AGROFORESTRY: A PROFITABLE LAND USE

Proceedings of the 12th North American Agroforestry Conference

June 4-9, 2011

Athens, GA

THE ECONOMICS AND ECOLOGY OF ALLEY CROPPING IN THE MID-WESTERN UNITED STATES

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Abstract: Our research involved examining the effects of alley cropping on insect biodiversity, crop yields, and small farm economics. We have investigated two alley cropping practices: a summer crop of alfalfa with black walnut and a winter crop rotation of canola and wheat with heartnut. We compared both practices at two alley widths to conventionally grown crops to determine which arrangement of crop and tree species produced the greatest return while providing the maximum ecological benefits. In the first practice with alfalfa, we found that alfalfa weevil mortality was significantly higher in alley cropped alfalfa compared to monocropped alfalfa, and that arthropod diversity was greater in alley cropped crops compared to conventionally grown crops. Alfalfa yield from wider alleyways was not significantly different from monocropped alfalfa. In the second practice with canola and wheat, alley cropping winter crops provided less competition with trees for water, nutrients and light while providing many of the same benefits found in the alfalfa-walnut system. Wheat yield was greater in monoculture than in wide or narrow alleyways, and greater in wide alleyways than in narrow alleyways the first rotation but not the second. All wheat treatments in both years produced economically significant returns. Canola yields were not significantly different between the alley cropped and monocropped treatments the first rotation. All canola treatments produced significant economic returns. Insect numbers in canola followed a similar pattern as those found in the alfalfa walnut practice, with more predators and greater diversity in the alley crops compared to the conventional crops. Our data suggest growing winter crops with nut trees can be a viable agronomic practice that provides ecological benefits as well.

Keywords: biodiversity, alfalfa, canola, wheat, insects

INTRODUCTION

The potential economic and ecological benefits of an agroforestry practice such as alley cropping are numerous. Alley cropping has the potential to diversify and stabilize income streams over short- and long-term time frames as well as increase biodiversity and reduce pest populations (Peng et al., 1993; Stamps et al 2002; Thevathasan and Gordon, 2004).

The basis for both improved economics and ecology lies in the diversification of plant material over that of traditional monoculture. Income from a yearly crop in combination with long-term returns from the trees can provide a profitable, stable income stream. Potential ecological benefits can be derived from the theories developed from crop polyculture studies (Baliddawa, 1985). Several mechanisms have been proposed for reduced herbivory by pest insects in diverse systems: (1) decreased host plant apparency; (2) increased interspecific competition among pest and non-pest species; and (3) improved natural enemy communities (Root, 1973; Risch et al., 1983; Baliddawa, 1985; Andow, 1991). Trees grown in association with agricultural crops have the potential to increase parasitization of some important agricultural insect pests. Middleton (2001) found a significant increase in the number of parasitoids and a significant increase in the ratio of parasitoids to herbivores in an alley crop compared to a monocrop.

One difficulty in designing an appropriate and profitable alley cropping practice is pairing compatible trees and crops. Numerous factors come into play, including competition between trees and crops for water, light, and nutrients, allelopathy, and practical management questions such as use and timing of equipment for crop and nut harvests.

Highly profitable crops such as alfalfa are summer, sun-loving crops, while wheat and canola, as grown in the Midwest, are considered "winter" crops, grown in the fall and spring. Alfalfa is one of the few crops grown in every state, and there is an interest in growing alfalfa in an alley crop configuration (Barnes and Sheaffer, 1995). However, little information is available on how alfalfa responds to shade environments that exist under trees (Lin et al., 1999), or how alfalfa pests respond to alley cropped alfalfa. A similar situation exists for wheat and canola; there is interest in alley cropping these crops but little is known about their response to the practice. We compared summer and winter crops because trees may present less competition to winter crops with reduced overlap of growing periods.

In a number of studies, we have examined both the ecology and economics of alfalfa, wheat and canola alley cropping. Our objectives were: (1) to determine the effect of nut alley cropping at wide and narrow alley spacings on field grown alfalfa, wheat and canola yield and quality; (2) to compare biodiversity and natural enemy communities between alley cropped and conventional crops; and (3) to evaluate and compare the economics of conventional monocrop practices with monocrop practices.

METHODS AND MATERIALS

Experiments were carried out at two sites, Hammonds Products near Stockton, MO (South East MO), and Shepherd Farms, Clifton Hill, MO (North Central MO). The Stockton site was black walnut at two alley widths (12.2 and 24.4 m) and intercropped with alfalfa and the Clifton Hill site was heartnuts intercropped with a rotation of wheat and canola at the same alley widths. Both sites had adjacent monoculture fields for controls.

Arthropods were sampled throughout the growing seasons of the crops with sweep netting every 10-14 days and, in the heartnuts, ground dwelling arthropods were sampled with pitfall traps in addition to sweep netting. Arthropods were sorted and identified in the laboratory to species or morphospecies. Yield quality and quantity was determined by sampling 1 m^2 plots within the dripline of the trees and near the center of plots and appropriate metrics were determined for each crop type. Financial models were used to estimate the economic viability of alley cropping. Readily available alfalfa, canola and wheat budgets were used to determine the financials of the crops.

RESULTS

Alfalfa yield in general did not differ significantly between the monoculture and the 24 m wide alleyways although there was a linear decrease in yield from the center of the alleyway towards the tree lines (Table 1). Alfalfa yield from 12 m wide alleyways was significantly less than from the wider alleyways and the monoculture field. Wheat yield over two years did not differ significantly among wide alleyways, narrow alleyways or conventional monoculture (Table 2). Canola yield the first year did not differ significantly among the three treatments (Table 3).

Table 1. Economics of alfalfa in an alley cropping practice; establishment and production in Southern Missouri by Brees and Carpenter (2006).

		T/acre	Costs/acre	Returns/acre[1]	Profit/(loss)
	Monoculture	3.9	$302	$390	$88
Establishment	24 m alley	3.0	$293	$300	$7
	12 m alley	2.0	$282	$200	($82)
	Monoculture	4.1	$260	$410	$150
Production	24 m alley	2.9	$254	$280	$26
	12 m alley	1.9	$250	$190	($60)

[1]alfalfa price calculated at an average $100/ton or $3 per 60 lb bale.

Table 2. Economics of wheat in an alley cropping practice; based on the enterprise budget by FAPRI, University of Missouri.

		bu/acre	Costs/acre	Returns/acre[1]	Profit/(loss)
2006	Monoculture	64.4	$208	$386	$178
	24 m alley	57.3	$196	$344	$148
	12 m alley	47.6	$186	$286	$100
2008	Monoculture	50.0	$208	$300	$92
	24 m alley	48.6	$196	$292	$96
	12 m alley	46.3	$186	$278	$92

[1]wheat calculated at an average $6/bushel.

Table 3. Economics of canola in 2007 in an alley cropping practice; based on the cost-return budget by the Jefferson Institute, Columbia, MO, and the Kansas State University Canola Farm Management Guide.

		lbs/acre	Costs/acre	Returns/acre[1]	Profit/(loss)
Jefferson Institute (birdseed)	Monoculture	1515	$119	$182	$63
	24 m alley	1476	$114	$177	$63
	12 m alley	1493	$109	$179	$70
K-State	Monoculture	1515	$191	$220	$59
	24 m alley	1476	$179	$214	$65
	12 m alley	1493	$168	$217	$79

[1]canola seed calculated at an average at $0.12/lb for birdseed (Jefferson Institute) and $14.50/cwt ($0.145/lb, K-State).

The economics of alfalfa in alley cropping indicates narrow alleyways would not be profitable and that wider alleyways would result in close to a break-even scenario (Table 1). Economic analysis of the wheat data indicated that growing wheat would be profitable enterprise in either narrow or wide alleyways (Table 2). Economic analysis of the canola indicated canola would be a profitable crop in either width alleyway (Table 3), similar to the wheat scenario.

Insect diversity was twice as great in alley cropped alfalfa than in monocropped alfalfa, and there were a greater number and variety of predators and parasites in both alley cropped alfalfa treatments compared to monocropped alfalfa (Table 4). There were no differences in numbers of taxa or individual arthropods for any category between 12 M and 24 M alleyways. Predator numbers and parasitic hymenoptera numbers were significantly higher in both the 12 and 24 m alleyways compared to the monoculture alfalfa on most sampling dates over all three years of the study. Data analysis of the pitfall data in the canola/wheat alley cropping practice confirm the findings in the alfalfa practice; there were more individuals, more species, and more predators in both ally cropping practices (narrow and wide alleyways) compared to the conventional monocrop, and there were no differences in arthropod populations between the wide and narrow alleyways (Table 5). Significantly more carabid beetles were found in the alley cropped winter crops compared to the monoculture crops.

Table 4. Species richness in alley cropped and monoculture alfalfa. Means in a row with different letters are significantly different from one another at $\alpha = 0.05$.

	Area		
Variable	Open	12 M	24 M
# Species	15.0 a	22.3 b	18.9 b
# Individuals	63.8 a	84.1 b	83.9 b
# Predator taxa	3.8 a	7.9 b	6.7 b
# Herbivore taxa	6.5 a	8.0 a	6.8 a
# Hymenoptera taxa	1.5 a	3.8 b	3.6 b
Total predators	4.8 a	10.2 b	9.1 b
Total herbivores	37.8 a	45.0 a	42.7 a
Total Hymenoptera	1.5 a	4.9 b	4.9 b

Table 5. Species richness in alley cropped and monoculture wheat. Means in a row with different letters are significantly different from one another at $\alpha = 0.05$.

	Area		
Variable	Open	12 M	24 M
# Species	6.7 a	8.9 a	8.3 a
# Individuals	10.2 a	16.4 b	16.8 b
# Predator taxa	3.0 a	4.0 a	4.2 a
# Herbivore taxa	1.2 a	1.1 a	1.0 a
# Hymenoptera taxa	0.2 a	0.3 a	0.3 a

DISCUSSION

Growing alfalfa in alleyways reduced overall yields compared to monoculture, although yields from wide alleyways and monoculture were similar at the first harvest date of each year. Narrow alleyways significantly reduced yield over the other treatments possibly because of competition for light or water. Consequently, the profitability of growing alfalfa as an alley crop with mature black walnut trees is reduced. On the other hand, the wheat and canola rotation produced significant yields that were profitable, though the first year yields and profits from alley cropped wheat was not as high as that of monoculture wheat. Canola profits were comparable among treatments, indicating growing canola in alley ways could be a viable production practice along with wheat.

Pairing crops and trees that are phenologically separate in an alley cropping practice appears to provide yields and profits comparable to monoculture, especially when adding the value to the tree crop.

Alley cropping improves arthropod diversity over traditional monoculture for both summer and winter crops. There were more species and individuals in both alley widths of alfalfa compared to the monoculture. Also, arthropod numbers were not significantly different between the narrow and wide alleyways, indicating that the benefits of alley cropping translate to wider widths and are not diluted with distance. Arthropod numbers and species richness was also greater in alley cropped wheat than in monoculture, paralleling the results of the alfalfa alley-cropping.

Parasitic hymenoptera and predators in general were more numerous and speciose in the alleys in walnut-alfalfa alley cropping over monoculture, and there was a tendency toward more ground dwelling predators in heartnut-wheat alley cropping over monoculture, as well. This indicates that the practice of alley cropping bestows a benefit to the arthropod community regardless of the composition of the crop/tree species combination. The two study sites were in widely different parts of the state, with differing soil types, elevations, weather patterns, crop compositions, and tree species and age, yet, the resulting benefits of an alley crop over monoculture in terms of the arthropod communities were strikingly similar between sites.

Our results indicate a common positive response by arthropods to the practice of alley cropping and not a response predicated on the individual plant components or design, suggesting alley cropping as a practice could be promoted as an environmentally sound practice regardless of site-specific considerations. Also, the combination of winter crops and trees appears to be a profitable enterprise above and beyond the positive environmental benefits.

ACKNOWLEDGEMENTS

This research was supported by the Missouri Agricultural Experiment Station, the Center for Agroforestry at the University of Missouri, and USDA-ARS Cooperative Agreement 58-6227-0-049. The results presented are the sole responsibility of the P.I. and/or MU and may not represent the policies or positions of the ARS or the USDA.

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