Performance of finishing *Nellore* beef steers in intensively managed pastures and silvopastoral systems in Southeast of Brazil

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Abstract. This study evaluated the average daily weight gain (ADG), stocking rates, and live weight gain per hectare (LWG) in different intensified animal production systems. The experiment was carried out from September 2020 to September 2021 at Embrapa Southeast Livestock, São Carlos, SP, Brazil. Thirty *Nellore* steers (285±21 kg of live weight and 12±13 months old) were randomly distributed into five treatments, with two replicates: 1) intensively managed and irrigated *Megathyrsus maximus* cv. Tanzânia pasture overseeded in the dry season with *Avena byzantina* and *Lolium multiflorum* (IHS); 2) intensively managed rainfed *M. maximus* cv. Tanzânia pasture (RHS); 3) intensively managed rainfed pasture with a mix of *Urochloa decumbens* cv. Basilisk and *U. brizantha* cv. Marandu (RMS); 4) intensively managed silvopastoral system with *U. decumbens* cv. Basilisk and Brazilian native trees (312 trees ha^{-1}) (LFS); and 5) extensively managed degraded pasture of *U. brizantha* cv. Marandu and *U. decumbens* cv. Basilisk (DP). Data were submitted to analysis of variance considering treatments and seasons as fixed effects, and the interaction between treatment×season was tested. Means were compared by the Fisher test at 5% using the PROC MIXED of SAS. For all parameters, significant interaction was found (P<.0001). In general, higher ADG, stocking rate and LWG values were found for IHS (0.82 kg d^{-1}, 6.03 AU ha^{-1} and 459.9 kg ha^{-1}, respectively), while the lowest values were found for DP (0.33 kg d^{-1}); for LFS (1.16 AU ha^{-1}); and for LFS and DP (71.0 and 68.9 kg ha^{-1}, respectively). It is important to consider that for LFS the competition for natural resources between the system components (pasture and trees) together with low temperatures and soil moisture during the autumn and winter seasons may explain the unexpected low performances. Overall, our results showed that more intensified systems allowed better animal performances when compared to DP.

Introduction

Agricultural activities need to improve many of its aspects in order to guarantee safe and nutritious food for a growing population, while minimizing the negative impacts to the environment and reducing the intensity of greenhouse gases (GHG) emissions per unit of food product (Ku-Vera et al. 2020). In this context, Brazil occupies a prominent position having the largest commercial cattle herd and being the largest exporter of beef, with 196.5 million heads and 2.5 million tons, respectively (ABIEC 2022). However, the country' most representative livestock production system is based on extensive pasture areas with animals presenting low zootechnical indices, reflecting the sustainability inefficiency of this activity (Oliveira Silva et al. 2017). To overcome this scenario, the intensification of pasture production systems can contribute to increase the productive efficiency of animals, meet the increase global demand for meat products and contribute to the social and financial stability of the country. Strategies such as liming, fertilization, improvement of pasture management, irrigation, overseeding of cool-season forage grasses species and the integration of pastures with forests have the potential to improve the sustainable use of natural resources and consequently increase the efficiency of pastoral systems. In order to evaluate the performance of Nellore steers in different pasture-based production systems, this study compared the average daily weight gain (ADG), stocking rates and live weight gain per hectare (LWG) among degraded pastures, intensified managed pastures and a silvopastoral system in Southeast Brazil.

Methods

The experiment was approved and followed the guidelines of the Ethic Committee on Animal Use – CEUA [nº 04/2019 of the Brazilian Agricultural Research Corporation – Embrapa, Brazil; and nº 08/2020 of the School of Veterinary Medicine and Animal Science/ University of São Paulo, Brazil] being carried at Embrapa Southeast Livestock, São Carlos, SP, Brazil for two years, and this partial result was obtained from September 2020 to September 2021. The soil is classified as Dystrophic Red-Yellow Latosol (FAO: Hapludox) and the climate is classified as subtropical humid (Köppen: Cwa) with two well-defined seasons: dry (from April to September) and rainy (from October to March). The treatments were classified according to different levels of pasture intensification with two replicates per system: 1) intensively managed and irrigated *Megathyrsus maximus* cv. Tanzânia pasture overseeded in the dry season with *Avena byzantina* and *Lolium multiflorum*

(IHS); 2) intensively managed rainfed *M. maximus* cv. Tanzânia pasture (RHS); 3) intensively managed rainfed pasture with a mix of *Urochloa decumbens* cv. Basilisk and *U. brizantha* cv. Marandu (RMS); 4) intensively managed silvopastoral system with *U. decumbens* cv. Basilisk and Brazilian native trees (312 trees ha^{-1}) (LFS); and 5) extensively managed degraded pasture of *U. brizantha* cv. Marandu and *U. decumbens* cv. Basilisk (DP). The IHS and RHS pastures (1.8 ha) were established in 2002. The RMS and DP pastures (3.1 and 2.0 ha, respectively) were established in 1996 with *U. brizantha* cv. Marandu. The DP pasture was considered degraded due to the absence of technology application, mainly liming, fertilization and adequate pasture management, with use of overgrazing. The LFS pasture (3.5 ha) was established with *U. decumbens* cv. Basilisk for more than 30 years, and in 2007 received a recovery process with lime and fertilization application before planting native tree species of the Atlantic Forest Biome. Each tree grove consisted of triple line rows, formed by a central line and two marginal ones, with a distance between rows of 17 m and spacing between trees in the line and between the central and marginal lines of 2.5 m × 2.5 m. The rows are in a near northeast-southwest orientation (transversally to the terrain declivity) and are composed of a population density of 545 trees ha^{-1}. In 2016 and 2020, 50% of the trees in the marginal line of each row were thinned, resulting 312 trees ha^{-1}. All pasture systems (except DP) received broadcast application of dolomitic limestone EVN (Effective Neutralizing Value = 70) and fertilization with ordinary superphosphate (OS, 18% of P_2O_5) and potassium chloride (KCl, 60% of K_2O) to reach 70% of base saturation, 20 mg dm^{-3} of phosphorus (P) and 4% of potassium (K) in the soil cation exchange capacity. Additionally, except for DP, all pasture systems received five split top-dressing nitrogen (N) fertilizations during the rainy season. The rates were of 80 kg N-urea ha^{-1} per application (totaling 400 kg N-urea ha^{-1} $year^{-1}$) for IHS and RHS, and 40 kg N-urea ha^{-1} per application (totaling 200 kg N-urea ha^{-1} $year^{-1}$) for RMS and LFS. Furthermore, IHS was also fertilized with N during the dry season with five split top-dressing fertilizations at the rate of 40 kg N-urea ha^{-1} (totaling 600 kg N-urea ha^{-1} $year^{-1}$), mowed at 25 cm from the soil in April for the overseeding with viable pure seeds of oats (60 kg ha^{-1}) and annual ryegrass (30 kg ha^{-1}), and sprinkler irrigation was applied using a Carborundum fixed center pivot (model PC 08-636/ L3/ G2S Lindsay Corporation, Omaha, Nebraska, EUA). The IHS and RHS pastures were divided into 12 paddocks and managed under rotational stocking with 3 days of occupation and 33 days of resting period. The RMS and LFS pastures were divided into 6 paddocks and managed under rotational stocking with 6 days of occupation and 30 days of rest. The DP pasture was managed under continuous stocking in two single paddocks. Pasture management was performed by adjusting the stocking rate following the "put and take" technique (Mott & Lucas 1952) as a function of the visual assessment of the forage mass availability in each paddock (Costa & Queiroz 2013). However, due to an intense water deficit in the dry period of the year and considering that the forage heights in the pastures were limiting the animals apprehension due to the proximity of the soil (Carvalho et al. 2007), the animals of the LFS and DP were transferred to other areas with similar pastures to avoid starvation at this time. Thirty *Nellore* steers (285±21 kg of live weight and 12±13 months old) were randomly distributed into the treatments (three per experimental unit) with water and a mineral-protein supplement *ad libitum*. The supplement contained the ingredient NH_4NO_3 and was formulated to achieve 0.1% of the body weight of the animals consumption. For evaluating animal performance, weighings were performed at beginning and at regular intervals of 28 days until the end of the experimental period to determine the average daily weight gain (ADG) (kg d^{-1}), the stocking rate [the number of animal units (AU = 450 kg live body weight) per area (AU ha^{-1})], and the live weight gain per hectare (LWG) (kg ha^{-1}). Data were submitted to analysis of variance considering treatments and seasons as fixed effects, and the interaction treatment×season was tested. Means were compared by the Fisher test at 5% using the PROC MIXED of SAS (SAS Institute Inc., Cary, North Carolina, USA).

Results and Discussion

The experimental period was marked by an intense water deficit in the dry period of the year, which presented accumulated rainfall of 92.9 mm; while the IHS in the same period received a replacement of 405.0 mm. Considering that the efficiency of grazing production systems is influenced by environmental issues (Cardoso et al. 2020) and by the management strategies imposed on pastures (Oliveira Silva et al. 2017), the treatments that presented betters forage mass accumulation and nutritional values to establish an adequate defoliation frequency during the experiment (Carvalho et al. 2007), allowed the animals to achieve a better animal performance. The average values of ADG, stocking rate and LWG for the different treatments and seasons, as well as the statistical probabilities of the fixed effects and interaction treatments×seasons are presented in Table 1. Significant interactions were found for all the evaluated parameters and are presented in Table 2.

Table 1. Performance of *Nellore* steers and stocking rate at different levels of pasture-based production systems intensification (DP, LFS, RMS, RHS and IHS) in the different seasons of the year.

Effects		Variables		
Treatments†	Seasons	ADG (kg d^{-1})	Stocking Rate (AU ha^{-1})	LWG (kg ha^{-1})
DP		0.331	1.68	68.9
LFS		0.429	1.16	71.0
RMS		0.574	2.56	201.7
RHS		0.608	3.73	310.3
IHS		0.817	6.03	459.9
	Spring	0.649	1.37	123.4
	Summer	0.720	4.71	404.3
	Autumn	0.665	4.05	289.9
	Winter	0.173	2.00	71.7
Means		0.548	3.03	222.3
Standard Error		0.028	0.069	14.903
Statistical Probabilities (P Value)				
Treatments		<.0001	<.0001	<.0001
Seasons		<.0001	<.0001	<.0001
Treatments × Seasons		<.0001	<.0001	0.0009

†Extensively managed degraded pasture of *U. brizantha* cv. Marandu and *U. decumbens* cv. Basilisk (DP), Intensively managed silvopastoral system with *U. decumbens* cv. Basilisk and Brazilian native trees (312 trees ha^{-1}) (LFS), Intensively managed rainfed pasture with a mix of *U. decumbens* cv. Basilisk and *U. brizantha* cv. Marandu (RMS), Intensively managed rainfed *Megathyrsus maximus* cv. Tanzânia pasture (RHS), Intensively managed and irrigated *M. maximus* cv. Tanzânia pasture overseeded in the dry season with *Avena byzantina* and *Lolium multiflorum* (IHS)

Table 2. Treatments × seasons interaction effects on performance of Nellore steers and stocking rate at different levels of pasture-based production systems intensification (DP, LFS, RMS, RHS and IHS)

Treatments†	Seasons			
	Spring	Summer	Autumn	Winter
Average Daily Weight Gain (kg d^{-1})				
DP	0.361 Db*	0.830 Aa	0.396 Cb	-0.261 Dc
LFS	0.543 Ca	0.623 Ba	0.568 Ba	-0.019 Cb
RMS	0.790 ABa	0.632 Bb	0.792 Aa	0.080 BCc
RHS	0.689 BCa	0.797 Aa	0.771 Aa	0.173 Bb
IHS	0.861 Aab	0.719 ABb	0.797 Aab	0.892 Aa
Stocking Rate (AU ha^{-1})				
DP	0.81 Cc	1.59 Db	2.41 Da	1.91B Cb
LFS	0.39 Dc	1.48 Da	1.73 Ea	1.03 Db
RMS	1.17 BCc	3.75 Ca	3.73 Ca	1.58 Cb
RHS	1.23 Bd	7.06 Ba	4.50 Bb	2.14 Bc
IHS	3.28 Ac	9.65 Aa	7.88 Ab	3.31 Ac
Live Weight Gain per hectare (kg ha^{-1})				
DP	28.2 Bbc	108.2 Cab	153.5 CDa	14.39 Bc
LFS	20.3 Bb	135.2 Ca	93.6 Dab	34.8 Bb
RMS	89.8 Bc	386.3 Ba	248.3 Cb	82.3 ABc
RHS	76.1 Bc	696.9 Aa	394.2 Bb	73.9 Bc
IHS	402.7 Ac	694.9 Aa	559.8 Ab	182.0 Ad

*Means followed by the same capital letter for the treatment factor within the same season and lowercase for the season factor within the same treatment do not differ by Fisher's test ($P < 0.05$). †Extensively managed degraded pasture of *Urochloa brizantha* cv. Marandu and *U. decumbens* cv. Basilisk (DP), Intensively managed silvopastoral system with *U. decumbens* cv. Basilisk and Brazilian native trees (312 trees ha^{-1}) (LFS), Intensively managed rainfed pasture with a mix of *U. decumbens* cv. Basilisk and *U. brizantha* cv. Marandu (RMS), Intensively managed rainfed *Megathyrsus maximus* cv. Tanzânia pasture (RHS), Intensively managed and irrigated *M. maximus* cv. Tanzânia pasture overseeded in the dry season with *Avena byzantina* and *Lolium multiflorum* (IHS)

Average daily weight gain

In spring, higher ADG values were found for IHS and RMS, evidencing the productive effects that *Megathyrsus* spp. was able to provide to the animals, while DP presented the lowest value, due the lack of pasture fertilization and overgrazing during winter. With greater forage mass availability in the summer, higher ADG values were found for DP, RHS and IHS and lower values for RMS and LFS. In DP, as a result of the return of the animals to the original experimental area, the stockpiled forage during spring was preponderant for the high ADG value in summer (Euclides et al. 2007), in addition to compensatory weight gain. Due to the beginning of seasonality in the autumn, in which there is a decrease in crude protein content and digestibility of the pastures (Detmann et al., 2014; Euclides et al., 2021), lower performences were found for LFS and DP. In winter, IHS was able to maintain the highest ADG possibly due the intercropping and applied irrigation techniques, while all the other treatments presented an evident ADG decrease, evidencing the climatic conditions imparing the productive and nutritive aspects of tropical pastures.

Stocking rate and live weight gain per hectare

During spring, the highest stocking rate and LWG were found in IHS, while LFS presented the lowest values, as a result of the lower availability of radiation to the pasture by the shading of trees (Domiciano et al. 2018; Bosi et al. 2020). In summer, IHS, RHS and RMS presented significant stocking and LWG increases justified by the pastures fertilization, while LFS and DP presented lower values, due to insufficient forage accumulation, which could be associated with the lack of sufficient radiation and fertilization, respectively. With the reduction of forage availability in autumn, stocking rates and LWG values decreased in IHS due to mowing and animal defoliation, and in RHS as a result of an intensive animal defoliation (Carvalho et al. 2007), while RMS, DP, and LFS were able to maintain their values. In winter, IHS continued to present the highest stocking and LWG values, while all the other treatments presented decreases, explained by the exhaustion of the productive and nutritive components of the pastures leading to performance losses (Cardoso et al. 2020).

Conclusions and/or Implications

More intensified systems allowed better performances in relation to the DP treatment. In addition, the competition for natural resources like light and water between the LFS system components (pasture and trees), in addition to low temperatures and soil moisture during the dry season of the year (autumn and winter), may explain the unexpected low performances found for this treatment.

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