Canopy characteristics and growth rate of bahiagrass monoculture and mixtures with rhizoma peanut

Caram, N.*; Sollenberger, L. E.*, Wallau, M. O.*, Wilson, C. H.*
* University of Florida, Gainesville.

Key words: grass-legume mixtures; grazing management; leaf area index; light interception; radiation use efficiency.

Abstract

Understanding relationships among canopy light interception (LI), canopy height and structure, and leaf area index (LAI) informs management decisions and can improve efficiency of forage-livestock systems. In a long-term experiment in Florida, USA, we assessed the LI, LAI and sward height relationships of rhizoma peanut (*Arachis glabrata* Benth., RP)-bahiagrass (*Paspalum notatum* Flügge) mixed swards compared with bahiagrass monoculture to determine whether changes in canopy structure affect herbage accumulation (HA) rate due to changes in radiation use. Treatments were arranged in a semi-factorial, split-plot design (r=4). Bahiagrass monoculture and bahiagrass-RP mixtures were whole-plot treatments. Sub-plot treatments were an undefoliated control, forage clipped to 5 cm when LAI > 3, and forage clipped to 5 cm when LAI > 3 and fertilized immediately after with 20 kg N ha^{-1}. During 2021, LI, LAI and canopy height were measured weekly using a LiCOR LAI-2200 and a rising plate meter (platemeters g1000), respectively. The proportion of bahiagrass and RP in total herbage mass was determined for each treatment in July 2021. Herbage accumulation rate was calculated as HA during the regrowth period divided by days between clipping events. The relationship of LI and LAI was assessed with a negative exponential model. Relationships of cumulative LAI and sward height and days after clipping were determined using regression analysis. Incorporating RP into bahiagrass increased LI at shorter sward height compared with bahiagrass monoculture due to a greater LAI mm^{-1} of sward height (190-220 vs. 150-160 mm). Fertilized mixtures achieved LAI_{95} faster than bahiagrass monoculture, however, changes in mixture canopy structure did not result in greater radiation-use efficiency compared with fertilized bahiagrass monoculture. Herbage accumulation rate decreased for mixtures containing more than 30% RP. Application of this information can improve the efficiency of grazing systems and maximize HA of bahiagrass-RP mixtures, either under rotational or continuous stocking.

Introduction

Recent research on rhizoma peanut (*Arachis glabrata* Benth.) and bahiagrass (*Paspalum notatum* Flügge) mixed pastures has revealed benefits of legume introduction compared with bahiagrass monoculture. The benefits include increased forage nutritive value, animal performance, and nitrogen cycling (Kohmann et al. 2018, Garcia et al. 2021, Jaramillo et al. 2021). Rhizoma peanut and bahiagrass have a similar decumbent to moderately erect growth habit and possess rhizomes. However, their photosynthesis pathway and canopy architecture are different and could affect the response to grazing management, as well as photosynthetic rate, leaf area, herbage bulk density and animal performance (Sollenberger and Burns 2001).

The greatest herbage accumulation rate for some forage species is thought to occur when the pasture is intercepting 95% of photosynthetically active radiation (PAR) (Brougham 1956). At this point, greater herbage accumulation is associated with a greater proportion of leaf and lesser proportion of dead material (Da Silva et al. 2015). Furthermore, herbage accumulation is often positively correlated with light interception and pasture height, the latter indirectly associated with the LAI (Vendramini et al. 2013). The canopy height and consequently the LAI at which the pasture intercepts 95% of PAR has been suggested as a criterion for ending the rest period of rotationally stocked pastures, or for determining the tallest height of continuously stocked pastures (Da Silva et al. 2015). It has also been suggested that animals be removed from rotationally stocked pastures when the canopy height is 40-50% that which was present when animals entered the paddock. These criteria may optimize herbage regrowth (Da Silva et al. 2015, Mullenix et al. 2016), improve pasture persistence (Ortega et al. 1992), and maximize instantaneous intake rate (Carvalho, 2013).

Therefore, species having different canopy architecture, leaf angle, canopy light extinction coefficients and radiation use efficiency, such as bahiagrass and rhizoma peanut, could intercept 95% of photosynthetically active radiation at different heights and points in a regrowth cycle. Consequently, this could affect the optimal grazing management of a mixture of these forages depending upon the proportion of each species in the mixture. Greater proportion of rhizoma peanut could be associated with a lesser sward height-LAI necessary to intercept 95% of PAR and lesser radiation use efficiency. Further, 95% LI may occur earlier in a regrowth cycle for the mixture than for bahiagrass monoculture, affecting the grazing management to optimize herbage accumulation. To improve the efficiency of grazing and maximize pasture growth rate, greater understanding is needed of the relationships among canopy LI, sward height, canopy structure, and LAI of bahiagrass-rhizoma peanut mixtures compared with bahiagrass monoculture. Here we assessed the effect of legume introduction into bahiagrass monoculture on LI, LAI and sward height relationships and addressed whether changes in canopy structure affect herbage accumulation rate due to changes in radiation use efficiency.

Methods

The experimental site is a long-term pasture in Gainesville, FL (29.72 N°, 82.35°W) arranged in semi-factorial, split-plot design with four replicates. Bahiagrass monoculture and bahiagrass-rhizoma peanut mixture were the whole-plot treatments. Sub-plot treatments were (1) an undefoliated control receiving no N fertilizer, (2) forage clipped to 5 cm when LAI > 3 and receiving no N fertlizer, and (3) forage clipped to 5 cm when LAI > 3 and fertilized immediately thereafter with 20 kg N ha^{-1} as ammonium nitrate. Each experimental unit was 1 m^2. During 2021, LI and LAI were measured weekly using a LiCOR LAI-2200, while the sward height was measured 5 times in each experimental unit using a rising plate meter (platemeters g1000). The proportion of bahiagrass and rhizoma peanut in total herbage mass was measured in each experimental unit in July 2021. The herbage accumulation rate was estimated for each experimental unit as herbage accumulated divided by number of days between clipping events.

The relationship of LI and LAI was assessed with a negative exponential model for each treatment, using *NLS.negExp* function in R. The relationships of cumulative LAI and sward height, and cumulative LAI and days after clipping were estimated using regression analysis. The differences between treatments were tested using *emtrends* in R ($\alpha = 0.05$). The herbage accumulation and radiation use efficiency were tested for treatments using ANOVA ($\alpha = 0.05$). All analyses were developed in R 4.2.1 (R Core Team).

Results and Discussion

The LI and LAI relationship fit a negative exponential curve for all pastures, as demonstrated by Brougham (1956). The LAI at which pastures intercepted 95% of incident light (LAI_{95}) ranged from 4.4 in bahiagrass monoculture, when clipped and fertilized, to 5.2 in the mixed control (Figure 1). However, the bahiagrass control achieved LAI_{95} at taller sward height (190-220 mm, LAI = 0.025 mm^{-1} of sward height) compared with the mixed control and clipped and fertilized mixture (150-160 mm; LAI = 0.037 mm^{-1} of sward height; $P < 0.05$). This difference in canopy height at LAI_{95} is likely due to differences in vertical distribution of species throughout the canopy and differences in leaf angle (Sinclair and Muchow, 1999). This confirms the hypothesis that both species have different canopy architecture and achieve the same LAI at different height.

Assessing the cumulative LAI response to days of regrowth, we found that mixed, fertilized pastures achieved LAI_{95} in fewer days following clipping to 5 cm than mixed, unfertilized pastures and bahiagrass monoculture pasture (Figure 2). The hypothesis is confirmed that differences in canopy structure of bahiagrass and rhizoma peanut could affect grazing management criteria based on LAI_{95} (Da Silva et al., 2015). The introduction of rhizoma peanut in bahiagrass pastures requires more frequent defoliation, i.e., fewer days of rest compared with bahiagrass monoculture, when grazed down to 5 cm. The difference in regrowth days among mixed and monoculture pastures was of 31 (83 vs. 52 days) and 16 days (48 vs. 32 days) for cut and cut + fertilized pastures, respectively (Table 1).

Although 95% LI occurred earlier in a regrowth cycle for mixed pastures compared with bahiagrass, it did not result in increased radiation use efficiency and herbage accumulation rate (Sinclair and Muchow, 1999). Conversely, there was only a significant effect of pasture management (undefoliated, clipped, and clipped and fertilized; $P < 0.001$). The greatest herbage accumulation rate occurred under clipped and fertilized pastures (39.3 kg DM ha^{-1} day^{-1}); it was intermediate for undefoliated pastures (27.8 kg DM ha^{-1} day^{-1}) and least for clipped pastures and unfertilized pastures (20.4 kg DM ha^{-1} day^{-1}). The radiation use efficiency was greater for clipped and fertilized pastures (0.39 g DM MJ^{-1}) compared with undefoliated and clipped pastures (0.21 and 0.24 g DM MJ^{-1}, respectively, as demonstrated by Sinclair and Muchow, 1999). Finally, when considering only the proportion of rhizoma peanut in each of the pastures, it appears that the herbage accumulation rate and radiation use efficiency decreased for mixtures with more than 30% legume. This suggests the inclusion of a C3 legume in mixture with a C4 grass may provide benefits in terms of nutritive value and efficiency of N use (Kohmann et al. 2018, Garcia et al. 2021, Jaramillo et al. 2021) without necessarily decreasing radiation use efficiency and herbage accumulation. However, legume proportion is important, and in the current study when legume proportion exceeded 30%, radiation use efficiency and primary production of mixtures were compromised.

Conclusions

Our results suggest that incorporating rhizoma peanut into bahiagrass monoculture increased LI at shorter sward height due to a denser canopy and greater LAI per mm of sward height. When fertilized with N, mixtures achieved LAI_{95} faster compared with bahiagrass monocultures. However, these changes in canopy structure did not result in greater herbage accumulation rate and radiation use efficiency compared with fertilized bahiagrass monoculture. Changes in herbage accumulation rate and radiation use efficiency were due to management practices, such as defoliation and fertilization, but not due to botanical composition. The application of this information can improve the efficiency of grazing systems and maximize herbage accumulation rate, either under rotational or continuous stocking of bahiagrass-rhizoma peanut mixtures. The well-known positive effects of incorporating rhizoma peanut, a C3 species, into bahiagrass monoculture, a C4 species, not compromise the radiation use efficiency and herbage accumulation of mixtures compared with bahiagrass monocultures.

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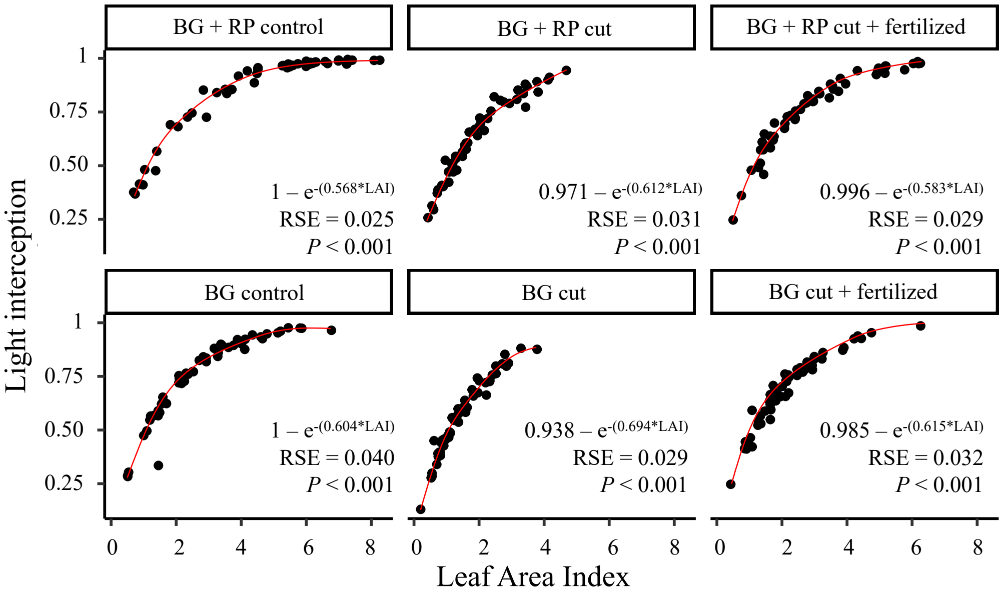

Figure 1 Negative exponential equation of light interception in relation to leaf area index for bahiagrass monocultures (BG) and BG-rhizoma peanut (RP) mixtures that were undefoliated and not fertilized with N, clipped to 5 cm and not fertilized with N, and clipped to 5 cm and fertilized with N.

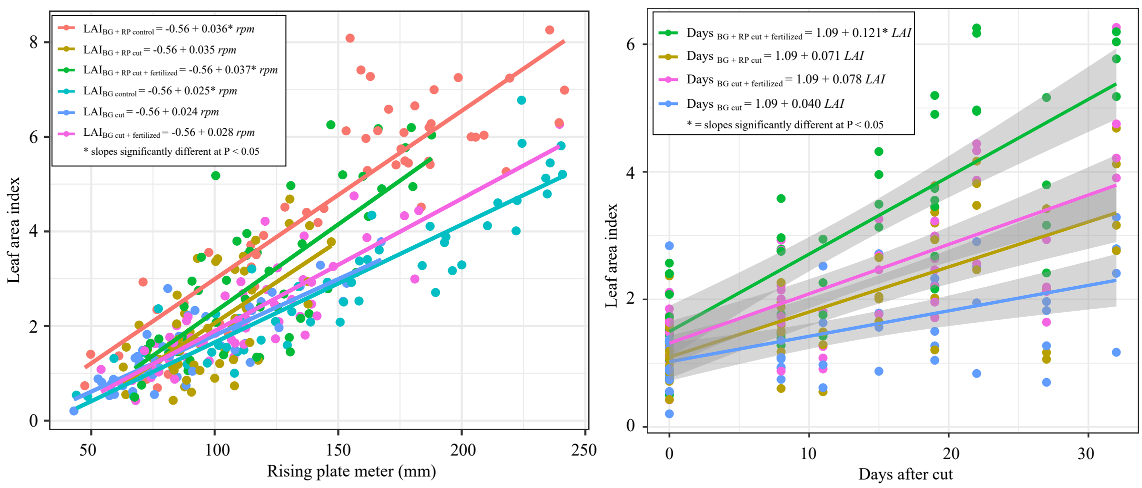

Figure 2 Leaf area index in relation to rising plate meter height for bahiagrass monocultures (BG) and mixtures with rhizoma peanut (RP) that were undefoliated and not fertilized with N, clipped to 5 cm and not fertilized with N, and clipped to 5 cm and fertilized with N (left panel). Leaf area index in relation to days after cutting for BG and BG-RP mixtures clipped to 5 cm and not fertilized with N or clipped to 5 cm and fertilized with N (right panel).

Table 1 Leaf area index at 95% canopy light interception (LAI_{95}), rising plate meter (RPM) at LAI_{95}, and regrowth days to LAI_{95} for bahiagrass monocultures (BG) and mixtures of BG with rhizoma peanut (RP) when undefoliated and not fertilized with N, clipped to 5 cm and not fertilized with N, or clipped to 5 cm and fertilized with N.

Treatment	LAI_{95}	RPM at LAI_{95}	Days to LAI_{95}
BG + RP control	5.2	160	-
BG + RP cut	4.8	153	52
BG + RP cut + fertilized	5	150	32
BG control	4.9	220	-
BG cut	4.4	200	83
BG cut + fertilized	4.8	190	48