Productivity Performance of Sheep in Silvopastoral Systems With Cashew Tree Compared to Grass Monoculture

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Abstract

The goal in this study was to evaluate the production of sheep and forage silvopastoral systems (SPSs) with cashew trees, compared to the production on grass monoculture. The treatments consisted of three grazing systems: one Massai grass monoculture (*Panicum maximum* cv Massai) (MONO), and two SPSs: intercrop of Massai grass + cashew tree (*Anacardium occidentale*) (SM) and intercrop of grass- Massai grass + Estilosantes Campo Grande (*Stylosanthes capitata* × *S. macrocephala*) + cashew tree (SME), in a completely randomized split plot design with four replications. The photosynthetically active radiation varied from 45 to 59% in SPSs, the presence of cashew trees created a microenvironment with lower temperatures and higher relative humidity throughout the day. Forage mass in the monoculture and in the SPSs was on average 2,116.65 kg dry matter (DM). ha^{-1}; the participation of the legume in the forage mass was 44%. Greater stocking rate was found in the monoculture, however the gain per area was higher in the SME. In the SPSs, crude protein content of the grass increased by 46.2%, and there was a higher forage intake and weight gain of sheep, mainly in the system with legume. The silvopastoral system with cashew trees, Massai grass, estilosantes and sheep is feasible to optimize land use, with better gain per animal and area in relation to grass monoculture.

Keywords: *Anacardium occidentale*, forage mass, intake, Massai grass, *Stylosanthes*

1. Introduction

Sheep farming for meat production is relevant in the Northeast region, whose population accounts for 64.2% Brazilian production, with annual growth in the number of agricultural properties with sheep production (IBGE, 2017). In these establishments, the option for fattening sheep on pastures grown mainly with grass monoculture is increasing. Although the productive potential of these forages is high, their permanence depends on the maintenance of soil fertility, that is, on the adoption of fertilization, since nutrient cycling in these ecosystems has a low capacity for nutrient replenishment (Boddey et al., 2004; Dubeaux Jr. et al., 2006). Another element to be observed in grass monocultures is the thermal comfort of the animals, as the high temperatures in these pastures influence animal performance (Sousa et al., 2015; AL-Dawood, 2017).

The adoption of silvopastoral systems (SPS), that is, the integration of pastures and tree species is an option to minimize these problems. Crop diversification in SPS favors nutrient cycling and water infiltration into the soil (Azar et al., 2013; Lima et al., 2018), also reduces the need for weed control in the cultivation of fruit trees (Pantera et al., 2018). Forage plants grown in intercrop with woody trees are less susceptible to climatic factors (Ferreira et al., 2011) and the microclimate created by the shade of trees provides best conditions of thermal comfort to the animals (Oliveira et al., 2019). SPS combine economic and environmental elements in production units, as they increase the inflow of financial resources throughout the year, for example, the combination of fruit production with the production of meat or milk (Azar et al., 2013; Pantera et al., 2018).

Among the tree species to compose SPS, the cashew tree stands out, because its fruiting period is concentrated in the interval of three months, in the dry period (Souza et al., 2021), time of the year in which the animals are out of the pasture. Another positive factor is the availability of light in the understory, which allows the growth of herbaceous forage plants (Rodrigues et al., 2012). Cashew tree is a high value species, due to its economic and social importance, cashew crop is widespread in the Brazilian Northeast region, where it occupies 586 thousand hectares, corresponding to 99% area with the crop in Brazil (Guanziroli et al., 2009), with a production of approximately 2 million tons of cashews and 134.5 thousand tons of nuts (IBGE, 2017).

In addition to the cultivation of grasses, intercropping with legumes have been evaluated to compose SPS. This grazing model is an alternative to improve the quality of the grazing animal diet, which may result in better animal performance (González-Arcia et al., 2012), besides contributing to improving soil fertility, and thus increasing the mass of forage in relation to grass monoculture (Pinheiro et al., 2021).

These results suggest the possibility of sheep production on pastures combined with fruit production in SPS with cashew trees. The hypothesis of this study is that the adoption of SPS, consisting of cashew trees, pasture and sheep, optimizes the efficiency of land use, by increasing forage productivity and improving animal performance. Thus, the objective of this study was to evaluate the mass, the morphological composition and the nutritional value of the forage for sheep, in an integrated system of cashew tree, grass and legume, compared to production on grass monoculture.

2. Material and Methods

2.1 Site and Experimental Treatments

The experiment was conducted from April 2013 to February 2014, at Embrapa Meio-Norte (5°06'18" S and 42°48'12" W), in Teresina, state of Piauí, Brazil. The soil in the area is Yellow Latosol, with the characteristics: Ca 1.0; Mg 0.4; K 0.18 and Al 0.1 cmol.dm^{-3}; available P 7 mg.dm^{-3}; pH in water 5.7; organic matter 13.5 g.kg^{-1}. The climate of the region, according to Köppen, is the tropical rainy savannah, Aw, with dry winter (June to November) and rainy summer (December to May) and rainfall concentrated from January to April.

During the experiment, at the end of the rainy season, the rainfall was 282.4 mm and the evapotranspiration was 5,597 mm, according to data collected approximately 500 m from the area. To correct water deficit, low pressure sprinkler irrigation was carried out, with a variable irrigation shift. Irrigation was performed whenever the actual evapotranspiration of the pasture subtracted from the effective rainfall approached the value of the water holding capacity of the soil, considering the availability of water in the soil equal to 0.5.

The treatments consisted of three systems: Monoculture of Massai grass (*Panicum maximum* cv Massai) (MONO) and silvopastoral systems (SPSs): Massai grass and cashew tree (*Anacardium occidentale*) (SM), and Massai grass and estilosantes Campo Grande (mixture 80:20 by weight of *Stylosanthes captata* and *S. macrocephala*) + cashew (SME). A completely randomized split plot design was adopted, with three treatments (systems), three grazing cycles (subplots) and four replications (paddocks), totaling 36 experimental units, to evaluate the structural characteristics of the pasture, forage production, forage nutritional value and stocking rate. To assess animal performance, a completely randomized design with three treatments (systems) and six replications (animals) was adopted.

The orchard was planted in 2001, with the cashew varieties CCP 76, CCP 09 and Embrapa 51, at 8 x 7 m spacing, in an area of 0.34 ha. Pasture was planted in 2011, under the canopy of cashew trees, in an area of 0.17 ha per treatment, planting in rows, with 30 cm spacing, from the trunk of cashew trees. In the area intercropped with the legume, every two rows of Massai grass were replaced with a row of estilosantes Campo Grande. In an area adjacent to the cashew orchard, a Massai grass monoculture area was planted. Cashew trees were pruned, in March 2013, keeping the canopy of the plants with a height of 2.76 m and a diameter of 3.52 m, following the recommended technique for management of cashew trees (Oliveira et al., 2008), in addition to providing light to the herbaceous layer, in order to favor pasture growth. In that month, the experimental area received a cut of uniformization at 20 cm from the soil (residue), except in the area with estilosantes, where only Massai grass received a cut of uniformization.

2.2 Pasture Management

The area was fertilized with 50 kg $P_2O_5.ha^{-1}$ as triple superphosphate. Nitrogen fertilization was divided into grazing cycles, totaling 200 kg N. ha^{-1}. year, as urea. In the system with legumes, the same amount of urea was applied only between the rows of grass.

The area of each system was divided into 10 paddocks, each with 170 m^2. Santa Inês sheep, approximately three months old, and average body weight of 21.6 ± 0.56 kg, with six test animals in each treatment, grazed pastures. Regulatory animals of the same category were also used, kept on pasture grown with Massai grass and introduced in the experimental paddocks to guarantee a post-grazing residual of 20 cm (variable stocking rate). Sheep were dewormed before the experiment and the presence of endoparasites was monitored every 17 days, using the FAMACHA® method (VanWyk and Bath, 2002) with deworming whenever the score was equal to or greater than 3. Water and mineral salt *ad libitum* were provided for the animals in the paddocks throughout the experimental period.

Pastures of the three systems were managed under rotational stocking with 3 days of occupation and 27 days of rest. Grazing cycles were repeated three times during the experiment, between April and June, totaling 54 days.

2.3 Morphological Composition, Forage Mass and Stocking Rate of the Pasture

The shading level was measured from photosynthetically active radiation (PAR), using a digital quantometer (CEPTOMETRO LP 80 ACCUPAR, Germany). Measurements took place on a day of full sun, in the East-West direction, under the cashew trees and at the center between the rows, from 7:00 AM to 5:00 PM, every two hours, being considered for analysis the mean PAR. To evaluate environmental conditions, temperature and relative humidity of the air at the height of the withers were measured using digital thermohygrometers, with evaluations performed in full sun and under the canopy of cashew trees. These measures were taken at 7:00 AM, 9:00 AM, 11:00 AM, 1:00 PM, 3:00 PM and 5:00 PM, on one day of each grazing cycle, in order to determine the diurnal variation of climatic conditions, and obtaining averages for the experimental period.

Forage mass, the mass of leaf blades, legume forage mass, mass of leaflets and inflorescences of the legume; the structural characteristics of the pasture (height, leaf/stem ratio and forage density) and the forage nutritional value, were evaluated in four grazing paddocks of each system, in three grazing cycles. In the pasture intercropped with the legume, the botanical composition of the pasture was also determined.

Pre-grazing forage was measured by collecting three samples at points representing the pasture height, with a $0.5m^2$ (1.0 m x 0.5 m) frame, 20 cm above the ground. The dry matter yield of each paddock was estimated according to the formula: Forage production = DM (sample) x area/area of the frame (m^2). To evaluate the forage morphological components, a representative aliquot was taken from the samples collected to determine forage mass. This aliquot was separated into leaf blade, stem and sheath, and dead material for the grass and leaves, stems and dead material for the legume, which were dried in a forced air oven at 55ºC for 72 hours to determine dry matter. Values of forage mass and morphological components were converted to kg DM. ha^{-1}.

2.4 Botanical Composition and Nutritional Value of the Diet

The nutritional value of the forage was determined from forage samples, collected in each paddock, at each grazing cycle, simulating the grazing by sheep. These samples were put in paper bags and pre-dried in a forced air circulation oven at 55 °C for 72 h. In chemical analysis, the dry matter (DM) and crude protein (CP) according to AOAC (2012) were determined. Neutral detergent fiber (NDF), acid detergent fiber (ADF) contents were obtained in an autoclave using F57 bags from Ankon with porosity of 25 microns (Ankon® Technology, New York, USA), as proposed by Senger et al. (2008). NDF and ADF fractions were corrected for ash after incineration in a muffle furnace (AOAC, 2012) and for protein, after determination of the nitrogen fractions of the residues (AOAC, 2012). The *in vitro* dry matter digestibility (IVDMD) and the *in vitro* organic matter digestibility (IVOMD) were determined according to the methodology described by Tilley & Terry (1963).

Forage dry matter intake by sheep (g DM.$animal^{-1}$.day^{-1}) was estimated in two grazing cycles, using an external indicator. The dry matter intake (DMI) was estimated by fecal excretion, using the formula: DMI (kg) = fecal excretion/(1-IVDMD). Fecal excretion was estimated using chromium oxide (Cr_2O_3) as an external indicator of digestibility, administered as recommended by Detmann et al. (2001). Fecal excretion was estimated using the formula:

FE Chr.ox. (g DM/day) = [Chr.ox. supplied(g/day) ÷ (% Chr.ox. in feces ÷ DM105ºC)

Where FE Chr.ox. is fecal excretion obtained by chromium oxide; Chr.ox. supplied and Chr.ox. in feces are the amounts of Cr_2O_3 supplied and excreted, respectively; % Chr.ox. in feces is the percentage of Cr_2O_3 in feces, and DM is dry matter at 105 °C. In each system, six sheep received, during 12 days, at 7h and 17 h, 1.0g Cr_2O_3, in absorbable capsules administered orally. Feces were collected for five days, directly from the rectum of the animals, following the same administration time as Cr_2O_3, preceded by seven days of adaptation. Feces samples were kept in a freezer (-5 to -10ºC). Composite samples of the five days of collection per animal were dried in a forced air oven at 50 ºC, ground to 1.0 mm and packed in plastic bags. Chromium concentration was obtained by the energy dispersive X-ray fluorescence (EDXRF) technique (MALVERN PanalyticalLtd, Malverne, UK)

The botanical composition of the sheep diet in the system with pasture intercropped with legumes was obtained by the principle of difference in the carbon isotopic ratio between C4 and C3 plants. Due to this difference in the discrimination of carbon-13 (^{13}C), C3 plants (legumes, temperate grasses and most fruit plants) have $\delta^{13}C$ between -24 and -32 ‰, while C4 plants (tropical grasses) have $\delta^{13}C$ between -8 and -12 ‰ (Gilbert et al., 2012). During feces collection, to determine the concentration of chromium in feces, forage samples were taken, simulating grazing, according to Norman et al. (2009). In paddocks of the system with legume, grass and legume samples were collected separately. Feces and forage samples were pre-dried at 55ºC for 72 hours and ground to 1.0 mm.

Isotopic analysis by combustion of samples under continuous helium flow was performed in an elemental analyzer (Carlo Erba, CHNS-1110 Milan, Italy), coupled to a Thermo Finnigan Delta Plus mass spectrometer (Thermo Scientific, Bremen,Germany) . The CO_2 gas resulting from the combustion of samples was analyzed in duplicate, with an analytical error of 0.3. The isotopic ratios were expressed by the delta notation (δ), in parts per thousand (‰), and compared to the international standard VPDB (Belemnitella americana fossil carbonate of the Pee Dee formation from the South Carolina/USA) and calculated using the formula: δ sample (‰) = [(R sample – R standard) ÷ R standard] × 1000.

2.5 Animal Performance

For performance assessment, animals were weighed every 15 days, after fasting for 12 hours. To calculate the stocking rate, and estimate the sheep weight gain per area, we considered the number of days regulatory animals remained in the paddocks in relation to the test animals.

2.6 Cashew Fruits

Weekly harvesting fruits from all plants in the area, using a collecting basket, evaluated fruit productivity (nuts) during the 2013 harvest, from August to November, when animals were not on pasture. After each harvest, nuts were separated from the apple, dried in the sun for 72 hours, and weighed. The sum of the weight values was used to express productivity, in $kg.ha^{-1}$

following the method described by Crisostomo et al. (2007).

2.7 Statistical Analysis

Data were analyzed using the ExpDes package of Software R, version 3.1.0 (Ferreira et al., 2011). For data related to pasture (forage mass and nutritional value), the system was considered the main plot and the grazing cycle as subplot (three), the paddock was considered as an experimental unit, with four replications. For individual body weight gain, the experimental unit was the sheep (six sheep per treatment) and for the gain per area, the four paddocks of each system were used as replication. The estimated means were compared by Tukey's test at $P < 0.05$ significance.

3. Results

The average reduction photosynthetically active radiation (PAR) ranged from 45% to 59%, between 7:00 AM and 5:00 PM. The maximum incident radiation, PAR, which occurred between 11:00 AM and 1:00 PM, was 1.796 μmols^{-1}m^{-2} in full sunlight and 754 μmols^{-1}m^{-2} in the understory of cashew trees, corresponding to shading of 58%. Cashew trees created a microclimate in the SPSs, at ambient temperature, it was lower than in full sun, between 07AM and 3PM, varying between 30 and 38ºC. The relative humidity of the air followed an opposite pattern, in the hottest hours of the day, it was 65% in shaded systems, while in full sun, it was 37.4% (Figure 1).

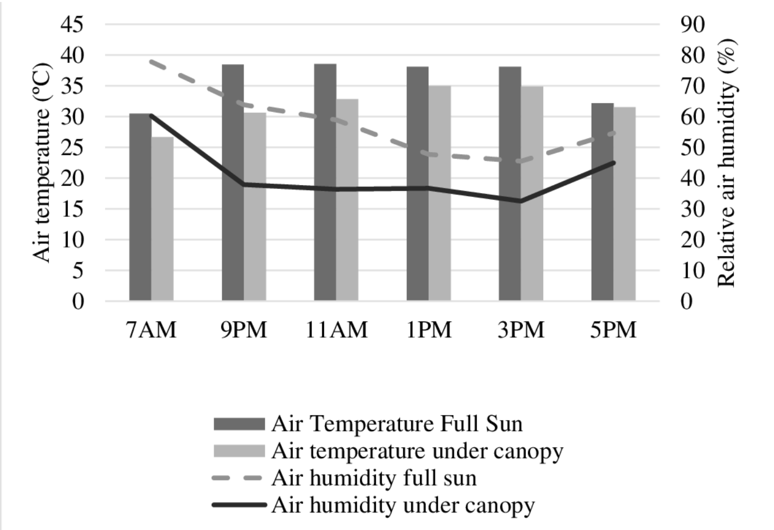

Figure 1. Temperature and relative humidity of the air in full sun, and under the canopy of cashew trees

3.1 Morphological Composition, Forage Mass and Stocking Rate of the Pasture

There was no significant interaction between the variables related to forage mass, sward structure, stocking rate and grazing cycles (Table 1). Forage mass was similar between the MONO and the SPSs ($P>0.05$), with a mean value of 2,116.6 ± 103.2 kg DM. ha^{-1}; in the SME with estilosantes Campo Grande, the participation of the legume was 44% forage. Grass mass in the SME was 1,371.93 kg DM. ha^{-1}, the shading resulted in a change in the Massai grass sward structure (P<0.05), with a reduction in leaf mass and consequently an increase in stem, in SPSs, leaf/stem ratio was about three times lower than in full sun; the leaf/stem ratio in estilosantes was 0.35. The highest stocking rate (P<0.05) occurred in the MONO, and did not differ (P>0.05) between SPSs.

Table 1. Forage mass and sward structure in Massai grass monoculture (MONO), silvopastoral system, cashew tree and Massai grass (SM) and silvopastoral system, cashew tree and Massai grass and estilosantes (SME)

Variables	MONO	SM	SME	SEM
Forage dry mass ($kg.ha^{-1}$)	$1,998.3^{a*}$	$1,885.2^{a}$	$2,466.3^{a}$	103.2
Dry mass of grass blades ($kg.ha^{-1}$)	$1,938.0^{a}$	$1,723.2^{ab}$	$1,225.7^{b}$	82.5
Leaf/Stem ratio	33.1	9.38	10.6	
Legume forage dry mass ($kg.ha^{-1}$)		-	1,094.3	-
Dry mass of leaflets and inflorescences of the legume ($kg.ha^{-1}$)	-	-	352.3	-
Leaf/Stem ratio			0.35	
Stocking rate ($AU.ha^{-1}$)	58.78^{a}	$45,63^{b}$	$43,86^{b}$	1.94

AU= animal unit (25 kg body weight). *Mean values followed by different letters, in the same row, are significantly different by Tukey's test at 5% significance level. SEM - standard error of the mean.

3.2 Botanical Composition and Nutritional Value of the Diet

The botanical composition of the diet revealed the predominance of ingestion of Massai grass (Table 2); in the SPSs, the intake of cashew leaves was not observed. In systems with Massai grass alone, due to the absence of spontaneous species, the grass corresponded to 100% forage ingested; in the SPSs, 82% diet was Massai grass and 18% was estilosantes (Table 2).

The crude protein (CP) content of Massai grass increased in the SPSs (P<0.05), however, there was no difference between the silvopastoral systems(P>0.05), that is, the presence of the legume did not influence the CP content of the grass (P>0.05). The highest content of CP was found for the legume (Table 3). The NDF and ADF of Massai grass was not influenced by shading (P<0.05); the NDF content of estilosantes Campo Grande was lower than in grass, however ADF was similar (P>0.05). The *in vitro* dry matter and organic matter digestibility did not differ between shaded and full sun grasses and did not differ between grass and legume (P>0.05).

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Table 2. Nutritional value of forage produced in Massai grass monoculture (MONO), silvopastoral system, cashew tree and Massai grass (SM) and, silvopastoral system cashew tree and Massai grass and estilosantes (SME)

Variables	MONO	SM	SME		SEM
			Massai grass	Estilosantes	
Crude protein (% DM)	9.3[c]	13.6[b]	13.8[b]	20.5[a]	0.64
Neutral detergent fiber (% DM)	65.00[a]	61.96[a]	61.95[a]	47.06[b]	1.17
Acid detergente fiber (% DM)	38.89[a]	38.52[a]	39.71[a]	38.49[a]	0.42
In Vitro Dry Matter Digestibility (%)	69.1[a]	71.3[a]	70.2[a]	67.7[a]	0.50
In Vitro Organic Matter Digestibility (%)	67.4[a]	69.0[a]	69.6[a]	65.9[a]	0.68

DM – dry matter

*Mean values followed by different letters, in the same row, are significantly different by Tukey's test at 5% significance level. SEM - standard error of the mean

DM intake by sheep on Massai grass pasture was 3,01 % body weight (BW), and 3.98% BW, in the SME, an increase of 32.2% ($P<0.05$). In the SM, there was a 15.3% increase in consumption compared to monoculture (Table 3). The intake of CP and DOM by sheep was higher in the SPSs ($P<0.05$). Higher consumption of CP and DOM by sheep was observed in SPSs ($P<0.05$), compared to MONO. The presence of the legume in the animals' diet resulted in the greatest differences between SME and MONO.

Table 3. Botanical composition of the diet, intake of dry matter and crude protein, and intake of digestible organic matter in monoculture of Massai grass (MONO), silvopastoral system, cashew tree and Massai grass (SM) and silvopastoral system, cashew tree and Massai grass and estilosantes (SME)

Variables	MONO	SM	SME	P-value	SEM
Botanical composition of the diet: Grass (%)	100	100	81		
Legume (%)	0	0	19		
Intake dry matter ($g.100g.\ body\ weight^{-1}.day^{-1}$)	3.01[b]	3.47[ab]	3.98[a]	0.0028	0.13
Crude proten intake ($g.day^{-1}$)	79.31[b]	174.99[a]	211.41[a]	0.0001	15.95
Digestible organic matter intake ($g.day^{-1}$)	593.17[b]	780.17[ab]	864.39[a]	0.0455	43.41

*Mean values followed by different letters, in the same row, are significantly different by Tukey's test at 5% significance level. SEM - standard error of the mean

3.3 Animal Performance on Pasture

The average daily gain of sheep varied between 35.83 and 69.33g.day^{-1}, in the SPSs, it was higher than in the MONO (P<0.05) (Table 4). Among the SPSs, it was higher (P<0.05) in the SME. There was no difference in weight gain per area between MONO and SM (P>0.05), however greater gain per area was recorded in the SME (P<0.05) (Table 4).

Table 4. Weight gain per animal and per area of sheep on monoculture of Massai grass (MONO), integrated crop livestock system, cashew tree + Massai grass (SM) and integrated crop livestock system, cashew tree + Massai grass + estilosantes (SME)

Variables	MONO	SM	SME	P-value	SEM
Average daily gain (g.animal^{-1}.day^{-1})	35.83^{b}	57.22^{ab}	69.33^{a}	0.0054	5.52
Daily gain/area (kg.ha^{-1}.day^{-1})	2.35^{b}	2.83^{b}	3.44^{a}	0.0232	0.23

*Mean values followed by different letters, in the same row, are significantly different by Tukey's test at 5% significance level. SEM - standard error of the mean

Cashew nut production occurred between September and November, after the end of the fattening period of sheep, the mean nut yield in the SPSs was 1,052.8 ± 52.4 kg. ha^{-1}. Thus, nut production was associated with sheep production with gains per area (54 days of fattening x daily gain. area^{-1}) of 152.82 and 185.76 kg. ha^{-1} for SM and SME, respectively.

4. Discussion

4.1 Morphological Composition, Forage Mass and Stocking Rate of the Pasture

Similarity in forage mass of Massai grass between monoculture and SPSs indicates that cashew tree shade did not affect grass growth (Table 1). The tolerance of Massai grass to shading was observed by other authors, who observed the maintenance of the growth in this grass up to 37% shading (Andrade et al., 2004; Paciullo et al., 2016). In the present study, shading varied from 45 to 59% and even so the forage mass did not differ between the systems under full sun and shading. The arrangement and density of cashew trees in the SPSs resulted in the creation of a microclimate in the understory, between 9:00 AM and 15:00 PM, the average temperature in full sun was 38ºC, under the canopy, 32ºC, a reduction of up to 6ºC (Figure 1).

Plant responses to light are mediated by the availability of water and soil fertility, so the lower temperature in SPSs may have been an indirect factor promoting the growth of Massai grass, due to the increase in water availability in the soil. Andrade et al. (2004) found that this grass grew with shading of up to 70%, due to the mitigation of water stress promoted by shading. SPSs are in the third year of cultivation; in the first year, the forage mass was

1,670.05 kg DM. ha^{-1} (Rodrigues et al., 2012), a value close to that observed in the present study, results indicating the system longevity.

In pasture of Massai grass under cashew trees, the same pattern was observed for other grasses when shaded, with a reduction in leaf mass, and an increase in stem mass (Table 1), a strategy of adaptation of these plants to low light (Paciullo et al., 2016; Geremia et al., 2018). In the present study, even with shading, leaf mass predominated. In estilosantes Campo Grande, the predominance was mass of stems, the leaf/stem ratio was 0.35; this result can be related to two factors, shading and selective grazing. This legume is influenced by shading; in an integrated crop livestock system with eucalyptus trees (*Eucaliptus urograndis*), there was a 74% reduction in forage mass and the elongation of stems, compared to cultivation in full sun (Araujo et al., 2017). The predominance of stems in the legume forage mass can also be associated with the selective grazing of sheep, which predominantly consumed the leaves, which resulted in stem accumulation (Table 1).

The stocking rate decreased between MONO and SME (Table 1), which can be related to a decrease in the mass of leaf blades of Massai grass caused by shading. Stocking rate in SPSs is satisfactory when compared to Massai grass pastures managed under rotational or intermittent stocking, with values between 2.15 and 2.37 AU. ha^{-1} (Euclides et al., 2008; Emerenciano Neto et al., 2018.). These results indicate that cashew cultivation areas can be managed for forage production, contributing to optimize land use efficiency in farms.

4.2 Botanical Composition and Nutritional Value of the Diet

Shading did not change the nutritional value of Massai grass, the contents of NDF and ADF, IVDMD and IVOMD were similar, except for the increase in the content of CP. Values of NDF and ADF are consistent with the management adopted for Massai grass, with 27 days of rest, with green material and without the presence of dead material. Other authors have also reported higher content of CP in grasses in integrated crop livestock systems (Paciullo et al., 2003; Lacerda et al., 2009). This increase can be related to improved soil properties seen in SPSs, for example higher microbial activity (Azar et al., 2013), greater decomposition of organic matter and nitrogen recycling (Wilson, 1996). A fact that may have contributed to greater recycling of N was the deposition of litter of cashew trees; the litter mass in cashew orchards was 4.0 t DM ha^{-1}. $year^{-1}$ with a recycling potential of 40 kg N ha^{-1}. $year^{-1}$ (Soares et al., 2008), the cultivation time was similar to the present study.

Sheep consumption and weight gain increased in SPSs; two factors may have contributed to this result. The increase in CP content in the grass favored the intake of forage, with an upward tendency between the monoculture (3.01% CP) and the SPSs with grass (3.47% CP), however the highest level of intake (3.98%) was verified in the SME, where the diet of the sheep had greater offer of CP and energy. Higher intake of forage when intercropping grass and legumes, compared to monocultures, were reported by other authors (Aroeira et al., 2005). Factors explaining the higher consumption in these pastures are the greater degradability of dry matter of the legume when compared to grasses (Paciullo et al., 2003) and the stimulus for diet diversification (Ribeiro Filho et al., 2013). The second factor influencing the performance of the animals can be related to changes in the environment resulting from the presence of cashew trees, the ambient temperature, between 9:00 AM and 3:00 PM in full sun, was 38ºC, with an average reduction of 6ºC, which should have favored forage intake. The exposure of small ruminants to thermal stress negatively affects forage intake and weight gain in hot regions (Neiva et al., 2004; Reunadeau et al., 2012; AL-Dawood, 2017).

4.3 Animal Performance on Pasture

Sheep weight gain in this study are within the range verified for fattening sheep in monoculture pastures in tropical regions without concentrate supplementation, between 26 and 90g.day^{-1} (Araújo et al., 2008; Fajardo et al., 2015). Greater gain occurred in the SME, whose stocking was similar to SM with grass and lower than in MONO, the average daily gain. animal^{-1} was the factor that defined this result. The presence of estilosantes in the pasture improved the quality of the diet and also the consumption of forage. Other authors found better performance of sheep in grassland pastures intercropped with legumes (Alalade et al; 2013)

The production of cashew nuts in SPSs was similar among the cashew clones grown in the area, the values obtained in this study (1,052 kg. ha^{-1}) were close to those verified in cashew cultivation under intensive management, 1,000 kg. ha^{-1}, (Oliveira, 2008), indicating that the orchard was not affected by the presence of forage and animals. The results of this study highlight the potential of integrated crop livestock systems with cashew and sheep, improving animal performance and diversifying production in regions that cultivate cashew trees. The commercialization of cashew apples and cashew nuts and the production of sheep for slaughter can result in additional income, which is important for the financial stability of productive units. This may encourage cashew and sheep producers, two activities present in all states in the Northeast region, to adopt this technology.

5. Conclusion

The silvopastoral system with cashew trees, legume – grass pasture resulted in highest performance of sheep and in the best efficiency of land use.

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