

Crop rotation also helps prevent soil nutrients from being depleted. Vegetables draw up a range of soil nutrients for growth: nitrogen, phosphorus, and potassium are the key or major nutrients. Members of the same vegetable family usually draw the same nutrients from the soil.

Crop rotation will prevent the soil from wearing out: heavy nitrogen, phosphorus, and potassium-feeding crops such as tomatoes are rotated with soil-building crops such as beans which add nutrients to the soil and then with light-feeding crops such as onions.

MAJOR PLANT FAMILIES AND SOME NOTES ON CROP ROTATION:

- **Onion Family (Amaryllis Family, Amaryllidaceae):** Garlic, onions, leeks, shallots. These are light feeders. Plant these after heavy feeders or after soil enrichers such as beans.
- **Cabbage Family (Brassica, Cruciferae):** Broccoli, Brussels sprouts, cabbage, cauliflower, cabbage, collards, cress, kale, kohlrabi, radishes, turnips. These are heavy feeders. These follow legumes. After these crops allow the garden to go fallow for a season or plant a cover crop. Add plenty of compost and organic matter to the garden.
- **Lettuce Family (Composite, Daisy Family, Asteraceae):** Artichokes, chicory, endive, lettuce. These are heavy feeders. Follow these crops with legumes.
- **Beet Family (Goosefoot Family, Chenopodiaceae):** Beets, spinach, Swiss chard. These are heavy feeders. Follow these crops with legumes.
- **Grass Family (Graminae):** Grains—corn, oats, rye, wheat. Follow these crops with members of the tomato or Solanaceae family.
- **Bean Family (Legume, Leguminosae):** Beans and peas, clover, vetch. These crops enrich the soil. Plant these crops before or after any other crop family.
- **Tomato Family (Nightshade Family, Solanaceae):** Eggplant, peppers, tomatoes, potatoes. These crops are heavy feeders. Plant these crops after members of the grass family. Follow these with legumes.
- **Squash Family (Cucurbitaceae):** Cucumbers, melons, summer and winter squash, pumpkin, watermelon. These crops are heavy feeders. Plant these crops after members of the grass family. Follow these crops with legumes.
- **Carrot Family (Umbellifer Family, Umbelliferae):** Carrots, celery, anise, coriander, dill, fennel. These are light to medium feeders. These crops can follow any other group. Follow these with legumes, onions, or let the garden sit fallow for a season.

You can use the notes above to accomplish crop rotation or you can simplify the rotation with a four-year plan.

SIMPLE FOUR-YEAR CROP ROTATION PLAN:

To follow a simple four-year crop rotation, divide your garden into four areas or plots: Plot 1

Two, Plot Three, and Plot Four. In each of the next four years, grow a different crop or different members of the four crop families in a different plot following this rotation:

- Plot One: Tomato family (year 1); Others—see list below (year 2); Bean family (year 3—but planting beans where onion family crops have just grown); Cabbage family (year 4).
- Plot Two: Cabbage family (year 1); Tomato family (year 2); Others—see list below (year 3 family (year 4—but avoid planting beans where onion family crops have just grown).
- Plot Three: Bean family (year 1—but avoid planting beans where onion family crops have Cabbage family (year 2); Tomato family (year 3); Others—see list below (year 4).
- Plot Four: Others—see list below (year 1); Bean family (year 2—but avoid planting beans where onion family crops have just grown); Cabbage family (year 3); Tomato family (year 4).

This four-year crop rotation intersperses members of the other vegetable families among the Tomato, Bean, and Cabbage families, and Others. Here is how they are grouped:

1. Tomato Family and others (Solanaceae family)

Tomatoes

Peppers

Eggplant

Potatoes

Beets

Carrots

Celeriac and celery

Parsnips

Salsify

Scorzonera

2. Bean Family (Leguminosae family)

Peas

Broad (fava) beans

French (green) beans

Runner beans

3. Cabbage Family and others (Brassica family)

Broccoli

Brussels sprouts
Cabbages
Calabrese (Italian sprouting broccoli)
Cauliflowers
Radishes
Rutabagas (Swedes)
Turnips

4. Others

Sweet corn
Squashes, zucchini, and pumpkins (marrow and courgettes)

Lettuces

Garlic—avoid planting beans in the same location after garlic
Leeks—avoid planting beans in the same location after leeks
Onions—avoid planting beans in the same location after onions
Shallots—avoid planting beans in the same location after shallots

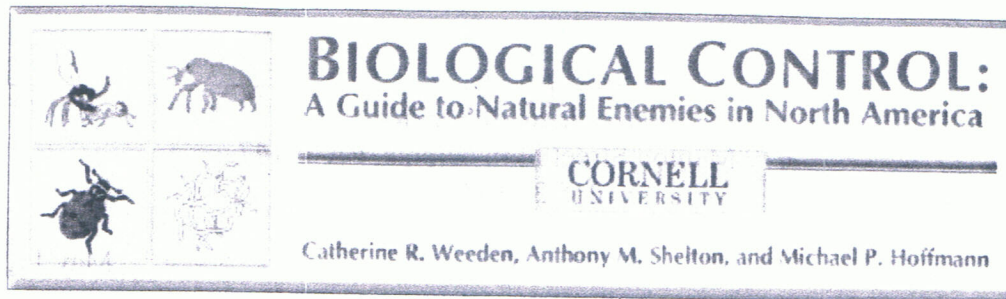
Perennial Vegetables

Not included in crop rotation are perennial vegetable crops which grow in the same spot for years in a row. Perennial crops include:

Asparagus
Globe artichokes
Jerusalem artichokes
Perennial herbs
Rhubarb
Seakale

SMALL GARDEN CROP ROTATION:

No garden is too small for crop rotation. A simple garden map showing where each crop is help you plan and plant a different crop in that spot next year. To plan crop rotation in a small garden, map out strips or blocks—rows or square feet—and avoid planting vegetables from the same family in that spot more than once every three years.



NEW Information and more pages are being added to this site on an ongoing basis.

Welcome to this Cornell University World Wide Web site! This guide provides photographs and descriptions of biological control (or biocontrol) agents of insect, disease and weed pests in North America. It is also a tutorial on the concept and practice of biological control and integrated pest management (IPM). Whether you are an educator, a commercial grower, a student, a researcher, a land manager, or an extension or regulatory agent, we hope you will find this information useful. The guide currently includes individual pages of approximately 100 natural enemies of pest species, and we envision continued expansion. On each of these pages you will see photographs, descriptions of the life cycles and habits, and other useful information about each natural enemy.

Four types of natural enemies are included in this guide and the guide logo shows, with links, representatives of each of the types. Clicking on any of the four parts of the logo, wherever it appears, will allow navigation to that section of the guide.



Parasitoids. This wasp is laying its egg inside an aphid where its young will develop. Parasitoid immatures develop on or inside a host, killing it as they mature. They emerge as adults and continue the

Predators. Lady beetles are well-known examples of predatory insects. A predator consumes many prey during its lifetime. The predators listed in this guide feed on insects and mites.

Pathogens. This nematode is just one example of a pathogen which may kill its host. Other pathogens include bacteria, viruses, fungi and protozoa. This section also includes antagonists which control plant diseases.

Weed Feeders. Weeds can be attacked by arthropods, vertebrates, and pathogens (fungi, viruses, bacteria, and nematodes). This weevil feeds only on one particular type of weed called purple loosestrife.

Homemade Fungicides

The following are some recipes for homemade fungicides that we have gathered from various sources, including the Alaska Master Gardeners Association, the Bio-Integral Resource Center (BIRC) and Penn State University. Not all of these recipes should be considered organic.

Organic Recipe for Mildew

- 1 tbspn. Baking Soda
- 1 tbspn. Olive Oil
- 1 tbspn. Liquid Coconut oil soap (such as Dr. Bonners Pure Castille Soap)
- 1 gallon water

Non-Organic Spray Formula: Mix into one gallon of water, in the order listed:

- 1 tbspn. of mild dishwashing soap (such as Palmolive or Ivory)
- 2 tbspn. of ultrafine horticultural oil (such as Sunspray™ oil)
- 1 heaping tbspn. of baking soda
- 1 tbspn. of fish oil/seaweed emulsion
- 3-5 drops of Superthrive®

Apple Cider Vinegar Fungicide: For leafspot, mildew, and scab

Mix 3 tablespoons of cider vinegar (5% acidity) with one gallon water and spray in the morning on infested plants.

Baking Soda Spray: for anthracnose, early tomato blight, leaf blight and spots, powdery mildew, and as a general fungicide Sodium bicarbonate commonly known as baking soda has been found to posses fungicidal properties. It is recommended for plants that already have powdery mildew to hose down all the infected leaves prior to treatment. This helps to dislodge as many of the spores as possibly to help you get better results. Use as a prevention or as treatment at first signs of any of the diseases.

To make: Mix 1 tablespoon baking soda, 2 1/2 tablespoons vegetable oil with one gallon of water. Shake this up very thoroughly. To this mix add 1/2 teaspoon of pure castille soap and spray. Be sure to agitate your sprayer while you work to keep the ingredients from separating. Cover upper and lower leaf surfaces and spray some on the soil. Repeat every 5-7 days as needed.

Chive Spray: For preventing apple scab and downy mildew on cucumber, pumpkin and zucchini.

To make: Put a bunch of chopped chives in a heat proof glass container, cover with boiling water. Let this sit until cool, strain and spray as often as two to three times a week.

Compost and Manure Teas: Many people have success with manure tea keeping blight and other pathogens away from plant. Soak the area around plants and use as a foliar spray. Do not use on seedlings as it may encourage damping-off disease.

To Make: Fill a 30 gallon trash can with water. Let sit for 24 hours to evaporate the additives (use rain water if you can). Add about 4 shovelfuls of manure to this and cover. Let it sit for 2-3 weeks, stirring once a day. Strain and apply as needed.

Various manures supply nutrients as follows:

Chicken manure: nitrogen rich. Use for heavy feeders such as corn, tomatoes and squash.

Cow Manure: contains potash, use for root crops.

um hydroxide). This converted the normally water-insoluble fat into a water-soluble soap. Commercial insecticidal soaps that are manufactured today contain a blend of selected fatty-acid chain lengths.

Mode of Action. When pesticidal soap touches the cuticle (outer body) of a susceptible insect, the fatty acids penetrate the insect's covering and dissolve into the membranes around its cells, disrupting their integrity. The cells leak and collapse, resulting in the dehydration and death of the insect. Susceptible insects become instantly paralyzed on contact with the soap; other insects become paralyzed for a short time, then recover. Soap can also penetrate the protective coating on plant tissue and fungi, causing dehydration and death.

Formulations. Pesticidal soaps are formulated as liquid concentrates and ready-to-use liquid sprays. A formulation of dry granules is currently being developed.

Safety. The principal value of soaps as pesticides is that they are virtually nontoxic to the user unless ingested in high doses. Even at high doses they have no serious systemic effects, although they can cause vomiting and general stomach upset. The LD₅₀ in rats of Safer™ Insecticidal Soap is greater than 16,500 mg/kg, and Safer's other soap products show similarly large margins of safety. At the doses found in commercial formulations, including concentrates, no mortality has been observed in test animals. Pesticidal soaps biodegrade rapidly in the soil. Refer to pp. 97-103 for a rundown of the safety precautions you should follow when applying any pesticide.

Soaps show relative selectivity in the range of insects they affect. Soft-bodied mites and sucking insects such as aphids, scale crawlers, whiteflies and thrips are the most susceptible. Some insects, including adult beetles, bees, wasps, flies and grasshoppers, are relatively unaffected, apparently due to resistance factors in the chemical composition of their

Table 7.1

Some Organisms Susceptible to Safer™ Insecticidal Soap^a

General Group	Specific Organisms ^b
aphids	cabbage, pea, bean, balsam wooly, spruce gall, many others
caterpillars	hemlock looper, tent caterpillars, Douglas-fir tussock moth
crickets	
earwigs	European earwig
fleas	cat flea, dog flea adults
flies	adult fruit flies, fungus gnats
grasshoppers	
lacebugs	
leafhoppers ^c	
mealybugs	
mites	two-spotted spider mite, red spider mite, bird mites, others
mosses, algae, lichens, liverworts	plant bugs
psyllids	pear psylla
sawflies	cherry, pear, and rose slugs (actually sawflies, not slugs)
scales	brown soft scale, some others
spittlebugs	
springtails ^d	
thrips	
whiteflies	greenhouse whiteflies, other whiteflies

^a Sources: Product labels and research papers provided by Safer, Inc.

^b If identified in the literature.

^c Efficacy highly variable.

^d When applied as a soil drench.

outer coverings. Slow-moving insects are more susceptible than highly mobile ones that can fly away from the spray. Thus, the adult forms of many beneficial insects, such as lady beetles, rapidly moving lacewings and syrphid flies, are not very susceptible; the flightless, soft-bodied

pre-adult forms of these insects are more susceptible.

Uses and Application. Specific uses of soap sprays are discussed throughout the book under various pest problems. Table 7.1 above lists the organisms that are susceptible to insecticidal soap. For sources of pesticidal

Table 7.2
Insects and Mites Killed or Repelled by Horticultural Oil Sprays^a

Scientific Name	Common Name	Scientific Name	Common Name
Aphids and Adelgids		<i>Oligonychus bicolor</i>	oak mite
<i>Aphis citricola</i>	citrus aphid	<i>O. ununguis</i>	spruce spider mite
<i>A. fabae</i>	bean aphid	<i>Panonychus ulmi</i>	European red mite
<i>A. pomi</i>	apple aphid	<i>Phytoptus pyri</i>	pear leaf blister mite
<i>Cinara</i> spp.	pine aphids	<i>Tetranychus urticae</i>	two-spotted spider mite
<i>Eulachnus agilis</i>	pine needle aphid		
<i>Hormaphis hamamelidis</i>	witch hazel leaf gall aphid	<i>Vasates aceriscrumena</i>	spindle gall mite
<i>Macrosiphum liriodendri</i>	tuliptree aphid	<i>V. quadripedes</i>	bladder gall mite
<i>M. rosae</i>	rose aphid		
<i>Myzocallis granovskyi</i>	hemlock wooly adelgid	Phylloxera and Psyllids	
		<i>Phylloxera</i> spp.	pecan phylloxera
		<i>Psylla pyricola</i>	pear psylla
Beetles		Sawflies	
<i>Diabrotica</i> spp.	corn rootworms	<i>Amauronemalus</i> spp.	locust sawflies
<i>Pyrrhalta luteola</i>	elm leaf beetle		
Bugs		Scales	
<i>Stephanitis pyrioides</i>	azalea lace bug	<i>Aonidiella aurantii</i>	California red scale
		<i>Asterolecanium</i> spp.	pit scales
Caterpillars		<i>Carulaspis juniperi</i>	juniper scale
<i>Archips</i> spp.	leafrollers	<i>Chionaspis pinifoliae</i>	pine needle scale
<i>Heliothis zea</i>	corn earworm	<i>Coccoidea</i> spp.	scales
<i>Malacosoma americanum</i>	eastern tent caterpillar	<i>Coccus hesperidum</i>	brown soft scale
<i>Spodoptera frugiperda</i>	fall armyworm	<i>Gossyparia spuria</i>	European elm scale
<i>Yponomeuta multipunctella</i>	euonymus webworm	<i>Lecanium corni</i>	lecanium scale
		<i>Lepidosaphes gloveri</i>	Glover scale
Fungus Gnats and Leafminers		<i>Macrosiphum liriodendri</i>	tuliptree scale
<i>Liriomyza</i> spp.	leafminers	<i>Melanaspis obscura</i>	obscure scale
<i>Lycoriella mali</i>	fungus gnat	<i>Neolecanium cornuparvum</i>	magnolia scale
		<i>Pulvinaria amygdali</i>	cottony peach scale
Mealybugs		<i>P. innumerabilis</i>	viburnum cottony scale
<i>Dysmicoccus wistariae</i>	taxus mealybug	<i>Saissetia oleae</i>	black scale
<i>Planococcus citri</i>	citrus mealybug	<i>Unaspis euonymi</i>	euonymus scale
Mites		Whiteflies	
<i>Aculus ligustri</i>	privet rust mite	<i>Bemesia tabaci</i>	sweet-potato whitefly
<i>Eotetranychus tillarum</i>	linden spider mite	<i>Trialeurodes vaporariorum</i>	greenhouse whitefly
<i>Epitrimerus pyri</i>	pear rust mite		

^a This list of species has been assembled from a number of research papers on the effectiveness of oils on various pest species. Many other insects and mites are no doubt also susceptible to oil sprays, so experimentation is encouraged.

Ten Common Vegetable Pests

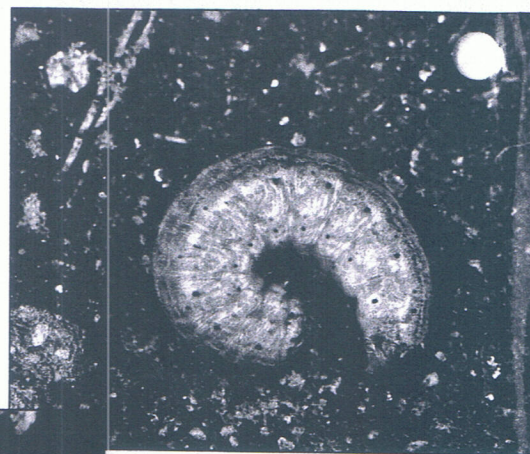
A look at what's eating your garden

Katharine D. Widin

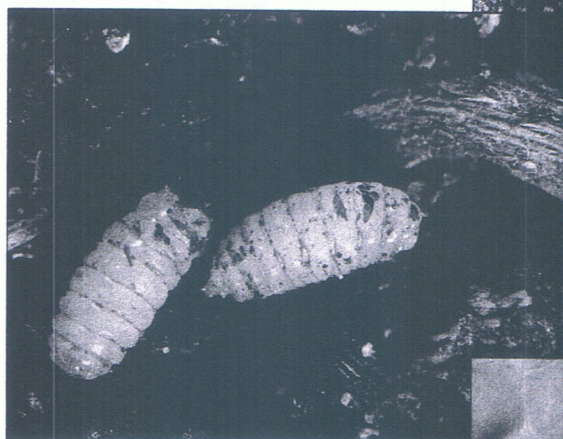
WHERE THERE ARE VEGETABLE gardens, there are vegetable-eating insects. Luckily, most problems are caused by a relatively small assortment of pests, and most of us soon learn to recognize the culprits. To reduce the damage, the most progressive gardener turns to cultural and biological controls as opposed to chemical pesticides, since the latter can kill beneficial organisms as well and can even threaten the health of the gardener.

Cultural controls begin with the layout of the plantings themselves. Each year I shift the vegetables in my garden to a location where they or their relatives were not growing the previous year. By practicing crop rotation, I help to prevent insects (and diseases) from building up large populations over the years.

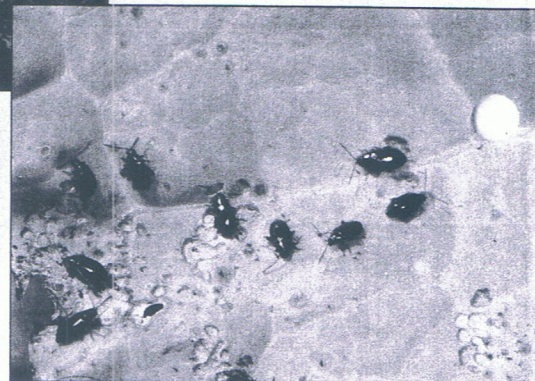
One of the best ways to reduce garden pests, and one that is often overlooked, is to thoroughly clean up garden refuse in the fall. After removing spent plants, till the soil six to eight inches deep. Till again more shallowly a few weeks later and again before planting in the spring. Tilling the soil exposes overwintering larvae, pupae,



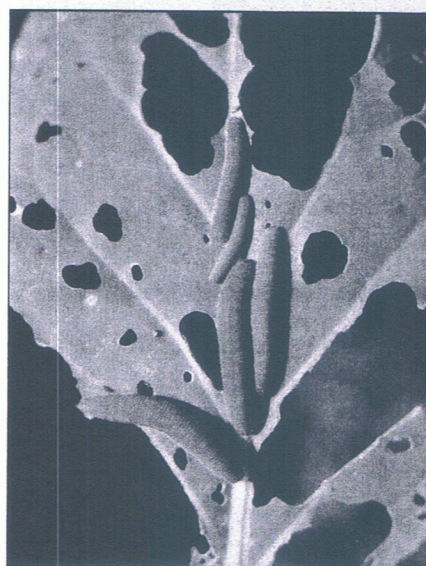
1. Cutworm



2. Cabbage-root maggots



3. Flea beetles



4. Cabbage worms



5. Mexican bean beetles



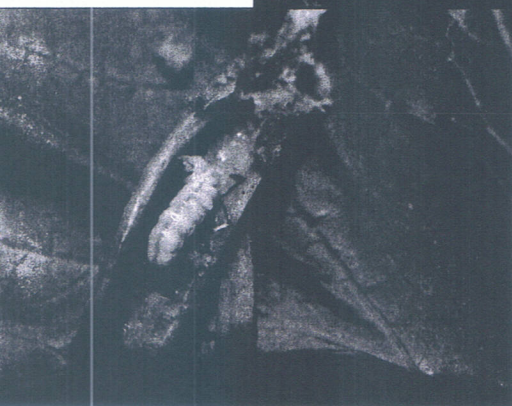
6. Colorado potato beetle



7. Striped cucumber beetles



8. Tomato hornworm



9. Squash-vine borer



10. Corn earworms

and adult insects to cold and dries them out. Many of the exposed insects will also become dinner for the resident bird population. Another way to reduce pests in the garden is to plant robust, healthy transplants, which will withstand and outgrow insect attacks better than spindly, weak ones.

None of this guarantees that pests won't find my vegetables, so wherever possible I try to see that they will encounter a barrier first. Placing row covers made of lightweight polyester or cotton netting over your vegetables is a simple way to prevent adult insects from laying eggs on or near their host plants. Covers must be put on immediately after the plants go in the ground, and their edges should be tight to the soil. In the case of plants like cucumbers and squash, which require insect pollination, covers will have to be taken off once the plants begin to bloom.

Even with covers in place, I check the plants every few days because insects sometimes get through. When this occurs, my first response is to pick them off by hand. Handpicking is a good way to control many insects. Walk through the garden every few days and check the upper and lower leaf surfaces for feeding damage and insect pests. I keep a jar of oil or kerosene handy and drop in whatever pests I find. If you decide you need to spray, do it when the pests are small and an infestation is in its early stages. Try hot pepper or garlic as repellents and diatomaceous earth or insecticidal soap as contact insecticides before resorting to stronger, more toxic solutions. *Bacillus thuringiensis*, known as *Bt*, is a biological control that is toxic to caterpillars. Purchasing ladybugs and praying mantises to control insects is usually unnecessary, since a gardener who is careful not to kill resident populations in the first place will find an adequate supply already at hand.

The following is a basic rogues' gallery of 10 vegetable pests, arranged roughly in the order that gardeners will encounter them during the year. Most years, gardeners can expect to meet up with at least some of them.


One of the first pests to appear during the season is the **cutworm**, which likes to feed on beans, tomatoes and their relatives, lettuce, corn, onions, and members of the cabbage family such as cabbage, broccoli, cauliflower, and Brussels sprouts. These smooth, dull-gray or brown caterpillars grow to be one to two inches long and are usu-

3. PROVIDE ALTERNATIVE FOOD SOURCES

When pest populations are low, beneficial insects will feed on pollen, nectar or plant juices to supplement or replace their insect diet.

4. INCORPORATE OTHER PEST MANAGEMENT STRATEGIES

In order to sustain their food source, beneficial insects must allow some of their prey to feed and reproduce. As a result, they will not always be able to solve all of your pest problems. Therefore, other methods of pest management in conjunction with your beneficials may be a good idea. Choosing plants that are resistant to pests works well. Pesticides are also an option, but should be used sparingly as pesticides are harmful to the environment as well as to beneficial insects. Before using a pesticide, research should be done to uncover any adverse effects that these pesticides may have on anything that you don't want harmed. Information on pesticides can be obtained through the use of gardening journals, library catalogs, and internet use.

Pollen Producing	Nectar Producing
	
Snowdrop Crocus Red Maple Dandelion Apple Strawberry Coltsfoot Grape Hyacinth Mustard Squash family Raspberry/Blackberry	Snowdrop Crocus Dandelion Strawberry Grape Hyacinth Mustard Squash family Raspberry/Blackberry Clover Alfalfa Queen Anne's Lace

ORDERING INSECTS FROM DISTRIBUTORS

Although it is very helpful to know how to identify and attract beneficial insects, sometimes it is much easier and more convenient to go to a distributor of beneficial insects and acquire a population of your own to release into your garden. After the insects have been ordered and released, you must keep them happy and satisfied with their new home so that they will want to stay and make a permanent home of your garden.

Following is a list of beneficial insect providers (these providers will package your insects and ship them to you):

The Beneficial Insect Co.
 (Glendale, NC)
www.thebeneficialinsectco.com

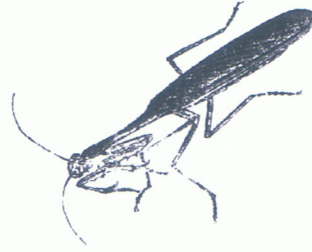
Natural Pest Controls
 (Orangevale, CA)
www.natpestco.com

Buglogical Control Systems
 (Tucson, AZ)
www.buglogical.com

SOME COMMON TYPES OF BENEFICIAL INSECTS

Praying Mantids (*Mantodea*)

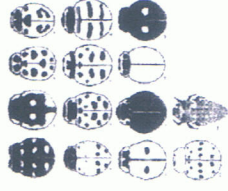
Mantids are very efficient and deadly predators that capture and eat a wide variety of insects and other small prey. They have a neck that allows the head to rotate 180* while waiting for a meal to wander by. Camouflage coloration allows mantids to sit on twigs and stems while they wait. Pesticides drastically reduce the number of mantids in a given area. If you want to encourage mantids, you should use as few pesticides as possible, and allow some vegetation to grow to provide cover for them.



Lady Beetles

(*Coleoptera, coccinellidae*)

Lady Beetles are the most commonly known of all beneficial insects. Both adults and larvae feed on may different soft bodied insects, but aphids are their main food source.



Adult lady beetles are dome shaped, oval, or convex. They are often shiny with short legs and antennae.

Wing covers are dark red-dish-orange to pale yellow with or without black spots or irregular marks. The head is concealed from above. growing pollen flowers. (see chart on page 2) and allowing weeds(dandelion, wild carrot, and yarrow) to grow can attract lady beetles to your area. Wheat is a combination of whey and yeast that can be sprayed on plants to attract lady beetles (wheat is an artificial diet). This product can be ordered online through www.agrobiologicals.com Protect egg clusters, larvae, and pupae on plants. To conserve lady beetles, use as few pesticides as possible.

Assassin Bugs

(*Hemiptera, reduviidae*)

Assassin bugs are generalist predators that feed on a variety of insects. These predators are closely related to plant sucking bugs. They have an elongated body with grasping forelegs and a pronounced head. Adult insects are brown in color and reach a length of 5 to 6.5 inches. Assassin

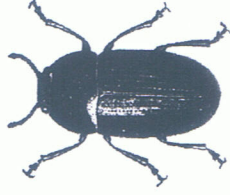


bugs feed on many different insects, but because they have sucking mouthparts, tend to feed on softer bodied prey such as caterpillars. These bugs can be attracted to the garden by a cover crop such as a border of alfalfa. Assassin bugs have a higher tolerance to insecticides and pesticides than do most other beneficial insects.

Ground Beetles

(*Coleoptera, Carabidae*)

Ground beetles eat soil dwelling pests, including slugs and snails. Sometimes they also feed on pests that are on plants. These beetles will seek cover in permanent pathways and perennial beds. The adult beetle ranges from 1/8 to 1 1/4 inches long. They are usually elongated, heavy bodied, and slightly or distinctly tapered at the head end. The ground beetle is generally dark, but can also be purple or metallic green or multi-colored.



Soldier beetles

(*Coleoptera, Cantharidae*)

These beetles are elongated, soft-bodied insects and about 1/2 inches long. Colors vary from yellow to red with brown or black wings and trim. Most of the larvae are carnivorous, feeding on insects in the soil. Larvae stay in damp soil and debris or loose bark. The adults are also predators, eating caterpillars, eggs, aphids, and other soft bodied insects.

Rove Beetle

(*Coleoptera, Staphylinidae*)

Rove beetles are important predators of maggots and mites. Most rove beetles are slender with a very slender and muscular, flexible abdomen. Adults range from .04" to 1.57" long, although all are less than .28" long. Adults are mostly nocturnal (meaning that they come out mostly at night). Providing a moist area especially with decaying plant or animal material can attract rove beetles. A good way to do this is to start a compost pile.



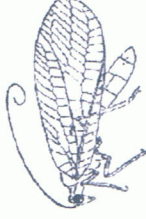
Flower Flies

(*Hemiptera, Anthocoridae*)

Flower flies feed on aphids. Adults are 1/2 inches long. They resemble bees and are yellow and black striped or black and white striped. Adult flower flies can be attracted by pollen and nectar producing plants.

Lacewings (*Neuroptera*)

Lacewings are green and brown with large eyes relative to their head. Adults are generally 1/2-3/4 inches long. These insects are generalist predators. They feed on aphids, mites, thrips, soft scales, and other soft-bodied prey. Adults are attracted by the odor of aphid honeydew and lay their eggs near aphid colonies.



For More Information about
Beneficial Insects:

Starcher, Allison Mia. **Good Bugs For Your Garden**. Chapel Hill: Algonquin Books, 1995. p 28-35

Metcalf, Robert Lee. **Destructive and Useful Insects: Their Habits and Control**. McGraw Hill, 1993. p. 23-32

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