Cover crops affect insect and spider populations in apple orchards

Manipulation of cover crops may improve biological control of some pests

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Cover crops, widely used in California orchards and vineyards, affect crop growth by altering nutrient availability, soil moisture and physical properties, and the prevalance of weeds, plant pathogens, and insect pests. The few entomological studies conducted indicate a significantly lower incidence of insect pests in orchards with rich floral undergrowth than in clean cultivated orchards, mainly because of increased abundance and efficiency of predators and parasitoids supported by alternative prey or hosts harbored by the cover crops. Invasion by pests such as aphids and leafhoppers can also be discouraged by displacing or smothering naturally occurring host plants with a cover crop.

We conducted a two-year study on the effects of cover crop manipulation on arthropod communities in three northern California apple orchards. Our objectives were to (1) compare population levels and fruit damage by insects such as codling moth, aphids, and leafhoppers in orchards grown under clean cultivation or with cover crops, (2) find out whether undersowing cover crops in orchards would enhance populations of resident beneficial insects, and (3) evaluate the effects of cover crop manipulation on tree growth and productivity.

Sebastopol field trials

The Sebastopol study, from April to September in 1982 and 1983, was in two adjacent insecticide-free apple orchards (variety Rome Beauty) 40 miles north of San Francisco, a typical dry-farmed apple-growing region. One (disked orchard) was kept free of ground vegetation by one spring and one late summer disking. The other (cover-cropped orchard) was undersown in the fall with approximately 20 pounds of bell bean (*Vicia faba*) seeds per acre. By early June, the cover was mowed and the residues allowed to remain on the soil as a straw mulch for the rest of the season.

We monitored the relative abundance of plant-feeding insects and associated natural enemies on five randomly selected trees, on cover crops, and on the orchard floor. In each orchard, we sampled the lower canopy of each tree for one minute with a D-Vac insect suction machine. A pitfall trap filled with 75 percent water and 25 percent antifreeze placed at the base of each tree captured ground-dwelling arthropods. Two Zoecon codling moth (*Cydia pomonella*) pheromone traps per orchard indicated peak flights of male moths.

Bell bean cover crop in a Sonoma County apple orchard.

To assess codling moth damage at the end of each season, we examined larval entries in 100 fruits collected from each of the five trees in each orchard. We counted and weighed all fruits from each tree to determine yields per tree and percentage of total fruit damaged. Weekly evaluations of the proportion of infested twigs per tree indicated aphid and leafhopper levels.

We assessed predation on tree foliage with 25 paper cards (3 × 4 inches), each containing 50 Mediterranean flour moth (*Anagasta kuehniella*) eggs per card, hung in five trees per orchard. Ground predation was indicated by 50 cardboard sheets (8½ inches square) each with 20 glued potato tuberworm (*Phthorimaea operculella*) larvae, randomly placed on the floor of each orchard. The cards and sheets were removed after 24 hours and remaining eggs and larvae counted.

Species composition, percent cover and biomass production of the ground vegetation were determined from five 2-square-yard quadrats randomly thrown on the cover crop three times during the season.

In 1982, substantially more male codling moths were caught in the disked orchard (a total of 275 caught on nine sampling dates) than in the cover-cropped orchard (164 moths). These differences did not occur during 1983, however. Densities of the rosy apple aphid (*Anuraphis roseus*) were slightly higher during May and June 1982 in the disked than in the cover-cropped orchard. In 1983, rosy apple aphids were detected only in the disked orchard, where they reached high numbers in early June. Leafhoppers (Homoptera: Cicadellidae) colonized the orchards late in the 1982 season, reaching substantially higher densities in the disked than in the cover-cropped orchard (fig. 1). No detectable leafhopper populations occurred during 1983 in either orchard.

In both years, populations of natural enemies remained low on the trees, and

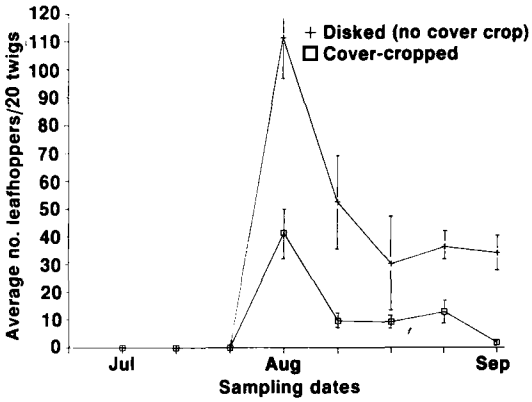

Fig. 1. Leafhoppers reached higher densities in the disked apple orchard than in the cover-cropped orchard.

no differences between orchards were apparent in seasonal abundances of common predators, such as Coccinellidae, Chrysopidae, and Cantharidae. Only spiders reached higher numbers on the trees with a cover crop early in the 1983 season. Despite these undetectable general differences in predator abundance, the number of *Anagasta* eggs removed from the trees was substantially higher in the cover-cropped orchard than in the disked orchard, especially during July and August in 1982 and 1983 (table 1).

As expected, disking primarily affected ground predators. In both years, ants and spiders were caught in pitfalls more consistently in the cover-cropped orchard than in the disked orchard, and carabid ground beetles appeared to be more prevalent in the disked orchard, especially from July on (table 2). Predators (especially ants) appeared to be more effective in removing *Phthorimaea* larvae in the cover-cropped than in the disked orchard (table 1).

A variety of general predators and parasitic Hymenoptera (mainly larger Braconidae and Ichneumonidae) were present on the cover-crop vegetation. Most were supported by the high numbers of alternative prey (especially aphids) harbored by the cover crop vegetation from early April through mid-June in both years. Leafhoppers were particularly prevalent on the cover crops in 1983.

In 1982, there were no apparent differences in fruit yields between the two orchards, but codling moth damage seemed slightly lower in the cover-cropped orchard. In 1983, however, cover-cropped trees produced considerably more fruit, although they were smaller, than did trees in the disked orchard. Codling moth incidence was substantially lower in the cover-cropped orchard (table 3).

Santa Cruz apple orchard

The Santa Cruz study took place in a 5-acre organic apple orchard of mainly two varieties (Newton pippin and Mutsu) in the University of California Santa Cruz farm. The orchard was divided into two 2½-acre sections, one planted with a cover-crop of bell beans and lana vetch (*Vicia dasycarpa*) and the other kept free of vegetation by cultivation during the entire season. We used the same sampling procedures as in Sebastopol from May through September 1983.

The total number of codling moth males caught in pheromone traps during the season was substantially higher in the disked section (80 moths) than in the cover-cropped section (31 moths) of the orchard. No differences in aphid infestation levels were detected between the two sections. Leafhopper densities were substantially higher in the disked section for 76 percent of the sampling times, generally resulting in a higher percentage of twigs infested with leafhoppers in the disked section.

Most D-Vac samples from trees in the cover-crop section yielded significantly more large parasitic Hymenoptera (Ichneumonidae, Braconidae and Chalcididae) than from trees in the disked section, and Coccinellidae were most numerous on the trees with a cover crop on six sampling dates. Egg removal was slightly higher, although not significantly, on trees in the cover-crop section (23.3 percent ± 8.8) than on those in the disked section (20.6 percent ± 7.4).

Pitfall traps yielded consistently higher numbers of spiders and carabid beetles on the orchard floor in the cover section than in the disked section throughout the season. In May and June, more Dermaptera were caught in the disked section, and ants also were more abundant in the disked section, but later in the season. Potato tuberworm larval removal by ground predators was higher in the cover-cropped section (70 percent ± 5.1, mean of two sampling dates) than in the disked section (60 percent ± 7.8).

Fruit numbers per tree and weight were similar in both sections. There were no differences in codling moth infestation. Apple scab (*Venturia inaequalis*), however, inflicted substantially more damage to fruit in the cover-cropped than in the disked section.

Cover crops in Courtland

The Courtland study was in a young orchard divided into 18 plots (47 by 6 yards each), with six cover-crop treatments (replicated three times): farmers' rye, tetraploid rye, ladino clover, salina strawberry clover, Mt. Barker subclover, and a natural weed complex. Cover crops were sowed at 5 pounds of seed per plot. The weedy plot included, in order of prevalence, curly dock, bristly ox-tongue, willow-herb, water smartweed, groundsel, sow thistle, and wild mustard. The plots were separated by two-yard strips of bare ground. No pesticides were used.

We measured plant height, biomass, density, and percent cover of cover crop and weed species in all plots three times in the season. Only ladino clover and salina strawberry clover remained in full bloom until mid-September, and in the weedy plot, only *Picris* bloomed until the end of the study.

We put five pitfall traps in the center of each plot and replaced them weekly. D-

TABLE 1. Removal rates of artificially placed prey by foliage and soil dwelling predaceous arthropods in an organic apple orchard with and without cover crop in northern California

	May		June		July		August	
Orchard	1982	1983	1982	1983	1982	1983	1982	1983
				% eggs removed* (± standard error)				
Cover	13.0 ± 4.3	20.3 ± 7.1	16.2 ± 2.1	—	52.0 ± 13.7	94.4 ± 21.7	67.0 ± 22.3	44.8 ± 18.4
Disked	13.1 ± 3.9	15.1 ± 3.4	13.4 ± 1.7	—	25.1 ± 9.8	35.1 ± 13.4	47.2 ± 19.8	20.6 ± 7.8
				% larvae removed† (± standard error)				
Cover	—	21.7 ± 7.3	47.7 ± 20.1	88.6 ± 37.3	90.0 ± 32.1	—	81.0 ± 37.9	90.0 ± 40.3
Disked	—	14.0 ± 4.6	54.8 ± 24.3	46.1 ± 14.7	72.0 ± 21.7	—	57.6 ± 23.1	65.9 ± 22.1

* Means derived from 25 paper cards, each with 50 glued *Anagasta kuehniella* eggs randomly placed in five trees in each orchard.
† Means derived from 50 cardboard cards, each containing 20 glued *Phthorimaea operculella* larvae randomly placed on the floor of each orchard.

TABLE 2. Total number of ground-dwelling arthropods caught during two years in pitfalls placed in an organic apple orchard with and without a cover crop in northern California

Arthropod guild	Disked orchard		Cover orchard	
	1982	1983	1982	1983
Carabidae (ground beetles)	1,555*	2,574	564	1,008
Formicidae (ants)	133	128	263	293
Spiders	158	203	470	770
Total arthropods	1,846	2,905	1,297	2,071

* Total numbers derived from five pitfall traps per orchard, collected in a period of 19 weeks.

TABLE 3. Apple production and codling moth (*Cydia pomonella*) damage in organic orchards with and without cover crop in northern California

Orchard and year*	Total no. of fruits/tree	Total fruit weight/tree	Fruit > 2½" diameter	Fruit with codling moth damage
		kg	%	%
Cover				
1982	214 ± 35.6†	29.1 ± 3.6	44.8 ± 9.8	68.0 ± 9.7
1983	334 ± 56.8	58.3 ± 9.7	87.6 ± 14.6	4.2 ± 0.7
Disked				
1982	260 ± 37.1	26.9 ± 4.5	39.0 ± 6.5	78.0 ± 9.7
1983	94 ± 11.7	15.5 ± 2.6	54.8 ± 11.0	38.9 ± 7.8

* Total rainfall during the growing season (April-October) was 341 mm in 1982 and 367 mm in 1983.
† Means ± S.E.

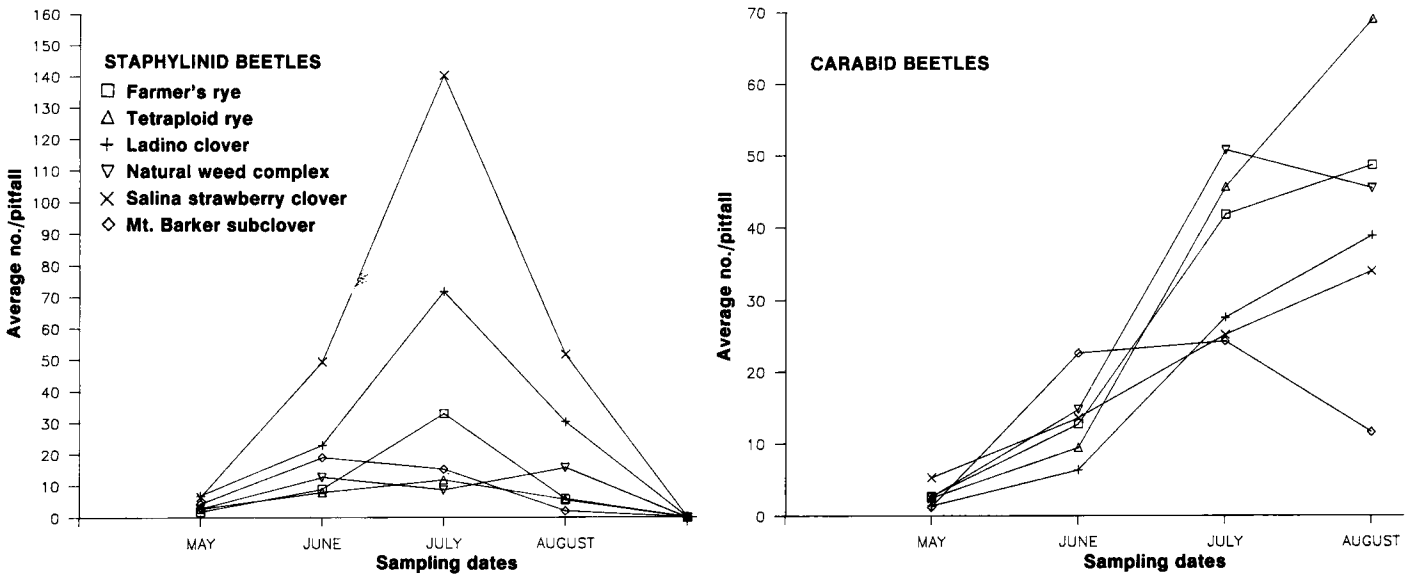

Fig. 2. Average number of two predator beetles caught in pitfall traps placed in plots with different cover crops in Courtland, California. Staphylinid beetles (left) were most abundant in rye and weedy cover plots after early June. Carabids (right) were most numerous in salina clover and ladino clover all season.

Vac samples were taken from three 2- by 2-yard quadrats in each plot every week.

The six types of cover crops differed markedly in height, biomass production, and development. The tallest were the two rye varieties and the weeds, especially curly dock and bristly ox-tongue. Bristly ox-tongue was dominant in the weedy plot. The two rye varieties, salina strawberry clover, and the weeds produced the largest seasonal biomass.

The most common plant-feeders associated with the cover crops were aphids, leafhoppers (*Empoasca*, *Draeculocephala*, and *Carneocephala*), and an array of nonpestiferous Diptera. Flies were most abundant in ladino and salina clover, and aphids were most commonly collected from Mt. Barker subclover and weeds. Although leafhopper populations decreased in all plots throughout the season, they were more frequently collected from the two rye varieties than from any other cover crop. *Lygus* also occurred in the different cover crops, but in low numbers.

The ladino and salina strawberry covers supported the highest numbers of common predators such as *Orius* spp., Nabidae, *Geocoris* spp., and some Reduviidae. Ichneumonidae were the most common parasitic Hymenoptera collected on all the cover crops, reaching highest numbers on ladino clover from mid-May to mid-June.

Common predators collected in pitfalls were Staphylinidae, Carabidae, and Lycosidae spiders. Prevalent carabid beetles collected in the pitfalls included nine species. Staphylinid beetles seemed most abundant in the rye and weedy cover plots from early June on, whereas carabid beetles appeared most abundant in the salina and ladino clover throughout the season (fig. 2).

Conclusions

Some arthropods showed consistent population responses to cover crop manipulation. The results suggest the following, tentative description of differences between systems with and without cover crops: Apple orchards with cover crops generally had (1) lower infestation levels of aphids, leafhoppers, and codling moth, (2) more species and more individuals of soil-dwelling predaceous arthropods, and (3) higher removal rates of artificially placed prey. In contrast, disked systems were generally characterized by greater numbers of plant-feeders on the trees, and by relatively low population levels of natural enemies.

The cover crops generally harbored large numbers of prey, such as aphids and leafhoppers, which attracted varying numbers of predators. High numbers of predators on the cover crops, however, did not necessarily translate into higher numbers on the trees. Experiments to test whether the common practice of mowing the cover crop forces natural enemies to move up to the trees could be useful in designing management plans for encouraging efficiency of natural controls. Although cover cropping significantly affected ground predator populations, these studies could not determine how these changes affected pest species on the trees. The data also did not indicate how realistically predation on artificial baits related to reduction of apple pests, such as codling moth, aphids, and leafhoppers.

The Courtland study suggested that the species of cover crop, its structural and developmental features, and the associated plant-feeding species determine its potential value as a reservoir of natural enemies. Legumes that remained in full bloom throughout the season sustained the highest populations of arthropods. As the foliage aged and deteriorated nutritionally, supporting fewer plant-feeding insects, the complex of predators and parasites narrowed in abundance and species composition.

Depending on the orchard system, cover crop complex, and associated arthropod species, it seems that manipulation of the ground cover can have a significant effect on the number of arthropods that inhabit the orchard by (1) directly affecting plant-feeding populations that discriminate between trees with and without cover underneath or (2) attracting and retaining soil- and foliage-inhabiting natural enemies by providing alternative food and habitat. Critical testing of these effects in a range of orchard systems may lead to improved biological control of certain orchard pests.

Miguel A. Altieri is Assistant Professor and Assistant Entomologist, and Linda L. Schmidt is Staff Research Associate, Division of Biological Control, University of California, Berkeley. *These studies were made possible by generous funding from the Jessie Noyes Smith Foundation, New York, and the University of California Appropriate Technology Program. Several students provided valuable help in the field and laboratory: John Herr, John Farrell, Javier Trujillo, Jamin Eisenbach, Maia Massion, Eric Engbeck, Debbie Hammel, Cliff Gold, and Octavio Ruiz. The enthusiastic and patient collaboration of Stephen Gliessman, UC Santa Cruz, and farmers Ken Ratzlaff, Sebastopol, and Joe Green, Courtland, is greatly appreciated.*