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Presenter Information

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Animal Performance in signalgrass monoculture or in silvopastoral Systems

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Abstract: Silvopastoral systems (SPS) can increase overall productivity and long-term income due to the simultaneous production of trees, forage, and livestock. This 2-yr study evaluated animal performance and herbage responses in C4-grass monoculture or in SPS in the sub-humid tropical region of Brazil. The experimental design was randomized complete block with three replications. Treatments were: *Urochloa decumbens* (Stapf.) R. Webster (Signalgrass) + *Mimosa caesalpiniifolia* Benth (SPS-Mimosa); Signalgrass + *Gliricidia sepium* (Jacq.) Kunth ex Walp (SPS-Gliricidia); and Signalgrass monoculture (SM). Response variables included herbage and livestock responses. Cattle were managed under continuous stocking with variable stocking rate. There was interaction between treatment × month for herbage mass. Green herbage accumulation rate ranged from 20 to 80 kg DM $ha^{-1}d^{-1}$ across months, with SPS-Mimosa presenting lower rates. Average daily gain was greater in SPS-Gliricidia, followed by SM, and SPS-Mimosa, respectively (0.77; 0.56; 0.23 kg d^{-1}), varying across months. Stocking rate ranged from 0.86 to 1.6 AU ha^{-1}. Total gain per area during the experimental period was greater for SPS-Gliricidia (423 kg BW ha^{-1}), followed by signalgrass in monoculture (347 kg BW ha^{-1}), and SPS-Mimosa (50 kg BW ha^{-1}). Silvopasture systems using signalgrass and gliricidia enhanced livestock gains compared with signalgrass in monoculture, and mimosa trees outcompeted signalgrass, reducing livestock gains. Silvopasture systems with tree legumes have potential to provide numerous ecosystem services and reduce C footprint of livestock systems in the tropics, however, the choice of tree species is key and determined by which ecosystem service is prioritized.

Introduction

Integrating trees into grasslands is an option to increase sustainability of livestock systems. Benefits of SPS include the delivery of more ecosystem services from different categories such as provisioning, regulating, supporting, and cultural services (Dubeux et al., 2017a). Grazing animals in SPS improve nutrient cycling because of faster nutrient turnover and soil organic carbon (Wesp et al., 2016), increasing soil carbon stock (Aryal et al., 2019), and leading to a more efficient land use (Dubeux Jr et al., 2017b). Further benefits include decreased greenhouse gas emissions, such as nitrous oxide and methane (Foley et al., 2011), and the additional source of income to producers coming from livestock (Esperschuetz et al., 2017). Numerous challenges occur when incorporating trees into grassland systems due to interactions among their components (e.g. trees, herbaceous vegetation, soil, and livestock). Growth of tree canopies reduces light reaching the understory, affecting forage physiology and morphology (Nascimento et al., 2019). These changes in the light environment will act directly on forage production, nutritive value, and livestock responses (Geremia et al., 2018).

We hypothesized that SPS with tree legumes promote animal performance by providing better quality forage and adding N to the system compared with grass monoculture, however, these responses vary with SPS and season of the year. The objective of this research was to evaluate pasture canopy structure and livestock responses in SPS and in grass monoculture in a sub-humid tropical region in Brazil.

Methods and Study Site

The study was carried out at the Experimental Station of Itambé (7°23' S and 35°10' W and 190 m above sea level), Agronomic Institute of Pernambuco-IPA. The soil in the experimental area is classified as an Ultisol (Apolinário et al., 2016). Average annual rainfall is 1200 mm and annual average temperature is 25°C. Treatments consisted of two SPS and one grass monoculture, as follows: 1. Signalgrass (*Urochloa decumbens* Stapf) + Mimosa [*Mimosa caesalpiniifolia* Benth]; 2. Signalgrass + Gliricidia [*Gliricidia sepium* (Jacq.) Kunth ex. Walp]; 3. Signalgrass monoculture. Treatments were allocated in a randomized complete block design, with three blocks (n = 12). Each experimental unit (paddock) had 1 ha and 14 double rows of tree legumes. Tree spacing in the double-row system was 15 x 1.0 x 0.5 m. Signalgrass herbage mass was determined using the double-sampling technique, described by Haydock and Shaw (1975). Briefly, every 28 days, direct measurements were obtained by harvesting six 0.25-m^2 quadrats per paddock, at ground level. Indirect measurement, the average canopy height, was measured using a sward stick (Barthram et al., 2000) at 60 random points, every 28 days. The average of these 60 scores was used in the regression equation to estimate herbage mass. After harvesting, green and dry material were separated per treatment. Grass samples were separated into stem (green and dry) and leaf blade (green and dry). Forage samples were oven-dried at 55°C for 72 h to a constant weight. Herbage mass (kg ha^{-1}) was expressed as total herbage mass (dry and green fractions) and green herbage mass (green fraction only). Green herbage accumulation rate (GHAR) was determined by placing four exclusion cages (1 m^2; 1 x 1 m) within each paddock. Cages were placed on sites representing the average pasture structure and relocated every 14 days to a new location within the paddock. Canopy bulk density (CBD) of signalgrass was expressed in kg DM ha^{-1} cm^{-1} and it was obtained by dividing the green herbage mass by the average canopy height measured with a ruler. A minimum of two crossbred Holstein x Zebu (193±70 kg) steers grazed paddocks under continuous stocking with variable stocking rate. Cattle were weighed every 28 days after a 12-h fasting period. Stocking rate adjustment was performed every 28 days adopting the method described by Sollenberger et al. (2005). Briefly, herbage allowance was adjusted based on green herbage mass (on a DM basis) and cattle body weight (BW), with target herbage allowance of 3 kg green DM kg^{-1} BW. Gain per area was estimated by multiplying ADG by the stocking rate and time interval between sampling dates. Cattle were weighed every 28 days after a 12-h fasting period. Animal performance was evaluated by assessing the average daily gain (ADG), estimated by the weight difference of the testers at the beginning and at the end of each cycle. Stocking rate was calculated based on the number of grazing days, estimated by multiplying the number of tester and "put and take" animals within each grazing cycle of 28 days. The data were submitted to statistical analysis using the Mixed procedure of the statistical package SAS 9.4 (2012).

Results

Average total herbage mass for signalgrass in monoculture was 3496 kg DM ha^{-1}, and average total HM for both SPS was 2266 kg DM ha^{-1}. Likewise, average green herbage mass of signalgrass monoculture was 2106 kg DM ha^{-1}, which was greater ($P \leq 0.05$) than the SPS treatments, which averaged 1305 kg DM ha^{-1}. Treatment × month interaction occurred for canopy green fraction, proportion of green leaf and green stem (Table 1), and for CP concentration of these plant fractions in signalgrass (Table 2). Steer ADG for these two systems was always greater than SPS-Mimosa (Table 3).

Table 1. Canopy green fraction and proportion of leaf blade and stem in the green fraction during the experimental period. Data averaged across replications and years.

Treatments*	Canopy green fraction (g kg^{-1})							
	Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**
Signalgrass†	740 aAB	780 aA	677 aABC	562 aCD	505 aD	497 aD	557 aD	605 aBC
SPS-Gliricidia	778 aA	763 aAB	667 aBC	552 aCD	463 aD	475 aD	477 aD	617 aC
SPS-Mimosa	805 aA	807 aA	655 aB	542 aBC	428 aC	468 aC	480 aC	618 aB
SEM	-- 25 --							
	Proportion of leaf and stem in the canopy green fraction							
	Leaf Blade (g kg^{-1})							
Signalgrass	662 abA	652 abA	594 aAB	498 abBC	425 abCD	534 bBC	333 aD	323 bD
SPS-Gliricidia	742 aA	734 aA	612 aB	516 aBC	458 aCD	495 bBC	356 aD	515 aBC
SPS-Mimosa	588 bB	605 bAB	546 aBC	432 bCD	322 bD	300 aA	200 bE	350 bD
SEM	-- 24 --							
	Stem (g kg^{-1})							

Signalgrass	338 abD	348 abD	406 aCD	502 abBC	575 abB	434 aC	667 bA	677 aA
SPS-Gliricidia	258 bE	266 bE	388 aD	484 aC	542 bB	505 aBC	644 bA	485 bC
SPS-Mimosa	412 aDE	395 aE	454 aD	568 bC	678 aB	700 bF	800 aA	650 aB
SEM	-- 15 --							

†Means followed by the same lowercase letters in the columns (treatments) and upper case letter within rows (sampling dates), within each response variable (leaf blade or stem), do not differ by Tukey test (P≤0.05). *Signalgrass in monoculture; SPS: silvopastoral systems. SEM = standard error of mean.

Table 2. Crude protein of green fractions (leaf blade and stem) during the experimental period. Data averaged across replications and years.

Treatments*	**Crude protein (CP) of canopy green fractions**							
	Leaf CP (g kg^{-1})							
	Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**
Signalgrass†	65 aAB	68 aAB	69 aA	63 abB	50 bC	52 bC	52 aC	51 bC
SPS-Gliricidia	70 aAB	72 aA	69 aABC	69 aABC	62 aBCD	62 aD	58 aD	62 aCD
SPS-Mimosa	54 bA	57 bA	58 bA	56 bA	62 aA	52 bA	53 aA	51 bA
SEM	-- 5 --							
	Stem CP (g kg^{-1})							
Signalgrass	10 bABC	15 aA	14 aAB	10 aABC	9 aBC	10 aABC	8 aC	10 aBC
SPS-Gliricidia	15 aA	13 aAB	13 aAB	11 aAB	11 aAB	9 aB	10 aB	11 aAB
SPS-Mimosa	12 abAB	13 aA	14 aA	8 aB	10 aAB	10 aAB	10 aAB	10 aAB
SEM	--- 1 --							

†Means followed by the same lowercase letters in the columns (treatments) and upper case letter within rows (sampling dates), within each response variable (leaf blade or stem), do not differ by Tukey test (P≤0.05). *Signalgrass in monoculture; SPS: silvopastoral systems. SEM = standard error of mean.

Table 3. Livestock responses during 2-yr experiment comparing silvopastoral systems using tree legumes with Signalgrass monoculture.

	Herbage Allowance (kg DM kg^{-1} BW)							
	Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**
Signalgrass†	3.1 aA	3.1 aA	3.0 aA	3.0 aA	3.0 aA	2.9 aB	3.0 aA	3.0 aA
SPS-Gliricidia	3.2 aA	3.1 aA	3.0 aA	3.0 aA	2.9 aA	2.9 aA	3.0 aA	3.0 aA
SPS-Mimosa	3.0 bA	2.9 bAB	2.4 bB	2.3 bC	---	---	---	---
SEM	----------------------- 0.02 ----------------------				--------------------- 0.04 ----------------------			
	Average daily gain (kg head^{-1} d^{-1})							
	Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**
Signalgrass†	0.93 aA	0.94 bA	0.52 aAB	0.38 aB	0.40 bB	0.36 aB	0.38 aB	0.55 aB
SPS-Gliricidia	1.11 aA	1.28 aA	0.89 aB	0.70 aBC	0.61 aBC	0.49 aC	0.43 aC	0.63 aBC
SPS-Mimosa	0.50 bA	0.44 cA	-0.01 bB	-0.03 bB	---	---	---	---
SEM	--------------------- 0.07 ---------------------				---------------------- 0.10 -----------------------			
	Stocking rate (steers ha^{-1})							
	Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**
Signalgrass†	3.7 aA	3.5 aA	2.0 aB	2.0 aB	2.0 aB	2.0 aB	2.0 aB	2.0 aB
SPS-Gliricidia	3.2 aA	3.2 aA	2.0 aB	2.0 aB	2.0 aB	2.0 aB	2.0 aB	2.0 aB
SPS-Mimosa	2.0 bA	2.0 bA	2.0 aA	2.0 aA	---	---	---	---
SEM	---------------------- 0.2 -----------------------							
	Gain per area (kg BW ha^{-1} 28 d^{-1})							
	Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**
Signalgrass†	95 aA	94 aA	37 aB	26 aB	22 bB	20 aB	21 aB	31 aB
SPS-Gliricidia	100 aA	112 aA	50 aB	39 aB	34 aB	27 aB	24 aB	35 aB
SPS-Mimosa	28 bA	25 bA	-1 bB	-2 bB	---	---	---	---
SEM	---------------------- 10 ----------------------				------------------------ 6 -----------------------			

† Means followed by the same lowercase letters in the columns (treatments) and upper case letter within rows (sampling dates), within each response variable, do not differ by Tukey test (P≤0.05). *Signalgrass in monoculture; SPS: silvopastoral systems. SEM = standard error of mean.

Discussion

Greater proportion of green fractions during the rainy months and resultant greater green herbage accumulation led to greater animal performance over this period. The combination of the greater proportion of lower-CP stems (relative to leaves) and the lower proportion of green fraction explains the overall lower CP concentration in the dry season. Nitrogen recycling from tree legumes might exert positive effect on forage nutritive value. In fact, Apolinário et al. (2016) indicated that gliricidia leaves have greater N concentration than mimosa leaves, and their enhanced litter decay rate, ultimately increases N available for signalgrass uptake. Lower ADG in SPS-Mimosa might have occurred because of lower herbage allowance. Greater ADG in SPS-Gliricidia can be a consequence of the presence of younger leaves and the legume contribution to the system. In a companion work, legume leaf biomass within the reach of the grazing animals (<1.5 m) ranged from 0 to 94 kg DM ha^{-1} at any given evaluation (Herrera et al., 2020, *under review*). Average daily gains observed in this study (0.56, 0.77, and 0.23 kg $head^{-1}$ d^{-1}, for cattle on signalgrass growing in monoculture, in SPS-Gliricidia, and in SPS-Mimosa, respectively), are in the range observed in the literature for growing animals grazing on signalgrass pastures (Santos et al., 2004).

Conclusions

Silvopastoral systems using tree legumes are an option to develop sustainable livestock systems; however, tree legumes differ in their ability to provide ecosystem services. In this 2-yr study, we compared herbage and livestock responses in two SPS using either Gliricidia or Mimosa combined with signalgrass and contrasted with signalgrass in monoculture. Greater animal productivity (average daily gain and gain per area) occurred for the SPS-Gliricidia, followed by Signalgrass in monoculture, and then SPS-Mimosa. Competition between the Mimosa tree and the herbaceous signalgrass canopy reduced green herbage accumulation rate, decreasing stocking rate and gain per area as a result. In general, both SPS had lower herbage mass compared with monoculture; however, greater crude protein concentration in signalgrass growing in SPS-Gliricidia compensated the lower herbage mass translating into greater livestock gains. Silvopastoral systems are a sustainable option for warm-climate regions. They have potential not only to support greater livestock gains, but also to provide other ecosystem services that benefit the entire society. If livestock production is the major desired ecosystem service, gliricidia is a better option to use with signalgrass in SPS compared with mimosa trees.

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