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Light relations and performance of signal grass in silvopastoral system

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ABSTRACT. The aim was to evaluate the influence of different spatial arrangements of trees [(3×2)×20 m, (2×2)×9 m and 2×9 m] and sampling sites (center of row spacing and side of tree rows) with regard to the amount and quality of light in the understory of silvopastoral systems and their effects on the production and chemical composition of pasture. The experimental design was a randomized block in a split plot, with three replications. The sampling site affected absolute irradiance, photosynthetic active radiation (PAR), light interception (LI) and red/far red ratio, with higher rates in the center of spacing. There were high and positive correlations between LI/leaf area index (LAI), LI/dry mater (DM) and LAI/DM in the center and LI/LAI and FAR/DM in the side of tree rows. Spatial arrangement (3×2)×20 m had higher rates for plant height (PH), DM and neutral detergent fiber rate, while (2×2)×9 m had high leaf/stem ratio and crude protein rate. In the case of the sampling site, higher rates of PH and DM were reported in the center. Forage composition was not affected by sampling sites. Highest production of DM was obtained in the (3×2)×20 m arrangement and improvements in forage composition were observed in denser arrangements.

Keywords: quality of light, shading, spatial arrangements, *Urochloa decumbens*.

Relações luminosas e desempenho do capim-braquiária em sistema silvipastoril

RESUMO. Objetivou-se avaliar a influência de diferentes arranjos espaciais de árvores ((3×2)×20 m, (2×2)×9 m e 9×2 m) e locais de amostragem (centro e lateral da entrelinha) na quantidade e qualidade de luz no sub-bosque de sistemas silvipastoris e seus efeitos na produção e composição bromatológica da pastagem. O delineamento utilizado foi blocos casualizados em parcelas subdivididas, com três repetições. O local de amostragem influenciou a irradiância absoluta, a radiação fotossinteticamente ativa incidente (RFAi), interceptação luminosa (IL) e relação vermelho/vermelho distante, sendo determinados maiores valores no centro das entrelinhas. Observou-se correlações altas e positivas entre IL/índice de área foliar (IAF), IL/produção de massa seca (PMS) e IAF/PMS no centro e IL/IAF e RFAi/PMS na lateral das entrelinhas. O arranjos espaciais (3×2)×20 m apresentaram maiores valores para altura da planta (AP), PMS e teor de fibra em detergente neutro, enquanto o (2×2)×9 m apresentou maiores valores para relação folha:colmo e teor de proteína bruta. Quanto ao local de amostragem, os maiores valores de AP e PMS foram observados no centro. A composição da forragem não foi influenciada pelos locais de amostragem. A maior PMS foi obtida no arranjo (3×2)×20 m e melhorias na composição da forragem foram observados nos arranjos mais adensados.

Palavras-chave: qualidade da luz, sombreamento, arranjos espaciais, *Urochloa decumbens*.

Introduction

Pasture is the main feed source for Brazilian cattle. However, most Brazilian pasturelands are degraded featuring productivity decrease and severe environmental damages to livestock activities. Silvopastoral systems (SPS) may be an alternative to increase the efficiency of cattle raising systems with low environmental impact. SPS are characterized by the integrated exploitation of trees, pastureland and animals to harvest products from these factors within the same area. SPS understory such assets as high incorporation of nutrients and improvements in soil characteristics, thermal comfort for animals (PAES LEME et al., 2005) and improvements in the nutritional value of pastures (SOARES et al., 2009).

Spacing between trees in SPS is a determining factor for the plant community´s development and longevity, exploited in its understory (PACIULLO et al., 2011). Wilson and Ludlow (1991) reported that, besides the reduction of luminosity, there are alterations in the spectrum characteristics of solar radiation falling on the systems´ understory. Knowledge on the solar radiation on the forest understory is highly relevant for the development of techniques for the system´s management. However, scanty information exists on this theme in the literature.

Current experiment investigates the influence of different space arrangements of eucalyptus trees (*Eucalyptus grandis* × *E. urophylla*) and sampling sites on the quantity and quality of light on the understory of silvopastoral system and their effects on the production and chemical composition of signal grass (*Urochloa decumbens* Stapf).

Material and methods

Current experiment was performed on the Experimental Farm Santa Rita, belonging to EPAMIG, in Prudente de Morais, Minas Gerais State, Brazil, a savannah zone, at 19° 27' 15''s and 44° 09' 11''W, altitude 732 m. Predominant soil may be classified as Oxisol (Red-Yellow Latosol), with a clayey texture (EMBRAPA, 2006). The region´s climate is Aw, with dry winters and rainy summers, according to Köppen´s classification. Climate averages during the experimental period are given in Table 1.

Table 1. Monthly rates of average temperature (AT), total sunshine and rainfall during the experimental period.

Month	AT (°C)	Total sunshine (hours)	Rainfall (mm)
Nov/11	22.29	182.20	264.90
Dec/11	23.40	89.30	452.90
Jan/12	23.53	196.80	383.40
Feb/12	24.30	230.20	31.80
Mar/12	23.73	214.60	203.40
Apr/12	23.30	245.00	55.30

Source: Meteorological Station - Embrapa Milho e Sorgo.

Experiment was carried out in a pasture area with *Urochloa decumbens* implanted a year after the planting of eucalyptus trees, clone GG 100 (*Eucalyptus grandis* × *E. urophylla*) in 2008.

Experimental design consisted of randomized blocks in split plots with three replications, on a 3×2 factorial scheme represented by spacing arrangements [(3×2)×20 m, (2×2)×9 m and 2×9 m] of eucalyptus and sampling sites in the pasture (center of row spacing and side of tree rows). Space arrangements under analysis were defined as follows: (3×2)×20 – two parallel lines with 3 m spacing between them, 2 meters between the trees in the lines and 20 m of row spacing, with a total of 434 trees ha^{-1}; (2×2)×9 – with two parallel lines with 2 m spacing between them, 2 meters between the trees in the lines and 9 m of row spacing, with a total of 909 trees ha^{-1}; 2 x 9 – with a simple line, 2 meters between the trees in the lines and 9 m of row spacing, with a total of 556 trees ha^{-1}. Cutting cycles were undertaken on November 2011 and on January, March and April 2012 in the split plots. Eucalyptus trees were planted in rows in an east-west direction.

Characterizing the evaluation cycles in November, January, February and March 2011-2012, four harvests in the pasture occurred when forage plants reached a height between 40 and 50 cm. Prior to each harvest, measurements of the pasture sward height were taken from the ground level to the curve of the upper leaves. Sampling at 15 cm from the ground were performed using a 1 m^2 square to evaluate the dry matter yield (DMY) and close to the ground to separate leaf blade and stems + leaf sheath and determine the leaf/stem ratio (L/S). An area (4.5×1 m) was sampled in the (2×2)×9 and 2 x 9 structural arrangements and an area of (10 × 1 m) was sampled in the structural arrangement (3×2)×20, from the center of the spacing to the side of the split.

Samples collected at 15 cm from the ground were weighed and dried in a forced air-circulation oven at 55°C during 72 hours. They were then processed in a Willey Mill with a 1 mm sieve, so that their chemical composition could be stored. Dry matter (DM) and crude protein (CP) rates were determined according to methodology by Detmann et al. (2012); rates of neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Van Soest et al. (1991).

The variables related to luminosity (absolute radiance – AR; photosynthetically active radiation – PAR; red/far red ratio - R/FR) were assessed in the second evaluation cycle. Spectrometer USB2000+ (Ocean Optics, USA) with optic fiber and cosine corrector was employed to obtain AR graphs (μW cm^{-2} nm^{-1}) at wavelengths corresponding to blue (between 460 and 480 nm), green (between 545 and 561 nm), red (between 520 and 670 nm) bands. Data received were processed with SpectraSuite Software. Measurements were collected between 11 am and 13 pm during days with little or no clouds, with the sensor at a height of 1.0 m. Irradiation measures were taken in the center of each spacing of each split, at a distance of 1.0 m of the tree rows, at the sides. Irradiation measures were also taken in bright sunlight in each day of evaluation.

R/FR was evaluated by LightScout Red/Far Red Meter (Spectrum Technologies, Inc.) at the same sites, dates and times in which irradiancy was measured. Average of three measures at the center of the row spacing and at the side of the tree rows spacing was obtained.

Monitoring of light interception by eucalyptus plants and by the forage plants was performed by two previously calibrated canopy ceptometers AccuPAR LP 80 which were employed to measure light interception and calculate the leaf area index (LAI). Readings were undertaken in an adjacent area to pasture at each minute during the evaluation day, from 11 am to 13 pm, and in each split plot at the same time, with the other equipment.

Light interception (LI) of the forage canopy was determined by the following equation:

$$LI = \left({}^{\text{FAR below the canopy}}/_{\text{FAR above the canopy}}\right) \times 100$$

LAI was estimated in an area without trees simultaneously to the monitoring of light interception by mean forage canopy based on PAR measured above and below the canopy, with variables related to canopy architecture, sun position and ground area.

The variables quality of light, light interception of the pasture, PAR, R/FR and DMY underwent Pearson´s linear correlation and their coefficients tested with *t*-test at 1 and 5% probability.

The results were submitted to analysis of variance and averages were compared by Tukey´s test at 5% significance. Computer statistical package SISVAR 5.1 was used (FERREIRA, 2007).

Results and discussion

Figure 1 shows absolute irradiance (AI) in spatial arrangements and sampling sites. Regardless of the spatial arrangement under analysis, sampling site changed AI rates especially in the 400 - 460 nm (violet and blue) wavelengths. The highest AI value observed among the spacing arrangements in the side of tree rows (32,1 μW cm^{-2} nm^{-1}) was equivalent to 58,36% of the value obtained in the center of the row spacing (55.0 μW cm^{-2} nm^{-1}). It may thus be presumed that greater closeness to sampling site with the row of trees caused a greater shading level on the place. In other words, the filter effect produced by the canopy of the trees was more intense on the side of tree rows rather than at the center of row spacing. Andrade et al. (2002) reported a higher shade level in areas close to the rows of trees which decreased as the central region of the spacing was evaluated. The above shows the great heterogeneity of solar radiation on the understory of silvopastoral systems (SPS).

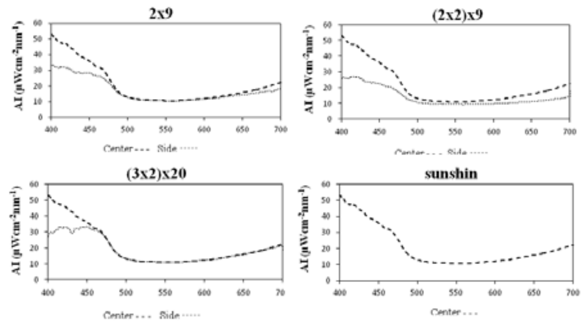

Figure 1. Spectrum of absolute irradiancy (AI) in μW cm^{-2} nm^{-1} representative of the second cycle (January 2012), in the three spatial arrangements, for sampling sites (center on row spacing and side of tree rows).

In the case of spatial arrangement, the three spaces showed the same behavior for AI in the center of the row spacing. Further, when results were compared to behavior given in broad sunshine, AI rates in the center of the row spacing were not affected by treetops shading. Response may have been influenced by the trees´ east-west direction, associated with the inclination of sun rays during the period in which AI was evaluated, or rather, in January when sun rays in the southern hemisphere fall almost vertically on the earth. It is possible there no radiation retention in the center of the row spacing for any spatial arrangement analyzed.

AI rate on the right side of the space had different types of behavior among the spatial arrangements evaluated. The spatial arrangement (3×2)×20 had a constant trend for AI rate in the side of tree rows on the 400 - 475 nm wavelength. Arrangements with smaller spacing between the tree rows (9 m) had a decreasing behavior for this rate within the same wavelength. Probably a greater spacing between the tree rows (20 m) may have provided a greater solar radiation sidewise the trees when compared to the other spatial arrangements evaluated.

The lowest AI rate in the side of tree rows, between the spatial arrangements studied, was registered in treatment (2×2)×9, whose result was always lower than that of AI in the center of the spacing throughout the hotosynthetically active radiation band (400 – 700 nm). AI rates in arrangement 2 x 9 in the two sampling sites were similar with regard to 490 – 640 nm wavelengths.

After such light spectrum, AI rate in the center of the spacing was higher than that reported in the side of tree rows. The adoption of double lines in the tree rows may have affected the result with greater retention of solar radiation in the side of tree rows when compared to spatial arrangement with simple rows. AI rates between the sampling sites were similar for treatment (3×2)×20 in the 475 – 700 nm band. The largest row spacing (20 m) provided high radiation falling in the side of tree rows when compared to other treatments. Although arrangement (3×2)×20 also has a double line of trees, which may decrease AI rates in the side of tree rows as occurred in treatment (2×2)×9, its greater spacing between trees probably provided greater diffused radiation in the center of row spacing.

Results provided by current analysis indicated relevant differences in quantity and quality of sun radiation in the understory of the silvopastoral system (SPS) due to the spatial arrangement of trees and sampling sites. Wilson and Ludlow (1991) reported that treetops absorb mainly photosynthetically active radiation which changes considerably the light´s quantity and quality that reaches the understory. It should be underscored that since a decrease in solar radiation occurred, it may bring severe differences in the photosynthetic activity of the plants cultivated in the silvopastoral system understory. In fact, AI rates between treatments were different in the wavelengths where absorption peaks of photosynthetic pigments occur (400 – 500 and 600 – 700 nm). Since SPS exploits integrally pasture and timber, spacing between tree rows should be underlined.

The variables photosynthetically active radiation incident (PARi), red/far red ratio (R/FR) and dry matter yield (DMY) were also affected by the sampling site, with higher rates in the center of the spacing (Table 2).

Results demonstrate that light quantity and quality were influenced by the sampling sites in the understory. Consequently, these characteristics affected directly the forage canopy growth with high DMY in the center of the row spacing. Similarly, Oliveira et al. (2007) reported that PAR in established silvopastoral systems had higher rates in the center of the inter-row.

Regardless of sampling sites, spacing in spatial arrangement (3×2)×20 had higher rates for variables PARi, LI pasture, LAI and DMY. It was observed during the experiment that less spacing in the spatial arrangements (9 m) caused more intense shading in the understory of the experimental units. Consequently, regardless of the sampling site, highest DMY rates occurred in spacing (3×2)×20. Oliveira et al. (2007) registered that the spacing of the tree community is a relevant factor for productivity and sustainability of the pasture since the spatial arrangement of trees directly affect shade level imposed by the system. As a general rule, most studies reported in the literature revealed that greater spacing among the trees provided higher rates of sun radiation, with high yield of the forage mass. Soares et al. (2009) reported that the production of forage mass was affected negatively by the shade level. In fact, decrease in production was linked to the low quantity and quality of radiation that reached the forage canopy.

Double line spacing arrangements had similar rates for PARi between sampling sites, whereas there was less PARi in simple arrangements. Although the difference between sampling sites was expected, low PARi rates observed in arrangement 2×9 may have been affected by a climatic factor such as the passage of clouds during measurements. Rossini et al. (2007) reported that the position of clouds significantly changed the configuration of the sky and, consequently, the distribution of irradiation. The same authors registered that the quantity and type of clouds may change for an instance the solar radiation falling on the ground.

In the case of R/FR, lowest rates were observed on the side of tree rows. Frank and Hofman (1994) reported that shading caused variations between wavelengths, mainly within the Red/Far Red interval. Probably a less favorable R/FR in the lateral region indicated that the tree tops modified more intensely the PARi profile with a decrease in the ratio.

Table 2. Photosynthetically active radiation incident (PARi), red/far red ratio (R/FR), light interception (LI) of pasture, Leaf Area Index (LAI) and dry matter yield (DMY) (kg ha^{-1}) in the two sampling sites of spatial arrangements in the second cycle (January 2012).

Arrangements	PARi		R/FR		LI pasture		LAI		DMY	
(m)	Center	Side	Center	Side	Center	Side	Center	Side	Center	Side
2×9	249.5	211.0	1.106	0.638	53.4	56.0	0.927	0.985	970.0	547.0
(2×2)×9	928.5	566.0	1.068	0.692	46.3	39.6	0.932	0.725	860.0	661.5
(3×2)×20	950.5	640.5	1.082	0.548	65.5	60.3	1.770	1.458	1784.0	724.5

Among the arrangements evaluated, the DMY on the side of tree rows was less than the rate in the center of row spacing. The behavior is also related to the highest shading level caused by the closeness of the tree rows. The low difference between DMY obtained in the center and lateral spacing in arrangements with lowest spacing (9 m) was probably due to the great number of trees and the great extension of pasture in the shade. Bernardino and Garcia (2009) stated that the growth of warm season grasses in areas under treetops may be limited to changes in light quality and quantity or by competition for water or nutrients, among other factors.

Significant correlations between the variables under analysis in the two sampling sites were reported (Table 3). There was a high and positive correlation between LI and LAI and between LI and DMY ($p < 0.01$) in the center row spacing. Results suggest that a greater leaf area caused a higher percentage of light interception by the forage canopy and, consequently, an increase of photosynthetic capacity and forage mass accumulation by the pasture.

Positive correlation between LI and LAI was reported in the side of tree rows ($p < 0.05$). However, the correlation between PARi and DMY was also high and positive, contrasting to the center of row spacing ($p < 0.01$).

Table 3. Pearson´s coefficient of co-relation between the variables photosynthetically active radiation incident (PARi), light interception of pasture (LI), leaf area index (LAI) and production of dry matter (DMY) in sampling sites (center and lateral spacing) in signal grass cultivated in the understory of silvopastoral systems.

	PARi	LI	LAI	DMY
	Center of spacing			
PARi	1	0.1759	0.5281	0.4278
LI		1	0.9288**	0.9650**
LAI			1	0.9935**
DMY				1
	Lateral spacing			
PARi	1	-0.1617	0.3233	0.9811**
LI		1	0.8815*	0.0321
LAI			1	0.5002
DMY				1

* **: statistically significant by *t*-test respectively at 5 and 1% probability.

A possible explication is based on the plants´ adaption response to shading. In fact, they are able to decrease the light compensation point to produce a higher photosynthesis with the least quantity of light. Plants actually have the ability to adapt themselves to shaded environments by the modifications of their morphophysiological characteristics. Modifications may include an increase of the shoot/root ratio, stem elongation, decrease in the number of tillers, increase of specific leaf area, alterations in leaf/stem ratio and leaf angle (BERNARDINO; GARCIA, 2009). Dias-Filho (2000) also observed an increase in specific leaf area and in leaf elongation rate in species of the genus *Urochloa* as a response to shading.

A significant effect for spatial arrangement, sampling site and interaction between evaluation cycle and spatial arrangement has been reported with regard to pasture height. Difference ($p < 0.05$) between the evaluation cycles were observed only on the (3×2)×20 arrangement (Table 4), with a greater height in cycles 1 and 4 and a lower one in cycle 3.

Table 4. Influence of spatial arrangements of the tree components at the height of signal grass, according to evaluation cycles.

Arrangements	Cycles*			
	1	2	3	4
2×9m	0.34a	0.36a	0.37a	0.37a
(2×2)×9m	0.28a	0.34a	0.29a	0.36a
(3×2)×20m	0.53a	0.41bc	0.35c	0.47ab
Full sunshine	0.60	0.54	0.41	0.62

*Cycles: 1 = November 2012; 2 = January 2012; 3 = March 2012; 4 = April 2012. Averages followed by the same small letter on the line do not differ by Tukey´s test at 5% probability.

More intense shading caused by smaller spaces produced lower pasture height when compared to treatment with greater spaces among the trees. Results indicated a possible limitation in the development of forage plants in the understory due to a more intense shading level, with the lowest pasture height in arrangements 2×9 and (2×2)×9. Corroborating current analysis, Andrade et al. (2001) registered that in the rainy period, the shading imposed by the eucalyptus may be a limiting factor to forage growth in the understory of silvopastoral systems. With regard to evaluated cycles, the greatest height of pasture in cycles 1 and 4 probably occurred because of more favorable climate conditions, especially more rainfall during the period. The above may be confirmed when the greatest pasture height obtained in cycles 1 and 4 occurred in full sunshine.

Regardless of spatial arrangements and evaluated cycles, highest rates for pasture height and dry matter of forage were recorded in the center of the row spacing (Table 5).

Table 5. Pasture height and dry matter (DM) rate of signal grass cultivated in a understory of silvopastoral system according to sampling site.

Variables	Sampling site	
	Center of row spacing	Side of tree rows
Height of pasture (m)	0.42a	0.33b
DM rate (%)	25.56b	27.89a

Averages followed by the same small letter on the line do not differ by Tukey´s test at 5% probability.

Since results of pasture height differ from data by Souza et al. (2007) and Martuscello et al. (2009), who reported higher rates in more shaded areas, indicating etiolated grow. Results evidence different responses of plants during different levels of shading. Other strategies may be involved to maintain the persistence and productivity of forage plants in environments with reduced luminosity, such as growth rate reduction of the forage, less tiller numbers, increase of the leaf/stem ratio and increase of leaf area.

Highest rate of forage DM rate was reported in the side of tree rows. Above result was not expected since DM rates in shady environments tended to be lower due to modifications in the micro-climate, with milder temperatures, more soil and air moisture (GOBBI et al., 2009) and less wind which caused less water loss by plants.

Significant effect of arrangement, cycle and cycle-sampling site interaction occurred in the case of the variable leaf/stem ratio (L/S). Although high L/S was reported in arrangement (2×2)×9, rate did not differ ($p < 0.05$) from that of arrangement 2×9 (Table 6).

Table 6. Leaf/Stem ratio (L/S) and dry matter yield (DMY) of signal grass cultivated in the understory of silvopastoral systems with different spatial arrangements.

Variables	Spatial arrangements			
	2×9 m	(2×2)×9 m	(3×2)×20 m	Full sunshine
L/S	1.25ab	1.39a	1.03b	
DMY (kg ha^{-1})	787.3b	465.8c	1325.1a	3325.9

Averages followed by the same small letter on the line do not differ by Tukey´s test at 5% probability.

Arrangement (2×2)×9 may have caused a decrease in growth rate and progress of maturity, which favored forage harvest with more leaves. Dias-Filho (2000) also reported an increase in L/S in forage of the genus *Urochloa* and they attributed such effects on shading. According to Soares et al. (2009) the shading can influence positively the L/S by structural, adaptive and competitive modifications especially in the leaves to increase the efficiency in light interception by the forage plant.

A difference between cycles was observed in the center of row spacing ($p < 0.05$), with higher L/S rates in cycle 4 (Table 7).

Table 7. Leaf/stem ration of the signal grass in sampling sites throughout the thinning cycles.

	Leaf/stem ratio			
	1	2	3	4
Center of row spacing	1.21b	0.88b	1.18b	1.57a
Side of tree rows	1.28a	1.22a	1.21a	1.27a

Averages followed by the same small letter on the line do not differ by Tukey´s test at 5% probability.

Results may have been affected by a decrease in rainfall within the cycle period and thus forage would have also decreased physiological maturity, providing a greater number of leaves during cutting. In fact, the last sampling cycle was characterized by a decrease in rainfall and temperature which may have affected in a more intense way the plants in the center of the row spacing.

There was a significant arrangement and interaction between arrangement and sampling site effect for the variable DMY. In the case of the spatial arrangement (Table 6), greatest forage production was obtained by arrangement (3×2)×20 which was probably caused by the great quantity of light in the understory when compared to the other spacing evaluated. When the number of trees increased (from the simple to the double) in the 9-m spacing arrangements, the production of dry matter decreased. Similar results have been reported by Paciullo et al. (2007) and Gobbi et al. (2009) who registered a decrease in forage DMY in proportion to the increase of shading level. Decrease in forage mass may have been due to low light intensity of the shaded environment which culminated in a step below the light compensation point of the forage plant. According to Paciullo et al. (2007), most reports on the decrease of forage mass under intense shading occur because of a significant decrease of photosynthetic rates of Cycle C_4 grass.

A significant difference only for arrangement (3×2)×20, whose production was higher in the center of row spacing, was reported in the decomposition of the effect of sampling sites with the arrangements (Table 8).

Table 8. Interaction between arrangement and sampling site for the dry matter yield (DMY) (g m^{-2}) in the two sampling sites of different spatial arrangements.

Arrangements	Sampling site	
	Center of row spacing	Side of tree rows
2×9 m	71,5a	67,6a
(2×2)×9 m	47,6a	50,0a
(3×2)×20 m	204,9a	87,5b

Averages followed by the same small letter on the line do not differ by Tukey´s test at 5% probability.

There was no difference between sites in simple and double arrangements with 9 m spacing. Results may be explained by the quantitative and qualitative effect of the space´s width on its exposure to solar radiation. It is believed that intensity of shading with 20 m spacing would be less in the central region. In fact, the above may explain a higher DMY in the site.

In normal conditions, C_4 plants have more energy demands for photosynthesis and may cause higher DMY rates in environments in which radiation amounts are greater (TAIZ; ZEIGER, 2009). The above corroborates reports in the literature where arrangements with more spacing favor pasture yield and thus animal production.

With regard to the nutritional value of forage in the understory (Table 9), an arrangement effect ($p < 0.05$) was reported for neutral detergent fiber (NDF) and crude protein (CP) rates.

Table 9. Mean rates (%) of neutral detergent fiber (NDF), acid detergent fiber (ADF), dry mass (DM) and crude protein (CP) rates of signal grass in understory and in broad sunshine.

Arrangements	Variables of nutritional value			
	NDF	ADF	% DM	% CP
2×9 m	60.37b	30.50a	26.58a	12.67ab
(2×2)×9 m	60.29b	29.12a	26.75a	14.46a
(3×2)×20 m	62.92a	30.79a	26.83a	10.37b
Sunshine	64.67	32.77	27.49	11.48

Averages followed by the same small letter on the line do not differ by Tukey´s test at 5% probability.

Arrangement (3×2)×20 had the highest NDF rate, with a 4.29% increase when compared to other spatial arrangements evaluated. Pasture cultivated in largest spaces between eucalyptus rows had the highest growth and development rates, which probably caused the highest accumulation of items of the vegetal cell wall. According to Deinum et al. (1996), plants in broad sunshine had a greater amount of sclerenchyma tissues and mesophyll cells with thicker walls than those in the shade. Results by Silva et al. (2011) showed that the mesophyll was thicker for the leaf in the sun. Current study also verified that plants grown in the sunshine had higher NDF rates.

Highest rate of CP was obtained in arrangement (2×2)×9 although there was no significant difference for spacing 2×9. As a general rule, denser arrangements have higher crude protein rates. Results follow Garcez Neto et al. (2010), who also reported an increase in CP rates in plants submitted to shading when compared to pastures cultivated in broad sunshine. Highest CP rate in plants in the shade may be associated with small size of cell under the shade (GOBBI et al., 2010), to higher nitrogen concentration in the leaves (CARVALHO et al., 1995) and to an increase in the amount of nutrients through the nutrient cycle (PACIULLO et al., 2007).

Conclusion

Spatial arrangement (3×2)×20 m and the center of row spacing provide greatest quantity and quality of light when compared to other treatments and sampling site which caused a greater production of forage mass. The chemical composition was positively affected by the spatial arrangements (2×2)×9 m and 2×9 m, regardless of the sampling site.

Further studies should be undertaken to evaluate pasture management and the efficiency of silvopastoral systems.

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