AN EVALUATION OF SUMMER COVER CROPS FOR AGROECOSYSTEM SERVICES IN SMALL GRAIN SYSTEMS

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ABSTRACT

Cover cropping has been gaining popularity in recent years, specifically for its ability to improve soil properties and suppress weeds. However, cover crop species differ in the agroecosystem services they provide. Our objective was to evaluate a variety of summer cover crop treatments and their ability to provide soil physical protection, increased yield and quality of subsequent small grains, nitrogen input reduction, and weed suppression. Six summer cover treatments were evaluated for these services in summer 2022 between wheat and barley crops on a silt loam soil in Loretto, Kentucky. The treatments included four cover crops (forage soybean (*Glycine max*), daikon radish (*Raphanus sativus* var. Longipinnatus), pearl millet (*Pennisetum glaucum*), and a mixture of forage soybean, daikon radish, and pearl millet) and two controls (weedy fallow and cash crop soybean (*Glycine max*)). Ground cover was measured in August 2022 while cover crop and weed aboveground biomass were collected just before termination in September. Pearl millet provided the greatest ground cover, aboveground biomass production, and weed suppression, with the mixture following directly behind. The cash soybean treatment provided the greatest soil inorganic N, while the pearl millet provided the lowest, and these differences corresponded with differences in small grain yield. Cover crop treatment did not have an effect on protein content of subsequent small grains. Our results suggest that pearl millet is a highly productive summer cover crop in Kentucky that is effective at soil protection and weed suppression but may have detrimental effects on small grain yields after short-term adoption.

INTRODUCTION

Cover crops are a key component of sustainable agriculture and have been gaining popularity in recent years for their ability to improve soil properties and suppress weeds (Wallander et al. 2021). In Kentucky, after wheat or barley harvest in late spring, land may be planted to double crop soybeans (*Glycine max*), planted to summer cover crops, or left fallow. Summer cover crops fit well between small grains crops in Kentucky, but the performance and benefits of different species are not well understood. They have the potential to lessen soil erosion, restore soil health and fertility, and may provide a high-quality forage for livestock. Previous research shows that summer cover crops have high biomass potential and therefore can be effective at building soil organic matter and can provide reduced fertilizer requirements, when leguminous cover crops are utilized (Mclelland et al. 2020 and Mahama et al. 2020). Different functional groups (e.g., grasses, legumes, and brassicas) can provide specific benefits, but mixtures may merge these benefits from individual species. Mixtures also may be more productive than monocultures due to complementary resource uptake patterns (Snapp et al. 2004).

The objective of this study was to provide new information about how cover crops grown in the summer may benefit a small grains system. We evaluated the agroecosystem services of summer cover crop monocultures and a mixture using several indicators (Table 1).

Table 1. Measurements used as indicators of the agroecosystem services assessed

Agroecosystem Service	Indicator
Soil Physical Protection	Canopy Cover
Weed Suppression	Proportional Biomass of Weeds
N Scavenging	Soil Inorganic N
Residue Persistence and N Release Potential	Cover Crop N% and Lignin%
Performance of Small Grains	Yield and Grain Protein

MATERIALS AND METHODS

The study site, established in summer 2022, is located in Loretto, KY on a floodplain soil with a silt loam surface texture. The study was conducted as a split-split plot randomized complete block design with summer cover crop as the main plot, small grain variety as the split plot, and nitrogen rate as the split-split plot. There are 4 replicates followed by wheat and 4 replicates followed by barley. The main plot treatments included four cover crops (forage soybean (*Glycine max*), daikon radish (*Raphanus sativus* var. Longipinnatus), pearl millet (*Pennisetum glaucum*), and a mixture of forage soybean, daikon radish, and pearl millet) and two controls (weedy fallow and cash crop soybean (*Glycine max*)). Soybean treatments were planted at seeding rates of 50lb/acre, daikon radish at 12lb/acre, pearl millet at 10lb/acre, and the mix planted at 1/3 of the seeding rate of the monocultures. Cover crops were planted mid-July 2022 and terminated mid-September. All treatments were mowed with the residue left in place, aside from the cash soybean treatment, which was mowed and bagged to imitate harvest as a forage. The three wheat varieties were Pembroke 2021, Pembroke 2014, and Truman, while the three barley varieties were Avalon, Calypso, and Flavia. Small grains were planted in late October 2022 with herbicide (2-4D, sharpen, and roundup) sprayed mid-September to control for weeds. The two N fertilizer levels were 35 and 70 lb N $acre^{-1}$, which were hand-broadcast mid-March 2023.

Summer canopy cover was measured in August, 22 days after emergence. Two photos of each plot were taken, uploaded into Canopeo, analyzed, and then averaged together (Patrignani and Ochsner 2015). Cover crop biomass was sampled mid-September with two $0.25m^2$ samples collected from each plot. The samples were separated by species (weeds all together) before drying. Each sample was dried at 65°C until a constant weight was achieved. Cover crop weighted averages of % nitrogen and lignin were calculated for each treatment based on the biomass proportion and nitrogen or lignin concentration of each species. Lignin and protein concentrations were determined using Near Infrared Spectroscopy, and protein was converted to nitrogen concentration assuming a conversion factor of 6.25 x N = protein. Soil sampling occurred in early November with main plots being sampled with 8-10 cores at 0-15cm. The samples were then analyzed for inorganic nitrogen using the 1M KCl extraction method for mineral soils and a colorimetric microplate analysis method (Crutchfield and Grove 2011).

The small grains were harvested with a research plot combine mid-June. The average protein and starch content was then calculated for each treatment from Near Infrared Spectroscopy results.

Statistical analyses were made using R version 4.4.1.(R Core Team 2021). Analysis of variance was used to determine statistically significant differences (p<0.05 significance level) and mixed effect models were performed using lmer package (Kuznetsova et al. 2017). Figures shown below were made with the ggplot2 package (Wickhan 2016).

RESULTS AND DISCUSSION

Cover Crops

Three weeks after planting, all treatments provided 80-90% canopy cover indicating that all treatments provided similar soil physical protection (data not shown). The cover crops produced between 1889 and 7260 lbs dry matter per acre. Cover crop biomass production and weed suppression was greater in pearl millet and the mix compared with the other treatments (Figure 1). Even in the mix treatment, pearl millet was the most competitive. In a Kentucky field with high summer weed pressure, pearl millet, in a monoculture or as the primary constituent of a mix, was the only cover crop species to provide a distinct advantage over weedy fallow in terms of biomass production.

The cash soybean treatment provided the greatest inorganic N following cover crop growth, which was 14.98 mg/kg in the top 30 cm, while pearl millet provided the least (8.19 mg/kg) (Figure 2). The mix and pearl millet had relatively low lignin and N concentrations compared to the other summer covers (Figure 3). The low N concentration may indicate slower decomposition during early stages, but the low lignin concentration may favor faster decomposition in later stages. Although the mix was not superior to all the monocultures based on measured parameters, it was more productive than the cash soybean, forage soybean, and daikon radish treatments, and as productive as pearl millet, the most productive monoculture.

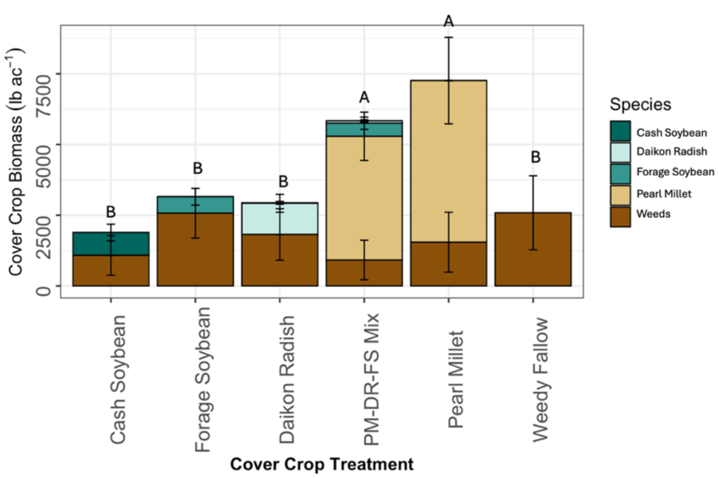

Figure 1. Aboveground biomass production and composition of cover crop treatments. Error bars are ± one standard deviation.

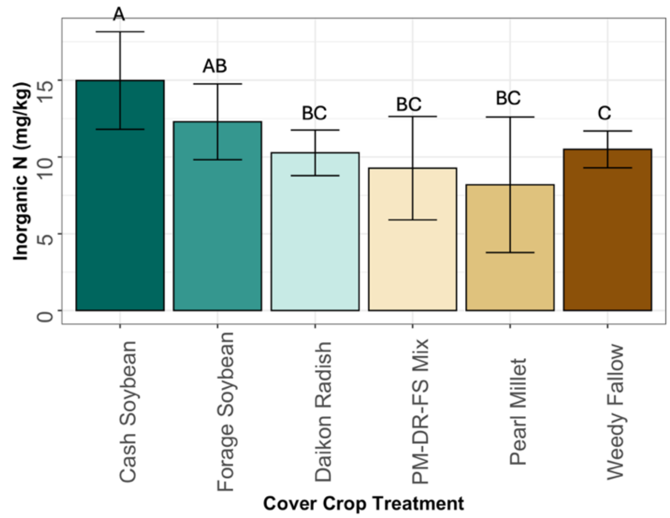

Figure 2. Inorganic N of soil (0-30cm) after cover crop termination. Error bars are ± one standard deviation.

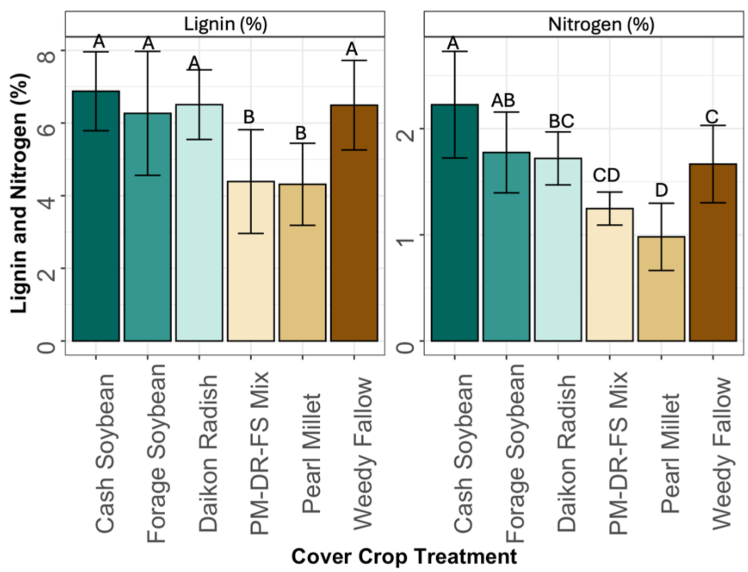

Figure 3. Lignin (left) and nitrogen (right) concentrations of cover crop treatments from NIRS results. Error bars are ± one standard deviation.

Small Grain Quality and Quantity

Wheat yield averaged 65.7 bu/acre across treatments and was higher in the cash soybean treatment than in the mixture and pearl millet treatments (Figure 4, left). Barley yield averaged 78.5 bu/acre across treatments and was higher in the cash soybean treatment than the pearl millet and weedy fallow treatments (Figure 4, right). There was a nitrogen rate effect across all cover crop species with the 70 lb/acre rate having higher yields in both wheat and barley. Protein content averaged 8.51 and 10.33% for wheat and barley, respectively, and did not differ among cover crop treatments (data not shown).

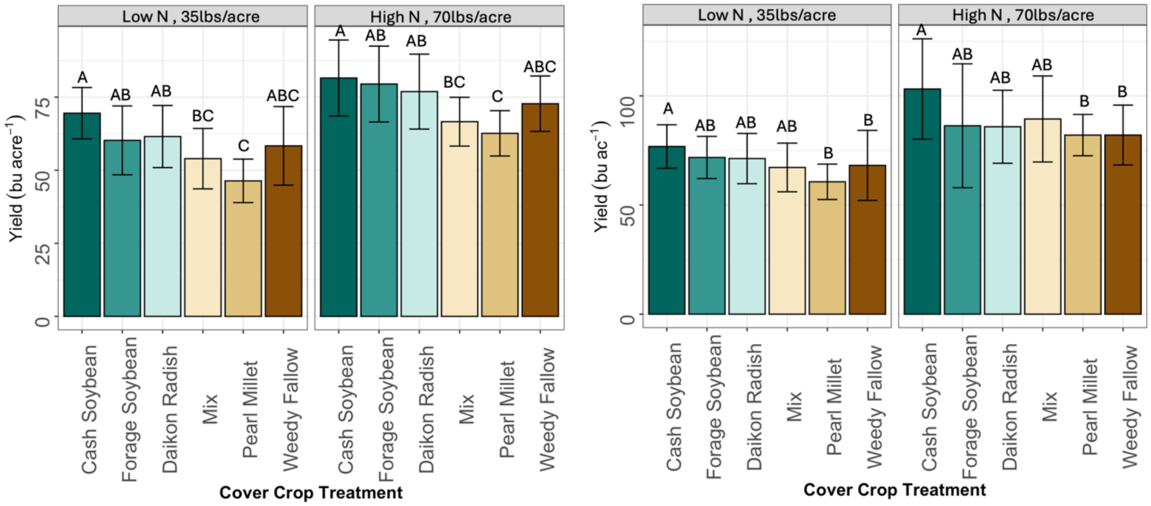

Figure 4. Wheat yield (left) in bu/acre by each cover crop treatment with a low N rate of 35 lb/acre (left) and high N rate of 70 lb/acre (right) applied to the small grains. Barley yield (right) in bu/acre by each cover crop treatment with a low N rate of 35 lb/acre (left) and high N rate of 70 lb/acre (right) applied to the small grains. All values were adjusted to a standard 13.5% moisture. Error bars are ± one standard deviation. Different uppercase letters indicate significant differences among cover crops within each cash crop and N rate level.

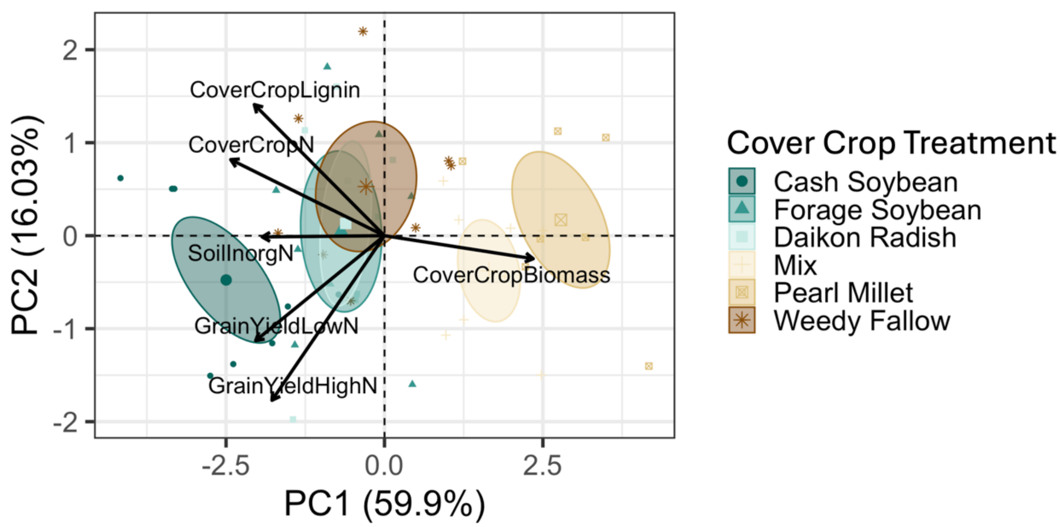

Figure 5. PCA Biplot showing measured cover crop parameters and yield of small grains.

The first two components of the PCA explained 60% and 16% of variation, respectively. PC1 primarily reflected a tradeoff between cover crop biomass production and soil inorganic N measured in the fall. The soil inorganic N concentration was also positively correlated with the N concentration and lignin concentration of cover crops as well as small grain yields. The cover crop treatments were oriented primarily along PC1, with the mix and pearl millet associated with higher cover crop biomass and the soybean treatments associated with lower cover crop biomass but higher available N and small grain yields (Figure 5). In summary, the trade-off between cover crop biomass production and nitrogen availability to small grains suggests that optimizing buildup of soil organic matter via high biomass cover crops may involve a yield depression or additional N fertilizer inputs for the cash crops.

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