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Productivity and nutritive value of brachiaria forage intercropping with eucalyptus in a silvopastoral system in the Brazilian Cerrado biome

Regina Maria Quintão Lana[1], Ângela Maria Quintão Lana[2], Guilherme Lanna Reis[3], Ernane Miranda Lemes[4]

[1]Agrarian Science Institute, Universidade Federal de Uberlândia – UFU. St. Amazonas n/n, Umuarama Campus. Build 2E. ZIP 38400-902. Uberlândia, state of Minas Gerais, Brazil
[2]Zootechny Departament, at Universidade Federal de Minas Gerais – UFMG. St. Presidente Antônio Carlos 6627, Pampulha Campus. P.O. box 567, ZIP 31270-901. Belo Horizonte, state of Minas Gerais, Brazil
[3]Engineering and Architecture Department, at Fundação Mineira de Educação e Cultura. St. Cobre 200, Cruzeiro. ZIP 30310-190. Belo Horizonte, state of Minas Gerais, Brazil
[4]Agrarian Science Institute, Post-Graduate Program in Agronomy, Universidade Federal de Uberlândia – UFU. St. Amazonas n/n, Umuarama Campus. Build 2E. ZIP 38400-902. Uberlândia, state of Minas Gerais, Brazil

***Corresponding author: rmqlana@iciag.ufu.br**

Abstract

In the Brazilian Cerrado biome there are two major limitations to livestock production: low soil fertility and periods of low rainfall that may occur in all seasons of the year. The period when green forage is available to cattle can be extended if trees are cultivated in pasture lands, which creates a microclimate that would improve soil moisture retention and would contribute to soil nutrients cycling. An experiment was conducted in Confins, Minas Gerais state, Brazil in order to evaluate the forage produced in a 15 year silvopastoral system. The system was composed of Eucalyptus tree species (150 trees ha^{-1}) and/or *Urochloa brizantha* (Stapf) Webster cv. Marandu forage. The pasture was sampled during the months of May, July and November of 2009, and forage production (quantitative and qualitative) and its bromatological composition were determined. The presence of trees in pasture did not reduce the production of dry matter forage during the studied period. Tree species also contributed to nutrient concentrations in forage, increasing levels of crude protein, mineral matter, phosphorus and calcium. In the area without trees, these levels were significantly lower than in the silvopastoral system. The silvopastoral system proved to be a sustainable option for animal production, contributing to the nutritive value of forage during the periods of insufficient rainfall.

Keywords: drought season, soil degraded areas, tree shading, farm sustainability, *Brachiaria brizantha*, Marandu grass.
Abbreviations: ADF_ acid detergent fiber, AFS_ agroforestry system, CP_ crude protein, DBH_ diameter at breast height DM_ dry matter, EE_ ether extract, FP_ forage production, LAI_ leaf area index, LIG_ lignin, MM_ mineral matter NDF_ neutral detergent fiber, SLA_ specific leaf area, SPS_ silvopastoral systems.

Introduction

The Brazilian Cerrado (Savanna like biome), has approximately 49.6 million hectares of cultivated pastures, mainly brachiaria grass, and is home to about 41% of the cattle in Brazil; more than half of the bovine meat of the country, which is approximately 10.5% of gross national agriculture revenue (Martha Júnior and Vilela, 2002). However, due to inadequate management, these areas are becoming increasingly less productive with an estimated 80% of the pastures in some stage of degradation (Peron and Evangelista, 2004). Inappropriate management often results in soil degradation, silted rivers and destruction of the remnant native vegetation (Serrão et al., 1998). Pasture degradation can be reversed by soil conservation, appropriate management of pastures, reduction of burned pastures and the implantation of silvopastoral systems (SPS) (Steinfeld et al., 2006). Silvopastoral systems involve the intercropping of trees with pastures with cattle often a component within the unit. The presence of the tree component in pasture can reduce the negative effects of climate on forage production. The area under trees will have a microclimate which will favor moisture retention and nutrient enrichment, promoting an extended period of green forage availability, benefiting tropical pastures, which normally have low nutritional value (Sanchez, 2001). The major difference between agroforestry and other agricultural production systems is the greater possibility of managing the agroforestry system, or its components, to facilitate increased rates of nutrient turnover or transfer within different compartments of the system (Nair, 1993; Nair et al., 1995). Silvopastoral systems have the potential to replace the benefits of the current cultivated grassland ecosystems, which mostly consist of monocultures of grasses, making the activity more sustainable economically and environmentally (Franke et al., 2001). The Cerrado biome, which is sensitive to rainfall changes, could increase animal production by the use of SPS's (Brassard and Barcellos, 2005). However, the impact of animal production in AFSs on global climate change has not been investigated. Indeed, if sustainable silvopastoral systems could be developed as viable alternatives to conversion of forest lands to support animal production, the above-stated high levels of ''carbon footprint'' of animal production in developing countries could be reduced considerably (Nair et al., 2008).

The profitability of silvopastoral systems has been demonstrated by several studies, as quoted by Silva (2003), who compared monoculture pastures and silvopastoral system with 250 and 416 trees per hectare. This system showed the best internal rates of return on the investment made, exceeding the net income obtained in monocultures.
Kanegae's et al. (2000) reports that the seasonal variations in water availability would be the main limitation of forage plant productivity in savannas. According to these researchers and also with Armando (2002), in Cerrado environment, there is a minor temperature oscillation and rainfall is usually concentrated during summer, while in winter monthly precipitation is less than 5 mm. The little production during drought period considerably limits animal production (Macedo, 1995). According to Carvalho et al. (1999), in the dry season the protein content of grass under the canopy of trees is much higher than the protein content of grass that is in full sun. During dry periods, the quantity of water in the soil surface is low, which makes it difficult for forage roots to obtain nutrients. On the other hand, deeper soil layers remain wet. Trees with deeper roots would have access to water stored in the underground (Kanegae et al., 2000). Considering the information raised, the main purpose of this study was to evaluate a 15 year SPS located in the Cerrado biome, related to forage production characteristics and forage nutritive value during the drought winter period and beginning of the rainy season.

Results and Discussion

Forage lignin, mineral matter and phosphorus content
According to mean estimates of three periods of collection (beginning, middle or end of drought period), management had a significant effect on production in forage LIG, mineral matter (MM) and phosphorus (P) (Table 1). Lignin, MM and P were significantly higher in the SPS ($p \leq 0.05$). The increase in MM and P levels is beneficial for animal nutrition, and can be related to a greater presence of soil organic matter in SPS (5.71 dag kg^{-1}) in relation to pasture (3.94 dag kg^{-1}). The greater amount of organic matter in the SPS promotes nutrients recycling and increases the water content in soil. According to Nair (1993), the term nutrient cycling refers to the continuous transferring of nutrients that are already present within a soil-plant system, such as a farming field. The land-use systems that are structurally and functionally more complex than either crop or tree monocultures result in greater efficiency of resource (nutrient, light and water) capture and utilization, and greater structural diversity that entails tighter nutrient cycles (Nair et al., 2008). While the above- and belowground diversity provides more system stability and resilience at the site-level, the systems provide connectivity with forests and other landscape features at the landscape and watershed levels (Nair et al., 2008). Phosphorus absorption by the roots occurs through diffusion of P that is dependent on the amount of water in the soil. Phosphorus is responsible for the photoenergetic, phosphorylation and photorespiration processes in plants. The higher P absorption in the SPS promotes greater absorption of other nutrients, hence producing higher levels of minerals and dry matter. In FPS, lower soil moisture reduces the absorption of nutrients and affects the physiological and metabolic processes of the plant. Presence of trees changes the behavior of winds on the surface area and the balance of photosynthetic active radiation (Monteith et al. 1991; Brenner, 1996), influencing the conversion of this radiation by the photosynthesis process (Ong et al. 1996). Phosphorus levels, were 5.9% higher ($p \leq 0.05$) (Table 1) in the SPS in comparison to the FPS. Castro el al. (2001) noticed that *U. brizantha* P levels tended to increase as the light level was reduced. These authors explain that, in most plants, light stimulates absorption of $H_2PO_4^-$, nevertheless there is no consensus in literature if light changes P concentrations due to variation in P concentration among forage species. Conversely, levels found by Andrade et al. (2002) were numerically equal among shaded and not shaded forage, with a difference of only 0.14%. In this experiment, shading due to the presence of trees appeared to significantly increase the availability of phosphorus (Table 1).

Sampling time

The effect of time of sample collection (beginning, middle or end of drought period) were significant to LIG, MM, EE, DM and P (Table 2). It was verified an interaction effect between production system and months of collection to the variables ADF, NDF, crude protein (CP) and Ca. Generally, it was observed that LIG, MM and DM, were superior in July, followed by November (Table 2). Though, EE and P were smaller in the month of July ($p \leq 0.05$). Lignin content was higher in forage collected in the middle of the drought period in July (Table 2). The interval between the first and second sampling were 60 days. During the drought period, forage in general, are already more fibrous and consequently, less digestible. In November, there was a decrease in the LIG content, because forages were fresh with new buds in the beginning of rain season. Thus, the LIG content of the organic material is considered to be the most important factor determining the rate of decomposition (Jama and Nair, 1996; Mafongoya and Nair, 1997). Ether extract (Table 2) is the nutrient fraction which provides most energy to forage, followed by proteins and carbohydrates (Berchioelli et al., 2006). Generally, the quantity of EE in forages is low, while the recommended value in total diet must be of 6% according to Prado (2009), and often times animals need supplementation, due to forage's low energetic value. The results presented here are in agreement with what occurs to pastures, as during regrowth, in November, there is a considerable increase of energetic quantity in younger plants (Carvalho et al., 2005).

Tree litter and cattle manure concentrate nutrients in the SPS with the cattle congregating near trees to avail of the shade provided (Durr and Rangel, 2002). However, in this work, the SPS has a high density of trees and the effect of concentration of cattle manure did not occur. The high levels of nutrients, MM, DM, LIG and P were most likely due to the presence of trees in the pasture.

U. brizantha cv. Marandu is a grass with regular tolerance to shade (Carvalho et al., 2005; Jorge et al. 2014). The grass production in the shade usually has inferior dry matter compared to its production in full sun. Though, in periods of less rain, this forage tended to have higher DM production where trees are present. Douglas et al. (2006) explained that there are seasonal variations of water quantity in soils under trees, tending to be higher in drier periods of the year in areas with trees, while, in rainy periods, areas without trees tend to present a greater quantity of water due to absence of trees which are responsible to increase the consumption of water at this time of the year.

According to Nair (1993), when tree biomass, mostly leaves, is used as a source of nutrients for crops, it is important to ensure synchrony between the release of nutrients (via decomposition) and their uptake by the crop. Daccarett and Blydenstein (1968) also did not find a reduction

Table 1. Means of lignin (LIG), mineral matter (MM) and phosphorus (P) for silvopastoral and forage production system. Confins, Minas Gerais, Brazil.

Production System	Lignin (%)	MM (%)	P (%)
Silvopastoral	12.38 A	8.29 A	0.18 A
Forage System (treeless)	10.33 B	7.77 B	0.17 B
CV (%)	19.12	11.36	13.98

Means followed by different letters differ the forage characteristics between the production systems (p<0.05) by SNK test.

Table 2. Means of lignin (LIG), mineral matter (MM), ether extract (EE), dry matter (DM) and phosphorus (P) in *U. brizantha* cv. Marandu for three periods during drought season. Confins, Minas Gerais, Brazil.

Period	LIG (%)	MM (%)	EE (%)	DM (%)	P (%)
May, beginning of drought	9.90 C	7.66 B	1.36 B	31.18 C	0.23 A
July, middle of drought	12.81 A	8.62 A	1.17 C	46.64 A	0.14 B
November, end of drought	11.36 B	7.82 B	1.94 A	31.35 B	0.14 B
CV (%)	19.12	11.36	22.66	9.64	13.98

Means followed by different letters differ the characteristics among the period of drought (p<0.05) by SNK test.

Table 3. Means of acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP) and calcium (Ca) in silvopastoral (SPS) and forage production (FPS) systems the drought season. Confins, Minas Gerais, Brazil.

Period	ADF (%)		NDF (%)		CP (%)		Ca (%)	
	SPS	FSP	SPS	FSP	SPS	FSP	SPS	FSP
May	36.56 aA	38.10 aA	79.07 aA	79.17 aA	9.34 aA	8.69 aA	0.66 aB	0.64 aA
July	34.84 aA	34.83 aB	65.49 aC	71.44 aC	7.48 aB	5.74 bB	0.82 aA	0.66 bA
November	35.62 aA	31.02 bC	76.53 aB	74.47 aB	9.98 aA	6.00 bB	0.38 bC	0.58 aA
CV (%)	6.02		4.88		27.15		18,57	

SPS: silvopastoral system; FPS: forage production system, no trees. Means followed by different letters differ the forage characteristics between the production systems (lowercase) and between collection months (uppercase) (p<0.05), by SNK test.

Table 4 . Estimates of means of leaf area index (LAI) and height for silvopastoral and forage production system. Confins, Minas Gerais, Brazil.

Production System	LAI	Height (cm)
Silvopastoral	3.49 A	18.77 A
Forage System (treeless)	2.95 B	13.93 B
CV (%)	25.50	41.00

Means followed by different letters differ the forage characteristics between the production systems (p<0.05) by SNK test.

Table 5. Estimates of means of leaf area index (LAI), forage production (FP) and height for silvopastoral and forage production system. Confins, Minas Gerais, Brazil.

Period	LAI	FP (g)	Height (cm)
May	3.77 A	591.41 A	16.18 B
July	3.27 A	191.55 B	6.73 C
November	2.64 B	639.54 C	26.16 A
CV (%)	25.50	45.61	41.00

SPS: silvopastoral system; FPS: forage production system, no trees.
Means followed by different letters differ the characteristics among the period of drought (p<0.05), by SNK test.

in dry matter of forage in the presence of different tree species, observing no difference in production DM among SPS or FPS systems.

Forage fibers, protein and Ca Acid detergent fiber, NDF, CP and Ca variables had an interaction effect between the production systems and the periods of collection (Table 3). Kephart and Buxton (1993) observed that forage subjected to shading had a significant positive correlation between SLA (specific leaf area) and in vitro organic matter digestibility and nitrogen (N) content in leaf blades, and a negative correlation between SLA and cell-wall lignin and neutral-detergent fiber. It is notable that NDF and CP in both cropping systems and ADF in the full sun, were significantly higher in May (beginning of the drought period) compared to the forage collected in July and November (during and immediately after the drought) (Table 3). However, Ca was significantly different in the forage collected in July in both cropping systems. But ADF in SPS and Ca, in full sun, was not significantly different during the three periods in this study ($p \leq 0.05$). Daccarett and Bludenstein (1968) pointed out that shaded forage can have higher levels of fiber. In this present work, levels of ADF were higher in SPS in the forage collected in November while NDF did not differ among systems during any of the collection periods. Crude protein and Ca levels were the highest in forage under shade in the silvopastoral system, compared to forage in full sun, during the drought and immediately after the drought season. The Ca levels were higher for SPS in July, but the opposite in November. ADF was higher in the forage in the SPS only after the dry period ($p \leq 0.05$) (Table 3). The high protein value observed in forage in shaded SPS is of great importance for animal nutrition. In general, the forage production system in Cerrado has low protein values in the dry season. The SPS has shown that even in times of drought this value has not decreased, showing its potential beneficial effect in improving nutrition of shaded pastures for cattle. According to Van Soest (1994) 1% of N is equal to 6.25% of CP considering this to be the minimum which satisfies rumen fermentation. Shaded paddocks have improved the efficiency of food conversion and survival of cattle (Bird et al., 1992). Study on availability of shade for dairy cows led by Carvalho (1991) showed increases in milk production and in its percentage concentration of solids, but not fat. The results of this work are in agreement with Reis (2007), who found that shaded pasture with ipê felpudo (*Zeyheria tuberculosa*) had 8.62% CP compared to a (*U. brizantha*) pasture with 5.19% CP. Andrade et al. (2002) found in shaded pasture a level of CP 50% higher than that found in full sun areas, suggesting increase in soil N with increase in organic matter under trees. The average values for CP, LIG and NDF found by Paulino et al. (2005) in FPSs, and by Lin et al., (2010) in SPSs are in agreement with what this study has found. In literature, however, there is no consensus about shading influence regarding levels of Ca in forage. Carvalho et al. (2005) and Castro et al. (2001) related higher levels of this nutrient to shaded forage. On the other hand, Andrade et al. (2002) found lower levels of Ca in shade forage when compared to a full sun system (0.21 mg kg^{-1} and 0.26 mg kg^{-1}, respectively). This was assigned to lower rate of this grass maturation, because Ca, for having low mobility, tends to be higher in older leaves.

Leaf area index

In Table 4 are the means of three months of collections, in both production systems. There was a significant effect of production system on leaf area index (LAI) and height.

It is noticeable that LAI and height were superior in SPS, compared to FPS ($p \leq 0.05$). Both variables are indicative of a higher production of leaves and stems. There was a significant difference in LAI, forage production (FP) and height variables among the three periods of collection (Table 5). The shift in biomass allocation, favoring aboveground structures in detriment of roots, is a common response to shade in grasses and broad leaf species (Hodge et al., 1997).

Leaf area index was higher in the first two collections. Forage production was higher in May and November. The higher forage production in May and November is due to greater plant development in these periods, which are periods close to the rainy season, compared to forage production in the middle of the drought period of July. This also explains the smaller forage height in July and taller height in November (Table 5).Trees contribute to the conservation of soil cooling and moisture, by protecting the area from direct sun light and winds that sweep the humid air (Gregory, 1995). Thus, the SSP increases absorption of nutrients by forage, resulting in a higher content of biomass and improving the bromatological quality of pastures. Beyond keeping the shade for the animals, the SSP increase the farmers profit and bring benefits for the local community.

Materials and Methods

Experimental area properties and treatments

The experiment was conducted in a silvopastoral system, located in Confins city, Minas Gerais state, Brazil. The geographic coordinates of the experimental area of this typical Cerrado biome are 19º54'32" South and 43º58'18" West, and the average maximum daily temperature in the area was 31.4ºC and relative humidity averaged 42% during the months of forage evaluation. The SPS was established in 1994 without any burning. The land was cleared, and eucalyptus seedlings were planted at a density of 150 trees ha^{-1}. The experiment consists of 1.5 hectares area in a soil homogeneous site. The eucalyptus trees (*Eucalyptus* sp.) in the experimental area were 15 to 25 meters high, with diameter at breast height (DBH) of 40 to 60 cm. The soil in the SPS is classified as a red-yellow latosol (Oxisol), with 651 g kg^{-1} of clay, 211 g kg^{-1} of silt and 138 g kg^{-1} of sand. The soil organic matter was 5.71 and 3.94 dag kg^{-1} for SPS and pasture (exclusive forage production system - FPS), respectively. The forage *Urochloa brizantha* (Stapf) Webster cv. Marandu (sin. *Brachiaria brizantha* cv. Marandu), were sown (8 kg ha^{-1} of commercial forage seeds with 50% germination) in the SPS and FPS at the same time as the eucalyptus seedlings were planted. The soil fertilization was made with 2.000 kg ha^{-1} of dolomitic lime two months before sown, 800 kg ha^{-1} of natural fosfate at sown, 100 kg ha^{-1} of KCl (50% at sown, 50% 30 days after) and 150 kg ha^{-1} of ureia (50 kg 30 days after sown, 50 kg at the midle and end of the raining season).

Cattle management and forage sampling

Cattle grazing practices depended on forage production during the seasons. An average of 6 animals per hectare was let to graze for three days followed by a 30-day rest period. *U. brizantha* productivity was measured quantitatively and qualitatively for three distinctive periods: at the beginning (May 15th, 2009), middle (July 25th, 2009) - period of greatest drought stress - and after (November 23rd, 2009) the drought season. At the implantation of the experiment a cut for standardization of forage was done at 30 cm above soil level. For each period of evaluation twelve random points were selected in each system (SPS and FPS). One squared meter collector made of steel grids was used to prevent animal interference and were placed at each identified location for forage evaluation. Leaf area index (LAI) was determined with the equipment LI 3100 (LI-COR, USA) model.

Samples analyses

After sample collections, the forage was weighted, pre-dried in an oven at 60ºC for 72 h, and then ground to pass through a 1 mm sieve. All bromatologic compositions of dry matter (DM), mineral matter (MM), ether extract (EE, crude fat) (Compêndio…, 1998), and crude protein (CP) were analyzed by Kjeldahl's methodology (Cunniff, 1995). Calcium and phosphorus were determined using permanganometric techniques, colorimetric and flame photometry, respectively. Forage composition was evaluated for neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin (LIG) separately (Robertson and Van Soest, 1982).

Statistical analysis

The experiment was conducted in a completely randomized design arranged in a split plot, with six repetitions. The Lilliefors and Bartlett tests were performed to verify normality and homoscedasticity of data, respectively. Then an analysis of variance (ANOVA) model was fitted, and the means were grouped with the Student Neuman Keuls (SNK) test. Statistical significance was determined at a family wise error rate of $\alpha = 0.05$.

Conclusions

This study suggests that it is possible to see a considerable increase in nutrient concentrations in shaded forage using silvopastoral systems. This increase was observed even in drought conditions, where forage protein values were high, which is important in meeting the maintenance requirements of ruminants. This is especially important in the Cerrado biome, which frequently experiences droughts. The presence of the tree species Eucalyptus did not interfere in forage dry matter production. Trees appeared to reduce forage water stress while simultaneously increasing mineral concentrations. This silvopastoral system appeared to be a sustainable option for animal production in areas with little rainfall.

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