ARTHROPOD COMMUNITIES IN TEMPERATE AGROFORESTRY: THEORY AND REALITY

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ABSTRACT

Alley cropping holds promise for increasing insect diversity and reducing pest problems by improving natural enemy complexes and adding competition to pest species. Experimental plots of traditionally grown alfalfa and plots of alfalfa intercropped between rows of black walnut trees were sampled with sweep nets prior to each cutting date for the forage. Comparisons were made between treatments. The presence of walnut trees appear to increase diversity and increase beneficial arthropods in alfalfa. Reality may accurately reflect theory for arthropod communities in an agroforestry practice.

Keywords: alley cropping, associational resistance, *Hypera postica, Juglans nigra*, *Medicago sativa*

INTRODUCTION

Interest in temperate agroforestry has increased substantially over the past several years because of its potential as an environmentally positive, sustainable, and potentially profitable set of land use practices. Knowledge of the complex interactions among trees, crops and their associated fauna is necessary to determine the viability of a particular agroforestry practice. While a significant amount of research has been conducted on the ecological interactions among components of tropical agroforestry practices, little information is available on these interactions in the temperate regions of the world (Jose et al. 2004; Thevathasan and Gordon 2004). Agroforestry's effect on insect populations, both pests and beneficials, in temperate alley cropping practices is particularly lacking (Nair 1991; Stamps and Linit 1998; Gillespie et al. 2000). In traditional agroecosystem and forestry management, increasing plant diversity has been suggested as a means to increase insect diversity and thus lower insect herbivore damage because of decreased host plant apparency, increased interspecific competition among pest and non-pest species, and improved natural enemy communities. Compared to polyculture of either annual crops or trees, agroforestry offers an opportunity to contribute substantially to ecosystem diversity, long-term sustainability and profitability.

Insect population theory and studies in polyculture of crops suggest agroforestry can reduce insect damage to crops by increasing the biodiversity of arthropods (Risch et al. 1983; Andow 1991; Tahvanainen and Root 1972; Root 1973). Parasitoid-caused mortality can be important in the regulation of pest populations. If ecological theory holds true, insect herbivory should be lower and associated natural enemy-caused mortality should be higher in agroforestry practices such as alley cropping compared to crops under conventional monocultural management.

Tahvanainen and Root (1972) suggested that multispecies plant associations have a synergistic interaction that reduces damage due to insect herbivores in comparison to damage in single-species plant systems. They called this phenomena "associational resistance." Two hypotheses have been proposed as the mechanism of associational resistance: (1) the resource concentration hypothesis and (2) the enemies hypothesis (Root 1973). The resource concentration hypothesis (Root 1973) suggests that plants are less apparent to insects in a multispecies environment than in a single species environment. The enemies hypothesis predicts that natural enemies will be more abundant in complex versus simple plant systems and their action will result in lower herbivore population densities in multiple species plant systems (Root 1973).

The theoretical underpinnings of diversity leading towards pest reduction are widely accepted in crop polyculture systems, though little research has been conducted in temperate agroforestry systems (Stamps and Linit 1998). Additionally, the difficulty in obtaining meaningful data from previously established agroforestry plots and/or designing proper experiments has limited research on the effects of temperate agroforestry on cropping systems in general (Stamps and Linit 1999). A pilot study (Stamps et al. 2002) indicated that natural enemies were more abundant and herbivorous insects less abundant in an agroforestry system as compared to a traditional cropping system, thus suggesting a positive benefit of agroforestry.

Following the above mentioned pilot study, we have conducted a series of experiments aimed at examining the potential benefits of temperate agroforestry practices, particularly alley cropping forages and nut trees, on insect biodiversity and pest amelioration. One objective in this study was to compare the arthropod community composition found in traditional monoculture alfalfa, *Medicago sativa* L., with that found in alfalfa intercropped with eastern black walnut, *Juglans nigra* L. Another objective was to examine the effects of alley cropping on the natural enemy complex of the alfalfa weevil, *Hypera postica* (Gyllenhal).

METHODS

We established 2.5 ha of alfalfa in 12.2 m wide alleyways among 27-year-old black walnut trees in 2001. A similar sized plot of alfalfa was established in an adjacent open field. Alley cropped and conventional alfalfa plots were divided into 4 replications each (36.5 m x 60 m). The alfalfa was cut at 10% bloom three times during the growing season. At approximately two week intervals, two sweep net samples were taken in each plot, one along the sampling area edge or along the tree line and one in the center of each replication, to determine the relative abundance of pests, beneficials, and other insects. Arthropods were identified to species or morphospecies. Insect abundance was compared statistically between alley cropped and conventionally grown alfalfa. Alfalfa weevil larvae were collected in all of the plots and placed in individual rearing cups. They were supplied with fresh alfalfa stems and leaves, and were allowed to complete their development. Mortality was monitored and the causes of mortality were noted to determine parasitism and disease rates. Two alfalfa samples (1/2 m^2) in each replication were taken prior to each cutting date, and alfalfa quantity and quality measures were determined.

We initiated a second study in 2002, establishing 5 ha of alfalfa in 12.2 and 24.4 m wide alleyways and in an adjacent open field. Black walnut trees were 17 years old in this area. Four replications in each of the three areas (12.2 and 24.4 m wide alleyways and open field) were sampled as in the previous study described above.

Two sampling dates from the spring of 2001 30 days apart were combined for analysis in the first study. Only a single sampling date, 1 June 2003, was analyzed for the second study. All statistical analyses were performed using SAS (SAS Institute, Inc., Cary, NC).

RESULTS AND DISCUSSION

In the first study comparing arthropods between 12.2 m alley cropped alfalfa and monocropped alfalfa, we found a significant difference in the total number of individuals but not the total number of taxa between the treatments (Table 1). There were twice as many herbivores in traditionally grown alfalfa compared to alley cropped alfalfa. While there was not a difference in predator numbers, predators were significantly more diverse and evenly distributed in the alley cropped alfalfa compared to the monocropped alfalfa. This reflects a significance difference seen in an earlier study with alfalfa and smooth bromegrass (Stamps et al. 2002). Both the Shannon index and the evenness index were significantly higher for total arthropods as well as the predator functional group found in alley cropped alfalfa (Table 1).

Table 1. Mean (± SD) number of taxa and individuals and diversity indices for arthropods from two sampling events in alley cropped (12.2 m spacing) and monocropped alfalfa.

	N	Alley cropped alfalfa[a]	Monocropped alfalfa
Number of taxa			
Herbivores	16	6.4 ± 2.3[a]	5.8 ± 2.3[a]
Predators	16	4.4 ± 1.8[a]	5.0 ± 2.8[a]
Parasitic hymenoptera	16	1.5 ± 0.9[a]	1.7 ± 0.9[a]
Other	16	2.1 ± 0.8[a]	1.9 ± 0.8[a]
Total	16	12.9 ± 4.0[a]	12.6 ± 4.7[a]
Number of individuals			
Herbivores	16	136.6 ± 121.7[a]	282.3 ± 221.0[b]
Predators	16	12.9 ± 10.4[a]	13.3 ± 11.1[a]
Parasitic hymenoptera	16	2.9 ± 2.8[a]	4.0 ± 3.2[a]
Other	16	29.1 ± 32.3[a]	18.8 ± 13.7[a]
Total	16	175.4 ± 153.3[a]	314.4 ± 236.1[b]
Diversity Indices			
Shannon herbivores	16	0.8 ± 0.5[a]	0.5 ± 0.2[a]
Evenness herbivores	16	0.4 ± 0.2[a]	0.3 ± 0.1[a]
Shannon predators	16	0.3 ± 0.2[a]	0.2 ± 0.1[b]
Evenness predators	16	0.3 ± 0.2[a]	0.1 ± 0.1[b]
Shannon parasitic hym	16	0.1 ± 0.1[a]	0.1 ± 0.1[a]
Evenness parasitic hym	16	0.1 ± 0.2[a]	0.1 ± 0.1[a]
Shannon total	16	1.4 ± 0.6[a]	0.9 ± 0.4[b]
Evenness total	16	0.5 ± 0.2[a]	0.4 ± 0.1[b]

[a]Means in a row with different superscript letters significantly differ from one another at " = 0.05.

In the second study comparing arthropods among 12.2 m and 24.4 m wide alleyways and monocropped alfalfa, we found significant differences in both taxa and individual numbers of arthropods among treatments. Total taxa, predator taxa and individuals, and parasitic hymenoptera taxa and individuals were significantly greater in both the 12.2 and 24.4 m alleyway alfalfa than in the monocropped alfalfa. Herbivore taxa and individuals did not differ among the treatments (Table 2). Sample sizes were not sufficient to produce other meaningful diversity indices.

Table 2. Mean (± SD) number of taxa and individuals for arthropods in two alley widths of alfalfa and in monocropped alfalfa.

	N	Alley cropped 12.2 m alfalfa[a]	Alley cropped 24.4 m alfalfa	Monocropped alfalfa
Number of taxa				
Herbivores	8	8.0 ± 3.1[a]	7.0 ± 1.4[a]	6.4 ± 1.8[a]
Predators	8	7.9 ± 1.8[a]	7.0 ± 1.9[a]	4.3 ± 1.8[b]
Parasitic hymenoptera	8	3.8 ± 1.5[a]	4.0 ± 1.4[a]	1.6 ± 1.3[b]
Total	8	22.3 ± 3.9[a]	19.8 ± 3.7[a]	15.1 ± 2.9[b]
Number of individuals				
Herbivores	8	45.0 ± 16.4[a]	42.0 ± 8.5[a]	40.3 ± 9.7[a]
Predators	8	10.2 ± 3.5[a]	9.3 ± 1.9[a]	5.8 ± 3.2[b]
Parasitic hymenoptera	8	4.9 ± 2.3[a]	5.4 ± 2.1[a]	1.9 ± 1.7[b]
Total	8	84.1 ± 22.5[a]	84.8 ± 16.3[a]	68.0 ± 18.0[b]

[a]Means in a row with different superscript letters significantly differ from one another at " = 0.05.

In the laboratory rearing study of alfalfa weevil, more weevils survived to adulthood from the monocropped alfalfa than from the alley cropped alfalfa. Though not significant, more larvae from alley cropped alfalfa than from monocropped alfalfa were killed by the parasitoid *Bathyplectes* and the fungus *Zoophthora phytonomi*. Total parasitism (*Bathyplectes* + *Zoophthora* + nematode) was significantly higher in the larvae from alley cropped alfalfa compared to larvae from monocropped alfalfa (Table 3).

Table 3. Alfalfa weevil (*Hypera postica*) mortality factors (%) between alley cropped alfalfa and monocropped alfalfa. A total of 283 larvae were monitored.

Mortality factor	N	Alley cropped alfalfa[a]	Monocropped alfalfa
Healthy adult weevil	4	35 ± 14[a]	42 ± 12[a]
Bathyplectes spp.	4	46 ± 10[a]	37 ± 14[a]
Zoophthora	4	17 ± 5[a]	11 ± 11[a]
Nematode	4	1 ± 2[a]	1 ± 2[a]
Unknown mortality	4	2 ± 2[a]	11 ± 9[a]
Total parasitism[b]	4	64 ± 12[a]	49 ± 9[b]

[a]Means in a row with different superscript letters significantly differ from one another at " = 0.05.
[b]Total parasitism = *Bathyplectes* ± *Zoophthora* ± nematode.

Alfalfa yield was significantly lower in the 12.2 m alleyways compared to the monoculture treatment in the first study. Yield was significantly lower in the narrower 12.2 m alleyways compared to 24.4 m alleyway and monocropped alfalfa in the second study, as well (see McGraw et al. elsewhere in these proceedings for a detailed analysis of alfalfa yield and quality measures among treatments).

Our results support the enemies hypothesis as the mechanism of associational resistance in alley cropped alfalfa. The multispecies complex of alfalfa and walnut trees harbored a greater diversity of arthropods than did the single-species alfalfa fields in both studies, and beneficial insects were in greater abundance in alley cropped alfalfa than in monocropped alfalfa. Our findings do not support the resource concentration hypothesis: the number of herbivore taxa and individuals were equal among the three treatments in the second study. The herbivore numbers were lower in alley cropped alfalfa in the first study, but this finding may be confounded by the poor performance of the alfalfa in the narrower alleyways.

For the data analyzed to date, the walnut trees appear to increase biodiversity, possibly reduce herbivore numbers (in the first study), increase natural enemy diversity and numbers (in both studies), and significantly increase parasitism of alfalfa weevil. The results presented here bode well for pest management in a temperate agroforestry setting, and indicate that reality may accurately reflect theory for arthropod communities in an agroforestry practice.

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