Biodiversity Conservation Practices in California Vineyards: Learning from Experiences

Bulletin from the California Sustainable Winegrowing Program

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Introduction: Why consider biodiversity in vineyards?

The conservation of biodiversity is considered an important element of sustainable agriculture. Numerous scientific studies and practical experiences have shown that biological diversity (as defined in Box 1) is a crucial factor in maintaining or increasing the sustainability and stability of farming systems.[1] The maintenance of biological diversity is also regarded as a key principle in organic farming operations, according to the U.S. National Organic Program guidelines and scientific evidence.[2]

Increasing numbers of winegrape growers in California are interested in the role of habitat conservation in their vineyards. Some are effectively implementing practices to conserve and enhance the diversity of plant and animals and landscapes in and around their vineyards.[3] These growers report positive impacts from these practices for both organic and non-organic vineyards, and for conservation purposes in the broader landscape. However, very few studies have been undertaken to measure and document the effects of these practices in specific vineyards. Responding to the need for more information, the California Sustainable Winegrowing Alliance, along with collaborating winegrape growers, and scientists from UC Cooperative Extension and Cal Poly San Luis Obispo, carried out an assessment of biodiversity conservation practices, focused on sites in the North Coast region. *(See end of report for acknowledgements.)*

The following is a summary of information from the study and from other related research and experiences. This bulletin is intended to provide insights that can be used for vineyard operations, throughout California, as part of sustainable winegrowing initiatives.

Box 1: What is biodiversity? How is it relevant to agriculture?

Biodiversity consists of genes, species, population, and landscapes, along with the composition, structures, functions, and interactions that occur at each level of the ecosystem.[4] Natural bio-diversity has provided the foundation for all agricultural plants and animals. In addition to producing valuable crops and livestock species, biodiversity in agricultural systems performs many ecological services, including recycling of nutrients, pollination, management of organisms that are undesirable for agriculture, regulation of the local hydrological cycle and microclimate, and storage of carbon.[5]

Biodiversity as Part of Ecosystem Management in Sustainable Winegrowing

Biodiversity conservation and enhancement is a key element of ecosystem management – which is encouraged in the California Sustainable Winegrowing Program and in other sustainable agriculture initiatives. Ecosystem management refers to *the application of ecological science to resource management to promote the long-term sustainability of landscapes and the delivery of essential goods and services produced in them to society.*[6]

In vineyard operations, ecosystem management includes practices that conserve or enhance natural resources and ecological processes in order to produce grapes. Ecosystem management practices protect or enhance ecosystem "services" that are normally provided by nature – meaning factors such as nutrient cycling, decomposition of wastes, pest and disease regulation, generation of soils, water flow, and climate regulation.

Examples of practices used for managing, conserving and enhancing biodiversity include habitat conservation and enhancement around or in vineyards, planting and incorporation of cover crops and other vegetation, protection and attraction of diverse wildlife species (such as raptors) and beneficial arthropods, use of compost and soil amendments that increase soil biodiversity, and other forms of species protection (See Box 2). These practices help growers produce grapes while minimizing negative impacts on natural resources. Effective ecosystem management also helps sustain vibrant and healthy communities and landscapes beyond vineyards. (*See Ecosystem management chapter in the Code of Sustainable Winegrowing Practices.)*[7]

Box 2: Practices for Biodiversity Management in and around Vineyards

A. Conservation and management of existing biodiversity

- Protection and conservation of native trees in and around vineyards
- Protection and conservation of vernal pools
- Conservation of native habitat and plant species and/or oak woodlands
- Protection of riparian habitat (including trees) along rivers or streams
- Maintenance or mowing of native vegetation between vine rows, serving as cover crops
- Maintenance of native vegetation on vineyard edges and landscaping
- Protection of native birds and wildlife (e.g, avoid fencing, avoid hunting, etc.)

B. Enhancement of biodiversity (planned)

- Planting trees in/around vineyards
- Planting vegetation in or around vineyards -- eg, hedgerows
  - Habitat corridors
  - "Islands of flowers/vegetation"
  - Insectaries and/or landscaping on edges
  - Planting diverse cover crops
- Use of compost or other soil amendments to enhance soil biodiversity
- Practices to attract birds (eg, birdboxes, perches)
- Practices to attract wildlife (eg, planting hedgerows, slash piles, providing food sources)
- Incorporating sheep, goats, or chickens for weed control or cover crop management

Project Objectives and Case Studies

A biodiversity project was undertaken by the California Sustainable Winegrowing Alliance and collaborators from August 2006 to December 2007, with the support of the National Fish and Wildlife Foundation. Features of the study are noted below.

Objectives and Case Study Focus

Two of the main objectives of the project were to:

- document the benefits of biodiversity and habitat protection in California vineyards (based on case studies), and
- identify practices for conserving or enhancing biological diversity in and around vineyards.

The study sites were five North Coast vineyards with habitat corridors or islands, including mature hedgerows or riparian vegetation (See Box 3 below). The analysis included monitoring of species of plants, arthropods, birds and small vertebrates to better understand their role in the vineyard ecosystem. The arthropod analysis focused on the western grape leafhopper (*Erythroneura elegantula*) and spider mites (*Eotetranychus willamettei* and *Tetranychus pacificus*), which are the two most significant arthropod pests in the region, and also looked at their natural enemies, including the leafhopper parasitoids *Anagrus* spp., predatory mites, and generalist predators such as minute pirate bugs and black hunter thrips.

Study Methods and Materials

The resources available for this project allowed for analysis during one season (2007). Data on insect and mite species were collected every two weeks during the main growing season (May to September 2007). The methods used for gathering data included placing sticky traps within the plant border habitat on the vineyard margin and in the vine canopy starting from the hedgerow at intervals of 10-20 meters. These traps were collected and changed every two weeks. *Anagrus* spp. (the most important parasite of leafhoppers), minute pirate bug nymphs (*Orius* spp.) and black hunter thrips (*Aelothrips* spp.) were counted on the cards as a measure of their activity.

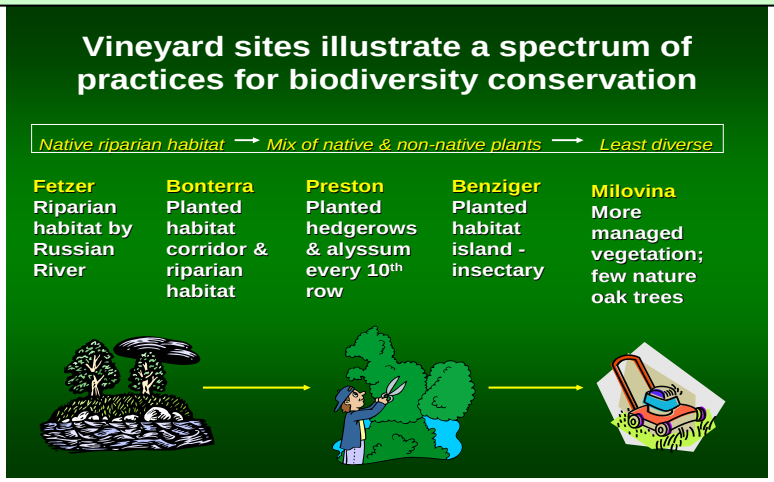
Nymphs of the leafhoppers were counted on 30 leaves per plot every two weeks; results are presented in average nymphs per leaf. Three times during the season, roughly at the end of the first, second and third generations, 30 leaves per plot were collected and analyzed to determine if the leafhopper eggs were live, hatched, and parasitized by *Anagrus* spp. Results are presented as percent parasitism, meaning parasitized eggs per total eggs per leaf. Spider mites and predatory mites were counted by brushing the insects from 10 leaves on a glass plate, and then counting 20% of the plate surface for an estimate of mites/leaf. (Only two of the five sites had high enough mite populations to analyze.)

Methods used for gathering data on the plant species and cover crops included observation and assessment by a botanist, and conversations with the vineyard managers. The methods used for gathering data on the small mammals and birds included field observation and inventory of species every two weeks, and placing planks in the vineyards, which serve as refuges for amphibians and small mammals, that were monitored regularly.

Box 3: Case Study Sites

The project team selected five sites in the North Coast. In four cases the vineyard operators had already implemented practices that were deliberately aimed to conserve habitat or protect biodiversity – specifically hedgerows, and/or habitat corridors or "islands," and also planted annual cover crops. All sites are certified organic with the exception of Milovina, which represented a more conventional approach to vegetation management, and did not have deliberate biodiversity conservation practices beyond a tree row at one end of the vineyard and non-tilled floor vegetation. These vineyards and their general locations are:

- Fetzer Vineyards – Hopland, California, Mendocino County
- Bonterra Vineyards – McNab Ranch, Ukiah, Mendocino County
- Preston Vineyards - Healdsburg, Dry Creek, Sonoma County
- Benziger Vineyards - Glenn Ellen, Sonoma County
- Milovina Vineyards - Hopland, Mendocino County



Summary of Results and Conclusions:

The vineyard sites included in this study have an abundance of predators and beneficial insects that can help manage pests. During 2007, none of these vineyard sites had suffered economically significant damage from insects, and the vineyard operators did not use insecticides. Most of these vineyard operators have not used insecticides in previous years as well, since insect pests have not been major problems. In 2007, two of the vineyards (Bonterra and Milovina) had signs of some insect predation, but the damage was not serious enough to affect grape yields.

The presence of habitat – including hedgerows, corridors, islands, or riparian habitat – in and around the vineyard seems to be correlated with the high density of beneficial arthropods. In most of the cases, the presence of beneficial arthropods was higher close to the habitat corridor or hedgerow, and likewise, the pest insects tended to be lower in those locations. In the case of Preston Vineyards, there were unusually high populations of predatory mites relative to spider mites, throughout the growing season. It appears likely that this elevated presence of beneficial mites is associated with the addition of alyssum as a cover crop, which was planted between the vines every 10 rows in the Preston vineyard. (See case studies following for more detail.)

Although the benefits of the wildlife species were not possible to quantify in this study, it is clear that the habitat management practices help to conserve and attract a diversity of wildlife species. Previous studies have also confirmed the value of habitat corridors for maintaining wildlife.[8] The only animals that are seen as pests are deer (which are kept out with deer fencing), gophers, voles, and ground squirrels. The vineyard managers have reported the value of raptors in and around their vineyards, mainly for gopher control. Several vineyard managers also express appreciation of having wildlife species that are protected in and around the vineyards. Further research is needed to quantify the ecosystem services provided by mammals and birds in vineyard systems. It would be valuable to continue monitoring and collecting data for at least one more season, to gain information over time and in additional sites.

Case Study Information and Results

Bonterra Vineyards, McNab Ranch

Bonterra Vineyards' McNab Ranch is located in Mendocino County, between Hopland and Ukiah. The vineyard features an abundance of biodiversity, including planted habitat corridors, oak woodlands, and tree-lined riparian vegetation. The McNab Ranch is in Knight's Valley, a classic "box canyon" that opens to the Russian River valley on the east side. The McNab Creek runs through this valley, and drains into the Russian River. The valley floor is surrounded by the Mendocino Mountains on three sides, which rise steeply to over 2200 feet elevation.

The ranch has been farmed using certified organic methods over ten years, and it is also certified biodynamic. Besides having 134 acres of vineyards, the ranch includes an acre of lavender, which is harvested for oils, two acres of olive trees, bee hives, landscaping with drought-resistant plants such as rosemary and lavender, a pond, and over 100 acres of conserved oak woodlands. Chickens are also allowed to graze in the vineyards, rotated through different sections, which can help to control some cut worms and beetles, and add fertility to the soil.

The riparian vegetation in this ranch has been deliberately maintained and conserved to protect the streams and the natural biodiversity. Several habitat corridors have also been planted throughout the vineyard (in the mid-to-late 1990s) to enhance biodiversity. These habitat conservation management practices are viewed by the vineyard managers as ways to increase the ecological stability of the vineyards, to attract beneficial insect species, and to create corridors that allow the passing of wildlife. Himalayan Blackberry, elderberry, and poison oak have been removed from the riparian zones, to avoid species that are known to harbor Pierce's Disease. Birdboxes and perches are also installed near the vineyard.

The study focused on the planted habitat corridor (or mature hedgerow) next to a Merlot block on the northwest side of the ranch. The vineyard is on a vertical shoot positioned trellis with an 8 foot by 5 foot spacing. The rootstock is 5 C. This vineyard site is on a gently sloping escarpment. The habitat corridor is on an ephemeral stream that drains into McNab Creek. The channel is approximately 5 feet wide and 3 feet deep. The stream banks were stabilized with mortared rock walls and then planted on both sides to form a corridor that is approximately 250 feet long and 30 feet wide. The habitat corridor consists mostly of exotic herbaceous flowering perennials, woody shrubs and small trees. There are some native willow trees as well. This corridor originally was established with 106 plant species, and the majority of these plants are still living. Of these, the predominant plants are listed in Table 1. These plants provide flower resources from early spring to October, which attract a variety of insect natural enemies and pollinators. The insect and mammal monitoring was done in the Merlot vineyard next to this habitat corridor or hedgerow. The planting also adds beauty and interest to the site.

Table 1: Plant Species in Bonterra Vineyards Habitat Corridor (hedgerow)

Species under 4 feet in height	***Species under 4 feet (continued)***
Asters (*Aster frikartii*)	Feather Grass (*Stipa arundinacea*)Euphorbia
Butterfly bush (*Buddleia davidii*)	(*Euphorbia lathyris*)
Lavender (*Lavendula angustifolia, L. dentat)*	Cone flower (*Echinacea purpurea*)
Rosemary *(Rosmarinus officinalis*)	Verbena (*Verbena peruviana*)
Willow (*Salix exigua*)	Crabgrass (*Digitaria sanguinalis*)
Cat mint (*Nepeta x fassenii*)	Flax (*Linum perenne*)
Scarlet gaura (*Gaura lindheimeri*)	
Hybrid rose (*Rosa* sp.)	***Species over 4 feet in height***
Coreopsis (*Coreopsis verticillata*)	Rosemary (*R. officinalis* 'Tuscan Blue')
Fever few (*Chrysanthemum parthenium*)	Butterfly Bush (*Buddleia davidii*)
Blanket flower (*Gallardia X grandiflora*)	Medlar (*Mespilus germanica*)
Fig (*Ficus carica*)	Pampas grass (*Cortaderia selloana*)
Oregano (*Origanum vulgare*)	Red Willow (*Salix exigua*)
Climbing rose (*Rosa* sp.)	Rose hybrids *(Rosa sp.)*
Pomegranate (Punica)	Pomegranate (*Punica granatum*)
Artemesia (*A*. X 'Powis Castle')	Fig (*Ficus carica*)
Fennel (*Foeniculum vulgare*)	Peach (*Prunus persica*)
Yarrow (*Achillea millefolium*)	Pineapple guava *(Feijoa sellowiana*)

The vineyard practices used in this Merlot block at Bonterra included the following:
Cover crops: Mix of bell beans, vetch, clover, planted in the fall; mowed in spring and summer, cultivated every other row.
Pest/Disease management: 2 applications of wettable sulfur and an organic copper fungicide (Nordox®), and 5 sulfur dustings. No treatments were used for insects or mites.
Soil amendments: Compost (2-3 tons per acre), fish emulsion and biodynamic preparations.
Weed control: Mechanical methods, under vines.

Results of Insect and Mite Monitoring*: (Please refer to Appendix for details.)*

- The highest densities of *Anagrus* spp. was nearest the hedgerow, and declined in subsequent plots. *Anagrus* spp. density was quite high at Bonterra compared to other sites, averaging about 40 per card overall.
- No *Anagrus spp.* were found in the hedgerow until late June-early July, and even then relatively few were found.
- Overall, the first generation leafhopper nymphal density peaked between 7-12 per leaf, whereas second generation peak was 1-3 per leaf. At first generation peak, the lower leafhopper densities were found in the two plots nearest the hedgerow (3m and 21m)
- At the peak of second generation leafhopper nymphal density (Aug. 10 & Aug. 27), the highest densities were found in the plot nearest the hedgerow (3m), although it should be noted that overall, density was 3-4 times lower in the second generation than the first.
- Spider mite density was relatively high, with overall peak between 20-80 mites/leaf. During the peak of spider mite activities, densities tended to be lowest in the two plots nearest the hedgerow, but there was no such pattern for predatory mites.



Observations revealed a great diversity of wildlife species at Bonterra Vineyards, as listed below. The only species that cause occasional problems are gophers and wild turkeys. Deer could also potentially damage the vines, but they are kept out of the vineyards with fencing.

Table 2: Wildlife Species observed at Bonterra

Mammals and amphibians		**Birds** (species undetermined)
• coyote(*Canis latrans*) • skunk (*Mephitis mephitis*), • opossum *(Didelphis virginiana* • raccoon *Procyon lotor*), • deer (*Odocoileus hemionus*) • gray fox (*Urocyon cinereoargenteus*), • wild pigs (Sus scofa) • rabbit*(Lepus californicus*), • gray squirrel (*Sciurus griseus*) • vole (*Microtus californicus*) • gopher (Thomomys bottae)	• mice *(uncertain species*) • bobcat (*Lynx rufus*) • mountain lion (*Felis concolor)-rare* • *porcupine (Eurethizon dorsatum)* • snakes - *several species* • lizards - *several species* • frogs – *several species* • salamander – *unknown species* • bats – unknown species	• owl • hawks • vulture • eagle • ducks • geese • heron • egret • woodpecker • mockingbird • pheasant Other unidentified birds

Preston Vineyards, Dry Creek, Sonoma County

Preston Vineyards, in Dry Creek, northern Sonoma County, is a diversified operation, and includes several planted hedgerows, a garden with diverse fruits and vegetables, and many planted trees and shrubs in the riparian zone along the creeks. Chickens are also maintained on site for egg production. The entire operation is certified organic, and is also certified by the Fish Friendly Farming® program. The Preston vineyard site is situated on an alluvial fan that slopes gently from the south to Dry Creek. The remnant native vegetation of the region outside of the vineyard is oak woodland consisting of valley oak, blue oak and interior live oak. The vineyard floor is managed with summer tillage and winter annual cover crops. In the spring, cover crops are mowed and incorporated into the soil.

The vineyard owner has incorporated five hedgerows (also called habitat corridors or insectary corridors), spread out through the vineyards. These hedgerows were established in 2004, in collaboration with a non-profit organization called Circuit Riders and with the Sotoyome Resource Conservation District, which received government funding for conservation projects. The study focused on the hedgerow planted next to a block of Zinfandel, a heritage clone. The vineyard spacing is 10 foot by 8 foot and it has a three-wire “California sprawl” trellis. This hedgerow consists of a mix of native and non-native herbaceous perennials and woody shrubs that covers an area 12 feet wide by 275 feet long. It is not associated with any stream or water course. The planting is not mature, and the plant material is actively expanding in size.

Most of the plant material is under 4 feet in height, and there are a few small trees. The hedgerow is in very good condition, and is regularly maintained, irrigated and mulched with rice straw. This block also includes corridors of alyssum (*Lobularia maritima)*, a plant species that is well known for attracting beneficial insects, planted every 12 rows between the vines, which is irrigated with microsprinklers. Alyssum is an annual plant that regenerates itself.

Table 3: Hedgerow Plants included in Preston Vineyards (next to Zinfandel block)

Plant Species	**Plant Species (continued)**
Asters (*Aster frikartii*)	Toyon (*Heteromeles arbutifolia*)
Penstemon (*Penstemon gloxinoides, P. heterophylla*	White thorn (*Ceanothus leucodermis*)
Butterfly bush (*Buddleia davidii*)	Lavender (*Lavendula angustifolia, L. dentata*)
California Buckwheat (*Eriogonum fasciculatum*	Scarlet sage (*Salvia splendins*)
Coffee berry (*Rhamnus californica*)	Sage (*Salvia greggii*)
Purple sage (*Salvia leucophyll)*	Coyote bush (*Baccharis pilularis*)
	Sticky monkey flower (*Mimulus aurantiacus*)

Vineyard practices used in this block include the following:
Cover crops: "Soil Builder" mix of cover crops seeded in October, disked under in March-April. The mix consists of bell beans, peas, vetch, oats, and mustard for nematode control.
Pest/Disease management: During the first 3 - 4 weeks of growth, used a combination of compost tea and milk whey from a goat dairy - a total of 6 applications of compost tea and whey, every 10 days. 3 applications of sulfur dust were then used, started 3 weeks later than the norm.
Soil amendments: Compost after harvest and before seeding cover crop; 5 tons/acre in 2006, 3 tons in 2007. Application of broad spectrum minerals.

Results of Insect and Mite Monitoring: *(Please see Appendix for details.)*

- *Anagrus* spp. and leafhopper density were generally low at this site, with overall Anagrus spp. Density about 10 per card, leafhopper density between .5 and 1.5 nymphs per leaf in the first generation and less than 1 per leaf in the second generation.
- There was no clear pattern between *Anagrus* spp. and either the hedgerow or alyssum.
- An interesting finding was that, although spider mite density at Preston was extremely low (less than 8 mites per leaf at peak), predatory mite density was relatively high (between 102 mites per leaf from mid-June to mid-September). It cannot be said with certainty that this is related to the hedgerow or alyssum corridors, but it is an unusual situation that warrants further study. (The vineyard owner feels this may be partly related to the very low use of sulfur, since the mite populations were higher before he significantly reduced his sulfur use.)

Many wildlife species have been observed regularly at Preston Vineyards, as noted below. The majority of these species are perceived by the vineyard owner as beneficial. The only animals which pose problems to the vineyard are gophers, but the vineyard owner has seen birds hunting gophers. Deer are rare in this area, partly due to the blockage by Dry Creek, so deer fencing is not used in most parts of this vineyard.

Table 4: Wildlife Species observed at Preston Vineyards

Mammals and amphibians		**Birds** (species undetermined)
• coyote(*Canis latrans*)	• bobcat (*Lynx rufus*) rare	• owl
• skunk (*Mephitis mephitis*),	• mountain lion (*Felis concolor)-rare*	• hawks
• opossum *(Didelphis virginiana*	• snakes - *several species*	• vulture
• raccoon *Procyon lotor*),	• lizards - *several species*	• eagle
• gray fox (*Urocyon cinereoargenteus*)	• frogs – *several species*	• ducks
• rabbit*(Lepus californicus*),	• salamander – *unknown species*	• geese
• gray squirrel (*Sciurus griseus*)	• bats – unknown species	• heron
• vole (*Microtus californicus*)		• egret
• gopher (Thomomys bottae)		• woodpecker
• mice *(uncertain species*)		• jay
		• mockingbird
		• starlings (and others)

Fetzer Vineyards, Sundial Ranch

The Sundial Ranch of Fetzer Vineyards is in Hopland, Mendocino County, and is planted along the Russian River in Sanel Valley directly across from the Fetzer winery. The site is on a flood plain formed between the Mendocino Mountains on the west, and the Mayacama Mountains on the East. The flood plain is formed in a fairly wide portion of the Sanel Valley (approximately 2 miles). The soil is a deep well-drained Russian River loam. The vineyard was planted in 1986 to Chardonnay on AXR-1 rootstock. The spacing is 6 x 10 feet and it is trained on a California 3 wire sprawl system. It is a productive certified organic vineyard, planted mostly in Chardonnay grapes. Phylloxera has been present in the vineyard since 1994.

The vineyard floor is usually managed by seeding every other row with a mixture of annual clovers every three years (similar to the McNab Ranch plantings), and then the resulting growth is mowed at least twice annually to a height of 4 inches. Alternate rows are tilled annually and seeded to a mix of annual grasses and legumes that include oats (*Avena fatua*), bell beans (*Vicia faba*), common vetch (V*icia*), purple vetch (*Vicia*), Daikon radish and other mustards (*Brassica* sp.) After three years, the middles are rotated. (In 2007, however, the cover crops were different, as indicated below.)

The focus on the study in this site was the riparian area adjacent to the vineyard which is mature, healthy and vibrant. The channel of the river is approximately 100 feet wide and 20 feet deep. The area that we surveyed is 300 feet long by 50+ feet wide. The vegetation in this area is typical of a climax riparian forest found in Northern California, consisting mostly of native trees and shrubs. The species in the riparian habitat are noted in Table 3 below. The vineyard owners have attempted to remove and cut back poison oak and blackberry, which are known to be a host species for Pierce's Disease. Several birdboxes are also installed in this vineyard.

Table 5: Species in the Riparian Habitat in Fetzer Vineyards, Sundial Ranch

I. Composition of Adjacent Riparian Area Vegetation, 0-6 Feet in Height	II. Composition of Adjacent Riparian Area Vegetation, 6-100+ in Height
Himalayan Black Berry (*Rubrus procerus*)	Box Elder (*Acer negundo*)
Wild Rose (*Rosa multiflora*)	Red Willow (*Salix exigua*)
Teasel (*Dipsacus sylvestris*)	Valley Oak (*Quercus lobata*)
Snow berry (*Symphoricarpos albus*)	Northern California Black Walnut (*Juglans hindsii*)
Poison Oak (*Rhus diversiloba*)	Grey Willow (*Salix sp.*)
Poison Hemlock (*Conium maculatum*)	Oregon Ash (*Fraxinus latifolia*)
	Fremont Cottonwood (*Populus fremontii*)

The vineyard management practices in 2007 for the Sundial Ranch included the following:
Cover crops: 97% clover (including crimson closer and rose clover) and 3% Queen Anne's Lace, seeded in the fall.
Soil amendments: Compost applied at 2 tons per acre in the fall.
Disease/Pest management: 3 applications of stylet oil - 1% solution in 75 gallons of water per acre, and 5 applications of sulfur dust 10-12 pounds per acre. No treatments were used for insects.
Weed management: Tillage under the vines.

Results of Insect and Mite Monitoring: (*Please see Appendix for details.)*

- Overall, leafhopper density was low at this site. (First generation peak was less than 1.5 nymphs per leaf.)
- Leafhopper density was consistently lower in the section nearest the riparian corridor from May 30 to July 6.
- *Anagrus* spp. density was low overall (about 20 per card), and showed no relationship to the riparian corridor.
- Minute pirate bug and black hunter thrips densities were high from May 18-June 24 (peaking at over 90 percent), and there appeared to be a relationship with the riparian corridor, as the highest densities of these generalist predators were in the section nearest the corridor for the first six weeks of this period.

The wildlife species observed in this vineyard were nearly identical to those observed at Bonterra Vineyards (See Table 2). However, mountain lions have not been seen, and coyotes and bobcats are rare in this site, probably because it is located much closer to a well-traveled road and buildings, compared to the Bonterra site.

Benziger Vineyards, Glen Ellen, Sonoma County

Benziger Vineyards is located in Sonoma County. Benziger has also incorporated many practices to protect and enhance biodiversity, including protecting trees and riparian habitat on the creeks that run through the vineyard, and planting various species in the landscaping. They have also established a wetlands reed-bed pond which is used for treating the winery wastewater, and also enhances biodiversity and attracts birds.

The study focused on an "island" of diverse insectary plants in the midst of a vineyard block. This island includes flowering herbaceous annuals and perennials at the center of the vineyard, which serves as a refuge for beneficial insects. The mix of plants provide flower resources from early April to late September, as noted in a previous study of this vineyard.[9]

Insects were monitored in the vineyard next to this insectary island. The insectary consists of mainly flowering plants which are very attractive for beneficial insects, butterflies, and birds. It also has a value for tourism, since Benziger receives thousands of visitors each year. The vineyards next to the insectary are Sauvignon Blanc and Cabernet Franc grapes. These vineyards are farmed with certified organic and biodynamic practices.

The vineyard practices in the block near the insectary are the following:
Cover Crop: Mix of peas, common vetch, barley, and oats.
Soil amendments: Compost applied at 2-3 pounds per acre, and biodynamic preparations (including 2 sprays of horn manure).
Disease/pest management: 2 sulfur dustings and one wettable sulfur application, and 6 applications of Serenade® (a biofungicide). No applications for insects and mites.
Weed control: Mechanical, under the vines.

Table 5: Plants in the Insectary "Island" at Benziger Vineyards

Plants that are intended to attract hummingbirds	Plants that are intended to attract butterflies and beneficial insects
	Butterfly Plants
Orange Carpet (*Zauschneria garrettii)*	Yellow Kangaroo Paws (*Anigozanthus flavidus)*
Sunset Hyssop (*Hyssopus officinalis)*	Wine Cups (*Callirhoe involucrata*)
Autumn Sage (*Salvia elegans)*	Whirling Butterflies *(Gaura lindheimeri)*
Texas Red Yucca (*Yucca gloriosa)*	Arctic Summer *(Verbascum bombyciferum)*
Firecracker Penstemon (*Penstemon gloxinoides)*	
Pineleaf Penstemon (*Penstemon pinifolius)*	***Insectary Plants***
Desert Beard Tongue (*Penstemon antirrhinoides)*	Moonshine Yarrow (*Achillea tomentosa*)
Mexican Sage (*Salvia leucantha)*	Blue Catmint (*Nepeta faassenii)*
Malibu Yellow (*Kniphofia uvaria)*	Prairie Coneflower (*Ratibida columnifera)*
Red Hot Popper (species unknown)	Russian Sage (*Perovskia atriplicifolia)*
	Blackeyed Susan (*Rudbeckia hirta)*
	Purple Coneflower *(Echinacea purpurea)*
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Results of Insect and Mite Monitoring: (*Please see Appendix for details.)*

- Overall, leafhopper and *Anagrus* spp. density was quite low at this site (less than 1 nymph per leaf), as was *Anagrus* spp. density (about 3 per card overall); and no spider mites or predatory mites were found.
- Despite low density of *Anagrus* spp., there was a pattern of declining density with increasing distance from the insectary.

A previous study undertaken in this site also showed the effectiveness of the insectary island in attracting beneficial insects. [10] Wildlife species observed at Benziger are similar to the species found at Bonterra (See Table 2) and Preston Vineyards, although mountain lions are rare in this area. Additional observations are needed to evaluate the wildlife in this site.

Milovina Vineyards, Hopland, Mendocino County

The Milovina Largo Vineyard is located between Hopland and Ukiah, in Mendocino County, in the Crawford Creek watershed. The land form is a broad box canyon. The valley floor is surrounded by the Mendocino Mountains on three sides, which rise steeply to over 2000 feet elevation. Parent material is uplifted marine sand stones with intrusions of basaltic serpentine rock.

The vineyard site for this study is on a small flood plain formed by alluvium from the surrounding steep hillsides. The soil is a well drained Cole loam. The study focused on the Chardonnay block, next to a streambed. In this vineyard, most native vegetation has been removed, but there are remnant large trees from an oak woodland that once covered the site. The stream channel is stable, but only a few large trees remain. The stream flows west to east, and drains into the Russian River approximately 1 mile to the east. Most of the streambank is covered with non-native grasses and forbs including annual ryegrass, wild oats, rip gut brome, soft chess and other low succession plants that are neatly mowed up to the rim of the water course. These plants are dry and brown by mid-summer. The channel is on the average 11 feet wide and 4 feet deep.

The vineyard is planted to Chardonnay on 101-14 rootstock. The vines are trained on a vertical shoot position trellis system. The vineyard floor is mowed in the spring. No cover crops are seeded, and annual grasses and forbs are mowed to under 4 inches in the spring. Weeds found include shepard's purse, annual bluegrass, scarlet pimpernel, annual ryegrass, soft chess and wild oats. The vineyard floor is dry and mostly free of green vegetation during the growing season. Along the small creek which is approximately 154 feet long, there are 6 mature Valley Oak trees *(Quercus lobata)*. Most of the trees are over 70 tall. Other vegetation is regularly removed. This site is by far the simplest of the five case studies from a floristic perspective.

Vineyard practices on this block included:
Cover crops: Only natural vegetation between vines which is mowed to under 4 inches in the spring for maintenance; no seeded cover crop.
Disease/Pest management: 4 wettable sulfur applications, 2 sulfur dustings, one application of Rally® (sterol inhibitor); No treatments for insects and mites.
Soil amendments: Potassium 3 times in season, Nitrogen one time in drip.
Weed control: Glysophate application one time under the vines only.

Results of Insect and Mite Monitoring: (*Please see details in Appendix)*

- This site had high densities of *Anagrus* spp. (about 70 per card overall), which seemed to decrease 50 meters from the tree line, increase at 70 meters, and decrease again at 90 meters.
- Leafhopper nymphal density was moderately low, but consistent (about 2 per leaf for a period of several weeks), but did not exhibit a clear generational distinction, and no pattern with respect to the tree line.
- This site had one of the highest densities of minute pirate bugs and black hunter thrips (peaking at between 15 and 40 per card). On most sampling dates the lowest density of these generalist predators was in the plot nearest the tree line.

The wildlife observed at this site included: deer, rabbits, gophers, raccoons, bobcats, coyote, heron, hawks, vultures, crows, owls, and heron. Once again, we do not have quantitative data on the frequency of siting, but it appears that the populations of wildlife in this site are less than in other sites, given the proximity to a very busy highway (101), and the relatively low amount of natural habitat. Nevertheless, there seems to be an abundance of large birds, which frequently pass through this valley.

See Appendix A for details and graphs from insect monitoring from all five sites.

Gaps and Further Research Needs

The data from these case studies showed interesting findings about the potential beneficial effects of plant and habitat biodiversity on the presence of insect populations and other species in these vineyards, as mentioned on page 4. Moreover, the vineyard sites had relatively abundant populations of beneficial insects, and they did not have any major pest problems. However, there are still gaps in understanding of the specific functions and impacts of the habitat conservation practices such as hedgerows and habitat corridors. Given the complexity of these vineyards and the ecosystem conditions, it is difficult to identify specific cause-effect conclusions. Limitations of time and resources for the project did not allow for further analysis at this stage. The results from these studies cannot be easily generalized to all vineyard systems in California's North Coast, but they do provide some noteworthy indications about the useful role of biodiversity conservation.

More research is needed to analyze biodiversity conservation practices in these sites and in other sites over time, and to address other questions and variables in the system such as:

- what are the specific effects of the different cover crop mixes (compared to the hedgerow/corridor effects) on the insect species in each case;
- what are the preferred plant species (or mix of species) to use in the habitat corridors/hedgerows that are effective for attracting beneficials;
- what variations are caused by climate-related or geographical variables in each case;
- what are the effects of timing of vineyard practices, particularly mowing of the cover crops (which usually releases more insects into the canopy, according to previous studies)[11], and shoot-thinning, or leaf removal (which can also reduce insect predation); and
- what climatic/site-specific factors influence the incidence of insects and other species.

We hope that these questions can be addressed in future studies, to provide further insights about functions and values of biodiversity conservation in agricultural ecosystems.

Acknowledgements:

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We also appreciate the important collaboration and information provided by the owners and vineyard managers of the study sites, particularly Chad Boardman of Bonterra Vineyards, David Koball of Fetzer Vineyards, Lou Preston of Preston Vineyards, Mark Birningham of Benziger Vineyards, and John Milovina of Milovina Vineyards.

This project is a part of the California Sustainable Winegrowing Program, and funding was generously provided by the National Fish and Wildlife Foundation. For further information about the Sustainable Winegrowing Program, please visit: http://www.sustainablewinegrowing.org.

ENDNOTES

[1] Altieri, M, C Nicholls, L Ponti, and A York, 2005, Designing Biodiverse pest-resilient vineyards through habitat management, Practical Winery and Vineyards, April/May; Altieri, M, 1999, The ecological role of biodiversity in agroecosystems, Agriculture Ecosystems and Environment, 74: 19-31; Nicholls, CI, M Parella, and M Altieri, 2000, "The effects of a vegetational corridor on the abundance and dispersal of insect biodiversity within a northern California organic vineyard," Landscape Ecology, 16: 133-146; Brodt, S, et al, 2005, Influence of farm management style on adoption of biologically integrated farming practices in California, Renewable Agriculture and Food Systems, 19(4): 237-247. Thrupp, LA, 1998, Cultivating Diversity: Agrobiodiversity and Food Security, World Resources Institute, Washington DC. www.fao.org/biodiversity, CAWG, 2002, California Vineyards and Wildlife Habitat, California Association of Winegrape Growers, Sacramento, CA.

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[5] Thrupp, LA, 1998, Cultivating Diversity: Agrobiodiversity and Food Security, World Resources Institute, Washington DC

[6] Chapin et al, 2006, quoted in CSWA, 2006, Code of Sustainable Winegrowing Practices, www.sustainablewinegrowing.org, p. 8-1.)

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[9] Altieri, M, Nicholls, N, Ponti, L, and York, A, 2005, Designing Biodiverse pest-resilient vineyards through habitat management, Practical Winery and Vineyards, April/May

[10] Altieri, M, Nicholls, N, Ponti, L, and York, A, 2005, Designing Biodiverse pest-resilient vineyards through habitat management, Practical Winery and Vineyards, April/May

[11] Nicholls, CI, M Parella, and M Altieri, 2000, "The effects of a vegetational corridor on the abundance and dispersal of insect biodiversity within a northern California organic vineyard," Landscape Ecology, 16: 133-146

Biodiversity Conservation Practices in California Vineyards:

APPENDIX A- Data from Case Studies on Insect Diversity

Supplemental information for the biodiversity study report[1]

This Appendix provides supplemental data for the report on a biodiversity project undertaken by the California Sustainable Winegrowing Alliance and collaborators from August 2006 to December 2007, with support of the National Fish and Wildlife Foundation. The study focused on case studies of mature hedgerows and "habitat corridors" that have been planted in or around vineyards, and in riparian corridors, in five vineyards in the North Coast region.

This appendix contains specific data from the insect monitoring in case study sites.

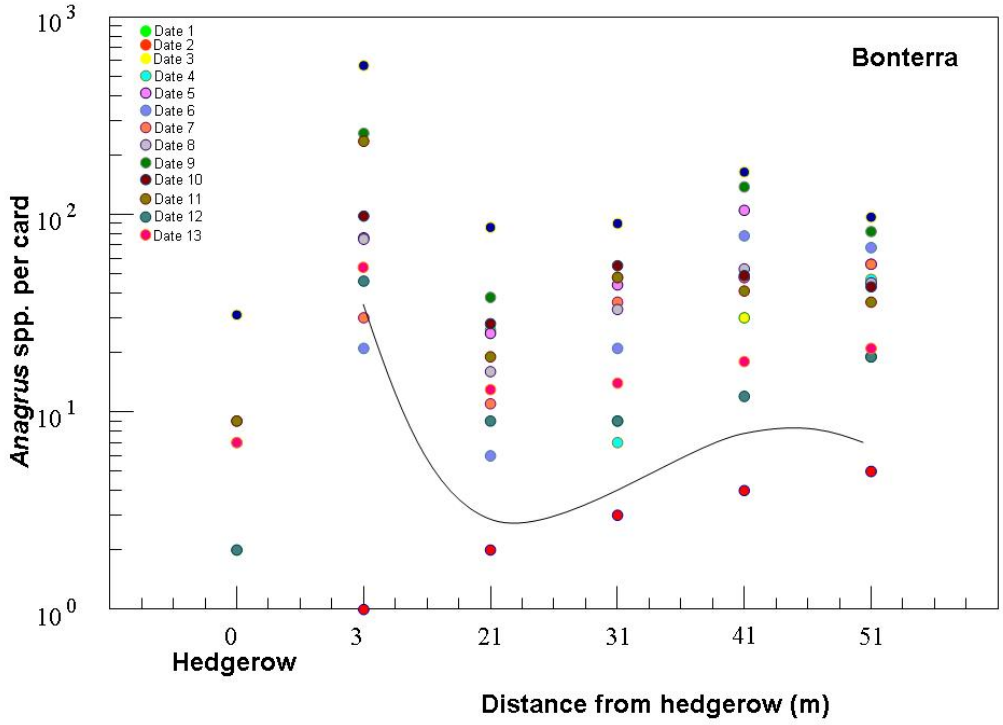


Fig. 1 Anagrus spp. density at Bonterra Vineyards, Ukiah, Mendocino County

[1] This data was prepared by Dr. Michael Costello, PhD, Professor at Cal Poly San Luis Obispo. Field data was gathered by Prahlada Papper, Mark Welch, and Elizabeth Church.

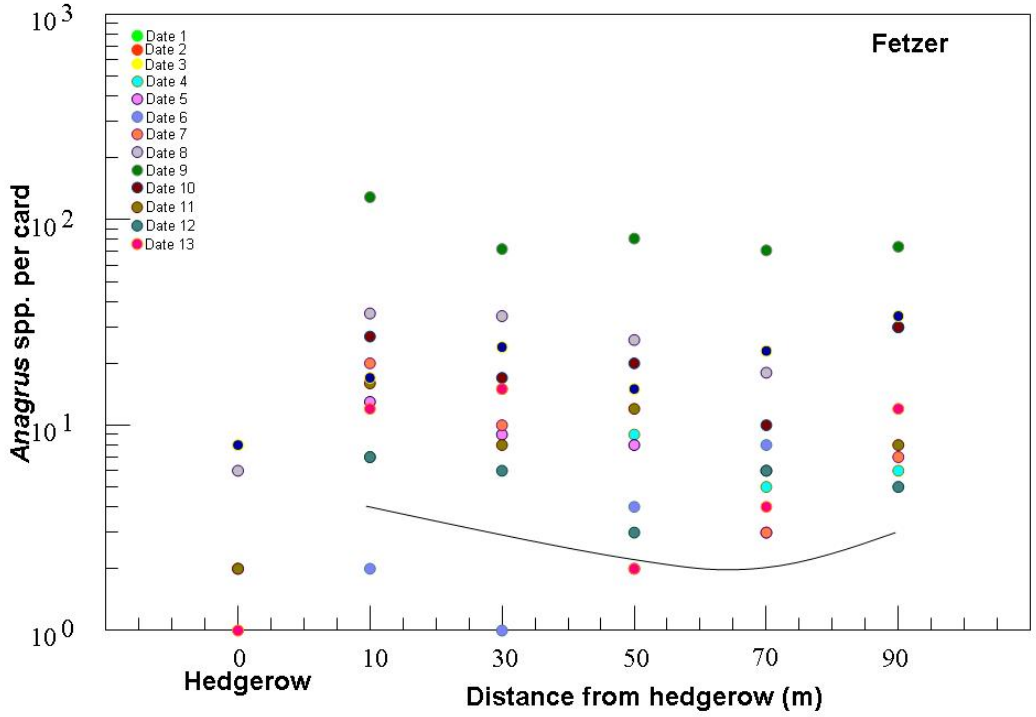


Fig. 2. *Anagrus* spp. density at Fetzer Vineyards, Hopland, Mendocino County

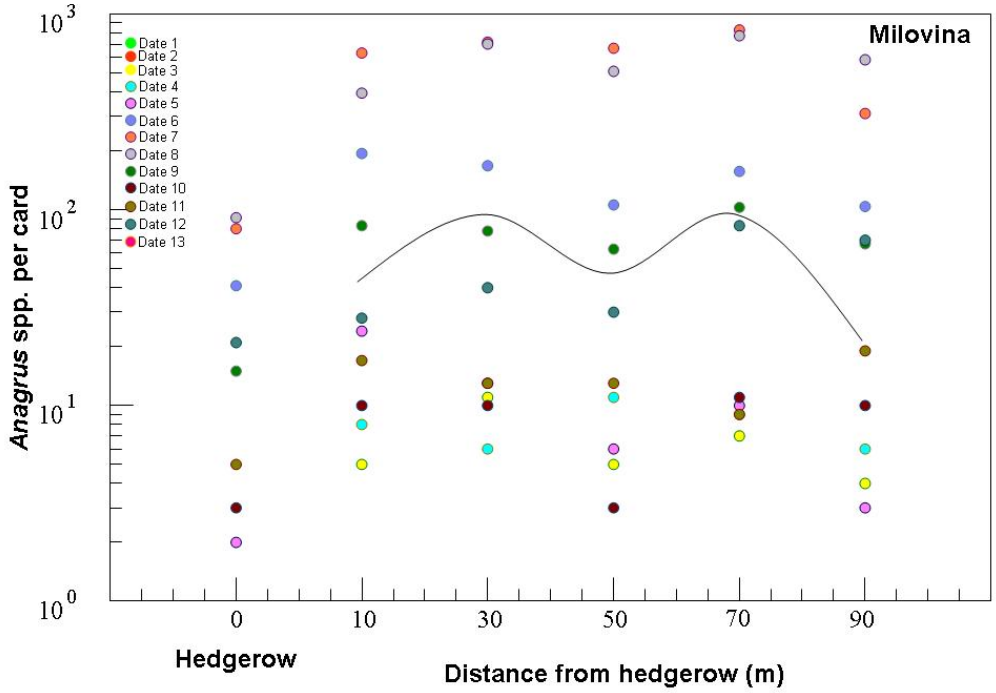


Fig. 3. *Anagrus* spp. density at Milovina

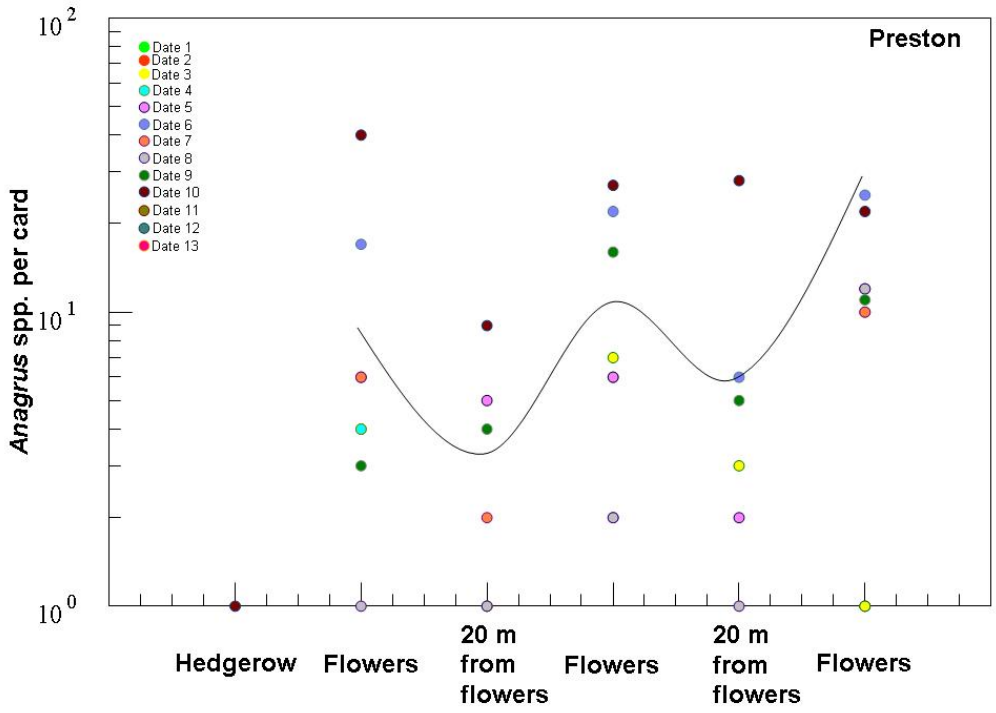


Fig. 4. *Anagrus* spp. density at Preston Vineyards, Dry Creek, Sonoma County

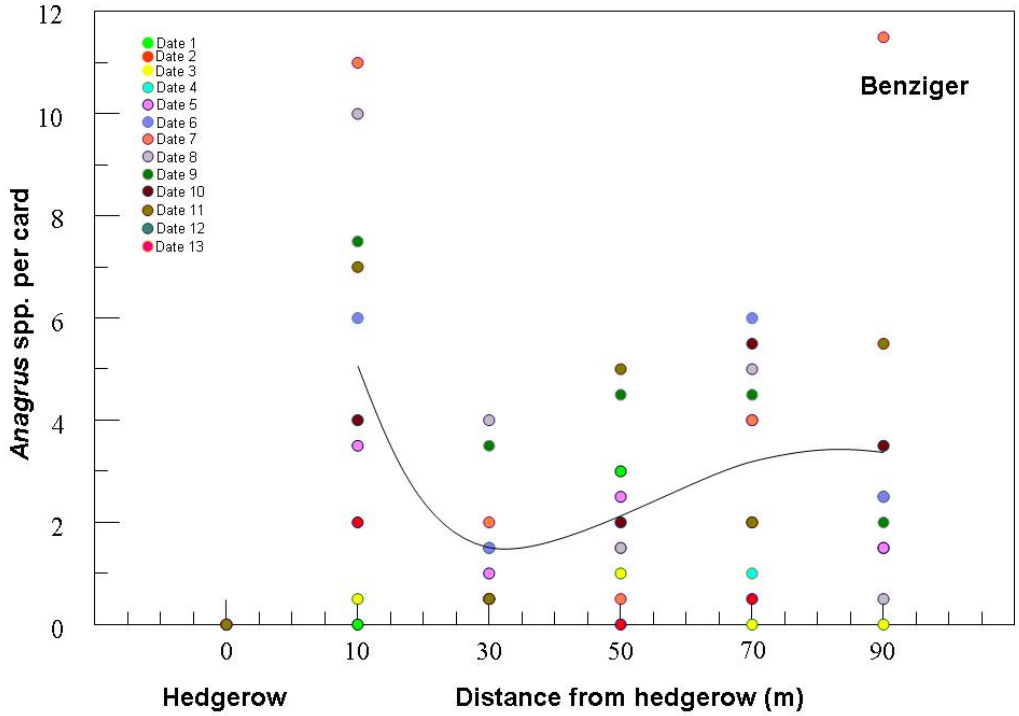


Fig. 5. *Anagrus* spp. density at Benziger Vineyards, Glen Ellen, S

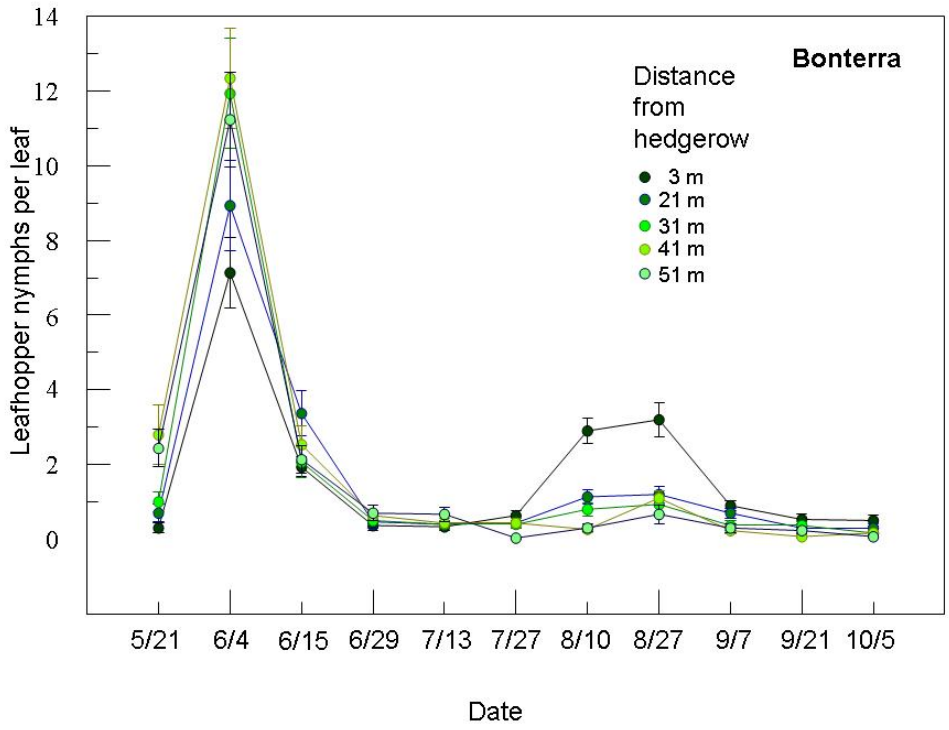


Fig. 6. Leafhopper nymphal density at Bonterra.

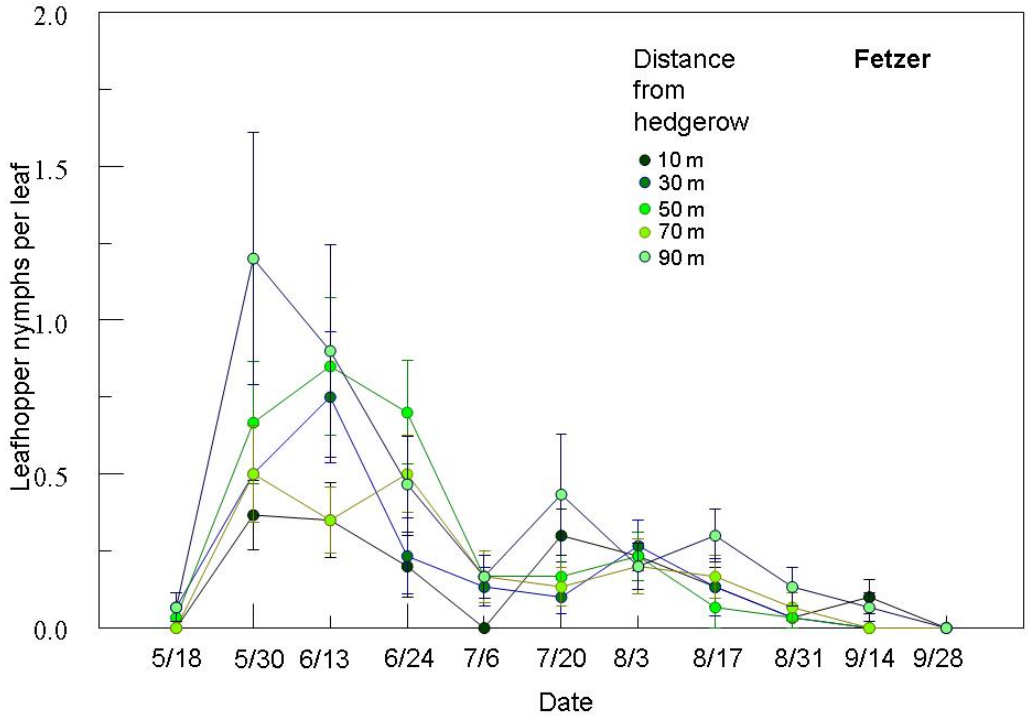


Fig. 7. Leafhopper nymphal density at Fetzer

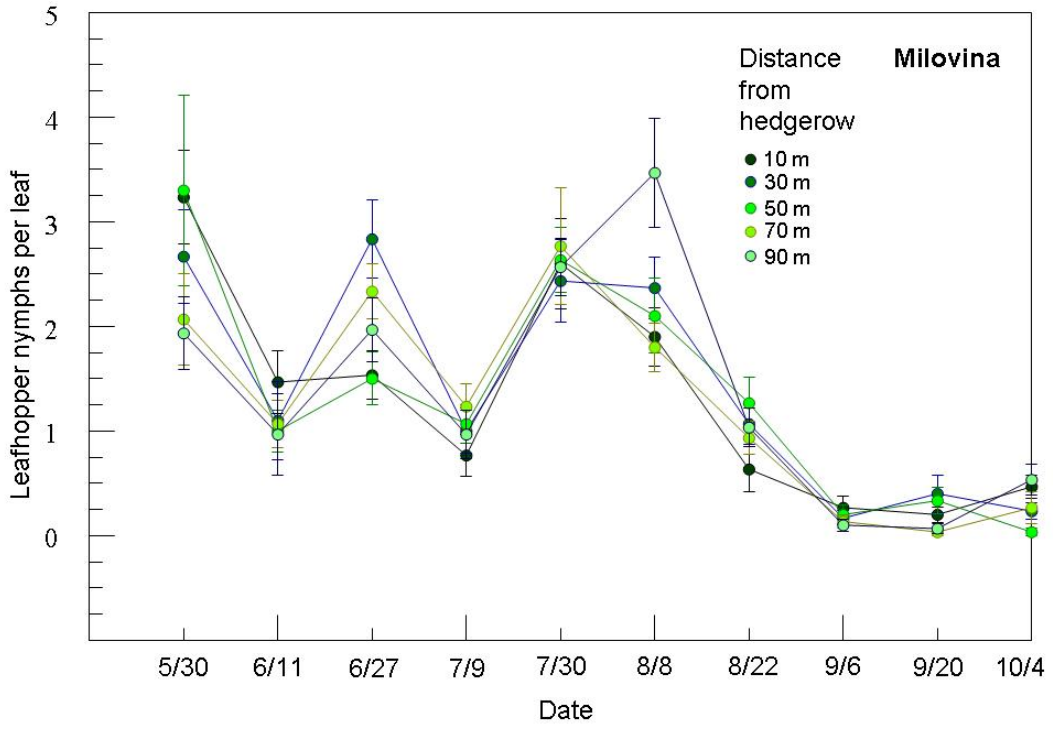


Fig. 8. Leafhopper nymphal density at Milovina

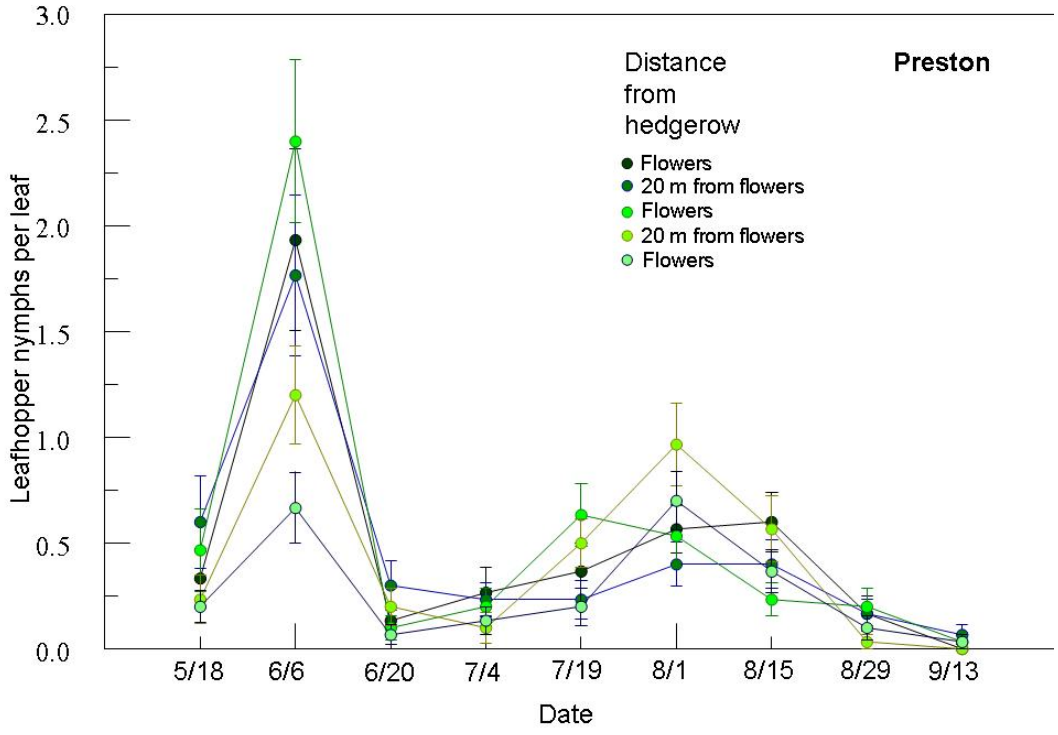


Fig. 9. Leafhopper nymphal density at Preston

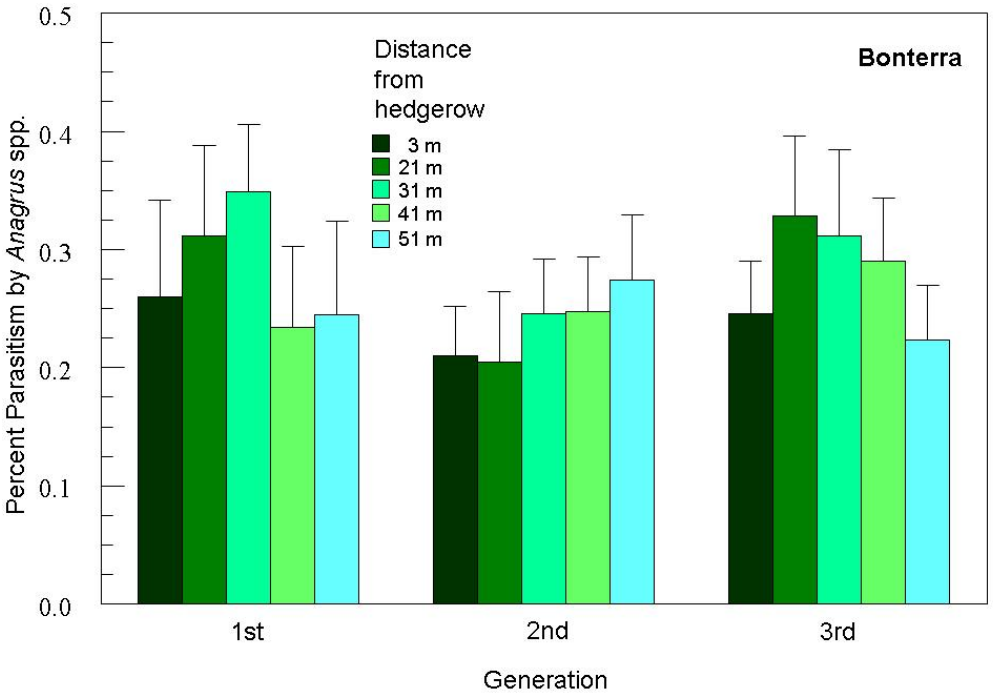


Fig. 10. *Anagrus* spp. parasitism at Bonterra

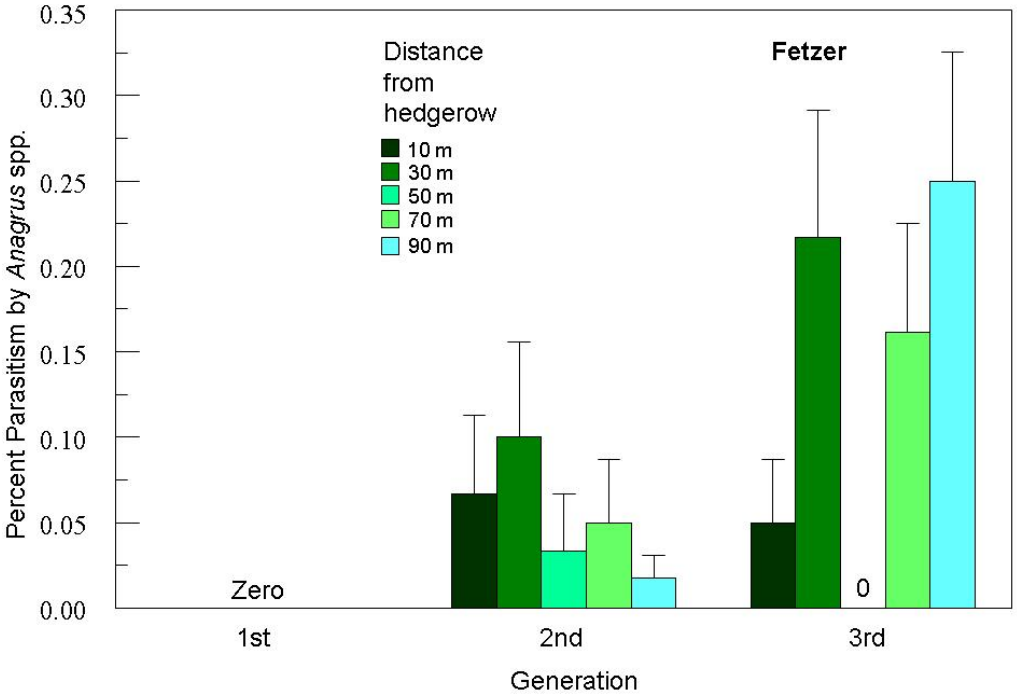


Fig. 11. *Anagrus* spp. parasitism at Bonterra

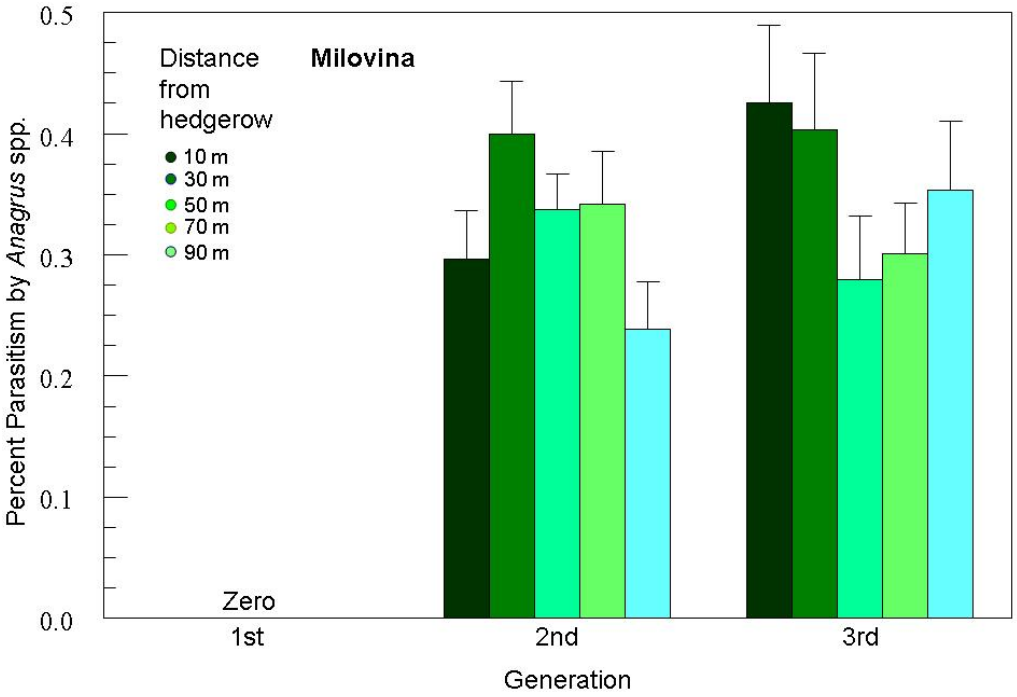


Fig. 12. *Anagrus* spp. parasitism at Milovina

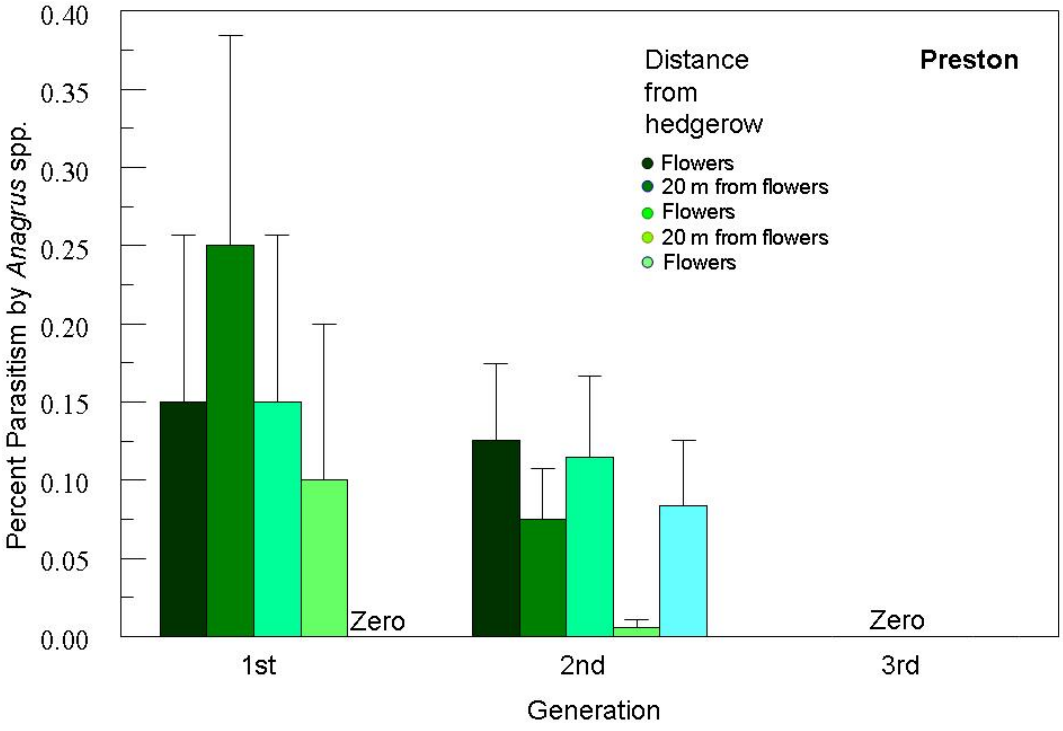
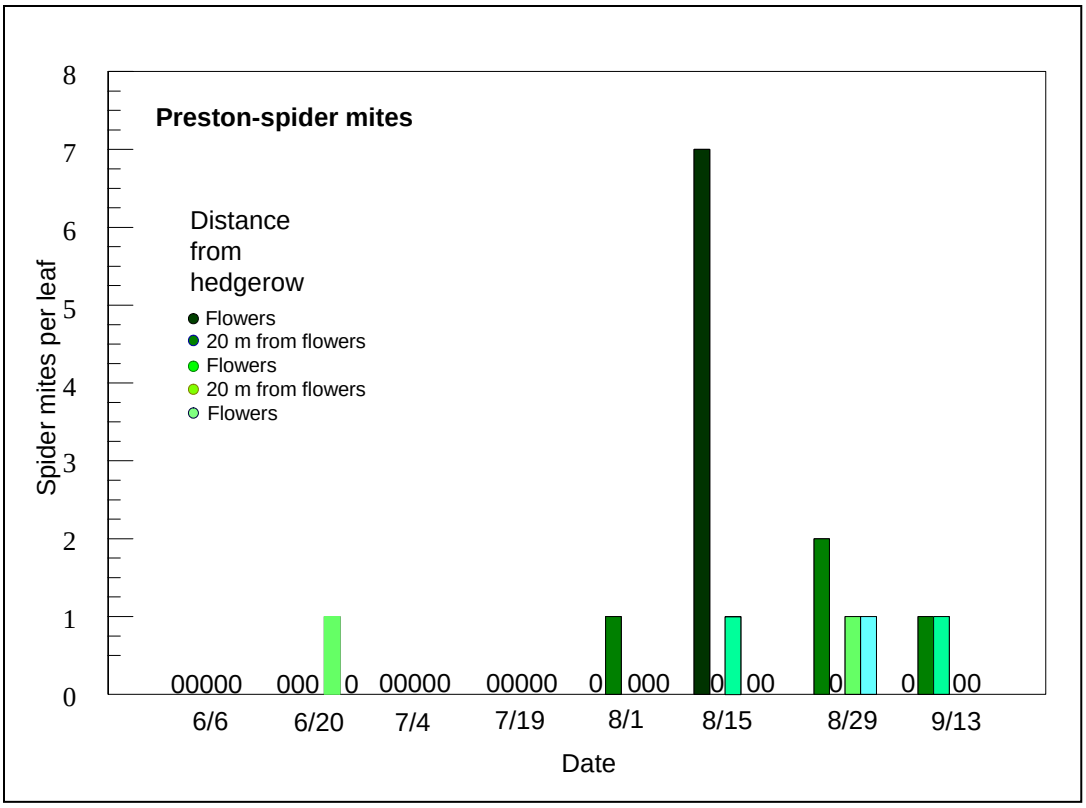


Fig. 13. *Anagrus* spp. parasitism at Preston



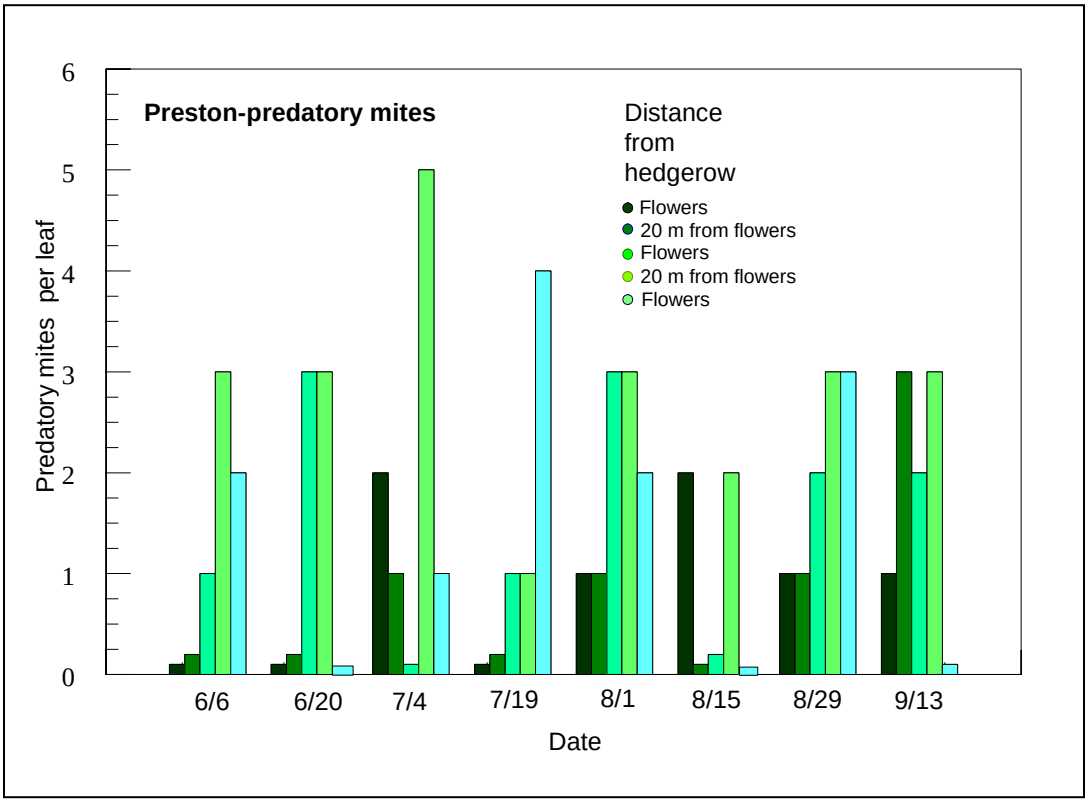
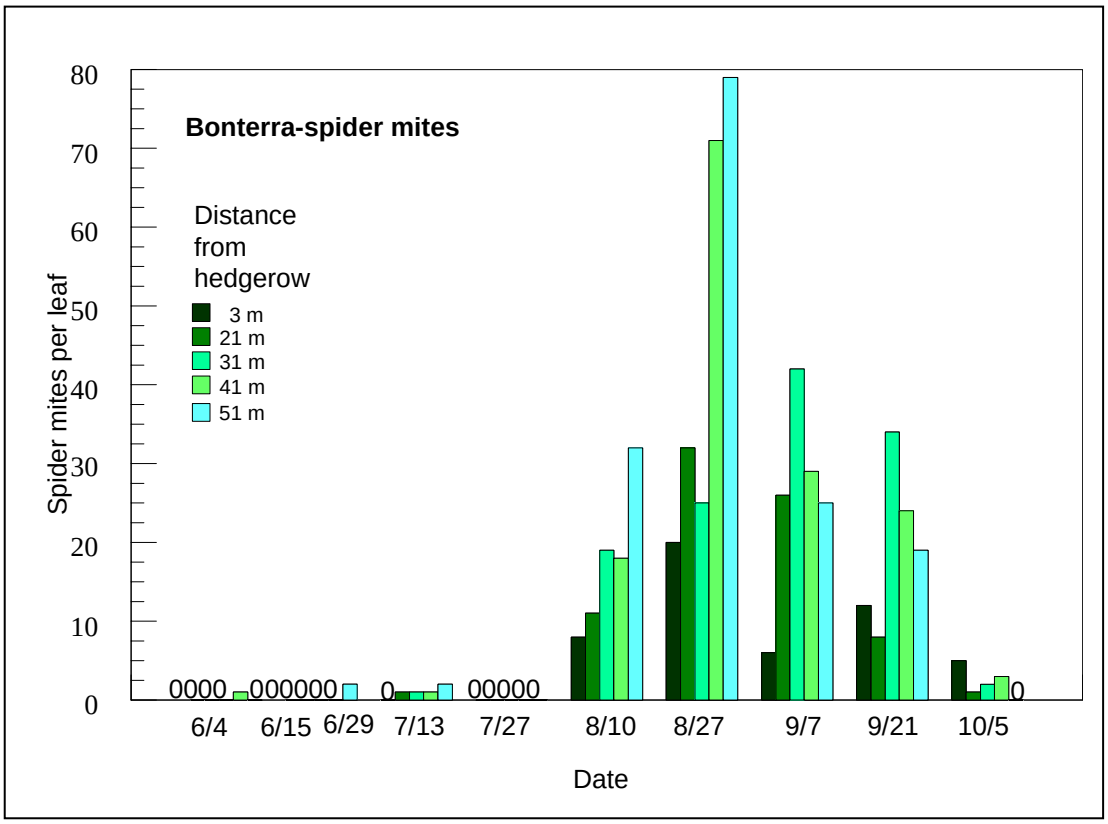


Fig. 14. Spider mite (Tetranychidae) and predatory mite (Phytoseiidae) density at Preston



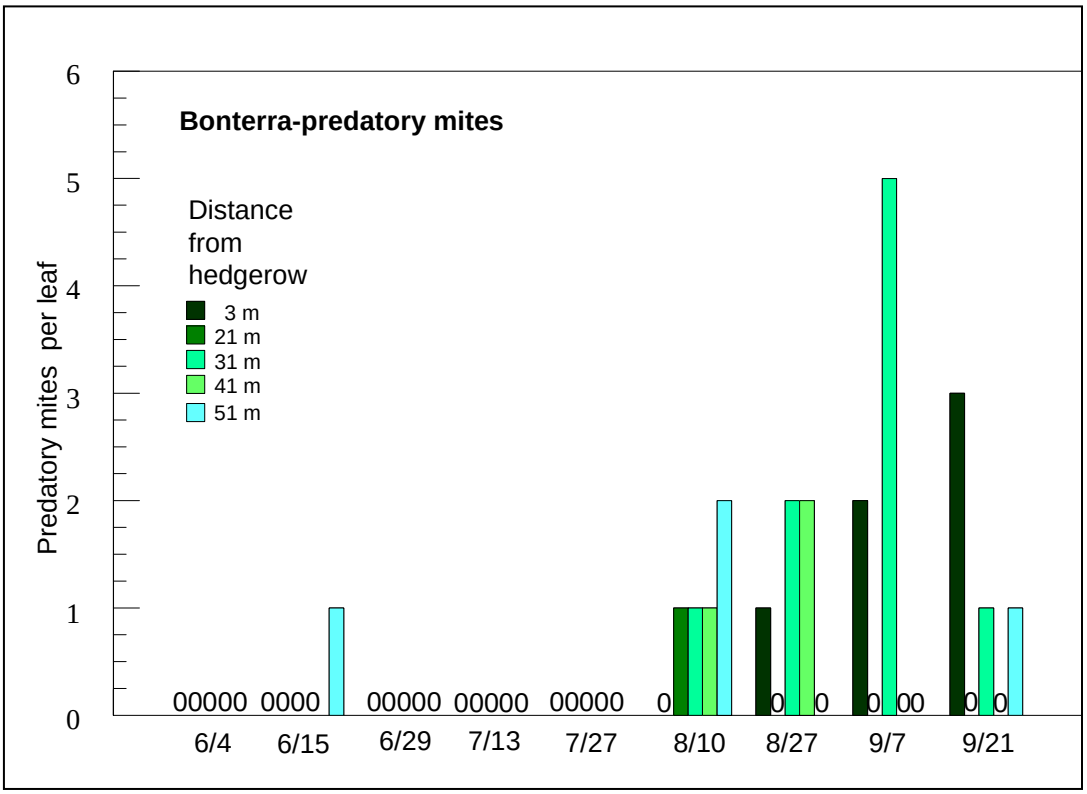


Fig. 15 Spider mite (Tetranychidae) and predatory mite (Phytoseiidae) density at Bonterra.

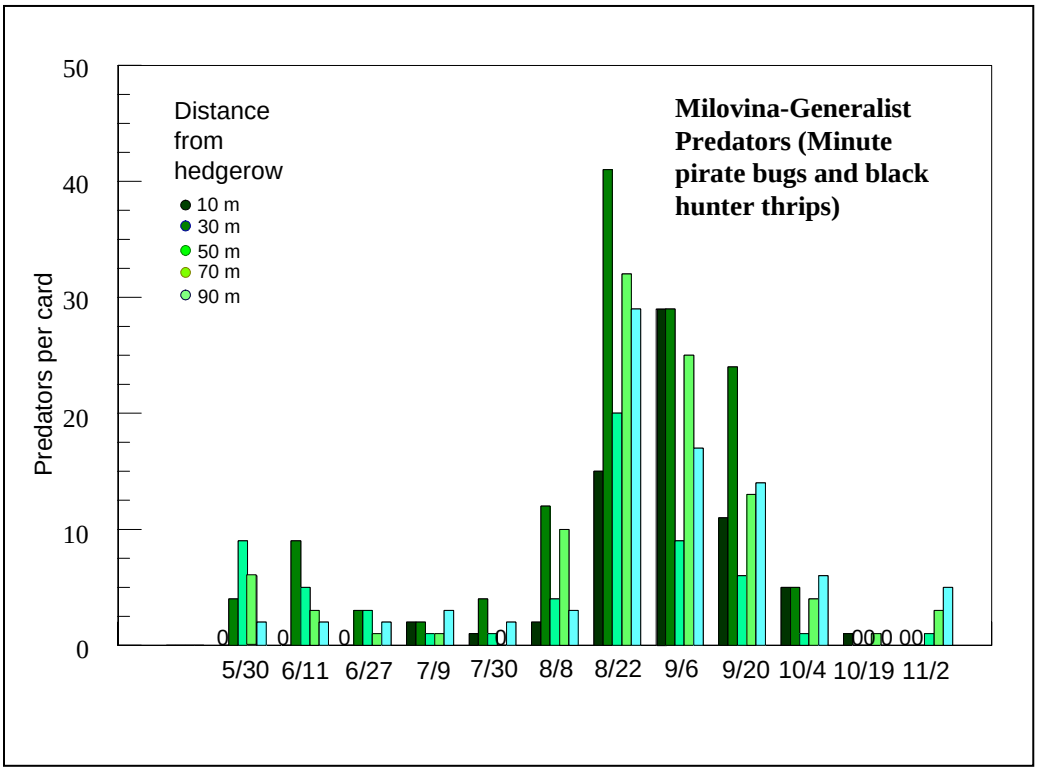


Fig. 16. Minute pirate bug and black hunter thrips density at Milovina.

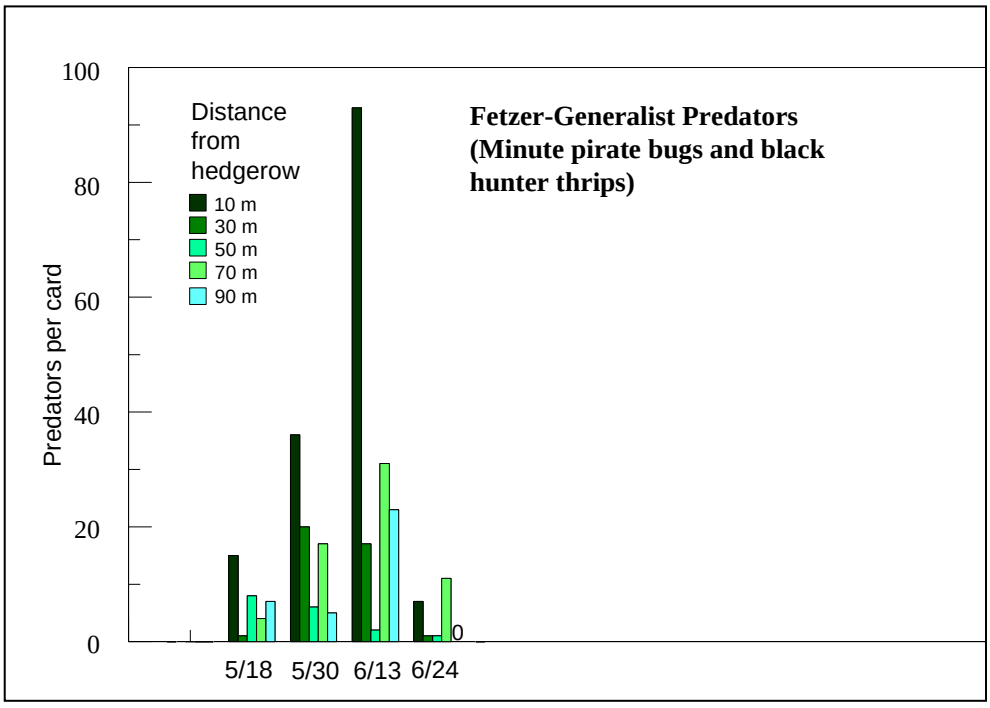


Fig. 17. Minute pirate bug and black hunter thrips density at Fetzer.