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Morphogenic, structural, productive and bromatological characteristics of Braquiária in silvopastoral system under nitrogen doses

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ABSTRACT. This study aimed to evaluate the effect of different doses of nitrogen fertilization on the morphogenic, structural, productive and chemical composition of *Urochloa decumbens* (Stapf) R. D. Webster cv. Basilisk in a silvopastoral system with eucalyptus. The experimental treatments consisted of pastures of Basilisk cultivar, fertilized with 0, 100, 200, 300 and 400 kg ha^{-1} year^{-1} of N, and intercropped with eucalyptus, clone GG 100 (*Eucalyptus grandis* x *E. urophylla*). The experimental arrangement followed a randomized block design with four replicates. The evaluated characteristics were: foliar appearance rate, phyllochron, leaf length, leaf elongation rate, leaf life span, foliar senescence rate, number of green leaves per tiller, number of senescent leaves per tiller, daily dry matter accumulation, dry matter production, crude protein, and neutral detergent fiber. In the conditions of the established silvopastoral system, nitrogen fertilization did not influence ($p > 0.05$) the morphogenic and structural characteristics of Basilisk cultivar, except for height ($p < 0.01$) and leaf: stem ratio ($p = 0.02$). The nitrogen fertilization of the *Brachiaria* grass with eucalyptus in the proposed structural arrangement does not modify ($p > 0.05$) the morphogenic characteristics. However, in ration to dry matter production, doses of up to 400 kg of N ha^{-1} are recommended.

Keywords: chemical composition; dry matter production; eucalyptus; leaf elongation rate; *Urochloa decumbens*.

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Introduction

In cattle production systems, sustainability can be achieved through the use of farming techniques that integrate different components such as the cultivation of trees and forage and the production of animals, characterizing a silvopastoral system (Bosi, Pezzopane, Sentelhas, Santos, & Nicodemo, 2014; Lopes et al., 2017a; Lopes et al., 2017b). Several studies (Abraham et al., 2014; Bosi et al., 2014; Paciullo et al., 2014) have pointed out that silvopastoral systems have a high potential to increase soil fertility, provide thermal comfort to animals, improve nutritional value of forage and animal performance, in addition to promote diversification in the source of income for the farmer. However, the shading promoted by trees in silvopastoral systems can modify the microclimate of pasture, altering, above all, the quantity and quality of forage produced (Abraham et al., 2014; Bosi et al., 2014; Kyriazopoulos, Abraham, Parissi, Koukoura, & Nastis, 2013; Reis et al., 2013).

According to Gómez, Guenni, and Guenni (2013), the mass production and nutritional value of forage grasses in association with tree species can be modified, which is determinant due to factors inherent to the tolerance of the species in the shade, the degree of shading provided by the trees and the competition among the plants, in relation to soil water and nutrients. Research on forage species which are tolerant to shade have pointed out that the morphogenetic and structural characteristics may also be altered when they grow in the shade, providing greater production potential than non-tolerant species in cultivation under low luminosity (Abraham et al., 2014; Bosi et al., 2014; Lopes et al., 2017a). Furthermore, according to the same authors, the chemical composition of forages can be influenced by the environment, mainly by the edaphoclimatic conditions. Therefore, it can be modified in silvopastoral systems. Thus, plants that develop in shaded environments, such as in sub-forests of silvopastoral systems, may present variations in the quality of the forage produced, when compared to plants that develop in full sun according to studies of Paciullo et al. (2014) and Lopes et al. (2017a). However, in grasses of the species *Brachiaria brizantha* cv. Marandu under shading, Reis et al. (2013) did not find the shadow effect on the nutritional value of the forage. Therefore, more studies are needed.

In the central and northern regions of the state of Minas Gerais, it is common to find acid soils and with low levels of nutrients and organic matter, which have caused insufficient forage masses in the pasture along with some degree of degradation, besides forage with reduced nutritional value nutritional (Lopes et al., 2017a; Reis et al., 2013). The application of nutrients in the soil, mainly nitrogen, could benefit the production and the nutritive value of the pasture (Bravin & Oliveira, 2014; Sales et al., 2014a). However, the restricted solar radiation associated with fertilization levels, under forage shade conditions, can affect the response efficiency of forage plants to the applied fertilizer, which depends on the forage species, the edaphoclimatic conditions, and the level of shading imposed by the sub-forest (Gómez et al., 2013; Kyriazopoulos et al., 2013; Lopes et al., 2017b; Reis et al., 2013).

This study aimed to evaluate nitrogen fertilization doses on the morphogenic, structural, productive and chemical composition of *Urochloa decumbens* (Stapf) R. D. Webster cv. Basilisk in a silvopastoral system with eucalyptus.

Material and methods

Location of the experiment

The experiment was conducted from December 2011 to May 2012 at the Experimental Farm of the Agricultural Research Company of Minas Gerais (EPAMIG), located in the municipality of Felixlândia, in the center-west of Minas Gerais (latitude 18°15 'S and longitude 44° 55'L). The climate of the region is classified as tropical savanna, with two distinct seasons, dry winter and rainy summer (Antunes, 1994), with average precipitation of 1,126 mm annually. In figure 1, precipitation and average temperature data are arranged in the experimental period.

The soil of the experimental area is classified as a dark red, dystrophic latosol with a clayey texture. Samples of soil taken in the 0-20 cm layer were submitted to analysis for determination of the following chemical parameters: calcium, magnesium, hydrogen + aluminum, aluminum, sum of bases and cation exchange capacity, and the results were 3.1; 1.0; 3.6; 0.3; 4.5 and 8.1 cmolc.dm^{-3}, respectively. The saturation of bases, residual phosphorus and potassium were 55.4%, 15.3 and 146 mg.dm^{-3}, respectively.

Treatments, management and experimental design

Experimental treatments consisted of pastures of *Urochloa decumbens* (Stapf) R. D. Webster cv. Basilisk, fertilized with 0, 100, 200, 300 and 400 kg ha^{-1} year^{-1} of N and intercropped with eucalyptus, clone GG 100 (*Eucalyptus grandis* x *E.urophylla*). The silvopastoral system was implemented in 2009, in an arrangement of 4 lines (3 x 3 x 3) + 10 m, that is, 4 eucalyptus lines spaced (3 meters) between plants with 3 meters between lines and 10 meters of spacing (Pacciullo et al., 2011). The silvopastoral system consists of the Basilisk cultivar and the *Eucalyptus grandis* tree species, which presented 10 cm of diameter at the breast height and 6m of height, respectively. The experimental plots were demarcated in the bands, with an area of 10 meters x 19 meters totaling 190 m². For nitrogen fertilization, urea was used as the source of nitrogen (N, 45%).

Before the experimental period, a standardization cut was carried out in the pasture, followed by phosphate fertilization (100 kg ha^{-1} of P_2O_5), based on the results of soil analysis and plant requirement.

The treatments were allocated to the experimental units in a randomized block design with four replicates, totaling 20 experimental units.

After the standardization cut, at the beginning of December 2011, 1/3 of the N dose of each treatment was applied for the first evaluation, performed on January 05, 2012. The rest of the nitrogen fertilization was applied after the second cut occurred on February 23, 2012. The subsequent cuts were made on April 13 and May 17, 2012, totaling four cuts. The interval between cuts corresponded to the period of time necessary for the canopy to reach a height of 30 cm.

After the evaluative cut, the pickets were grazed by adult cattle in maintenance, aiming the forage consumption under real grazing conditions. The cows were removed when the height of pasture residue reached 15 cm (Sales et al., 2014a). The grazing period lasted on average three days after the assessments in the plots.

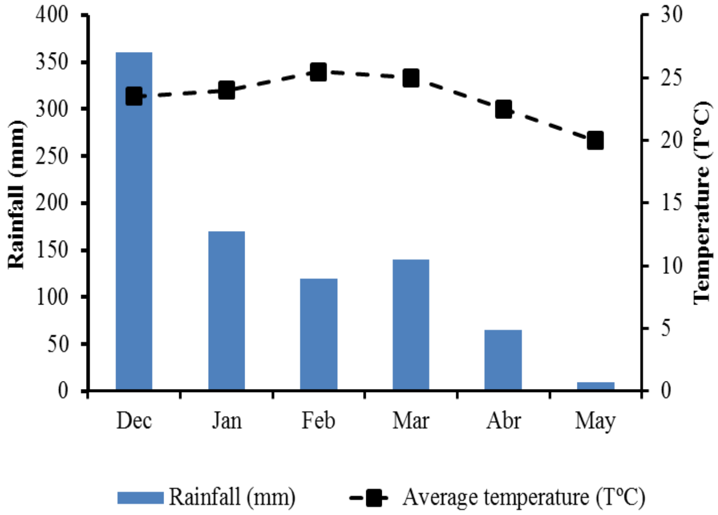

Figure 1. Rainfall and temperature averages during the experimental period. Source: EPAMIG, Felixlândia, Minas Gerais.

Forage mass

To determine the forage mass of the experimental units, a square with an area of 1m^2 was used, launched four times randomly within the useful area of each plot. Forage cutting was performed at a height of 15 cm from the soil, and the collected material was placed in plastic bags and weighed to determine the green matter production (GMP) per hectare. With the homogenized material, two sub samples of approximately 300g were used for fractionation in leaf, leaf sheath and dead material, to determine leaf blade/stem (L:C) ratio and percentage of dead material (DM). After fractionation of the plant, the samples were taken to a forced ventilation oven at 55°C for 72 hours to determine the pre-dry matter (DM) content. The dry matter production (DMP) was determined by multiplying GMP by the final dry matter content and the values were converted to tons of DM ha^{-1}.

Morphogenetic and structural characteristics of pasture

For morphogenetic and structural analyzes of the canopy during the regrowth period, six basal tillers per plot were randomly selected in different clumps (Paciullo, Aroeira, Morenz, & Heinemann, 2006). The tillers were identified with yarns of different colors for better identification. The evaluations were carried out weekly (every 7 days) during the period from January 17 to February 7, 2012. With the aid of a ruler, the length of leaf blades, the length of the pseudo-stem of the base of the tiller were measured soil up to the last leaflet of the expanded leaflet, and the number of new leaves emerged on each of the tillers was counted. Senescence was determined by the sum of the measurements of the senescent parts of the tiller leaves.

The data recorded were used to calculate the following variables according to Mazzanti, Lemaire, and Gastal (1994), Paciullo et al. (2006), Sales et al. (2014b) and Sales et al. (2014a):

- Leaf appearance rate (LAR): it was calculated by dividing the total number of leaves in the tiller by the regrowth period, expressed in leaf day^{-1};

- Phyllochron (day leaf^{-1}): it was calculated by dividing the regrowth period by the total number of leaves in the tiller, expressed in day leaf^{-1};

- Final length of the leaf (FLL): to determine the final length of the leaf, the fully expanded leaves were measured from their insertion in the ligule to the leaf apex. Only the leaves of the evaluated tiller were measured, and with the ligule totally exposed;

- Leaf elongation rate (LER): it was calculated by the difference between the final and initial leaf lengths divided by the number of days between measurements;

- Final length of the pseudo-stem (FLP): it was calculated based on the soil level up to the last expanded leaflet of each tiller. The result was divided by the sum of the pseudo-stem length of each till by the number of tillers under evaluation;

- Pseudo-stem elongation rate (PER): it was calculated by the difference between the final and initial lengths of the pseudo-stem divided by the number of days between measurements;

- The lifespan of a leaf (LL) was given as the number of days of their complete expansion to death. These observations and records, performed during the rest period, started after the animals left the grazed picket and were repeated in each grazing cycle, until the next grazing season.

- The leaf senescence rate (cm day^{-1}. tiller) was calculated by dividing the total final length of the senescent tissue by the number of days involved.

- Number of green leaves per tiller (NGLT): Average number of expanded and expanding leaves per tiller, disregarding senescent leaves;

- Number of senescent leaves per tiller (NSLT): Average number of leaves in senescence per tiller

- The daily dry matter accumulation rate was obtained by the ratio of the total dry matter production to the number of days of the experimental period.

Chemical composition

The dry matter (DM) and crude protein (CP) contents were determined according to the methodology of Association Official Analytical Chemist (AOAC, 2005). The components of neutral detergent fiber (NDF) and acid detergent fiber (ADF), hemicellulose (Hem) and lignin were obtained according to the sequential analysis proposed by Van Soest, Robertson, and Lewis (1991), without the use of the amylase enzyme. The contents of neutral detergent insoluble nitrogen (NDIN) and acid detergent insoluble nitrogen (ADIN) were determined according to Licitra, Hernandez, and Van Soest (1996).

Statistical analysis

The variables data were submitted to analysis of variance, and when significant by the F test, the variables were submitted to the regression study between the independent variable (inclusion doses) and the dependent variables obtained in the experiment, through the statistical program SISVAR (Ferreira, 2014), at 5% probability.

Results and discussion

In the conditions of the established silvopastoral system, nitrogen fertilization (N) did not influence the morphogenic and structural characteristics of Basilisk cultivar ($p > 0.05$), except for height ($p < 0.01$) and leaf: stem ratio ($p = 0.02$; Table 1).

The height increased linearly with increasing doses of N application, with an increase of 0.01 cm for each unit of N. For the leaf: stem ratio, there was a behavior contrary to height, since the means adjusted to the linear decreasing regression analysis. The increase in the structure of the forage canopy is justified as a function of the mechanism in the plant in search of luminosity, especially in conditions of reduced luminous intensity as in sub-forests. The plant with high index of leaf area competes with each other for the luminosity (Paciullo et al., 2011). As a strategy to maximize the light interception, it lengthens the height, consequently, increasing the height of the fodder stand, decreasing the ratio leaf: stem. In addition to the effects of physiological maturity, plant growth is stimulated by the availability of N in the soil, which when absorbed by plants, via roots, acts on the multiplication of the cellular phytomers and mitotic processes, consequently accelerating the physiological maturity (Pandey, Verma, Dagar, & Srivastava, 2011).

In general, as the same level of shading was equal for the treatments, it can be verified that the luminous intensity may have contributed, in isolation, on most of the characteristics of the forage canopy, even in conditions of high application of N (400 kg ha^{-1}). Also, it is possible that N volatilization losses could have occurred in this system, since the canopy height variation in the highest N dose and in the control treatment was 16.8%, which was low considering the high dose applied. This implies that the growth, although increasing, was slow due to the limitation and quality of the light radiation caused by the arboreal component due to the distance (10 meters) between rows (Paciullo et al., 2011). In studies evaluating different row spacing in agroforestry systems, Paciullo et al. (2011) verified that the maximum daily incident radiation in summer (1.788 μmol m^{-2} s^{-1}) occurs when the width of the rows is 12.5 m from the trees, which justifies the low light incidence in distance of lower roots, mainly during the early morning and late afternoon, according to the solar elevation, because the tree roots are arranged north/south.

Table 1. Morphogenic and structural characteristics of *Urochloa decumbens* cv. Basilisk under doses of nitrogen in silvipastoral system.

Item	Doses of N (kg ha^{-1})					CV	P>F
	0	100	200	300	400		
LAR, leaf day^{-1}	0.100	0.100	0.116	0.120	0.112	20.5	0.50
Phyllochron, day leaf^{-1}	10.5	12.7	9.0	10.9	11.8	17.9	0.13
FLL, cm	10.18	10.24	9.51	12.03	12.44	8.68	0.31
LER, cm tiller^{-1} day^{-1}	0.403	0.370	0.402	0.466	0.421	13.22	0.34
FLP, cm	21.44	20.08	20.95	22.80	22.45	5.92	0.16
PER, cm tiller^{-1} day^{-1}	0.256	0.276	0.356	0.4194	0.373	16.96	0.26
LL, days	29.59	45.51	42.30	39.24	36.37	9.47	0.48
Leaf senescence rate, cm tiller^{-1} day^{-1}	0.084	0.077	0.071	0.105	0.122	11.23	0.25
Density, tiller^{-1} m^{-2}	636	976	765	850	1021	25.8	0.15
Height, cm[3]	33.03	34.83	34.23	39.66	38.58	5.74	0.01
leaf: stem ratio[4]	1.24	1.03	1.06	0.94	0.91	10.74	0.02
NGLT,	3.24	3.15	3.23	3.18	3.05	15.05	0.97
NSLT	0.537	0.472	0.407	0.500	0.277	22.28	0.58
Total number of tillers	57.16	60.33	61.22	63.50	62.44	19.6	0.12
Number of basal tillers	52.66	53.66	55.18	58.00	56.55	25.8	0.15

LAR - Leaf appearance rate; FLL – Final length of the leaf; LER – Leaf elongation rate; FLP – Final length of the pseudo-stem; PER – Pseudo-stem elongation rate; LL – Lifetime of a leaf; NGLT – Number of live leaves per tiller; NSLT – Number of senescent leaves per tiller; CV – Coefficient of variation (%); P – Probability; [3] $\hat{Y} = 32.7 + 0.01X$; $R^2 = 0.76$; [4] $\hat{Y} = 1.20 - 0.0008X$; $R^2 = 0.83$

Nutritionally, the reduction of the blade: stem ratio is not interesting for the animals, since the leaf presents better nutritional value than the stem (Monção et al., 2016; Oliveira et al., 2016). In addition, the way of harvesting by the animal is favored in canopy with greater presence of leaves, as well as, the biting rate is smaller, favoring the necessary intake of dry matter by the animals in a shorter period. With this, more time will be spent for rumination and leisure. Therefore, an leaf: stem ratio less than 1 is not interesting, fact verified in this research in doses up to 200 kg ha^{-1} of N, since it can interfere negatively in the animal performance and in the recycling of the nutrients of the soil.

The increase in the height of the forage canopy with nitrogen fertilizer application positively affected the production of green matter ($p < 0.01$) and dry matter production (DMP; $p < 0.01$). There was an increase of 0.004 t ha^{-1} of DM for each kilogram of N applied, and at a dose of 400 kg ha^{-1} of N, the DMP was increased in 88.8% in relation to the pastures without fertilization with N (1.96 t ha^{-1}; Table 2).

The highest DMP with N doses occurred due to increasing accumulation of DM ($p = 0.02$) in the order of 0.00003 t ha^{-1} DM per day. Using N-P-K fertilizer, Lopes et al. (2017a) verified increase in DMP and rate of accumulation of *B. decumbens* under different levels of shading. Guenni, Seiter, and Figueroa (2008) verified that plants grown under shade accumulate N in tissues, but this do not correspond in increase in DMP. Thus, the variation in DMP is justifiable.

Table 2. Production characteristics and chemical composition of *Urochloa decumbens* cv. Basilisk under doses of nitrogen in silvipastoral system.

Item	Doses of N (kg ha^{-1})					CV	P>F
	0	100	200	300	400		
Green matter production [1]	8.48	12.02	11.65	16.47	17.3	11.5	0.01
Dry matter production [1]	1.96	2.69	2.9	3.61	3.7	11.6	0.01
DM accumulation rate[2-3]	0.011	0.015	0.017	0.021	0.023	14.4	0.02
Stem, %	41.4	45.7	46.1	47.8	47.2	5.41	0.02
Leaf, %	50.2	45.1	47.9	44.6	45.7	5.74	0.06
Senescent material, %	8.4	9.2	6.0	7.6	7.1	27	0.30
Dry matter, %	23.02	22.46	21.49	21.02	20.76	4.01	0.11
Crude protein, %	5.56	6.60	7.06	7.41	8.52	11.27	0.16
Neutral detergent fiber, %	61.88	63.3	60.91	60.69	60.16	4.13	0.17
Acid Detergent Fiber, %	37.07	37.46	35.46	35.38	34.82	3.65	0.01
Hemicellulose, %	24.81	25.83	25.44	24.7	22.94	11.9	0.83
Cellulose, %	15.79	23.42	23.42	16.53	11.14	11.03	0.03
Lignina, %	11.85	12.06	20.18	18	8.32	14.06	0.01
NDIN[4], % MS	0.129	0.105	0.142	0.151	0.171	5.54	0.01
ADIN[2-5], % MS	0.264	0.175	0.24	0.334	0.395	27.4	0.37

[1]t ha^{-1}; [2]DM – dry matter content; [3] t ha day^{-1}; [4]NIDN – Neutral detergent insoluble nitrogen; [5]ADIN - Acid detergent insoluble nitrogen; CV – Coefficient of variation (%); P – Probability. $\hat{Y}$ Dry matter production $= 0.004X + 2.1$; $R^2 = 0.94$; $\hat{Y}$ DM accumulation rate $= 0.00003X + 0.01$; $R^2 = 0.98$; $\hat{Y}$% Stem $= 0.014X + 42.9$; $R^2 = 0.74$; $\hat{Y}$ Acid detergent fiber $= -0.007X + 37.3$; $R^2 = 0.81$; $\hat{Y}$ Cellulose $= -0{,}0002X^2 + 0.08X + 16.6$; $R^2 = 0.91$; $\hat{Y}$ Lignin $= -0.0002X^2 + 0.08X + 10{,}0$; $R^2 = 0.68$; $\hat{Y}$ NDIN $= 0.0001X + 0.11$; $R^2 = 0.70$

The fractionation of the plants showed that the proportion of stem increased (0.014% kg^{-1} of N) linearly with the application of N, being that the difference between the dose of 400 kg ha^{-1} of N and the control treatment of 14 percentage units. The height of the canopy and the reduction in the blade: stem ratio is justified by the increase in the proportion of stem with the increasing fertilization with N. The proportion of leaf (p = 0.06) and senescent material (p = 0.30) was not modified with increasing application of N in the soil, with a mean of 46.7% and 7.7%, respectively.

In relation to the chemical composition, the content of DM (p = 0.11), crude protein (CP, p = 0.16), neutral detergent fiber (NDF, p = 0.17), hemicellulose (p = 83) and acid detergent insoluble nitrogen (ADIN, P = 0.37) were not affected by the doses of nitrogen fertilizer in the silvopastoral system. The averages of these characteristics were 21.7, 7.03, 61.4, 24.7 and 0.28%, respectively.

The content of acid detergent fiber (ADF) reduced linearly (0.007% kg^{-1} N) with the application of increasing doses of N, while the content of neutral detergent insoluble nitrogen (NDIN) increased by 0.0001% kg^{-1} of N. The cellulose and lignin contents were adjusted to the quadratic regression model, with the maximum point reached at 200 kg ha^{-1} of N.

It is difficult to verify in the literature the effect of shading on the contents of the components of the cell wall of forages (Lin, McGraw, George, & Garrett, 2001; Paciullo et al., 2008; Sousa et al., 2010). The variations in the levels of ADF and lignin seem to be related to the dilution provided by the nitrogen fertilization, which increases the cellular content to the detriment of the wall (Van Soest, 1994). The opposite occurs with stage of maturity of the plant (Lin et al., 2001). Furthermore, Paciullo et al. (2011) reported that under conditions of high shading level, plants tend to etiolate at maturity, which may result in increases in forage fiber content, a fact verified in this research with the increase of plant height and the reduction of the relation leaf: stem. According Paciullo et al. (2011), the etiolation (growth in the absence of light) consists of a strategy of the plant to increase the forage canopy in search of luminosity, and this increase usually occurs by stretching the stem.

Although the animal performance has not been evaluated, the data verified in this research imply that the application of N in the pasture, by raising the DMP, can increase the rate of animal stocking per unit area, which is important when there is low availability of area and when it is intended to increase the weight gain per area. Without use of N, Santos, Santos, Neiva, and Neves Neto (2016) did not verify improvement in the performance of lambs in agroforestry system, using *Panicum maximun* cv. Mombaça, in relation to conventional systems. According to the authors, intense shading may have contributed to the low accumulation of forage, limiting forage intake and animal performance. In addition, the question of the spacing between rows is very indefinite, especially in the different edaphoclimatic conditions and Brazilian regions, which reinforces the importance of further studies with the animal unit.

Conclusion

The nitrogen fertilization of the *Brachiaria* grass in consortium with eucalyptus, in the structural arrangement proposed in this research, does not modify the morphogenic characteristics of the forage. However, in relation to the production and rate of accumulation of dry matter, it is recommended to apply doses close to 400 kg of N ha^{-1}. It is suggested to carry out economic feasibility studies for the application of N in pasture of *Brachiaria* grass under shading influence.

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