Grazing Management Affects Establishment Performance of Rhizoma Peanut Strip Planted into Bahiagrass Pasture

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ABSTRACT
Establishing rhizoma peanut (Arachis glabrata Benth.; RP) in strips into existing bahiagrass (Paspalum notatum Flügge) pastures has potential to increase forage nutritive value, decrease N fertilizer use, and improve N cycling. Grazing the grass–legume mixture in the year after planting may be possible, but appropriate grazing management strategies have not been defined. The objectives were to determine (i) the effect of year-after-planting (Y2) grazing management on ‘Florigraze’ RP performance when strip planted in bahiagrass swards, and (ii) the interaction of Y2 defoliation strategies with those imposed in the year of planting (Y1). Treatments were the factorial combinations of four Y1 defoliation strategies (no defoliation, hay production, simulated continuous stocking, and rotational stocking every 28 d) and three Y2 grazing frequencies (simulated continuous, 28 d, and 42 d to a 15-cm bahiagrass stubble height). Grazing pastures in Y2 reduced RP contribution relative to that at the end of Y1. Canopy cover and frequency decreased from 30 to 10% and 80 to 50%, respectively, due to Y2 grazing for both Y1 no defoliation and hay production treatments. Cover remained below 10% in Y2 for both Y1 simulated continuous and rotational stocking treatments. Spread of RP into adjacent bahiagrass was greater in Y2 plots that in Y1 were not defoliated or were used for hay production (~27 cm) than grazed (~0 cm) plots. Results indicate that grazing during Y2 negatively affects RP establishment regardless of grazing frequency or RP cover at the beginning of Y2. Cattle preference for RP resulted in overgrazing; thus, if grazing occurs during RP establishment, target endpoints should be based on RP strips not the surrounding bahiagrass.

RHIZOMA PEANUT is a warm-season perennial forage legume with comparable nutritive value to alfalfa (Medicago sativa L.) (Beltranena et al., 1981; Prine et al., 1981), documented persistence under grazing (Ortega-S. et al., 1992), and ability to compete effectively with perennial grasses in mixed pastures (Williams, 1994). In multiyear studies, weight gain of yearling beef steers (Bos spp.) grazing a RP monoculture was 0.97 kg d−1 (Sollenberger et al., 1989), and 6- to 12-mo-old dairy heifers (Bos taurus) gained 0.6 kg d−1 on pastures that were 90% RP (Hernández Garay et al., 2004). Steer liveweight gain per hectare was 130 kg greater for animals grazing RP compared with N-fertilized (120 kg ha−1 yr−1) bahiagrass pastures (Sollenberger et al., 1989). Greater animal production was attributed to sustained greater crude protein and in vitro digestible organic matter concentrations of RP compared with bahiagrass, especially in the latter half of the growing season (Sollenberger et al., 1989).

In addition to its impact on forage nutritive value and animal response, the capacity of RP and other legumes to fix atmospheric N₂ make them an attractive alternative to inorganic fertilizer as

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a source of N for grasslands (Muir et al., 2011). Thus, use of legumes should improve long-term pasture persistence while maintaining and improving productivity of low-input forage–livestock systems (Thomas, 1995). Ortega-S et al. (1992) evaluated RP persistence under a wide range of residual forage mass after grazing and length of rest interval between grazing events. The authors reported that it was possible to maintain ≥80% RP contribution based on botanical composition by weight across a relatively wide range of rest intervals if RP residual dry matter after a grazing event was at least 1700 kg ha⁻¹ (≥15-cm stubble height).

Planting RP in strips into existing bahiagrass pastures was proposed as a strategy to reduce establishment costs and expand use of RP in low-input grazed grassland systems in the US Gulf Coast region (Castillo et al., 2013a,b). Production of hay during the year of planting promoted establishment of RP compared with either rotational stocking every 28 d or simulated continuous stocking (Castillo et al., 2013a). Entries of RP with decumbent (‘Ecoturf’ and ‘Arblick’) and intermediate (‘Florigraze’) growth habits were noted to have greater potential for establishment ability and spread potential under the strip-planting approach compared with upright types (‘UF Peace’) (Mullenix et al., 2014).

Although establishment of RP in monoculture generally requires two growing seasons (Prine et al., 1986) before intense utilization, there are no data describing the effect of a range of grazing practices in the year following planting of RP in strips in existing bahiagrass pastures. Because producers wish to minimize disruption to their grazing program, research is needed to determine if grazing can be implemented during the year after planting RP in strips. Thus, the current experiment was designed to compare grazing management strategies during the year after planting following imposition of different defoliation practices in the year of planting that resulted in a range of RP cover and frequency. The objectives were to evaluate (i) the effect of the year after planting grazing frequency on RP canopy cover, frequency, spread, and botanical composition when Florigraze RP was strip planted in bahiagrass swards; and (ii) the interaction of the year after planting grazing frequency with defoliation strategies imposed in the year of planting.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted for 2 yr at the University of Florida Beef Research Unit (29°43′ N; 82°21′ W) near Gainesville, FL. Adjacent plot areas were planted in 2010 and 2011 (Castillo et al., 2013a), and the 2010 planting was used for the current experiment in 2011, while the 2011 planting was used for the current experiment in 2012. The soils at the experimental site were classified as Sparr fine sand (loamy, siliceous, subactive, hyperthermic Grossarenic Paleustalfs) and Pomona sand (sandy, siliceous, hyperthermic Ultic Alaquods). Initial characterization of the surface soil (0–15 cm deep) indicated soil pH of 6.2 and Mehlich-1 extractable P, K, and Mg of 43, 46, and 63 mg kg⁻¹, respectively. Based on the recommendations for growth of RP in Florida, the area was fertilized at the beginning of the growing season with 30 kg ha⁻¹ of K, using muriate of potash. Total rainfall was 1029 and 1499 mm in 2011 and 2012, respectively, compared with the 30-yr average of 1238 mm. Greater rainfall in 2012 was due to tropical storm Debby, which provided 300 mm of rainfall in June. The last freeze event in spring occurred on 14 March 2011 and 5 March 2012, and first freeze event at the end of the growing season occurred on 14 Nov. 2011 and 26 Nov. 2012. The timing of freeze events was typical for this location.

Treatments and Experimental Design

The 12 treatments were the factorial combinations of four Y1 defoliation strategies and three Y2 grazing managements. Treatments were allocated in a split-plot arrangement in three replicates of a randomized complete block design. The main-plot factor was Y1 defoliation strategy, and the subplot factor was Y2 grazing management. Each subplot measured 9-m wide and 5-m long. The width of each experimental unit consisted of a 4-m-wide strip planted to Florigraze RP bounded on both sides by 2.5-m-wide strips of well-established bahiagrass sod (>10 yr).

Defoliation strategies for Y1 were described in detail by Castillo et al. (2013a). Briefly, they were (i) control (no defoliation of the planted RP strip with adjacent bahiagrass harvested every 28 d to 10-cm stubble height), (ii) hay production (RP strip and adjacent bahiagrass both harvested every 28 d to 10-cm stubble height), (iii) simulated continuous stocking (pastures grazed weekly to 15-cm bahiagrass stubble height), and (iv) rotational stocking (pastures grazed every 28 d to 15-cm bahiagrass stubble height). The four main-plot treatments were included because they resulted in varying levels of RP contribution by the end of Y1 (RP cover of 8 to 33% and RP frequency of occurrence of 30 to 80%) (Castillo et al., 2013a). This provided opportunity to investigate the effect of grazing management options during Year 2 across a wide range of initial levels of RP.

Year-after-planting grazing management treatments were (i) simulated continuous stocking (same as Treatment 3 from Y1), (ii) rotational stocking with a 28-d rest period (RS-28; equal to Treatment 4 from Y1), and (iii) rotational stocking with a 42-d rest period (RS-42). Grazing ended on a given subplot treatment when bahiagrass sod growing at the edges of the RP strip was monitored frequently using a ruler and animals were removed from the plots when the average height of 10 measures per experimental unit reached 15 cm. Grazing management treatments were chosen based on the study conducted by Ortega-S. et al. (1992).

The methodology used to impose Y2 treatments was mob stocking (Allen et al., 2011), meaning that a high stocking density (four 350-kg animals per plot) was used for a short grazing period (~0.5–1 h). While the animals were grazing, height of the bahiagrass sod growing at the edges of the RP strip was monitored frequently using a ruler and animals were removed from the plots when the average height of 10 measures per experimental unit reached 15 cm. Grazing started on 28 June 2011 and 3 July 2012 when average sward height was 20 cm based on RP and bahiagrass and continued according to the treatment schedule throughout the growing season. There were a total of four and three grazing events per year for RS-28 and RS-42 treatments, respectively.
Response Variables
The effects of Y1 defoliation treatment were tested only in terms of Y2 responses. Thus, all response variables reported were measured in Y2 (2011 for the 2010 planting and 2012 for the 2011 planting). Initial measurements of RP canopy cover and frequency of occurrence were taken on 28 June 2011 (on plots planted in 2010) and 26 June 2012 (on plots planted in 2011), before Y2 treatments were applied.

Canopy Cover and Frequency
Rhizoma peanut canopy cover in the planted strip was estimated visually near midseason of Y2 (August) and at the end of the season (October). A 1-m² quadrat (0.5 by 2 m) was placed in the center of the RP strip at a permanently marked location in each experimental unit so that canopy cover was estimated in the same area over time. The quadrat was divided into 100 10- by 10-cm squares (five rows of 20), and canopy cover was estimated visually by the same observer in 20 stratified 10- by 10-cm squares (four squares in each row of 20 squares) per quadrat and averaged to obtain an overall cover estimate per quadrant location. Frequency of occurrence was a measure of the relative distribution of RP in the strip. It was determined on the same dates and at the same quadrat locations as canopy cover. Presence or absence of RP was determined in 20 stratified 10- by 10-cm squares per quadrant location. Frequency was calculated as the percentage of the total number of cells assessed where RP was present.

Spread
Spread was estimated as the distance from the center of the planted RP strip to the farthest point where identifiable above-ground RP plant parts were found. Spread was determined one time on the day before the last grazing event of the season on 17 and 25 Sept. 2011 and 2012, respectively. A transect was positioned through the center of the RP strip running the length of the plot. At the 1.5- and 3.5-m points along the 5-m transect, a line, perpendicular to the transect, was extended on each side. The average of the four measurements provided an estimate of RP spread for each experimental unit. Because the first and last rows (closest RP rows to the adjacent bahiagrass sod) of RP in the strip were planted 175 cm away from the center of the RP strip, spread values were reported as the difference of estimates of spread minus 175 cm.

Botanical Composition
Botanical composition by weight was defined as the percentage RP of the total biomass harvested. Two 0.25-m² quadrats per plot were clipped to a 15-cm stubble height in the middle of each RP strip near midseason in August and toward the end of the growing season in September in both years (2011 and 2012). The average of the two quadrats provided an estimate for each sampling date. Regrowth of herbage growing in the strip was at least 3 wk old when sampling occurred. Fresh herbage was collected and separated into grass and RP components and dried at 60°C until constant weight. Botanical composition was calculated by dividing weight of the RP component by the sum of the weight of all other herbage plus RP. No botanical composition data were collected from the simulated continuous stocking treatment because RP plants did not reach the 10-cm sampling height.

Bahiagrass Herbage Harvested
Herbage harvested was measured before each grazing event for the two rotational stocking treatments. One 0.25-m² quadrat was clipped to a 15-cm stubble in the bahiagrass portion of the experimental unit. The collected herbage was weighed fresh and dried at 60°C until constant weight to determine dry matter concentration and to calculate herbage harvested. In the simulated continuous stocking treatment, sampling occurred biweekly before the last grazing event. This treatment was sampled more frequently because a cage technique was used to restrict grazing from sampling units and because cages should not remain in one area for an extended period lest forage mass or sward structure become very different than the surrounding pasture. Thus, on simulated continuous stocking pastures, one 0.5-m² circular exclusion cage per plot was positioned at a representative location in the bahiagrass sod. A 0.25-m² area from the center of the caged area was harvested biweekly before grazing. The cages were moved to a new location for the next 2-wk period as soon as grazing was completed. Herbage harvested was not measured in the RP strip because RP plants generally did not reach the target stubble height (15 cm) during Y2.

Statistical Analysis
Data were analyzed using PROC GLIMMIX of SAS (SAS Institute, 2010). Sampling date was considered a repeated measurement with an autoregressive covariance structure. Block and year were considered random effects. Defoliation strategy (Y1 treatments), grazing management (Y2 treatments), and their interactions were considered fixed effects.

Interaction effects were analyzed using the SLICE procedure, and mean separation was based on the PDIFF and SLICEDIFF procedures of LSMEANS using SAS. Plots of model residuals were used to check normality, and in the case of non-normal distributions, data transformations were used. Square root transformation was used for canopy cover and botanical composition data. Treatments were considered different when P ≤ 0.05.

RESULTS AND DISCUSSION
Rhizoma Peanut Canopy Cover
There was no Y1 defoliation strategy × Y2 grazing management interaction effect (P > 0.05). Grazing pastures in Y2 severely reduced RP canopy cover relative to that observed at the end of Y1 regardless of Y2 grazing strategy. There were effects of Y1 defoliation strategy and sampling date on canopy cover (P < 0.001 for both). Canopy cover was greatest and similar across sampling dates for Y1 control and hay production treatments. Sampling date interaction with both Y1 defoliation strategy and Y2 grazing management treatments approached significance (P = 0.06 for both). The interaction effect for Y1 treatments occurred because canopy cover leveled off at 3% by mid-season (P = 0.23 for mid- vs. late season) in Y1 simulated continuous and rotational stocking treatments compared with control and hay production plots where RP cover
continued to decrease until late season (~16% for midseason vs. ~10% by late season; \( P < 0.01 \)) (Fig. 1).

Rhizoma peanut canopy cover for Y2 grazing management treatments decreased from an initial level of ~15% to 5% by late season for all treatments. The Y2 treatment \( \times \) sampling date interaction occurred because canopy cover was greater in midseason compared with late season (9 and 5%, respectively) for RS-42, while it leveled off by midseason for simulated continuous stocking and RS-28 treatments (Fig. 1). For all Y2 treatments, cattle first grazed the planted RP strip close to soil level before initiating grazing of adjacent bahiagrass, resulting in the observed decrease of RP contribution in the grass–legume mixture over time. Lower canopy cover in grazed plots compared with hayed and nondefoliated plots was reported for strip-planting RP (Castillo et al., 2013a; Mullenix et al., 2014). Those experiments evaluated up to 28-d rest intervals between grazing events for strip-planted swards. We hypothesized that more lenient grazing, represented by RS-42, would provide superior RP cover, but this did not occur because of selective grazing of RP strips by cattle leading to very low stubble heights in the planted strip.

**Rhizoma Peanut Frequency**

Frequency was affected by Y1 defoliation strategy and sampling date. In addition, sampling date by Y1 defoliation strategy approached significance (\( P = 0.06 \)). Frequency followed a similar pattern of response as RP canopy cover, with Y1 control and hay production treatments being similar (71 and 67% averaged over sampling dates, respectively) and greater than simulated continuous (25%) and rotational stocking (25%). Frequency of RP decreased (\( P < 0.05 \)) from 78 to 53% in the Y1 control and from 79 to 54% in the Y1 hay production treatment from early to late season of Y2, respectively; while for simulated continuous and rotational stocking, frequency remained below 31% all season (Fig. 2). The sampling date by Y1 defoliation strategy interaction approached significance because frequency decreased for Y1 hay and control treatments compared with either of the Y1 grazing treatments. Similar responses for grazed plots compared with hayed plots were observed by Castillo et al. (2013a) and Mullenix et al. (2014). Late-season RP frequency was ~20% for plots grazed in both Y1 and Y2, and these values are similar to those reported by Castillo et al. (2013a).
continuous stocking have been reported previously and have been attributed to longer intervals between defoliation events and associated greater average leaf area index and uniformity of grazing height for rotationally stocked pastures (Stewart et al., 2005; Sollenberger et al., 2012).

**Botanical Composition**

There were effects of Y1 defoliation strategy, Y2 grazing management, and interaction of Y2 grazing management with sampling date. The RP component of the harvested forage was ≤11% during the growing season. Year 1 defoliation strategy responses segregated in pairs; Y1 control (10%) and hay production (11%) treatments were similar and both treatments were greater than Y1 simulated continuous and rotational stocking (7 and 8%, respectively). The interaction of Y2 grazing management with sampling date occurred because during midseason RP in the harvested forage was greater in RS–42 (10%) than RS–28 (2%), while there was no difference in late season (~5% for both treatments) (Table 1). The reason for the slight increase in RP contribution from mid- to late season for RS–28 is not known. Similar to canopy cover and frequency responses, lack of interaction of Y1 by Y2 treatments indicates that irrespective of the initial condition of RP due to defoliation strategy during Y1, grazing in Y2 reduced RP contribution to ~5% by the end of the season.

**Spread**

There were Y1 defoliation strategy effects on spread when measured at the end of Y2. Spread of RP in Y1 control and Y1 hay production treatments was not different (23 and 31 cm, respectively), and both treatments were greater than both Y1 rotational and simulated continuous stocking (Fig. 3). In the latter treatments, the RP rows closest to the bahiagrass sod were lost, reducing the potential for RP spread into the existing bahiagrass pasture. Similar results were reported by Castillo et al. (2013a). Defoliation management during Y1 determined the potential of RP to spread in Y2, but there were no differences in spread among Y2 grazing management treatments.

**Bahiagrass Herbage Harvested**

There were Y2 grazing management effects on bahiagrass production. Herbage accumulation from RS–28 and RS–42 was similar (~1.5 Mg ha yr⁻¹) and greater than simulated continuous stocking (~1.3 Mg ha yr⁻¹). Similar trends for greater herbage accumulation in rotational vs. continuous stocking have been reported previously and have been attributed to longer intervals between defoliation events and associated greater average leaf area index and uniformity of grazing height for rotationally stocked pastures (Stewart et al., 2005; Sollenberger et al., 2012). Bahiagrass herbage accumulation was low in the current study because no N fertilizer was applied.

**SUMMARY AND CONCLUSIONS**

Hay production or no defoliation of the RP-planted strip during Y1 resulted in greater Y2 RP canopy cover, frequency, and spread than when the RP strip was grazed during Y1. However, grazing during Y2 reduces and may override the potential positive effects of the previous year’s management strategy because of preference of grazing animals for herbage in the RP–bahiagrass strip over the adjacent bahiagrass. Greatest success of strip-planted RP in bahiagrass may be achieved if the swards are not grazed for at least 2 yr. If grazing does occur during the first 2 yr after planting, grazing management targets for the endpoint of grazing should focus on the strip planted to RP as opposed to the bahiagrass component of the pasture. Based on the data of Ortega-S. et al. (1992), cattle should be removed when the RP planted strip is grazed to a height of 15 to 20 cm. Once RP is established, less stringent attention to grazing management of the mixture is possible, as RP has persisted for more than 30 yr in mixed pastures with bermudagrass [Cynodon dactylon (Pers.) L.] and bahiagrass (Sollenberger et al., 2014).

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