Scientific Paper

Productive performance of weaner cattle in rotational grazing of *Bothriochloa pertusa* (L) A. Camus in Colombia

Sergio Luís Mejía-Kerguelén *https://orcid.org/0000-0003-2498-756X*, Emiro Andrés Suárez-Paternina *https://orcid.org/0000-0003-2271-7160*, Liliana Margarita Atencio-Solano *https://orcid.org/0000-0001-8425-1621*, José Jaime Tapia-Coronado *https://orcid.org/0000-0002-3621-5316*, Yacerney Paternina-Paternina *https://orcid.org/0000-0001-9046-5167*, Hugo Ramón Cuadrado-Capella *https://orcid.org/0000-0002-9607-9125*

Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), CI Turipaná. Cereté, Colombia. E-mail: smejia@agrosavia.co

Abstract

Objective: To evaluate the effect of the resting period and stocking rate on the productive response of weaner cattle in rotational grazing of *Bothriochloa pertusa* (L) A. Camus, on the savannas of Córdoba, Colombia.

Materials and Methods: Forty-eight commercial Zebu cattle, were used with average weight of 200 ± 15 kg, in which three stocking rates were evaluated (2, 4 and 6 animals ha^{-1}) and two resting periods (20 and 28 days), in a complete randomized block design, with 3 x 2 factorial arrangement, for six treatments in total. The yield, nutritional quality of the forages and daily weight gain of the animals, were evaluated. The direct and indirect costs were recorded, and from them the net profit, cost-effectiveness and balance point were determined.

Results: The dry matter yield showed significant differences (p < 0,05), being higher in the treatments with stocking rate of 2 animals ha^{-1} and resting times of 20 (T1) and 28 (T2) days, with mean values of 1 055,4 and 1 265,4 kg DM ha^{-1}, respectively. The nutritional composition of dry matter was not affected by the evaluated factors. The mean daily gain was significantly higher (p < 0,05) in treatment T1, for a value of 0,612 kg animal^{-1} day^{-1} as average. The treatments of the moderate stocking rate (4 animals ha^{-1}) showed higher cost-effectiveness, which reduced the cost of the produced beef kilogram.

Conclusion: From the productive and economic point of view, meat production through weaners on *B. pertusa* grasslands is more cost-effective when a moderate stocking rate is used.

Keywords: *Bothriochloa pertusa*, stocking rate, weight gain, cost-effectiveness

Introduction

In Colombia, ruminant feeding is constituted mainly by tropical grasses, because it is the most practical and economical way to do it (Mejía-Kerguelén *et al*., 2019a). At present, it is estimated that in the country there are about 20 988 289 ha established of pastures and forages. From them, the Caribbean region contributes 30 % of the total established area (IGAC, 2014). In this region, *Bothriochloa pertusa* (L) A. Camus is one of the most widely established grasses in animal husbandry systems (Mujica-Rodríguez and Burbano-Erazo, 2020). Nevertheless, due to inefficient management practices and adverse climate conditions, this pasture shows low yields and nutritional quality (Tapia-Coronado *et al*., 2019), which are more evident during the dry seasons, when dry matter yields can be reduced by 30-80 % (Mejía-Kerguelén *et al*., 2019a; Roncallo-Fandiño *et al*., 2020).

The cattle production systems of the region are characterized by low adoption of technologies and use of inputs. The soils where these systems are developed show high degree of degradation, which limits forage production and animal response (Mejía-Kerguelén *et al*., 2019b).

Consequently, the productive indicators that are reported are not encouraging. Low stocking rates (< 1 animal ha^{-1}), low production per animal (weight gain < 300 g animal^{-1} day^{-1}) and per area unit (< 300 kg beef ha^{-1} year^{1}), late age at slaughter (> 42 months) and carcass yields lower than 50 %, are recorded (FEDEGAN, 2018). In the face of this problem, it is necessary to conduct studies aimed at generating sustainable models of beef production, which link rotational systems, stocking rate management and grassland renovation, in order to improve the productivity and profitability of the animal husbandry systems of the region.

Some studies have proven that the renovation and establishment of rotational grassland systems have increased pasture yields and nutritional composition. Likewise, increases have been reported in animal response (Roncallo-Fandiño *et al*., 2012; Mejía-Kerguelén *et al*., 2019b).

Received: October 18, 2020
Accepted: December 20, 2020

How to cite this paper: Mejía-Kerguelén, S. L.; Suárez-Paternina, E. A.; Atencio-Solano, Liliana M.; Tapia-Coronado, J. J.; Paternina-Paternina, Y. & Cuadrado-Capella, H. R. Productive performance of weaner cattle in rotational grazing of *Bothriochloa pertusa* (L) A. Camus in Colombia. *Pastos y Forrajes*. 43 (4):333-341, 2020.

Considering that animal husbandry is the main economic activity of the Córdoba department and that, especially, the hilly savannas of this department are developed on *B. pertusa* grasslands, studies are needed which combine different management practices to increase the productive and economic indicators of the animal husbandry system. In this context, the objective of this research was to evaluate the effect of the resting period and stocking rate on the productive response of weaners on *B. pertusa* grasslands in the Córdoba savannas, Colombia.

Materials and Methods

Location. The trial was conducted in a farm located in the Chinú municipality, Córdoba department, in Colombia, with predominance of tropical subhumid climate, moderate- to low-fertility soils, slightly undulated relief, average rainfall of 1 334 mm/year, average temperature of 28 ºC, and relative humidity of 75 %. The dry season begins in December and extends from four to five months.

Experimental animals. Forty eight commercial Zebu animals were used, with average initial weight of 200 ± 15 kg, from cattle auctions. They were evaluated during eight months, which comprised a rainy season and a dry season.

Soil chemical characteristics. The farm shows soils with clayey texture, acid pH, very low phosphorus content, moderate sulfur content, high cation exchange capacity, high potassium deficiency, normal Ca/Mg ratio, high Ca and Mg content, and low content of minor elements, such as Fe, Cu, Zn and B (table 1).

Treatment and experimental design. Three stocking rates were evaluated: low stocking rate (LSR), moderate stocking rate (MSR) and high stocking rate (HSR), which consisted in 2, 4 and 6 animals ha^{-1}, respectively, and two resting periods (20 and 28 days); distributed in a complete randomized design, with 3 x 2 factorial arrangement, for a total of six treatments: T1) LSR and 20 resting days, T2) LSR and 28 resting days, T3) MSR and 20 resting days, T4) MSR and 28 resting days, T5) HSR and 20 resting days and T6) HSR and 28 resting days.

Experimental area and animal management. The area utilized for grazing was 12 ha, established with *B. pertusa*. It was divided into 12 modules of 1 ha. In six of these modules six divisions were established, in order to establish a 24-day grazing cycle (four days of occupation and 20 resting days); while in the six remaining modules a 32-day grazing cycle was implemented (four days of occupation and 28 resting days), in eight divisions.

Before introducing the animals in the paddocks, a mechanical cut was done for pasture homogenization. Afterwards, the land was chiseled at a depth between 30 and 40 cm, in order to decompact and allow higher aeration and water infiltration in the soil. Considering the low organic matter content, and with the purpose of promoting the pasture recovery in the high and moderate stocking rates, it was fertilized with 100 and 50 kg of nitrogen ha^{-1} year^{-1} in the grasslands under high and moderate stocking rate, respectively, without fertilizing in the low stocking rate. The fertilization was carried out during the rainy season, after each grazing. The animals were daily provided with mineralized salt at a rate of 80 g animal^{-1} d^{-1}. During the dry season, the stocking rates were reduced in half and 1 kg day^{-1} of cotton (*Gossypium herbaceum* L.) seed was supplied.

The sanitary management consisted in applying the vaccines, demanded by the Colombian Agricultural Institute ICA, as well drugs for the control of endoparasites and ectoparasites. The water supply was performed through an internal aqueduct system, provided with a PVC drinking trough, with capacity of 500 L, connected to a hydrant through a bayonet.

Studied variables

Forage yield. To determine the forage yield and floristic composition the availability by frequency method was used in the next paddock to be grazed. For such purpose, the methodology proposed by Franco-Quintero *et al.* (2006) was applied. Five spots were identified on the biomass, with the utilization of a 0,25-m^2 frame. To each spot a qualification of 1-5 was assigned, where one corresponds to low biomass availability and five to higher availability.

Table 1. Soil physical and chemical characteristics.

Indicator	pH	OM	Ca	P	Mg	K	Na	CEC	S	Cu	Fe	Zn	Mn
		g/100g	cmol(+)/kg	mg/kg	cmol(+)/kg				mg/kg				
Value	5,39	1,32	32,5	5,3	11,0	0,27	0,35		15,8	0,4	1,2	0,4	24,8

Each spot was cut and weighed with a digital scale (Ohaus model CS 5000), and 40 launchings were carried out per hectare for identifying the species present inside each frame. The dry matter was determined through the NTC4888 method (ICONTEC, 2000), with a 250-g sample of green forage.

Nutritional quality. The nutritional quality of the forage and the supplements was determined from composite samples, during the rainy and dry season. The samples were collected through the grazing simulation method proposed by Mestra-Vargas *et al*. (2020). Five hundred grams were taken, which were dried in a forced-air stove at 60 ºC, during 48 h. Afterwards, they were ground in a Willey mill, with a one-millimeter sieve. The samples were processed in the Animal Nutrition Laboratory of AGROSAVIA, located at the Turipaná Research Center. Crude protein was determined by the Kjeldahl method, neutral detergent fiber (NDF) and acid detergente fiber (ADF) according to the AOAC (2002), and the *in situ* dry matter degradability (DMDIG) through the nylon bag technique, described by Ørskov *et al*. (1980).

Animal response. The initial and monthly weight of the animals was recorded until the end of the trial, with a Tru-Test® electronic portable scale. They were individually weighed to determine the daily weight gain (MDG) by the following equation: MDG = (final weight – initial weight) /number of days

Economic analysis. For the elaboration of the economic analysis the methodology suggested by Agreda (1990), which comprised the record of the direct and indirect costs, and from it the following indicators were determined:

Net income (NI): Difference between gross income (GI) and total production cost (TC), IN = GI-TC

Profitability (Prof)**:** Relation between net income and total cost production,

$$\text{Prof} = \frac{\text{GI - TC}}{\text{TC}} *100$$

Balance point (Peq): Maximum quantities of kilos that should be produced to balance the incomes with the costs,

$$\text{Peq} = \frac{\text{CP}}{\text{PV}}$$

Statistical analysis. Variance analysis was carried out, after fulfilling the data normality and homogeneity assumptions. For such purpose, the *Shapiro-Wilk* and *Levene* tests, respectively, were used. For the data analysis, the GLM procedure of the statistical analysis package SAS V9.2 (SAS Inc. North Carolina, USA) was used. The means of the treatments were compared through Tukey's test, with a significance level of 5 %.

Results and Discussion

According to the statistical analysis, interaction was found ($p < 0,05$) between the evaluated factors (stocking rate and resting days) on the forage yield (table). The grasslands that sustained the treatments of the low stocking rates LSR20 (T1) and LSR28 (T2) recorded the highest DM yields, with values of 1 055,4 and 1 265,4 kg DM ha^{-1}, respectively.

The highest DM yield in the grasslands of low stocking rates can be due to a lower grazing pressure, which could have contributed to the fact that not all the biomass was consumed by the animals, which allowed to have higher photosynthetic area and recovery capacity.

In this regard, Vanegas-Moreno (2015) states that the residual leaves are the ones that contribute to make the photosynthesis of a pasture after grazing.

Table 2. Average DM yield and floristic composition of the grasslands.

Treatment		kg DM ha^{-1}	Grass, %	Legumes, %	Weeds, %
Stocking rate	Resting days				
CB	20	1055,4^{a}	70,5	18,6	10,9
CB	28	1265,4^{a}	73,0	15,4	11,6
CM	20	620,7^{bc}	72,5	15,0	12,5
CM	28	803,1^{ab}	69,6	19,4	11,0
CA	20	512,0^{c}	69,8	18,7	11,5
CA	28	653,7^{bc}	71,5	16,6	11,9
VC %		15,4	18,7	35,3	41,2

Different letters in the same column statistically differ according to Tukey ($p < 0,05$)
LSR: low stocking rate, MSR: moderate stocking rate, HSR: high stocking rate, VC: variation coefficient etras diferentes en una misma columna difieren estadísticamente según Tukey ($p < 0,05$)

Likewise, Rincón-Castillo (2011) asserts that the photosynthetic activity of the pastures is affected when there is overgrazing. Thus, grasslands will require longer recovery time for the accumulation of organic reserves.

Torregroza *et al*. (2015), when evaluating different stocking rates in grasslands of *Urochloa hibrido* CIAT 36087, reported that the forage availability was reduced when the stocking rate increased. A similar performance was observed in this study, in which the high stocking rates recorded the lowest forage yields.

It could be observed that the highest DM yields occurred at 28 days of resting with regards to the yields at 20 days (table 2). The lower yields at 20 days can be ascribed to the low accumulation of organic reserves, which generated lower growth of the grass. Similar results were reported by Rincón-Castillo *et al*. (2008) when evaluating two cutting frequencies in *Urochloa decumbens* Stapf. and *Urochloa brizantha* cv. Toledo. These authors referred higher DM quantity at 28 days with regards to 14 resting days. Similar performance was observed by Garay-Martínez *et al*. (2018) in grasses of the *Cenchrus* genus and *Urochloa* hybrids.

Vanegas-Moreno (2015) states that the restoration rate of reserve carbohydrates is associated to the photosynthetic rate, and the latter depends on the residual material. The average DM yield recorded in this study is within the values referred by Tapia-Coronado *et al*. (2019). These authors indicated that the pasture *B. pertusa* shows variability in the forage yield, due to the rain seasonality. These yields can decrease up to 60 % in the dry season, which seriously affects the individual performance and productivity per surface unit.

Regarding the floristic composition of the grasslands, no significant differences were found among treatments. Nevertheless, predominance of the grass was observed regarding the legume and weed component (table 2).

Among the legumes, *Desmodium escorpiurus* (Sw.) Desv. and *Alysicarpus vaginalis* (L.) DC. were identified as the ones with higher contribution. As average, the participation of the legumes was close to 17 %. This is favorable because they have high protein content, which contributes to improving the quality of the basis diet and animal response (Schultze-Kraft *et al*., 2018). In addition, legumes aid the sustainability of grasslands, because they fix atmospheric nitrogen to the soil, which can be utilized by the companion grasses in the system.

The nutritional composition of DM was not affected by the evaluated factors (table 3). However, this result differs from the report by Torregroza *et al*. (2015), because these factors did not find significant effect of stocking rate on the nutritional quality of the pasture *Urochloa hibrido* CIAT 36087. Nevertheless, they referred higher CP contents than those referred in other works. The differences among the results can be associated to the high nitrogen doses used by the above-cited authors for the fertilization of the grasslands. In this regard, Rezende *et al*. (2015) showed that the application of high nitrogen doses contributes to increasing the

Table 3. Nutritional composition and dry matter digestibility of the pasture *B. pertusa*.

Treatments		CP, %	NDF, %	ADF, %	DMDIG, %	ME, Mcal kg DM^{-1}
Stocking rate	Resting days					
LSR	20	7,9	65,3	37,7	59,5	2,14
LSR	28	7,4	67,7	39,8	57,8	2,00
MSR	20	9,3	65,4	36,8	60,2	2,17
MSR	28	7,2	64,9	38,1	59,2	2,10
HSR	20	9,9	63,9	36,3	60,6	2,18
HSR	28	8,2	64,5	37,2	59,2	2,13
P - value		0,7052	0,995	0,8444	0,8976	0,9639
SE ±		0,369	1,022	0,872	0,679	0,024
VC %		23,8	7,3	8	4,1	4,1

LSR: low stocking rate, MSR: moderate stocking rate, HSR: high stocking rate, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, DMDIG: dry matter digestibility, ME: metabolizable energy, VC: variation coefficient.

CP content in the grasses, especially in the soluble fraction.

The results in this study differ from the ones found by Merlo-Maydana *et al*. (2017), who stated that the CP content is reduced as the age of utilization of the pasture increases. These authors ascribe the decrease of the CP content of the forages to the season and cutting age, as well as to the plant structures, the stem proportion being the one with lower nutritional content.

The variation in the quality of tropical grasses has been studied in Colombia by Mojica-Rodríguez *et al*. (2017) and Ángulo-Arroyave and Rosero-Noguera (2018), who have proven that the decrease in the nutritional content mainly obeys the water deficit that appears in the dry season, as well as the traditional management practices.

Vanegas-Moreno (2015) states that the CP concentrations are reduced due to the low metabolic activity of the grasses, as the utilization age advances. Lara-Mantilla *et al*. (2010) reported that at higher age of the pasture increases are shown in the fractions of the cell wall, which generates lower deposit of easily-digested nutrients in the protoplasm.

Although no significant differences were found in this study for the fractions NDF, ADF, DMDIG and energy contribution, Suárez-Paternina *et al*. (2018) reported that higher NDF content means lower DM intake, due to its slow degradation and low passage rate through the rumen. Likewise, forages with an ADF concentration of approximately 40 %, usually show lower digestibility, for which the intake and energy contribution are affected (Merlo-Maydana *et al*., 2017).

For the MDG, there was interaction ($p < 0,05$) between the factors (stocking rate x resting days). In this context, higher MDGs were observed (0,612 kg animal $^{-1}$ day^{-1}) in the treatment with low stocking rate and 20 resting days (T1), which were statistically significant ($p < 0,05$), than the ones found in the treatments of high stocking rate, with 20 (T5) and 28 (T6) resting days (table 4).

The higher MDG in treatment T1 could be related to the higher forage availability (table 2), which could have generated higher selectiveness by the animals, because there was lower competition.

Similar results were found by Torregroza *et al*. (2015), who when evaluating different stocking rates in grasslands of *U. hibrido* CIAT 36087, observed that in the low and moderate stocking rates the highest MDGs were recorded. This performance was ascribed to the higher forage offer and nutritional quality, and to the higher selectiveness exerted by the animals.

Roncallo-Fandiño *et al*. (2012), when evaluating the forage production and animal response in grasslands of *B. pertusa* associated with *Leucaena leucocephala* in the Cesar Valley, found weight gains of 0,659 kg animal^{-1}day^{-1}, higher than those found in this work. These differences can be related to the higher number of resting days offered to the grasslands (33 days in the rainy season and 55 days in the dry season), which contributed to increase the grass and legume yields. They can also be associated to the

Table 4. Weight gain per animal and surface unit in *B. pertusa* grasslands.

Treatments		kg animal $^{-1}$ day^{-1}	kg ha^{-1} day^{-1}	kg ha^{-1} year^{-1}
Stocking rate	Resting days			
LSR	20	0,612^{a}	1,23^{c}	448,9
LSR	28	0,542^{ab}	1,09^{c}	397,8
MSR	20	0,477^{abc}	1,91^{ab}	697,1
MSR	28	0,476^{abc}	1,91^{ab}	697,1
HSR	20	0,364^{c}	2,18^{a}	795,7
HSR	28	0,398^{bc}	2,39^{a}	872,3
P - value		0,001	0,001	-
SE ±		0,019	0,019	
VC %		34,6	34,8	-

Different letters in the same column statistically differ according to Tukey ($p < 0,05$)
LSR: low stocking rate, MSR: moderate stocking rate, HSR: high stocking rate,
SE: standard error, VC: variation coefficient

significant nutrient contributions of the legume and to the lower stocking rate used. Nevertheless, Roncallo-Fandiño *et al*. (2020), when studying the productive response of growing male cattle in two animal husbandry farms of Cesar Valley, in Colombia, found average weight gains of 0,282 kg animal^{-1} day^{-1} in *B. pertusa* grasslands, value that is lower than the one recorded in this study.

Regarding the gain per surface unit, the analysis showed differences in the interaction ($p < 0,05$) between the studied factors. The treatments with high and moderate stocking rates recorded the highest values (as average 2,18, 2,39, 1,91 and 1,91 kg ha^{-1} d^{-1}, respectively); while in those with low stocking rate (2 animals ha^{-1}) the beef production per hectare was 1,23 and 1,09 kg ha^{-1} day^{-1}, respectively (table 4).

The above-stated facts could be explained by the effect of the stocking rate increase, which causes decrease of the individual production, but increases production per hectare. Hence the best performance was obtained with the stocking rate of 6 animals ha^{-1}. Similar result was found by Torregroza *et al*. (2015), who concluded that the effect of the stocking rate caused gradual increase in the beef production per hectare.

Table 5 shows the production costs per surface unit for each of the treatments. The ones that had high stocking rates recorded the highest production costs with regards to the treatments of the moderate and low stocking rates.

The higher production costs observed in the high stocking rates were mainly due to the higher number of acquired animals, which represented 30 and 60 % increase as average with regards to the costs recorded in the moderate and low stocking rates, respectively. Likewise, the higher number of acquired animals in the high stocking rates generated higher cost in the animal supplementation item. Another aspect that contributed to these treatments showing the highest production costs was the nitrogen fertilization implemented in the grasslands.

Weaner production in *B. pertusa* grasslands is viable and cost-effective from the technical and economic point of view, because the incomes exceeded the production costs (table 6). The highest total incomes were recorded in the treatments with high stocking rates, and were obtained due to the commercialization of 1 497,8 and 1 553,7 kg of live animals. This generated a net profit per hectare of $1 194 663 and $1 442 706. However, in the treatments of the moderate stocking rates, profits similar to the ones shown by the treatments of the high stocking rates were observed. This performance can be ascribed to the MDG in the animals of the moderate stocking rates (table 4). The lower production cost was also obtained in the treatments of the moderate stocking rates, with average cost-effectiveness of 28 %.

When relating the production costs with the kilograms of live animals produced, it was established that the treatments of the moderate stocking rates produced the kilogram of live animal meat at a lower cost, which was as average $125 and $263 lower than the one recorded in the treatments

Table 5. Production costs ($) per hectare per year for each of the evaluated treatments.

Item	Treatment					
	Low stocking rates (2 animals ha^{-1})		Moderate stocking rates (4 animals ha^{-1})		High stocking rates (6 animals ha^{-1})	
	20 days	28 days	20 days	28 days	20 days	28 days
Agricultural activities/ha	127 982,0	122 196,0	134 686,0	137 946,0	151 186,0	1544 46,0
Equipment and tools/ha	6 713,0	6 713,0	6 713,0	6 713,0	6 713,0	6 713,0
Labor/ha	372 622,0	372 622,0	372 622,0	372 622,0	372 622,0	372 622,0
Purchase of animals/ha	1 434 600,0	1 434 600,0	2 875 350,0	2.875.350	4 303 800,0	4 303 800,0
Animal health/ha	7 410,0	7 410,0	14 820,0	14 820,0	22 230,0	22 230,0
Animal supplementation/ha	157 200,0	157 200,0	314 400,0	314 400,0	470 200,0	470 200,0
Direct costs/ha	2 106 528,0	2 100 742,0	3718 592,0	3721 852,0	5326 752,0	5 330 012,0
Indirect costs/ha	219 000,0	219 000,0	219 000,0	219 000,0	219 000,0	219 000,0
Total production cost/ha	2 325 528,0	2 319 742,0	3 937 592,0	3 940 852,0	5 545 752,0	5 549 012,0

Table 6. Analysis of the economic returns per hectare ($) in the evaluated treatments.

Item	Treatment					
	Low stocking rates (2 animals ha^{-1})		Moderate stocking rates (4 animals ha^{-1})		High stocking rates (6 animals ha^{-1})	
	20 days	28 days	20 days	28 days	20 days	28 days
Production costs/ha	2 325 528,0	2 319 742,0	3 937 592,0	3 940 852,0	5 545 752,0	5 549 012,0
kg commercialized, live animal	635,0	596,7	1 122,3	1 121,2	1 497,8	1 553,7
Price kg of beef, $	4 500,0	4 500,0	4 500,0	4 500,0	4 500,0	4 500,0
Total income/ha	2 857 815,0	2 685 353,0	5 050 418,0	5 045 490,0	6 740 415,0	6 991 718,0
Net profit/ha/year	532 287,0	365 611,0	1 112 826,0	1 104 638,0	1 194 663,0	1 442 706,0
Annual cost-effectiveness, %	22,9	15,8	28,3	28,0	21,5	26,0
Costs beef kilo ($)	3 662,0	3 887,0	3 508,0	3 515,0	3 702,0	3 571,0
Balance point beef, kg	517,0	515,0	875,0	876,0	1 232,0	1 233,0

of high and low stocking rate, respectively (table 6). Likewise, the treatments of the moderate stocking rates destined 78 % of the beef production to level the incomes with the production costs; while in the low and high stocking rates they allotted 83 and 80 %, respectively. This indicates that the treatments of the moderate stocking rates were the most efficient ones in beef production.

Conclusions

The stocking rate affected the DM yields. The highest yields were found in grasslands that maintained the low stocking rates. Likewise, in the low stocking rates the highest individual weight gains of the animals were shown. However, in the high stocking rates the highest gains per surface unit were recorded.

From the economic point of view, beef production through weaners was more cost-effective in the treatments that maintained the moderate stocking rates. Similarly, in the moderate stocking rates the kilogram of live animal beef was produced at a lower cost.

Recommendations

The renovation of grasslands, accompanied by fertilization, organic if possible, is recommended, as well as the implementation of rotational systems with grazing cycles lower than 28 days, with stocking rate of 4 animals ha^{-1} in the rainy season, which are reduced to half in the dry season.

Acknowledgements

The authors thank the Ministry of Agriculture and Rural Development (MADR, for its initials in Spanish) for funding the resources for the development of the research project "Management alternatives of *B. pertusa* grass in animal husbandry systems of the low tropic", in the framework of agreement 1506.

Authors' contribution

- Sergio Luís Mejía Kerguelén. Data analysis and interpretation and manuscript writing.
- Emiro Andrés Suárez Paternina. Data analysis and interpretation and manuscript writing.
- Liliana Margarita Atencio Solano. Data analysis and interpretation and manuscript writing.
- José Jaime Tapia Coronado. Data analysis and interpretation and manuscript writing.
- Yacerney Paternina Paternina. Data analysis and interpretation and manuscript writing.
- Hugo Ramón Cuadrado Capella. Data analysis and interpretation and manuscript writing.

Conflict of interests

The authors declare that there are no conflicts of interests among them.

Bibliographic references

Agreda, V. *Metodología para análisis económico de sistemas de producción*. San José, Costa Rica: RISPAL, 1990.

Angulo-Arroyave, R. & Rosero-Noguera, R. Producción de forraje y calidad nutricional del pasto angleton climacuna (*Dichanthium annulatum*-Forssk-Stapf) para la producción de heno en La Dorada (Caldas). *Rev. prod. anim*. 30 (2):12-17. http://scielo.sld.cu/pdf/rpa/v30n2/rpa02218.pdf, 2018.

AOAC International. *Official methods of analysis*. 17th ed. 1st rev. Gaithersburg, USA: AOAC International, 2002.

FEDEGAN. *Fichas de caracterización departamental*. Bogotá: Federación Colombiana de Ganaderos.

https://www.fedegan.org.co/estadisticas/documentos-de-estadistica, 2018.

Franco-Quintero, L. H.; Calero-Quintero, D. & Durán-Castro, C. V. *Manejo y utilización de forrajes tropicales multipropósito*. Palmira, Colombia: Universidad Nacional de Colombia Sede Palmira. https://repositorio.unal.edu.co/bitstream/handle/unal/8429/9789584411754.pdf?sequence=1&isAllowed=y, 2006.

Garay-Martínez, J. R.; Joaquín-Cancino, S.; Estrada-Drouaillet, B.; Martínez-González, J. C.; Joaquín-Torres, B. M.; Limas-Martínez, A. G. *et al.* Acumulación de forraje de pasto buffel e híbridos de *Urochloa* a diferente edad de rebrote. *Ecosistemas y recur. agropecuarios*. 5 (15):573-581, 2018. DOI: https://doi.org/10.19136/era.a5n15.1634.

ICONTEC. *Alimentos para animales. Determinación del contenido de humedad y materia volátil. NTC 4888*. Bogotá: Instituto Colombiano de Normas Técnicas y Certificación. https://tienda.icontec.org/gp-alimentos-para-animales-determinacion-del-contenido-de-humedad-y-materia-volatil-ntc4888-2000.html, 2000.

IGAC. *Los pastos es la cobertura que reina en los suelos de la región Caribe*. Bogotá: Instituto Geográfico Agustín Codazzi. https://igac.gov.co/es/noticias/los-pastos-es-la-cobertura-que-reina-en-los-suelos-de-la-region-caribe, 2014.

Lara-Mantilla, Cecilia; Oviedo-Zumaqué, L. E. & Betancur-Hurtado, C. A. Efecto de la época de corte sobre la composición química y degradabilidad ruminal del pasto *Dichanthium aristatum* (Angleton). *Zootecnia Trop*. 28 (2): 275-282. http://ve.scielo.org/pdf/zt/v28n2/art13.pdf, 2010.

Mejía-Kerguelén, S.; Tapia-Coronado, J. J.; Atencio-Solano, Liliana M. & Cadena-Torres, J. Producción y calidad nutricional del forraje del sorgo dulce en monocultivo e intercalado con maíz y frijol. *Pastos y Forrajes*. 42 (2):133-142. http://scielo.sld.cu/pdf/pyf/v42n2/2078-8452-pyf-42-02-133.pdf, 2019a.

Mejía-Kerguelén, S. L.; Suarez-Paternina, E.; Atencio-Solano, Liliana; Ibáñez-Miranda, Ketty I.; Martínez-Atencia, Judith; Tapia-Coronado, J. J. *et al.* *Modelo productivo de carne bovina en la región Caribe colombiana* Bogotá: Corporación Colombiana de Investigación Agropecuaria-AGROSAVIA, 2019b.

Merlo-Maydana, F. E.; Ramírez-Avilés, L.; Ayala-Burgos, A. J. & Ku-Vera, J. C. Efecto de la edad de corte y la época del año sobre el rendimiento y calidad de *Brachiaria brizantha* (A. Rich.) Staff en Yucatán, México. *J. Selva Andina Anim. Sci*. 4 (2):116-127, 2017.

Mestra-Vargas, Lorena I.; Barragán-Hernández, W. A.; Medina-Herrera, D. A. & Flórez-Díaz, H. Evaluación técnica-económica de la frecuencia de suplementación de novillos en pastoreo en Córdoba, Colombia. *Agron. Mesoam*. 31 (2):353-366, 2020. DOI: https://dx.doi.org/10.15517/am.v31i2.38389.

Mojica-Rodríguez, J. E. & Burbano-Erazo, E. Efecto de dos cultivares de *Megathyrsus maximus* (Jacq.) en la producción y composición de la leche bovina. *Pastos y Forrajes*. 43 (3):169-175. http://scielo.sld.cu/pdf/pyf/v43n3/2078-8452-pyf-43-03-177.pdf, 2020.

Mojica-Rodríguez, J. E.; Castro-Rincón, E.; Carulla-Fornaguera, J. & Lascano-Aguilar, C. E. Efecto de la edad de rebrote sobre el perfil de ácidos grasos en gramíneas tropicales. *Corpoica Cienc. Tecnol. Agropecuaria*. 18 (2):217-232, 2017. DOI: https://doi.org/10.21930/rcta.vol18_num2_art:623.

Ørskov, E. R.; Hovell, F. & Mould, F. The use of the nylon bag technique for the evaluation of feedstuffs. *Trop. Anim. Prod*. 15 (3):195-213. https://www.semanticscholar.org/paper/The-use-of-the-nylon-bag-technique-for-the-of-Oerskov-Hovell/acc150f1d92ad10e113af9897b80d1198efa80d8, 1980.

Rezende, A. V. de; Rabêlo, F. H. S.; Rabelo, C. H. S.; Lima, Poliana P.; Barbosa, Larissa de Á.; Abud, Marcella de C. *et al.* Características estruturais, produtivas e bromatológicas dos capins Tifton 85 e Jiggs fertilizados com alguns macronutrientes. *Semina: Ciências Agrárias*. 36 (3):1507-1517, 2015. DOI: https://doi.org/10.5433/1679-0359.2015v36n3p1507.

Rincón-Castillo, A. Efecto de alturas de corte sobre la producción de forraje de *Brachiaria* sp. en el piedemonte Llanero de Colombia. *Corpoica Cienc. Tecnol. Agropecuaria*. 12 (2):107-112, 2011. DOI: https://doi.org/10.21930/rcta.vol12_num2_art:219.

Rincón-Castillo, A.; Ligarreto-Moreno, G. A. & Garay, E. Producción de forrajes en los pastos *Brachiaria decumbens* cv. Amargo y *Brachiaria brizantha* cv. Toledo, sometidos a tres frecuencias y a dos intensidades de defoliación en condiciones del piedemonte llanero colombiano. *Rev. Fac. Nac. Agron. Medellín*. 61 (1):4336-4346. https://www.redalyc.org/articulo.oa?id=179914077010, 2008.

Roncallo-Fandiño, B.; Murillo, J.; Rodríguez, G.; Bonilla, Ruth R. & Garrido, María F. Producción de forraje y respuesta animal en suelos del valle del Cesar en proceso de recuperación. *Corpoica Cienc. Tecnol. Agropecuaria*. 13 (1):89-96, 2012. DOI: https://doi.org/10.21930/rcta.vol13_num1_art:244.

Roncallo-Fandiño, B.; Soca-Pérez, Mildrey & Ojeda-García, F. Comportamiento productivo de bovinos macho en desarrollo en dos explotaciones ganaderas del valle del Cesar en Colombia. *Pastos y Forrajes*. 43 (3):212-220. http://scielo.sld.cu/scielo.php?script=sci_abstract&pid=S0864-03942020000300220, 2020.

Schultze-Kraft, R.; Rao, I. M.; Peters, M.; Clements, R. J.; Bai, C. & Liu, G. Tropical forage legumes for environmental benefits: An overview. *Tropical Grasslands-Forrajes Tropicales*. 6 (1):1-14, 2018. DOI: https://doi.org/10.17138/TGFT(6)1-14.

Suárez-Paternina, E. A.; Maza-Angulo, L. A.; Barragán-Hernández, W.; Patiño-Pardo, R.; Bustamante-Yanez, M. de J. & Vergara-Garay, O. Efecto de la suplementación con semilla de algodón y maíz molido sobre el consumo y el desempeño productivo de ovinos de pelo colombiano. *Rev. MVZ Córdoba*. 23 (Supl):7048-7061, 2018. DOI: https://doi.org/10.21897/rmvz.1426.

Tapia-Coronado, J. J.; Atencio-Solano, Liliana M.; Mejía-Kerguelén, S. L.; Paternina-Paternina, Y. & Cadena-Torres, J. Evaluación del potencial productivo de nuevas gramíneas forrajeras para las sabanas secas del Caribe en Colombia. *Agron. Costarricense*. 43 (2):45-60. https://revistas.ucr.ac.cr/index.php/agrocost/article/view/37943/38908, 2019.

Torregroza, L.; Reza, S.; Suárez, E.; Espinosa, M.; Cuadrado, H.; Pastrana, I. *et al.* Producción de carne en pasturas irrigadas y fertilizadas de Brachiaria híbrido cv. Mulato II en el valle del Sinú. *Corpoica cienc. tecnol. agropecu*. 16 (1):131-138, 2015. DOI: https://doi.org/10.21930/rcta.vol16_num1_art:391.

Vanegas-Moreno, Luz Á. *Dinámica de crecimiento y criterios de pastoreo para optimizar el uso de praderas* Brachiaria brizantha *cv toledo*. Tesis investigativa para optar al título de Magister en Ciencia Animal. Bogotá: Universidad de La Salle, 2015.