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Evaluation of Cover-Crop Mixes for Agronomic Performance and Forage Quality under Mississippi Conditions

R. Lemus and J. A. White

Abstract

A variety of species and mixes can be used for cover crops based on multiple goals in the South. The objective of this demonstration was to quantify forage biomass production of different cover crop mixes along with their nutritive value, nutrient removal potential, and postharvest soil nutrient cycling. The demonstration was conducted from fall 2015 to spring 2016 at the H. H. Leveck Animal Research Farm on the campus of Mississippi State University in a Marietta fine sandy loam soil. Four cover crop mixes were planted on October 6, 2015, in unreplicated strips. Soil samples were collected before establishment and 2 months after the crop residue was incorporated into the soil. Precipitation was 7 inches above normal for the period of the study, and average high temperatures were 3.4°F above normal. Soil test nutrients increased for K, Ca, and Mg compared with the baseline soil sample collected at establishment. There was also an increase in OM and CEC but a decrease in soil-test P postharvest. Biomass production for the cover crop mixes was significantly different ($P<0.0409$). Nutrient removal differences in the biomass for P, K, Ca, and Mg were observed among cover-crop mixes. Forage quality for all parameters (CP, ADF, NDF, FAT, IVTDMD, and LIG) were significantly different among cover-crop mixes. Long-term studies with cover-crop mixes are needed to pair planting date with harvest, along with the right management practices and adaptability to optimize benefits.

Abbreviations: CCM = cover crop mix; N = nitrogen; K = potassium; P = phosphorous; Ca = calcium; Mg = magnesium; OM = organic matter; CEC = cation exchange capacity; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; IVTDMD = in vitro dry matter digestibility; LIG = lignin; CV = coefficient of variation; LSD = least significant difference.

Key words: cover crops, nutrient removal, forage quality, forage yield.

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Introduction

In the last decade, there has been an increased interest in cover crops for soil benefits and the ability to provide other ecosystem services (i.e., erosion control, forage crop, water filter, etc.) (Clark 2012). It is important to note that the benefits of cover-crop management might take several years or decades to develop, depending on crop-management practices and the goal of the farm enterprise. In forage systems, producers use cover crops for grazing as a way to increase animal performance and recover the production costs associated with the establishment of cover-crop systems. Forage systems can also serve as conduits for cover-crop management, but grazing management and intensity can have major impacts on biomass cover, crop residue (a function of forage growth, senescence, removal, and decomposition), root production, and soil physical characteristics (Mapfumo et al. 2002).

A variety of species and mixes can be used for cover crops based on multiple goals in the Southeast. A partial list of adapted species includes brassicas (*Brassicaceae sp.*), annual ryegrass (*Lolium multiflorum*), the small grains [wheat (*Triticum aestivum*), triticale (*Secale* × *Triticum*), cereal rye (*Secale cereale*), and oat (*Avena sativa*)], annual legumes [arrowleaf (*Trifolium vesiculsum*), ball (*T. nigrescens*), berseem (*T. alexandrium*), crimson clovers (*T. incarnatum*), and hairy vetch (*Vicia villosa*)], and perennial legumes [white (*T. repens*) and red (*T. pretense*) clover].

Unger and Vigil (1998) indicated that cover crops are better suited for the humid and subhumid regions of the U.S. where precipitation might have better distribution during the growing season. They also indicated that the performance of cover-crop systems will depend on species selection for the mix, planting date, species compatibility to compete with one another, N uptake mechanisms, etc.

In a 2-year study with 18 treatments of multispecies cover-crop mixes, Finley et al. (2016) indicated that increasing the number of species in the stand increased biomass, but no biomass increase was observed when mixing cover-crop species that were complementary in phenology or N uptake. They also indicated that the increasing crop biomass was positively correlated with weed suppression, decreasing N leaching, and increasing biomass N accumulation.

A 6-year study by Lawason et al. (2015) looked at the performance of cereal rye and hairy vetch when comparing cover-crop seeding mixtures, planting dates, and termination dates as monocultures or mixtures. They indicated that delaying planting by 2.5 weeks reduced winter cover by 65%, biomass by 50%, and biomass N accumulation by 40%. They also indicated that terminating the study in April instead of March yielded reductions in biomass and N accumulation similar to those observed by delaying planting.

Annual cover crops can be utilized as part of a grazing system in which they can enhance soil benefits if they are managed correctly. This means taking precautions to reduce compaction and erosion, as well as ensuring that adequate residue is left behind to encourage nutrient cycling. It is important to note that some forage species might be more hardy and productive during the winter, while other species might achieve the most growth starting in the spring.

Grasses such as annual ryegrass and small grains such as wheat, oats, and cereal rye are very active during Mississippi's mild winters, while some clovers might have more growth in the spring and early summer. Legumes are slow growers and expensive to establish, but they have the added benefit of fixing atmospheric nitrogen as well as increasing forage nutritive value when compared with grasses (Snapp et al. 2005).

Kuo and Jellum (2002) indicated that total soil N accumulation was greatest under vetch followed by binary mixtures (vetch with cereal rye or annual ryegrass) and lowest for grass monocultures of cereal rye or annual ryegrass. Dean and Weil (2009) indicated that rape and cereal rye decreased soil NO_3–N in fall and spring throughout the sampled profile (0- to 70-inch depth). Snapp et al. (2005) indicated that cereal cover crops produce the largest amount of biomass and should be considered when the goal is to rapidly build soil organic matter. They also indicated that legume/cereal or brassica/cereal mixtures might be better suited over a wide range of environmental niches.

Cover crops can be used in forage systems because they can provide species diversity, reduce erosion, build organic matter, fix N, improve nutrient cycling, adjust C:N ratios, and provide better livestock integration by filling the production and nutritional quality gaps (Delgado and Gantzer 2015). They can also serve as a key component of integrated crop-livestock systems by offering high-quality forage during the winter.

In a 7-year study with grazed and nongrazed cover crops in disked and no-tillage systems, Franzluebbers and Stuedemann (2015) indicated that grazed cover crops did not affect the C and N active soil fractions. They also indicated that cover crops in the conventional tillage system provided a significant C and N pool to the soil at the 0- to 12-inch depths—similar to the no-till system. This crop-livestock system agrees with findings provided by Sarrantonio (2007), where cover crops can contribute to increased C sequestration and improve soil quality.

Franzluebbers and Stuedemann (2015) also indicated that grazing of cover crops can be recommended as a strategy to promote greater adoption of cover cropping throughout the Southeast. To optimize the benefits, livestock should not graze the cover crop under wet soil conditions or until adequate growth is present (more than 1.5 tons of biomass per acre) (Franzluebbers and Stuedemann 2008). Grazing should start at a minimum height of 8 inches, and plants should be grazed down to 4 inches to maintain adequate residue that will allow faster recovery and canopy closure to serve the intended primary purpose.

Forage cover crops have been at the forefront of this approach in sustainable cropping systems, but there is little information about two crucial factors: (1) how cover-crop management affects the system and (2) specific agronomic traits (yield and quality) of commercially available cover-crop mixes. Greater information is needed on yield potential of forage cover-crop mixes in Mississippi (Varco et al. 1991). The objective of this study was to quantify forage biomass production of different cover-crop mixes along with their nutritive value, nutrient removal potential, and postharvest soil nutrient cycling.

Materials and Methods

This study was conducted from fall 2015 to spring 2016 at the H. H. Leveck Animal Research Farm on the campus of Mississippi State University (33°25'12" N, 88°47'24" W, elevation 305 feet) in a Marietta fine sandy loam soil (Fine-loamy, siliceous, active, thermic Fluvaquentic Eutrudepts).

Four cover-crop mixes (CCM) (Table 1) provided by Pennington Seed (Athens, Georgia) were planted on October 6, 2015, in unreplicated strips (Figure 1). Each strip was 50 feet by 50 feet in size. Each strip was fertilized with 100 pounds per acre of 15-5-10 fertilizer at planting. Cover-crop mixes were planted at the recommended seeding rates provided by Pennington Seed with no adjustment for pure live seed (PLS) using an 18-row Aitchison GrassFarmer 2018 Drill Series (Reese Engineering Ltd., Palmerston North, New Zealand).

A composite soil sample was collected from the entire field before establishment of the cover-crop mixes (October 2015) at a 6-inch depth to establish a nutrient baseline. Soil samples were also collected 2 months (May 2016) after the incorporation of the cover-crop residue. Soil test analysis was conducted by the Mississippi State University Soil Testing Laboratory. Six 2-square-foot sampling quadrants were randomly collected to ground level on March 8, 2016, from the center of each strip to estimate dry matter yields. Biomass was incorporated into the soil after sampling using a disk.

Samples were dried in a forced-air oven at 130°F until no other change in moisture could be observed. Samples were ground to pass a 1 mm screen using a Wiley mill (Thomas Scientific, Swedesboro, New Jersey) and analyzed for CP, NDF, ADF, fat and IVTDMD, and LIG concentration using a Foss DS2500 Near Infrared Reflectance Spectroscopy (NIRS) instrument (Foss North America, Eden Prairie, Minnesota). The mixed-grass hay equation developed by the NIRS Forage and Feed Testing Consortium (Hillsboro, Wisconsin) was used on all samples.

Sampling quadrants within each CCM were used as the replicated experimental units to perform statistical analysis. Data was further analyzed using PROC GLM in SAS, and the least significant difference was used to determine differences between CCM at $\alpha = 0.05$ (SAS, 2016).

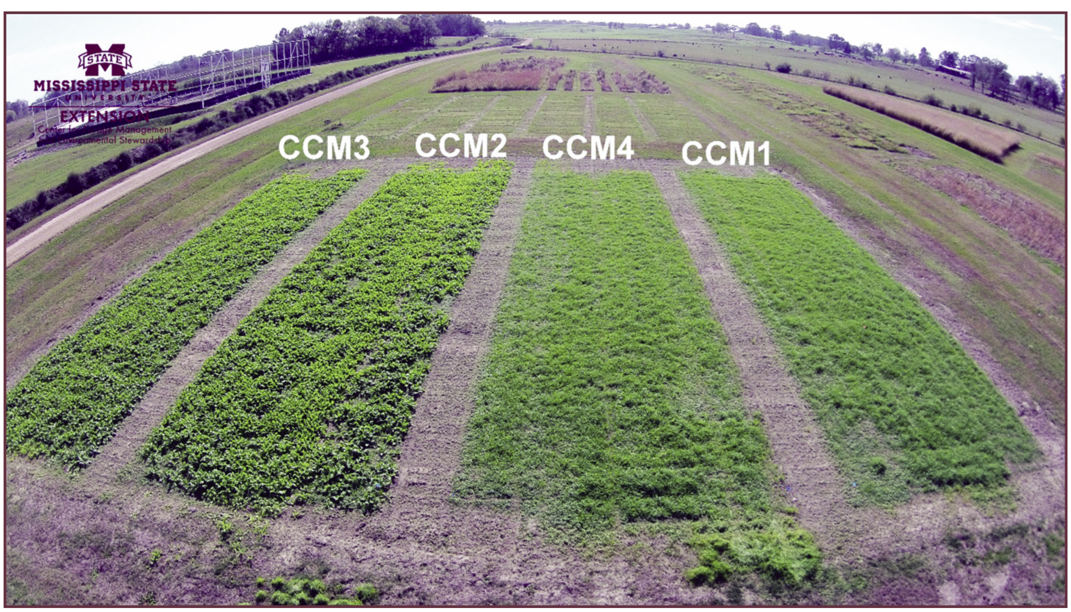

Figure 1. Field strips of cover-crop mixes on November 16, 2015.

Table 1. Cover-crop mixes, composition, and seeding rates at Starkville, Mississippi.

CCM	Forage-mix composition		Seeding rate (lb/A)
Mix 1 (CCM1)	Radish (34%)	Crimson clover (66%)	15.0
Mix 2 (CCM2)	Cereal rye (85%)	Crimson clover (15%)	50.0
Mix 3 (CCM3)	Cereal rye (75%)	Crimson clover (20%) Red clover (5%)	50.0
Mix 4 (CCM4)	Radish (40%)	Annual ryegrass (60%)	12.5

Results and Discussion

Weather Data

Weather data [precipitation, temperature, and growing degree days (GDD)] are presented in Table 2. Precipitation was 7 inches above normal for the period of the study (October 2015 to May 2016). Precipitation deficit above 1 inch was observed at the beginning and end of the study period. Slight rainfall deficits were observed in January and April. Overall average temperature for the duration of the study was 3.4°F above normal. Lower temperatures were observed only during January. Throughout the duration of the study, there were 552 GDD above normal with shorter growing periods observed in January and May.

Soil Nutrient Analysis

Soil nutrient analysis is presented in Table 3. There was a slight increase in soil pH in the cover-crop mixes compared with the initial composite soil value. This finding could be related to soil moisture gradient differences during the pre- and postsampling periods.

Soil test P was much lower in all cover-crop mixes in May (postharvest) compared with the initial baseline value before establishment. P was 43% lower for CCM; 113%, CCM; 280%, CCM3; and 13%, CCM4.

There was a small difference in soil test K for CCM1 and CCM2 2 months after incorporation of the crop residue compared with the initial K level. On the other hand, soil test K was 39% greater than the initial soil K content for CCM3 and 20% for CCM4. Soil test Mg was slightly less for CCM1 and CCM3 and slightly greater for CCM3 and CCM4 than the initial value. Soil test Ca increased in all cover crops mixes compared with the initial soil baseline value: 12% for CCM1, 38% for CCM2, 11% for CCM3, and 25% for CCM4. Organic matter concentration and CEC had a slight increase in each cover-crop mix compared with the initial soil baseline value. Organic matter increased 12% in CCM2,10% in CCM3, and 6% in CCM4. Increase in OM in May might be related to cooler soil, which would have reduced microbial activity and decreased decomposition rates and nutrient cycling. Cation exchange capacity is dependent on mineralogy, OM, and cation. Cation exchange capacity concentrations were greater for all treatments at postharvest compared with initial values and could be related to greater OM in the treatments.

Table 2. Precipitation, average temperature, and growing degree days (GDD) — monthly, season total, long-term average (LTA), and departure (Dep) from 30-year average — at Starkville, Mississippi.[1]

Variable	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	Season
	in	*in*	*in*	*in*	*in*	*in*	*in*	*in*	*in*
Precip.	2.5	8.4	7.5	4.5	8.3	7.7	4.3	3.2	46.4
LTA	4.1	4.7	5.2	5.4	5.7	4.9	4.9	4.6	39.4
Dep	-1.6	3.7	2.3	-0.9	2.6	2.9	-0.6	-1.4	7.0
	°F	*°F*	*°F*	*°F*	*°F*	*°F*	*°F*	*°F*	*°F*
Temp.	65.8	57.8	55.8	41.5	49.1	58.2	64.2	70.8	57.9
LTA	62.8	53.5	44.7	42.1	46.2	53.8	62.0	70.6	54.5
Dep	3.0	4.3	11.1	-0.6	2.9	4.4	2.2	0.2	3.4
	°F	*°F*	*°F*	*°F*	*°F*	*°F*	*°F*	*°F*	*°F*
GDD[2]	495	266	236	13	108	289	434	631	2472
LTA	405	175	63	37	63	186	371	640	1940
Dep	90	91	173	-24	45	103	63	-9	532

[1]Numbers reflect data during forage production year from October 2015 to May 2016.
[2]Growing degree days base 50.

Table 3. Soil test analysis before and after the study at Starkville, Mississippi, for samples collected at 6-inch depth.								
Soil sampling	**pH**	**P**	**K**	**Ca**	**Mg**	**S**	**OM**	**CEC**
		lb/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*	%	%
Before[1]								
Composite	6.3	243	133	3288	243	204	1.42	11.60
After[2]								
CCM1	6.5	170	131	3684	224	206	1.43	13.01
CCM2	6.6	215	135	4522	235	229	1.59	14.86
CCM3	6.3	135	185	3645	258	225	1.56	12.63
CCM4	6.7	215	163	4120	252	216	1.50	13.66

[1]Soil cores were collected on September 15, 2015, over the entire field before the establishment of the study.
[2]Soil samples were collected in each cover crop mix strip on May 15, 2016, after incorporating the biomass in mid-March.

Although there were trends in changes in soil nutrients parameters, there could be confounded differences and variability due to the lack of plot-to-plot soil sampling before the initiation of the demonstration. Differences in monthly sampling have also indicated that soils are more acidic in fall than spring, and related to moisture (Larry Oldman, personal communication, December 5, 2016).

Biomass Yield and Nutrient Removal

Biomass production for the cover-crop mixes was significantly different ($P<0.0409$) (Figure 2). There was no difference between CCM1, CCM3, and CCM4. The only significant difference was observed between CCM2 and CCM3, with CCM4 having 41% greater biomass. Biomass could also be affected by species competition in which clover populations were reduced due to earlier competition from the aggressive growth of the grasses in the mix.

Nutrient content in the biomass for N, P, K, Ca, and Mg are presented in Table 4. There was no significant difference among treatments in biomass N accumulation. However, CCM2 and CCM3 had the greatest accumulations. Potassium removal was significant among treatments ($P<0.0001$). Potassium removal was 20% greater for CCM2 and 110% greater for CCM3 compared with mean K removal. On the other hand, CCM1 was 240% and CCM4 was 68% below the K removal mean. Phosphorus, Ca, and Mg removal followed similar trends to K removal. Phosphorus, Ca, and Mg removal were greater for CCM2 and CCM3 when compared with the mean, while CCM1 and CCM4 were below the mean.

Although nutrient removal by cover-crop mixes can be a function of yield and nutritive value, this data suggests that N removal can be more related to species competition and species root morphological architecture that might allow the extraction of nutrients from deeper areas in the soil profile. In this case, radish could allow extraction of

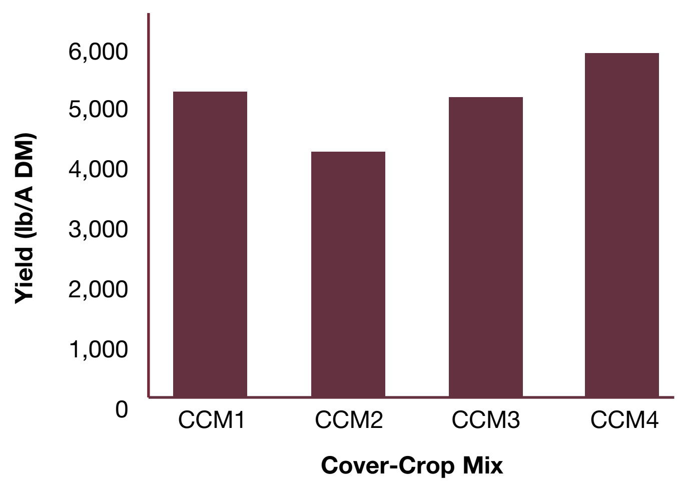

Figure 2. Biomass production of cover-crop mixes in Starkville, Mississippi, during the 20015–16 growing season.

Table 4. Nutrient removal (N, K, P, Ca, and Mg) of cover-crop mixes during the 2015–16 growing season in Starkville, Mississippi.					
CC Mix	**Nutrient removal**				
	N	**K**	**P**	**Ca**	**Mg**
	lb/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*
CCM1	67.4	16.2	6.9	60.7	9.8
CCM2	92.6	65.8	10.3	83.4	15.6
CCM3	94.8	104.4	11.9	84.4	14.5
CCM4	87.6	32.7	9.2	66.5	11.1
$LSD_{0.05}$	NS	26.5	2.4	17.0	3.4
CV (%)	23.8	40.2	20.5	19.1	22.5
P<F	0.1139	0.0001	0.0022	0.0168	0.0060

nutrients from deeper soil horizons, while cereal rye and annual ryegrass can increase the soil volume for nutrient uptake due to their extensive fibrous root system (Karathanasis et al. 2014).

Forage Quality

Forage quality for all parameters (CP, ADF, NDF, FAT, IVTDMD, and LIG) were significantly different among cover-crop mixes (Table 5). Crude protein concentration was higher in cover-crop mixes containing cereal rye (CCM2 and CCM3). It was expected that CCM1 would have higher CP due to crimson clover being in the mix, but the small legume percentage in the mix could have been outcompeted by the rapid growth of the cereal rye earlier in the season, along with often saturated soils that tend to favor grasses over clovers.

Acid detergent fiber and NDF concentrations were also lower for CCM2 and CCM3 compared with the other cover-crop mixes. Fat concentration was much lower in the CCM2 compared with the rest of the treatments. In vitro dry matter digestibility (IVTDMD) concentration followed the same pattern observed with CP with greater digestibility for CCM2 and CCM3. There were no significant differences in LIG concentration between CCM2 and CCM3 or CCM1 and CCM4. The differences in forage quality among cover-crop mixes could be related to species composition in the mix, percent composition of each species, and competition among species in the plot.

Table 5. Forage quality parameters (CP, ADF, NDF, FAT, IVTDMD, and LIG) of cover-crop mixes during the 2015–16 growing season in Starkville, Mississippi.

CC Mix	Parameters					
	CP	ADF	NDF	FAT	IVTDMD	LIG
	DM %	*DM %*	*DM %*	*DM %*	*DM %*	*DM %*
CCM1	8.2	38.2	63.1	3.6	70.1	4.5
CCM2	14.0	31.6	38.6	1.8	84.7	3.9
CCM3	11.6	33.8	46.5	3.0	85.9	3.0
CCM4	9.4	38.4	63.0	3.5	71.2	4.8
$LSD_{0.05}$	1.4	2.9	3.0	0.5	3.3	0.7
CV (%)	11.1	16.9	4.7	13.2	3.5	13.6
P<F	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002

Conclusions

The integration of cool-season cover-crop mixes into forage cropping systems could bring added costs and/or benefits to a livestock enterprise. The added cost is associated with seed, equipment, fuel, and labor. Despite the incurred cost, there is still room to evaluate the performance of mixes where growth, poor establishment, or intraspecies competition can impact forage production. Benefits include suppression of weed competition, increased nutrient cycling, extended grazing season, and increased livestock performance.

It is important to select mixes that will optimize forage production and nutritive value while leaving crop residue that can provide benefits to either perennial or annual warm-season forage systems. Besides providing soil cover, decaying cover crops may release substantial amounts of nutrients that can benefit the following cropping systems provided that environmental conditions and microbial activity can increase nutrient cycling.

To date, the use of cover crops in forage systems could be constrained by economic, biological, and management factors. The best scenario involves managing them to meet forage production goals, such as biomass yield and quality. Management of annual forages such as annual ryegrass, small grains, brassicas, and annual legumes should focus solely on biomass production that can increase profitability while improving soil quality or health.

Adoption of cover-crop mixes among forage producers in the South is slow, but farmer education along with continued research and demonstrations can aid in increasing the adoption of cover-crop practices that can improve soil quality and forage production. Continued research should focus on binary or tertiary cover-crop mixes that allow for optimizing forage yields during the winter while sequestering carbon, reducing nutrient loss, and increasing nutrient cycling. Long-term studies with cover-crop mixes are needed to determine planting and harvesting timing and to determine other management practices and adaptability that will optimize benefits. There is a need to evaluate long-term field trials that will be able to measure and delineate the effects among cover-crop mixes on soil health and productivity and the interactions between species in mixtures.

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