INFLUENCE OF A SILVOPASTORAL SYSTEM ON FORAGE PARAMETERS IN THE BRAZILIAN SAVANNA

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ABSTRACT – The association between pasture and tree is known as silvopastoral systems (SPS). Aimed at evaluating the forage produced in these systems, an experiment was conducted in Lagoa Santa, Minas Gerais, Brazil, 19º 35' 36'' S, 43º 51' 56'' W; altitude 747m. The system has been under development since 1984, through the natural regeneration of pioneer trees, of the *Zeyheria tuberculosa* Vell. Bur. species which are native to the Brazilian savanna. *Brachiaria brizantha* cv. Marandu (BBM) was the chosen forage and was collected in Jan 2006, a typical month of hydric stress. The production was assessed in terms of quantity and quality. In the density studied, 160 trees ha^{-1}, the presence of trees in pastures of BBM caused no reduction in dry matter production (DMP) from forage. Tree components reduced the weather stress and enhanced the nutritional aspects of forage, increasing the crude protein (CP), phosphorus (P), and potassium (K) levels. Trees did not influence the calcium (Ca^{2+}), neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin levels. Therefore, the SPS showed the potential to extend the forage quality availability.

Key Words: Deforestation, pastures, shedding, sustainability, trees.

INFLUÊNCIA DO SISTEMA SILVIPASTORIL NOS PARÂMETROS DA PASTAGEM NO CERRADO BRASILEIRO

RESUMO – A associação entre pastagem e árvore é conhecida como sistema silvipastoril (SPS). O objetivo do estudo foi avaliar a forragem produzida nestes sistemas. O experimento foi conduzido em Lagoa Santa, Minas Gerais, Brasil, 19º 35 '36'' de latitude sul e 43º 51' 56' de longitude oeste, em altitude de 747m. O sistema vem sendo desenvolvido desde 1984, por meio da regeneração natural de árvores pioneiras, do Zeyheria tuberculosa *Vell. Bur., espécie nativa do cerrado brasileiro. A* Brachiaria brizantha *cv. Marandu (BBM) foi a forrageira escolhida. Esta foi coletada em janeiro de 2006, um mês típico de estresse hídrico. A produção foi avaliada em termos de quantidade e qualidade. Na densidade estudada, 160 árvores* ha^{-1}*, a presença de árvores em pastagens de BBM não causou redução na produção de matéria seca (PMS) de forragem. Os componentes da árvore reduziram o estresse climático e incrementaram aspectos nutricionais da forragem, aumentando a proteína bruta (PB), fósforo (P) e potássio (K). Árvores não influenciaram os teores de cálcio (*Ca^{2+}*), fibra em detergente neutro (FDN), fibra em detergente ácido (FDA) e lignina. Portanto, o SPS mostrou o potencial de aumentar a disponibilidade de forragem de qualidade.*

Palavras-chave: Árvores, desmatamento, pastagem, sombreamento, sustentabilidade.

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1. INTRODUCTION

For the first 20 years of the XXI century, there are predictions of increases in consumption of 87% for meat and 75% for milk within developing country populations, which represents 75% of the world's population. In this context, the ruminants play an important role as they demand fewer grains per unit of meat produced than do monogastrics (Nicholson et al., 2001).

In the Brazilian Savanna (Cerrado), there are approximately 49.6 million ha of cultivated pastures, which are covered mainly by *Brachiaria*. These pastures are home to nearly 41% of all Brazilian cattle, which accounts for half of the national meat production (Martha Júnior & Vilela, 2002). Nevertheless, it is estimated that 80% of these pastures are degrated. The productivity of beef cattle in a degraded pasture may be six times lower than in a well managed pasture (Peron & Evangelista, 2004). The stocking rate is lower than one animal unit ha^{-1}. These undesirable indices result from improper cultural practices during the establishment and management of these pastures, such as inadequate fertilizer use and overgrazing, which can lead to a decline in soil fertility. The loss of productivity results in a decrease in soil cover and, consequently, an increase in soil compacting, a reduction of water infiltration, and erosion, thus affecting watersheds and compromising the sustainability of natural resources (Macedo, 1995).

Degradated pastures can be limited and recovered through pasture proper management, the minimizing of social exclusion, and the introduction of SPS (Steinfeld et al., 2006), which can be defined as an association of trees and pastures. The presence of trees in the pastures creates a microclimate in their influence area, in turn favoring humidity retention and soil nutrient enrichment, as well as extending the forage availability and improving its quality. The tropical forages usually contain a low nutritional quality, which becomes even lower as they mature (Sanchez, 2001).

In the Cerrado, these systems may favor animal production. Brassard and Barcellos (2005) reported that the soil of this biome is very sensible to changes in pluviosity as it presents low water reserve supply. According to Armando (2002), in this environment, there is low oscillation of annual temperature (from to 18 25ºC), and the precipitation is about 1200-1500 mm, accumulated mainly during the summer, while during the dry season, from approximately April to September, the monthly precipitation tends to be less than five millimeters.

During the dry season, there is low water availability in the soil surface layers, while the deepest layers remain humid. However, there are often periods without precipitation during the rainy season that affect the soil water potential. Nevertheless, most of the trees, as they have deep root systems, may access the subsoil water reserves (Kanegae et al., 2000) and lift water to shallow soil layers, where the grassy roots also have access (Ludwig et al., 2004). Brassard and Barcellos (2005) add that during periods without precipitation the plants produce a high level of photosynthesis, which in turn implies a high level of demand for water.

Despite the many benefits that the trees provide to the pasture, the native animals, and the environment, in Brazil, are most eliminated during the pasture's implementation process (Carvalho et al., 1994). If the tree's shade is less than 50%, the grass productivity is not greatly affected. Increments of pasture productivity under leguminous trees (Daccarett and Blydenstein, 1968) could also observed. Even trees that do not fix N_2 can be recognized as soil fertility improvers (Buresh and Tian, 1998).

The objective of this experiment was to assess both the effect of an SPS implemented within a Brazilian Cerrado that was under production and the quality of BBM during a period of hydric stress.

2. MATERIALS AND METHODS

Description of the study sites

This experiment was conducted in an SPS, within the Brazilian savanna biome, at the private Grota Funda farm, in Lagoa Santa, Minas Gerais, Brazil, 19º 35' 36'' S, 43º 51' 56'' W, at an altitude of 747m above sea level. The system has been under development since 1984 through the natural regeneration of the native tree species, *Zeyheria tuberculosa* Vell. Bur. (ZT) of the Bignoniaceae family. This species was selected for inclusion in the SPS due to its wood quality, fast growth, straight trunk, intermediate canopy density, and resistance to cattle grazing. It is a very useful species in restoring degraded areas, as its seeds are easily spread by the wind. During natural regeneration, undesirable species were removed, and at least 4 m was maintained between ZT trees. Currently, the trees are 15-23 m tall with a chest diameter of 40-

60 cm. The density adopted was 160 trees ha^{-1}. No fire was used during the set-up, and limestone and phosphate rock were applied according to soil analysis. The forage chosen as a component of the SPS was *Brachiaria brizantha* cv. Marundu (BBM), which replaced a pasture of *Hyparrhenia rufa* (Viana et al., 2002).

During the previous summer of the present experiment, weekly assessments of maximum and minimum temperatures of the air showed that, on average, the values of maximum temperature were 4.8°C higher in the monoculture area in relation to the area under the influence of trees, while the minimum temperatures were 0.4°C higher in the system with trees (Sousa, 2005).

An adjacent pasture (the control area) was also planted using the same methodology; however, in this site, all the trees were cut down in the initial stages of the process. Originally, both areas were very regular and presented many similarities; the only difference during regeneration was the management of trees. The total area, including the SPS and the control area, consisted of approximately two hectares. The stocking rate (bovine) in both pastures was adjusted to the forage production and ranged from 0.8 to 1.5 animal units ha^{-1}. According to the USDA classification, the soil is registered as a Typic Acrustox, while in the Brazilian classification it is registered as red-yellow latosoil. The soil also presented 651 $g.kg^{-1}$ of clay, 211 $g.kg^{-1}$ of silt, and 138 $g.kg^{-1}$ of sand. In table 1, some chemical soil attributes of the evaluated systems are presented.

Data collection

Soil and forage were sampled with nine sampling points taken in each system (Figure 1). The forage parameters were assessed after collection in January 2006. This month was chosen due to the severe dry

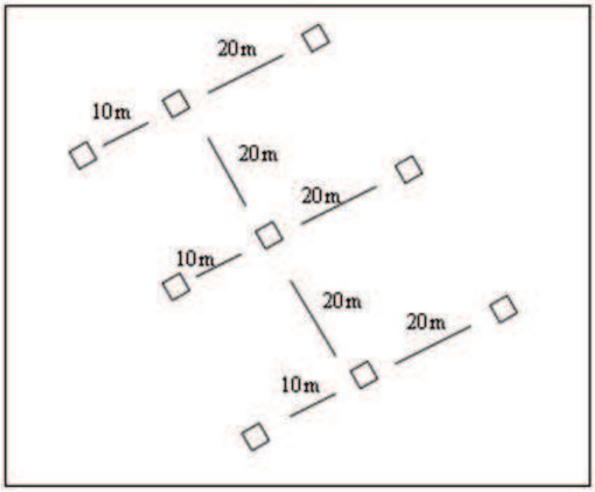

Figure 1 - Forage and soil sampling diagram: three parallel lines were traced, 40m in length each, cutting the center of each system in a diagonal form. The first and third diagonal lines were 10m and 20m from the central line, respectively. In each line, three samples were collected 20m from each other, totaling nine sampling points in the SPS and nine points in an area out of its influence, which was set as the control treatment.

Table 1 - Chemical attributes of soils under silvopastoral system (SPS) and monoculture (Lagoa Santa-2006)

Variable	Depth (cm)					
	Monocultura			SPS		
	0-10	10-20	20-40	0-10	10-20	20-40
pH (H_2O –1:2,5)	4.86±0.22	4.75±0.23	4.75±0.11	4.64±0.28	4.61±0.19	4.64±0.11
Phosphorous (mg dm^{-3})	2.57±0.86	1.79±0.75	1.09±0.35	1.89±0.58	1.71±0.33	1.06±0.21
Potassium (mg dm^{-3})	135.87±35.69	70.13±14.72	42.5±17.46	95.63±36.90	82.5±30.26	49.37±35.84
Calcium (cmolc dm^{-3})	0.67±0.31	0.39±0.19	0.23±0.07	0.76±0.27	0.6±0.17	0.27±0.14
Magnesium (cmolc dm^{-3})	0.59±0.36	0.27±0.24	0.13±0.07	0.56±0.21	0.41±0.13	0.12±0.05
Aluminum (cmolc dm^{-3})	1.74±0.55	2.31±0.33	2.5±0.17	1.71±0.50	1.96±0.28	2.35±0.21
H + Al [a] (cmolc dm^{-3})	9.5±1.56	10.11±1.41	10.05±0.46	8.9±1.58	8.99±1.11	9.31±0.73
Sum of bases (cmolc dm^{-3})	1.6±0.68	0.84±0.46	0.45±0.14	1.57±0.45	1.22±0.30	0.54±0.17
CEC [b](cmolc dm^{-3})	3.34±0.27	3.13±0.18	2.96±0.09	3.29±0.11	3.17±0.17	2.86±0.15
CEC7 [c](cmolc dm^{-3})	11.1±0.96	10.95±1.00	10.51±0.44	10.49±0.49	10.21±0.85	9.85±9.85
Bases saturation (%)	15±7	8±6	4±1	15±6	12±4	6±2

[a]Hydrogen plus Aluminum (H + Al), [b]effective cation exchange capacity (CEC), [c]cation exchange capacity at pH 7.0 (CEC7)

conditions presented as compared to other months. Before the collection, in the end of December 2005, the forage was cut to 30cm in height. Next, the pasture was preserved to avoid grazing. Thirty days after the first cut, all the BBM plants over 30cm were harvested for measurement. The square tool (1 m^2) was used for each collection point.

In February 2006, 15 days after forage sampling, a Dutch auger was used to collect soil samples at the following depths: 0-10, 10-20, and 20-40 cm. Meteorological data was supplied by the meteorology department at the Tancredo Neves International Airport located in the neighboring city of Confins at the following geographic coordinates: 19º54' 32'' S and 43º58' 18'' W. The minimum, maximum, and average temperatures, as well as the relative humidity during the period, were 17.6, 23.5, 34.9, and 76%, respectively. The rainfall during 2005 was 1432 mm. Figure 2 presents the profile of rainfall distribution during the period in which the forage growth was studied, which occurred from December 22, 2005 to January 20, 2006, when 44.6 mm of rainfall was recorded.

The annual litterfall from tree leaves, fruits, and branches was estimated. For this purpose, four traps (net panels, with a mesh of 4 x 6 mm) were randomly distributed throughout the area under the trees' influence. Each trap consisted of an area of 27 m² and was placed 1.5 m off the ground. In 2005, 12 collections at 30 day intervals were carried out.

Laboratory analysis

Forage productivity was assessed. After having been harvested, the forage was weighed, dried at 60ºC for 72 hours, and then milled to <1 mm. The samples were analyzed for dry matter content (DMC) and ash (Brasil M. A. Abastecimento, 1998). P, Ca^{2+}, and K^+ were determined using calorimetric, permanganometric, and flame photometric techniques, respectively (Cunniff, 1995). The CP (6.25 x total nitrogen (N) content) was determined by means of Kjeldahl digestion (Cunniff, 1995). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were assessed through the sequential analysis of fiber. In a similar manner, lignin was estimated by dissolving samples in a 72% H_2SO_4 solution for three hours (Robertson & Van Soest, 1982).

After collection, the litter was sorted into leaves, branches, fruit, and other (fractionated material of variable composition during the year). The litter was analysed for the same parameters of forage, except NDF and ADF. Its OM content was estimated as the difference between the DM and the ash content. The carbon (C) content was estimated as 50% of the OM. These analyses were carried out at the Animal Nutrition Laboratories of the Schools of Veterinary Sciences at the Federal University of Minas Gerais (UFMG) and at PUC-MG.

The soil chemical analyses were carried out at the Soil Analysis Laboratory of the Federal University of Uberlândia, Minas Gerais, according to EMBRAPA

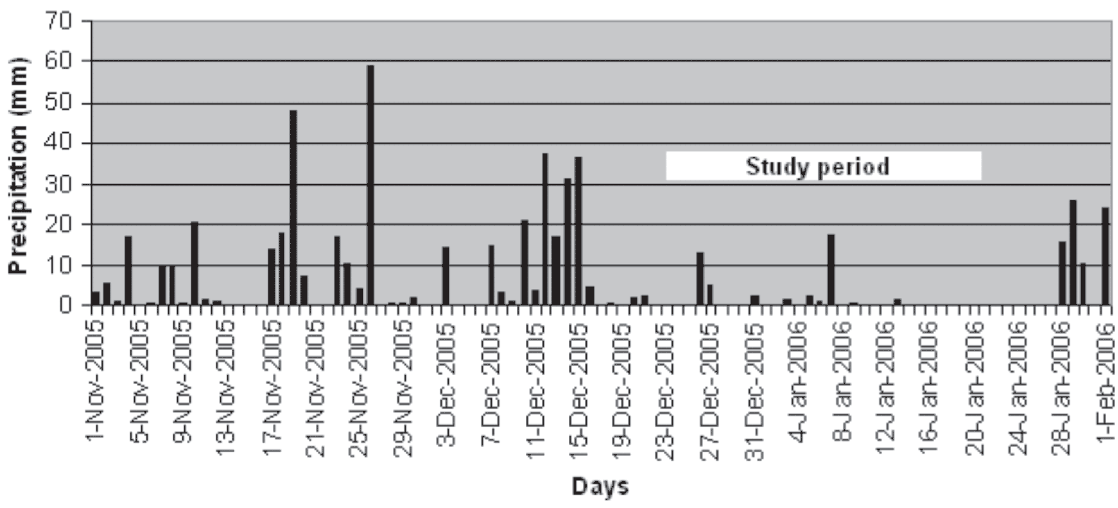

Figure 2 - Profile of the distribution of rainfall during the study period of growth of forage, which occurred from December 2005, 22nd to January 2006, 20th (Lagoa Santa/MG)

Table 2 - Average and standard deviation values of annual contribution of *Zeyheria tuberculosa* Vell. Bur. to soil in a silvopastoral system in the Cerrado biome (Lagoa Santa/MG - 2005)

Variable	Avarage composition of litter (%)	Kg ha^{-1} $year^{-1}$
Total dry matter	100	4360.2
Ash	3.88 ± 0.94	169.23
Organic matter	96.12 ± 0.94	4191.0
Carbon	55.74 ± 0.43	2430.78
Calcium	0.61 ± 0.29	26.5
Phosphorus	0.07 ± 0.04	3.2
Nitrogen	1.79 ± 0.55	78.0
Potassium	0.90 ± 0.59	39.4
Lignin	45.04 ± 8.00	-
Carbon/Nitrogen	31.10 ± 11.03	-
Lignin/Nitrogen	25.16 ± 9.46	-

(1999). For the pH analyses, 25 ml of extractant were added to 10 cm^3 of finely air-dried soil and then read by a previously calibrated pHmetry. For the Ca^{2+} and Magnesium (Mg^{2+}) analyses, 100 ml of KCl 1 mol L^{-1} were added to 10 cm^3 of soil (TFSA), and, after 16 hours at rest, was read by an atomic absorption spectrophotometer. For P and K, 100 ml of solution extractor (H_2SO_4 0.025 mol L^{-1} and HCl 0.05 mol L^{-1}), $Mellich^{-1}$, was added and read by the atomic absorption spectrophotometer and the flame photometry, respectively. The organic matter (OM) was determined by Walkley Black. For the determination of copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn), a DTPA solution was used. The cation exchange capacity at pH 7.0 (CEC7) extracts H were retained when the soil was negatively charged to pH = 7.0. In contrast, the CEC extracts presented only bases (Ca + Mg + K) and Al^{+3} in the pH soil, not presenting the H which is adsorbed in the CEC.

Statistical Analysis

Lilliefors and Bartlett tests were used to check normality and homoscedasticity, respectively. Soil data, according to depth and soil litter, were presented as descriptive statistics (mean and standard error) aimed at characterizing such variables in each system. Forage data was submitted to the analysis of variance and further Fisher tests to compare experimental groups for all variables. Regression models of forage attributes depending on soil variables (average value among the depths) were also studied using the backwards procedure. The adjusted coefficient of determination was used in the selection of models. Pearson's correlations between soil attributes and forage variables were also performed.

3. RESULTS AND DISCUSSION

The values of Ca^{+2} and bases saturation (BS) were slightly higher in the SPS than in the monoculture. On the other hand, the opposite occurred for the pH, P, K, and aluminum (Al^{+3}) attributes (Table 1).

It is estimated that 160 trees ha^{-1}, during one year, added more than four Mg ha^{-1} of OM to the pasture (Table 2). The N, P, and Ca^{+2} contributions were considerable, while the P contribution was reduced. The carbon/nitrogen (C/N) and lignin/nitrogen ratios were 31.10 and 25.16, respectively.

Caution is called for when attributing the improvement of soil fertility and the consequent increase in forage yield to the trees. The higher nutrient contents under tree crowns may be influenced by the leaf litter and the presence of cattle which, when using the shade of the trees, concentrates the nutrients in one place (Durr & Rangel, 2002). However, the present study assessed a system with a high density of trees, in which the effect of the concentration of animal dejections would not commonly occur. The N content of the studied litter (1.79%) (Table 2) allowed for nutrient mineralization as it was slightly over the critical limit necessary for mineralization to occur (1.74%), as reported by Andrade et al. (2002).

Some litter parameters of the ZT tree (Table 2) were higher than the data presented by Andrade et al. (2001) who reported on the litter of Eucalyptus species. According to this author, the litter produced by the Eucalyptus species presented N and P contents of 0.63% and 0.04%, respectively, and a C/N ratio of 86.0. In the present study, these variables in the native tree were: 1.79%, 0.07%, and 26.81, respectively. Andrade et al. (2001) informed that the tropical grasses, as well as Eucalyptus, produce a litter of low nutrient content, mainly N, P, and K. Therefore, the litter from SPS formed by tropical grasses and Eucalyptus is of low quality, much similar to that produced by the monoculture of grasses. In this light, the choice of trees to form the system must be criterious, avoiding negative interactions among the components.

Table 3 shows the results from BBM availability and composition. The green matter production (GMP) (P<0.05) in the system with trees. However, due to a lower DMC (P<0.001), the DMP was similar between the systems. These results are in agreement with Vetaas (1992) who reported that the trees modify the microclimate through the interception of sunlight between 45% and 60%, thus reducing soil temperature and evaporation. Moreover, the tree component improves the rate of water infiltration into the soil and is capable of pumping water from deeper layers of soil to the most superficial, to which the roots of forage have access. Likewise, the greatest amount of moisture available in environments with the presence of trees most likely influences the lower dry matter content found in the shaded grass (P <0.001)(Table 3).

Carvalho et al. (2002) defines the BBM used in this study as intermediate shade tolerant. These authors found that the shaded BBM presented a lower DMP (P <0.01) than that in the open area. However, during periods of reduced rainfall, the grass under the influence of trees tended to produce greater quantities of DM. Douglas et al. (2006) explained that there are seasonal variations in the amount of water in the soil under the trees, which tend to be higher in the driest periods of the year in the area containing trees, while in periods of rain, the soil of the area without trees tends to contain higher amounts of water due to increased consumption of water and the interception of rainfall by trees. Depth also influences water levels. The layer of soil between 2 to 4 m in depth contains less water in the area with trees than in the area without.

The soil under the influence of trees due to a higher OM content, has a greater capacity to store water (Douglas et al., 2006). In the current study, the levels of soil organic matter showed a correlation of moderate magnitude with the forage DMP: 0.5353 (P <0.05) (Table 4). Durres and Rangel (2003) stated that the soil enrichment provided by trees and grasses use the available water in the soil more efficiently, thus there is more DMP per unit of water transpired. This phenomenon justifies the increased growth of grasses under the canopy of trees in semi-humid climates as compared to open areas, which, despite being exposed to more light, do not necessarily carry out a greater amount of net photosynthesis due to hydric stress. It should be noted that the shading should be light to moderate, which when combined with the enrichment of the soil under trees and low rainfall would result in a greater forage production in shaded areas.

Daccarett and Blydenstein (1968) also reported no reduction in the availability of forage dry matter under the influence of trees. However, Carvalho et al. (1994) reported that the trees shade reduced production of BBM. Nevertheless, hydric stress, which caused the increased availability of DM, proved to be due to a higher amount of dead material.

A lower DM content in shaded forage may result in greater juiciness and flavor, especially in the dry

Table 3 - Average and standard deviation values of atributes of *Brachiaria brizantha* cv. Marandu (BBM) under influence of *Zeyheria tuberculosa* Vell. Bur. (SPS) and witouth their influence (monoculture) (Lagoa Santa/MG – 2006)

Variable	System		Probability	CV (%)
	Monoculture	SPS		
GMP (g m^{-2}) [a]	193.30±71.70	295.8±121.55	**	33.79
DMP (g m^{-2}) [b]	76.54±28.33	79.24±27.20	-	30.60
DMC (%) [c]	39.84±4.90	28.12±4.44	***	13.23
Crude protein (%)	5.19±0.53	8.62±1.37	***	15.84
Ash (%)	7.11±0.62	7.84±0.62	*	8.82
Calcium (%)	0.45±0.07	0.41±0.06	-	14.19
Photasium (%)	1.80±0.63	3.03±0.47	**	24.12
Phosporus (%)	0.07±0.02	0.11±0.03	**	26.81
NDF (%) [d]	72.69±2.01	72.68±1.47	-	2.36
ADF (%) [e]	58.43±2.44	56.40±2.53	-	4.21
Lignin (%)	6.97±0.48	7.25±0.99	-	9.82

[a]Green matter production (GMP), [b]dry matter production (DMP), [c]dry matter content (DMC), [d]neutral detergent fiber (NDF), [e]acid detergent fiber (ADF) [-], ***, **, * - (Fisher test: P>0,05; P<0,001; 0,01; 0,05, respectively)

season when the grass appears to be excessively dry (Andrade et al., 2002). According to Daccarett and Bludenstein (1968), the shaded forage may contain higher fiber content. However, in this study, the values of NDF, ADF, and lignin were similar among the grasses of the studied systems (Table 3). Carvalho et al. (2002) also found no statistical difference between the percentage of NDF from shaded and sunlight forage: 73.92 and 73.12%, respectively.

The CP contents were higher (P<0.001) in the shaded forage than in the forage from the monoculture. It is emphasized that a diet with less than 7% of protein is insufficient for a satisfactory ruminal fermentation, thus leading to a reduction of food intake by animals (Van Soest, 1994). If the diet consumed by animals presents lower protein levels than previously mentioned, it becomes necessary to supplement this nutrient.

Table 4 presents the correlation values between forage and chemical soil attributes. A significant association between pH and most of the forage attributes could be observed. In contrast, this relation was not significant when comparing the soil and forage contents of P and K (P>0.05). There was, however, a significant association between Al^{+3} with NDF and ADF of -0.6350 and -0.6450(P<0.01), respectively.

The soils parameters of OM, pH, and K presented a correlation with the largest number of productive and qualitative aspects of forage (Table 4). Rigatto et al. (2005) also found correlations between the latter two attributes with characteristics of forage. Conversely, Andrade et al. (2001) reported that in tropical monocultures of grass, a reduction in the availability of N over time tends to be the main cause of degradation of established pastures.

Acid soils with a high Al saturation may aggravate the effect of low water availability, as it affects the growth of roots at depth (Andrade et al., 2001). However, the levels of Al showed no important correlation with the attributes of forage analyzed in the present study (Table 4).

In studies conducted in Patagonia, most of the root biomass of grasses was found up to 20 cm deep; therefore, there was no competition for water with the trees that exploit deeper layers (Gyene et al., 2002). However, in a savanna with less than 650 mm rainfall, the trees do in fact compete with grasses for water. The lower availability of this element was the main limitation for the development of shaded grass, while in open areas, the productivity was limited by lower levels of N in the soil. However, the production of both appeared to be similar (Ludwig et al., 2004).

The appearance of grasses collected in both systems was similar to that described by Andrade et al. (2002). These authors reported that the leaves of shaded forage

Table 4 - Pearson correlations between chemical soil and forage attributes (Lagoa Santa/MG – 2006)

Chemical soil tributes	Forage atributes										
	GMP [a]	DMP [b]	DMC [c]	Ash	Calcium	K [d]	P [e]	CP [f]	NDF [g]	ADF [h]	Lignin
pH	-0.7494***	0.5657*	-0.4823*	-	0.6415**	-0.7273**	-0.5521*	-0.6369**	-	-	-
Phosphorus	-	-	-	-	-	-	-	-	-	-	-
Potassium	-	-	-	-	-	-	-	-	-0.5648*	-0.5724*	-
Sulfur	-	-	-	-		-	-	-	-	-	-
Calcium	-	-	-	-	0.6312**	-	-	-	-	-	-
Magnesium	-	-	-	-	0.5120*	-	-	-	-	-	-
Aluminum	-	-	-	-	-	-	-	-	-	-	-
H+Al [i]	-	-	-	-	-	-	-	-	-	-	-
Sum of bases	-	-	-	-	0.5646*	-	-	-	-	-	-
CEC [j]	-	-	-	-	-	-	-	-	-	-	-
CEC7 [k]	-	-	-	-	-	-	-	-	-	-	-
Bases saturation	-	-	-	-	0.4855*	-	-	-	-	-	-
Organic matter	-	0.5353*	-	-	0.5442*	-	-	-0.5282*	-	-	-
K / CEC 7	-	-	-	-	-0.4499*	-	-	-	-0.6350**	-0.6453**	-

[a]green matter production (GMP), [b]dry matter production (DMP), [c]dry matter content (DMC), [d]potassium (K), [e]phosphorus (P), [f]crude protein (CP), [g]neutral detergent fiber (NDF), [h]acid detergent fiber (ADF), [i]hydrogen plus aluminum (H+Al), [j]effective cation exchange capacity (CEC), [k]cation exchange capacity at pH 7.0 (CEC7) -, ***, **, * (t test: P>0.05; P<0.001; 0.01; 0.05, respectively)

presented an intense dark green color contrasting with the green-clear of samples from the open area, which is indicative of N deficiency in the soil. The CP content, 50% higher in shaded forage than in the non-shaded forage, was attributed to the higher content of N in soil under trees.

The significant regression equations of forage attributes due to soil variables and their respective coefficients of determination are presented in table 5. In general, for each assessed characteristic of the forage, the magnitude and regression coefficients were distinct between the two systems. The Ca^{+2}, K, and lignin forage content were influenced by a greater number of chemical soil attributes in both systems. The same occurred with P and ash content in the SPS forage. A great number of common regression coefficients - pH, P and SSO_4^{-2} – influenced the K forage contents. In some equations, such as protein content, an R^2 of 0.9781 in the monoculture could be observed; however, no significant model for the SPS could be formulated.

Although the light does not act directly in the absorption of nutrients by plants, the levels in these plant tissues are affected by some biological processes, such as respiration, transpiration, and photosynthesis (Castro et al., 2001). Different coefficients of regression in the magnitude, nature, and number of soil attributes influenced forage parameters (Table 5). This complexity can be explained by several factors that are not evaluated in this study, but that act distinctly in the two systems, such as moisture, temperature, light, and impact of wind. Thus, according Feldhake (2001), in an SPS, the trees produce a far more complex effect than simply the contribution of N to the soil. The shadow at appropriate levels, even if artificial, can increase the production and the forage N levels. In temperate grasses, the increase in the N levels was attributed to changes in the morphology of the shaded grass. On the other hand, in the tropical grasses, this increase was credited to the increased availability of N due to more intense microbial activity in the shade. However, in the present study, there was no correlation between the N levels from the forage and those in the soil (Table 4). Gottingen and Zimmermann (1989) reported the occurrence of physiological changes in shaded plants that result in higher N levels. These authors report that the shaded plant has its metabolism changed, thus reducing the amount of N compounds for glycogenesis, in turn causing a greater accumulation of N in their tissues.

In this study, no difference (P>0.05) between the Ca^{+2} levels of the forages analysed (Table 3) could be

Table 5 - Regression parameters of *Brachiaria brizantha* cv. Marandu (BBM) in function of soil attributes in soils under monoculture and silvopastoral system (SPS) (Lagoa Santa/MG – 2006)

Variável	Sistema	Model	R^2
GMP [a]	Monoculture	3466.78 - 664.72 pH + 395.15 Ca [e] - 2.77 K [f]	0.7735
	SPS	-34.38 + 232.59 P [g]	0.7778
DMC [b]	Monoculture	50.55 – 6.48 P – 0.31 K + 9.81 $S\text{-}SO_4^{-2}$ [h]	0.7414
	SPS	-168.11 + 52.24 pH – 60.68 Ca – 0.18 K	0.9750
Ash	SPS	17.48 + 8.85 CEC [i] – 0.42 AS [j] – 0.91 BS [k]	0.7918
Calcium	Monoculture	0.47 + 0.08 Mn [m] – 0.0022 Fe [n] – 0.16 $S\text{-}SO_4^{-2}$ +0.004 K	0.9581
	SPS	0.26 – 0.0013 K – 0.07 Zn [p] + 0.36 Mg [q] + 0.02 (H+Al) [r]	0.9864
Potassium	Monoculture	28.66 – 5.73 pH – 1.03 $S\text{-}SO_4^{-2}$ + 1.41 P – 0.02 K	0.9953
	SPS	42.60 – 6.91 pH – 1.45 P – 0.08 AS – 0.09 $S\text{-}SO_4^{-2}$	0.9809
Phosphorus	SPS	1.50 – 0.34 pH + 0.33 SB [t] - 0.39 Mg – 0.0004 K	0.9864
CP [c]	Monoculture	2.78 – 0.02 K + 0.71 BS – 6.31 SB	0.9781
NDF [d]	Monoculture	118.05 – 9.39 P – 0.33 AS – 39.94 B [u]	0.9499
	SPS	302.93 + 16.25 $S\text{-}SO_4^{-2}$ + 0.75 Fe + 138.37 Ca – 141.19 CEC	0.9156
Lignin	Monoculture	2.45 – 25.66 Ca + 11.10 SB + 1.94 Cu [v] + 0.01 Fe	0.8685
	SPS	65.32 – 3.44 Al + 0.07 Fe – 2.11 Mn – 16.26 CEC	0.9577

[a]green matter production (GMP), [b]dry matter content (DMC), [c]crude protein (cp), [d]neutral detergent fiber (NDF), [e]calcium (Ca), [f]potassium (K), [g]phospurus (P), [h]sulfur ($S\text{-}SO_4^{-2}$), [i]cation exchange capacit (CEC), [j]aluminum saturation (AS), [k]bases saturation (BS), [m]manganese (Mn), [n]ferrum (Fe), [p]zinc (Zn), [q]magnesium (Mg), [r]hydrogen plus aluminum (H+Al), [t]sum of bases (SB), [u]boron (B), [v]copper (Cu)

observed; however, they did show positive correlations with levels of this nutrient and of organic matter in the soil: 0.6312 (P <0.01) and 0.5442 (P<0.05), respectively (Table 4). No consensus has been reached regarding the influence of shade on the Ca^{+2} level of the forage. Carvalho et al (1994) and Castro et al. (2001) reported higher levels of this nutrient in the shaded forage. On the other hand, Andrade et al. (2002) found lower levels in the shaded grass when compared to the non-shaded: 0.21 and 0.26, respectively. These values were attributed to the fact that the shaded forage takes longer to mature and that Ca^{+2}, due to its low mobility, tends to be higher in older leaves.

P levels were found to be higher (P<0.01) (Table 3) in the shaded forage and negatively correlated with the values of pH soil: -0.5521 (P<0.05) (Table 4). Moreover, the levels found by Andrade et al. (2002) were similar for both shaded and unshaded forages: 0.14%. Castro et al. (2001) found that the B. brizantha P levels tended to increase as the luminosity reduced. These authors explain that in most plants, light stimulates the absorption of H_2PO_4; however, no consensus as to whether or not luminosity affects forage P levels has ever been reached, due mainly to the variation among forage species.

The K levels were higher in the shaded forage when compared to that from the open area (P<0.01) (Table 3), which is in agreement with findings from Carvalho et al. (1994) and Andrade et al. (2002). The values reported by Andrade et al. (2002) regarding forage with and without the influence of trees were of 3.34 and 2.77, respectively. Andrade et al. (2001) also concluded that potassium fertilization increased the levels of K in forage. Nevertheless, in the current experiment, no correlation (P>0.05) between the levels of this element in the soil with those in the forage could be observed. Furthermore, the levels of this nutrient showed negative correlations with pH values, -0.7273 (P<0.01), and MO, -0.4880 (P<0.05) (Table 4). Therefore, other factors may have influenced the K levels. According to Silva-Pando et al. (2002), the shade in fact influences optimal rates of fertilization.

Nair (1998) warned of the dangers of assessing the SPS using only one single variable, defending that the sum of these variables can prove more beneficial as the SPS can provide a wide range of products and services. This can be observed in the work of Kallenbach et al. (2006) who compared the production of Lolium multiflorum Lam and Secale cereale L., with and without the influence of Pinus rigida Mill. These authors concluded that the shaded area produced approximately 20% less DM of forage than did the open area. In contrast, until the trees reach six to seven years of age, no difference in meat production when comparing the areas with and without trees could be observed. It is believed that the tree protection, when faced with extreme temperatures, may have offset the lower forage production. Thus, as Jansen et al. (1997) reports, some potential benefits of trees in pastures, such as shade for livestock, risk of erosion reduction, and increase in biodiversity, are difficult to calculate on an economical scale. Nonetheless, according to Tapia-Coral et al. (2005), despite the environmental benefits, these systems should be used as an alternative for areas which have already cleared and not as a replacement for primary forests.

4. CONCLUSIONS

Under the assessed conditions, the presence of tree species *Zeyheria tuberculosa* Vell. Bur in pastures of BBM did not affect the DMP of forage. The trees apparently alleviated the hydric stress and influenced forage mineral composition. No change in the levels of NDF, ADF and, lignin could be observed. Nevertheless, the trees favored the forage quality, represented by increasing CP levels. The CP levels of the open area forage were insufficient to meet the maintenance requirements of ruminants. Some attributes of forage showed a correlation with soil attributes. The lack of correlation of other variables in the BBM may indicate the influence of other factors, such as shade and microclimatic conditions offered by trees. The silvopastoral system, therefore, has the potential of becoming a feasible option for sustainable livestock production, thus contributing to the nutritional value of forage during a period of reduced rainfall.

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