Nutrient Return from Plant Litter and Cattle Excretion Grazing on N-Fertilized Grass or Grass-Legume Pastures in North Florida

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Nutrient return from plant litter and cattle excretion grazing on N-fertilized grass or grass-legume pastures in North Florida

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Abstract
Nutrient recycling via plant litter and livestock excreta is an important ecosystem service provided by grasslands. This study determined nutrient return via these pathways in three grazing systems. The experiment was conducted from May to October (2016 and 2017) and treatments were: 1) Nitrogen fertilized bahiagrass (*Paspalum notatum* Flügge) pastures (112 kg N ha^{-1}) during the warm-season, overseeded with a mixture (56 kg ha^{-1} of each) of 'FL 401' cereal rye (*Secale cereale*, L.) and 'RAM' oat (*Avena sativa*, L.) during the cool-season (BGN); 2) Ecoturf Rhizoma peanut (*Arachis glabrata* Benth.)/bahiagrass pastures during the warm-season, overseeded with similar rye/oat mixture fertilized with 34 kg N ha^{-1} plus a mixture of clovers (*Trifolium incarnatum* L., *T. pretense* L., and *T. nigrescens* L.) during the cool-season (BGRP); 3) unfertilized bahiagrass pastures during the warm-season, overseeded with similar rye/oat grass/clover mixture + 34 kg N ha^{-1} during the cool-season (BG). Litter mass was evaluated every 5wk. Litter decomposition was evaluated with incubation periods of 0, 2, 4, 8, 16, 32, 64, 128, and 256 days. Urine and fecal samples were collected for N concentration analysis. There was a net return of 47 kg N ha^{-1} season^{-1} via litter in all three systems without differing among them. In addition, litter decomposition rates were not different in the three systems. Conversely, N returned via excreta (urine and feces) was greater (63, 27, and 51 kg N ha^{-1} season^{-1}) than that returned via litter (58.6, 41.6, and 41.2 kg ha^{-1} season^{-1}). When assessing the proportions of N returning to the system via litter or excreta, no differences were observed among treatments, and on average 65.1 % of the N returned via excreta vs. 34.9 % returning via litter. The introduction of legumes could reduce the inputs from N fertilizers in grazing systems and keep the productivity similar because of more efficient N cycling.

Introduction
Nutrient cycling is an important supporting ecosystem service in grasslands and may possibly be affected by the type of forages, as well as management aspects such a stocking rate and N fertilizer application. Different grazing strategies can affect the size of nutrient pools such as C, N, P, and S in the ecosystem (Piñeiro et al., 2009). One of the most limiting nutrients in grasslands is N, and forage legumes might provide an alternative source of N, given their ability for biological N_2 fixation (BNF), providing greater nutritive value for cattle, when compared with C4 grasses (Muir et al., 2011). Through the southeastern United States, bahiagrass (*Paspalum notatum*) is among the most widely perennial planted pastures, providing sufficient forage for beef cattle from spring to early autumn (Chambliss and Sollenberger, 1991). Bahiagrass is relatively more capable of tolerating heavy, continuous stocking, which often results in stand loss in other forage species (Sollenberger et al., 1988). Properly managing bahiagrass pastures, which includes adjusting the stocking rate according to the herbage mass and appropriate fertilizer application, increases the efficiency of nutrient cycling with little potential for negative impact on the environment (Sigua & Hubbard, 2010). Furthermore, integrating forage legumes into grazing systems provides alternatives to reduce dependency on commercial N fertilizer and to enhance nutrient cycling in grasslands. Rhizoma peanut (*Arachis glabrata*) is a warm-season perennial legume that is well adapted to Florida and the US Gulf Coast region. Planting rhizoma peanut in strips into existing warm-season grass pastures has been advocated as an alternative method for its incorporation (Castillo, et al., 2013). The two major pathways of nutrient return in grazing systems are litter and excreta (Dubeux, et al., 2014). Plant litter is generally defined as the above-and belowground plant residues that undergoes partial decomposition and transformation by physical, chemical, or biological processes (Cotrufo et al., 2015). Establishing grass-legume mixtures is a practical way to increase plant litter quality, thus enhancing nutrient cycling and nutrient turnover during litter mineralization (Dubeux et al., 2007). The overall objective of this study was to estimate the N returns via plant litter and excreta in three grazing systems. We hypothesized that inclusion of legumes will result in more efficient N cycling than in the N-fertilized system.

Methods and Study Site

The grazing experiment was conducted at the University of Florida, North Florida Research and Education Center (NFREC) located in Marianna, FL (30°52'N, 85°11' W, 35 m a.s.l.). The perennial pastures were planted in 2014. Treatments consisted of three year-round forage systems. The first system (BGN) included N-fertilized (112 kg N ha^{-1} yr^{-1}) 'Argentine' bahiagrass pastures during the warm-season, overseeded with a mixture (56 kg ha^{-1} of each) of 'FL 401' cereal rye and 'RAM' oat during the cool-season with a second application of 112 kg N ha^{-1} yr^{-1}. Total annual fertilization for this treatment was 224 kg N ha^{-1} yr^{-1}. System 2 (BGRP) included 'ecoturf' rhizoma peanut and bahiagrass pastures during the warm-season, overseeded with a similar rye-oat mixture, fertilized with 34 kg N ha^{-1} plus a mixture of clovers (16.8 kg ha^{-1} of 'Dixie' crimson, 6.7 kg ha^{-1} of 'Southern Belle' red, and 3.4 kg ha^{-1} of 'ball' clover) during the cool season. System 3 (BG) included unfertilized bahiagrass pastures during the warm-season, overseeded with a similar rye-oat and clovers mixture than system 2, fertilized with 34 kg N ha^{-1} during the cool season. Pastures were continuously stocked with variable stocking rate. Two tester Angus crossbreed steers (*Bos* sp.) remained on each pasture throughout the season. Cattle of similar age, weight, and breed were allocated as needed to maintain similar herbage allowance (HA) among treatments, which was assessed every 14 d according to the methodology described by Sollenberger et al. (2005). Water, shade, and minerals were provided. Fecal and Urine samples were collected for posterior analysis of N concentration through the Dumas dry combustion method, using a Vario Micro Cube (Elementar, Hanau, Germany), after samples were ball milled using a Mixer Mill MM400 (Retsch, Haan, Germany) at 25 Hz for 9 min. Treatments were replicated three times in a randomized complete block design, and each pasture was considered the experimental unit. Litter was collected and incubated within each treatment having two replicated sampling units for each time point, and each pasture remaining as the experimental unit. The incubation times were 4, 8, 16, 32, 64, 128, and 256 d. The litter bags were placed on the ground, in sets of six (one for each incubation time), at two different locations within each pasture, and covered with existing litter from the given experimental unit. After each incubation period, all bags were dried in a forced-air oven at 55°C to a constant weight and N was analyzed through the Dumas dry combustion method. The Mixed Procedure of SAS (SAS Inst., Cary, NC) was used, and the model included the fixed effects of treatment, block and year were considered random effects.

Results

Herbage allowance during the warm season of 2016 and 2017 was 1.17, 1.16 and 1.16 kg DM kg LW^{-1} in BGN, BGRP, and BG, respectively (Figure 1). The stocking rate was least in the BGRP system (Figure 1) when compared with the other two systems ($P < 0.01$).

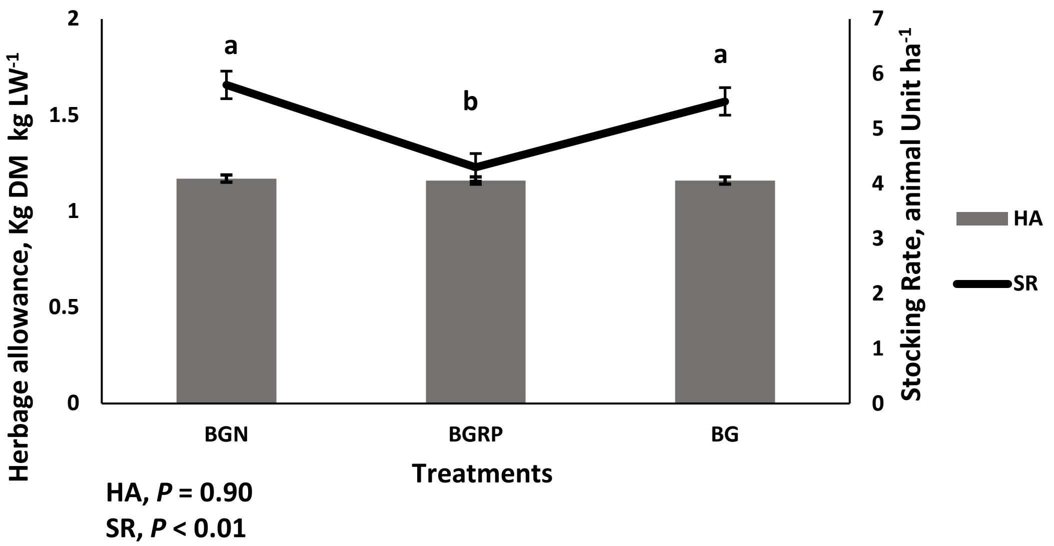

Figure 1. Herbage allowance and stocking rate during the warm season of 2016 and 2017, in three grazing systems.

BGN = bahiagrass with N fertilizer; BGRP = bahiagrass and rhizoma peanut; BG = bahiagrass.
[a,b,c] Means differ, $P \leq 0.05$.

Total N from excreta did not differ among treatments ($P \geq 0.05$) and the N that returned to each system was 59, 42, and 42 kg N ha^{-1} $season^{-1}$ in BGN, BGRP, and BG, respectively. Similarly, the N that returned via litter did not differ among treatments ($P \geq 0.05$) and the N returned was 63, 27, and 51 kg N ha^{-1} $season^{-1}$ in BGN, BGRP and BG, respectively. The proportion of N that return to the system via excreta or litter did not differ among treatments ($P \geq 0.05$). The percentage of N returned via excreta on average was 65.1 % and via litter was 34.9 %.

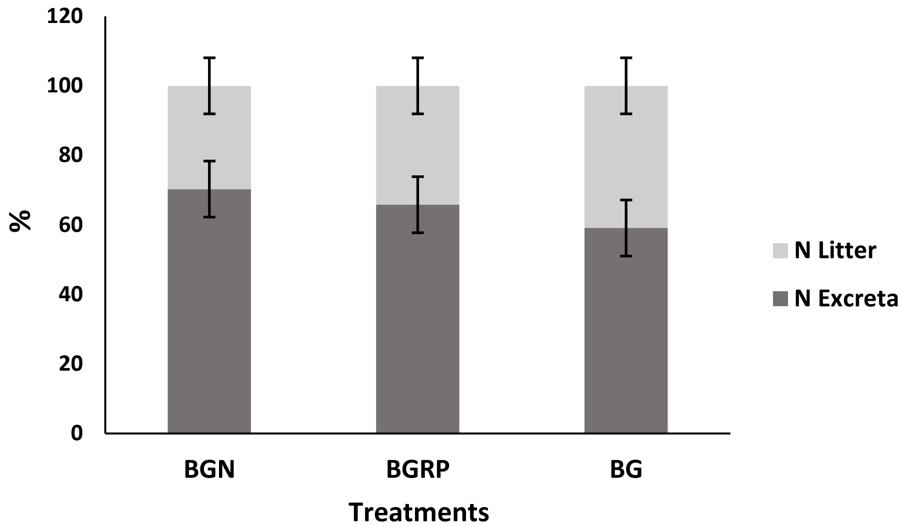

Figure 2. Proportion of N return via excreta and litter during the warm season of 2016 and 2017, in three grazing systems.

BGN = bahiagrass with N fertilizer; BGRP = bahiagrass and rhizoma peanut; BG = bahiagrass.

Discussion and Conclusion

The stocking rate was greater in the two systems with bahiagrass, despite the difference in N fertilization. Stocking rate in the rhizoma peanut was lower during the summer, affecting the annual average. The strip-planting approach used to establish the rhizoma peanut provided opportunity for selection, however, it resulted in overgrazing of the rhizoma peanut strips, reducing its productivity. This finding highlights the importance of forage legumes providing N to the grazing system and replacing inorganic N fertilizer. In grazing systems, one of the major N exchange pathways occur when ruminants graze legumes. The consumed N is transformed, assimilated, and the majority of it returns to the soil via urine and feces (Dubeux, et al., 2007). Animal excreta return nutrient to the soil ranges from 70 to 90% of the total intake (Williams & Haynes, 1990). The proportion of N returning via dung and urine in this study was 65% and the amount of N that return in the grazing system can be significant and often concentrated in certain areas. However, the entry of nutrients is not uniform through the pasture, due to animal behavior and the partitioning of nutrients between feces and urine (Afzal & Adams, 1992). Management strategies such as rotational stocking with short grazing periods are alternatives for a better distribution of the nutrients through the pasture (Sollenberger et al., 2002). The BG systems receiving 34 kg N $ha^{-1}yr^{-1}$ recycled 80% of the N recycled in the grass system receiving 224 kg N $ha^{-1}yr^{-1}$, indicating the potential of forage legumes to add N to grasslands. This also highlights the N losses from N fertilization, that result in lesser amount of N recycled to the pasture. Despite of greater N-fertilizer additions, there was no significant difference in N-returns via plant litter across the three systems. This is indicative of the importance of forage legumes for nutrient cycling in grazing systems (Dubeux et al., 2007). Overall, approximately 2/3 of the N returned via excreta and 1/3 returned via litter. Nitrogen from excreta is more readily available, however, it is more prone to losses and unevenly distributed. Nitrogen from litter is more evenly distributed and decays slowly along the growing season, reducing N losses. Integration of forage legumes into livestock systems result in better quality litter and greater efficiency of N cycling, if compared with inorganic fertilizer (Jaramillo, 2020). In the current study, animal performance was similar for the N-fertilized grass system (224 kg N ha^{-1} yr^{-1}) compared with the grass-legume system using rhizoma peanut and fertilized with only 34 kg N ha^{-1} yr^{-1}. On average, the estimated amount of N recycled in the grass-legume system with rhizoma peanut is 119 kg N ha^{-1} yr^{-1} (Dubeux et al., 2020), and that was similar to 234 kg N ha^{-1} yr^{-1} of N fertilizer. Therefore, on average each 1 kg of N recycled in the grass-legume system was equivalent to approximately 2 kg of N fertilizer (Dubeux et al., 2020). In conclusion the N return via excreta and litter was similar in the three systems indicating that the introduction of legumes could reduce the inputs of N inorganic fertilizers in grazing systems.

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