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Corn grain and forage yield in a perennial legume living mulch system in east-central Mississippi

Abstract

Perennial living mulch cover crops have the potential to mitigate environmental impacts on erosive soils, offset nitrogen (N) requirements in corn (*Zea mays* L.), and generate highly nutritious feedstocks for differed feeding. The objectives of this research were to 1) compare corn grain yield across multiple perennial legume living mulch species and cultivars and 2) evaluate forage production parameters of the same living mulch species as potential baleage crops in east-central Mississippi. A field trial was conducted from fall 2023 to fall 2025 at the Coastal Plain Branch Experiment Station in Newton, MS. The study was comprised of a randomized complete block design with three replications including three species and five cultivars, including: white clover [*Trifolium repens* L.; 'Regal Graze' and 'Marco Polo'); red clover (*Trifolium pratense* L.; 'Kenland' and 'GA-9908'); and alfalfa (*Medicago sativa* L.; 'Bulldog 805'). Baleage was harvested from plots each spring prior to corn establishment. Herbage mass (HM), crude protein (CP), and total digestible nutrients (TDN) did not differ between treatments. HM, however, declined by 38% across all treatments from year to year. Corn grain yield varied among treatments, with plots seeded in Regal Graze white clover having greater yield than all other treatments besides Marco Polo white clover in year 1 (77 bu ac^{-1}), and all treatments in year 2 (121 bu ac^{-1}). Our results indicate that baleage and corn grain production can simultaneously be achieved in living mulch systems, however additional N sources are required to meet corn grain yield goals.

Abbreviations: Herbage mass, HM; crude protein, CP; total digestible nutrients, TDN; pure live seed, PLS.

Introduction

Corn acreage for 2025 was up 13% from 2024 with an estimated 98.7 million acres planted and a forecast of 4.30 billion bushels (USDA NASS, 2025). Since 2020, fertilizer, specifically nitrogen (N), has constituted 33 to 44% of corn operating costs (USDA ERS, 2025). Fertilizer input costs, combined with environmental impacts from N runoff into the Gulf of America have increased regulatory pressure and N use reduction and mitigation (Mee, 2006). Along with increasing operating costs, land degradation in the form of tillage practices and subsequent soil erosion has decreased crop yields by an estimated 6%, causing $2.8 billion in annual economic losses in the Midwestern USA alone (Thaler, et al. 2021). One option to address these challenges is the use of perennial cover crops, or living mulches, to minimize the impact on erosive soils (Scheaffer and Moncada, 2012), supply scavenged nutrients to subsequent crops (Teasdale et al., 2007), improve soil formation and function (Hall et al., 1984), and reduce herbicide use (Hartwig and Ammon, 2002) through improved agronomic management (Sanders et al., 2017).

Perennial legume living mulches have been investigated extensively in southern cropping systems with various methods of corn establishment and mulch suppression techniques (Hill et al., 2021; Sanders et al., 2017). Suppression techniques are implemented to remove significant amounts of biomass and facilitate corn planting. Techniques have included strip tillage (Martin et al., 1999), mowing (Martin et al., 1999), and broadcast or banded herbicides (Duiker and Hartwig, 2004; Sanders et al., 2017). One technique not thoroughly investigated is the use of mowing and removing biomass in the form of baleage for deferred feeding for livestock. Baleage is the process in which nutritious feedstuffs are harvested, baled at high-moisture (typically between 45-65%) and wrapped in plastic to exclude oxygen and allow fermentation for ensiling. This process results in substantial cost savings due to decreased time required for dry-curing, nutritional value preservation, reduced storage loss, and greater utilization during feeding (Pruitt and Lacy, 2013). By managing and harvesting the living mulch as a crop itself, this offers growers the opportunity to generate additional revenue through multiple crops grown on the same land base, while simultaneously removing mulch biomass and residue that impedes spring corn planting, and potentially contributing organic N to the subsequent corn crop. The objectives of this project were twofold: 1) compare corn grain yield across multiple perennial legume living mulch species and cultivars; 2) evaluate forage production [herbage yield (HM) and nutritive value (crude protein – CP; total digestible nutrients – TDN)] and N contribution of living mulch species as potential baleage crops in east-central Mississippi.

Materials and Methods

A field trial was conducted at the Coastal Plain Branch Experiment Station (CPBES) in Newton, MS (32^{o}20’05.11”N, 89^{o}05’09.60”W) over two full cropping seasons (corn + living mulch) beginning in the fall of 2023 (fall 2023 to fall 2024 – year 1; fall 2024 to fall 2025 – year 2). The soil at the site was a Prentiss fine sandy loam (fine, siliceous, semiactive, thermic Glossic Fragiudults). The experiment consisted of a randomized complete block design (RCB) with three replications. The experimental area was in annual forage crop (winter annual species) prior to this field trial. No weed pressure ratings or inventories were collected before or during this experiment was undertaken. Prior to planting, the plot area was sub-soiled (KMC 6700 Rip/Strip), disked (International Harvester 10A), and cultipacked (Tuffline BCP). Living mulch treatments included the following species and cultivars: white clover [*Trifolium repens* L.; ‘Regal Graze’ and ‘Marco Polo’); red clover (*Trifolium pratense* L.; ‘Kenland’ and ‘GA-9908’); and alfalfa (*Medicago sativa* L.; ‘Bulldog 805’). A non-planted control was included within treatment designation. Plots were seeded in the fall of 2023 at 3, 10, and 20 lb pure live seed (PLS) ac^{-1} for white clover, red clover, and alfalfa plots, respectively, on 7.5 in row spacing (Truax Flex II Series Grass Drill). All plots received 2 ton ac^{-1} of poultry litter (85 lb ton^{-1} K_2O; 46 lb ton^{-1} N; 59 lb ton^{-1} P_2O_5; 6.8 pH) in the fall of each year. No other fertilizer was applied to the experimental area throughout the duration of the trial. Plots measured 10 ft x 100 ft and were located inside an 8 ft exclusion fence to prevent depredation of plots from wildlife.

In the spring of each year, all plots were mowed with a disc mower (Kuhn GMD 28), raked (Vermeer VR820), and baled (John Deere 450M). Prior to mowing, samples were collected from each plot by clipping aboveground biomass to a 3 in stubble height from three randomly placed 2 ft x 2 ft quadrants. Samples were weighed, placed in a forced-air oven for approximately 72 hr at 140°F, and reweighed to determine percentage moisture and to calculate dry matter for HM analysis. Dried samples were then ground (Thomas-Wiley Laboratory Mill, Thomas Scientific) to pass through a 0.03 in sieve and were analyzed using near-infrared reflectance spectroscopy (NIRS; SpectraStar 2600XTR; Ucal Calibration Software v3.0). Nutrient analysis was determined using the 2024 legume hay equation (NIRS Forage and Feed Testing Consortium) in which CP and TDN were derived. TDN was calculated as the sum of the digestible fiber (dNDF), CP, fat, and carbohydrate components (Saha et al., 2014).

Immediately following baleage harvest and removal, corn was planted into baleage stubble using a 4-row no-till vacuum planter on 30-in row spacings (1759 MaxEmerge Plus VacuMeter; John Deere) equipped with spike-toothed row cleaners (Martin-Till) and wave coulters, along with 20-pt dimple closing wheels (Martin-Till) for residue management. Target population was 28k seed ac^{-1} (Larson 2023). The corn cultivar used each year was Innvictis A1457VT2P. No pre-emerge or post-emerge herbicides, insecticides, or fungicides were applied to any plot except a single glyphosate (3 lb a.i. gal^{-1}; 2 qt ac^{-1}) application made at planting for the control plots. No N was applied to corn at any time throughout the duration of the trial. To determine corn grain yield, corn was harvested from the center two rows using a plot combine (SPC-40; Almaco) equipped with an on-board moisture and weighing system (Seed Spector LRX; Almaco).

Seed moisture, test weight, and total bu ac^{-1} were calculated for each plot. A complete list of field activities and dates of application can be found in **Table 1**.

Table 1. Dates of field activities and related information regarding planting of living mulch and corn, and harvest of baleage and corn grain at the Coastal Plain Branch Experiment Station (CPBES) in Newton, MS (year 1 – 2023-2024; year 2 – 2024-2025).

Operation	**Information**[a]	**Year 1**	**Year 2**
Living mulch			
Fertilize	poultry litter	Oct 9, 2023	Sep 18, 2024
Plant	clover/alfalfa	Oct 9, 2023	
Harvest	baleage	May 1, 2024	Apr 28, 2025
Corn crop			
Plant	corn	May 1, 2024	May 1, 2025
Harvest	corn	Sep 3, 2024	Sep 17, 2025

[a]See text for specific rates.

All statistical analysis was conducted using analysis of variance (ANOVA) in SAS (SAS Institute, 2013). Treatment effects were analyzed via repeated measure, mixed-effects ANOVA in the procedure PROC GLIMMIX. Replication was included as a random effect. Living mulch cultivar was the fixed effect. Normality of the model was checked to determine if transformations were necessary. Mean separations were based on Tukey's protected least significant difference (LSD) and differences were considered significant at $\alpha = 0.05$ probability level.

Results and Discussion

Environmental conditions

Daily temperature (°F) and precipitation (in) observations were recorded from a weather station located < 0.5 mi from the experimental site (DAWC, 2025; **Figure 1**). Total rainfall for 2023 was 48.9 in, 10 in below the 30 yr average (58.8 in). This deficit was primarily observed during the late summer and fall months leading up to legume establishment. Mean temperatures for 2023 were 2.7 °F above the 30 yr average (66.1 °F). For 2024, rainfall was slightly above the 30 yr average (0.4 in), while the average temperature was 2.4 °F above average. For 2025, a wetter than average spring, followed by a drier than average summer and early fall led to below average total rainfall for the year. That same year also recorded above average temperatures by 3.2 °F.

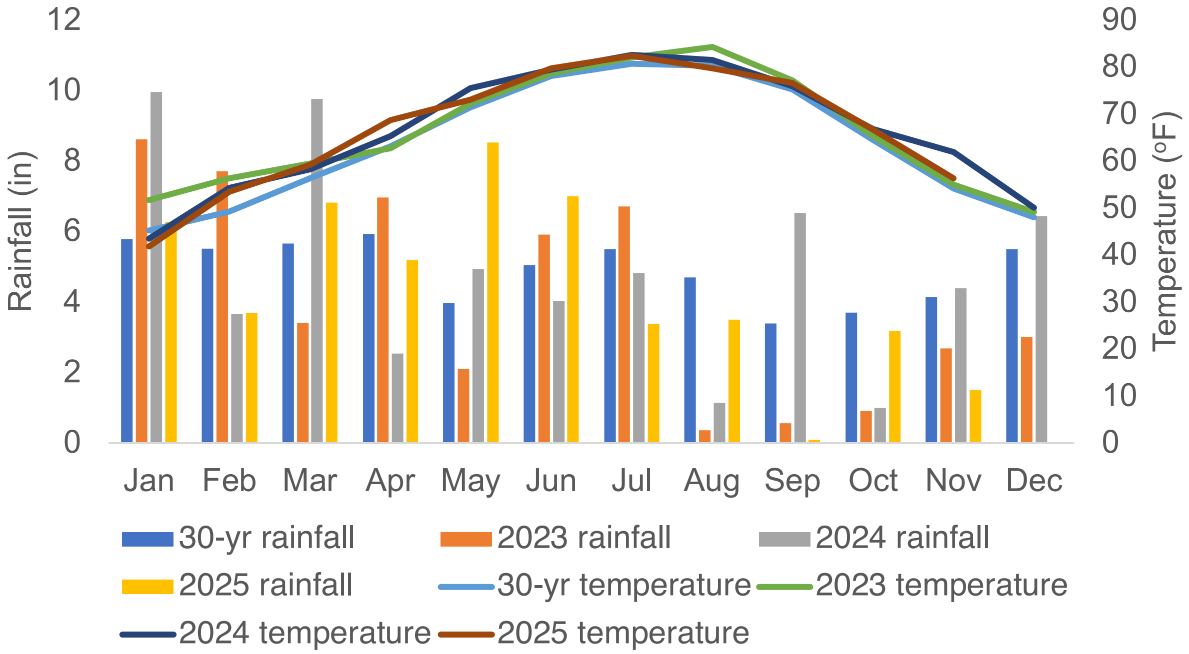

Figure 1. Total monthly rainfall (in) and mean monthly temperature (°F) with 30-yr (1993-2023) historical means from the Coastal Plain Branch Experiment Station (CPBES); Newton, MS.

Forage production

Mixed model analysis showed differences affected by year for all variables measured, therefore year was used as a repeated measure. Herbage mass (HM) and nutritive value (CP and TDN) were analyzed from samples collected just prior to baleage harvest (May 1, 2024; Apr 28, 2025) for each year of the experiment. No differences were observed between living mulch treatments for HM (*P* = 0.0930). Mean HM across all cultivars was 6823 and 2636 lb DM ac^{-1} for year 1 and year 2, respectively (**Figure 2**). All cultivars had significantly lower HM in year 2 compared to year 1 ($P < 0.0001$). For alfalfa, this was anticipated. Alfalfa stands in Mississippi have been shown to be reduced to 20% of the original stand by the third growing season when combined with a warm-season crop (White and Lemus, 2015). In monoculture, alfalfa HM has been observed to decrease by 30% in the second growing season on a fine sand (Rushing et al., 2020). Our results showed a 35% decrease in alfalfa HM, even when plots were only harvested once. Red clover HM decreased by 38 and 42% for Kenland and GA-9908 cultivars, respectively (**Figure 2**). Red clover, especially in light textured Coastal Plains soils, is considered a short-lived perennial (2-3 years) and does not persist well in more southern locations (Hoveland et al., 1981). In Mississippi on a silty clay, however, HM remained similar across 4 cultivars harvested multiple times across two years (White, 2022) suggesting that the addition of corn could have suppressed red clover regrowth following corn planting, resulting in decreased HM the following season. White clover was reduced by 41 and 34% for Regal Graze and Marco Polo cultivars, respectively (**Figure 2**). First year HM for white clover living mulch systems was greater than those reported elsewhere (Hill et al., 2018). In Georgia, Durana white clover HM was reported at 2482 and 2937 lb DM ac^{-1}, a 15% increase from year to year. In our field trial, mean HM was 5425 and 2050 lb DM ac^{-1} in year 1 and 2, respectively. Environmental conditions did not limit HM potential from 2024 to 2025, suggesting that like red clover, the addition of a corn crop increased competition and limited legume regrowth following baleage harvest each spring.

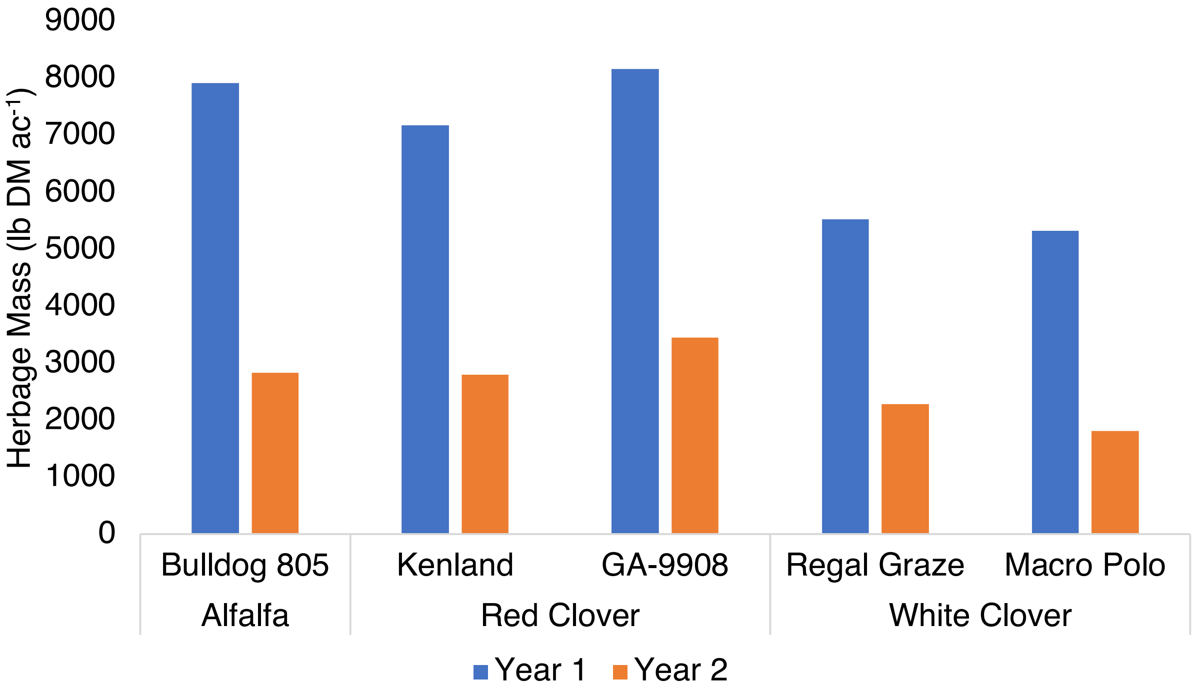

Figure 2. Herbage mass (HM; lb DM ac^{-1}) from plots harvested in the spring at the Coastal Plain Branch Experiment Station (CPBES); Newton, MS in 2024 (Year 1) and 2025 (Year 2).

No differences were observed for CP from samples collected at baleage harvest for each year ($P = 0.0749$; **Figure 3**). Mean CP ranged from 20 to 30% across both harvests and did not differ between years ($P = 0.2602$). From a livestock feeding perspective, this far exceeds the protein requirement for lactating beef cows, breeding stock, and growing calves (Karisch and Parish, 2023). Alfalfa CP values observed in our field trial were like those reported from the same location in other years (Rushing et al., 2020). Mean alfalfa CP ranged from 23.5 to 25.0% across two years reported by Rushing and others (2020), while those in this field trial ranged from 21.3 to 25.4%. In white clover, reported CP values in Mississippi ranged from 25 to 30% at immature stages (Watson and Knight, 1978). These were similar to those in our field trial, which measured 27.6 and 26.9% across both years for Regal Graze and Marco Polo cultivars, respectively. Red clover mean CP was 22.2 and 23.7% across both years for Kenland and GA-9908, respectively.

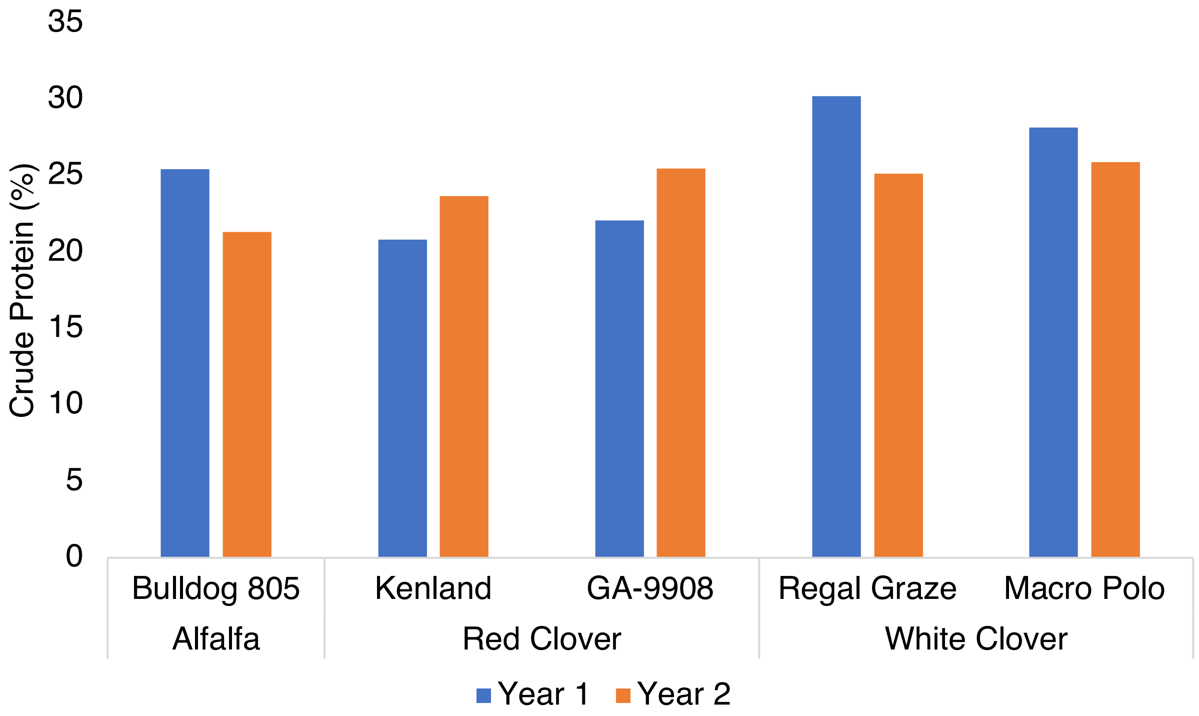

Figure 3. Crude protein (CP; %) from plots harvested in the spring at the Coastal Plain Branch Experiment Station (CPBES); Newton, MS in 2024 (Year 1) and 2025 (Year 2).

Total digestible nutrients (TDN) also did not differ between living mulch cultivars (*P* = 0.1799) or by year (*P* = 0.1402; **Figure 4**). Mean TDN was 50% for Bulldog 805 alfalfa, 47 and 48% for Kenland and GA-9908 red clover, and 54% for both Regal Graze and Marco Polo white clovers. Though not statistically significant, the lower values observed for the red clover cultivars was likely due to maturity at the time of baleage harvest. Lignin concentrations were greater in red clover cultivars during harvest, which was a result of more reproductive plant tissue, increased inflorescence, and seed production (data not reported). TDN values across all living mulches were slightly below energy requirements for beef cattle diets, regardless of age or sex (Karisch and Parish, 2023).

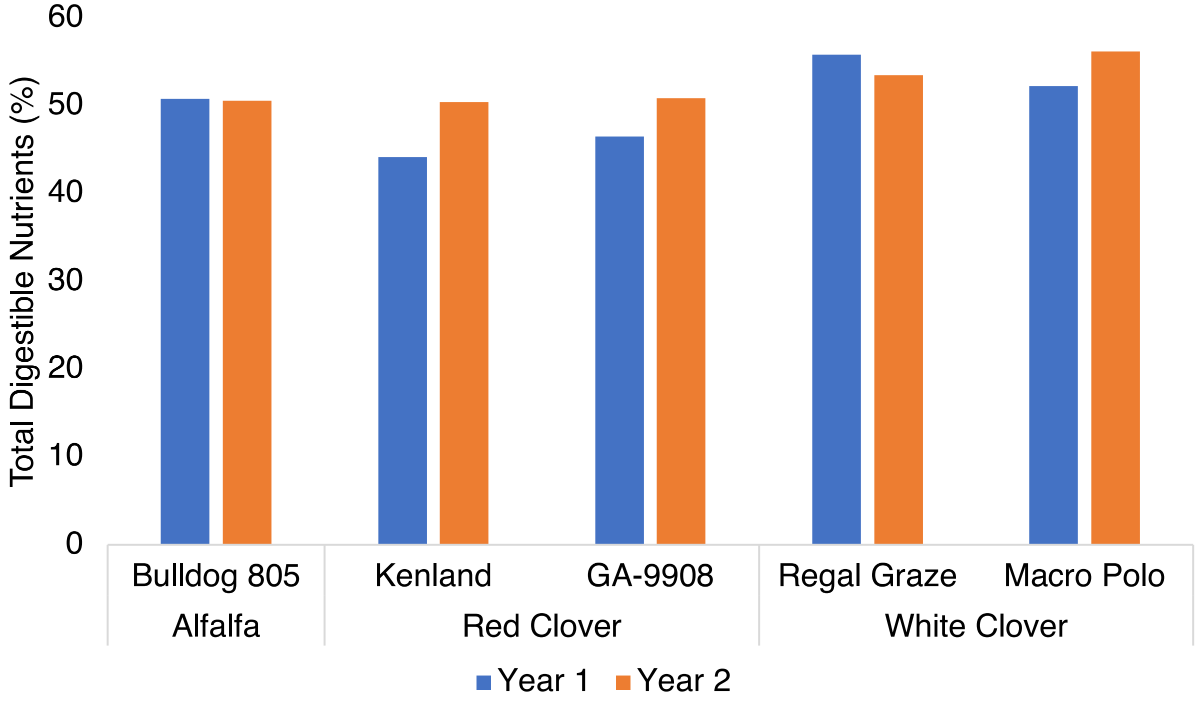

Figure 4. Total digestible nutrients (TDN; %) from plots harvested in the spring at the Coastal Plain Branch Experiment Station (CPBES); Newton, MS in 2024 (Year 1) and 2025 (Year 2).

Nitrogen contribution was calculated from CP and HM values from baleage samples (**Figure 5**). These values were derived by multiplying CP (%) x HM (lb DM ac^{-1})/6.25. The 6.25 constant is the average N concentration of protein molecules (Lalman and Holder, 2024). N content at the time of baleage harvest did not differ between living mulch treatments ($P = 0.4126$) but did differ between years ($P < 0.0001$). Mean N content in year 1 was 271 lb ac^{-1} compared to 102 lb ac^{-1} for year 2. Differences between years are a direct result of HM. Estimated N release from white clover plots in a living mulch system in Georgia was 124 and 132 lb ac^{-1} in two consecutive years (Hill et al., 2018). These values are similar to those we observed in the second year of our field trial where HM was similar to those reported by Hill and others (2018). As clover biomass declines, N release increases. However, because HM was harvested and removed from our plots in the form of baleage, the contribution of N from clover would be expected to be minimal.

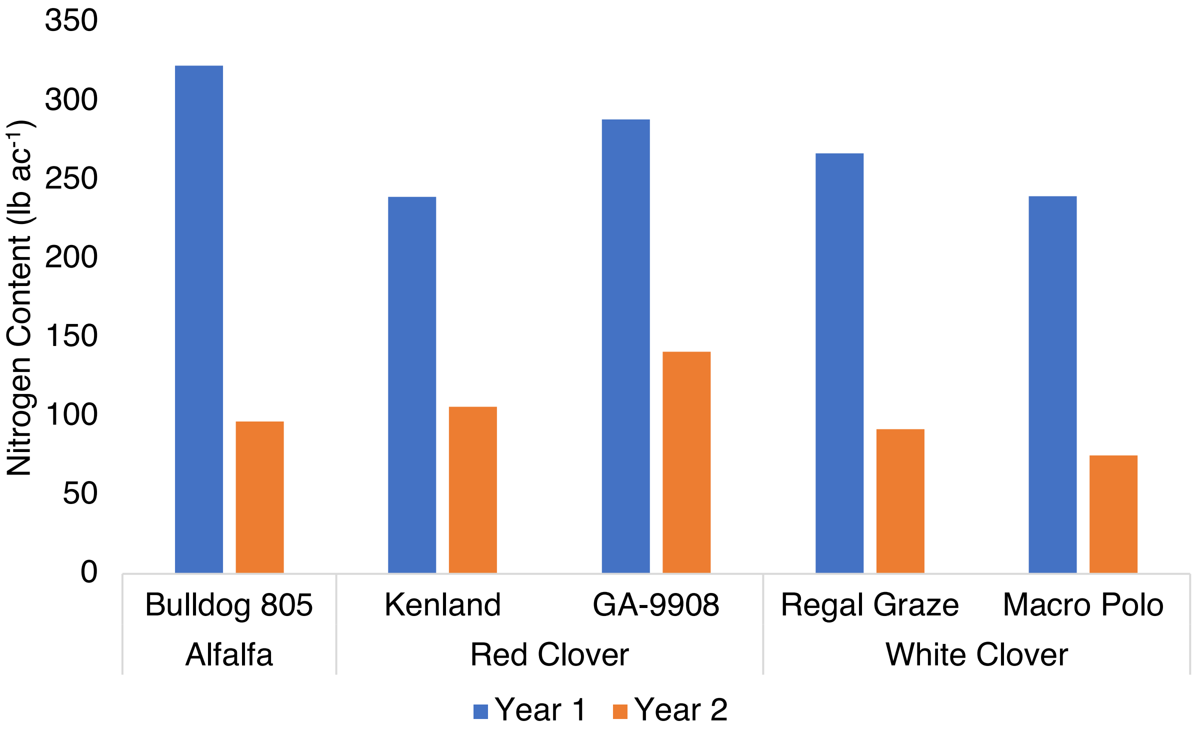

Figure 5. Nitrogen content (lb ac^{-1}) from samples collected at corn planting from plots harvested at the Coastal Plain Branch Experiment Station (CPBES); Newton, MS in 2024 (Year 1) and 2025 (Year 2). Nitrogen content was calculated by multiplying crude protein (%) x herbage mass (lb DM ac^{-1})/6.25.

Corn grain yield

Corn was harvested on Sep 3, 2024 and Sep 17, 2025 (**Table 1**). The effect of living mulch on corn grain yield was significant ($P < 0.0001$; **Figure 6**). For year 1, plots harvested in Regal Graze (77.3 bu ac^{-1}) and Marco Polo (71.4 bu ac^{-1}) were greater than the unplanted control (49.3 bu ac^{-1}). Bulldog 805 (60.3 bu ac^{-1}) was similar to the control. The two red clover cultivars (GA-9908 30.6 bu ac^{-1}; Kenland 17.9 bu ac^{-1}) had mean corn grain yields that were less than the control. For year 2, plots harvested in the Regal Graze (121.7 bu ac^{-1}) living mulch were greater than all other cultivars, along with the control. Marco Polo (89.7 bu ac^{-1}) mean corn grain yield was similar to Kenland red clover (64.9 bu ac^{-1}) but was greater than all other treatments except Regal Graze. GA-

9908 (61.4 bu ac^{-1}) and Bulldog 805 (44.7 bu ac^{-1}) were similar to the unplanted control (53.8 bu ac^{-1}).

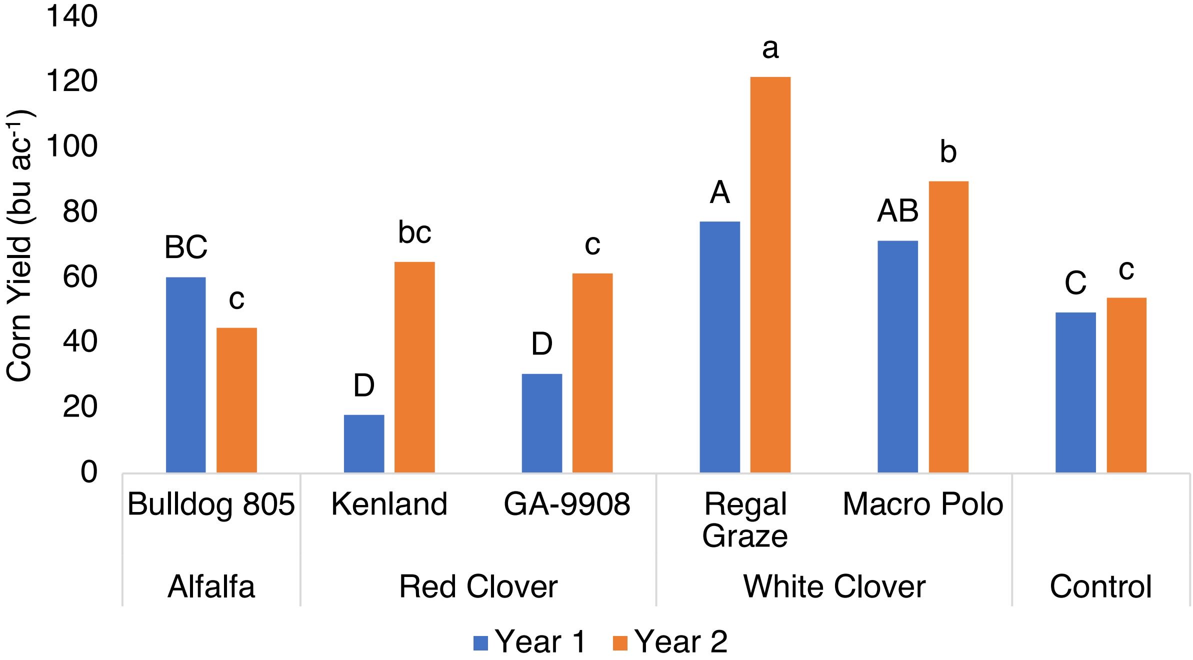

Figure 6. Corn grain yield from plots harvested in the fall at the Coastal Plain Branch Experiment Station (CPBES); Newton, MS in 2024 (Year 1) and 2025 (Year 2). *Uppercase letters denote significant differences at the α = 0.05 for year 1. **Lowercase letters denote significant differences at the α = 0.05 for year 2.

Mean corn grain yields observed in this two-year field trial were well below average for Mississippi. The Mississippi average corn yield for 2024 was 187 bu ac^{-1}, while the national average was 183 bu ac^{-1} (USDA NASS, 2024). For 2025, the statewide average was estimated to be 179 bu ac^{-1} (Coblentz, 2025). Current N recommendations for Mississippi corn production are 1.3 lb of actual N for each bushel of corn yield goal (Larson, 2024). Nitrogen deficiency during vegetative or reproductive growth stages can be detrimental to grain yield (Lee et al., 2015). For our field experiment, our objective was to observe the capacity for perennial legume living mulches to contribute associative N with no additional N applications. In previous work, N credits have been calculated using the University of Georgia potentially mineralizable N calculator (https://aesl.ces.uga.edu/mineralization/ ; Hill et al., 2021). They observed that N contribution from a white clover living mulch system was difficult to estimate, thus recommended a single application of 40 lb N ac^{-1} at the V6 growth stage for normal growth (Andrews et al., 2018; Andrews et al., 2020). As discussed above, because living mulch HM was removed from our plots in the form of baleage, minimal N contribution would be expected. Based on our results, additional inorganic forms of N should be applied in order to meet expected corn grain yield goals and maximize productivity if HM is removed via baleage.

Conclusion

Generating greater revenue in agricultural production systems while simultaneously minimizing costs and impact on the environment is the ultimate goal in most enterprises. Results from our field trial demonstrate that perennial legume species can generate substantial amounts of high quality feedstuffs which can be harvested as baleage. However, intercropping corn with these legumes results in diminished forage yields in subsequent years. Also, corn yields will be drastically reduced when no-till planted into baleage crop residue without additional N applications. Based on the species and cultivars evaluated, Regal Graze white clover demonstrated the greatest capacity to fill both roles as a baleage crop and living mulch for corn production, especially in the first year of production following establishment. Additional research investigating N management in this baleage/corn grain production system is needed. Also, including non-corn planted plots for living mulch comparisons would be beneficial in validating perennial legume contribution and persistence over time without competing against corn.

Conflict of Interest

The authors declare that there is no conflict of interest.

Acknowledgement

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Literature Cited

Coblentz, B. 2025. Big state corn harvest in 2025 is nearly complete. Mississippi State Cooperative Extension Service. Accessed December 4, 2025.

DAWC. 2025. Delta Agricultural Weather Center. Mississippi State Cooperative Extension Service. Accessed December 4, 2025.

Hartwig, N. and H. Ammon. 2002. 50th anniversary – invited article – cover crop and living mulches. Weed Science. 50:688-699. https://doi.org/10.1016/0167-8809(90)90111-P.

Hill, N.S., M. Levi, N. Basinger, A. Thompson, M. Cabrera, J. Wallace, E. Saikawa, A. Avramov, and J. Mullican. 2021. White clover living mulch enhances soil health vs. annual clover. Agronomy Journal. 113:3697-3707. https://doi.org/10.1002/agj2.20768.

Hoveland, C.S., R.L. Haaland, W.B. Webster, V.H. Calvert II, R.A. Moore, JR., J.T. Eason, M.L. Ruf, L.L. Walker, H.C. Hoyle, L.A. Smith, and H.W. Grimies, Jr. 1981. Performance of red clover varieties in Alabama. Alabama Cooperative Extension Service. Accessed December 5, 2025.

Karisch, B. and J. Parish. 2023. Beef Cattle Nutrient Requirements. Publication 2528. Mississippi State Cooperative Extension Service. Accessed December 5, 2025.

Lalman, D. and A. Holder. 2024. Nutrient requirements of beef cattle. Publication E-974. Oklahoma State Cooperative Extension Service. Accessed December 5, 2025.

Larson, E. 2023. Corn planting suggestions for a potentially early season. Mississippi Crop Situations. Accessed May 7, 2026.

Larson, E. and L. Oldham. 2024. Corn Fertilization. Publication 3591. Mississippi State Cooperative Extension Service. Accessed December 5, 2025.

Lee, R.D., G.H. Harris, K. Harrison, W. Porter, E. Prostko, D. Buntin, B. Kemerait, P. Sumner, N. Smith, and A. Smith. 2015. A guide to corn production in Georgia 2015. CSS 01-2016. Department of Crop and Soil Sciences, University of Georgia, Athens.

Martin, R., P. Greyson, and R. Gordon. 1999. Competition between corn and a living mulch. Canadian Journal of Plant Science. 79:579-586. https://doi.org/10.4141/P98-089.

Mee, L. 2006. Reviving dead zones. Scientific American. 295(5):78-85. https://www.jstor.org/stable.10.2307/2606.

Pruitt, J.R. and R.C. Lacy. 2013. Economics of baleage for beef cattle operations. Publication 330. Louisiana State University Ag Center. Baton Rouge, LA.

Rushing, J.B., R.W. Lemus, J.G. Maples, and J.C. Lyles. 2020. Impact of poultry litter application on alfalfa grown in Mississippi. Crop, Forage, and Turfgrass Management. https://doi.org/10.1002/cft2.20049.

Saha, U., D. Hancock, and D. Kissel. 2014. How do we calculate relative forage quality in Georgia? Georgia Cooperative Extension Service. Accessed December 2, 2025.

Sanders, Z.P., J.S. Andrews, U.K. Saha, W. Vencill, R.D. Lee, and N.S. Hill. 2017. Optimizing agronomic practices for clover persistence and corn yield in a white clover-corn living mulch system. Agronomy Journal. 109:2025-2032. https://doi.org/10.2134/agronj2017.02.0106.

SAS Institute. 2013. SAS version 9.2. SAS Institute.

Scheaffer, C.C. and K.M. Moncada. 2012. Cropping systems. In. Introduction to agronomy: Food, crops, and environment. Delmar, Clifton Park, NY. p. 339-367.

Teasdale, J.R., C.B. Coffman, and R.W. Mangum. 2007. Potential long-term benefits of no-tillage and organic cropping systems for grain production and soil improvement. Agronomy Journal. 99:1297-1305. https://doi.org/10.2134/agronj2006.0362.

Thaler, E.A., I.J. Larsen, and Q. Yu. 2021. The extent of soil loss across the US Corn Belt. Proceedings of the National Academy of Science. https://doi.org/10.1073/pnas.1922375118.

USDA-ERS. 2025. Fertilizer prices stable at onset of 2025 planting season, below highs of 2021 and 2022. Accessed December 2, 2025.

USDA-NASS. 2024. Mississippi Crop Production. Accessed December 4, 2025.

USDA-NASS. 2025. USDA Crop Production Forecast. Accessed December 2, 2025.

Watson, V.H. and W.E. Knight. 1978. White clover production in Mississippi. Research Bulletin 886. Mississippi Agricultural and Forestry Experiment Station (MAFES). Accessed December 5, 2025.

White, J.A. 2022. Yield summary for perennial clovers and alfalfa. Mississippi Agriculture and Forestry Experiment Station (MAFES). Accessed December 5, 2025.

White, J.A. and R. Lemus. 2015. Alfalfa establishment, performance, and persistence in Mississippi when planted into a bermudagrass sward. American Journal of Plant Sciences. https://doi.org/10.4236/ajps.2015.613224.