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FARMSCAPING

TO ENHANCE BIOLOGICAL CONTROL

PEST MANAGEMENT SYSTEMS GUIDE

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Hedgerow of insectary plants at Fong Farms Ltd. in Woodland, CA.

Abstract: *This publication contains information about increasing and managing biodiversity on a farm to favor beneficial organisms, with emphasis on beneficial insects. The types of information farmscapers need to consider is outlined and emphasized. Appendices have information about various types and examples of successful "farmscaping" (manipulations of the agricultural ecosystem), plants that attract beneficials, pests and their predators, seed blends to attract beneficial insects, examples of farmscaping, hedgerow establishment and maintenance budgets, and a sample flowering period table.*

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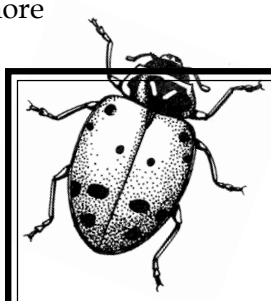
Introduction

"Farmscaping" is a whole-farm, ecological approach to pest management. It can be defined as the use of hedgerows, insectary plants, cover crops, and water reservoirs to attract and support populations of beneficial organisms such as insects, bats, and birds of prey.

In some respects, beneficial organisms should be considered—and managed as—mini-livestock. The larger varieties of livestock are healthier and reproduce more readily when provided an adequate and nutritious diet. Likewise, "mini-livestock" require adequate supplies of nectar, pollen, and herbivorous insects and mites as food to sustain and increase their populations. The best source of these foods is flowering plants. Flowering plants are particularly important to adults of the wasp and fly families, which require nectar and pollen sources in order to reproduce the immature larval stages that parasitize or prey on insect pests.



Beneficial insects should be viewed as mini-livestock. They will be healthier, reproduce more readily, and be more effective biocontrols when provided habitat with an adequate and easily available diet of nectar, pollen, and herbivorous insects and mites.

However, using a *random* selection of flowering plants to increase the biodiversity of a farm may favor pest populations over beneficial organisms. It is important to identify those plants, planting situations, and management practices that best support populations of *beneficial* organisms.

Farmscaping, like other components of sustainable agriculture, requires more knowledge and management skill on the part of the grower than conventional pest management. The investment in knowledge and management may yield such benefits as:

- A reduction in pesticide use
- Savings in pesticide costs
- Reduced risk of chemical residues on farm products
- A safer farm environment and more on-farm wildlife.

However, farmscaping is not a magical cure for pest problems. It is simply an ecological approach to pest management that can be an integral component of a biointensive integrated pest management (IPM) program.

The use of farmscaping to increase beneficial organism habitat must be understood and practiced within the context of overall farm management goals. For example, when considering planting a perennial hedgerow the producer should evaluate the various costs and benefits likely to be associated with a hedgerow. Growers with farmscaping experience will likely be the best source for this kind of information.

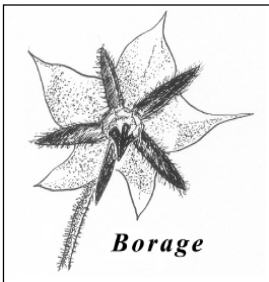
Farmscape Planning

There are probably as many approaches to farmscaping as there are farmers. Some growers, after observing a cover crop harboring beneficial insects, plant strips of it in or around their crop fields. The advantages of this kind of approach are:

- It is simple to implement
- It is often very effective
- The farmer can modify the system after observing the results.

Problems arise when the beneficial insect habitat, unbeknownst to the grower, also harbors pest species. (For a more detailed discussion of this topic, visit: http://www.lib.uconn.edu/CANR/ces/ipm/

general/htms/cvercrop.htm). In other instances the beneficials may not exist in numbers sufficient to control pest populations *during the time when pest populations generally increase*. Predator/prey population balances are influenced by the *timing* of availability of nectar, pollen and alternate prey/hosts for the beneficials. Therefore, there is a strong argument to be made for having year-round beneficial organism habitat and food sources. The "beneficial habitat season" may be extended by adding plants that bloom sequentially throughout the growing season or the whole year.



When Do They Bloom?

The ATTRA Phenology Resource List provides additional resources about time-of-bloom at:

http://www.attra.org/attra-pub/phenology.html

A sample blooming chart for California plants can be found in Appendix F.

When contemplating farmscaping, consideration should be given to the cost of developing beneficial habitat and maintenance of the habitat as well as the cost of any land that might be taken out of production. In any case, a more systematic, research-oriented approach to farmscaping can often help the grower avoid mistakes and develop desirable habitats that match the needs of the beneficial organisms as well as the pest management needs of the farm.

The following are key considerations in crafting a farmscaping plan:

1. Ecology of Pests and Beneficials

- What are the most important (economic) pests that require management?
- What are the most important predators and parasites of the pest?
- What are the primary food sources, habitat, and other ecological requirements of both pests and beneficials? (Where does the pest infest the field from, how is it attracted to the crop, and how does it develop in the crop? Where do the beneficials come from, how are they attracted to the crop, and how do they develop in the crop?)

2. Timing

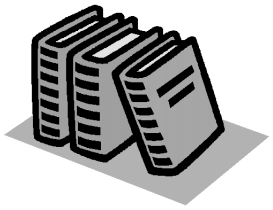
- When do pest populations generally first appear and when do these populations become economically damaging?
- When do the most important predators and parasites of the pest appear?
- When do food sources (nectar, pollen, alternate hosts, and prey) for beneficials first appear? How long do they last?
- What native annuals and perennials can provide habitat?

3. Identification of Strategies

- Reduction of pest habitat (i.e., reduce/alter overwintering pest sites, or reduce/alter locations from which pest invades.)
- Augmentation of beneficial habitat (insectary establishment; consider both perennial options—permanent plantings such as hedgerows—and annual options.)
- Trap Crops—planted specifically to be more attractive to the pest than is the crop to be harvested. This is due to the timing of the appearance of the trap crop or the fact that it is physiologically more attractive to the insect. (Please see appendices D and G for descriptions of planting systems that can be used in farmscaping.)

4. Insectary Establishment

- Seed and plant sources
- Cost of ground preparation, planting and maintenance (irrigation, weeding, etc.) for:
  - ♦ at least one year following establishment of perennials
  - ♦ needed number of plantings per season of beneficial habitat (remember that many annuals provide pollen or nectar for only a few weeks during the cropping season, so that either relay plantings or plant species mixes may be needed for beneficial habitat.)
- Equipment needs (Cost estimates for installation and first-year maintenance of a typical hedgerow in California are given in Appendix E.)



Resources

For information about crop pests, their parasites and predators, and the ecological requirements of both, contact your local county extension service (under county listings in the phone book) or state Cooperative Extension Service (CES):

http://www.reeusda.gov/hrd/state2.pdf

Biological Control: A Guide to Natural Enemies of North America:

http://www.nysaes.cornell.edu/ent/biocontrol/

To receive a free copy of Suppliers of Beneficial Organisms of North America, call the California EPA's Department of Pesticide Regulation:
(916) 324-4100 or download from:

http://www.cdpr.ca.gov/docs/dprdocs/goodbug/benefic.htm

Other Considerations

Weather

Weather variations from year to year may cause a particular management practice to be beneficial one year and problematic the next. A flexible approach is needed in order to adjust beneficial habitat according to weather variations. An observant eye is the grower's most valuable tool in this respect.

Perennial vs. Annual

The type of cropping system, perennial vs. annual, is an important factor in farmscaping. Perennial systems such as orchards possess an inherent ecological stability derived from the variety of tree-based habitats, which are not harvested or destroyed as in annual systems. Adding a cover crop to an orchard can increase and complement the biodiversity of the system.

Ideally, cover crops (CCs) in orchard systems should be selected and managed for the following attributes (1) :

- ♦ CCs should not harbor important orchard pests
- ♦ CCs should have some ability to divert generalist pests from the orchard crop
- ♦ CCs should confuse specialist pests visually or olfactorily (by smell) and thus reduce their colonization of orchard trees
- ♦ CCs should be capable of altering host-plant nutrition (without negatively impacting the crop) and thereby reduce pest success
- ♦ CCs should reduce dust and thereby reduce spider mite outbreaks
- ♦ CCs should change the microclimate and thereby reduce pest success
- ♦ CCs should increase natural enemy abundance or efficiency, thereby increasing biological control of arthropod pests.

Studies of commercial pecan orchards in Oklahoma (2) and almond plantations in California (3) have demonstrated the efficacy

of managing cover crops for pest control in orchard systems. In all instances, this farmscaping technique resulted in significant reductions in pesticide applications.

Annual cropping systems are much less stable than perennial ones. Depending on the amount of tillage involved, the ecology of annual systems, both above and below ground, is dramatically altered every year. To help anchor the ecology of an annual system, consider planting "permanent" insectary strips or hedgerows in or along an annual crop field.

The idea of undisturbed beneficial habitat distributed at intervals in or around crop fields is a theme common to many farmscaping techniques. Depending on the plant species, these "perennial islands" provide food resources for beneficial organisms as well as overwintering sites from which crops can be colonized in the spring. Kenny Haines, a vegetable grower in North Carolina who practices farmscaping, notes that his insectary strips provide a "meetin' place" for the beneficials. Springtime environments of annual cropping systems are characterized by extremes of temperature, sunlight and humidity—conditions in which colonization and survival of beneficials is unlikely without good habitat nearby. For details on how some farmers (including Kenny Haines) incorporate a "permanent" component into their annual fields, see Appendix D.

Healthy Soil Ecology

Many organisms, including pest insects associated with both perennial and annual crops, spend part of their life cycle in the soil. A diverse soil ecology maintained with regular additions of organic matter helps to regulate populations of both pest and beneficial organisms (4, 5, 6).

Insectary Plants: Characteristics and Strategies

Experimentation is the key to finding a successful combination of planting systems, ground covers/mulches, and management practices that work best for the unique soil and environmental conditions of a particular farm and crop.

As a first step, the producer should choose plants that provide good habitat for the desired predators or parasites, and at the same time, do not harbor insects that are likely to become pests. For example, subterranean clover harbors many beneficials like big-eyed bugs, and also harbors relatively few *Lygus* species. pests. Avoid aggressive, invasive plants and those that may act as reservoirs for diseases that attack surrounding crops. (See box on page 9 for more information about invasive plants.)

Cover crops that are good insectary plants include buckwheat, sweet clover, faba beans, vetch, red clover, white clover, mustards, and cowpeas. Herbaceous plants that are good insectary plants and which may be planted in strips include species in the carrot (Apiaceae=Umbelliferae), sunflower (Asteraceae=Compositae), and mint (Lamiaceae) families. (Refer to appendices A, B, and C for detailed information on pests, beneficials, and seed blends for plants that attract beneficials.)

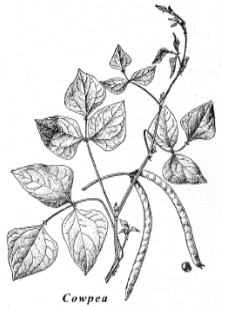
In many instances, floral structure is an important consideration. Beneficials with short mouthparts, such as the tiny parasitic wasps, find it easy to obtain nectar and pollinate plants in the parsley and sunflower families because of the small, shallow flowers these species provide. Plants that possess extrafloral nectaries (nectar sources outside the flower), such as faba beans, cowpeas, vetch, and several native ground covers, provide beneficials with easy access to an important food source in addition to the nectar and pollen of their flowers.

Recent work in Georgia investigated the importance of different food sources—extrafloral nectaries, honeydew (a liquid emitted by whiteflies, aphids, scales, and leafhoppers, composed of unused portions of plant sap as well as certain waste products of the insects), sucrose, or no food sources—on

Microplitis croceipes, a parasitoid of the corn earworm in cotton (7). Important findings included:

- Retention of the wasp and parasitization rates were highest in cotton plots in which wasps were able to feed on extrafloral nectar.
- Retention of the wasp and parasitization in patches with honeydew was comparable to patches without food—probably due to the rapid decrease in quality of honeydew as it dries, combined with low quantity per site and general low detectability of this food by the parasitoid. Honeydew is scattered about randomly within a field and on a plant. Extrafloral or floral nectaries, on the other hand, are always found at the same location on a particular plant, making it easier for beneficials to locate this food source.
- Important characteristics of an ideal food source in the field are high quality, high quantity per site, high detectability, and high predictability of the food location. *Nectar sources possess all these qualities*.

To summarize this research, some species of parasitic wasps will stay in an area with nectar sources—either floral or extrafloral—and this results in a higher parasitization rate of host pests in that area. This makes sense, because the wasp can spend more time hunting for hosts and less time hunting for food. Many crop plants do not provide sufficient food for hungry parasitoids. As a consequence, parasitoids will disperse from target areas in search for food. After feeding, parasitoids may not return to original target areas, especially when the distance between food and host locations is too great or when the food locations also harbor hosts (7). Because nectar sources are so important to many beneficials, non-invasive plants with floral or extrafloral nectaries might be considered prime candidates for use in farmscaping.



Important characteristics of an ideal beneficial insect food source in the field are high quality, high quantity per site, high detectability and high predictability of the food location. Nectar sources possess all these qualities.

A study in California (8) revealed that beneficials in fact do feed on nectar and pollen provided by insectary plants, and will move up to 250 feet into adjacent crop lands. Further research is needed to determine the optimum spacing of insectaries within a particular crop and ecosystem so that parasites spend most of their time controlling pests (as opposed to searching for food) and producers know how much land insectaries will require and where they are most effectively placed.

The appearance of beneficials should be timed to coincide with peak need for biological control of pests associated with the main crop. Another way of looking at this is that an insectary crop should grow and bloom at a time that best meets the needs of beneficials for pollen, nectar, or alternate hosts. Strategies to prolong bloom include planting cover crops in strips on successive planting dates. Planting a mix of plants, particularly perennials, that bloom in succession and that meet the habitat needs of desired beneficials is another farmscaping option. It may be helpful to develop a diagram, such as the one below (from Appendix F), when planning habitat that will have something in flower year-round.

Common Name	Genus/ sp.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Willow	*Salix spp.*	■	■	■	■								
California lilac	*Ceanothus spp.*		■	■	■	■							
Mule fat	*Baccharis viminea*		■	■	■	■							
Coffeeberry	*Rhamnus californica*				■	■							
Hollyleaf cherry	*Prunus ilicifolia*				■	■							
Yarrow*	*Achillea millefolium*				■	■	■	■					
Silverlace vine	*Polygonum aubertii*				■	■	■	■	■	■	■	■	
Toyon	*Heteromeles arbutifolia*					■	■						
Golden sticky monkeyflower	*Mimulus guttatus*					■	■	■	■	■			
Elderberry	*Sambucus mexicana*					■	■	■	■	■			
California buckwheat**	*Eriogonum fasciculatum*					■	■	■	■	■	■	■	■
Deergrass	*Muhlenbergia rigens*						■	■	■	■			
Creeping boobialla	*Myoporum parvifolium*						■	■	■	■	■		
California fuchsia	*Zauschneria californica*						■	■	■	■	■		
Narrowleaf Milkweed	*Asclepias fascicularis*						■	■	■	■	■		
St. Catherine's lace	*Eriogonum giganteum*						■	■	■	■	■	■	■
Coyote bush	*Baccharis pilularis*	■									■	■	■

Source: Kimball and Lamb, 1999. *(See p. 36)*

The migration of certain species of beneficials from the cover crop(s) to the main crop is sometimes associated with senescence (or post-bloom period) of the cover crop. In these instances, mowing the cover crops in alternate strips may facilitate their movement while the remaining strips continue to provide refuge for other beneficial species. Sickle-bar mowers are less disruptive to beneficials than flail mowers and rotary mowers.

Mulches

Although this publication generally focuses on *living* habitat, clearly some beneficial organisms, such as spiders and ground beetles, benefit from mulches (or a habitat that mimics some of the effects of mulches, such as that found in "no-till" fields). Much of the benefit lies in the fact that mulches provide overwintering habitat for these organisms in a moderated microclimate (9).

Trap Crops

A related strategy in farmscaping is the selection of plants that *attract* pests. These "trap crops" can then be plowed down or managed in some fashion that takes advantage of a vulnerable stage in the crop pest life cycle. See Appendix D for examples of farmers using trap crops.

Farmscaping for Birds and Bats

Birds and bats are important insect predators, particularly during the spring when they are raising young. Their activities complement each other. Birds are generally active during the day and feed on caterpillars and other insects, while bats feed during dusk and into the night on mosquitoes, moths, and other nocturnal insects.

Birds and bats are both amenable to living in artificial shelters—free-standing or attached to a building. This could be a slightly modified structural component of a building, such as nest shelves along eaves for barn swallows (10) or a spaced board attached to a beam for bat habitat. Bats, frequently found in man-made structures, prefer places that are warm, dry, and protected from disturbance (11).

Both birds and bats will benefit from having a small pond or body of water on the property or nearby. Bats require a watering area ideally 10 feet long, as they drink "on the fly." Birds will be content with birdbath-size and larger water bodies.

One difficulty in farmscaping for birds is that some birds' diets change from insects to seeds (or to fruit) after they have finished rearing their young. The following table lists some bird species that may be considered for farmscaping efforts.

Bird Species	**Comments** (10, 12, 13)
Bluebird	Nest boxes should be located 5–6' above the ground—best facing a tree or artificial perch. Place multiple houses 30 yards apart to allow individual birds to establish territories. The opening should be 1.5" in diameter.
Chickadees	Feed mostly in hedgerows and wooded borders. Nest boxes best located near or in trees, hedgerow, etc., 5–15' above the ground. Will overwinter.
Wrens	Feed on insects on ground and plants. Locate nest box close to stick piles and garden. Generally a summer resident only. Opening should be .75" in diameter
Barn Swallow	Attracted by nest shelves under eaves or other structures. Beware of droppings. Opening should be 1.5" in diameter
Robin	Common insectivore, but consumes small fruits and cherries.
Starling	Common insectivore, but will eat small fruit and hollow out large fruit (apples). May forage in large flocks.

Bats not only eat insects that are a nuisance to humans (a small brown bat can devour up to 600 mosquitoes in an hour), but can provide significant agricultural pest control services. In one season, a typical colony of about 150 big brown bats in the Midwest eats 50,000 leafhoppers, 38,000 cucumber beetles, 16,000 June bugs, and 19,000 stink bugs (11)—not to mention thousands of moths such as adult cornborers, earworms, and cutworms.

Bat Housing

The easiest way to construct bat housing is to simply add a sheet of plywood to a barn or house wall with ¾" spacers between the sheet and wall. Placing the long axis of the plywood vertically will allow for greater temperature variation in the bat space. (See pages 13–14 for contacts who know about bat habitat and housing.)

Other construction considerations include (11):

- Use exterior-grade plywood with exterior-grade staples and bolts.
- Minimum bat house dimensions are 32" tall, 14" wide, with 3–6" landing pad below the opening.
- Provide 1–4 roosting chambers, spaced at ¾". Landing pad and roosting chamber should be roughened or have a durable textured surface for the bats to grasp—no sharp points to tear bat wings!
- Front and side venting should be appropriate for local climate.
- All seams should be caulked to avoid leaks.
- Treating bat houses with diluted bat guano or allowing some weathering of a new bat house may help attract new "renters".

Considerations when locating a bat house (11):

- Any place that already has bats is best, particularly agricultural areas (vs. urban areas) due to insect abundance and habitat variety.
- Place the bat house near water—within a quarter mile is ideal.
- Place it near some sort of protective cover like a grove of trees—don't place houses *in* a grove of trees, but 20–25 ft. away due to predator concerns, and at least 10 ft. above the ground.
- Don't place bat houses near barn owl boxes—the barn owl is a bat predator. Place the two types of boxes a fair distance from each other facing in opposite directions.
- Do *not* mount bat houses on metal buildings (too hot for bats) or in locations exposed to bright lights.
- In California, bat houses in barns and on the north and west sides of buildings have had the greatest rate of occupancy. This may not be true for locations in other parts of the country.
- Paint the exterior with three coats of outdoor paint. Available observations suggest that the color should be black where average high temperatures in July are 80–85° F, dark colors (such as dark brown or gray) where they are 85–95° F, medium or light colors where they are 95–100° F, and white where they exceed 100° F. Much depends upon amount of sun exposure; adjust to darker colors for less sun. (14)

For further information about bats and bat houses, contact:

Bat Conservation International
P.O. Box 162603, Austin, TX 78716
(512) 327-9721
http://www.batcon.org/

or contact,
Rachael Freeman Long
Yolo County Farm Advisor
UC Cooperative Extension
(530) 666-8143

A Recap: Steps to Farmscaping

Habitat enhancement for beneficial organisms can provide the foundation for a biologically intensive Integrated Pest Management (IPM) program. The steps presented below may help when attempting to increase the "directed diversity" of an agricultural ecosystem:

1. Keep good records of where, when, and what pests occur on the farm.

2. Obtain as much information as you can about both the pest's and the beneficial organism's life cycle and habitat requirements. Where are eggs laid and when do they hatch? Where does the pest/beneficial feed and how long does it need to develop into an adult? Where does the pest/beneficial overwinter and in what form? This information will not only aid in farmscaping, but will also aid pest management.

3. Make a list of tools that are available to create a friendlier habitat for the beneficials (or a more unfriendly habitat for pests). This may include various combinations of: insectary plants, crop rotations, hedge rows, intercropping schemes, planting or harvesting time and methods, etc. Beware of aggressive insectary or hedgerow plants.

4. Select those tools listed in #3 that best fit into your cropping system, rotation, equipment, and labor availability. Remember, permanent plantings will require maintenance during the first few years after planting. (See Appendix E for a general cost table.)

5. Experiment, observe the results, fine tune the system, and experiment again. Try something new—a variation on something that's already being done.

6. Start simple and small, then develop the farmscaping as experience and observations dictate.

The Nature Conservancy runs a website that has a comprehensive list of invasive plants using both scientific and common names. Pictures as well as tips for managing the plants are also included:

http://tncweeds.ucdavis.edu.

Federal Cost Share Programs for Habitat Development

USDA/NRCS

Conservation Reserve Program (CRP)
http://www.fsa.usda.gov/dafp/cepd/12crplogo/tableof.htm

Under the "new" CRP, erosion control remains a top priority, but now water quality and wildlife habitat improvement are also emphasized. Continuous sign-up is available to farmers implementing special projects such as filter strips, riparian buffer strips, windbreaks, and wildlife habitat plantings (hedgerows could be included in these categories). Participating farmers must sign up for a minimum of 10 years (with an option to renew for an additional 5 years) and develop a conservation plan that takes certain acres out of production. In return, the farmer receives annual rental payments on the land from the government, up to $50,000 per person per year. Participating farmers can also apply for 50% cost share on implementation of conservation practices agreed to in the conservation program (15). For more information, contact your local Natural Resources Conservation Service (NRCS) office.

Environmental Quality Incentive Program (EQIP)
http://www.nrcs.usda.gov/NRCSProg.html#Anchor-Environmental

This program supports implementation of conservation plans that include structural, vegetative, and land management practices on eligible land. Five- to ten-year contracts are made with eligible producers. Cost-share payments (up to 75%, $10,000 maximum/year, $50,000 maximum/contract), may be made to implement one or more eligible structural or vegetative practices, such as animal waste management facilities, terraces, filter strips, tree planting, and permanent wildlife habitat. These plans are developed in cooperation with NRCS and approved by the Farm Service Administration County committee. Incentive payments can be made to implement one or more land management practices, such as nutrient management, pest management, and grazing land management. For more information, contact your local Natural Resources Conservation Service (NRCS) office.

Wildlife Habitat Incentive Program (WHIP)
http://www.nhq.nrcs.usda.gov/OPA/FB96OPA/WhipFact.html

Similar in many ways to the EQIP program, WHIP is a voluntary program for people who want to develop and improve wildlife habitat primarily on private lands. NRCS offers both technical assistance and cost-share payments to help establish and improve fish and wildlife habitat. The cost-share agreement generally lasts from 5 to 10 years from the date the agreement is signed. NRCS will pay up to 75 percent of the cost of installing the wildlife habitat practices as long as NRCS or its agent has access to monitor the effectiveness of the practices. NRCS helps participants prepare a wildlife habitat development plan in consultation with the local conservation district. The plan describes the landowner's goals for improving wildlife habitat, includes a list of practices and a schedule for installing them, and details the steps necessary to maintain the habitat for the life of the agreement. This plan may or may not be part of a larger conservation plan that addresses other resource needs such as water quality and soil erosion.

Wetlands Reserve Program
http://www.wl.fb-net.org/
http://www.wl.fb-net.org/st-prog.htm

For additional information about the Wetlands Reserve Program, which may have some applicability to farmscaping, please visit the website or call your local NRCS office.

US Fish and Wildlife Service (USFWS)

Partners for Wildlife
http://partners.fws.gov/index.htm

The Partners for Fish and Wildlife Program (formerly named the Partners for Wildlife program) is a proactive, voluntary program of the U.S. Fish and Wildlife Service that provides technical and financial assistance to private (non-federal) landowners to voluntarily restore wetlands and other fish and wildlife habitats on their land. The program emphasizes the reestablishment of native vegetation and ecological communities for the benefit of fish and wildlife in concert with the needs and desires of private landowners. The Service also enlists the assistance of a wide variety of other partners to help restore wildlife habitat on private lands. These partners include other federal agencies, tribes, state and local governments, conservation organizations, academic institutions, businesses and industries, school groups, and private individuals.

The USFWS provides financial and technical assistance to private landowners through voluntary cooperative agreements. Landowners agree to maintain restoration projects as specified in the agreement, but retain full control of the land. Depending on the project, landowners can apply for cost share on up to 50% of the expense of implementing the plan. Landowners and national, state, and local organizations can serve as partners with the USFWS in carrying out restoration work on private lands.

*This **pending draft legislation**, being considered for passage in 2001, may have significant opportunities for farms to implement sustainable practices in the future. Due to the nature of this legislation, we felt it important to include draft language of the legislation in this document to provide sustainable agriculture practitioners with information about a possible future resource.*

Conservation Security Act 2000

Summary: The Conservation Security Act (CSA) of 2000 provides financial assistance to help farmers and ranchers find viable solutions to agricultural, environmental, and economic concerns. The CSA rewards producers for good stewardship in appreciation of the many nonmarket environmental and social benefits that these practices provide society. The Act balances federal funding for conservation on working lands with existing funding for land retirement, providing farmers access to payments for whole-farm resource planning.

Conservation Purposes: The Conservation Security Program (CSP) created by the CSA addresses the full range of conservation concerns related to agriculture, including:

- conservation of soil, water, energy, and other related resources
- soil, water, and air quality protection and improvement
- on-farm conservation and regeneration of plant germplasm
- wetland and wildlife habitat restoration, conservation, and enhancement
- greenhouse gas emissions reduction and carbon sequestration
- and other similar conservation goals

Participation: Participation in the program stipulates that land practices must achieve resource and environmental benefits, but does not require the removal of land from production. Practices do not need to be newly introduced to the farm/ranch; producers can be rewarded for good stewardship practices implemented prior to enrollment in the CSP. Participants are responsible for developing conservation security plans that identify targeted resources, practices, and implementation schedules. Participants are granted maximum flexibility for choosing land management, vegetative, and structural practices suitable for individual farms. In certain instances, the plan may include an on-farm research or demonstration component.

Tiers: Participants have the choice of enrolling in one of three tiers:

- Tier I participants address priority resource concerns on all or part of their farms/ranches. Practices may include soil and residue management, nutrient management, pest management, irrigation management, grazing management, wildlife habitat management, contour farming, strip cropping, cover cropping, and related practices.
- Tier II participants address priority resource concerns on the whole farm/ranch and meet applicable resource management system criteria. Tier II practices entail adoption of land use adjustment practices such as resource-conserving crop rotations, rotational grazing, conversion to soil-conserving practices, installing conservation buffer practices, restoration of wildlife habitats, prairies, and/or wetlands, and other related practices.
- Tier III participants satisfy the requirements of tiers I and II, while integrating land use practices into a whole-farm, total-resource approach that fosters long-term sustainability of the resource base.

Payment and Eligibility: Payments are based on the natural resource and environmental benefits expected from plan implementation, the number and timing of management practices established, income forgone due to land use adjustments, costs related to on-farm research, and several other factors. Bonuses are also offered to beginning farmers, joint participation by operators within a small watershed, and plans that optimize carbon sequestration and minimizes greenhouse gas emissions. Payments may not exceed $20,000, $35,000, and $50,000 for Tier I, II, and III contracts, respectively.

Funding: The program is funded out of the Commodity Credit Corporation and all eligible producers will receive contract payments for the requisite number of years. CCC funding is also provided for technical assistance, education and outreach, and monitoring and evaluation.

Summary

The goal of farmscaping is to prevent pest populations from becoming economically damaging. This is accomplished primarily by providing habitat to beneficial organisms that increase ecological pressures against pest populations. Farmscaping requires a greater investment in knowledge, observation, and management skill than conventional pest management tactics, while returning multiple benefits to a farm's ecology and economy. However, farmscaping alone may not provide adequate pest control. It is important to monitor pest and beneficial populations so that quick action can be taken if beneficials are not able to keep pest populations in check. Measures such as maintaining healthy soils and rotating crops are complementary to farmscaping and should be integrated with farmscaping efforts. Biointensive Integrated Pest Management (IPM) measures, such as the release of commercially-reared beneficials (applied biological control) and the application of "soft" pesticides (soaps, oils, botanicals) can be used to augment farmscaping efforts.

Help us to better help farmers.

If you have suggestions for improvements in this publication, areas about which you'd like more information or detail, ideas, case studies, or sources of good farmscaping information (articles or websites),
please call ***Rex Dufour*** *at* ***1-800-346-9140****,*
or email at ***rexd@ncat.org****.*

Please fill out the feedback form on the back page of this publication.
Thank you!

References:

1) Bugg, R.L. and C. Waddington. 1994. Managing cover crops to manage arthropod pests of orchards. Agricultural Ecosystems & Environment. Vol. 50. p. 11–28.

2) Bugg, R.L., M. Sarrantonio, J.D. Dutcher, and S.C. Phatak. 1991. Understory cover crops in pecan orchards: Possible management systems. American Journal of Alternative Agriculture. p. 50–62

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12) Duval, Jean, S. Sobkowiak. 1995. Birds and bats: The orchard pest patrol. Sustainable Farming, Vol. 6 No. 1. p. 6, 7.

13) Brittingham, M.C. 1992. Controlling birds on fruit crops. Northland Berry News. September. Vol. 6, No. 3. p. 7, 8.

14) Bat Conservation International Website. 2000 http://www.batcon.org/bhra/bhcriter.html

15) Robins, P. 1999. Cost share programs for resource conservation and wildlife habitat development. p. 89–91. In: Bring Farm Edges Back to Life! Yolo County Resource Conservation District, Woodland, CA. 105 p.

Useful Contacts for Farmscaping Information

Central Coast Wilds specializes in farmscape planning, installation, and management. They provide information and native plants in order to meet several farm system goals:

- beneficial insect habitat
- wind break
- erosion control
- riparian stabilization
- non-point source water pollution reduction

http://www.centralcoastwilds.com/farmscape.html

Dr. Robert Bugg
Cover Crops/Restoration Ecology
UC-Sustainable Agriculture Research & Education Program (SAREP)
Davis, CA 95616
(530) 754-8549
rlbugg@ucdavis.edu

Dr. Bugg works with the Biologically Integrated Orchard Systems (BIOS) project and is knowledgeable about beneficial insects associated with various cover crops.

W.E. Chaney
Farm Advisor, Entomology/vegetable crops
UC-Cooperative Extension
1432 Abbot St.
Salinas, CA 93901
(831) 759-7359
FAX: (831) 758-3018
wechaney@ucdavis.edu

Bill Chaney has done work on enhancing biological control of aphids through the use of insectary plants grown in fields of vegetables.

Dr. James Dutcher
University of Georgia
Coastal Plain Experiment Station
P.O. Box 748
Tifton, GA 31793
(912) 386-3374

Dr. Sharad Phatak
University of Georgia
Coastal Plain Experiment Station
P.O. Box 748
Tifton, GA 31793
(912) 386-3901
phatak@cpes.peachnet.edu

Both Dr. Phatak and Dr. Dutcher have done extensive research into biological control, and the Coastal Plain Experiment Station is a center of innovative research in this area.

Diane Mathews Gehringer
2774 Silver Creek Rd.
Kutztown, PA 19530
(610) 285-4317

Ms. Gehringer, formerly with the Rodale Institute, is knowledgeable about biological control.

Bat Habitat

Rachael Long
Farm Advisor
UC-Cooperative Extension
70 Cottonwood St.
Woodland, CA 95695
(530) 666-8143

Jim Kennedy
Bat Conservation International
P.O. Box 162603
Austin, TX 78716
(512) 327-9721

Dr. Steve Cross
Southern Oregon State College
1250 Siskiyou Blvd.
Ashland, OR 97520-5071
(541) 552-6749

Bat Houses

Natural Insect Control
R.R. #2
Stevensville, Ontario
Canada LOS ISO
(905) 382-2904
FAX: (905) 382-4418

Peaceful Valley Farm Supply
P.O. Box 2209 #P
Grass Valley, CA 95945
(530) 272-4769
http://www.groworganic.com

The Green Spot
Dept. of Bio-Ingenuity
93 Priest Rd.
Nottingham, NH 03290
(603) 942-8925
FAX: (603) 942-8932

Danny Smith
P. O. Box 703
La Porte, Tx. 77572-0703
genes96597@aol.com
FAX: (281) 471-6477
http://home.earthlink.net/~riverdan2/wildlife.htm

Seed Suppliers

See Appendix C

Windbreaks, Shelterbelts and Hedgerows

Mary Kimble
Yolo Country Resource Conservation District
221 W. Court St., Ste. 1
Woodland, CA 95695
(530) 662-2037 ext. 3

The Yolo County Conservation District is doing some excellent ongoing work concerning hedgerow establishment, plant selection, types of beneficials attracted, and budgets for hedgerow installation and maintenance.

Bruce Wight
National Windbreak Forester
USDA Natural Resources Conservation Service (NRCS)
Federal Building
100 Centennial Mall North
Lincoln, NE 68508-3866
(402) 437-5178 ext. 36
bwight@telspec.itc.nrcs.usda.gov
http://www.unl.edu/nac/

The folks at USDA's National Agroforestry Center have technical information about the benefits, planting, maintenance, and impact on wildlife of windbreaks, hedgerows, snowfences.

Useful Websites

Biological Control: A Guide to Natural Enemies of North America

http://www.nysaes.cornell.edu/ent/biocontrol/

This site, *Biological Control: A Guide to Natural Enemies of North America* provides photographs and descriptions of over 100 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). Excellent photos and lifecycle descriptions supplemented with diagrams.

Insect Parasitic Nematodes

http://www.oardc.ohio-state.edu/nematodes/

This site has much useful information about the use of insect parasitic nematodes: the biology and ecology of nematodes, how to use nematodes, a list of suppliers, and more! An extremely useful section provides full citation for research papers according to author, title, or abstract. Research papers can also be searched for according to Order and Family of target insect. To get to this section, click on: Search Publications⇒Keyword Search Page (just underneath the "author, title, abstract" search engine)⇒Insects. Then you may choose the Order and Family of your choice.

Useful Websites *continued*

ATTRA's Phenology Resource List

http://www.attra.org/attra-pub/phenology.html

This website has descriptions of dozens of websites that contain information about plant phenology. Some sites are state or region-specific; other sites have information about specific groups of plants and when they flower at a particular location.

SELECTV (selective) D-base on pesticide effects on non-target arthropods

http://www.ent3.orst.edu/Phosure/database/selctv/selctv.htm

The SELCTV (pronounced as "selective") database was created in 1986/87 by Karen M. Theiling, then a research student working towards a Master's thesis, under the supervision of Professor Brian Croft in the Department of Entomology at Oregon State University, Corvallis. The database represents a relatively comprehensive compilation of the worldwide published literature describing pesticide effects on non-target arthropods (Theiling & Croft, 1988) during the period from 1921 to 1985, with a small number of entries from publications dated between 1986 and 1994. The principal database table contains approximately 12,500 data records, 99.7% of which originate from the pre-1986 literature. Each record in the principal table represents one screening of a pesticide on one natural enemy taxon under conditions described in the source publication.

Additional Reading

Articles:

Anonymous. 1994. Beneficial seed blends. Common Sense Pest Control. Spring. p. 18.

Anonymous. 1994. How can you make bugs stay? Growing for Market. June. p. 1–2.

Bachmann, Janet, et al. 1995. Habitat enhancement for beneficial insects in vegetable and fruit farming systems. SARE/ACE Annual Report AS92-2. Southern Region. p. 87.

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Gilkeson, Jill, and Joel Grossman. 1991. *The Organic Gardening* guide to important beneficial insects and mites of North America. Organic Gardening. May-June. p. 46–56.

Additional Reading *continued*

King, Shawn, and William Olkowski. 1991. Farmscaping and IPM. The IPM Practitioner. October. p. 1–12.

Kite, Patricia. 1990. Attract these insects. Organic Gardening. April. p. 71–72.

Phatak, Sharad. 1992. An integrated sustainable vegetable production system. HortScience. Vol. 27, No. 7. p. 738–741.

Pickett, C.H. and R.L. Bugg (eds.) 1998. Enhancing Biological Control: Habitat Management to Promote Natural Enemies of Agricultural Pests. University of California Press. 422 p.

Platt, J.O., et al. 1999. Effect of buckwheat as a flowering border on populations of cucumber beetles and their natural enemies in cucumber and squash. Crop Protection. Vol. 18. No. 5. June. p. 305–313.

Poncavage, Joanna. 1991. Beneficial borders. Organic Gardening. May-June. p. 42–45.

Pottinger, Lori. 1994. Improve your pest-control batting average. Farmer to Farmer. December. p. 5.

Pottinger, Lori. 1994. Take a walk on the wild side. Farmer to Farmer. October. p. 6–7.

Prokopy, Ronald J. 1994. Integration in orchard pest and habitat management: A review. Agriculture, Ecosystems and Environment. August. p. 1–10.

Farmscaping Books:

Pickett, C.H. and R.L. Bugg (eds.). 1998**. Enhancing Biological Control: Habitat Management to Promote Natural Enemies of Agricultural Pests.** University of California Press, Berkeley, CA. 422 p.

This book provides detailed technical insights into habitat manipulation for biological control. Each chapter is written by an expert about a particular aspect of habitat management (i.e., The Role of Spiders and Their Conservation in the Agroecosystem, or, Within-field and Border Refugia for the Enhancement of Natural Enemies). This volume is a must for researchers in this field as well as a useful reference for farmscaping practitioners.

For ordering information:
Univ. of California Press, CPFS,
1095 Essex St.
Richmond, CA 94801
(609) 883-1759
FAX: (609) 883-7413

Bring Farm Edges Back to Life! How to Enhance Your Agriculture and Farm Landscape with Proven Conservation Practices for Increasing the Wildlife Cover on Your Farm. 1999. 4th Edition. Yolo County Resource Conservation District, Woodland, CA. 105 p.

This is a great resource for farmers and land managers, though a fair amount of the information is specific to the Lower Sacramento Valley. Contains much useful information about establishing habitat for wildlife—from hedgerows and native perennial grass stands to riparian enhancement and tailwater ponds. Also includes information nuggets on how to attract beneficial insects, birds and bats, planting techniques and weed control, and cost share programs (Federal, State (CA) and local) for habitat enhancement.

To order: Send $18/copy (includes postage and handling) with check payable to "Yolo County RCD" to:
Yolo County RCD
221 West Court St., Ste. 1
Woodland, CA 95695

Additional Reading *continued*

A Whole-Farm Approach to Managing Pests. 2000. Sustainable Agriculture Network. 20 p.

This bulletin from the Sustainable Agriculture Network (SAN) outlines how to use ecological principles to control pests on your farm. Contains successful strategies and a resource listing.

Ordering information:
Sustainable Agriculture Network
(301) 405-3186
http://www.sare.org/san/htdocs/pubs/

Biocontrol/IPM Books:

Beers, E.H., J.F. Brunner, M.J. Willett and G.M. Warner (eds). 1993. **Orchard Pest Management: A Resource Book for the Pacific Northwest**. Good Fruit Grower. Yakima, WA. 276 p.

"*Orchard Pest Management* is an outstanding resource book for growers, consultants, orchard managers, and those interested in the latest findings on integrated pest management tactics, not only in the Pacific Northwest, but throughout the United States. It explains in detail the philosophy of IPM, and the tools and tactics needed to implement this management approach. All the information is presented in an easily readable style both the neophyte and expert can follow. The book is comprehensive, well written and organized, and amply illustrated with colorful photographs and excellent line drawings and graphics…." - Dr. Larry A. Hull, Professor of Entomology, Penn. State University. We agree.

Ordering information:
Washington State Fruit Commision
1005 Tieton Drive
Yakima, WA 98902
(509) 575-2315
FAX: (509) 453-4880

Flint, M.L. and S.H. Dreistadt. 1998**. Natural Enemies Handbook. The Illustrated Guide to Biological Pest Control.** U.C. Press, Berkeley. 154 p.

This book is an illustrated guide to the identification and biology of beneficial organisms including natural enemies of plant pathogens, nematodes, weeds, and arthropods. Many excellent photos and informative diagrams and tables make this book a good reference for farmers, farm managers and students. This book does not cover farmscaping.

Ordering information:
(510) 642-2431, *or* (800) 994-8849
e-mail: danrcs@ucdavis.edu
Website: http://danrcs.ucdavis.edu

Foster, R. and B. Flood. **Vegetable Insect Management With Emphasis on the Midwest.** 1995. Meister Publishing Company, Willoughby, OH. 206 p.

The chapters of this well-formatted book are organized according to vegetable crop and written by experts on that crop. The focus is on IPM and the charts, diagrams, drawings, and pictures all contribute to an exceptionally well-designed book that is easily readable but dense with useful information. An excellent resource for midwestern vegetable growers and IPM practitioners.

To Order: Unfortunately, *Vegetable Insect Management* is sold out.
Contact:
Meister Publishing Company
37733 Euclid Avenue
Willoughby, OH 44094
(800) 572-7740
FAX: (440) 942-0662
e-mail: meisterpro_sales@meisternet.com

Additional Reading *continued*

Hoffman, M.P., and A.C. Frodsham. 1993. **Natural Enemies of Vegetable Insect Pests.** Cornell Cooperative Extension. 63 p.

This book focuses on the life cycle of natural enemies of insect pests. It includes a general discussion about each family of natural enemies, within which details are provided about some species, including appearance and life cycle, pests attacked and relative effectiveness. With its diagrams and pictures, this book is a good reference for agricultural field workers.

Ordering information:

Resource Center
7 Business/Technology Park
Cornell University
Ithaca, NY 14850
(607) 255-2080
FAX: (607) 255-9946
e-mail: DIST_Center@CCE.Cornell.EDU
Order code: 139NVP
$14.95 postage included

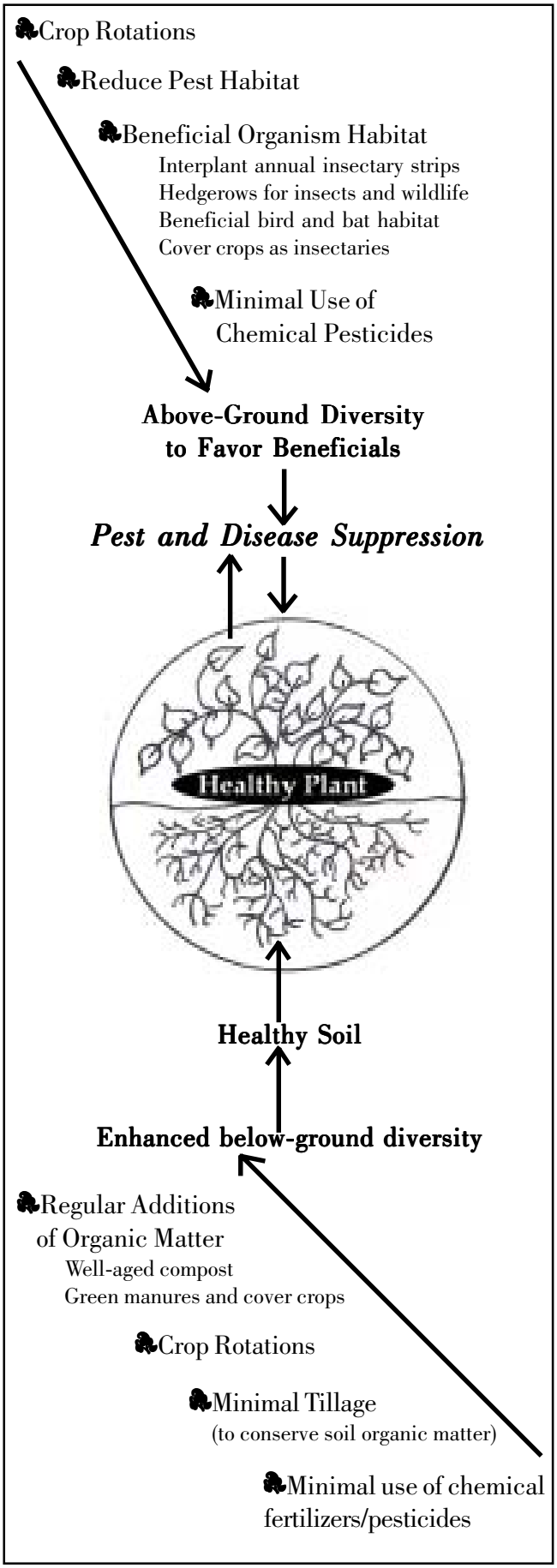
Mahr, Daniel L., and Nino M. Ridgeway. 1993. **Biological Control of Insects and Mites: An Introduction to Beneficial Natural Enemies and their Use in Pest Management.** North Central Region Publication No. 481. Cooperative Extension
Service, University of Wisconsin. 91 p.

This book provides a good introduction to biological control of insects and mites with a geographic focus on the north central U.S. A brief review of insect biology, types of pests, and crop damage is followed by sections on natural and artificial types of insect pest control. A third of the book, accompanied by good photos and diagrams, focuses on the families of natural enemies that provide biological control of insects and mites. The remaining text gives an overview of biological control techniques, with a focus on periodic release of natural enemies. Information on conservation of natural enemies is a bit thin, but overall a very good reference and overview of the subject.

To order:

Send $13.50/copy ($11 + $2.50 for shipping) with check payable to "Extension Publications" to:

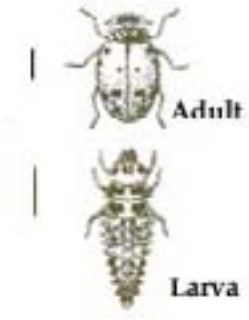
University of Wisconsin
Cooperative Extension Publications
45 N. Charter St.
Madison, WI 53715



Appendix A

Plants that Attract Beneficials (A1)		
Beneficial	**Pests**	**How to attract/conserve**
Aphid midge (*Aphiodoletes aphidimyza*) (Larvae are aphid predators)	Aphid	Dill, mustard, thyme, sweet clover; Shelter garden from strong winds; Provide water in a pan filled with gravel (A2).
Aphid parasites (*Aphidius matricariae* and others)	Aphid	Nectar-rich plants with small flowers (anise, caraway, dill, parsley, mustard family, white clover, Queen Anne's lace, yarrow). Don't use yellow sticky traps (A2).
Assassin bug (Reduviidae family)	Many insects, including flies, tomato hornworm, large caterpillars	Permanent plantings for shelter (e.g., hedgerows)
Bigeyed Bugs (*Geocoris* spp. of Lygaeid Family) (lines represent actual size)	Many insects, including other bugs, flea beetles, spider mites, insect eggs and small caterpillars. Will also eat seeds (A12).	Can build up in cool-season cover crops such as berseem clover (*Trifolium alexandrium*) and subterranean clovers (*Trifolium subterraneum*). Can be found on common knotweed (*Polygonum aviculare*) as well (A11).
Braconid wasp (Braconidae family)	Armyworm, cabbageworm, codling moth, gypsy moth, European corn borer, beetle larvae, flies, aphid, caterpillars, other insects	Nectar plants with small flowers (caraway, dill, parsley, Queen Anne's lace, fennel, mustard, white clover, tansy, yarrow), sunflower, hairy vetch, buckwheat, cowpea, common knotweed, crocuses, spearmint (A2, A3, A4, A6).
Damsel bug (Nabidae family)	Aphid, thrips, leafhopper, treehopper, small caterpillars	Anything in the sunflower family as well as goldenrod, yarrow, alfalfa.
Ground beetle (Carabidae family)	Slug, snail, cutworm, cabbage-root maggot; some prey on Colorado potato beetle, gypsy moth and tent caterpillar	Permanent plantings, amaranth; white clover in orchards, mulching.

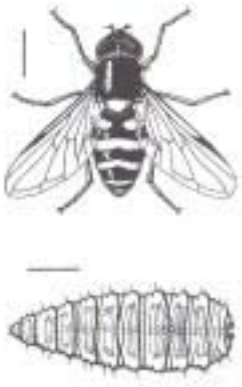
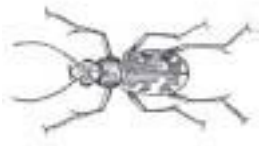
Appendix A

Plants that Attract Beneficials (A1) *continued*		
Beneficial	**Pests**	**How to attract/conserve**
Lacewing, Neuroptera Family (*Chrysoperla* and *Chrysopa* spp.) Top: adult; Middle: larva; Bottom: eggs (lines represent actual size) After Extension Service 4-H Handbook	Soft-bodied insects including aphid, thrips, mealybug, scale, caterpillars, mite	Carrot family (caraway, Queen Anne's lace, tansy, dill, angelica), sunflower family (coreopsis, cosmos, sunflowers, dandelion, goldenrod), buckwheat, corn, holly leaf cherry (*Prunus ilicifolia)*, flowering bottle tree (*Brachychiton populneum),* soapbark tree (*Quillaja saponaria)*. Provide water during dry spells (A2, A3, A4, A6, A7).
Ladybird beetle or ladybug (*Hippodamia* spp. and others)  (lines represent actual size) After USDA Bull. 2148	Aphid, mealybug, spider mite, soft scales	Once aphids leave a crop, lady beetles will also. To retain active lady beetles , maintain cover crops or other hosts of aphids or alternate prey (A11). Carrot family (fennel, angelica, dill, tansy, bishop's weed (*Ammi*), Queen Anne's lace), sunflower family (goldenrod, coreopsis, cosmos, golden marguerite (*Anthemis*), dandelion, sunflower, yarrow), crimson clover, hairy vetch, grains and native grasses, butterfly weed (*Asclepias*), black locust, buckwheat, euonymus, rye, hemp sesbania (*Sesbania exaltata*), soapbark tree, buckthorn (*Rhamnus*), saltbush (*Atriplex* spp.), black locust (*Robinia pseudoacacia*) (A2, A3, A4, A6, A7, A8).
Mealybug destroyer (*Cryptolaemus montrouzieri*)	Mealybug	Carrot family (fennel, dill, angelica, tansy), sunflower family (goldenrod, coreopsis, sunflower, yarrow) (A2).

Appendix A

Plants that Attract Beneficials (A1) *continued*		
Beneficial	**Pests**	**How to attract/conserve**
Minute Pirate Bug (Anthocorid Family, *Orius* spp.) (line represents actual size) After Oregon Exp. Station Bull. 749	Thrips, spider mite, leafhopper, corn earworm, small caterpillars, many other insects	Effective predators of corn earworm eggs. Carrot family (Queen Anne's lace, tansy, coriander, bishop's weed, chervil), sunflower family (cosmos, tidy tips (*Layia*), goldenrod, daisies, yarrow), baby-blue-eyes (*Nemophila*), hairy vetch, alfalfa, corn, crimson clover, buckwheat, blue elderberry *(Sambucus caerulea*) willows, shrubs. Maintain permanent plantings or hedgerows (A2, A4, A6, A7, A9).
Parasitic nematodes	Nematodes	Marigolds, chrysanthemum, gaillardia, helenium, *Eriophyllus lanatum*, horseweed (*Conyza canadensis*), hairy indigo, castor bean, *Crotalaria* spp., *Desmodium* spp., sesbania, mexicantea (*Chenopodium ambrosioides*), shattercane (*Sorghum bicolor*), lupines, *Phaseolus atropurpurens* (A10).
Praying mantis (*Mantis* spp.)	Any insect (including beneficials)	Cosmos, brambles. Protect native species by avoiding pesticides (A3).
Predatory mite (*Typhlodromus* spp.) After Oregon Extension Service	Spider mite	There are many species of predatory mites with ecological requirements—especially with respect to humidity and temperature—particular to the species. Avoid use of insecticides. Provide beneficial refugia for non-crop habitat of non-crop mite prey.
Predatory thrips (Thripidae family)	Spider mite, aphid, other thrips, Oriental fruit moth, codling moth, bud moth, peach twig borer, alfalfa weevil, whitefly, leafminer, scale	There are several species of predatory thrips. Predatory thrips populations may be conserved/maintained by having non-crop populations of plant-feeding mites (e.g., European red mite, two-spotted spider mite), scales, aphids, moth eggs, leafhoppers, and other thrips.
Rove beetle (Staphylinidae family) 	Aphid, springtail, nematode, flies; some are parasitic on cabbage-root maggot	Permanent plantings; interplant strips of rye, grains, and cover crops; mulch beds; make stone or plant walkways in garden to provide refuges.

Appendix A

Plants that Attract Beneficials (A1) *continued*		
Beneficial	**Pests**	**How to attract/conserve**
Spider	Many insects	Caraway, dill, fennel, cosmos, marigold, spearmint (A2, A6).
Spider mite destroyer (*Stethorus* spp.)	Spider mite	Carrot family (dill, fennel, etc.), mustard family (sweet alyssum, candytuft, etc.).
Spined soldier bug (*Podisus maculiventris*)	Fall armyworm, sawfly, Colorado potato beetle, Mexican bean beetle	Sunflower family (goldenrod, yarrow), bishop's weed; Maintain permanent plantings (A7).
Syrphid fly (Hover flies) (Syrphidae family)  (lines represent actual size) After USDA Bull. 1930	Aphid	Carrot family (Queen Anne's lace, dill, fennel, caraway, tansy, parsley, coriander, bishop's weed), the sunflower family (coreopsis, Gloriosa daisy, yarrow, cosmos, sunflower, marigolds), candytuft, sweet alyssum, ceanothus, holly-leaved cherry (*Prunus ilicifolia*), buckwheat, scabiosa, spearmint, coyote brush (*Baccharis pilularis*), knotweed (*Polygonum aviculare*), California lilacs (*Ceanothus* spp.), soapbark tree, meadow foam (*Linnanthes douglasii*), baby-blue-eyes (*Nemophila*); (A2, A3, A4, A5, A6, A7).
Tachinid fly (Tachinidae family) After U.S.D.A	Cutworm, armyworm, tent caterpillar, cabbage looper, gypsy moth; some attack sawfly, Japanese beetle, May beetle, squash bug, green stink bug, sowbug	Carrot family (caraway, bishop's weed, coriander, dill, parsley, Queen Anne's lace, fennel), goldenrod, sweet clover, *Phacelia* spp., sweet alyssum, buckwheat, amaranth, buckthorn, *Heteromeles arbutifolia* (A2, A3, A4, A6, A7).
Tiger beetle (Cicindelidae family)  After MA State Board of Agriculture, 1862	Many insects	Maintain permanent plantings and some exposed dirt or sand areas.

Appendix A

Plants that Attract Beneficials (A1) *continued*		
Beneficial	**Pests**	**How to attract/conserve**
Chalcid wasps (many families, including Trichogrammatidae) (line represents actual size) After USDA Bull. 1642	Spruce budworm, cotton bollworm, tomato hornworm, corn earworm, corn borer, codling moth, other moths	Maintain a diversity of plants, including dill, anise, caraway, hairy vetch, spearmint, Queen Anne's lace, buckwheat, common knotweed, yarrow, white clover, tansy, cowpea, fennel, cosmos, chervil. For orchards, provide a mix of clover and flowering weeds (A2, A3, A6).
Whitefly parasitic wasp (*Encarsia formosa*)	Greenhouse whitefly, sweet potato whitefly	Carrot family (Queen Anne's lace, dill, fennel, tansy), sunflower family (yarrow, sunflower, cosmos, coreopsis) (A2).

Sources:

A1) Gilkeson, Linda and Joel Grossman. 1991. The organic gardening guide to important beneficial insects and mites of NorthAmerica. Organic Gardening. May-June. p. 46–55.

A2) Poncavage, Joanna. 1991. Beneficial borders. Organic Gardening. May-June. p. 42–45.

A3) Kite, Patricia. 1990. Attract these insects. Organic Gardening. April. p. 71–72.

A4) Bugg, Robert L. 1990. Biological control of insect pests in sustainable agriculture. Components. UC Sustainable Agriculture Research and Education Program. Vol. 1, No. 3. 7 p.

A5) Bugg, Robert L. 1993. Habitat manipulation to enhance the effectiveness of aphidophagous hover flies (Diptera: Syrphidae). Sustainable Agriculture/Technical Reviews. UC Sustainable Agriculture Research and Education Program. Winter. p. 12–15.

A6) Cicero, Karen. 1993. Making a home for beneficial insects. The New Farm. February. p. 28–33.

A7) Merrill, Richard. 1995. It's a bug-eat-bug world. Fine Gardening. April. p. 64–67.

A8) Reynolds, William. 1994. Attracting beneficial insects to the farm field. The Grower. July. p. 1–4.

A9) Grossman, Joel. 1991. Insect plants. IPM Practitioner. September. p. 10.

A10) William, R.D. 1981. Complementary interactions between weeds, weed control practices, and pests in horticultural cropping systems. HortScience. August. p. 10–15.

A11) Bugg, R.L. 1999. Beneficial insects and their associations with trees, shrubs, cover crops, and weeds. pp. 63-65. In: Bring Farm Edges Back to Life! Yolo Country Resource Conservation District, Woodland, CA. 105 p.

A12) Flint, M.L. and S.H. Dreistadt. 1998. Natural Enemies Handbook. The Illustrated Guide to Biological Pest Control. U.C. Press. Berkeley. p. 93.

Appendix B

Pests and Associated Beneficial Insects	
Pest	**Beneficial that attacks it**
Alfalfa weevil	Predatory thrips, *Bathyplectes* wasps, *Tetrastichus incertus* (wasp parasite)
Aphid	Aphid midge, aphid parasites, syrphid fly, ladybug, parasitic wasp, big-eyed bug, damsel bug, mealybug destroyer, soldier beetle, lacewing, braconid wasp, predatory thrips, rove beetle, syrphid fly
Armyworm	Big-eyed bug, braconid wasp, spined soldier bug, tachinid fly
Beetles	Braconid wasp
Bud moth	Predatory thrips
Cabbage looper	Tachinid fly
Cabbage-root maggots	Ground beetle, rove beetle
Cabbageworm	Braconid wasp
Caterpillars in general	Assassin bug, lacewing, Trichogramma wasp, braconid wasp, damsel bug, minute pirate bug
Codling moth	Braconid wasp, predatory thrips, Trichogramma wasp
Colorado potato beetle	Ground beetle, spined soldier bug
Corn earworm	Big-eyed bug, minute pirate bug, Trichogramma wasp, lacewing
Cotton bollworm	Trichogramma wasp
Cutworms	Ground beetle, tachinid fly
European corn borer	Braconid wasp, Trichogramma wasp
Flea beetles	Big-eyed bug
Flies	Braconid wasp
Green stink bug	Tachinid fly
Gypsy moth	Braconid wasp, ground beetle, tachinid fly
Japanese beetle	Tachinid fly
Leafhopper	Big-eyed bug, damsel bug, minute pirate bug

Appendix B

Pests and Associated Beneficial Insects *continued*	
Pest	**Beneficial that attacks it**
Leafminer	Predatory thrips
Looper	Big-eyed bug, parasitic wasps
Lygus bugs	Big-eyed bug, braconid wasp, *Anaphes iole*
May beetle	Tachinid fly
Mealybugs	Ladybug, big-eyed bug, mealybug destroyer, lacewing
Mexican bean beetle	Spined soldier bug
Mites	Ladybug, big-eyed bug, lacewing, minute pirate bug
Nematodes	Rove beetle
Oriental fruit moth	Predatory thrips
Peach twig borer	Predatory thrips
Psyllids	Big-eyed bug
Sawfly	Spined soldier bug, tachinid fly
Scales	Lacewing, predatory thrips
Slugs	Ground beetle, parasitic nematodes
Snails	Ground beetle
Soft scales	Ladybug
Sowbug	Tachinid fly
Spider mite	Ladybug, minute pirate bug, predatory mite, predatory thrips, spider mite destroyer, western predatory mite
Springtails	Rove beetle
Spruce budworm	Trichogramma wasp
Squash bug	Tachinid fly
Tent caterpillar	Ground beetle, tachinid fly
Thrips	Ladybug, minute pirate bug, big-eyed bug, damsel bug, lacewing
Tomato hornworm	Big-eyed bug, assassin bug, Trichogramma wasp
Treehoppers	Damsel bug
Whiteflies	Lacewing, predatory thrips, whitefly parasitic wasp (*Encarsia* spp.)

Appendix C

Seed Blends, Plants and Sprays to Attract Beneficial Insects (C1, C2)		
Blend	**Planting information (from manufacturers/suppliers)**	**Supplier**
Good Bug Blend™	Since the mix blooms nearly year-round, Good Bug Blend should be planted in areas that can go a little wild, such as field borders, ditchbanks, fence rows, etc. Generally, you need to plant only 1–5% of your land with this mix for good results. Crimson, rose and sweet clovers, subclovers, alfalfas, gypsophila, *Eriogonum fasiculatum*, white alyssum, nasturtium, yarrow, carrot, dill, daikon, celery, radish, fennel, caraway, chervil, coriander, and more. Drill or broadcast seed at 10–15 lb./acre (1 lb. /1,000 sq. ft.) in any but the coldest months of the year. Large-scale growers: if you are planting in fall, add vetch at 5 lb./acre. If you are planting in spring, add 10 lb. of buckwheat and 10 lb. of cowpeas/acre.	Peaceful Valley Farm Supply P.O. Box 2209 Grass Valley, CA 95945 (916) 272-4769 http://www.groworganic.com/
Low Growing Good Bug Blend	A mix of annuals and perennials under 2 feet tall, for use below trees, cane berries, vines or along border areas with height limitations. This mix performs best with regular drip, sprinkler or furrow irrigation during dry periods. It blooms 6–10 months/year and contains: carrot, chervil, coriander, clovers (crimson, white, rose), subclovers, nasturtium, parsley, alyssum and yarrow. Drill or broadcast at 10–15 lb./planted acre (1lb./1,000 sq. ft.).	Peaceful Valley Farm Supply (see above)
Border Patrol™	For best results sow this mix 4–6 weeks prior to planting your garden. Border Patrol has more color, but is less effective than Good Bug Blend. Species include white evening primrose, wild buckwheat, baby blue eyes, candytuft, bishop's flower, black-eyed susan, strawflower, nasturtium, angelica and yarrow.	Peaceful Valley Farm Supply (see above)
Good Bug Food (Spray)	This product is a food source for beneficial insects. In their adult stage, these insects need pollen and sugars, which are often not present in sufficient quantities. Beneficial insects especially need additional food during dry periods. Derived from Brewer's Yeast and powdered milk, Good Bug Food can attract and increase beneficial populations as much as tenfold. Mix one part food with an equal part of honey or sugar. Paint this mixture onto cardboard or wooden stakes and place in your garden or greenhouse.	Peaceful Valley Farm Supply (see above)
All Purpose Insectary Plant Blend™ (Pacific Seed)	Plant swaths through crop areas. White clover, yellow clover, yarrow, cilantro, caraway, fennel, parsley, sweet alyssum, tidy tips, baby's breath, cosmos. Use ½ lb./1500 sq. ft. or 10–12 lb./acre.	Harmony Farm Supply P.O. Box 460 Graton, CA 95444 (707) 823-9125 http://www.harmonyfarm.com/

Appendix C

Seed Blends, Plants and Sprays to Attract Beneficial Insects (C1, C2) *continued*		
Blend	**Planting information (from manufacturers/suppliers)**	**Supplier**
Beneficial Blend™ (made by Lohse-Mill)	Barley, cereal rye, subclover, berseem clover, crimson clover, white clover, yellow clover, alfalfa, mustard, coriander, sweet alyssum, yarrow, buckwheat. Use ½ lb./1500 sq. ft. or 10–12 lb./acre.	Harmony Farm Supply (see above)
Border Patrol™	Beneficial insect attractant flowers. Formulated by Clyde Robin wildflower company, this is a mix of flower seeds specially chosen to attract beneficial insects and provide homes for them. One can covers 350 square feet and it's recommended for use as a border around the garden or between beds. Works best if it's planted a few weeks before the rest of the garden; first blossoms will appear in 45–90 days. Many of the flowers are perennials which will bloom year after year; the mix includes evening primrose, wild buckwheat, baby blue eyes, black-eyed susan, straw flowers, nasturtiums, bishop's flowers, angelica, and yarrow.	Bountiful Gardens 18001 Shafer Ranch Road Willits, CA 95490 (707) 459-6410
Haven™ Flowering Herbs	Haven is a blend of popular culinary herbs (dill, fennel). These herb varieties have small flowers (tiny predators can't reach the nectar of large blossoms), with abundant nectar and a long flowering period. The flowers attract a wide variety of the most desirable beneficial insects. Sow the seeds after danger of spring frost.	Gardens Alive! 5100 Schenley Place Lawrenceburg, IN 47025 (812) 537-8650 http://www.gardens-alive.com/
Haven™ Cover Crop	Blend of leguminous cover crops provides a habitat for beneficial insects. Sow in spring on soil that is to lie fallow for the season. When tilled under, the plants add nitrogen to the soil and reduce the need for additional fertilizing. Includes ladino, red clover, white clover, hairy vetch.	Gardens Alive! (see above)
Bug Pro™ (spray)	BugPro provides the protein beneficial insects need to induce egg-laying, when a natural insect diet is not available. BugPro effectively attracts lady beetles and lacewings to your garden. 5 lbs. makes 10 gallons, covers 10,000 sq. ft. Spray or drop on foliage where you want to attract beneficials.	Gardens Alive! (see above)
no specific blends	Nursery that sells plants at three different sizes, including many ornamental and useful plants from around the world. California lilac, willows, shrubs, wildflowers, grasses.	Forestfarm 990 Tetherow Road Williams, OR 97544 (541) 846-7269 http://www.forestfarm.com/search/plant.asp
no specific blends	Niche Gardens is a mail-order and retail nursery. They specialize in nursery-propagated wildflowers and natives, perennials, ornamental grasses and unusual trees and shrubs.	Niche Gardens 1111 Dawson Road Chapel Hill, NC 27516 (919) 967-0078

Appendix C

Seed Blends, Plants and Sprays to Attract Beneficial Insects (C1, C2)		
Blend	**Planting information (from manufacturers/suppliers)**	**Supplier**
No specific blends	Specializes in **native grasses**, including: Bentgrass, Tufted Hairgrass, Slender Hairgrass, Squirrel Tail, Slender Wheatgrass, Blue Wild Rye, Idaho Fescue, Calif. Fescue, Meadow Barley, Calif. Barley, Junegrass, Creeping Wild Rye, Calif. Onion Grass, Hartford's melic, Deergrass, Nodding Needlegrass, Foothill Needlegrass, Purple Needlegrass, One sided Bluegrass. **Sedges/Rushes:** White Root Sedge, Slender Sedge, Torrent Sedge, Baltic Rush, Flat Bladed Rush, and Common Rush. **Forbs:** Yarrow, Narrow-leaf Milkweed, Purple Aster, Calif. Poppy, Gum Plant. **Legumes:** Small-flowered Lupine, Arroyo Lupine, Yellow Lupine, Bull Clover, and Tomcat clover.	Hedgerow Farms 21740 County Rd. 88 Winters, CA 95694 (916) 662-4570
Beneficial Blend™	Cereal rye, barley, subclover, common vetch, yellow clover, white clover, crimson clover, LM 331 alfalfa, mustard, Queen Anne's lace, coriander, baby's breath, buckwheat, baby-blue-eyes, bishop's weed, fennel, celery, yarrow, sweet alyssum.	Lohse Mill, Inc P.O. Box 168 Artois, CA 95913 (916) 934-2157 http://www.forages.css.orst.edu/Resources/Vendors/Seed/Lohse/index.html
Beneficial Insect Food (spray/paste)	Ready to use, just add water. Beneficial Insect Food supplies the pollen and nectar sources that beneficials (Ladybugs, Lacewings) need, to go with the protein they get from eating other insects. Helps attract beneficials, aids in increased reproduction, and keeps them in your garden and greenhouse. May also be made into a paste.	Garden City Seeds 778 Hwy 93 North Hamilton, MT 59840 (406) 961-4837
no specific blends	West Coast natives including California lilac, grasses, perennial buckwheat and wildflowers.	Cornflower Farms P.O. Box 896 Elk Grove CA 95759 (916) 689-1015
no specific blends	Herbs, mints, vetch, Queen Anne's lace, yarrow and other wildflowers.	Richter's 357 Hwy 47 Goodwood, ON L0C 1A0 Canada (905) 640-6677

Sources:

C1) Beane, Kerry. 1994. Beneficial seed blends. Common Sense Pest Control. Spring. p. 18.

C2) Poncavage, Joanna. 1994. Attract beneficial insects. Organic Gardening. December. p. 44.

Appendix D

Examples of Farmscaping		
Cropping System & Problem	**Location; Strategy (*e.g.* beneficial habitat, trap crop) and Details**	**Researcher and Contact Information**
Stink bugs in Pecans	**Texas**: Trap crop of black-eyed peas for stink bugs. When the growers compared the average dollar losses from stink bugs between the trap-cropped sites and the non-trap-cropped sites they found that the non-trap-cropped sites sustained $29.29 more stink bug associated losses than did the trap-cropped orchards. It cost the growers approximately $2,112.50 (about $211.25/acre of peas) to establish and maintain the trap-cropped peas. When spread over the 650 acres of the pecan farm being affected by the presence of the trap crops, the growers spent $3.25/acre (of pecans) to establish and maintain the trap crops. The growers determined for every dollar they spent establishing and maintaining the trap crops, they prevented $9.01 in kernel damage from stink bugs. See also: http://www.sarep.ucdavis.edu/cgi-win/sare/sare.exe/id=689	Kyle Brooksheir Box 216 Van Horn, TX 79855 (915) 283-2506
Thrips on pepper plants	**Florida**: Cover crops and weeds as beneficial insect habitat for thrips control. During the summer of 1994 the participants tried Alyce clover and Aeschynomene, both legumes, as cover crops. Rank growth of the latter resulted in these being mowed soon after peppers were planted. The participants also monitored insect populations in a native weed species, *Wedelia triloata*, found growing abundantly on the ditch banks. This particular weed harbored large numbers of a non-destructive species of thrips, as well as predatory insects, and will be examined further in the future. Future testing of such nursery areas will include a more critical selection of cover crops. The researchers will be seeking plants with a prostrate growth habit that does not interfere with farming operations and that will continue to flower through Florida's winter season. The research found that cover crops are helpful in providing refuges for predatory insects, but more covers with prostrate growth and a winter flowering period need to be identified. USDA entomologists predict that the range of the melon thrips, *Thrips palmi*, will extend north into Georgia, and west to the Pacific Ocean. Accordingly, nearly all of the nation's winter pepper production is at risk. http://www.sarep.ucdavis.edu/cgi-win/sare/sare.exe/id=687	Ted & Trudy Winsberg Green Cay Farms Rt. 1 Box 331B Boynton Beach, FL 33437 (407) 499-5345
Establishing Hedgerows as Beneficial Insect Habitat	**California**: perennial plants and native grasses as hedgerows for beneficial insect habitat for various row crops.	Mary Kimble 221 W. Court St., Ste. 1 Woodland, CA 95695 (530) 662-2037 ext. 3
Lygus bug on strawberries	**California**: Annual trap crop of one dormant and one semi-dormant alfalfa variety, two radish varieties (Daikon and the edible variety Cherry Belle) and sweet alyssum (Carpet of Snow variety). Preliminary indications are that lygus moving in from surrounding fields settle on the annual trap cop mix. The trap crop can then be treated by chemicals or vacuumed, thereby avoiding any chemical applications to the strawberries.	Sean Swezey/Polly Goldman U.C. Santa Cruz Santa Cruz, CA (831) 755-2889

Appendix D

Examples of Farmscaping *continued*		
Cropping System & Problem	**Location; Strategy (*e.g.* beneficial habitat, trap crop) and Details**	**Researcher and Contact Information**
Integrated sour cherry orchard design effects on pest management	**Michigan**: The orchard systems include an integrated system of Alternative Insect Management (AIM); and a Permaculture System (PER). A third system, Integrated Pest Management (IPM) which is currently used by progressive growers is included for comparison. AIM is based on fundamental changes in the orchard ecosystem, including mixed species hedgerow barriers to reduce pest immigration and enhance beneficial arthropod abundance; insect pheromone mating disruption; endophytic grasses to inhibit pest abundance; mass trapping; tree mulches and alternative groundcovers to reduce weed competition and enhance biological diversity.	Charles Edson IPM Program, Center for Integrated Plant Systems, Michigan State Univ. B18 Food Safety and Toxicology Bldg East Lansing, MI 48824 (517) 353-5134
Strip-Intercropping clover-alfalfa mix with vegetables for insect pest control	**California**: Pest break strips (D1) have been effective for enhancing biological control in potatoes and several other row crops. Pest break strips have a dual role: 1) as trap crops, they divert pests away from market crops; and 2) as insectary crops, they grow beneficial insects helping to provide biological control of pests in adjacent rows of vegetable crops. This report noted that control was "Good to excellent. Insect predators and parasites keep aphids and caterpillars under control; leafhopper and leaf miner prefer alfalfa in pest break strips to other hosts." The large-scale trials occurred on a farm in central California. Managers made pest break strips five to seven beds wide (80-inch bed width) at intervals of 350 feet across the farm. Several mixes of grasses, legumes and wildflower were tested for effectiveness in supporting beneficial insects. The most effective mix was found to be predominantly alfalfa (60%) mixed with Dutch white clover, strawberry clover, berseem clover and crimson clover (10% each).	Nature Farming Research and Development Foundation 6495 Santa Rosa Road Lompoc, CA 93436 (805) 737-1536 FAX: (805) 736-9599
Green peach aphid on lettuce	**California**: W.E. Chaney of the UC Cooperative Extension in Salinas, CA, has done field trials interplanting insectary plants (which provide beneficial insects pollen and nectar) with vegetables for biological control of the green peach aphid. He used sweet alyssum interplanted every twenty rows in a field of lettuce. Alyssum was chosen because it can be seeded instead of using transplants, and will flower in about 30 days. It does not attract either aphids or tarnished plant bugs, is not aggressive, and provides a good food source for parasitic wasps. By adding sweet alyssum and other pollen and nectar plants to monoculture vegetables, natural enemies such as the green peach aphid parasite, Diaretiella rapae, will have a chance to play a greater role in vegetable pest control. Under ideal conditions, Diaretiella rapae parasitized 90-95 percent of available host aphids (D2). Cheney's trial in lettuce provided sufficient reduction of aphids to do without other controls. However, 5 percent of the production area was lost to alyssum. It should be noted that during the course of this research, changes in the lettuce pest complex led to a situation in which the pea leafminer, *Liriomyza huidobrensis*, was increasing in importance relative to the green peach aphid. As a result, local growers did not adopt this system.	W.E. Chaney U.C. Cooperative Extension 1432 Abbot St Salinas, CA 93901 (408) 759-7350

Appendix D

Examples of Farmscaping *continued*		
Cropping System & Problem	**Location; Strategy (*e.g.* beneficial habitat, trap crop) and Details**	**Researcher and Contact Information**
Cabbage aphid in broccoli	**Oregon**: In an on-farm research trial exploring the use of beneficial insectary flowers to increase the abundance of predatory insects, experimental plots using the insectary plant *Alyssum maritima* showed a significant increase in predacious syrphid flies caught in traps and in number of syrphid eggs laid on broccoli leaves. Parasitism of the cabbage aphid was doubled in the alyssum plots. Bugg and Ellis (D4) observed that flowers of canola attracted adults of the following species of hoverflies (Syrphidae): *Allograpta obliqua* (Say), *Sphaerophoria* spp., *Syrphus* spp., and *Toxomerus* spp. Larvae of all of these species are predators of aphids.	John Luna Oregon State University Dept. of Horticulture Corvallis, OR 97331 (541) 737-5430
Diamondback moth on Crucifers	**Florida**: Trap crops of highly fertilized collards planted in a border around cabbage fields are more attractive to egglaying adult female diamond back moths (dbms). This resulted in minimal damage from dbm to cabbages. In commercial cabbage fields, two rows of collards were planted around perimeters with seven collard plants planted on the ends of each cabbage row. Cabbage fields with collards required 75-100% fewer chemical applications than those without collards. Marketability from both collard and non-collard fields was the same.	Everett Mitchell USDA-ARS 1600 S.W. 23rd Dr. Gainesville, FL 32604 (352) 374-5710
Black Flea beetles on crucifers	**Eastern Colorado**: Radish cultivar, "Japanese Daikon" as trap crop interplanted at 2" intervals within broccoli rows, which were planted 16" apart. This technique reduced the numbers of black flea beetles colonizing broccoli compared to plots without interplanted radishes or with interplanted radishes at lower densities (D7).	Mohammed Al-Dogghairi 1700 W. Plum St. #57F Ft. Collins, CO 80521 (970) 491-3005 or 5261
Azalea lace bug on Landscape/ ornamentals	**New Jersey**: The presence of flowering plants--shasta daisy plugs (Little Princess *Chrysanthemum maximum* and *Marconi leucanthemum superbum*) and coriander (*Coriander sativum*)--reduced lacebug numbers because of the buildup of syrphids, lady beetles and other unidentified predators. There appears to be a seasonal impact of flower species on the duration of predator species and abundance. Coriander flowered earlier but more briefly than the two daisy species, and appeared to harbor less diversity than the daisy. However, there were more species of syrphids in the coriander. The azaleas were small, and researchers believe that many released lacewings left the plots. The flowers and azaleas established well, so prospects for clear results are high in 1999.	Paula M. Shrewsbury Rutgers University Dep. of Entomology, J.B. Smith Hall, P.O. Box 231 New Brunswick NJ, 08903 (908) 932-9324
Leafhoppers and flower thrips in vineyards	**California**: This study suggests that the creation of corridors of sequentially flowering native plant species can serve as a key strategy to allow natural enemies emerging from riparian forests to disperse over large areas of otherwise monoculture sytems. This study examined distributions and abundance of western grape leafhopper, *Erythroneura elegantula*, its parasitoid, *Anagrus* spp., western flower thrips, *Frankliniella occidentalis*, and generalist predators (D6).	Miguel Altieri Center for Biological Control University of California Berkeley, CA 94720 (510) 642-9802 agroeco3@nature.berkeley.edu

Appendix D

Examples of Farmscaping *continued*		
Cropping System & Problem	**Location; Strategy (*e.g.* beneficial habitat, trap crop) and Details**	**Researcher and Contact Information**
Leafhoppers and spider mites in vineyards	**California**: If properly managed, winter annual, legume/grass (oat/vetch) cover crops can reduce the reliance of grape growers on insecticides and miticides used to control leafhoppers and spider mites. Two systems: 1) the cover crop as dry mulch by cutting the cover crop biomass and placing it on row berms for weed suppression to reduce herbicide use, 2) cover crop was cut and left in row middles. If sulfur dust (used for disease control) was used sparingly in late Spring and early Summer, the presence of these cover crops increased early season activity of predatory mites, resulting in reduced spider mite infestations. Similarly, where leafhopper numbers were not very low and cover crops were properly maintained through early July, the presence of cover crops resulted in reduced infestations of leafhoppers. These reductions were attributed to enhanced activity of certain groups of spiders, which consistently attained higher densities in the presence of cover crops compared to the clean-cultivated systems. Leafhoppers were also utilizing the cover crops as non-host crops, which may have resulted in less time spent on vines.	Frank G. Zalom Extension Entomologist Department of Entomology University of California Davis, CA 95616 (916) 752-8350 FAX: (916) 752-6004 E-Mail: fgzalom@ucdavis.edu
Aphids in Cereals (D3)	**England**: Recent research in England indicates that by planting border stips of *Phacelia tanacetifolia* Bentham (a North American annual that is a good source of pollen for syrphids--syrphid larvae feed on aphids) along cereal fields, significant reductions of aphid populations can be obtained. Increased populations of syrphid flies extended up to 180 meters (195 yards) from the border strips. The researcher notes that in seasons of early crop maturity, syrphid fly larvae may not be able to decrease aphid populations due to lack of attractiveness of the "older" wheat to ovipositing syrphids.	Janice M. Hickman Department of Biology, School of Biological Sciences, Biomedical Sciences Building The University, Southamption, SO16 7PX UK
Pest in Vegetables	**North Carolina**: Organic vegetable grower plants an insectary strip every 36 feet or so (i.e., if growing canteloupes on 6 foot rows, the 7th row will be an insectary strip, or if growing peppers on 3 foot rows, every 13th row will be planted in an insectary strip). Rye/vetch mixtures are planted in the fall and will flower early in the spring and are plowed down and sequentially replaced with buckwheat prior to the rye/vetch going to seed. For example, one week a third of the rye/vetch rows may be plowed down and replaced with buckwheat. A few weeks later, another third will be plowed down, etc. This way, there is habitat as well as continual pollen and nectar sources for beneficial insects throughout most of the year. During the summer, the buckwheat is also replaced sequentially as it senesces. The farmer states that this system has been very successful.	Kenny Haines Looking Back Farms Rt. 2, Box 600D Tyner NC, 27980 (252) 426-2218 FAX: (252) 426-9661
Pests in Cotton (D6)	**Texas**: This study examined the predator flux between adjacent planted cotton and grain sorghum fields. It was found that there was a general influx of generalist predators (*Orius* spp.--minute pirate bug, and *Hippodamia convergens*--convergent lady beetle) from sorghum to cotton, although dispersion of predators works in both directions and may be dependant on both crop phenology and associated food resources (i.e., lack of or abundance of herbivorous prey).	Jarrad R. Prasifka Biological Control Lab Department of Entomology Texas A&M University, College Station, TX 77843-2475 (409) 862-3407 email: jrp7200@labs.tamu.edu

Appendix D

Examples of Farmscaping *continued*		
Cropping System & Problem	**Location; Strategy (*e.g.* beneficial habitat, trap crop) and Details**	**Researcher and Contact Information**
Phylloxera on Grapes	**California**: A recent 2-year field study (D8) by UC Davis researchers found that soil management practices can significantly influence the amount of root damage resulting from phylloxera-induced fungal infections. The researchers found that per-unit root populations of phylloxera did not significantly differ between organically managed vineyards (OMV) and conventionally managed vineyards (CMV), when both were infested with phylloxera. However, root samples from OMVs displayed significantly less root necrosis (9%) caused by fungal pathogens than did samples from CMVs (31%). Organic vineyard management is characterized by use of cover crops and composts and no synthetic fertilizers or pesticides. This study sampled four OMVs in Sonoma, Napa and Mendocino counties. Eight CMVs were initially sampled in these counties and San Joaquin County. This was later reduced to five CMVs for practical reasons. All vines except for those in San Joaquin (own-rooted) were on AXR#1 rootstock. No significant differences between OMVs and CMVs were found for single year comparisons of percent organic matter, total nitrogen, nitrate and percent sand/silt/clay. The pooled data for the two years tell a slightly different story: OMVs soil had a significantly higher (by .5%) percent organic matter (%OM) than CMVs soil and over all vineyards and all years there was a weak but significant inverse correlation between root necrosis and soil %OM. Cultures of the necrotic root tissue also revealed some interesting differences: significantly higher levels of the beneficial fungus *Trichoderma* were found in OMVs in 1997 (but not in 1998) and significantly higher levels of pathogens *Fusarium oxysporum* and *Cylindrocarpon* spp. were found in CMVs in 1998 (but not in 1997).	Dr. Jeffrey Granett 380B Briggs Hall (530) 752-7650 FAX: (530) 752-1537 jgranett@ucdavis.edu

Sources:

D1) Dietrick, E.J., J.M. Phillips and J. Grossman. 1995. Biological Control of Insect Pests Using Pest Break Strips. Nature Farming Research and Development Foundation. Lompoc , CA. (booklet)

D2) Grossman, Joel and W. Quarles. 1993. Strip intercropping for biological control. The IPM Practitioner. April. p. 1–11.

D3) Hickman, J.M. and S.D. Wratten. 1996. Use of *Phacelia tanacetifolia* strips to enhance biological control of aphids by hoverfly larveae in cereal fields. Journal of Economic Entomology. August. p. 832–840.

D4) Bugg, R.L., and R.T. Ellis. 1990. Insects associated with cover crops in Massachusetts. Biological Agriculture and Horticulture. Vol. 7. p. 47–68.

D5) Prasifka, J.R., P.C. Krauter, K.M. Heinz, C.G. Sansone and R.R. Minzenmayer. 1999. Predator conservation in cotton: using grain sorghum as a source for insect predators. Biological Control. Vol.16. p. 223–229.

D6) Nicholls, C., M. Parrella and M.A. Altieri. 2000. Establishing a plant corridor to enhance beneficial insect biodiversity in an organic vineyard. Organic Farming Research Foundation. Winter. Number 7. p. 7–9.

D7) Grossman, Joel. 1999. Radish and flea beetles. The IPM Practitioner. July. p.14.

D8) HortScience 34(6): 1108-1111. 1999. Differences in grape phylloxera-related grapevine root damage in organically and conventionally managed vineyards in California. To browse archives for the full article,visit: http://ashs.frymulti.com/hortscience.asp

Appendix E

Hedgerow Installation and Maintenance Cost Estimates

For one hedgerow 1400 feet long x 15 feet wide (~.5 acre) planted with a strip of native grasses next to a line of shrubs.

Labor costs are estimated at $10/hr.

Task	Date of Cost Estimate	Labor	Material	Equipment	Total
Hedgerow Installation					
Hedgerow design	Nov. 96	$260.00	Survey flags: $8.00		$268.00
Roundup: summer weed control	Aug. 96	$20.00	Roundup $30.00	ATV+sprayer: $8.08	$58.08
Disk: pre-plant weed control	Oct. 96	$10.00		Tractor+disc: $18.08	$28.09
Bed preparation: plants/grasses	Oct. 96	$10.00		Tractor+bedshaper: $14.33	$24.33
Fertilize-preplant (tablets)	Nov. 96	$20.00	Fertilizer: $43.50		$63.50
Plant trees, shrubs, and forbs	Nov. 96	$120.00	Plants: $500		$620.00
Install 2' Tubex tree tubes	Nov. 96	$50.00	Tubex: $172.00		$222.50
Plant grasses (broadcast)	Nov. 96	$20.00	Seed: $275.00		$295.00
Harrow to cover grass seed	Nov. 96	$10.00		ATV+harrow: $4.04	$14.04
Roundup: annual weed control	Nov. 96	$10.00	Roundup: $15.00		$25.00
Ronstar-G: apply in plant row	Nov. 96	$10.00	Ronstar-G" $75.00		$85.00
Install drip irrigation system	Mar. 97	$100.00	Drip supplies: $200.00		$300.00
Total Installation		$640.00	$1,319.00	$44.54	$2,003.54

Task	Date of Cost Estimate	Labor	Material	Equipment	Total
Hedgerow Maintenance					
2,4 D: Broadleaf weed control	Mar. 97	$10.00	2,4 D: $20.00	ATV+sprayer: $4.04	$34.04
Hoe hedge plant row*	Mar.-Sep.97	$250.00			$250.00
Irrigate twice/mo.	Mar.-Oct.97	$250.00	Emitters/plugs: $8.25		$258.25
Mow grasses: annual weed control	Apr. 97	$10.00		Tractor+mower: $10.19	$20.19
Remove Tubex	Apr-May 97	$20.00			$20.00
Roundup: spot-spray	May-Jun 97	$20.00	Roundup: $15		$35.00
Fertilize: preplant (tablets)	Sep. 97	$10.00	Fertilizer: $8.70		$18.70
Replant trees, shrubs & forbs	Sep. 97	$80.00	Plants: $100.00		$180.00
2,4 D: spot-spray in grasses	Sep. 97	$10.00	2,4 D: $10.00		$20.00
Flame: annual grass weed control	Oct. 97	$10.00	Propane: $15.00	ATV+flamer: $4.04	$29.04
Ronstar-G: entire hedgerow	Oct. 97	$20.00	Ronstar-G: $225.00		$245.00
Mow grasses twice: weed control	Mar-May 98	$20.00		Tractor+mower: $20.38	$40.38
Hoe hedge plant row	Jun-Jul 98	$120.00			$120.00
Irrigate twice/mo.	Apr-Sep 98	$200.00			$200.00
Hoe hedge plant row	Jun-Jul 98	$120.00			$120.00
Herbicide: 2,4 D (in grasses)	Aug. 98	$10.00	2,4 D: $10.00		$20.00
Total Maintenance		**$1,160.00**	**$411.95**	**$38.65**	**$1,610.60**
Total Cost		**$1,800.00**	**$1,730.95**	**$83.19**	**$3,614.14**

Source:

E1) Kimball, Mary, and C. Lamb. 1999. Establishing Hedgerows for Pest Control and Wildlife. p. 19. In: Bring Farm Edges Back to Life! Yolo County Resource Conservation District, Woodland, CA. 105 p.

Appendix F

Flowering Periods of California Native Insectary Plants

Common Name	Genus/ sp.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Willow	*Salix spp.*	■	■	■	■								
California lilac	*Ceanothus spp.*		■	■	■	■							
Mule fat	*Baccharis viminea*		■	■	■	■							
Coffeeberry	*Rhanmus californica*				■	■							
Hollyleaf cherry	*Prunus ilicifolia*				■	■							
Yarrow*	*Achillea millefolium*				■	■	■	■					
Silverlace vine	*Polygonum aubertii*				■	■	■	■	■	■	■	■	
Toyon	*Heteromeles arbutifolia*					■	■						
Golden sticky monkeyflower	*Mimulus guttatus*					■	■	■	■	■			
Elderberry	*Sambucus mexicana*					■	■	■	■	■			
California buckwheat**	*Eriogonum fasciculatum*					■	■	■	■	■	■	■	■
Deergrass	*Muhlenbergia rigens*						■	■	■	■			
Creeping boobialla	*Myoporum parvifolium*						■	■	■	■	■		
California fuchsia	*Zauschneria californica*						■	■	■	■	■		
Narrowleaf Milkweed	*Asclepias fascicularis*						■	■	■	■	■		
St. Catherine's lace	*Eriogonum giganteum*						■	■	■	■	■	■	■
Coyote bush	*Baccharis pilularis*	■									■	■	■

*Insects prefer common yarrow over the ornamental (salmon-colored) yarrows. Yarrow reseeds itself well.
**California buckwheat is very attractive to beneficials, but also very sensitive to overwatering.

Source:

F1) Kimball, Mary, and C. Lamb. 1999. Establishing Hedgerows for Pest Control and Wildlife. p. 16. In: Bring Farm Edges Back to Life! Yolo County Resource Conservation District, Woodland, CA. 105 p.

Appendix G

Farmscaping Practices Defined

The practices described below can be integrated with an array of cultivation schemes. Each farm can take advantage of the variety of farmscaping tools available to create a cropping system especially suited to its unique environment.

Practice	Description
Companion planting	A mix of species of plants within a row or bed--was rated difficult to manage by farmers in one study (G1) due to varying cultural needs such as planting time, irrigation needs, and harvesting.
Strip planting, Strip cropping	The practice of growing two or more crops in different strips across a field wide enough for independent cultivation, (e.g., alternating six-row blocks of soybeans and corn, or alternating strips of alfalfa with cotton) was rated as most easily adapted to vegetable production systems (G1). Like intercropping, strip cropping increases the diversity of a cropping area, which in turn may help "disguise" the crops from pests. Another advantage is that one of the crops may act as a reservoir and/or food source for beneficial organisms. However, much more research is needed to study the complex interactions between different crops and their pest and predator complexes.
Multiple cropping	The production of more than one crop on the same land in one year. Depending on the type of cropping sequence used, multiple cropping can be useful as a weed control measure, particularly when the second crop is interplanted into the first.
Interplanting	The seeding or planting of a crop into a growing stand, such as overseeding a cover crop into a grain stand.
Intercropping	The practice of growing two or more crops in the same, alternate, or paired rows in the same area. This technique is particularly appropriate in vegetable production. The advantage of intercropping is that the increased diversity helps "disguise" crops from insect pests, and if done well, may allow for more efficient utilization of limited soil and water resources.
Cover crops	Cover crops and green manures can be integrated into both perennial and annual cropping systems. Cover crops, often a legume or grass species, prevent soil erosion and suppress weeds. A cover crop can also be used as a green manure.
Green manures	Generally incorporated into the soil to provide nitrogen and organic matter for subsequent crops. When incorporated, some cover crops in the Brassica family (such as rapeseed, broccoli and radish) have the ability to suppress nematode pests (G2). Left in the field as residues, rye, wheat, and some other grasses will provide greater than 90 percent weed suppression (G3,G4).
Windbreaks Shelterbelts and Hedgerows	These are linear barriers of trees, shrubs, perennial forbs and grasses that are planted along field edges or other unused areas. When done correctly, they reduce windspeed and, as a result, modify the microclimate in the protected area. Aside from providing a microclimate favorable to beneficial organisms, shelterbelts also protect against wind erosion of soil, decrease the dessicating effect of winds on crops, help enhance snow distribution and provide wildlife habitat.
Permanent border	A strip of permanent vegetation bordering a field. A border such as this can be modified to attract beneficial insects throughout the cropping season if the proper plants are used and sufficient water is made available.

Sources:

G1) Bachmann, Janet, et al. 1995. Habitat enhancement for beneficial insects in vegetable and fruit farming systems. SARE/ACE Annual Report AS92-2. Southern Region. p. 87.

G2) http://www.hort.purdue.edu/newcrop/proceedings1996/v3-615.html

G3) Doll, Jerry and Tom Bauer. 1990. Rye: More than a mulch for weed control. Paper presented to Wisconsin Crop Improvement Association. Madison, WI. 7 p.

G4) Worsham, A.D. 1984. Crop residues kill weeds. Crops and Soils Magazine. November. p. 18–20.

The electronic version of **Farmscaping to Enhance Biological Control** is located at:
HTML
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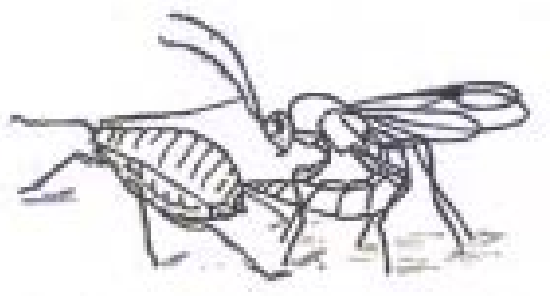

by Rex Dufour
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December 2000

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Feedback

1. What information do you think is missing from this publication?

2. Do you know someone implementing farmscaping techniques on their farm? Can you pass on their address and phone number?

3. Do you know of farmscaping-related research that would improve this publication?

4. Do you know of a good farmscaping-related website not listed in this publication?

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