APPENDIX 2

Biological Controls

If you were to ask a farmer or backyard gardener how to control a plant pest, you might be given the name of a chemical spray. If not used properly, though, chemical pesticides can be harmful to the environment and may become ineffective if the insects develop resistance (see Chapter 15). **Biological controls** provide an alternative to synthetic chemical sprays.

Chemical sprays may promote pest invasions because they may kill beneficial insects along with the undesirable ones. In addition, the pests, through mutations, may become resistant to the sprays. In undisturbed natural areas, weeds are never a problem, and even though pests may be present, they seldom destroy the community. Why is this so? You may recall from your reading that all members of a community are in ecological balance with one another. The plants produce a variety of substances that may either repel or attract insects, inhibit or promote the growth of other plants, and generally contribute to the health of the community as a whole.

Virtually all insects have their own pests and pathogens, as do most other living organisms. Each pest ensures, at least indirectly, that the various species of a community are perpetuated. This principle of nature can be applied, to a certain extent, to farming and gardening. The following are some general and specific biological controls now in widespread use. Others showing promise for the future are included.

General Controls

Establishment of Beneficial Organisms

The living organisms discussed here as biological control agents are typically available for purchase from commercial vendors. An Internet search will identify sources.

Ladybugs (Family Coccinellidae)

The small and often colorful beetles called *ladybugs,* and particularly their larval stages, consume large numbers of aphids, thrips, insect eggs, weevils, and other pests. While ladybugs may be purchased, if given a chance, they probably will establish themselves without being imported. When obtained from outside of the local area, they should be placed in groups at the bases of plants on which pests are present, preferably in the early evening after watering.

Lacewings (Families Chrysopidae and Hemerobiidae)

Lacewings are slow-flying, delicate-winged insects that consume large numbers of aphids, mealybugs, and other pests. They lay their eggs on the undersides of leaves, each egg being borne at the tip of a slender stalk. The larvae consume the immature stages of leafhoppers, bollworms, caterpillar eggs, mites, scale insects, thrips, aphids, and other destructive pests.

Praying Mantis (Family Mantidae)

About 20 species of *praying mantis* are now established in the United States. These are voracious feeders that prey somewhat indiscriminately on flying insects and sometimes even on other mantises. They can be established by tying their egg cases to tree branches or at other locations above the ground. The egg cases, which form compact masses about 2.5 to 5.0 centimeters (1 to 2 inches) long, are obtainable from commercial sources.

Trichogramma Wasps (Family Trichogrammatidae)

Trichogramma wasps are minute insects, mostly less than 1 millimeter (1/25 inch) long; they parasitize insect eggs and are known to have significantly reduced populations

of well over 100 different insect pests, including alfalfa caterpillars, armyworms, cabbage loopers, cutworms, hornworms, tent caterpillars, and the larvae of many species of moths. As with other insects used as biological controls, trichogramma wasps should not be released unless there are pest eggs in the vicinity, as the wasps may otherwise parasitize eggs of beneficial butterflies and other useful insects.

Ichneumon Wasps (Family Ichneumonidae)

The *ichneumon wasps* belong to a very large family of wasps that are mostly stingless. These tiny wasps tend to be slender and have long ovipositors that are sometimes longer than the body. Most insects are parasitized by at least one species of ichneumon; many species parasitize the larval stages of insects, consuming the host internally after hatching from eggs deposited on the body; alternatively, they may complete development in a later stage. Ichneumons will usually appear naturally in a backyard or farm population of pests if toxic sprays and other unnatural conditions have not interfered with their normal activities.

Tachinid Flies (Family Tachinidae)

Many members of the large family of *tachinid flies* resemble houseflies or bumblebees. All parasitize other insects, including a large variety of caterpillars, Japanese beetles, European earwigs, grasshoppers, gypsy moths, tomato worms, sawflies, and various beetles.

Mites (Family Phytoseiidae and others)

Species of several genera of mites prey on red spider mites and have been used successfully to control other mites and scale insects.

Mosquito Fish (Gambusia affinis)

Mosquito fish have been added to bodies of fresh water all over the world to control mosquitoes. The fish feed on mosquito larvae, particularly as the larvae rise to the surface for air. One mosquito fish can consume thousands of larvae per day.

Use of Pathogenic Bacteria

Bacillus thuringiensis (Bt) is one of several pathogenic bacteria registered for use on edible plants in the United States. It reproduces only in the digestive tracts of caterpillars and is harmless to humans and all other wildlife, including earthworms, birds, and mammals. It is exceptionally effective against a wide range of caterpillars, such as tomato hornworms and fruitworms, cabbage worms and loopers, grape leaf rollers, corn borers, cutworms, fall webworms, and tent caterpillars. It is mass-produced and sold in a powdered spore form at nurseries and garden supply stores under the trade names of *Dipel, Biotrol,* and *Thuricide*. The powder is mixed with water and applied as a spray.

Establishment of Toads and Frogs

It has been estimated that a single adult toad will consume about 10,000 insects and slugs in one growing season. Toads and frogs feed at night when snails, slugs, sowbugs, earwigs, and other common pests are active.

Use of Beneficial Nematodes

Several species of these abundant microscopic roundworms are notorious for damaging economically important crops when they invade plant roots and other underground organs. Most species, however, are either harmless or beneficial to plants. They have been used successfully in parasitizing cabbage worm caterpillars, codling moth larvae, Japanese beetle grubs, and tobacco budworms and have shown considerable potential against other pests. One species that has been particularly effective in controlling ants, beetles, bugs, flies, wasps, and many other insects is the caterpillar nematode (*Neoaplectana carpocapsae*). It carries a symbiotic bacterium (*Xenorhabdus nematophilus*), which multiplies rapidly in the host, killing most insects within 24 hours after initial contact.

Use of Limonoid Sprays

Limonoids are bitter substances found in the rinds, seeds, and juice of citrus fruits (especially grapefruit). If the rinds and seeds of two or three fruits are ground up and soaked overnight in a pint of water, and the solid material is strained out, the liquid may then be sprayed on plants. The bitter principle apparently stops or reduces the feeding of larvae on the foliage. In experiments, limonoid sprays have proved effective against corn earworm, fall armyworm, tobacco budworm, and pink bollworm, but undoubtedly will deter many other pests as well.

Use of Liquefied Pest Sprays

Jeff Cox, an editor of Rodale's *Organic Gardening* magazine, called attention to this method of pest control in the magazine in October 1976, and again in May 1977. Insect pests or slugs are gathered in small quantities and liquefied with a little water in a blender. The material is then further diluted with water and sprayed throughout the infested area. It is not known why spraying with "bug juice" is effective against pests. It is known, however, that virtually all organisms harbor viruses. It has been theorized that even the inactive viruses carried by healthy insects and slugs may somehow be activated in the process of liquefaction. The viruses would be spread throughout an entire yard or farm if all parts of the area were sprayed. Most viruses are highly specific, generally attacking a single species of organism. M. Sipe, a Florida entomologist who recommended the "bug juice" technique, also suggested that the odor of the liquefied insects possibly attracts their predators and parasites or that the insects' distress **pheromones** (naturally produced insect chemicals that influence sexual or other behavior) are released by the blender, with the pheromones acting as an insect repellent. Possibly the observed effects of spraying "bug juice" are the result of a combination of viruses, predator attraction, and repellent pheromones. Sipe warns that

if one tries this method of pest control, care should be taken to use only pest species and only those that are doing significant damage. Failure to heed this warning could disrupt the activities of natural predators and other natural controls present. This approach needs extended testing and investigation of its safety for use by humans, but test results over the past 20 years in various areas of North America have yielded impressive results with no evidence of harm to humans or beneficial organisms.

Use of Resistant Varieties

Many plants have genetic mechanisms to protect themselves against pests and pathogens. In some cases, resistance is controlled by many genes and is difficult to breed into improved cultivars. However, other forms of resistance are controlled by major genes, which breeders have introduced into cultivars. Several tomato varieties, for example, are listed as being *VFN*. The letters *V* and *F* indicate a resistance to *Verticillium* and *Fusarium* (common pathogenic fungi), while the letter *N* denotes a resistance to *root-knot nematodes.*

Interplanting with Plants That Produce Natural Insecticides or Substances Offensive to Pests

Many plant species produce substances that repel a significant number of pests, but none produce anything that repels all pests. Among the best-known plant producers of insect repellents are marigolds; garlic; and members of the Mint Family, such as pennyroyal, peppermint, basil, and lavender.

Specific Controls

Weeds

Table A2.1 provides information from the Weed Science Society of America about biological control of weeds through use of insects and plant pathogens known to decrease weed populations. The best-known example of this strategy is the introduction of a moth to control the prickly pear cactus in Australia. This has effectively controlled the cactus for over 50 years.

Insects

The maintenance of ecological balance in nature includes a vast array of predator-prey relationships between animals, birds, insects, and other organisms. Specific biological controls for several types of insect pests, in addition to the general controls previously discussed, are given in Table A2.2.

Companion Planting

Despite the scientific evidence on the subject to date, a significant amount of the "backyard biological control" that is practiced today is based primarily on empirical information. Such information has been obtained from thousands of gardeners and farmers who have tried various techniques with their plantings and pest controls. As a result, they have come to conclusions that certain things work, while others do not, but they have not deliberately set up controlled experiments, nor have they necessarily understood the scientific basis for what they have observed. This does not mean that their observations are not useful or that they are invalid. In fact, such empirical observations have often been the inspiration for investigations and experiments by scientists. The scientific investigations have sometimes revealed that the empirical observations were biased or not carefully made or that erroneous conclusions had been drawn, but frequently, sound scientific bases for these observations have been uncovered.

Further insights into how plants inhibit or enhance the growth of others and into the nature of their resistance to disease- or insect-repelling mechanisms continue to be discovered. Observations of such phenomena in the past have led organic gardeners and others to the practice of *companion planting,* which involves the interplanting of various crops and certain other plants in such a way that each species derives some benefit from the arrangement. The companion planting list in Table A2.3, based primarily on empirical information, appeared in the February 1977 issue of *Organic Gardening and Farming* magazine. It is included here with the permission of Rodale Press, Inc.

Additional Reading

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Table A2.1 Weeds and Agents Involved in Their Biological Control

Weed	Agent(s) of Biological Control
Alligator weed (*Alternanthera philoxeroides*)	Flea beetles (*Agasicles hygrophila*)
Bladder campion (*Silene cucubalus*)	Tortoise beetle (*Cassida hemisphaerica*)
Brazil peppertree (*Schinus terebinthifolius*)	Weevil (*Bruchus atronotatus*) and others
Brushweed (*Cassia surattensis*)	Imperfect fungus (*Cephalosporium* sp.)
Curly dock (*Rumex crispus*)	Rust (*Uromyces rumicis*)
Curse (*Clidemia hirta*)	Thrip (*Liothrips urichi*) and others
Cypress spurge (*Euphorbia cyparissias*)	Sphinx moth (*Hyles euphorbiae*)
Dalmatian toadflax (*Linaria dalmatica*)	Leaf miner (*Stagmatophora serratella*) and others
Emex (*Emex australis*)	Seed weevils (*Apion antiquum*) and others
Gorse (*Ulex europaeus*)	Seed weevils (*Apion ulicis*) and others
Halogeton (*Halogeton glomeratus*)	Casebearer (*Coleophora parthenica*) and others
Hawaiian blackberry (*Rubus penetrans*)	Sawflies (*Pamphilius sitkensis, Priophorus morio*) and others
Jamaica feverplant (puncture vine) (*Tribulus terrestris*)	Weevils (*Microlarinus* spp.)
Joint vetch (*Aeschynomene virginica*)	Imperfect fungus (*Colletotrichum gloeosporioides*)
Klamath weed (*Hypericum perforatum*)	Leaf beetles (*Chrysolina* spp.), buprestid beetle (*Agrilus hyperici*)
Lantana (*Lantana camara*)	Seed weevil (*Apion* sp.), ghost moth (*Hepialus* sp.), plume moth (*Platyptilia pusillidactyla*), hairstreaks (*Strymon* spp.), and others
Leafy spurge (*Euphorbia esula*)	Wood-boring beetle (*Oberea* sp.) and others
Mediterranean sage (*Salvia aethiopis*)	Snout beetles (*Phrydiuchus* spp.)
Milkweed vine (*Morrenia odorata*)	Oomycete fungus (*Phytophthora citrophthora*), rust (*Aecidium asclepiadinum*)
Prickly pear (*Opuntia* spp.)	Moth (*Cactoblastis cactorum*), cochineal insects (*Dactylopius* spp.), and others
Puncture vine (*see* Jamaica feverplant)	Weevils (*Microlarinus* spp.)
Scotch broom (*Cytisus scoparius*)	Seed weevil (*Apion fuscirostre*) and others
Skeleton weed (*Chondrilla juncea*)	Gall mite (*Aceria chondrillae*), root moth (*Bradyrrhoa gilveolella*), rust (*Puccinia chondrillina*), powdery mildews (*Erysiphe cichoracearum, Leveillula taurica*)
Spiny emex (*Emex spinosa*)	Seed weevil (*Apion antiquum*)
Tansy ragwort (*Senecio jacobaea*)	Seed fly (*Hylemya seneciella*), cinnabar moth (*Tyria jacobaeae*), leaf beetle (*Longitarsus jacobaeae*)
Thistles:	
Bull thistle (*Cirsium vulgare*)	Weevil (*Ceuthorrhynchidius horridus*), tortoise beetle (*Cassida rubiginosa*)
Canada thistle (*Cirsium arvense*)	Weevil (*Ceutorhynchus litura*), flea beetle (*Altica carduorum*), stem gall fly (*Urophora cardui*)
Diffuse knapweed (*Centaurea diffusa*)	Seed fly (*Urophora affinis*)
Italian thistle (*Carduus pycnocephalus*)	Flea beetles (*Rhinocyllus conicus, Psylliodes chalcomera*), weevil (*Ceutorhynchus trimaculatus*)
Milk thistle (*Silybum marianum*)	Flea beetle (*Rhinocyllus conicus*)
Musk thistle (*Carduus nutans*)	Weevils (*Ceutorhynchus trimaculatus, Ceuthorrhynchidius horridus, Rhinocyllus conicus*), flea beetle (*Psylliodes chalcomera*)
Perennial sowthistle (*Sonchus arvensis*)	Peacock fly (*Tephritis dilacerata*)
Plumeless thistle (*Carduus acanthoides*)	Tortoise beetle (*Cassida rubiginosa*), seed weevil (*Rhinocyllus conicus*), weevil (*Ceuthorrhynchidius horridus*)
Russian thistle (*Salsola kali var. tenuifolia*)	Casebearer (*Coleophora parthenica*) and others
Slenderflower thistle (*Carduus tenuiflorus*)	Weevil (*Ceutorhynchus trimaculatus*)
Spotted knapweed (*Centaurea maculosa*)	Seed fly (*Urophora affinis*) and others
Star thistle (*Centaurea nigrescens*)	Weevil (*Ceuthorrhynchidius horridus*)
Yellow star thistle (*Centaurea solstitialis*)	Seed fly (*Urophora siruna-seva*)
Water hyacinth (*Eichhornia crassipes*)	Weevils (*Neochetina bruchi, N. eichhorniae*), moth (*Sameodes albiguttalis*)
Water purslane (*Ludwigia palustris*)	Snout beetle (*Nanophyes* sp.)

Table A2.2 Biological Controls for Several Types of Insect Pests

Insect	Control
Ants (about 8,000 spp. within the Superfamily Formicoidea)	Ants that carry aphids into trees and consume ripening fruits can be prevented from getting farther than the trunk by applying a band of sticky material around the trunk. A commercial preparation sold under the trade name of *Tanglefoot* is particularly effective. A water suspension of ground hot peppers (*Capsicum* spp.) used as a spray can act as an ant deterrent. *Caution:* Many ants are beneficial to a balanced ecology; they should not be decimated indiscriminately.
Grasshoppers (there are several families of grasshoppers, but the insects that usually constitute the most serious pests are species of *Melanoplus, Family Acrididae*)	In 1980, the Environmental Protection Agency permitted private companies to begin the mass culture of a protozoan, *Nosema locustae,* for use in controlling rangeland grasshoppers. Tests have shown that properly timed applications of spores mixed with wheat bran can reduce grasshopper populations by up to 50%.
Gypsy moths (*Porthetria dispar*)	Parasitic wasps (*Apanteles flavicoxis, A. indiensis*) imported from India lay their eggs in gypsy moth caterpillars and kill large numbers.
Japanese beetles (*Popillia japonica*)	The pathogenic bacterium *Bacillus popillae,* which is sold commercially, is specific for Japanese beetle larvae. It causes what is known as "milky spore disease" in the grubs while they are still in the soil, and it is very destructive.
Mealybugs (*Pseudococcus* spp.)	The small brown beetles called *crypts* (*Cryptolaemus montrouzieri*) effectively control mealybugs in greenhouses and also outdoors on apple, pear, peach, and citrus trees.
Mosquitoes (*Culex* spp., *Anopheles* spp., and others)	The bacterium *Bacillus thuringiensis* var. *israelensis* has proved to be very effective in destroying mosquito larvae. A fungus (*Lagenidium giganteum*) has also proved highly effective against mosquito larvae if the temperature is above 20°C (68°F).
Red spider mites (*Tetranychus telarius*)	Predatory mites (*Phytolesius persimilis,* which works best when weather is not hot, and *Amblyseius californicus,* which is more effective in hot weather) effectively control populations of red spider mites.
White flies (*Trialeurodes vaporariorum*)	A minute wasp, *Encarsia formosa,* parasitizes white flies exclusively. The wasps have been known to be very effective in greenhouses. Alternatively, white flies are attracted to the color yellow. Large numbers of white flies are trapped when a yellow board is sprayed or painted with any sticky substance and placed in the vicinity of the pests.

Table A2.3 Companion Plants

Plant	Companions and Effects
Asparagus	Tomatoes, parsley, basil
Basil	Tomatoes (improves growth and flavor); said to dislike rue; repels flies and mosquitoes
Beans	Potatoes, carrots, cucumbers, cauliflower, cabbage, summer savory, most other vegetables and herbs; around house plants when set outside
Beans (bush)	Sunflowers (beans like partial shade, sunflowers attract birds and bees), cucumbers (combination of heavy and light feeders), potatoes, corn, celery, summer savory
Beets	Onions, kohlrabi
Borage	Tomatoes (attracts bees, deters tomato worm, improves growth and flavor), squash, strawberries
Cabbage Family	Potatoes, celery, dill, chamomile, sage, thyme, mint, pennyroyal, rosemary, lavender, beets, onions. Aromatic plants deter cabbage worms
Carrots	Peas, lettuce, chives, onions, leeks, rosemary, sage, tomatoes
Catnip	Plant in borders; protects against flea beetles
Celery	Leeks, tomatoes, bush beans, cauliflower, cabbage
Chamomile	Cabbage, onions

Table A2.3 Companion Plants

Plant	Companions and Effects
Chervil	Radishes (improves growth and flavor)
Chives	Carrots; plant around base of fruit trees to discourage insects from climbing trunk
Corn	Potatoes, peas, beans, cucumbers, pumpkin, squash
Cucumbers	Beans, corn, peas, radishes, sunflowers
Dill	Cabbage (improves growth and health), carrots
Eggplant	Beans
Fennel	Most plants are supposed to dislike it
Flax	Carrots, potatoes
Garlic	Roses and raspberries (deters Japanese beetle); with herbs to enhance their production of essential oils; plant liberally throughout garden to deter pests
Horseradish	Potatoes (deters potato beetles); around plum trees to discourage curculios
Lamb's quarters	Nutritious edible weed; allow to grow in modest amounts around corn plants
Leek	Onions, celery, carrots
Lettuce	Carrots and radishes (lettuce, carrots, and radishes make a strong companion team), strawberries, cucumbers
Lovage	Plant here and there in garden
Marigolds	The workhorse of pest deterrents; keeps soil free of nematodes; discourages many insects; plant freely throughout garden
Marjoram	Here and there in garden
Mint	Cabbage family; tomatoes; deters cabbage moth
Mole plant	Deters moles and mice if planted here and there throughout the garden
Nasturtium	Tomatoes, radishes, cabbage, cucumbers; plant under fruit trees. Deters aphids and pests of cucurbits
Onion	Beets, strawberries, tomato, lettuce (protects against slugs), beans (protects against ants), summer savory
Parsley	Tomato, asparagus
Peas	Squash (when squash follows peas up trellis), plus grows well with almost any vegetable; adds nitrogen to the soil
Petunia	Protects beans; beneficial throughout garden
Pigweed	Brings nutrients to topsoil; beneficial growing with potatoes, onions, and corn; keep well thinned
Potato	Horseradish, beans, corn, cabbage, marigold, limas, eggplant (as trap crop for potato beetle)
Pot marigold	Helps tomato, but plant throughout garden as deterrent to asparagus beetle, tomato worm, and many other garden pests
Pumpkin	Corn
Radish	Peas, nasturtium, lettuce, cucumbers; a general aid in repelling insects
Rosemary	Carrots, beans, cabbage, sage; deters cabbage moth, bean beetles, and carrot fly
Rue	Roses and raspberries; deters Japanese beetle; keep it away from basil
Sage	Rosemary, carrots, cabbage, peas, beans; deters some insects
Southernwood	Cabbage; plant here and there in garden
Soybeans	Grows with anything, helps everything
Spinach	Strawberries
Squash	Nasturtium, corn
Strawberries	Bush beans, spinach, borage, lettuce (as a border)
Summer savory	Beans, onions; deters bean beetles
Sunflower	Cucumbers
Tansy	Plant under fruit trees; deters pests of roses and raspberries; deters flying insects; also Japanese beetles, striped cucumber beetles, squash bugs, deters ants
Tarragon	Good throughout garden
Thyme	Here and there in garden; deters cabbage worm
Tomato	Chives, onion, parsley, asparagus, marigold, nasturtium, carrot, limas
Turnip	Peas
Valerian	Good anywhere in garden
Wormwood	As a border, keeps animals from the garden
Yarrow	Plant along borders, near paths, near aromatic herbs; enhances essential oil production of herbs