soils.

Estimating How Much Organic Fertilizer to Use

Estimating how much organic fertilizer to use is a challenge. We have to estimate both the amount of nutrients our crop needs, and the availability of the nutrients in the organic fertilizer. Two standard methods for estimating fertilizer needs are through soil tests and extension bulletins.

Soil Tests

A soil test will give you the levels of nutrients in your soil and a recommendation for how much fertilizer to add each year based on your soil test results and the crops you are growing. You don't need to test your soil every year—testing every 3 to 5 years is enough.

Washington State University and Oregon State University no longer test soils, but private labs in both states do tests for garden soils. Extension county offices have lists of testing labs. If you have not worked with a lab before, call them to make sure they are set up to do soil tests and make recommendations for garden soils. Ask the lab:

- If they routinely test garden soils for plant nutrients and pH
- If they use WSU or OSU test methods and fertilizer guides
- If they give garden recommendations for organic fertilizers
- How much a test costs
- How quickly you will get results

Extension Bulletins

If the cost of a soil test is large compared with your normal gardening costs, you can estimate your fertilizer needs using extension bulletins instead of soil tests. These bulletins usually give recommendations for synthetic fertilizers. You will need to adapt these for the lower nutrient availability in most organic fertilizers.

Tips for Estimating Organic Fertilizer Rates

- Organic fertilizers having large proportions of available nutrients (such as bat guano and fish emulsions) can be substituted in direct proportion for synthetic fertilizers.
- For other packaged fertilizers, apply according to their nutrient availability. Composts, rock phosphate, and plant residues generally have lower nutrient availability than more concentrated animal products (bloodmeal, bone meal, and high-nitrogen chicken manure). Recommendations on the package often are a good guideline for application rates. Check the recommendations against other products to make sure they seem reasonable.
- The nutrient concentration and availability in manures varies widely depending on the type of manure and its handling. Application rates range from 5 gallons per 100 to 150 square feet for high-nitrogen chicken manure to 1 inch deep for steer or horse manure composted with bedding. Estimate application rates based on your manure choice.
- Observe your crops carefully. It is sometimes hard to estimate how much organic fertilizer to use. Lush plant growth and delayed fruiting and flowering are signs of high amounts of available nitrogen, and may indicate overfertilization. You can experiment with different fertilizer rates in different parts of a row and see if you notice differences. Plan your experiment carefully, so you are confident that any results come from the fertilizer rates, rather than differences in soil, watering, or other management.
- Soil testing also is valuable in understanding the nutrient status of your soil. Many established gardens have high levels of soil fertility, and crops will grow just as well using less fertilizer.

Plant Disease Control

Some people think that controlling plant diseases always means spraying with chemical pesticides. Pesticides are only one of the many techniques and tools used to combat diseases. An organic gardener can use many of the methods available, but also must be willing to put in extra time and effort to accomplish the job. A basic understanding of plant diseases is essential if you are to be successful.

Plant Disease Principles

A plant disease is a process that harms all or part of the functions of a plant. It also may affect plant structures. It is abnormal and harmful in some way.

Plant diseases are generally divided into two groups based on their cause:

1. *Nonparasitic diseases* are induced by some cultural or environmental factor such as nutrient deficiencies, extreme cold or heat, toxic chemicals (air pollutants, weed killers, or too much fertilizer), mechanical injury, or lack of water. These diseases cannot be spread to healthy plants, and their control depends solely on correcting the condition causing the disease. Two-thirds to three-fourths of plant problems fall in this group of "diseases."
2. *Parasitic diseases* are caused by living organisms (pathogens), which derive their food by growing as parasites upon plants. The most common causes of parasitic diseases are fungi, bacteria, viruses, and nematodes. Only one-fourth to one-third of plant problems are in this group of diseases.

Fungi are organisms that lack the green coloring (chlorophyll) found in seed-producing plants and, therefore, cannot manufacture their own food. Between 50,000 and 100,000 different species of fungi of many types and sizes exist, but not all are harmful. In fact, some, such as mycorrhizal fungi, are extremely beneficial to plant growth. Most are microscopic, but some, such as the mushrooms, are quite large. Most fungi reproduce by spores.

Bacteria are very small one-celled organisms that reproduce by simple fission. They divide into two equal halves, each of which becomes a fully developed bacterium.

Viruses are so small they cannot be seen with the ordinary microscope. Many viruses that cause plant diseases are transmitted from one plant to another by insects, usually aphids or leafhoppers. Viruses also are very serious problems in plants propagated by bulbs, roots, and cuttings, because the virus is easily carried along in the propagating material.

Nematodes are small eel-shaped worms that reproduce by eggs. The number of eggs produced by one female nematode and the number of generations in a season depend on soil temperature. Therefore, nematodes usually cause more problems in warmer areas of the country. Most nematodes feed on the roots and lower stems of plants, but a few attack the leaves and flowers.

It is helpful to think of a parasitic plant disease as a process involving three factors: a host plant, a pathogen (microorganism), and the environment that affects both. The concept is illustrated in Fig. 1.

The host plant will have certain characteristics, such as being resistant or susceptible to a particular pathogen. In turn, the pathogen will have characteristics that make it successful or unsuccessful as a

cause of disease on the particular host. Environmental factors (such as moisture, temperature, and nutrition) affect both the host and the microorganisms that cause disease and play a vital role in the disease development process.

Ingredients for a plant disease epidemic would be a large population of a susceptible crop, an abundance of an aggressive pathogen, weather, and microclimatic conditions around the plants that favor rapid development of the disease. The probable outcome could be changed only by changing the relationship among the three factors—host, pathogen, and environment. When you begin to change this relationship, you are attempting to control the plant disease. Your success will depend on many factors, including your understanding of the particular disease and the management options available.

Methods of Combating Plant Diseases

Attempts to control plant diseases can be frustrating, expensive, and unsuccessful if you do not choose the best method for the particular plant disease. The phrase, "plant disease management," is a realistic description because we seldom "eradicate" disease. The incidence and severity of many plant diseases can be controlled until they are not major limiting factors in the production of a crop. As with insects and weed pests, we must battle plant disease almost every year on many crops.

Exclusion

This process involves controlling a plant disease by preventing the introduction of a pathogen to an area where it is not already present. That area can be a country, state, an individual garden, or an area of a garden.

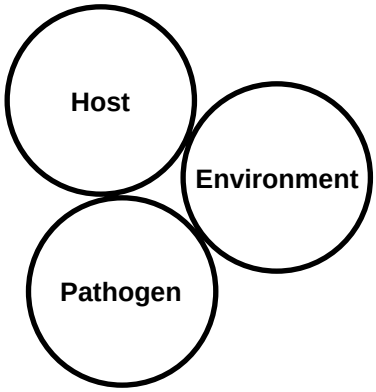
Upon entering this country, and even some states, you may be asked if you are carrying living plants, fruits, vegetables, or plant products. Such inspection is a method of preventing entry of certain insect and disease pests. Washington has restrictions concerning the introduction of certain plants into this state. When ordering plant materials through catalogs, you may find your order returned with a note stating these plants cannot be shipped to Washington. For instance, grape plants or cuttings are not permitted to enter the state to protect the grape industry from the introduction of several virus diseases not yet known to be present in Washington.

Individual gardeners should be sure that the plants they put into their own yards are as free from disease as possible. We highly recommend using certified planting material, when available. In Washington, certification programs on potatoes, strawberries, raspberries, and fruit trees are effective in controlling virus diseases on these crops. Plants will display a state inspection tag if they qualify for certification.

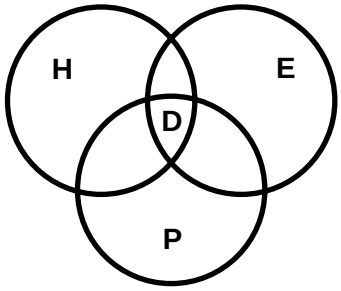
Eradication

Eradication of plant disease organisms (pathogen) is carried out in a number of ways. Many of these we commonly refer to as "cultural control practices." They include crop rotation and sanitation. In most situations, however, we do not actually eradicate the organism, but reduce it to a level minimizing significant loss.

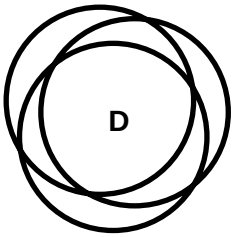
Crop rotation. Rotating crops is as old as agriculture and is based as much on superstition and art as on scientific fact. Continuous cropping in one area can perpetuate and build up pathogenic organisms. Crop rotation, however, is not always effective because of the various microorganisms and their different capabilities of survival. A 3- to 5-year rotation is suggested for home gardens. The rotation should include plants from different families. Cabbage, cauliflower, and broccoli, for example, are all related and would not be considered good choices of sequence in a rotation. Potatoes, corn, cole



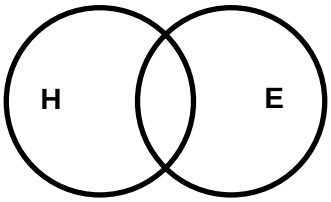
1. No disease.



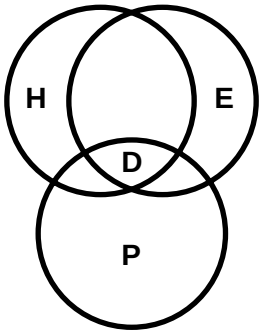
2. Normal combination of factors requires no control.



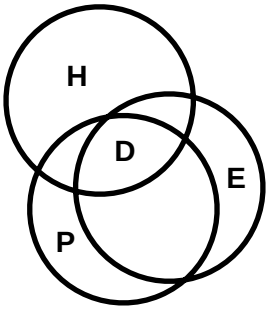
7. Epidemic level—control needed.



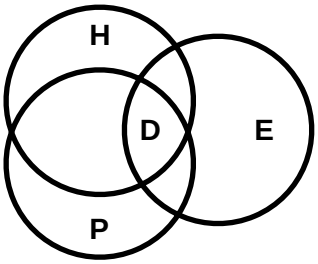
3. Control by exclusion.
Prevent introduction of pathogen.



6. Control by eradication.
Reduce pathogen population by sanitation or crop rotation.



4. Control by resistance.
Planting varieties resistant to disease is the best method of control.



5. Control by protection.
Modify the environment with cultural or chemical practices.

Fig. 1. Three factors of parasitic plant disease and levels of control. The disease (D) is represented in the areas where the circles overlap.

crops (cabbage, broccoli, turnips, radishes, cauliflower, etc.), legumes (peas and beans), and leafy vegetables would be examples of more logical sequence crops.

Sanitation can be defined as the removal and destruction of diseased or dead plants or plant parts as soon as the maladies are noticed. It is a common and effective plant disease control technique. A reduction in the population of disease organisms results in less chance for serious disease outbreak. Destruction of volunteer plants, overwintering host plants, infected crop residue, and diseased plants would be good sanitation.

Sanitation in handling vegetatively propagated materials is of utmost importance in preventing the spread of virus diseases. Remove and destroy virus-infected plants (roguing). These plants cannot be cured. They act as potential disease sources.

Pruning diseased twigs and branches is helpful in controlling diseases such as brown rot, Coryneum blight of stone fruits, anthracnose, and European canker of apples. Make pruning cuts well below the diseased area (3-6 inches) to be sure you remove all diseased tissue. After cutting into diseased tissue, disinfect the shears before making another cut. Disinfect shears by washing them with soap and water and swabbing with rubbing alcohol. Also disinfect shears when you complete work on each tree. Leave until last those trees in need of pruning for disease control. This will lessen the chance of spreading the disease. Destroy pruned-out plant parts.

Fruits such as strawberries, raspberries, or beans which are infected with gray mold (Botrytis) must be destroyed if you want to keep this disease under control without the use of fungicide sprays. Raking up and destroying leaves infected with apple scab is beneficial in breaking the life cycle of this disease.

Diseased plant materials *should not be composted*. Thoroughly hot composting (reaching a temperature of 140°F/60°C) will inactivate most disease organisms. Incomplete or cold composting, however, will spread the disease.

Controlling weeds also can be important in preventing disease. Certain weeds can act as a source of inoculum (disease). Wild blackberries, for instance, often are infected with virus diseases and the bacterium responsible for crown gall.

Protection

Fungicides are used in disease control to protect the plant from infection; thus, they need to be applied **before** the plant is diseased. In only a limited number of situations can fungicides actually cure a plant once it is diseased. However, the fungus that causes powdery mildew is located on the outside of the plant and is vulnerable to fungicide sprays after infection has taken place.

Elemental sulfur has fungicidal properties, and some organic gardeners are not opposed to its use. To be used as a fungicide, it must be very finely ground. Sulfur fertilizer is coarse and will not act as an effective fungicide. Sulfur, available as a fungicide, can be applied either as a dust or mixed with water and applied as a spray. Plant damage can result if elemental sulfur is used when temperatures are above 85°F/29°C. (See warning for elemental sulfur under Insect Management). Lime sulfur is acceptable as an organic material and is commercially available.

Copper fungicides also are acceptable to some organic gardeners. Bordeaux mixture (a mixture of copper-sulfate and lime) and fixed coppers (such as Microcop) are available to home gardeners. If you choose to use any of these fungicides, be sure to follow label directions and precautions and use them only on plants indicated on the label.

There are *nonfungicidal* methods to protect plants from disease. These generally involve avoiding situations that favor plant disease development.

Planting site. Choosing the right planting site is important. This involves wide geographic considerations, as well as specific sites in a yard or garden. For example, because of the severe disease problems on apricots, cherries, and peaches (Coryneum blight, brown rot, bacterial canker, and peach leaf curl), the fruits are not easily grown in western Washington. The drier, warmer climate of eastern Washington is the place to grow these fruits. Small fruits offer another example: raspberries require soils with excellent drainage to avoid root rot problems. Good winter water drainage is as important as summer drainage. In contrast, blueberries tolerate wet soils.

Planting date. Date of planting also can influence disease development. Planting too early, especially pumpkin or squash, can lead to seed rot and damping-off of young seedlings. Delaying planting until the soil has warmed allows the young plants to grow faster and, thus, avoids rotting organisms. On the other hand, planting peas early avoids virus disease problems. Aphids, which transmit these viruses from clover-type plants to peas, are not active during the early part of the growing season; thus, the peas avoid infections by developing before exposure to the virus-carrying aphids.

Planting conditions. Good air circulation and light penetration help avoid the humid conditions that promote disease. Overcrowding creates micro-environments favoring plant disease.

Fertilization. Properly fertilized plants are generally more resistant to disease than those under nutritional stress. Overfertilization, leading to an abundance of soft, luxuriant growth, also may lead to disease losses.

Moisture. Avoid diseases by proper watering. Avoid using overhead irrigation (applying water through sprinklers which wet the leaf surfaces) when possible. Applying water directly to the soil surface by digging furrows adjacent to rows, and using soaker hoses are better alternatives. If you must use overhead sprinklers, water in the morning so the foliage has a chance to dry before evening. Late afternoon watering allows the foliage to remain continuously wet throughout the night, a practice which invites disease. Most infective propagules (such as fungus spores) which initiate plant disease require moisture to germinate and cause infection. Thus, cultural practices that help foliage become dry or remain dry aid in control of plant disease, especially foliar diseases.

Handling. Proper handling before and after harvest can prevent rots from certain diseases. Late blight of potatoes is a good example of a harvest disease. Late blight not only causes a severe foliage disease, but also results in a storage rot if the tubers become infected. Tubers get infected during harvest when they contact the fungus on the diseased vines. To prevent tuber infection cut the vines and remove from the area 10-14 days before harvesting tubers. Cut the vines an inch or so below the soil surface. Not only will the tubers not contact the disease, but this 2-week curing period promotes a toughening of the potato skins which will help prevent wounding during harvest.

Another example of harvest disease is Botrytis gray mold, which can be responsible for rotting of berries before or after they have been picked. This postharvest rot can be avoided by picking the berries during cool parts of the day, by keeping picked fruit out of the sun, and by placing them in cool storage as soon as possible. They should not be washed until they are ready to be consumed or processed, since moist surfaces allow germination of the spores of rotting organisms.

Soil pH. Soil acidity also can influence the development of certain diseases. Potato scab, for instance, is most severe in soils that have a neutral to alkaline pH. Thus, additions of lime, wood ashes, and manure increase

the severity of potato scab. Club root of cabbage and other cole crops, acts in just the opposite manner. Applications of lime have reduced the severity of this fungus disease.

Genetic Resistance

Choosing crop varieties resistant to one or more pathogens is the most economical and desirable way to avoid disease losses. When selecting varieties for disease resistance, it is important to know whether the disease is a potential problem in your area. For example, apple varieties resistant to fire blight are desirable in eastern Washington; since the disease is essentially never a problem in western Washington, fire blight resistance is not a criterion for selecting a variety to grow there.

Locating information on disease resistance often is difficult and sometimes impossible. Generally, seed catalogs and other sources will advertise certain varieties as having specific disease resistance. If this information is not given, assume the variety is susceptible. Treat cautiously a general statement that a variety has good disease and pest resistance. The resistance it possesses may have no application to the disease problems in your area.

Small Fruit Disease Resistance

Many varieties of berry fruits can be grown in Washington. Each, however, has a different tolerance to various diseases. Tables 5 and 6 and the following section summarize the information available on small fruit disease resistance.

Black Raspberries

Black raspberries are subject to several diseases that cause rapid deterioration of individual plants and seriously limit the productivity and life of the plantings. The diseases include Verticillium wilt, anthracnose, and streak, mosaic, and curl viruses. Breeding and testing go on continuously throughout the United States to develop or find varieties resistant or tolerant to these diseases. Results have not been successful.

Table 5. Tolerance of strawberry varieties to disease.

Disease	Plant tolerance	Variety
Viruses (aphid transmitted)	Tolerant	Shuksan, Totem, Benton
	Intermediate	Rainier
	Susceptible	Hood, Quinault
Red stele root rot	Resistant	Quinault, Hood, Totem, Rainier, Shuksan, Benton
Gray mold	Least susceptible	Shuksan, Totem
	Moderately susceptible	Hood, Rainier, Benton
Powdery mildew	Tolerant	Hood, Totem, Benton, Tristar
	Moderately susceptible	Shuksan
	Very susceptible	Quinault, Redcrest
Verticillium wilt	Resistant	Tristar
	Susceptible	Vesper*
	Very susceptible	Earlidawn*

*Varieties adapted to eastern Washington.

Table 6. Tolerance of red raspberry varieties to root rot.

Tolerance level	Variety
Tolerant	Newburgh, Sumner, Latham
Susceptible	Willamette, Meeker, Chilcotin, Heritage, Tulameen
Very susceptible	Canby, Skeena, Comox

Insect Management

In the past, many people grew good gardens using few, if any, insecticides. While a few of our pests are recent imports from other countries, for the most part we face the same insects found here before synthetic insecticides were developed. New approaches to insect management have evolved. These, combined with many old-time mechanical and cultural practices, make it possible to grow reasonably pest-free garden produce without using synthetic insecticides.

Most seasonal gardeners use a decision-making process called Integrated Pest Management (IPM), whereby they continuously monitor for pests. When a pest is discovered, have it accurately identified and learn about its life cycle, behavior, and host crops. This information allows choosing effective management methods and timing them properly. Then, if unacceptable damage occurs, you can employ these methods to suppress the pest to tolerable levels.

Gardening successfully without synthetic insecticides requires more knowledge on the part of the gardener. It may also require additional work, since many alternative pest management approaches are labor intensive. Organic gardeners should be willing to accept some produce less perfect than that from gardens or farms which employ pesticides.

Alternative pest control methods may be biological, cultural, mechanical, or a natural, less toxic insecticide. A gardener often uses a combination of approaches to solve a pest problem. These alternative methods are described below.

Biological Control of Insect and Mite Pests

Biological control is the use of any form of life to control a pest. A controlling agent may be a disease organism, a predacious or parasitic insect, predacious spiders and mites, insect-feeding birds, rodents, toads, or any other vertebrates. A number of companies now supply insect and mite predators and parasites to gardeners. For a current and complete listing, refer to magazines on organic gardening. Your Extension office may have partial lists. Many of these beneficial organisms occur naturally, but often effective numbers develop too late to control the pest before severe damage occurs. Keep in mind that when introducing an insect to prey upon or parasitize a pest, its numbers only can increase in nature if it has sufficient prey to feed upon. If you are experiencing little insect damage or the pest species are in low numbers or absent, the beneficial organisms must move elsewhere, where food is available to survive.

To allow beneficials that feed on pests to increase in number sufficiently to control pest insects, you must accept a certain

amount of insect damage. You can't have insect-free garden produce and encourage beneficial insects at the same time. Releasing predators or parasites can be highly beneficial in establishing them in new areas.

Biological control is seen as three different approaches: conservation, augmentation, and classical (introduction) biological control. Conservation is seen as "protecting" what is already there. This is achieved by encouraging native, natural enemies through providing a "user friendly" environment (i.e., using selective natural insecticides such as *Bacillus thuringiensis*). Augmentation is seen as adding to what is already there or should be there (i.e., purchasing and releasing natural enemies). Classical biological control is the releasing of foreign beneficials to control introduced pests in areas where their natural enemies do not exist (i.e., cinnabar moth to control tansy ragwort). Gardeners can and do use conservation and augmentation commonly. Classical biological control is normally carried out by government agencies.

A number of beneficial organisms are becoming available to home gardeners. The more important of these and some of the indigenous natural enemies are discussed here.

Lady Beetles

Organic gardeners have long used lady beetles as an approach to aphid control. The process includes purchasing the beetles in bulk quantities and releasing them at the site. The idea is a good one; however, aspects of the beetle's biology thwart the total effectiveness of such a practice. These beetles overwinter as adults in large masses in the forests or hillsides. They are collected at this time and kept in cold storage until they are sold. The beetles often are released in large numbers on a single site (backyard) and expected to remain. The aphid population frequently is not large enough at the time of release to support such a population of lady beetles, so they do what any hungry animal would do under such circumstances, they leave the area in search of sufficient food. Many entomologists believe most species of lady beetle must undergo a dispersal flight after overwintering before they settle down, mate, and lay eggs. This is a phase missing in the beetle at the time of purchase. When released they take flight and leave the area. Thus, the beneficial effects are only realized by unknowing, nonpaying neighbors. Some growers have used this technique for many years. Since several are doing so on an area-wide basis, they apparently are achieving success accidentally by trading beetles through random multi-directional dispersal flight.

Predator Mites[1]

Several species of predator mites feed on harmful plant-feeding mites. The most common beneficial mites include *Typhlodromus*, *Phytoseiulus*, and *Amblyseius* species. These tiny predator mites are usually smaller (about 1/100 to 1/50 inch long) than the plant-feeding mites, two-spotted mite, and European red mite upon which they feed. They usually are teardrop shaped and yellowish or clear in color. Beneficial mites overwinter as adult females on trees and in soil debris. They become active in April and May and begin to feed on available prey. Female mites consume about 70 to 80 prey during their 6-week lifetime. Ten or more generations can be produced per year. Several predator mite species are available commercially.

Predacious Ground Beetles[1]

Predacious ground beetles, or carabids, are large beetles ($^1/_4$ to $1^1/_4$ inch), usually black or dark metallic in color. Most species have the same characteristic shape. Elongate and wormlike larvae are fast moving. They capture prey with large mandibles. Both larval and adult stages feed at night on a variety of insects such as cutworms and

[1]Adapted from PNW343 *Beneficial Organisms Associated with Pacific Northwest Crops*

maggots. Some species also feed on snails and slugs. Adults are the wintering stage, and larval development takes about 1 year. Carabids forage in most Northwest gardens.

Green Lacewing[1]

Adult lacewings (*Chrysopa* spp.) are light green. They have two pair of large membranous netlike wings. They usually are 1/2 to 3/4 inch long. Adults feed on aphid honeydew and plant fluids. The larvae reach 1/3 inch long at maturity and resemble tiny light brown alligators. They feed primarily on aphids, capturing them with their sicklelike mandibles. Each lacewing may consume as many as 750 aphids during its larval stages. Several generations are produced each season. Lacewings are available commercially.

Syrphid Flies, Flowerflies[1]

These brightly colored flies closely resemble bees and wasps but do not sting. The adults often hover around flowers, where they feed on nectar and honeydew from aphids and scale insects. The blind sluglike larvae usually are pale green to brown and characteristically tapered toward the head. Throughout the growing season the larvae feed on aphids and other soft-bodied insects. Black oily smears of excrement on plant foliage are typical signs of syrphid fly feeding. Many generations occur each year. Syrphids are not yet available commercially.

Aphid Parasites[1]

These small (less than 1/4 inch), solitary wasps parasitize and kill aphids. Their life cycle is closely synchronized with that of their host. The adult female wasp deposits an egg inside an aphid host. The hatching wasp larva eventually kills its host by consuming its internal tissues and organs. The dead aphid "mummy" has a bloated look, appears bronze or gray in color, and is quite distinct from unparasitized aphids. Inside the aphid mummy, the mature wasp larva spins a cocoon in which to pupate, and emerges as an adult through a hole on the top part of the aphid. Numerous overlapping wasp generations occur each season. The wasps do not bite or sting people. Many of these wasp species are available for purchase.

Fungi[1]

Insects are susceptible to attack by many naturally occurring disease organisms such as fungi, viruses, bacteria, and protozoa. Because aphids have sucking mouthparts, they are commonly attacked by fungal diseases. The germ tubes produced by fungal spores penetrate their host directly. You can easily recognize aphids killed by a fungal epidemic. They will be attached to a leaf and appear fuzzy or "moldy." Fungus epidemics, limited by moisture and temperature, generally do not occur unless relative humidity is greater than 90%. A few commercially developed fungi are available for aphid control. Gardeners may notice naturally occurring epidemics of fungi, which can kill entire aphid populations. Some common fungi include *Beauveria*, which attack beetles, and *Entomophthora*, which attack flies and grasshoppers.

At least one commercial fungal agent is available for controlling certain insect pests. Always read the label to see what plants you may use controls on.

Nematodes[1]

Insect-parasitic (entomopathogenic) nematodes attack and kill insects, primarily those living in soil. The nematodes enter insects through natural body openings and release bacteria into the insect's body cavity. The bacteria kill the insects, and the nematodes then multiply by eating the insect cadavers and the bacteria. Insect-parasitic nematodes are available commercially.

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[1]Adapted from PNW343 *Beneficial Organisms Associated with Pacific Northwest Crops*

Follow label directions for the temperature and moisture requirements of the nematodes.

Other Beneficials

You will run across many other beneficial insects and spiders. These include tachina flies, whose larvae are internal parasites of certain caterpillars; many predacious bugs (damsel bugs and pirate bugs) overcome prey with their powerful forelegs and sucking beaks. Various crab and wolf spiders also add to the array of beneficials in the garden. Always observe the behavior of these insects and their relatives to see what they're doing. They often turn out to be beneficials, or at least harmless to plants.

Insect Disease Organisms

Strains of bacteria called *Bacillus thuringiensis* (B.t.) produce a toxin that kills many caterpillar pests. The insecticidal toxin is sold under various trade names. There are strains of this bacteria specific to fungus gnat and mosquito larvae. Another strain is specific to elm leaf beetle and the Colorado potato beetle. Buy the appropriate strain of B.t. to control the target pests. Since B.t. is essentially a stomach poison, apply it when the target pests are in feeding stages. *Target pests are controlled more completely when they are treated as young larvae.*

Birds

Birds are far more important in preventing insect outbreaks than in controlling them. All bird species feed on insects to some degree. The fly-catchers, swallows, warblers, vireos, creepers, nuthatches, and woodpeckers are almost entirely insectivorous, while blackbirds, robins, crows, gulls, magpies, and even the birds of prey—the hawks and owls—commonly feed on insects.

To develop bird numbers near gardens, encourage those species which feed largely on insects. If you encourage all species of birds, including those which damage gardens, such as starlings and blackbirds, you may be asking for trouble. Encourage insect-feeding birds by providing cover, water, supplementary feed (particularly during winter and spring), and discouraging cats and other predators.

Bug Juice Sprays

"That plants and animals commonly die of disease without human intervention is obvious to gardeners. It is the basis for the folk pest control recipe for grinding up sick or dead insects and spraying the bug juice to spread the pathogens (microorganisms that cause the disease) and kill more pest insects. However, spraying homemade bug juice around your house may not be a good idea since some microorganisms and fungi found on the dead bodies of insects are pathogenic to humans and might get into the "juice." But the idea of using microbes that cause disease in plants and insects to control pests is not a bad one. A number of such microbial products are available commercially."

Olkowski, Daar and Olkowski. 1991. *Common-Sense Pest Control: Least Toxic Solutions for Your Home, Garden, Pets and Community.*

Attract insectivorous birds to your home by planting ornamentals that provide suitable bird cover and food. Some especially valuable plants are

Dogwood (*Cornus* spp.)
Mountain Ash (*Sorbus* spp.)
Russian Olive (*Elaeagnus* spp.)
Firethorn (*Pyracantha* spp.)
Crabapple (*Malus* spp.)
Elderberry (*Sambucus* spp.)
Cotoneaster (*Cotoneaster* spp.)
Western Red Cedar (*Thuja plicata*)
Sumac (*Rhus* spp.)
Holly (*Ilex* spp.)
Hawthorn (*Crataegus* spp.)
Highbush Cranberry (*Viburnum trilobum*)
Cherry and Wild Plum (*Prunus* spp.)
Serviceberry (*Amelanchier* spp.)

The Washington State Department of Fish and Wildlife has many useful publications that address backyard wildlife sanctuaries. One in particular that will help you to encourage desirable birds is called *Nest Boxes for Birds.*

Besides encouraging wild birds, some gardeners use domestic fowl for pest control. Chickens, ducks, and geese eat insects with great relish. They also eat slugs and many weeds, so they can be wonderful garden helpers.

Manage the domestic birds carefully. If they have access to vegetables such as lettuce and spinach, they will eat your crop. Keep them away from small or tender plants, since they can trample and break plants.

Some have employed geese in commercial orchards and small fruit farms. In strawberry fields, remove them during fruit season, since they love the berries.

Chickens usually are allowed access to gardens between crops. They weed, eliminate every insect they can scratch out of the soil, and fertilize—all at the same time. Some gardeners have experimented with "chicken tractors." These are small, portable, henhouses with attached runs. The outdoor run is built the exact same size as the gardener's vegetable beds. The "tractor" is moved from bed to bed as the soil needs the attention of the chickens.

Domestic fowl need proper care and feeding. They also need your protection. Birds allowed to forage may be preyed upon by dogs, raccoons, or coyotes.

Cultural and Mechanical Control of Insect and Mite Pests

Many cultural practices reduce the susceptibility of garden plants to insect attack. In many instances mechanical devices or physical destruction work well. Here are some of the more popular techniques.

1. Rotate your garden plot. This is easier if you have a large property, but even in a small garden you can change the sequence of plants grown in different areas. Try to grow a particular crop in a bed or section of the garden no more often than one year out of three. Rotate by plant family (cabbage family) or group (root crops). Should you develop a soil problem, such as wireworms or white grubs, you may want to use even longer rotations before growing tuber or root crops, (potatoes or carrots).

   Avoid or restrict growing insect-susceptible crops. Unfortunately, we have no nonsynthetic insecticides suitable for soil insects. White grubs, wireworms, cabbage maggots, onion maggots, carrot rust fly, and other soil insects may continue to bother you unless you use fallowing or exclusion techniques where appropriate.
2. Fertilize, cultivate, and water well to induce good, healthy growth. Insect injury is less damaging on a healthy plant. Note: Fast release of high nitrogen fertilizers can lead to aphid, scale, or whitefly problems. Using slow-release

fertilizer with a moderate proportion of nitrogen may minimize these pest problems.

3. Use interplantings (as opposed to solid plantings of a given species) to isolate the infestation and reduce damage.
4. Handpick and destroy pests when feasible by knocking pests from foliage into a bucket containing a mixture of water and soap. Remember many garden pests are nocturnal, so you may have to do this at night using a flashlight.
5. Use transplants. The longer a plant is growing in a garden, the greater its exposure to potential insect attack. Plants of the cabbage family will avoid early and often devastating attacks of cabbage maggot if you purchase healthy, mature transplants. A healthy transplant will more likely overcome subsequent insect attack than a small plant developing from seed in the garden.
6. Practice sanitation. Since many garden insects overwinter in plant debris, spade under old plants, (spinach and lettuce) during the summer, or add these plant residues to your compost. The cabbage aphid, for example, may overwinter as an egg on the cabbage plant; the adult asparagus beetle overwinters in the hollow stems of asparagus; and several species of leafhopper overwinter in or on plant debris. Immediately dispose of your reject onions, since the onion maggot will continue to breed in them. Whenever a garden plant is no longer producing, spade it in or relegate it to the compost pile.

   Keep your garden free of weeds and volunteer plants: these can harbor pests—particularly certain aphids which may transmit disease organisms. Tall grasses and weeds that border your flower or vegetable garden provide good cover for slugs, so keep the grass and weeds trimmed. Piles of rocks, wood stacks, or old pots also can harbor slugs.
7. Cultivating a garden exposes pests that live near the soil surface to birds and injures or kills some insects. Fall cultivation also exposes pests to the rigors of winter.
8. Planting your crop prior to emergence of a particular pest or late planting to avoid resident first generations of the pest can reduce but not necessarily eliminate damage. For example, planting peas early can help reduce crop loss due to viruses transmitted by pea aphid in susceptible varieties. Check with your local authority on this approach since pest populations often peak at different times depending on geographical location.
9. Certain colors attract some insects. You can use this behavior against them. An effective example is capturing whiteflies in greenhouses where yellow cards or boards are hung every few feet among the plants and covered with sticky substances. Whiteflies are attracted to the yellow card and become stuck on the board. In many instances 100% control of whiteflies is not necessary (hobby greenhouses). Most plants can tolerate a low level of whiteflies. Heavyweight motor oil (SAE 90) also is an effective

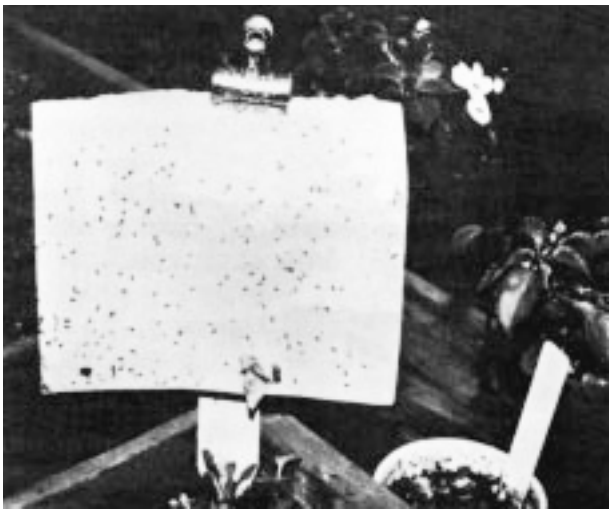

Figure 2. Sticky yellow card for trapping whiteflies and fungus gnats.

trapping material and is easier to wipe off the boards. This may work on whiteflies outdoors, although tests have not been conducted to determine the effectiveness. These traps also catch a substantial number of fungus gnats.

10. Use trap crops. Pests prefer some plants more than those in your vegetable garden. Use them to steer pests away from your more desirable plants. For example, certain aphids populate nasturtiums before they move onto other susceptible plants. Destroy aphids on the nasturtiums before they become abundant, or they will overflow onto other garden plants. This technique often works.
11. Row or bed covers, wire, nylon, or muslin screen cages are useful in garden plots for excluding many insects from the crops they normally infest. Lightweight fabric, sometimes called floating row cover, is especially easy to use since it does not require any support frames. These row covers have been effective at keeping cabbage maggots from cole crops, radishes, or turnips; carrot rust fly from carrots and parsnips; and spinach leafminers from spinach, chard, and beet tops. They also can be used to keep out pea leaf weevils until seedling peas have reached the four– to six–expanded leaf stage, at which point they are tolerant to weevil. Note: Row covers can make your pest problem worse if you employ them on already infested soils where the pests have overwintered. They only can be used effectively on sections of garden where the pest did not occur the previous year, so use them in conjunction with careful crop rotation. (Hotcaps designed to enhance heat conditions will accomplish the same end if built right.)
12. Stale beer placed in cans sunk in the soil is attractive to slugs, which find the containers, crawl in, and drown. This material can be attractive to many insects, including beneficial ones such as carabid ground beetles. To protect these, leave a one-inch rim above the soil line. The best way to control slugs is still to eliminate their hiding places (tall grassy or weedy areas).
13. Plant "sleeves." Milk cartons with both ends cut out and placed snugly in the soil enclosing the plant will serve as a physical barrier to many pests. For additional protection apply a band of sticky or greasy material, like Vaseline, to the exterior of the carton.
14. Other "insect barriers" are useful if some part of the known biology or behavior of the pest in question lends itself to manipulation by these methods. For example, most root weevils are night feeders. As day approaches, they drop off rhododendrons and other host plants to the litter below, where they hide. They do not fly. If the main trunk is the only access to crawling back up the plant to feed on foliage, the trunk is an ideal place to consider a barrier. Wrap a strip of plastic or plant wrapping paper snugly around the base of the trunk with a sticky material for an efficient barrier to root weevils. Check the strip from time to time, since debris

Fig. 3. The use of floating row covers can reduce the presence and damage of such pests as cabbage root maggots by 100%.

and insect accumulation will make it ineffective over time. Remove during winter.

15. Resistant varieties. Many plant species have varieties that are moderately or highly resistant to plant pests. Unfortunately, many are not available to or known by name to the home gardener. See EB0970, *Root Weevil Control on Rhododendrons*, for species and varieties of rhododendrons and azaleas that demonstrate resistance to root weevils.

    Pest-plant relationships for strawberries and raspberries follow.

    Strawberry. Strawberry varieties have little resistance to major pests such as root weevils and aphids. However, resistance to the two-spotted spider mite has been found in the Linn variety. All other varieties are susceptible. The Totem variety is extremely susceptible.

    Raspberry. Red raspberry has little resistance to the major pests. However, resistance to the raspberry aphid, an insect which spreads virus diseases, can be found in Canby, Haida, Skeena, and Nootka varieties.

16. Water. A stream of water from a hose will control aphids on certain garden plants. The force of the well-directed spray will kill or dislodge the aphids. Those that are dislodged but withstand the force rarely make it back to the host plant. Include this method regularly in your normal gardening operations. Do not spray plants with water at night if they are highly susceptible to foliar diseases. Spray during the daytime so foliage has a chance to dry rapidly.
17. Other methods. Some publicity favors light traps, reflective materials, such as aluminum foil, irradiation, electric shock, repellents, and the use of sex lures (pheromone traps). We cannot recommend these methods at present. Eventually they may be of considerable value. Combination light traps and electrocution grids are fascinating as a potential insect control tool. In the garden area, they only serve to "pull" in pests from neighboring gardens. Recent reports indicate that they kill an extra ordinary number of beneficial insects.

Companion Planting

"Many gardening books and magazines have published lists of plants that are said to protect neighboring plants by repelling pests, a concept sometimes called companion planting. Research in this area has been limited but it has consistently shown no overall benefits under controlled conditions. For instance, University of California research showed that while a cabbage plant surrounded by four companion plants of various herbs had fewer imported cabbage worm eggs laid on it than a control plant not surrounded by herbs, yield reduction was severe due to the close proximity of the herb plants and competition for resources. When the number of companion plants per cabbage was reduced to two, the herbs gave no significant pest protection and yields were still substantially lower."

Mary Louse Flint. 1990. *Pests of the Garden and Small Farm: A Grower's Guide to Using Less Pesticide.*

Natural Insecticides

The most commonly used natural insecticides and miticides are listed and discussed briefly below. These materials are "natural" inasmuch as they are derived from plants and bacteria or from elements taken from nature.

Pyrethrins

Pyrethrins derive from the dried flowers of a species of *Chrysanthemum* and have been used for controlling insects since ancient times. Since they provide "quick knockdown" and have very short residual effects, they must be used often. They frequently are sold with an activator or synergist (piperonyl butoxide or peperonyl cyclonene). The use of pyrethrins without these low hazard and safe activators would be much less effective, difficult to obtain, and almost prohibitive in cost. The pyrethrins kill insects only by contact. They are effective against a wide range of garden pests, especially the soft-bodied forms, but will not control mites. Do not spray around fish ponds. Consult the label for specific usages.

Neem

Hundreds of products come from the seeds and bark of the neem tree. At least one product is a fungicide. The active ingredient best known as an insecticide is azadirachtin. It is extremely safe for humans and pets. It can act as a contact poison, a systemic, or a growth regulator (interferes with normal molting). Neem products are effective against many caterpillars, flies, whiteflies, scales, and somewhat effective on aphids.

Dormant and Summer Oils

Petroleum oils were used for insect control as early as 1787 and are still popular, although not used as extensively as they might be. Apply them only on woody plants. Two principal types exist: the dormant oils only should be applied on trees or shrubs in the dormant or delayed-dormant condition; summer oils can be used during the growing season but also are restricted to woody plants. Applying a strictly dormant oil during the growing season will severely burn foliage. For summer use, purchase oil especially prescribed for this purpose and apply only on those plants for which the material is recommended. Some special oils can be applied either summer or winter; however, the concentration used in summer is far less.

Oils control many insects and their eggs, such as overwintering leafroller, aphid and mite eggs, as well as nymphs and adults of aphids, scale insects, and mites. Dilute these oils first with water. They contain emulsifying agents that allow them to mix when added to water. The oils cause little or no harm to most beneficial insects. Pests rarely develop resistance to these sprays. Used correctly, they are nonhazardous to human health. Do not apply oils during freezing weather.

Lime-Sulfur

Liquid lime-sulfur is an "old timer" that is still in use. Use it much the same as for the dormant oils diluted with water. Do not apply to apricot trees at any time; you may injure the foliage. Use only on woody plants and only during the dormant season, or up to prebloom on some plants. The only exception is on caneberries where it can be used for dryberry mite and redberry mite in the spring when vegetative buds are 1/2 inch long. This material is particularly effective against pearleaf blister mites, rust mites and their close relatives, as well as for many insect eggs. These sprays also have fungicidal value. On fruit trees, lime-sulfur often is mixed with dormant oil to increase its efficiency. Use lime-sulfur with caution when you treat ornamentals near your house. The

spray drift when dried is difficult to remove from buildings and may cause stains on painted surfaces.

Elemental Sulfur

A finely ground powder, elemental sulfur, can be applied either as a dust or spray. In addition to controlling fungus diseases, it also will give some control of spider mites, especially during hot weather. Warning: if you plan to can the produce, do not use sulfur on most vegetables just before harvest. Small amounts of sulfur in the "preserve" will produce sulfur dioxide which can cause the container to explode. It also may cause off-flavor. Sulfur can be used safely on berries and other fruits without these hazards and on vegetables eaten fresh, dried, or processed for freezing. Sulfur is very safe—in fact, it is an element essential for good health.

Soaps

Soap diluted with water has been recommended for certain soft-bodied insects, such as aphids, since 1787. Most often these natural soaps were derived from either plants (coconuts, olive, palm, cotton seed) or from animal fat (whale oil, fish oil, or lard). Household soaps vary tremendously in composition and purity; also in effectiveness and potential to harm crops. Use soaps specifically registered and sold for use as insecticidal soaps.

Spinosad

This organic insecticide is produced by an actinomycete fungus, *Saccharapolyspora spinosa*. It is used for managing certain Lepidoptera, such as cabbageworm, cabbage looper, diamondback moth, armyworm, and cutworm. It has a low toxicity to fish, birds, and wildlife in general. However, it is toxic to bees for three hours following treatment, so do not apply to blooming plants during the day.

Garlic Sprays

"Modern studies confirm that garlic oil exhibits antibacterial, antifungal, amebicidal and insecticidal qualities..."

"..although garlic does kill pest insects and some pathogens, it also kills beneficial insects and microbes. Thus we do not recommend it as an all-purpose spray for garden use."

"We do not recommend garlic for aphid control since it kills the natural enemies of the aphids as well as the pests; insecticidal soaps are preferable."

Olkowski, Daar & Olkowski. 1991. *Common-Sense Pest Control: Least Toxic Solutions for your Home, Garden, Pets and Community.*

Certified Organic Produce

Most organic gardeners supplement their harvest with fruit and vegetables purchased at the store. Many retail outlets carry clearly identified organic products in separate sections of the fresh, frozen, or canned good aisles. In addition, many Farmers Market vendors sell organic produce. To obtain lists of local Farmers Markets in your area, go to: http://www.wafarmersmarkets.com/ and click on Market Directory. Other sources for organic produce are Community Supported

Agriculture (CSA) farms. These farms sell "shares" which entitle buyers to weekly deliveries of fresh produce during a defined season. For a list of CSA farms in western Washington, go to the Seattle Tilth web site, http://www.seattletilth.org, and click on the annually updated Community Supported Agriculture Directory.

The Washington State Department of Agriculture (WSDA) Organic Food Program is charged with certifying organic farms in the state. They maintain a list of certified producers which can be found at: http://agr.wa.gov/FoodAnimal/Organic/default.htm.

For more information on certification procedures or about how to become certified, contact:

Organic Food Program
WSDA
PO Box 42560
Olympia, WA 98504-2560
(360) 902-1805

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Using horticultural spray oils to control orchard pests. Willett, M. and P.H. Westigard. Pacific Northwest Extension Bulletin PNW328. 1998. 8 pp.

Online Resources:

HortSense Fact Sheets.
http://pep.wsu.edu/hortsense

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Use pesticides with care. Apply them only to plants, animals, or sites 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.

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