D.C. Martins
https://orcid.org/0000-0001-6494-1123
S.A.C. Araújo
https://orcid.org/0000-0003-4852-923X
S.D.J. Villela
https://orcid.org/0000-0002-7762-3746
R.G. Almeida
https://orcid.org/0000-0002-8048-2833
L.D. Silva
https://orcid.org/0000-0002-7328-5807
J.R. Paschoaloto
https://orcid.org/0000-0001-9517-3817
P.G.M.A. Martins
https://orcid.org/0000-0002-5446-0331

Animal performance and nutritional characteristics of Piatã-grass in integrated systems

[*Desempenho animal e características nutricionais de capim-piatã em sistemas integrados*]

D.C. *Martins*[1], S.D.J. *Villela*[1]*, R.G. *Almeida*[2], S.A.C. *Araújo*[3],
L.D. *Silva*[1], J.R. *Paschoaloto*[1], P.G.M.A. *Martins*[1]

[1]Universidade Federal dos Vales do Jequitinhonha e Mucuri - Diamantina, MG
[2]Embrapa - Centro Nacional de Pesquisa de Gado de Corte - Campo Grande, MS
[3]Instituto de Ciências Agrárias - Universidade Federal dos Vales do
Jequitinhonha e Mucuri - Unaí, MG

ABSTRACT

The objective was to evaluate animal performance and nutritional characteristics of *Brachiaria brizantha* cv. BRS Piatã in two integrated systems, during the summer and winter, five years after the initial establishment of the area. The randomized block experimental design was adopted with treatments consisting of a control (five native trees per hectare) and an integrated crop-livestock-forestry (ICLF) system with 227 eucalyptus trees per hectare. Animal performance, canopy height, soil cover, forage mass (leaf, stem and senescent material), and forage nutritive value were evaluated. Differences between systems were observed in forage mass (total, leaf, stem and senescent material), soil cover and forage nutritive value in both seasons. Shading conditions provided by eucalyptus in the ICLF system lead to a reduction in forage mass and neutral detergent fiber content, and to an increase in crude protein and *in vitro* organic matter digestibility. However, no effect on animal performance was obtained. The presence of trees improves the forage nutritive value without impacting animal performance in integrated systems.

Keywords: agrosilvopastoral systems, forage yield, integrated crop-livestock-forest system, *Urochloa brizantha*

RESUMO

O objetivo foi avaliar o desempenho animal e as características nutricionais de Brachiaria brizantha *cv. BRS Piatã em dois sistemas integrados, durante o verão e o inverno, cinco anos após o estabelecimento inicial da área. O delineamento experimental em blocos ao acaso foi adotado com tratamentos constituídos por um controle (cinco árvores nativas por hectare) e um sistema integrado lavoura-pecuária-floresta (ILPF) com 227 eucaliptos por hectare. Desempenho animal, altura do dossel, cobertura do solo, massa de forragem (folha, caule e material senescente) e valor nutritivo da forragem foram avaliados. Diferenças entre os sistemas foram observadas na massa de forragem (total, foliar, caule e material senescente), na cobertura do solo e no valor nutritivo da forragem em ambas as estações. As condições de sombreamento proporcionadas pelo eucalipto no sistema ICLF levaram a uma redução na massa de forragem e no teor de fibra em detergente neutro e a um aumento na proteína bruta e na digestibilidade* in vitro *da matéria orgânica. No entanto, nenhum efeito no desempenho animal foi obtido. A presença de árvores melhora o valor nutritivo da forragem, sem impactar o desempenho animal em sistemas integrados.*

Palavras-chave: produção de forragem, sistemas agrossilvopastoris, sistemas integrados lavoura-pecuária-floresta, Urochloa brizantha

INTRODUCTION

Agrosilvopastoral systems have been used as an alternative to diversify land use, in a sustainable and rational manner in which crop, livestock, and forestry are conducted simultaneously or sequentially (Young, 1997). These systems are used to reestablish degraded pasture areas and have a potential to improve animal comfort, soil fertility, forage quality, and carbon sequestration, in addition to diversifying revenue sources for producers without decreasing animal production (Murgueitio *et al.*, 2011; Oliveira *et al.*, 2014; Paciullo *et al.*, 2014, 2017).

In Brazil, producers are increasingly employing integrated systems since tree planting is recommended as an alternative to restore degraded pasture areas because of the diversity of species in these systems, and crop rotation makes it possible to control soil erosion, reduces soil compaction and improves soil properties (Dias-Filho, 2006, 2015). On the other hand, shade from trees may restrict forage yield, especially in tropical grasses. Some species are tolerant to moderate degree of shading, depending on plant ability to adapt, morphologically and physiologically, to a given light level (Dias-Filho, 2000). This acclimation capacity to a reduced light environment is important to determine their competitive potential in that specific environment (Dias-Filho, 1997, 2006; Nandal *et al.*, 1999).

Reduction in pasture productivity has important implications when selecting shade-tolerant grass species to be utilized in integrated systems, especially because forage production is directly related with animal performance. According to Euclides *et al.* (2009), leaf availability has a great correlation with intake, grazing time and body weight (BW) gain of animals. In this sense, studies evaluating the interaction between trees, grasses and animal production are needed. *Brachiaria brizantha* is classified as medium tolerant to shade (Shelton *et al.*, 1987; Humphreys, 1991). However, few studies reporting evaluation of the Piatã cultivar in integrated crop-livestock and/or crop-livestock-forestry systems are available in the literature. Thus, the objective herein was to evaluate animal performance and nutritional characteristics of Piatã-grass (*Brachiaria brizantha* cv. BRS Piatã) in integrated systems during summer and winter.

MATERIAL AND METHODS

Animals utilized in this study were cared for by acceptable practices and all research procedures were approved by the Institutional Committee of Ethics on the Use of Animals from Embrapa National Center for Beef Cattle Research (protocol number 014/2014).

The experiment was conducted from December 2013 to August 2014 at the Embrapa National Center for Beef Cattle Research, in Campo Grande, Mato Grosso do Sul State, Brazil (54°37′W, 20°27′S, and 530m altitude). According to the Köppen-Geiger climate classification (Kottek *et al.*, 2006), the experimental area is located in the transition between Cfa and AW tropical humid. During the experimental period, the average minimum and maximum temperatures were 20.1 and 25.5ºC, and the monthly minimum and maximum rainfall average values were 17.7 and 170.8mm, respectively (Table 1).

The experimental site, established in 2008 as a strategy of pasture restoration by cultivating soybean followed by Piatã-grass (previously described by Oliveira *et al.*, 2014, 2018), consisted of two integrated crop-livestock-forestry (ICLF) systems and one integrated crop-livestock system. However, in the present study, only one ICLF system was evaluated. Soil was classified as dystrophic red latosol with clayey texture, with the following chemical characteristics in the 0 to 20cm layer at the beginning of the experiment: clay content of $41\pm5\%$; Mehlich-1 extractable P ranging from 0.29 to 0.42mg dm^{-3}; base saturation ranging from 26% to 34%; and aluminum saturation ranging from 10% to 23%.

Treatments consisted of two integrated systems: (1) ICLF system, with simple wide spaced tree (*Eucalyptus grandis* x *Eucalyptus urophylla*; H13 clone) rows, 22 x 2m tree spacing and 227 trees per hectare; and (2) an integrated crop-livestock system (control; CTRL), with five scattered native trees (*Gochnatia* and *Dipteryx* species) per hectare, which is commonly found in ordinary production systems of the region. During the experimental period, the initial and final average ICLF tree height was 25 and 27m, respectively.

Table 1. Monthly average temperature and rainfall at the Embrapa National Center for Beef Cattle Research, in Campo Grande, Mato Grosso do Sul State, Brazil (54°37′W, 20°27′S, and 530m altitude) in 2013 and 2014

Month	Temperature (°C)		Rainfall (mm)	
	2013	2014	2013	2014
January	25.5	24.6	218.3	162.3
February	24.7	25.1	215.8	111.8
March	24.9	24.3	187.2	163.3
April	22.5	24.1	210.8	52.6
May	22.2	20.6	14.9	165.5
June	21.0	20.7	36.5	51.1
July	19.7	20.1	0.0	115.2
August	20.2	23.0	0.0	17.7
September	23.4	25.5	105.5	66.0
October	24.5	27.0	122.2	19.7
November	25.2	24.7	249.6	217.8
December	25.5	24.9	170.8	359.4

The experimental area was divided into four 1.5-ha paddocks (two paddocks for each treatment). A continuous grazing method was adopted for pasture management with varying stocking rate. A total of ten Nellore heifers (initial BW=180±13.6kg) were randomly assigned to paddocks and an extra area, adjacent to the experimental site. In each paddock, two heifers were used to evaluate animal performance, and the remaining heifers were used to keep predetermined sward heights in a put-and-take stocking management. Heifers had free-choice access to water and commercial mineral supplement throughout the experiment. Individual heifer BW was measured every 28 days after a 16-hour period of water and feed withdrawal. Average daily gain (ADG) and BW gain per hectare were calculated to assess animal performance. In addition, stocking rate, calculated as the number of animal units (considering a 450kg adult animal) per hectare, was determined.

Forage assessments were performed every 28 days. Ten forage samples were randomly collected from each paddock, in each system. A 1.0m² square plot was used to assess total biomass, which was obtained by clipping and harvesting all above ground forage parts. Canopy height was measured by using a graduated ruler before forage clipping. Forage was clipped at the ground level by using an electric clipper. Soil cover was visually appraised after forage harvesting. The harvested material was weighed to estimate forage production and transferred to the laboratory to sort leaf lamina, stem sheath, and senescent material. Each component was dried at 55°C in a forced-air oven to a constant weight, and then forage mass values were measured.

To evaluate nutritive value, leaf and stem sheath samples were ground in a Wiley mill (Thomas Model 4 Wiley Mill; Thomas Scientific, Swedesboro, NJ, USA) to pass through a 1-mm stainless steel curved round-hole sieve. Samples were analyzed for dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), and *in vitro* organic matter digestibility (IVOMD) using a near-infrared spectroscopy (model NR 5000, Metrohm NIRS Systems, Herisau, Switzerland), according to the method described by Marten *et al.* (1989).

The randomized block experimental design was utilized with two replicates for animal performance evaluation and four replicates for forage characteristics assessment. Evaluations were performed during the summer (December, January, and February) and winter (June, July, and August). Data were subjected to analysis of variance and means were separated for comparison by F-test using the GLM procedure of SAS (version 9.1; SAS Institute Inc., Cary, NC, USA). Significance was set at $P \leq 0.05$.

RESULTS

For animal performance, no differences ($P>0.19$) were observed between systems for ADG, stocking rate, and BW gain in both seasons (Table 2).

Table 2. Performance of Nellore heifers in integrated crop-livestock-forest (ICLF) and crop-livestock (control; CTRL) systems

Item	Summer				Winter			
	ICLF	CTRL	SEM	*P*-value	ICLF	CTRL	SEM	*P*-value
Stocking rate (AU ha^{-1})[a]	3.3	3.6	0.1	0.5160	1.2	1.18	0.01	0.3118
Average daily gain (g animal^{-1} day^{-1})	581.4	475.4	48.9	0.3724	82.5	272.5	67.9	0.1922
Body weight gain per hectare (kg ha^{-1})	268.7	238.6	24.9	0.6573	13.75	45.42	11.32	0.1911

SEM = standard error of the mean

[a] Stocking rate was calculated as the number of animal units (considering a 450kg adult animal) per hectare

Differences (P≤0.01) were detected between ICLF and CTRL systems for DM content of forage components (total, leaf, and stem), canopy height, and soil cover during the summer (Table 2). In the ICLF system, a 19.7cm reduction in canopy height was obtained and approximately 30% greater soil cover was observed compared to CTRL system. During the winter, a similar effect on soil cover was observed. During the summer, canopy height was shorter in ICLF than CTRL, consequently resulting in greater total DM (Table 3).

Table 3. Characteristics and forage mass of Piatã-grass (*Brachiaria brizantha* cv. BRS Piatã) in integrated crop-livestock-forest (ICLF) and crop-livestock (control; CTRL) systems during summer and winter

Item	Summer				Winter			
	ICLF	CTRL	SEM	*P*-value	ILCLF	CTRL	SEM	*P*-value
Canopy height (cm)	78.7	98.4	2.6	0.0010	32.6	35.1	0.9	0.1614
Soil cover (%)	60.7	86.8	3.4	0.0010	75.8	94.1	2.6	0.0001
Forage mass (kg DM ha^{-1})								
Total DM	2308.0	3412.0	174.0	0.0141	1577.2	2433.1	130.1	0.0141
Leaf DM	633.9	1069.4	72.0	0.0006	271.8	415.2	25.8	0.0026
Stem DM	1401.0	1974.3	96.7	0.0009	279.6	460.9	32.1	0.0020
Senescent DM	272.5	368.4	37.0	0.2035	1025.7	1557.0	87.4	0.0006

DM = dry matter; SEM = standard error of the mean.

Forage CP and NDF were affected by the different systems. Leaf and stem CP content was greater (P<0.01) in ICLF compared with CTRL. On the other hand, NDF content was greater (P<0.01) in CTRL compared with ICLF. Leaf and stem IVOMD were greater (P≤0.03) in ICLF compared with CTRL (Table 4).

Table 4. Nutritive value of Piatã-grass (*Brachiaria brizantha* cv. BRS Piatã) components from integrated crop-livestock-forest (ICLF) and crop-livestock (control; CTRL) systems during summer and winter

Nutritional characteristics, %	Summer				Winter			
	ICLF	CTRL	SEM	*P*-value	ICLF	CTRL	SEM	*P*-value
Leaf								
Crude protein	10.5	7.7	0.5	0.0026	13.5	11.2	0.3	0.0001
Neutral detergent fiber	69.9	72	0.4	0.0086	66.5	68.5	0.3	0.0012
In vitro organic matter digestibility	54.9	50.5	0.8	0.0059	69.9	64.2	0.9	0.0002
Stem								
Crude protein	4.6	3.1	0.3	0.0010	5.5	4.9	0.2	0.0337
Neutral detergent fiber	80.1	82.4	0.4	0.0025	78	75.8	0.4	0.0036
In vitro organic matter digestibility	41.1	39	0.7	0.0325	43.9	47.5	0.7	0.0017

SEM = standard error of the mean

DISCUSSION

The presence of trees modifies the microclimate and, because of their upper position relative to forage canopy, the tree leaves absorb light preferentially, decreasing the amount of photosynthetic active radiation that reaches the understory (Feldhake *et al.*, 2005; Garcia *et al.*, 2011). In the present study, the difference in forage characteristics of both integrated systems indicates that shade provided by eucalyptus affected forage mass, although the senescent material was not affected in the summer and canopy height, during the winter. Grasses, when under adverse conditions (i.e., shading), culminate in senescence and death, and consequently are not kept in the system (Givnish, 1988). In the present study, although there was shading in both summer and winter and in either system, no difference was detected; even in the winter, the senescent DM content was lower in the ICLF than in CTRL system.

According to Gómez *et al.* (2013), under reduced sunlight conditions, recently expanded leaves keep their functional integrity for photosynthesis during longer periods, thus the efficiency in using light is maintained. During the winter, both systems presented similar canopy height, despite the shading provided by the eucalyptus in the ICLF system. As listed in Table 1, during the winter season, the average monthly rainfall was 61.3mm, whereas in the summer was 148.3mm. It is well known that forage growth is strongly susceptible to weather conditions, especially water availability (Ludlow and Ng, 1977).

Nutritive value of forage in the ICLF system was greater than the CTRL system, reflecting the positive influence of shade, which may be associated with a few factors. Wilson (1996) related this phenomenon to increased soil moisture, which improves organic matter degradation and nitrogen recycling. Thus, the increased CP content in the forage could be associated with an increased nitrogen flow into the soil. Another mechanism related with a delay in the ontogenetic development of plants cultivated under shading could explain that phenomenon (Sousa *et al.*, 2010). In this manner, forages tend to be physiologically younger, maintaining increased metabolic levels for longer periods. Likewise, Neel *et al.* (2016) also observed a delay in pasture morphological

maturity in an integrated system with trees compared to full sunlight system. Furthermore, the shaded conditions could reduce cell size, which, with a constant amount of N per cell, may have a concentrating effect (Kephart and Buxton, 1993; Garcia *et al.*, 2011). Indeed, the reduced NDF content of the forage in the ICLF system may be associated with a decreased rate of photoassimilates for the development of the secondary cells, as well as the content of the wall and its constituents (Kephart and Buxton, 1993; Deinum *et al.*, 1996).

The increased nutritional value of forage under shading conditions, especially as a result of high CP, may contribute to improved animal performance (Yamamoto *et al.*, 2007; Bocquier and González-García, 2010; Paciullo *et al.*, 2010; Sousa *et al.*, 2010). Nevertheless, despite ICLF system presenting higher forage nutritive value, animal performance did not differ between systems because of the decreased forage mass, especially leaf mass, which is the preferred component selected by grazing animals (Brâncio *et al.*, 2003).

In conclusion, shade provided by eucalyptus in the ICLF system seems to be interesting because of the improvement in forage nutritive value. In addition, the eucalyptus tree at a density of 227 trees per hectare after 5 year of system establishment does not impair animal performance, even with reduction in total forage mass production.

REFERENCES

BOCQUIER, F.; GONZÁLEZ-GARCÍA, E. Sustainability of ruminant agriculture in the new context: feeding strategies and features of animal adaptability into the necessary holistic approach. *Animal*, v.4, p.1258-1273, 2010.

BRÂNCIO, P.A.; NASCIMENTO JUNIOR, D.; EUCLIDES, V.P.B. *et al.* Avaliação de três cultivares de *Panicum maximum* Jacq. sob pastejo: composição da dieta, consumo de matéria seca e ganho de peso animal. *R. Bras. Zootec.*, v.32, p.1037-1044, 2003.

DEINUM, B.; SULASTRI, R.D.; ZEINAB, M.H.J.; MAASSEN, A. Effects of light intensity on growth, anatomy and forage quality of tropical grasses. *Neth. J. Agric. Sci.*, v.44, p.111-124, 1996.

DIAS-FILHO, M.B. *Estratégias de recuperação de pastagens degradadas na Amazônia brasileira*. Belém, PA: Embrapa Amazônia Oriental, 2015. 25p.

DIAS-FILHO, M.B. Growth and biomass allocation of the C_4 grasses *Brachiaria brizantha* and *B. humidicola* under shade. *Pesq. Agropec. Bras.*, v.35, p.2335-2341, 2000.

DIAS-FILHO, M.B. Physiological response of *Solanum crinitum* Lam. to contrasting light environments. *Pesq. Agropec. Bras.*, v.32, p.789-796, 1997.

DIAS-FILHO, M.B. *Sistemas silvipastoris na recuperação de pastagens tropicais degradadas*. Belém, PA: Embrapa Amazônia Oriental, 2006. 30p.

EUCLIDES, V.P.B.; MACEDO, M.C.M.; VALLE, C.B. *et al.* Valor nutritivo da forragem e produção animal em pastagens de *Brachiara brizantha*. *Pesq. Agropec. Bras.*, v.44, p.98-109, 2009.

FELDHAKE, C.M.; NEEL, J.P.S.; BELESKY, D.P.; MATHIAS, E.L. Light measurement methods related to forage yield in a grazed northern conifer silvopasture in the Appalachian region of eastern USA. *Agroforest. Syst.*, v.65, p.231-239, 2005.

GARCIA, A.R.; MATOS, L.B.; LOURENÇO JÚNIOR, J.B. *et al*. Variáveis fisiológicas de búfalas leiteiras criadas sob sombreamento em sistemas silvipastoris. *Pesq. Agropec. Bras.*, v.46, p.1409-1414, 2011.

GIVNISH, T.J. Adaptation to sun and shade: a whole-plant perspective. *Aust. J. Plant Physiol.*, v.15, p.63-92, 1988.

GÓMEZ, S.; GUENNI, O.; BRAVO DE GUENNI, L. Growth, leaf photosynthesis and canopy light use efficiency under differing irradiance and soil N supplies in the forage grass *Brachiaria decumbens* Stapf. *Grass Forage Sci.*, v.68, p.395-407, 2013.

HUMPHREYS, L.R. *Tropical pasture utilisation*. Cambridge: Cambridge University Press, 1991. 206p.

KEPHART, K.D.; BUXTON, D.R. Forage quality responses of C_3 and C_4 perennial grasses to shade. *Crop Sci.*, v.33, p.831-837, 1993.

KOTTEK, M.; GRIESER. J.; BECK, C. *et al.* World map of the Köppen-Geiger climate classification updated. *Meteorol. Z.*, v.15, p.259-263, 2006.

LUDLOW, M.M.; NG, T.T. Leaf elongation rate in *Panicum maximum* var. *trichoglume* following removal of water stress. *Aust. J. Plant Physiol.*, v.4, p.263-272, 1977.

MARTEN, G.C.; SHENK, J.S.; BARTON II, F.E. *Near infrared reflectance spectroscopy (NIRS), analysis of forage quality*. Washington: USDA, ARS, 1989. 110p. (Agriculture Handbook 643).

MURGUEITIO, E.; CALLE, Z.; URIBE, F. *et al*. Native trees and shrubs for the productive rehabilitation of tropical cattle ranching lands. *Forest Ecol. Manag.*, v.261, p.1654-1663, 2011.

NANDAL, D.P.; RANA, P.; KUMAR, A. Growth and yield of wheat (*Triticum aestivum*) under different tree spacings of *Dalbergia sissoo* based agrisilviculture. *Indian J. Agron.*, v.44, p.256-260, 1999.

NEEL, J.P.S.; FELTON, E.E.D.; SINGH, S. *et al*. Open pasture, silvopasture and sward herbage maturity effects on nutritive value and fermentation characteristics of cool-season pasture. *Grass Forage Sci.*, v.71, p.259-269, 2016.

OLIVEIRA, C.C.; ALVES, F.V.; ALMEIDA, R.G. *et al*. Thermal comfort indices assessed in integrated production systems in the Brazilian savannah. *Agroforest. Syst.*, v.92, p.1659-1672, 2018.

1032

Arq. Bras. Med. Vet. Zootec., v.72, n.3, p.1027-1033, 2020

OLIVEIRA, C.C.; VILLELA, S.D.J.; ALMEIDA, R.G. *et al*. Performance of Nellore heifers, forage mass, and structural and nutritional characteristics of *Brachiaria brizantha* grass in integrated production systems. *Trop. Anim. Health Prod.*, v.46, p.167-172, 2014.

PACIULLO, D.S.C.; CASTRO, C.R.T.; GOMIDE, C.A.M. *et al*. Soil bulk density and biomass partitioning of *Brachiaria decumbens* in a silvopastoral system. *Sci. Agric.,* v.67, p.598-603, 2010.

PACIULLO, D.S.C.; GOMIDE, C.A.M.; CASTRO, C.R.T. *et al*. Morphogenesis, biomass and nutritive value of *Panicum maximum* under different shade levels and fertilizer nitrogen rates. *Grass Forage Sci.*, v.72, p.590-600, 2017.

PACIULLO, D.S.C.; PIRES, M.F.A.; AROEIRA, L.J.M. *et al*. Sward characteristics and performance of dairy cows in organic grass-legume pastures shaded by tropical trees. *Animal*, v.8, p.1264-1271, 2014.

SHELTON, H.M.; HUMPHREYS, L.R.; BATELLO, C. Pastures in the plantations of Asia and the Pacific: performance and prospect. *Trop. Grassl.*, v.21, p.159-168, 1987.

SOUSA, L.F.; MAURÍCIO, R.M.; MOREIRA, G.R. *et al*. Nutritional evaluation of "Braquiarão" grass in association with "Aroeira" trees in a silvopastoral system. *Agroforest. Syst.*, v.79, p.189-199, 2010.

WILSON, J.R. Shade-stimulated growth and nitrogen uptake by pasture grasses in a subtropical environment. *Aust. J. Agric. Res.*, v.47, p.1075-1093, 1996.

YAMAMOTO, W.; DEWI, I.A.; IBRAHIM, M. Effects of silvopastoral areas on milk production at dual-purpose cattle farms at the semi-humid old agricultural frontier in central Nicaragua. *Agric. Syst.*, v.94, p.368-375, 2007.

YOUNG, A. *Agroforestry for soil management*. 2.ed. Wallingford, UK: CAB International, 1997. 320p.