Habitat Management in Vineyards

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Habitat Management in Vineyards

A growers manual for enhancing natural enemies of pests.

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Typical grape production in California is done in monocultures which are expanding at a rapid rate resulting in the simplification of the landscape. One of the known problems with monocultures is that the diversity, abundance and activity of natural enemies of pests is drastically decreased due to the removal of vegetation which provides critical food resources and overwintering sites necessary for the longevity, reproduction and survival of many predators and parasites. Since the onset of such simplification farmers have been faced with a major ecological dilemma arising from the homogenization of vineyard systems: increased vulnerability of crops to insect pests and diseases, many of them devastating when infesting uniform and homogeneous large-scale monocultures. Many scientists are concerned that as vineyards expand, natural vegetation acting as refugia decline and consequently the contribution to pest suppression by biocontrol agents using these habitats is diminishing. In fact many pest problems affecting today's vineyards have been exacerbated by such habitat simplification trends.

One of the main ecological options to rectify this habitat decline is to increase the vegetational diversity of vineyards and surrounding landscapes. Plant biodiversity is crucial to crop defenses: the more diverse the plants and associated animals and soil-borne organisms that inhabit a vineyard system, the more diverse the community of pest-fighting beneficial organisms (predators, parasitoids, and entomopathogens) the farm can support.

In this manual we explore practical steps to restore agricultural biodiversity at the field and landscape level thus breaking the monoculture nature of vineyards and reducing their ecological vulnerability. The most obvious advantage of diversification is a reduced risk of crop failure due to invasions by unwanted species and subsequent pest infestations. The manual focuses on ways in which increased plant biodiversity can contribute to stabilizing pest population by creating an appropriate ecological infrastructure within and around vineyards.

Biodiversity in vineyards: types and roles

Biodiversity refers to all species of plants, animals, and microorganisms existing and interacting within a vineyard, many of which play important ecological functions such as pollination, organic matter decomposition, predation or parasitism of pests. These ecosystem services are largely biological; therefore their persistence depends upon maintenance of ecological diversity in the vineyards. When these natural services are lost due to biological simplification, the economic and environmental costs can be quite significant. Economically, in viticulture the burdens include the need to supply crops with costly external inputs such as insecticides, since vineyards deprived of functional biodiversity lack the capacity to sponsor their own pest regulation.

Biodiversity in vineyards includes the vines, cover crops, weeds, arthropods, soil fauna and microorganisms. In general the type and abundance of biodiversity in vineyards depends on three main features:

- The diversity and type of vegetation within and around the vineyard and the permanence of these plant communities
- The quality of soil, its organic matter content, cover level and biological activity
- The intensity of management and types of inputs used depending on whether the vineyard is conventional, organic or in transition.

The biodiversity components of vineyards can be classified in relation to the role they play in the functioning of the vineyard systems. Vineyard biodiversity can be grouped as follows:

- *Productive biota*: the vines and other crops or animals chosen by farmers
- *Functional biota*: organisms that contribute to productivity through pollination,

biological control (predation and parasitism of pests), organic matter decomposition, nutrient mineralization, etc
- *Destructive biota*: weeds, insects pests, microbial pathogens, etc., which farmers aim at reducing through cultural management.

The above categories of biodiversity can further be recognized as two distinct components. The first component, *planned biodiversity*, includes the vines, and other crops or animals purposely included in the vineyard by the farmer. The second component, *associated biodiversity*, includes all soil flora and fauna, herbivores, predators, parasites, decomposers. that inhabit the vineyard or that colonize from surrounding environments and that thrive in the system depending on its management (use of chemicals or organic inputs, etc) and the vegetational diversity of the system. The relationship of both types of biodiversity components is illustrated in **Figure 1**. Planned biodiversity has a direct function, as illustrated by the arrow connecting the planned biodiversity box with the ecosystem function box. Associated biodiversity also has a function, but it is mediated through planned biodiversity. Thus, planned biodiversity also has an indirect function, which is realized through its influence on the associated biodiversity. For example, the cover crops in a vineyard provide biomass to enhance soil organic matter and fertility, so the direct function of this second species (cover crops) is to improve soil quality. Yet along with the cover crops come parasitic wasps that seek out the nectar in the cover's flowers. These wasps are in turn the natural parasitoids of pests that normally attack the vineyard. The wasps are part of the associated biodiversity. The cover crops then improve soil fertility (direct function) and attract wasps (indirect function). Obviously the type and abundance of associated biodiversity is influenced by the kind of vegetation that surrounds the vineyard, with vineyards immersed in a more heterogeneous landscape exhibiting a more diverse array of associated organisms.

By promoting the right type of functional biodiversity in vineyards it is possible to enhance ecological processes that provide key services such as the activation of soil biology, the recycling of nutrients, the regulation of pests by beneficial arthropods and antagonists, and so on. A key challenge is to identify the type of biodiversity that is desirable to maintain and/or enhance in the vineyard in order for them

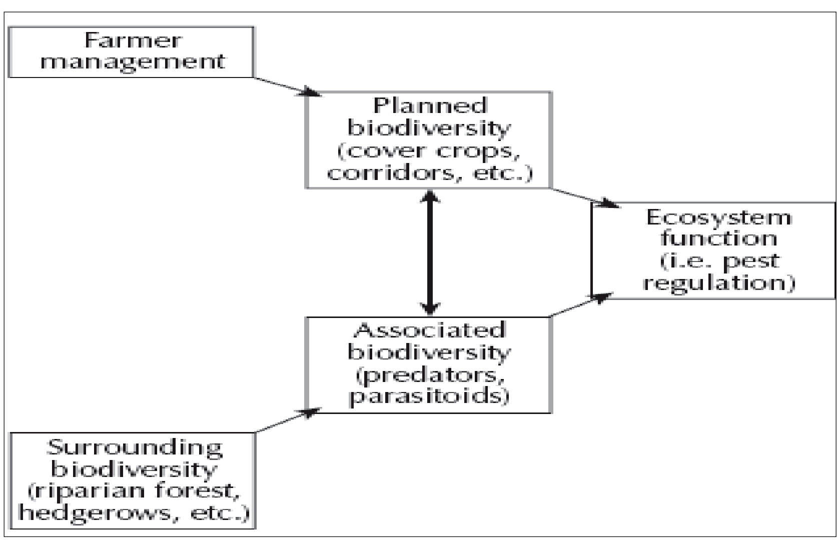


Figure 1. The relationships between planned and associated biodiversity in promoting pest regulation in vineyards.

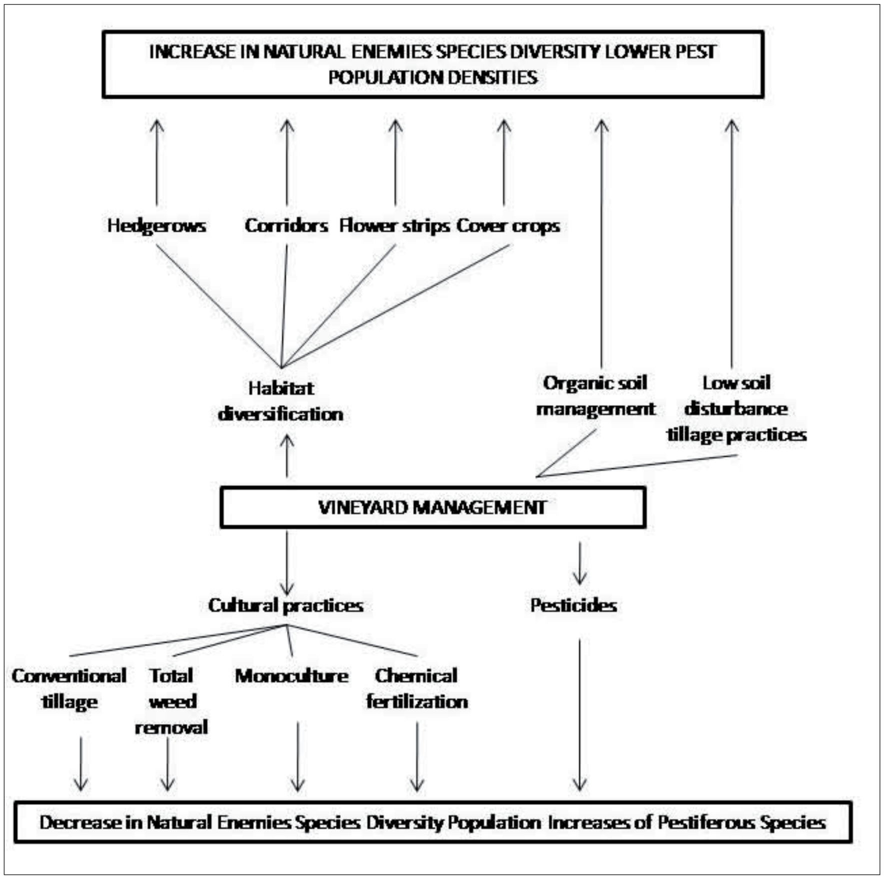


Figure 2. The effects fo agroecosystem management and associated cultural practices on the diversity and abundance of natural enemies and the densities of insects pests

to carry out key ecological services, and then to determine the best practices that will encourage the desired beneficial organisms. There are many agricultural practices and designs that have the potential to enhance functional biodiversity, and others that negatively affect it (**Figure 2**.)

Biological control: a key ecological service in vineyards

One major ecological service provided by biodiversity in vineyards is the regulation of abundance of undesirable organisms through predation and parasitization. Every insect herbivore is attacked to some degree by one or more natural enemies (also called beneficial insects) , thus predators, parasites, and pathogens act as natural control agents resulting in the regulation of herbivore numbers in a particular ecosystem. This regulation is known as biological control defined as "the action of parasites, predators, or pathogens in maintaining another organism's population density at a lower average than would occur in their absence". Biological control can be self-sustaining and distinguishes itself from all other forms of pest control by acting in density and/or a density-dependent manner, that is: natural enemies increase in intensity and destroy a larger population of the population as the density of that population increases, and visa-versa. The goal of biological control is to hold a target pest below economically damaging levels — not to eliminate it completely — since decimating the population also removes a critical food resource for the natural enemies that depend on it.

Applied biological control is essentially a strategy to restore functional biodiversity in agroecosystems by adding, through augmentative releases of natural enemies, "missing" entomophagous insects in the crop field. This practice is not commonly followed in vineyards and instead farmers rely on strategies aimed at conserving and enhancing naturally occurring predators and parasitoids through habitat management. The idea is to attract early in the season a complex of beneficials and provide them with habitat and alternative food so that they can build up in numbers and remain in the farming system throughout the season.

To complete their life cycles, natural enemies need more than prey and hosts; they also need refuge sites and alternative food. Many adult parasites and predators sustain themselves with pollen and nectar from flowering weeds or from alternative hosts or prey present in non-crop vegetation within or around vineyards. Research has shown that by adding plant diversity to monocultures, it is possible to create habitat conditions which favor natural enemy abundance and effectiveness. In plant diverse cropping systems there is generally an increased abundance of arthropod predators and parasitoids due to enhanced availability of alternate prey, nectar sources and suitable shelter.

Habitat management is based on the notion that one of the most powerful and long-lasting ways to minimize economic damage from pests is to boost populations of existing naturally occurring beneficial organisms by supplying them with appropriate habitat and alternative food sources.

Natural enemies of vineyard pests

Most vineyards are inhabited by a diversity of natural enemies, but their abundance will depend on whether growers use toxic pesticide and if they maintain a reasonable amount of plant diversity in the vineyard. Each main pest attacking vines has one or two natural enemies **(Table 1)** which if present early enough in the season and in sufficient numbers can usually keep pest populations below damaging levels.

Table 1. Main insect pest of vineyards and their key natural enemies (Guerra, 2010).

Main Pests	Main Beneficials
Western grape leafhopper (*Erythroneura elegantula* O.) **Variegated leafhopper** (*Erythroneura variabilis* B.)	**Anagrus wasp** (*Anagrus* spp.) **Spiders** (Ex. *Cheiracantium* spp., *Metaphidippus* spp., *Oxiopes* spp., *Theridion* spp.) **Whirligig mite** (*Anystis agilis*) **Green lacewings** (*Chrysoperla* spp.) **Brown lacewings** (*Hemerobius* spp.)
Grape mealybug (*Pseudococcus maritimus*) **Longtailed mealybug** (*Pseudococcus longispinus*) **Obscure mealybug** (*Pseudococcus viburni*) **Vine mealybug** (*Planococcus ficus* S.)	**Mealybug destroyer** (*Cryptolaemus montrouzieri* M.) **Green lacewings** (*Chrysoperla* spp., *Chrysopa* spp.) **Brown lacewings** (*Hemerobius pacificus*) **Flies:** Cecidomyiids (*Diadiplosis koebelei* K.) **Many parasitoids**
Pacific spider mite (*Tetranychus pacificus* Mc.) **Willamette spider mite** (*Eotetranychus willamettei*)	**Predaceous mites:** Phytoseiids (*Galendromus occidentalis*)

Leafhopper enemies: The main parasitoid of leafhoppers is a tiny wasp called *Anagrus* which parasitizes leafhopper eggs, and in the process, it destroys them. *Anagrus* can typically kill 90 percent of the western grape leafhopper (WGLH) eggs present in a vineyard, whereas they rarely kill more than 40 percent of the variegated leafhopper eggs, which are laid deeper in the leaf tissue. Natural predators that feed on leafhoppers include spiders, the whirligig mite , green lacewings and a species of tiger fly.

Mealybug enemies: There a four spieces of mealy bugs that attack grapes although the most dominant are the grape mealybug and the vine mealybug which is the most problematic. One of the most effective mealybug predators is the "mealybug destroyer," a lady beetle whose success resides in its camouflage. The wax-like filaments of the mealybug destroyer larvae, resembling those of the mealybug, allow this lady beetle to feed on the mealybugs without disturbance from foraging ants. Other mealybug predators include the lady bug beetle *Hyperaspis sp*, lacewings and *Cecidomyiid* flies. Green and brown lacewings can also feed on mealybugs. Several naturally occurring parasitoids also attack grape mealybugs and a host of parasitoid species introduced from other countries. Ant control is a necessary component of any mealybug biological control program

Mite enemies: The most important predators of spider mites are other predatory mites (*phytoseiid* species). Predaceous mites can be released in the vineyard, but release time, rather than rate, seems to be a crucial factor. Fall releases of *phytoseiid* mites provides excellent control of spider mites the following season, whereas summer releases seem to have little effect. Other spider mite predators although less effective, include six-spotted thrips, minute pirate bugs, and the lady beetle mite destroyer *Stethorus picipes*.

Enemies of moth pests : Economically important moth species in grape vineyards include the omnivorous leafroller, orange tortrix, grape leafroller and the western skeletonizer. Green lacewings as well as various spider species are important predators of moth larva. Eggs of these moths are generally parasitized by *Trichogramma* wasps and the larvae by a number of wasps in the *Braconid, Ichneumonid, Chalcid* and *Eulophid* families, as well as *Tachinind* parasitic flies. Although a new pest in California, it is known that several species of parasitic wasps can parasitize the eggs, larvae and pupae of *Lobesia botrana*. *Trichogamma* species are known egg-parasites of European grapevine moth. Studies are needed to determine how early in the season *Trichogamma* species begin to parasitize *L. botrana* eggs, if other species of native parasites attack the larval or pupal stages, and the impact these parasites have in reducing moth densities and their damage.

Conserving natural enemies

Naturally occurring beneficials, at sufficient levels, can take a big bite out of pest populations. To exploit them effectively, it is important to:

1) identify which beneficial organisms are present;

The following characteristics are typical of vineyards that host plentiful populations of beneficials insects:

- **Small fields surrounded by natural vegetation.**
- **Diversified cropping systems with year-round cover crops and hedges that include perennials and flowering plants.**
- **Crops are managed organically or with low chemical inputs, including modest sulphur applications.**
- **Soils are high in organic matter and are biologically active.**
- **Soils covered with mulch or cover crops throughout the year.**

2) understand their individual biological cycles and their food and habitat requirements;
3) try to find out where do these beneficials overwinter, when do they appear in the field, where do they come from, what attracts them to the crop, how do they develop in the crop and what keeps them in the field;
4)When do the beneficials' critical resources — nectar, pollen, alternative hosts and prey — appear and how long are they available? Are alternate food sources accessible nearby and at the right times? Which native annuals and perennials can compensate for critical gaps in timing, especially when prey are scarce?

Once most of this information is known, farmers can make changes in vineyard management to meet the needs of beneficials and enhance their populations .

To conserve and develop rich populations of natural enemies, it is important to avoid cropping practices that harm beneficials such as insecticide applications, hedge removal and herbicide use that eliminates weeds in and around fields. Instead, substitute methods that enhance their survival. Even small changes in farming routines can substantially increase natural enemy populations during critical periods of the growing season. The simple use of straw mulch provides humid, sheltered hiding places for nocturnal predators like spiders and ground beetles. Good soil tilth and generous quantities of organic matter can stimulate a useful diversity of pest-fighting soil organisms. Carefully selected flowering plants placed as strips within the field or in margins are important sources of beneficial insects that move into adjacent fields to help regulate insect pests.

Diversification of vineyards to enhance biological control : experiences in California

Managing vegetation surrounding vineyards to meet the needs of beneficial organisms:

Several studies indicate that the abundance and diversity of entomophagous insects within a vineyard is dependent on the plants species composition of the surrounding vegetation. The distribution and abundance of natural enemies in the crop field is determined by the distance to which natural enemies disperse into the crop from the borders. The role of riparian habitats and especially of wild blackberry patches near vineyards in enhancing the effectiveness of the wasp *Anagrus epos* in parasitizing the grape leafhopper is well known (**Figure 3)**. It is also known that French prunes harbor an economically insignificant leafhopper whose eggs provide *Anagrus* with an overwinter host site. Based on this knowledge, researchers established that French prunes adjacent to vineyards could also serve as overwintering sites for A. epos and found higher leafhopper parasitism in grape vineyards adjacent to prune tree refuges. Since the effect of prune refuges is limited to a few vine rows downwind thus A. epos exhibits a gradual decline in vineyards with in-

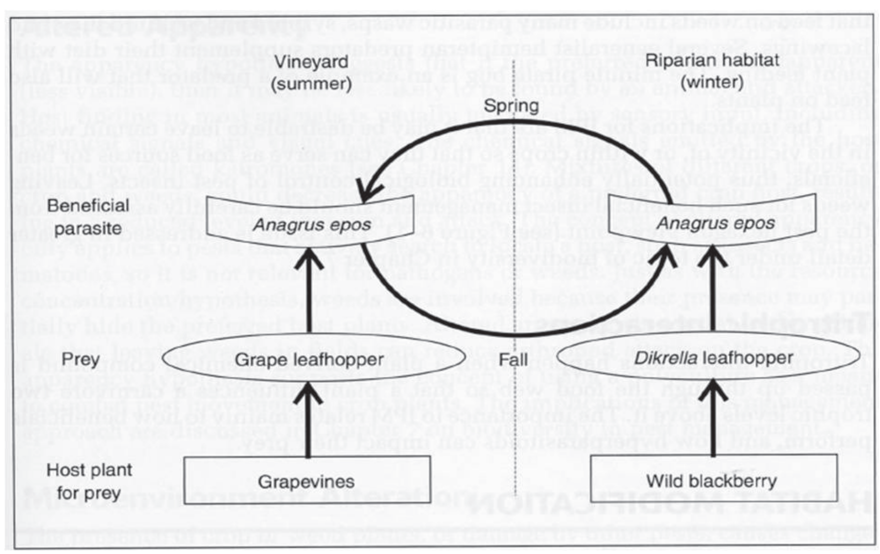


Figure 3. The role of wild blackberry as a winter habitat for Anagrus wasps providing a bridge for early spring vineyard colonization by wasps (Doutt and Nakata, 1973)

creasing distance from the re fuge (**Figure 4)**. This poses an important limitation to the use of prune trees as the colonization of grapes by *Anagrus* is confined to field borders leaving the central rows of the vineyard void of biological control protection. To overcome such limitation some growers have established vegetational corridors composed of flowering species that cut across the vineyard, serving as a biological highway for the movement and dispersal of natural enemies from riparian forest into the center of the vineyard. These new landscape structures enhance movement of beneficials beyond the "normal area of influence" of adjacent habitats or refuges.

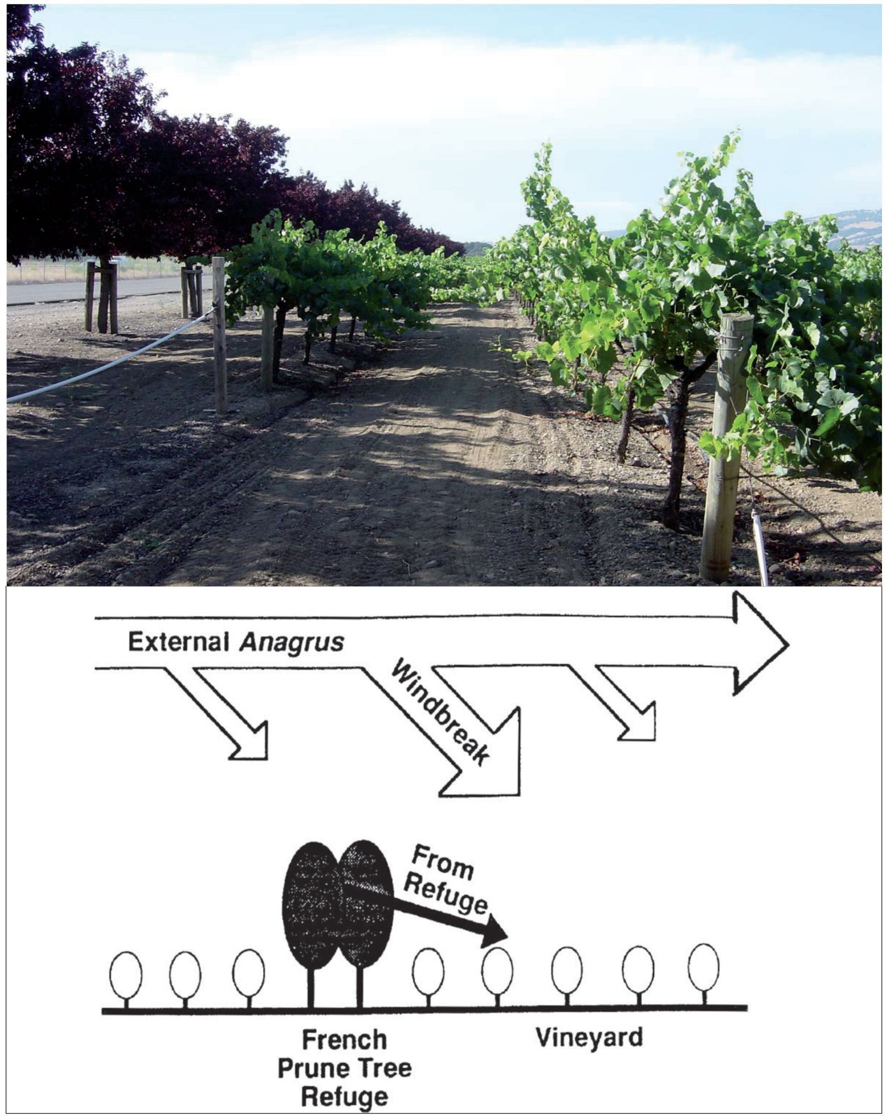


Figure 4. French prune tree refuges as a source of Anagrus wasps early in the season (Corbett and Rosenheim, 1996)

In Mendocino county a 600 m corridor composed of at least 65 flowering species including fennel (*Foeniculum vulgare*), yarrow (*Achillea millefolium*), *Erigeron annuus*, *Buddleja* spp. and other flowering plants was established cutting across a vineyard. Adult leafhoppers exhibited a clear density gradient reaching lowest numbers in vine rows near the corridor and increasing in numbers towards the center of the field. The highest concentration of adult and nymphal leafhoppers occurred after the first 20–25 rows (30–40m) downwind from the corridor (**Figure 5).** The abundance and spatial distribution of generalist predators in the families *Coccinellidae, Chrysopidae, Anthocoridae, Nabidae* and *Syrphidae* was influenced by the presence of the corridor which channeled dispersal of the beneficals into adjacent vines (**Figure 6).** Predator numbers were higher in the first 25m adjacent to the corridor which probably explains the reduction of leafhoppers observed in the first 25 - 30 vine rows near the corridor.

Other growers leave sections of undisturbed habitat distributed at intervals in or around vineyards. Depending on the plant species, these "perennial islands" provide shelter and food resources to predators and parasitic wasps as well as overwintering sites from which vineyards can be colonized in the spring. This is the approach used in a vineyard in Sonoma County where an island of flowering herbaceous annuals and perennials was created at the center

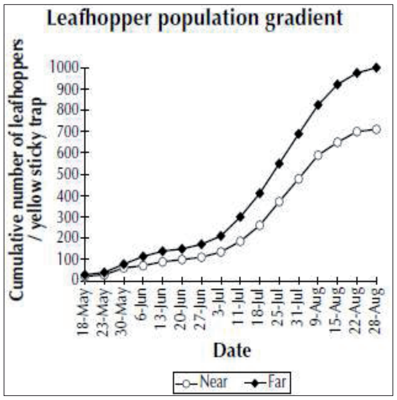


Figure 5. Population of leafhoppers near (<25 m) and far from a corridor (Nicholls et al, 2001)

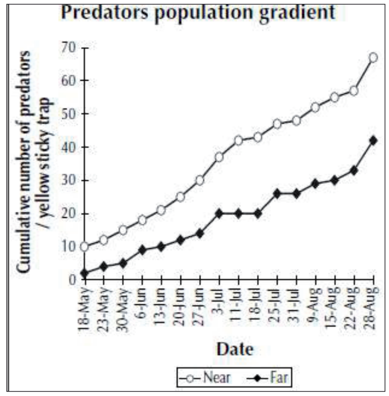


Figure 6. Population of predators near (< 25m) and far from a corridor (Nicholls et al, 2001)

of a vineyard and which acts as a push-pull system for natural enemy species. During the 2004 season, sampling revealed that the island acts as a source of pollen, nectar, and neutral insects which serve as alternate food throughout the growing season to a variety of predator and parasites, including *Anagrus* wasps. Catches in yellow sticky traps placed inside the island and at various distances within the vineyard, suggest that many natural enemies moved from the insectory island into the vineyard (up to 60 meters). *Orius* sp. and Coccinellids are prevalent colonizers at the beginning of the season, but later syrphid flies and *Anagrus* wasps start dispersing from the island into the vineyard (**Figure 7)**. Parasitization of leafhopper eggs by *Anagrus* wasps was particularly high on vines near the island, with parasitization levels

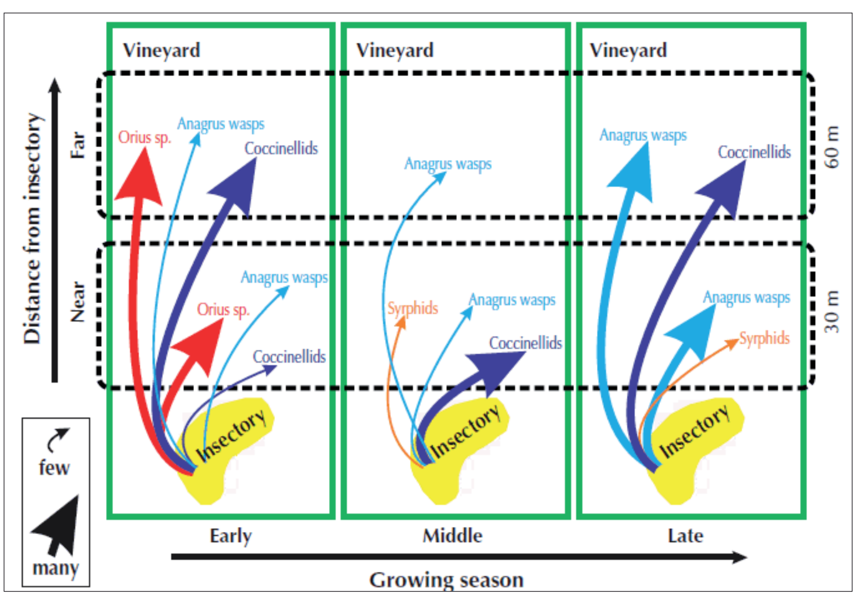


Figure 7. Dispersal of Anagrus wasps and generalist predators from the island into de vineyard.

decreasing towards the center of the vineyard away from the island.

Planting cover crops to enhance natural enemies. Growers have many options to include cover crops in their vineyards (Appendix I). Among the many benefits of cover crops (protect soils from erosion, improve soil fertility, improve soil structure, and water holding capacity) the provision of habitat for predator and parasitic arthropods stands out (**Figure 8).** Researchers have reported lower populations of mites in vineyards with cover crops due to enhanced populations of predaceous mites **(Figure 9)**, although improved water penetration, greater soil fertility and reduced dust associated with cover crops may also be responsible for observed effects on mites. Growers report experiences of reduced leafhopper problems when cover crops are planted in lieu of conventional insecticide applications. In many cases such biological suppression has not been sufficient from an economic point of view. Part of the leafhopper reduction found in cover-cropped vineyards may be due to the reduced vigor resulting from the nutrient and water competition, as it has been found out that when vine vigor is reduced, leafhopper populations are also reduced.

The low effectiveness of winter cover crops to reduce pests, is due to the fact that this vegetation dries early in the season or is mowed or plowed under at the beginning of the growing season, leaving vineyards in late spring and summer as virtual monocultures without floral diversity. For this reason new habitat management approaches emphasize the maintainance of a flowering cover that blooms early and throughout the season in order to provide habitat and a well-dispersed alternative food source, as well as microhabitats, for a diverse community of natural enemies. In a Mendocino vineyard maintaining floral diversity throughout the growing season using a mixture of buckwheat and sunflower reduced substantially the abundance of western grape leafhoppers and western flower thrips while the abundance of associ-

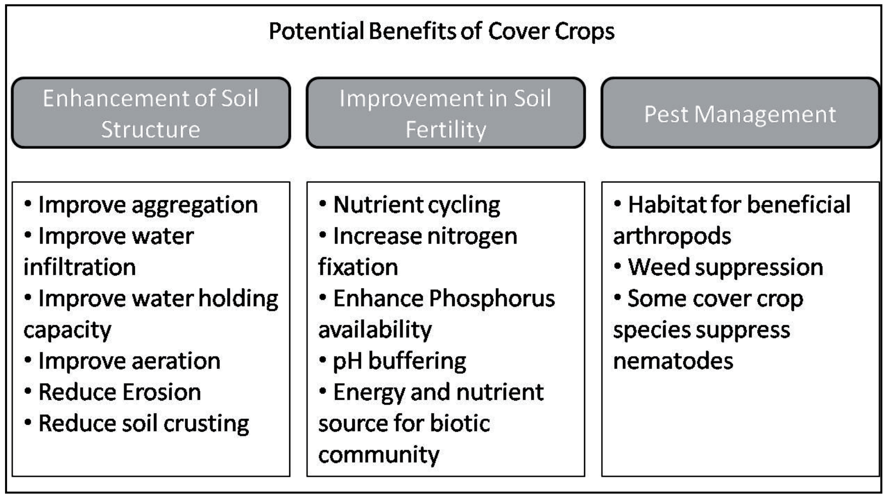


Figure 8. The multiple benefits of cover crops in vineyards

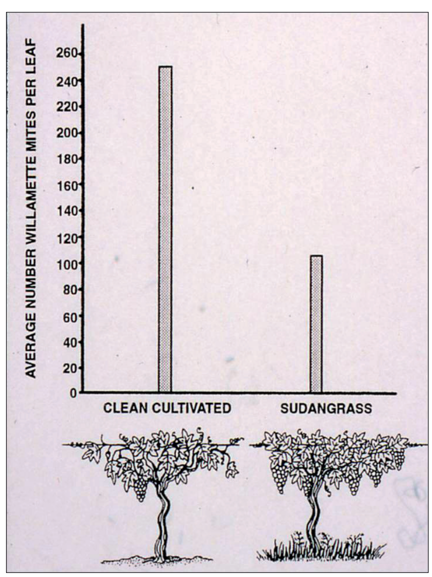
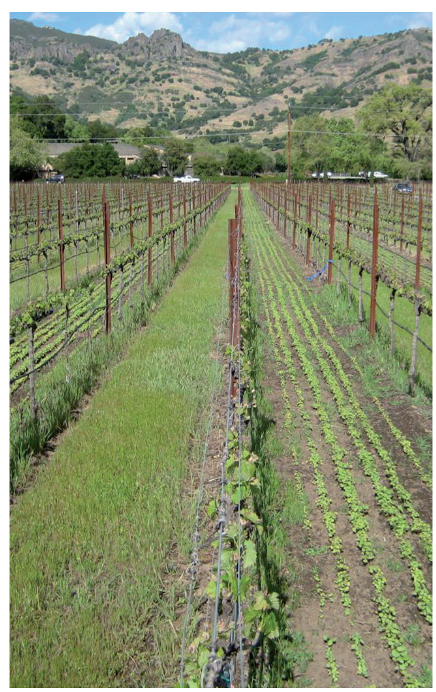


Figure 9. Effect of a sudan grass cover on Willamette mite abundance (Flaherty, 1969)



ated natural enemies increased **(Figure 10)**. In the same vineyard, mowing every other row the cover crops forced movement of *Anagrus* wasps and predators into the vines. Before mowing, leafhopper nymphal densities on vines were similar in the selected cover-cropped rows. One week after mowing, numbers of nymphs declined on vines where the cover crop was mowed, coinciding with an increase in *Anagrus* densities in mowed cover crop rows. During the second week such nymphal decline was even more pronounced coinciding with an increase in numbers of *Anagrus* wasps in the foliage **(Figure 11).**

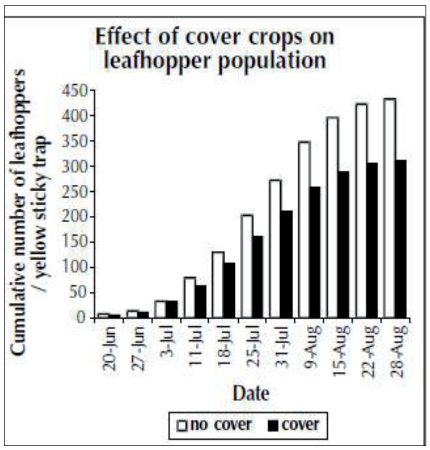
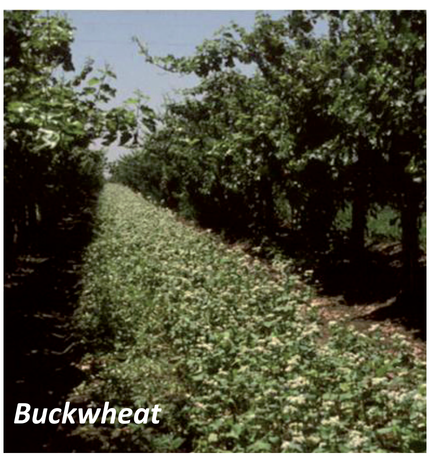


Figure 10. Reduction of leafhopper densities in a vineyard with a buckwheat - sunflower cover crop (Nicholls et al, 2000)



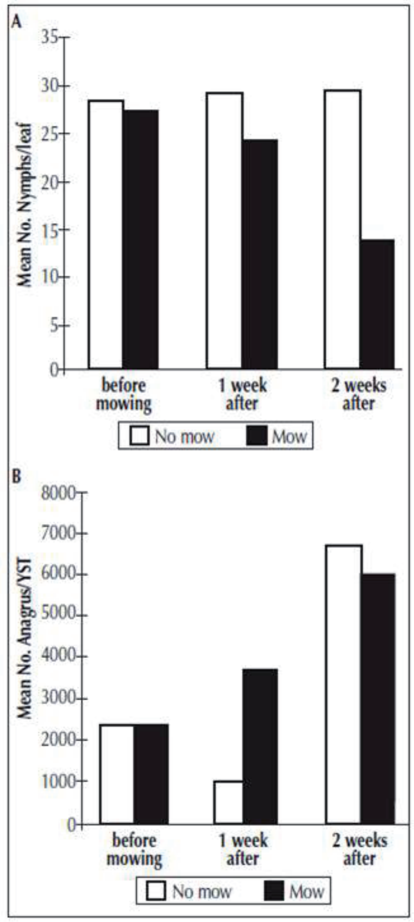


Figure 11. Effects of moving a flowering cover crop on leafhopper nymphal densities and numbers of Anagrus wasps (Altieri et al, 2005)

New approaches for floral resource provisioning with cover crops

Working collaboratively since 2007 with a number of commercial growers in Napa and Sonoma counties our research group has devised a new strategy of Floral Resource Provisioning (FRP) testing the potential of several flowering plants to enhance biological control of leafhoppers and other pests. The project measured the impact of intercropping of five plant species that flower in sequence (**Figure 12**). Species tested include 'Annual Buckwheat' (*Fagopyrum esculentum*), 'Lacy Phacelia' (*Phacelia tanacetifolia*), 'Sweet Alyssum' (*Lobularia maritima*), 'Bishops Weed' (*Ammi majus*) and 'Wild Carrot' (*Daucus*

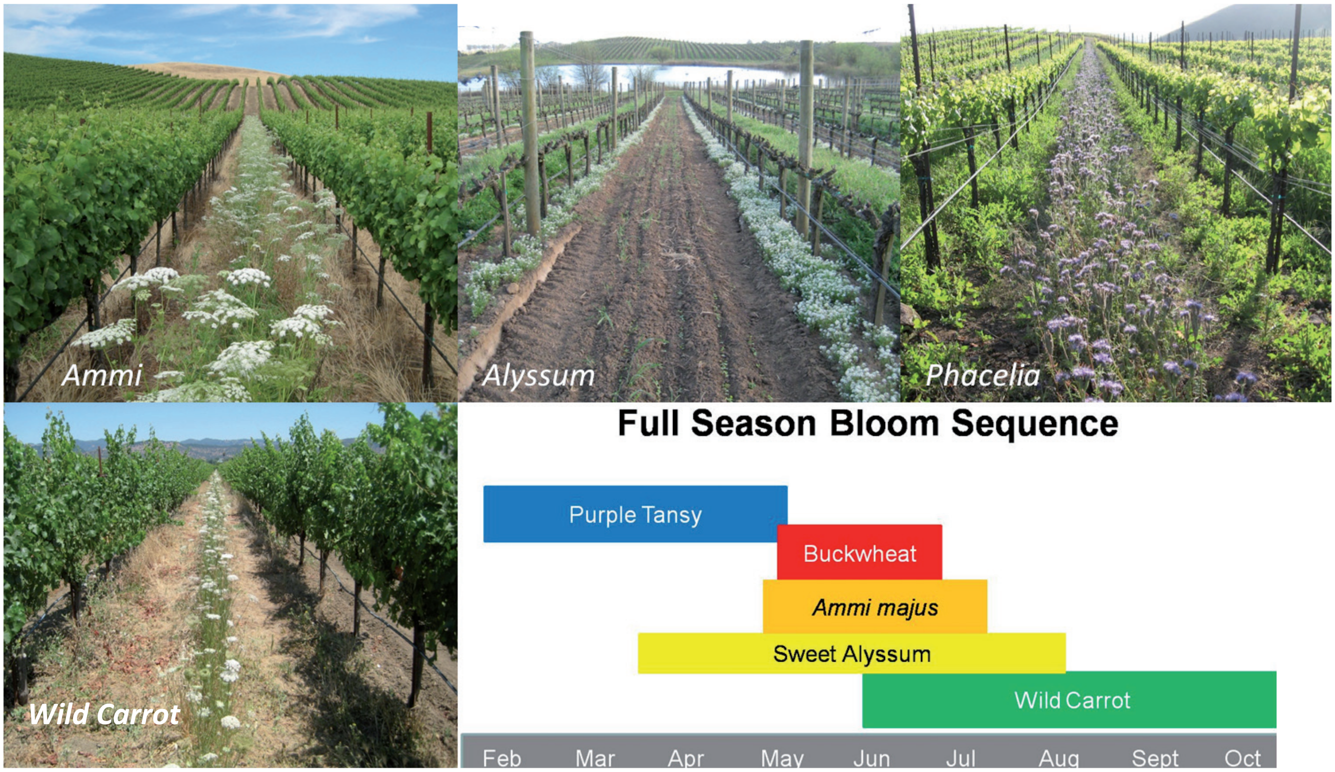


Figure 12. Flowering sequence of five cover crops plants ensuring year - round refuge, pollen and nectar for natural enemies.

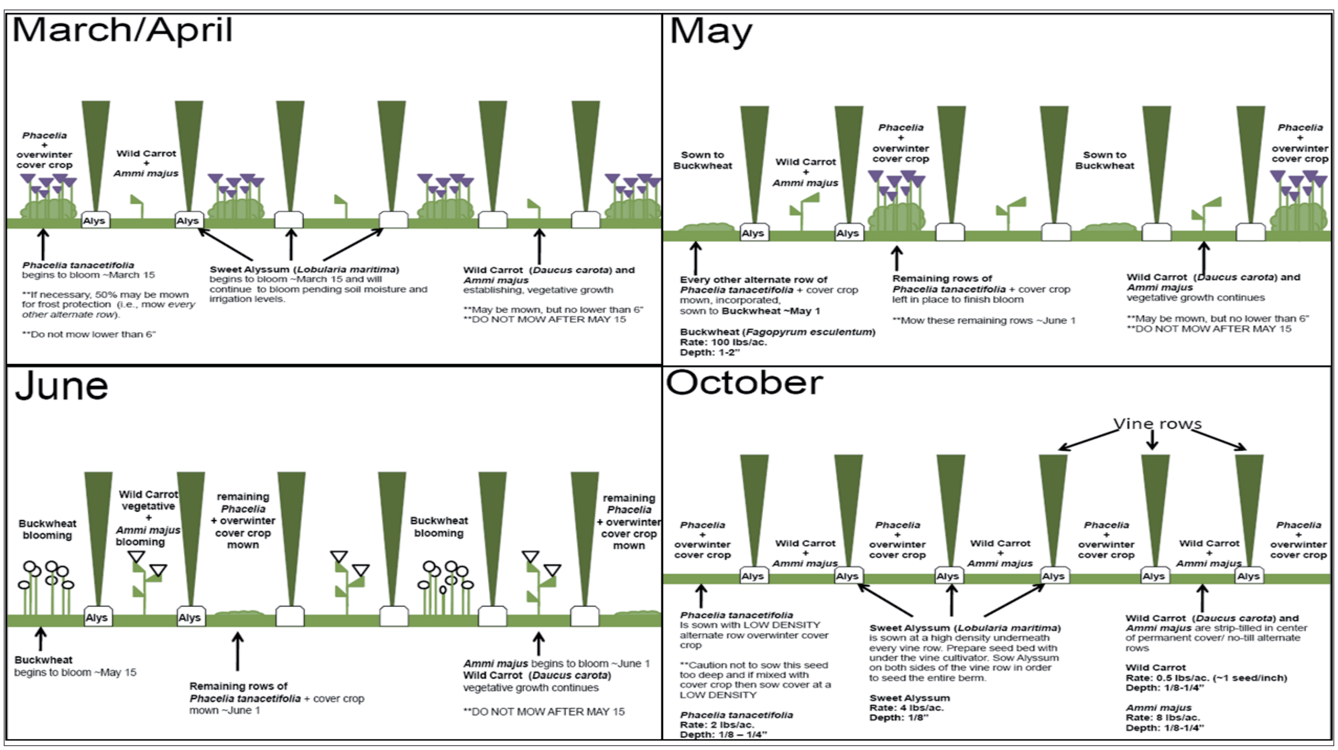


Figure 13. Sequential and spatial design of flowering strips within vineyards.

carota) which are deployed in the vineyard in the sequential and spatial design described in appendix II, includes information on seeding times, rates, and sowing depths for the five flowering plant species (**Figure 13)**.

So far reseach results from trials conducted in various vineyards has shown that when the weather allows for good establishment of flowering ground covers this results in a consistent decreasing trend in pest densities. At research sites with the highest pest pressure and good cover crop establishment, there appears to be a significant effect of the flowers. In 2009, Grower trials revealed that leafhopper nymph densities were lower in 6 of 7 blocks with the flowering ground cover plots when compared to farmer controls without cover crops, and these differences were especially noticeable at three separate research sites where pest densities reached greater than 2 nymphs per leaf **(Figure 14)**

Sweep netting of the flowering covers showed that these plants attracted a great diversity of generalist predators reaching substantial abundance levels when compared to resident vegetation. As seen in **Figure 15**, the predator species guilds changed with the species of flowers and as the season progressed and certain flowers senesced, predators moved to new flowering plants in the sequence. In four of seven vineyards many predators reached higher densities on the canopy in blocks with flowers than in control plots. These predators detected in the vine canopy of the treatment plots

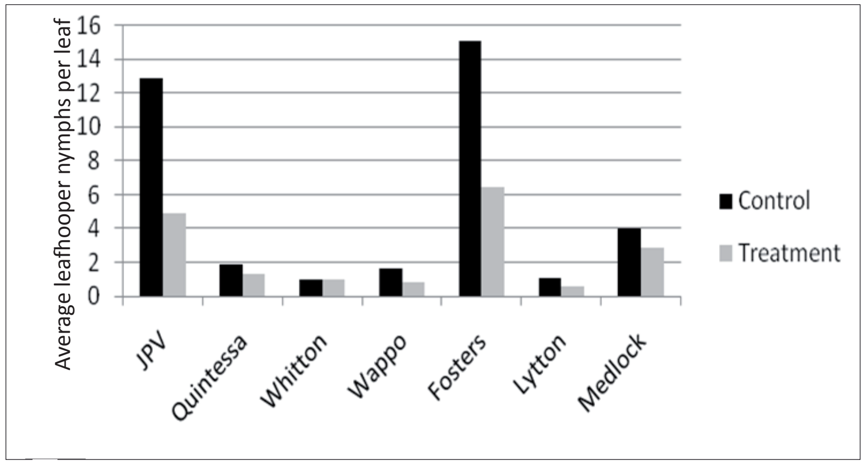


Figure 14. Peak leafhopper nymph density at all Grower Trial sites in 2009

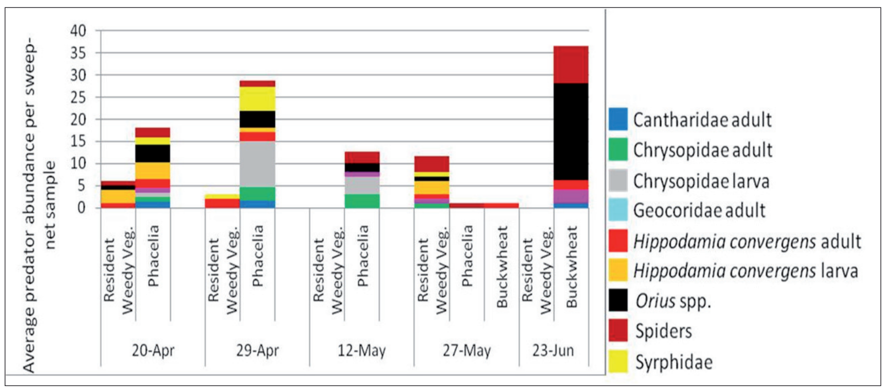


Figure 15. Predator diversity and abundance on ground covers at Fosters Grace (2009)

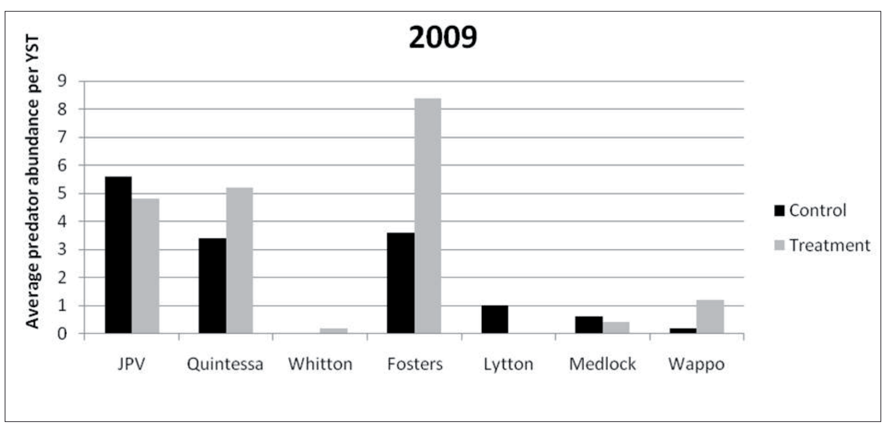


Figure 16. Predator abundance in the vine canopy in seven surveyed vineyards

were also found in the flowers, suggesting that these arthropods move from the covers to the vines **(Figure 16)**. More detailed analysis is needed to determine which species of predators are attracted to which flowers. For example, the minute pirate bug *Orius* is predominantly found on buckwheat and wild carrot but rarely on *P. tanacetifolia*, but more of these relationships between flowers and predators need to be determined.

Guidelines for implementing a habitat management strategy in vineyards

The most successful examples of habitat management systems are those that have been fine-tuned by farmers to fit their particular circumstances as each farm is a unique ecosystem with its own associated biodiversity and set of environmental conditions tied to the geographic location and overall management. Before implementing a habitat diversification strategy specific to fit the needs of a particular farm, it is important to follow same basic steps (See also Appendix III for additional tips).

- Identify which key natural enemies are present in the vineyard (on the canopy and on the soil), on weeds, cover crops and the surrounding vegetation.
- Learn more about the biology of these beneficial arthropods and what they need to thrive.
- Create an inventory of existing habitat and plant resources in and around the vineyard (are there sufficient floral resources, are flowers attractive to key natural enemies, do predators and parasites move from flowers to the vines?)
- Do existing plant habitats and associated flowers match the needs of naturally occurring natural enemies?
- Is there a need to add lacking flower resources and habitat with additional plants species in the form of cover crops, flower strips, hedge or border insectory plantings? What plant species should be added?
- Do these added plant resources provide year round shelter and nectar sources either floral or extrafloral to key beneficials? Do they bloom at a time that best meets the needs of beneficials for pollen, nectar or alternate hosts? Have these plants resources been planted at optimal spacing within the vineyard or at the right distance of vineyard.

Diverse and complex vineyards may be harder to manage, but when properly implemented, habitat management leads to the establishment of the desired type of plant biodiversity and unique ecological infrastructure necessary for attaining optimal natural enemy diversity and abundance. A key feature of that infrastructure are flower resources. When choosing flowering plants to attract beneficial insects it is important to note the size and shape of the blossoms, because that's what dictates which insects will be able to access the flowers' pollen and nectar. For most beneficials, including parasitic wasps, the most helpful blossoms should be small and relatively open. Plants from the Compositae, Lamiaceae, and Umbelliferae families are especially useful (Appendix IV).

Timing of flower availability is as important to natural enemies as blossom size and shape. Many beneficial insects are active only as adults and only for discrete periods during the growing season; they need pollen and nectar during these active times, particularly in the early season when prey are scarce. One of the easiest ways farmers can help is to provide beneficials with mixtures of plants with relatively long, overlapping bloom times.

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Appendix I.

Cover cropping options for vineyards

The majority of growers use an annually tilled and seeded system of cover crops to conserve moisture in their vineyards. Cover crops are planted in the fall, allowed to grow until some point in the spring (usually when the cover crops is flowering) when the ground can be easily cultivated, and then mowed and tilled into the soil. Cover crop species typically used in this system include annual small grains (barley, oats, triticale), winter peas, common vetch, bell beans, daikon radish, Persian clover and others

Other growers use a no-till system with annual cover crops which are tilled initially and seeded with species that will reseed themselves on an annual basis. Thereafter, the vineyards are mowed in spring and early summer. Tillage is restricted to only beneath the vines. Subterranean clovers, rose clovers, crimson clover, red clover, berseem clover, bur medic, bolansa clover, and Persian clover are all suited for this farming system. Grasses that can be used include Blando brome and Zorro fescue.

Perennial species are commonly used in vineyards planted on fertile sites. Many of the perennial grasses are very competitive with grape vine roots, and will have a devigorating effect on the vineyard. This may be desirable if the vineyard is seriously out of vegetative balance. There is a range of cover crops that vary from being slight (fine fescues) to intermediate in their competitiveness (perennial rye, orchard grass , tall fescue), to very competitive such as perennial rye grass, tall fescue, and orchard grass. Irt may be desirable to include perennial legumes in a sward of grasses, as they will supply nitrogen for the grasses but will also provide habitat for generalist predator and parasitoid insects.

Appendix II. Agronomic recommendation for establishment of flowering strips within vineyards.

Sowing Rates, Depth, and Timing

more detailed instructions on following page

Species	Location	Rate	Depth	Sown
Purple Tansy *Phacelia tanacetifolia*	(1) Sow *Phacelia* by itself to alternate alleys OR (2) Sow *Phacelia* with LOW DENSITY overwinter legume/grass cover crops, sown to alternate alleys. In spring every other alternate alley is mowed after flowering (April/May) and then sown to annual Buckwheat. Take caution not to sow *Phacelia* too deep. Lightly cover all seed with roller or brushes.	2 lbs/ac.	1/8 - 1/4"	Oct 15
Sweet Alyssum *Lobularia maritima*	Prepare seed bed with under vine cultivator (see notes on following pages). Seed must be sown on either side of vine row to cover entire berm.	4 lbs/ac.	1/8 – 1/4"	Oct 15
Wild Carrot *Daucus carota*	Strip-tilled in center of permanent cover/ no-till alternate alleys. Seed can be mixed with rice hulls to facilitate sowing. Take caution not to sow *Daucus* too deep.	0.5 lbs/ac.	1/8 –1/4"	Oct 15
Ammi majus	If used, mix with Wild Carrot and sown both species simultaneously.	8 lbs/ac.	1/8-1/4"	Oct 15
Buckwheat *Fagopyrum esculentum*	Sown into every other alternate alley of *Phacelia*/cover-crop following spring mow and incorporation (i.e., sow to every 4th alley).	100 lbs/ac.	1/4-1/2"	May 1

Alternate Treatment Options

Growers unable to implement the full experimental treatment as outlined may trial one of the following alternate options.

Option	Fall (Oct. 15)	Spring (May 1)
1	*Phacelia* sown to alternate rows (with or without cover crop depending on your practices) *Ammi* + *Daucus* (sown to alternate rows)	No additional spring management. Mow cover crops as usual.
2	*Phacelia* sown to alternate rows (with or without cover crop)	Mow every other row of cover crop in April. Sow Buckwheat to these rows. (i.e., Buckwheat sown every 4th row-middle)
3	Alyssum sown at high density (4lbs/ac.) underneath vine row.	Mow cover crops as usual. Sow Buckwheat to alternate rows.
4	Alyssum underneath vine row.	Mow cover crops as usual
5	*Phacelia* + cover crop (alt. rows) Alyssum underneath vine row.	Mow every other row of cover crop in April. Sow Buckwheat to these rows (i.e., Buckwheat sown every 4th row-middle)
6	*Phacelia* + cover crop (alt. rows) *Ammi majus* (alt. rows)	No additional spring management
7	*Phacelia* + cover crop (alt. rows) *Ammi majus* (alt. rows)	Mow cover crops as usual. Sow Buckwheat to alternate rows.
8	*Phacelia* + cover crop (alt. rows) Alyssum underneath vine row *Ammi* (alt. rows)	Mow cover crops as usual. Sow Buckwheat to alternate rows.
9	*Phacelia* + cover crop (alt. rows) Alyssum underneath vine row *Ammi* + *Daucus* (alt. rows)	Mow cover crops as usual. Sow Buckwheat to alternate rows.

Options #3,4,5 have choice of sowing Alyssum underneath vine row in the early spring rather than fall.

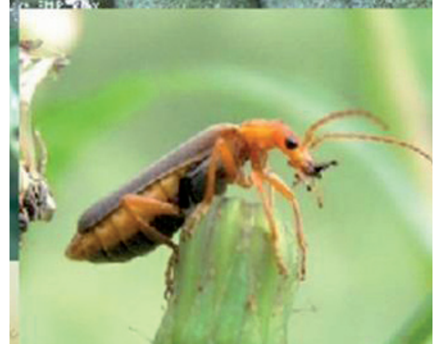
Appendix III.

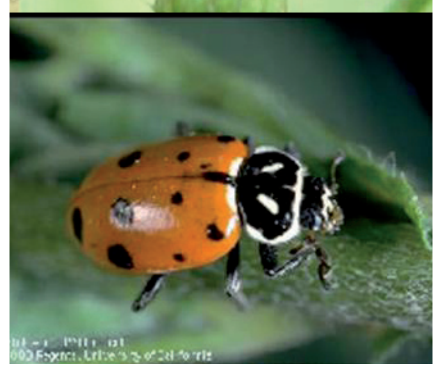
Guidelines to be considered when implementing habitat management strategies in vineyards

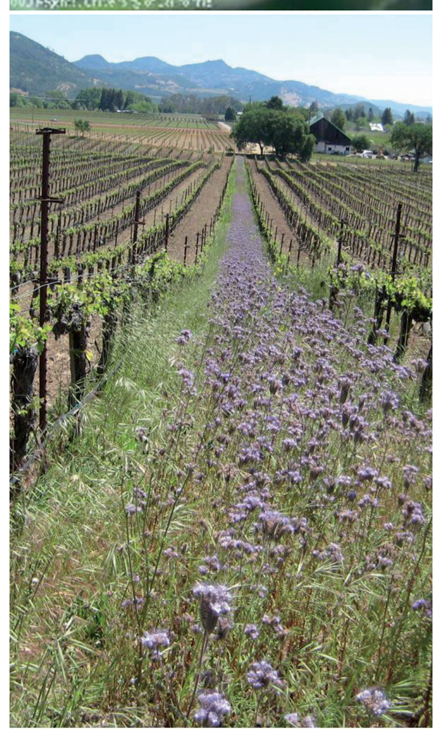
- **Select the most appropriate plant species;**
- **Determine the most beneficial spatial and temporal arrangement of such plants, within and/or around the fields;**
- **Consider the spatial scale at which the habitat enhancement operates (e.g., field or landscape level);**
- **Understand the predator-parasitoid behavioral mechanisms influenced by the habitat manipulation;**
- **Anticipate potential conflicts that may emerge when adding new plants to the agroecosystem (i.e., in California blackberries,** *Rubus* **sp., around vineyards increase po pulations of the wasp** *Anagrus epos***, a parasotoid of the grape leafhopper *Erythroneura* spp., but can also enhance abundance of the sharpshooter, which serves as a vector of Pierce's disease);**
- **Develop ways in which the added plants do not upset other agronomic management practices, and select plants that have multiple effects, such as improving pest regulation while at the same time contributing to soil fertility and weed suppression.**

Enhancing Above ground Biodiversity: A Checklist For Viticulturalists

- **Diversify the vineyards by including more species of crops and livestock.**
- **Use legume-based cover crop mixtures**
- **Establish every 2,3, 5 vine rows strips of flower mixtures that bloom sequentially**
- **Leave strips of wild vegetation at field edges.**
- **Plant a diversity of trees and native plants as windbreaks or hedgerows.**
- **Establish corridors that cut across the vineyard and that connect to riparian or other natural forest.**
- **Leave areas of the farm untouched or purposely planted with flowering shrubs and herbs as habitat for plant and animal diversity.**
- **Provide a source of water for birds and insects.**







Appendix IV. Flower families useful to attract beneficial insets in veneyards

Plants with flowers provide essential food for natural enemies that ensures their survival, but they also influence their reproductive capacity and natural enemy longevity. To retain beneficials in a vineyard is essential to have both annual and perennial plants blooming throughout the growing season so that an abundant food supply for natural enemies is readily available. It is also critical for flowers to be accessible to natural enemies and there are certain flower types more accessible as food source. Plants in the carrot family (Umbelliferae) are suitable because they have exposed nectarines (nectar-producing glands). Color is also important, yellow, orange, and withe flowers seem to be particularly attractive to a range of parasitoids. The following plants within various families are suggested as useful for attracting natural enemies:

List of some useful flowering plants that can be used within or around vineyards to attract natural enemies

Brassicacea **- Mustard family: sweet alyssum (*Lobularia maritima*), wild mustard (*Brassica kaber* and other *Brassica* spp) , yellow rocket (*Barbarea vulgaris*)**
Compositae**-Aster family: coneflower *Echinacea* spp, *Coreopis* spp, Cosmos, tansy (*Tanacetum vulgare*), yarrow (*Achillea* spp), blackeyed susan (*Rudbeckia hirta*), Prairie coneflower (*Ratibida columnifera*)**
Umbelliferae **- Carrot family: bishop's weed (*Ammi majus*), caraway (*Carum carvi*), coriander (*Coriandrum sativum*), dill (*Anethum graveolens*), fennel (*Foeniculum vulgare*), wild carrot (*Daucus carota*), bisnaga (*Ammi visnaga*), wild parsnip (*Pastinaca sativa*)**
Leguminosae **- Pea family: alfalfa (*Medicago sativa*), vetch (*Vicia atropurpureum*), V. *vilolosa , V. cordata , V. benhali*, faba (*Vicia faba*) , sweet clover (*Melilotus spp*), clovers (*Trifolium fragiferum, T. subterraneum, T. hirtum, T. incarnatum*), Breseem clover (*Trifolium alexandrinum*), common pea (*Piusm sativum*)**
Lamiaceae **- Mint family: blue catmint (*Nepeta faassenii*), Russian sage (*Perovskia atriplicifolia*)**
Other plants: baby blue eyes (*Nemphila menziesii*), buckwheat (*Fagopyrum esculentum*), cinquefoil (*Potentilla spp*) and milkweeds (*Asclepias spp*), Lacy phacelia (*Phacelia tanacetifolia*).

As an added benefit, many of these flowers are excellent food for bees, enhancing honey production, or they can be sold as cut flowers, improving farm income.