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Using Clovers as Living Mulches To Boost Yields, Suppress Pests, and Augment Spiders in a Broccoli Agroecosystem

Cerruti R[2] Hooks,[a] Raju R. Pandey,[b] and Marshall W. Johnson[c]
[a]CTAHR Department of Plant and Environmental Protection Sciences; [b]Himalayan College of Agricultural Sciences and Technology, Kathmandu, Nepal; [c]Department of Entomology, University of California, Riverside

Summary

A field study was conducted to examine the influence of intercropping broccoli (*Brassica oleracea* L.) with three living mulches on caterpillar pest and spider densities and crop yield. Broccoli was grown in bare ground or intercropped with strawberry clover (*Trifolium fragiferum* L.), white clover (*Trifolium repens* L.), or yellow sweetclover (*Melilotus officinalis* L.). Lepidopteran (butterfly and moth) eggs and caterpillar densities were significantly greater on broccoli in bare-ground plots compared with broccoli intercropped with clover during the late broccoli growth cycle. More spiders were found on bare-ground broccoli during early crop growth; however, during the later growth period, spider counts were significantly higher on broccoli in intercropped plots. The number of insect contaminants found in harvested broccoli crowns were significantly less in intercropped than in bare-ground broccoli plots. The weight of harvested crowns was similar in intercropped and bare-ground habitats.

Introduction

An established cover crop that is interplanted and grown with an annual row crop is known as a living mulch. Living mulches can provide many benefits to a cropping habitat, including weed control, reduced erosion, enhanced fertility, and improved soil quality (Lanini et al. 1989). However, recent studies have shown that when living mulches are undersown with a vegetable crop they can also help reduce injury imposed by insect pests (Costello and Altieri 1995, Hooks et al. 1998, Hooks and Johnson 2001). Undersowing is the intercropping of an economically important crop with an undersown plant species that has no direct market value but is used to diversify the agroecosystem or influence the main crop.

The impact on insect pest densities of undersowing vegetable crops with living mulches has been examined mainly in *Brassica* crops (Asman et al. 2001; Hooks and Johnson 2001, 2002). In most of these studies, fewer insect pests were found on interplanted vegetable crops (Hooks and Johnson 2003 and references therein). However, *Brassica* crops are typically slow growing and do not compete well with background vegetation. Therefore, most of these studies reported significant yield reductions, possibly caused by interspecies competition.

Several strategies may be implemented to limit competition among *Brassica* crops and their companion plants. These strategies may include

- proper fertilization and irrigation of the main crop
- use of vigorous or rapidly growing crop cultivars
- optimal spacing between the main crop and companion plants
- use of less competitive background plants (e.g., low canopy height)
- timely planting of the main crop and companion plant
- planting the intercrop at a lower seed rate or in narrower strip
- suppression of the intercrop (e.g., mowing, reduced fertilization and irrigation) at critical times
- use of a self-suppressing companion plant (i.e., one that dies during the critical period of crop growth)
- use of non-crop borders surrounding the field crop.

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Each approach should be viewed with caution and weighed against its potential to negate any positive benefits of pest suppression.

This publication describes a field experiment that was part of a continuing effort to refine management of lepidopteran pests in broccoli by mixed cropping and undersowing it with other plant species. The primary purpose of this study was to determine if specific undersown living mulches would have the ability to suppress lepidopteran pest densities without reducing crop yields to economically unacceptable levels. We focused on cover crops in the genus *Trifolium* partially because of their low-growing structural similarities to yellow sweetclover. Additionally, because spiders were recurrently observed preying on various lepidopteran caterpillars (Hooks and Johnson 2002), their densities were compared among undersown and bare-ground broccoli.

Materials and methods

Experiment layout

The field experiment was conducted during the summer 2000 at the University of Hawai'i at Mānoa's Poamoho Research Station on O'ahu. The four cropping systems examined were broccoli plants undersown with: (1) yellow sweetclover (*Melilotus officinalis* L.) seeded at 72 g per row, (2) strawberry clover cv. O'Conners (*Trifolium fragiferum* L. seeded at 58 g per row, (3) white clover cv. New Zealand (*Trifolium repens* L.) seeded at 54 g per row, and (4) broccoli monoculture used as a check treatment. Experimental plots were 11 m x 11 m with each treatment replicated four times and arranged in a randomized complete block design.

The living mulches were sown on 10 July 2000 in all of the undersown plots. Undersown plots contained 10 rows of broccoli with 11 rows of the living mulch species and monoculture plots contained 10 rows of broccoli. Broccoli seedlings, cv. Liberty (Petoseed Co., Saticoy, California), were grown for 5 weeks in the greenhouse before being manually transplanted on September 18 and 19.

Clover growth

The spread of the clover canopies was monitored weekly beginning 16 days after broccoli planting (DAP) until broccoli harvest. Five areas between two adjacent clover rows in each plot were randomly selected, excluding border rows, and the distance of exposed soil surface (not covered by clover canopy) between rows was measured.

Arthropod census

Caterpillar pest stages and predators on broccoli plants were sampled at 7-day intervals until the harvest period. Sampling was stratified according to plant structure (5 upper, 10 middle, and 10 lower positioned leaves). Egg, caterpillar, and pupa stages of the diamondback moth, *Plutella xylostella* L., imported cabbageworm, *Pieris rapae* L, and cabbage looper, *Trichoplusia ni* Hübner, were counted separately.

Broccoli yield

The diameter and weight of 16 broccoli crowns, chosen at random from the interior rows of each plot, were measured at harvest time. The heads were then completely dissected and examined for insects, insect parts, and associated contaminants (e.g., frass, webbing, cocoon).

Statistical analysis

The effects of habitat type on the experimental parameters were analyzed using analysis of variance (Proc GLM, SAS Institute, Cary, NC 1990) and predetermined orthogonal comparisons to separate mean differences. Within the model, the following predetermined contrasts were conducted: broccoli-clovers vs. monoculture; true clovers (white and strawberry) vs. yellow sweetclover; and strawberry clover vs. white clover. Because eggs of moths and butterflies were acutely low, all species were pooled together by stage (e.g., egg, larvae) prior to final analysis. The criteria for significance was $P < 0.05$.

Results

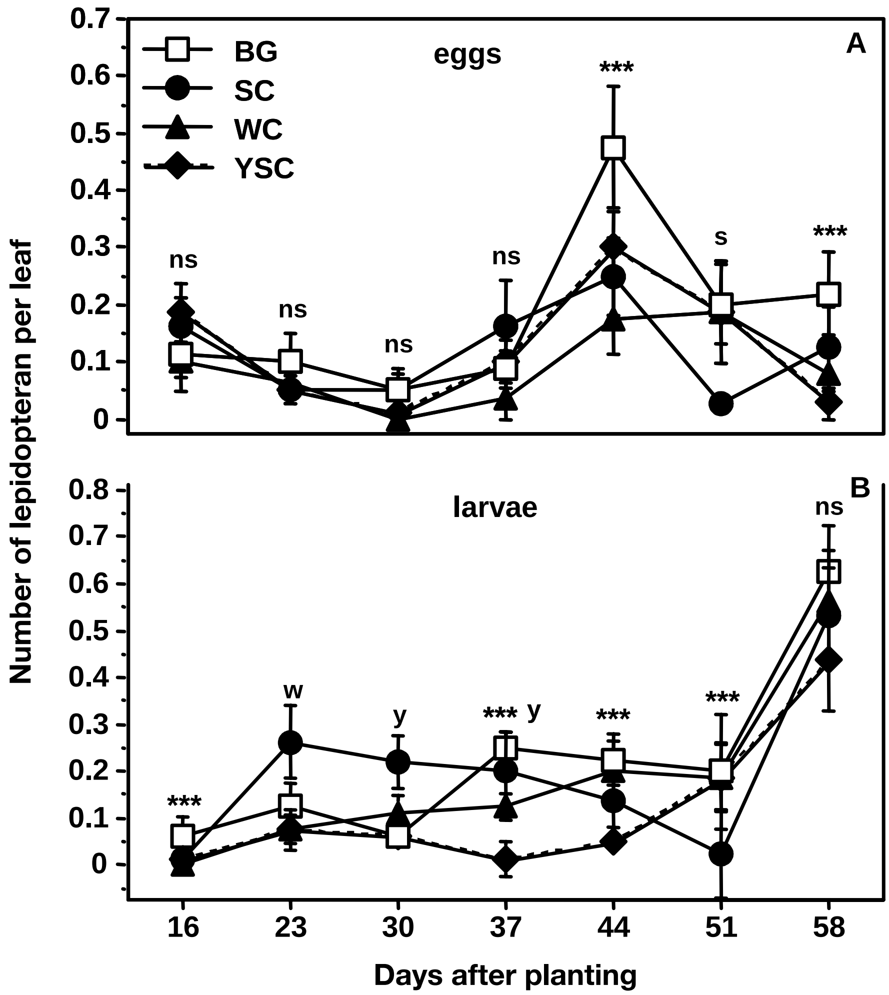
Clover growth

The yellow sweetclover canopy expanded over the soil surface faster than the other undersown living mulches. Subsequently, the amount of exposed soil surface area between broccoli rows was significantly less in broccoli–yellow sweetclover contrasted with broccoli undersown with strawberry clover and white clover on each sampling date. Strawberry clover canopy development occurred at the slowest rate and was significantly less than that of white clover on most dates.

Arthropod census

Effect of clovers on leidopteran pest densities. Lepidopteran populations were low during the experiment. Approximately 85, 10, and 5 percent of the lepidopteran fauna observed were *P. rapae, T. ni,* and *P. xylostella,*

Figure 1. Mean population densities of lepidopteran (a) eggs and (b) larvae in bare-ground broccoli (BG); broccoli–strawberry clover intercrop (SC); broccoli–white clover intercrop (WC); and broccoli–yellow sweetclover intercrop (YSC). * indicates intercrops significantly less than bare ground; s indicates (SC) significantly less than (WC); w indicates (WC) significantly less than (SC); y indicates (YSC) significantly less than (SC + WC); and ns means no significant differences exist (*P* > 0.05).**

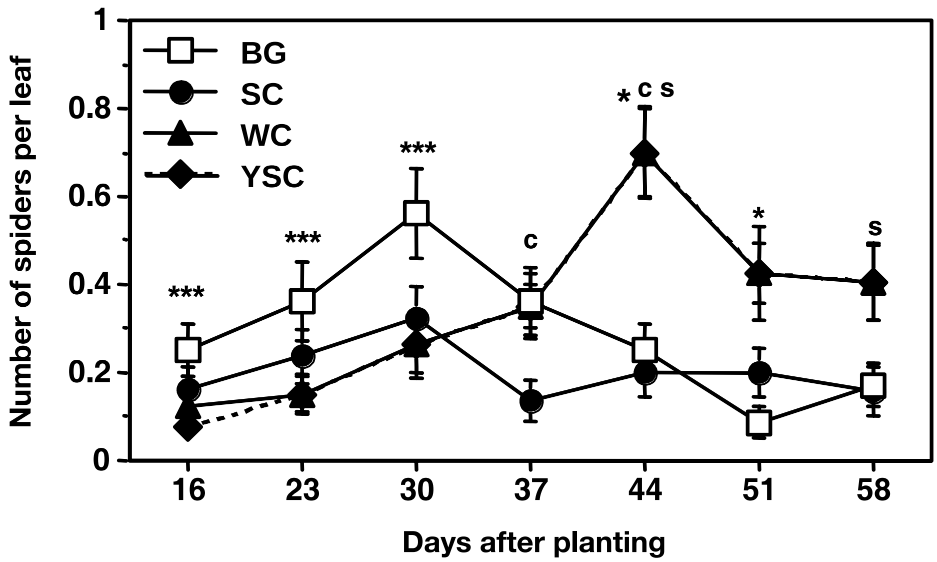


respectively. From early to mid-season, no significant differences were detected in the abundance of eggs among broccoli habitats (Figure 1a). However, during the late broccoli growth cycle, more eggs were found in monoculture than in undersown broccoli. Similarly, more caterpillars were recorded in monoculture compared with undersown broccoli from mid- to late season (Figure 1b).

Impact of clovers on spider abundance. At the experimental site, four spider species frequently inhabit *Brassica* plants. *Nesticodes* (= *Theridion*) *rufipes* Lucas (Theridiidae), *Neoscona oaxacensis* Keyserling (Araneidae), *Oxyopes* sp. (Oxyopidae), and *Cheiracanthium mordax* L. Koch (Clubionidae) composed approximately 77, 13, 7, and 3 percent of the spider fauna, respectively. Significantly fewer spiders were encountered on broccoli plants with clovers compared with bare-ground broccoli during the initial three sampling dates. However, during the later part of the broccoli growth cycle, this trend reversed, and more spiders were found on broccoli plants in clover than in bare-ground plots (Figure 2).

Additionally, fewer spiders were found on broccoli grown with the true clovers (e.g., strawberry clover, white clover) compared with plants grown with yellow sweetclover during mid-season. Fewer spiders were also observed on broccoli plants undersown in strawberry

Figure 2. Mean population densities of spiders in bare-ground broccoli (BG); broccoli–strawberry clover intercrop (SC); broccoli–white clover intercrop (WC); broccoli–yellow sweetclover intercrop (YSC). * indicates (BG) significantly less than intercrops; * indicates intercrops significantly less than (BG); c indicates (SC + WC) significantly less than (YSC); s indicates (SC) significantly less than (WC); and ns means no significant differences exist (P $\geq$ 0.05).**



clover compared with white clover from mid- to late season.

Crown contamination

At harvest, broccoli crowns were infested with various stages of *Pieris rapae*, *Trichoplusia ni*, and *Plutella xylostela* (Table 1). *T. ni* caterpillars and pupae were the most abundant lepidopteran contaminants encountered in broccoli heads. However, significantly more individuals of all three species were found in crowns harvested from bare-ground broccoli compared to undersown broccoli.

Crop yield

The largest crowns by diameter and mass were harvested from broccoli undersown with strawberry clover or white clover (Table 2). These crowns weighed significantly more than those harvested from broccoli–yellow sweetclover plots. Yellow sweetclover plots contained the smallest crowns, by weight.

Discussion

The purpose of this study was to determine if undersown clovers could reduce lepidopteran pest densities without reducing crop yields to unacceptable levels. We found that the number of insect contaminants per broccoli crown was significantly reduced on plants undersown with strawberry clover and white clover compared to bare-ground broccoli without causing any yield reductions. Additionally, spider densities found on broccoli plants seemed to be influenced by the amount of clover canopy. As the clover canopies expanded and approached the broccoli plants, more spiders were found on the broccoli foliage.

Impact on spider abundance

During the early part of the season, the living mulches may have negatively influenced biological control activity on broccoli plants by serving as a "sink" for spiders. Spiders may have preferred the micro-environment and prey selection within the clovers and thus did not colonize neighboring broccoli plants. Similar observations were made in previous field experiments in which fewer spiders were found on broccoli plants intercropped with peppers or yellow sweetclover, but as the season progressed these differences diminished.

Table 1. Mean number of lepidopterans per broccoli head in four broccoli habitats during summer 2000 (mean ± SE).

Habitat	*Pieris rapae*	*Trichoplusia ni*	*Plutella xylostella*	Total
Bare ground	0.15 + 0.05	0.58 + 0.10	0.13 + 0.05	0.87 + 0.05
Broccoli-SC	0.08 + 0.04	0.10 + 0.04	0.00 + 0.00	0.18 + 0.06
Broccoli-WC	0.05 + 0.03	0.00 + 0.00	0.02 + 0.02	0.07 + 0.03
Broccoli-YSC	0.05 + 0.03	0.12 + 0.05	0.03 + 0.02	0.20 + 0.06
Contrast[1]		*P*-value		
BG vs. LMs	0.03	0.01	0.006	< 0.0001
TCs vs. YSC	0.07	0.54	0.45	0.39
SC vs. WC	0.50	0.62	0.67	0.20

[1]SC (strawberry clover), WC (white clover), YSC (yellow sweetclover), BG (bare ground, broccoli monoculture); LMs (living mulches) includes broccoli-SC, broccoli-WC, and broccoli-YSC; TCs (true clovers) includes broccoli-SC and broccoli-WC.

Conclusion

Using undersown living mulches seems to be promising in reducing lepidopteran pest densities and increasing the activity of spiders in broccoli plantings. In this study, white clover appeared to be more suited for the broccoli system. White clover expands over the soil surface faster than strawberry clover and may therefore be a better weed suppressor. For those farmers looking to create more sustainable cropping practices or practicing organic farming, undersowing may be a valuable addition to their crop production practices.

This field trial showed that it is possible to lower insect pest density while maintaining crop quality and yield. However, insect pest management is only one potential benefit of using leguminous living mulches. Other potential benefits not examined during this study include nematode and weed suppression and enhancement of soil nitrogen. However, before an undersown companion plant is chosen for insect suppression purposes, its impact on other important organisms associated with the crop should be considered.

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Table 2. Mean head size per broccoli plant in four habitats during summer 2000.

	Broccoli parameters[1] (mean ± SE)	
Habitat	Diameter (cm)	Weight (kg)
Bare ground	13.0 + 0.35	0.35 + 0.01
Broccoli-strawberry clover	14.7 + 0.35	0.40 + 0.02
Broccoli-white clover	14.4 + 0.24	0.39 + 0.01
Broccoli-yellow sweetclover	13.7 + 0.28	0.33 + 0.01
Effect[2]	*P* -Values	
Planned contrast		
BG vs. LMs	0.0002	0.11
TCs vs. YSC	0.03	0.0005
SC vs. WC	0.71	0.51

[1]Multiply cm by 0.394 to obtain inches, and multiply kg by 2.2 to obtain pounds.
[2]SC (strawberry clover), WC (white clover), YSC (yellow sweetclover), BG (bare ground, broccoli monoculture); LMs (living mulches) include broccoli-SC, broccoli-WC, and broccoli-YSC; TCs (true clovers) include broccoli-SC and broccoli and broccoli-WC.

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