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The ecology and economics of insect pest management in nut tree alley cropping systems in the Midwestern United States

W.T. Stamps [a,*], R.L. McGraw [a], L. Godsey [b], T.L. Woods [a]

[a] Division of Plant Sciences, University of Missouri, Columbia, MO 65211, USA
[b] Center for Agroforestry, University of Missouri, Columbia, MO 65211, USA

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ABSTRACT

The potential ecological benefits of an alternative agronomic practice such as alley cropping are numerous, but the practice is unlikely to be adopted unless it is economically viable. We investigated insect pest dynamics, crop yields, and small farm economics in an alley cropping practice of alfalfa and black walnut compared to conventionally grown alfalfa. We examined the mortality factors affecting alfalfa weevil, *Hypera postica* (Gyllenhal), under normal monocultural alfalfa management and under an agroforestry practice of intercropping alfalfa with black walnut trees at two alley widths, 12.2 and 24.4 m. Alfalfa yields were determined for three harvest cycles over 2 years in the same system. Black walnut and alfalfa financial models were used to determine the economic viability of alfalfa-black walnut alley cropping based on yield results. We found that alfalfa weevil mortality was significantly higher for two of the four sampling dates in alley cropped alfalfa compared to monocropped alfalfa. Alfalfa yield from wider alleyways was not significantly different from monocropped alfalfa for the first harvest date, but lower thereafter, while yield from narrower alleyways was significantly lower than both wider alleyways and monocropped alfalfa. Financial models indicated alley cropping alfalfa at wider alley widths provided positive cash flow. Our results suggest alley cropping alfalfa with black walnut provides both ecological and economic benefits.

1. Introduction

The potential ecological benefits of an agroforestry practice such as alley cropping are numerous. Alley cropping may increase biodiversity (Peng et al., 1993; Stamps et al., 2002; Thevathasan and Gordon, 2004), reduce runoff contamination (Nair and Graetz, 2004), and improve carbon sequestration (Montagnini and Nair, 2004), but if it is not economically viable, growers will not adopt the practice.

The potential for positive ecological outcomes from alley cropping arises from theories found in agricultural polyculture. Many of the potential benefits of agroforestry are derived from increased diversity compared to traditional agricultural management practices (Stamps and Linit, 1998). Increasing plant diversity through polyculture has been explored as a means to increase insect diversity and lower insect herbivore damage (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). Stamps et al. (2002) found alley cropped forages (alfalfa, *Medicago sativa*, and smooth bromegrass, *Bromis inermis*) harbored a more even and diverse fauna than adjacent monocrops. Peng et al. (1993) found greater diversity of airborne arthropods in an alley cropping system of furniture trees and pea, *Pisum sativum* L cv. Soloara, than in pea alone.

Insect natural enemies can regulate the population densities of many leaf-feeding insects. Agroecosystems can be modified to enhance the impact of beneficial insects, particularly parasitoids, as suggested by the natural enemies hypothesis (Root, 1973). Enhancements may include an increase in sources of adult parasitoid food (e.g., flowers or aphid honeydew), resting sites and places for mating (Altieri, 1992; Murphy et al., 1996; Idris and Grafius, 1995; Dyer and Landis, 1996). 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.

* Corresponding author. Tel.: +1 573 882 0193; fax: +1 573 882 1469.
E-mail address: stampst@missouri.edu (W.T. Stamps).

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Regardless of the real and potential ecological benefits of agroforestry, economics will always be the driving force behind acceptance of an agroforestry practice. Alley cropping has the potential to diversify and stabilize income streams over short- and long-term time frames. Growing hardwood trees, especially for timber, is inherently a long-term enterprise with highly variable economic yearly returns. The presence of a yearly crop could potentially provide an alternative income stream, provided the crop is compatible with alley cropping.

Alfalfa is the most important and popular forage grown in the United States and can be readily sold as a hay crop. It 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.

Alfalfa weevil, one of the major pests of alfalfa in the Midwest USA, is subject to a number of parasitoids and diseases, primarily *Bathyplectes* species Ichneumonid wasps and the fungal pathogen *Zoophthora phytonomi* (Arthur) (Brunson and Coles, 1968; Bryan et al., 1993; Los and Allen, 1982). While cultural practices such as the manipulation of harvest time can be effective in controlling the alfalfa weevil, both the parasites and the fungus also can be effective agents in keeping the weevil population below economic thresholds. Cultural practices such as alley cropping may enhance the effectiveness of these agents.

In this study, we examined numerous aspects of alley cropping. Our objectives were: (1) to determine the effect of black walnut alley cropping at wide and narrow alley spacings on field grown alfalfa forage yield and quality; (2) to examine alfalfa weevil and its natural enemies in forage grown in an alley cropped system and in a traditional monoculture system; and (3) to evaluate and compare the economics of conventional monocrop practices with alley crop practices.

2. Methods and materials

2.1. Study area

We established 2.5 ha of alfalfa variety WL 322GZ in 12.2 and 24.4 m wide alleyways among 17-year-old black walnut trees in August 2002 at the Hammons Products Sho-Neff Black Walnut Plantation (37°50′ N, 93°50′ W) near Stockton, MO, USA. The walnut trees were planted as seedlings of unknown wild-stock origin (from the Missouri Department of Conservation State Nursery, Licking, MO, USA) in 1985. Tree spacing was originally 3 m between trees within rows with 12.2 m alleyways between rows. We measured the height of the black walnut trees with a Haga altimeter (Haga GmbH & Co. KG, Nurnberg, Germany) and the tree height averaged 9.5 m. Diameter at breast height was measured on two trees per plot and averaged 22 cm. The trees had been active nut producers for several years.

A 2.5 ha plot of alfalfa without trees was established in a field immediately adjacent to the tree area. The soil in the alley crop area and the open area was a Cliquot-Bolivar complex (fine-loamy, mixed, active, thermic Ultic Hapludalf) with a pH of 6.1 and both areas had been managed in the same way since the establishment of the walnut trees. Alfalfa variety WL 322GZ was seeded at 22.5 kg ha^{-1} in the alleyways and in the open field in August of 2002. Alfalfa had not been grown in the area prior to our planting.

2.2. Alfalfa weevil sampling

Alley cropped and conventional alfalfa plots were divided into four replications each. Alleyways were an alternating series of 12.2 and 24.4 m alleyways with the alley cropped alfalfa plots buffered on each side by 2 additional alley cropped rows of alfalfa. Each replication within a 500 m long alleyway was approximately 100 m long and the width of the alleyway, either 12.2 or 24.4 m for the narrow and wide alleyways, respectively. The replications in the open field were 12.2 m $\times$ 100 m. The replications in each of the three areas were sweep sampled twice for alfalfa weevil larvae prior to the first cutting, ca. 2 weeks apart, over 2 years. Each sweep sample consisted of 20 standard sweeps randomly diagonal across each replication. Thirty randomly selected larvae per replication were placed individually in rearing cups at room temperature (21 ± 5 °C) and were supplied with fresh weevil-free alfalfa bouquets every 2–3 days to complete their development. The alfalfa bouquets were harvested from alfalfa weevil-free fields to minimize the inadvertent introduction of mortality agents post-weevil collection. The bouquets were not treated with a fungicide, but the fungal infection rate of the weevils in the laboratory closed matched field observations, indicating any fungal infections originated with the weevils themselves, not the subsequent provided alfalfa.

Each treatment was represented by 120 larvae (4 replications, 30 larvae per replication) on each collection date. Collection dates were 30 March 2004, 15 April 2004, 4 April 2005, and 18 April 2005. Collection dates were timed to correspond to peak activity by mortality agents. Sampling at earlier dates could have under-estimated *Bathyplectes anurus* (Thompson) parasitism because the wasp attacks later instars of the alfalfa weevil larvae.

Mortality was monitored and the causes of mortality were noted to determine parasitism and disease rates. The appearance of small oblong cocoons with a white band around the middle indicated parasitism by *Bathyplectes curculionis* (Thomson) or *B. anurus* (Brunson and Coles, 1968; Bryan et al., 1993). We did not differentiate the wasp species, but the dominant species (90+%) in the area at the time was *B. anurus* (B. Puttler, pers. comm.).

Fungal *Z. phytonomi* infection was determined by visual confirmation under a microscope of live conidia or resting spores (Los and Allen, 1982; B. Puttler, pers. comm.) and nematode presence was determined by dissection. Voucher specimens of the weevils and parasitoids are stored at the Forest Insects Lab on the campus of the University of Missouri.

2.3. Alfalfa yield sampling

The alfalfa was cut at 10% bloom three times during the growing season. We determined alfalfa yield from samples collected immediately prior to cutting. Alfalfa samples were cut from two 1.0-m^2 areas within each plot, one at the dripline and one in the center of each plot, on 21 May, 24 June, and 7 August in 2003 and 19 May, 23 June and 22 July in 2004. We dried the alfalfa samples in a forced-air oven at 55 °C for 48 h and weighed them to determine dry matter yield.

Data were analyzed with SAS PROC MIXED tests (SAS Institute, 2001). The random effect in the MIXED procedure was replication within year. The appropriate interactions and treatments were compared with least squares means.

2.4. Financial models

Financial models were used to estimate the economic viability of alley cropping. We used the Black Walnut Financial Model Ver. 2.0 from the University of Missouri Center for Agroforestry web site to calculate the financials for the black walnut part of the plantation (Godsey, 2007). We used the alfalfa budgets found in the Farm Business Management Guide FBM 3101 for alfalfa establishment and production in Southern Missouri to determine the alfalfa financials (Brees and Carpenter, 2006). All values in the