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Forage production and productive performance of Nellore heifers in agrosilvopastoral systems

Produção de forragem e desempenho produtivo de novilhas Nelore em sistemas agrossilvopastoris

Producción de forrajes y desempeño productivo de novillas Nelore en sistemas agrossilvopastoriles

Received: 09/21/2020 | Reviewed: 09/25/2020 | Accept: 10/02/2020 | Published: 10/04/2020

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Abstract

Agrosilvopastoral system is a type of production that involves the soil-forage-animal interface, both of which are benefited by the system. Hence, the present study evaluated the effects of agrosilvopastoral system on the quantitative and qualitative characteristics from pasture, and the animal performance during the feeding period of Nellore heifers. The treatments included: Soil-forage-animal – 357 eucalyptus trees per hectare (LFA_{14x2m}); Soil-forage-animal – 227 eucalyptus trees per hectare (LFA_{22x2m}); and Soil-animal – Five native trees remaining per hectare (CON). The forage used was *Brachiaria brizantha* cv. BRS Piatã and having as trees planted the *Eucalyptus urograndis* clones H 13. Treatment effects (P <0.05) for forage accumulation and pasture height, which were lowest in LFA_{14x2m} compared to the others. Total forage dry mass in CON treatment was significantly greater (P <0.05) compared to the other treatments, showing maximum production in March. The LFA_{14x2m} treatment was favorable for greater forage quality, showing an effect on chemical composition (P <0.05), compared to other treatments. Whereas, in November the LFA_{22x2m} treatment was better for neutral detergent fiber. January and March, the treatments were similar (P >0.05) for average daily gain, while in November period, LFA_{14x2m} treatment showed the lowest value (P <0.05). The lowest weight gain by area (November) occurred in the LFA_{14x2m} treatment (P <0.05), although in March the LFA_{14x2m} treatment stocking rate was similar to the others. Forage production and animal performance are altered by the trees densification in agrosilvopastoral systems. The chemical composition of pasture is better in systems with a higher trees density.

Keywords: Agricultural crops; Agroforestry; Beef cattle; Forage quality; Stocking rate.

Resumo

O sistema agrossilvopastoril é um tipo de produção que envolve a interface solo-forragem-animal, ambos beneficiados pelo sistema. Assim, o presente estudo avaliou os efeitos de sistemas agrossilvopastoris sob as características quantitativas e qualitativas da pastagem e o desempenho animal durante o período de alimentação de novilhas Nelore. Os tratamentos incluíram: Solo-forragem-animal - 357 eucaliptos por hectare (LFA_{14x2m}); Solo-forragem-animal - 227 eucaliptos por hectare (LFA_{22x2m}); e Animal-solo - 5 árvores nativas remanescentes por hectare (CON). A forragem utilizada foi *Brachiaria brizantha* cv. BRS Piatã e as árvores plantadas foram clones H 13 de *Eucalyptus urograndis*. Efeitos de tratamento (P<0,05) para acúmulo de forragem e altura do pasto, foram menores para LFA_{14x2m} em relação aos demais. A massa seca total da forragem no tratamento CON foi significativamente maior (P<0,05) em relação aos demais tratamentos, apresentando máxima produção no mês de março. O tratamento LFA_{14x2m} foi favorável para maior qualidade da forragem, apresentando efeito para a composição química (P<0,05), comparado aos outros tratamentos. Enquanto que, em novembro o tratamento LFA_{22x2m} foi melhor para a fibra em detergente neutro. Em janeiro e março, os tratamentos foram semelhantes (P>0,05) para ganho médio diário, enquanto no período de novembro, o tratamento LFA_{14x2m} apresentou o menor valor (P<0,05). O menor ganho de peso por área (novembro) ocorreu no tratamento LFA_{14X2m} (P<0,05), embora no mês de março a taxa de lotação do tratamento LFA_{14x2m} tenha sido similar aos demais. A produção de forragem e o desempenho animal são alterados pelo adensamento de árvores em sistemas agrossilvopastoris. A composição química da pastagem é melhor em sistemas com maior densidade de árvores.

Palavras-chave: Agrofloresta; Culturas agrícolas; Gado de corte; Qualidade de forrageiras; Taxa de lotação.

Resumen

El sistema agrosilvopastoril es un tipo de producción que involucra la interfaz suelo-forraje-animal, ambos beneficiados por el sistema. Así, el presente estudio evaluó los efectos de los sistemas agrosilvopastoriles sobre las características cuantitativas y cualitativas del pasto y el rendimiento animal durante el período de alimentación de las novillas Nelore. Los tratamientos incluyeron: Suelo-forraje-animal- 357 eucaliptos por hectárea (LFA_{14x2m}); Suelo-forraje-animal- 227 eucaliptos por hectárea (LFA_{22x2m}); y Animal-suelo - 5 árboles nativos restantes por hectárea (CON). El forraje utilizado fue *Brachiaria brizantha* cv. BRS Piatã y los árboles plantados fueron clones H 13 de *Eucalyptus urograndis*. Los efectos del tratamiento (P<0,05) para la acumulación de forraje y la altura del pasto fueron menores para LFA_{14x2m} en comparación con los otros. La masa seca total de forraje en el tratamiento CON fue significativamente mayor (P<0,05) en comparación con los otros tratamientos, presentando su máxima producción en marzo. El tratamiento LFA_{14x2m} fue favorable para una mayor calidad de forraje, mostrando un efecto sobre la composición química (P<0,05), en comparación con otros tratamientos. En noviembre, el tratamiento LFA_{22x2m} fue mejor para la fibra detergente neutra. En enero y marzo, los tratamientos fueron similares (P>0,05) para la ganancia diaria promedio, mientras que, en noviembre, el tratamiento LFA_{14x2m} tuvo el valor más bajo (P<0,05). La menor ganancia de peso por área (noviembre) ocurrió en el tratamiento LFA_{14x2m} (P<0,05), aunque en marzo la carga ganadera del tratamiento LFA_{14x2m} fue similar a las demás. La producción de forrajes y el rendimiento animal se ven alterados por la densificación de los árboles en los sistemas agrosilvopastoriles. La composición química del pasto es mejor en sistemas con mayor densidad de árboles.

Palabras clave: Agroforestería; Calidad del forraje; Carga ganadera; Cultivos agrícolas; Ganado vacuno.

1. Introduction

The agrosilvopastoral system refers to production techniques in which, animals, forage plants, and trees are integrated in the same management unit, providing synergistic benefits between the system components. In this system, the production characteristics and quality from grasses can be affected. Therefore, the knowledge of the field structure, use of incident radiation, growth and senescence processes, plants composition under shading conditions, can define strategies for grass management (Rigueiro-Rodríguez et al., 2012). However, some positive effects are observed in the pasture, such as soil conservation, nutrient cycling, and nutritional value of forage species (Almeida et al., 2012; Paciullo et al., 2011).

However, forage type to be chosen is of great importance, since shading caused by tree species may hinder or favor forage growth, which will depend on shading degree, due the amount of solar radiation that is intercepted by the trees (Coelho et al., 2014). Grasses of the genus *Brachiaria* are considered excellent tropical forages, because they are easy to establish, good soil cover, good quality, good performance in the shade, and good animal support capacity.

Agroforestry system has been used as an optimization alternative for livestock areas, for diversifying production, promote microclimate favorable to the development of forages and provide thermal comfort to animals, factor that reflects on animal performance (Paciullo et al., 2009). The nutritional improvements of pasture, resulting from tree influence and greater soil nutrient availability, indicate the possibility of increase in forage intake and weight gain of grazing animals (Rigueiro-Rodríguez et al., 2012).

A complementary benefit is observed in this system (agrosilvopastoral) as the increment in animal production, which provides a more competitive meat production chain both at national and international conditions, through production of better quality carcasses, short cycle livestock, and quality feed (Balbino et al., 2012). Ensure new levels of production and environmental conditions in the sustainability ambit (Euclides et al., 2010).

This study was carried out to evaluate the effects of agrosilvopastoral system on the quantitative and qualitative characteristics from pasture, and the animal performance during the feeding period of Nellore heifers.

2. Materials and Methods

This experiment was conducted at the Embrapa Gado de Corte (Campo Grande, MS, Brazil) in the period corresponding to the end of the dry season, and beginning of the water season. During the experiment, the environmental temperature ranged from 35°C to 20°C, with an average of 27°C and 42% humidity, 178 μmol/m² global radiation, and 1,560mm of total precipitation as rain. The experimental area consists of dystrophic red latosol, characterized by clayey texture, acid pH, low base saturation, high aluminum concentration, and low phosphorus content (Santos et al., 2018). According to Köeppen (1948), the climate of region is in the transition band between Cfa and Aw humid tropical.

Animals and treatments

In the evaluation of animal performance for three-agrosilvopastoral system, the continuous grazing method with variable stocking rate was used, and each paddocks was grazed by two use-animals (Nellore heifers) with initial body weight of 183.2 ± 13.5 kg. Regulators-animals with similar weight to the use-animals were used to control and/or maintain pasture height of each paddocks (minimum 30 cm).

The experimental area was provided with drinkers and feeders, totalizing an area of 18 hectare, divided into 12 experimental paddocks with approximately 1.5 hectare each. Nellore heifers were randomly assigned to one of three agroforestry treatments. The treatments included: Soil-forage-animal – With 357 eucalyptus trees per hectare (LFA_{14x2m}); Soil-forage-animal – With 227 eucalyptus trees per hectare (LFA_{22x2m}); and Soil-animal – With five native trees remaining per hectare (CON). The forage used was *Brachiaria brizantha* cv. BRS Piatã, and having as trees planted the *Eucalyptus urograndis* clone H 13.

Sampling were carried out in the months of November, January, and March corresponding to the climatic conditions representative of the seasons: spring, summer and autumn, respectively. Thus, being able to monitor with greater comprehensiveness the challenges faced by animals throughout the year, in the focus region, where the experiment was carried out.

Sampling

Forage accumulation rate was estimated using five exclusion cages (1.0 x 1.0 m) per paddocks. The cages were located at points representative of the average pasture height, with mass and morphological composition similar to grazing areas. However, the forage accumulation rate was obtained by means of the difference between the forage masses collected within (current cut) and without (previous cut) of the cage, considering only the green portion of the plant (leaf and stem), divided by the number of days between the samplings. Forage mass within and without the cage were obtained by cutting close to the ground. After each cut, the cages were relocated to other points of the paddocks following the same methodology.

Forage mass of the paddocks (kg/ha) was evaluated at the beginning of each period by the square (0.50 m^2) method and randomly thrown at 10 points per paddocks (Souza et al., 2015). Forage within the square was cut close to the ground and harvested. Pasture height was obtained using a graduated ruler, in which the measurement was taken from the ground level to the curvature of the fully expanded leaves, in each experimental unit (paddocks).

The chemical composition of pasture are presented as g/kg of DM. Nitrogen concentration was determined by the Kjeldahl method (ID 988.05) (AOAC, 2005). Following the determination of nitrogen concentration, crude protein was calculated by multiplying the nitrogen content by a factor of 6.25. The neutral detergent fiber (NDF) content was measured according to the recommendations of Mertens (2002) using α-amylase and was expressed inclusive of residual ash. *In vitro* digestibility of organic matter was performed using F57 filter bags (Ankom Technology, NY, USA) with dimensions of 5.0 x 5.0 cm and a porosity of

50 mm, which were incubated in the Daisy-II Fermenter (Ankom Technology, NY, USA) for 48 h (Tilley & Terry, 1963).

Animal performance were performed with weighing every 49-days in order to record weight gain, during an experimental period of 148-days. The determination of average daily gain was calculated by the difference in animals weight divided by the number of days between weighing. The stocking rate was calculated through the average weights from use and regulators animals, by the number of days they remained on the paddocks (Petersen & Lucas Jr., 1968). Animal weight gain per area was obtained through multiplying the average daily gain from use-animals, by the number of animals (use and regulator animals) maintained by picket and month.

Statistical analyses

Data were analyzed by using the ANOVA procedure of SAS (SAS, 2004) to perform a complete randomized block experiment in split-plot scheme with three replications. Treatments consisted of integrated LFA_{14x2m}, LFA_{22x2m}, and CON systems, while the subplots treatments correspond to time of the year (spring and summer), and the split-plots treatments corresponded to sampling places. For each studied variable, the mean and standard error of the mean (SEM) were calculated and differences between means were evaluated using Tukey Test ($P \leq 0.05$).

3. Results and Discussion

A treatment effect was detected ($P < 0.05$) for forage accumulation, which was lowest in LFA_{14x2m} treatment than others. However, the January period was the greater *v*. November period in LFA_{22x2m} treatment (Table 1). The lowest forage accumulation is explained due to the shade that trees provide to the pasture, since, the LFA_{14x2m} treatment present more trees per experimental area. According to Varella et al. (2012), the greater the spacing between tree lines, the greater the radiation penetration in the forage stratum, favoring the biomass accumulation. Corroborating this statement Barros et al. (2018) evaluated the behavior of *Brachiaria brizantha* cv. BRS Piatã cultivated under two shading levels, concluded that the forage mass was smaller at the highest tree density level.

Table 1. Quantitative characteristic of pasture according to the period of year, in three types of agrosilvopastoral systems[1]

Production system	November	January	March
Daily forage accumulation (kg/d)			
CON	48^{aB}	59^{aA}	68^{aA}
LFA_{22x2m}	26^{bB}	64^{aA}	56^{abA}
LFA_{14x2m}	22^{bB}	29^{bB}	43^{bA}
Total forage dry mass (kg DM/ha)			
CON	$1{,}726^{aC}$	$2{,}007^{aB}$	$2{,}867^{aA}$
LFA_{22x2m}	839^{bC}	$1{,}230^{bB}$	$2{,}172^{bA}$
LFA_{14x2m}	464^{bB}	637^{cB}	$1{,}024^{cA}$
Pasture height (cm)			
CON	30^{abB}	42^{bA}	43^{aA}
LFA_{22x2m}	34^{aC}	56^{aA}	47^{aB}
LFA_{14x2m}	24^{bB}	25^{cB}	49^{aA}

[1]CON = With five native trees remaining per hectare (soil-animal); LFA_{22x2m} = With 227 eucalyptus trees per hectare (soil-forage-animal); LFA_{14x2m} = With 357 eucalyptus trees per hectare (soil-forage-animal).
Means with different uppercase letters (months) in the same line and different lowercase letters (treatments) in the same column are significantly different by Tukey test ($P \leq 0.05$).
Source: Authors.

Total forage dry mass in CON treatment was significantly greater ($P < 0.05$) than the other treatments, showing its maximum production in March. This result should be related to the environment of lower competition for light, nutrients and water only for forage specie. For this reason, plant growth, including aerial and/or root part, depends on the availability of favorable environmental factors for each species (Barros et al., 2018).

Pasture height in LFA_{22x2m} treatment was significantly greater while LFA_{14x2m} treatment was the lowest. In this case, of pastures cultivated when shaded, they present strategies in response to the smaller amount of light, in order to reach a higher extract in search of solar radiation, which starts the stem stretching process (Silva et al., 2009). In addition to this situation, in general, the possible the high values of pasture height obtained in this work are related to climatic conditions, high temperatures, and higher water availability, due to the high precipitation rates occurred during the evaluation period.

The crude protein and *in vitro* digestibility of organic matter contents from *Brachiaria brizantha* cv. BRS Piatã were greater ($P < 0.05$) in LFA_{14x2m} treatment than the other

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treatments. However, the November and March period presented the best results for these variables (Table 2). The result of the present study is in agreement with research conducted by Paciullo et al. (2011); claim that pasture areas under influence and/or in agroforestry systems are benefit as to the crude protein content when compared to exclusive pasture systems. This improvement is attributed to the higher recycled nitrogen in the ecosystem and the higher soil moisture content. Corroborating with this statement, Almeida et al. (2012) observed in their research that pastures in shaded areas have lower forage dry mass, which is offset by higher crude protein and *in vitro* digestibility of organic matter content.

Table 2. Chemical characteristics of forage collected by grazing simulation, according to the period of the year, in three types of agrosilvopastoral systems[1]

Production system	November	January	March
Crude protein (%)			
CON	10.1^{bA}	7.55^{bB}	10.9^{cA}
LFA_{22x2m}	13.8^{aA}	14.4^{aC}	12.6^{bB}
LFA_{14x2m}	13.8^{aB}	11.6^{aC}	15.3^{aA}
Neutral detergent fiber (%)			
CON	70.1^{aA}	71.3^{aA}	71.7^{aA}
LFA_{22x2m}	64.6^{bB}	70.7^{aA}	69.1^{bA}
LFA_{14x2m}	66.6^{bA}	68.2^{bA}	66.9^{cA}
In vitro digestibility of organic matter (%)			
CON	66.2^{bA}	61.1^{bB}	63.4^{bB}
LFA_{22x2m}	73.8^{aA}	63.1^{abC}	66.0^{bB}
LFA_{14x2m}	72.8^{aA}	66.3^{aB}	70.5^{aA}

[1]CON = With five native trees remaining per hectare (soil-animal); LFA_{22x2m} = With 227 eucalyptus trees per hectare (soil-forage-animal); LFA_{14x2m} = With 357 eucalyptus trees per hectare (soil-forage-animal).
Means with different uppercase letters (months) in the same line and different lowercase letters (treatments) in the same column are significantly different by Tukey test ($P \leq 0.05$).
Source: Authors.

The neutral detergent fiber content was greater ($P < 0.05$) in LFA_{14x2m} treatment than the others in the months of January and March. Whereas, in November period the LFA_{22x2m} treatment was better. Possibly the lowest neutral detergent fiber content can be attributed to the lower total forage dry mass production and the lower forage height. Barros et al. (2018) studying *Brachiaria brizantha* observed lower contents of neutral detergent fiber in shaded environment when compared to full sunlight conditions, being the same behavior found in the present work.

Furthermore, the higher neutral detergent fiber content under high light conditions may be associated with a higher proportion of sclerenchyma tissue, with a larger number of cells and thicker cell walls when compared to shading conditions (Deinum et al., 1996). Corroborating with this statement Gobbi et al. 2011 observed that one of the most noticeable changes in shaded plants is the increase in their specific leaf area, which can affect the structural characteristics of cells, such as smaller proportion and thickness of epidermis, thinner cell wall, and reduction of buliform cells. Whereas, plants that grow in full sunlight are often thicker. Thus, these changes directly influence the nutritional value of forage.

Therefore, fiber promotes an adequate digestive function, creating a homogeneous rumen environment, controlling the retention or escape of rumen particles (Van Soest, 1994). However, the physical and chemical characteristics of fiber directly influence rumen filling and dry matter consumption by the animal.

In the months of January and March, the treatments were similar ($P > 0.05$) for average daily gain; while in November period, the lowest value ($P < 0.05$) for average daily gain was 330 grams/day for LFA_{14x2m} treatment (Table 3). The lowest result for animal performance is directly related to forage availability, whereas the average crude protein and *in vitro* digestibility of organic matter contents observed in the LFA_{14x2m} system (13.8 and 72.8%, respectively), are considered adequate for animal development.

Table 3. Performance parameters from Nellore heifers according to the period of the year, in three types of agrosilvopastoral systems[1]

Production system	November	January	March
Average daily gain (g/d)			
CON	607^{aA}	579^{aA}	569^{aA}
LFA_{22x2m}	447^{abB}	691^{aA}	567^{aAB}
LFA_{14x2m}	330^{bB}	587^{aA}	646^{aA}
Total body weight (kg/ha)			
CON	85^{aB}	72^{aB}	109^{aA}
LFA_{22x2m}	49^{bC}	76^{aB}	106^{aA}
LFA_{14x2m}	41^{bB}	50^{bB}	77^{bA}
Stocking rate (UA/ha)			
CON	1.11^{aB}	1.23^{aB}	2.16^{aA}
LFA_{22x2m}	0.90^{aB}	1.01^{aB}	2.06^{aA}
LFA_{14x2m}	0.93^{aAB}	0.75^{aB}	1.33^{bA}

[1]CON = With five native trees remaining per hectare (soil-animal); LFA_{22x2m} = With 227 eucalyptus trees per hectare (soil-forage-animal); LFA_{14x2m} = With 357 eucalyptus trees per hectare (soil-forage-animal).
Means with different uppercase letters (months) in the same line and different lowercase letters (treatments) in the same column are significantly different by Tukey test ($P \leq 0.05$).
Source: Authors.

Total body weight in LFA_{14x2m} treatment was the lowest ($P < 0.05$) in all months of evaluation when compared to CON and LFA_{22x2m} treatments. Whereas, the stocking rate was greater during March period for all treatments. As already mentioned and proven before, the results related to the animal performance are correlated to the higher forage accumulation and total forage dry mass production. While for the stocking rate the agroforestry system does not promote differences in forage carrying capacity, thus being in agreement with results found by Paciullo et al. (2009), studying with *Brachiaria* in agrosilvopastoral and conventional systems, indicated a similarity in the pasture carrying capacity of the systems, similarly observed in the present work.

In comparison, the agrosilvopastoral practice can provide positive results in animal performance, since, in conventional production systems (without any kind of shading) animals may show reduced in feed intake, reduced metabolic rate, and increased body temperature, consequently, the reduced weight gain (Mitlöhner et al., 2001; Souza et al., 2010). Corroborating this statement Silva et al. (2009) working with Zebu crossbred cattle, observed that animals submitted to shading conditions had the best results regarding productive performance, when compared to animals in traditional production systems. Whereas, according to Ferro et al. (2016) evaluating zebu animals (Nellore) submitted to different levels of shading did not observe any difference in production data, and these results are justified by the authors due to the greater racial adaptation to thermal stress, which is in accordance with results of the present work.

In addition, another factor related to animal performance is the animal forage intake capacity, through possible changes in structure of forage morphological components, due to climatic factors throughout the year. However, the higher presence of stems in the pasture stratum reduces the grazing animals intake rate (Drescher et al., 2006).

4. Conclusion

In conclusion, the performance of Nellore heifers is altered through of tree densification as well as quantitative pasture production. The densification of arboreal plants improves the quality of tropical pasture, with higher contents of crude protein and digestibility.

Acknowledgements

Financial support for this research was provided by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES (Brasília, Brazil), Empresa Brasileira de Pesquisa – Embrapa Gado de corte (Campo Grande, Brazil), and Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq (Brasília, Brazil).

Conflict of interest

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Ethics statement

This experiment was approved by the committee for ethics in the use of animals (CEUA) of the Empresa Brasileira de Pesquisa – Embrapa Gado de Corte.

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