Scientific Paper

Beef production in rational grazing system

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Abstract

Objective: To characterize the growth dynamics of fattening males under rational Voisin grazing conditions on soils with undulated to rough topography, in the humid tropics of Los Santos, Panama.

Materials and Methods: The trial was conducted in a production area of 8,40 ha, divided into 24 paddocks of 0,35 ha as average. The pastures were managed according to the principles and concepts of rational Voisin grazing. Fifty-three steers with Zebu basis and its F1 and F2 crossings (Zebu x Holstein) were used, divided into two fattening groups. The first fattening period (27 animals) lasted 150 days, and the second (26 animals), 79 days. The initial weights were 369 and 401 kg, for the first and second groups, respectively. The animals were weighed every 30 days to determine live weight gain per period and individual daily gain. The data were processed by variance analysis and Duncan's test was used for $p < 0,05$.

Results: The grazing pressure was high (4,63 kg DM/100 kg LW/day), with an average pasture availability of 23,2 kg DM/a/day. The animals of the first fattening cycle averaged 0,653 kg/day, with a beef production per hectare of 336,63 kg. In the second cycle, they gained 0,670 kg per day; while beef production was 145,55 kg/ha. The two continuous fattening periods allowed the farmer to sell more than 24 t of live beef in one year.

Conclusions: It is concluded that the fattening of Zebu bulls and its F1 and F2 crossings in a Voisin rational grazing system is feasible, because average gains close to 0,700 kg/animal/day are obtained, without weight loss at times of higher food shortage.

Keywords: bovidae, weight gain, pastureland management

Introduction

With Panama's entrance to the World Trade Organization (WTO) and the recent free trade agreements with Central America and the United States, great challenges are presented for Panamanian animal husbandry, which will have to be overcome in the short and medium term. For such purpose, local beef production systems will have to be more efficient and competitive, to face the possibility of importing products and also exporting them to other countries (Domínguez-Escudero, 2015). From this, the need to achieve an effective transition from current production systems to those capable of simultaneously promoting food and nutritional security, increasing agricultural productivity, providing prosperity for present and future generations, is derived, and all this, without degrading natural resources and ecosystems and even reversing the current conditions of degradation (IICA, 2019).

In this context, Voisin rational grazing (VRG) emerges as an alternative for animal husbandry to be a sustainable activity, through the rational use of all available resources, and the integration of all existing knowledge, tools, theories and laws about forage production and animal production (Domínguez-Escudero, 2019).

The effective use of VRG helps to eliminate overgrazing and the disappearance of the cover of adapted species, protects the soil and strengthens the root system, by creating sufficient reserves in the roots to allow vigorous regrowth, thus contributing to adaptation and mitigation (Milera-Rodríguez *et al*., 2019). There are results about the rational management of different cultivated grasses and its effect on the stability of the floristic composition, dry matter (DM) availability, nutrient recycling, soil biota, underground phytomass, reduction of pests and diseases and animal production (Milera-Rodríguez *et al*., 2019).

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Based on these antecedents, the purpose of this research was to characterize the growth dynamics of fattening males in Voisin rational grazing on undulated to rough topography soils, in the humid tropics of Los Santos, Panama.

Materials and Methods

Location and duration of the trial. The research was conducted at the Pajonales cattle husbandry farm, located at km 4,5 of the Nuario village, Las Tablas district, Los Santos province, Republic of Panama, at coordinates UTM N 575584, W 831759, at an altitude of 484 m.a.s.l., with undulated to rough topography. The total area of the farm is 13,5 ha, of which 9,65 are dedicated to cattle grazing in a VRG system, divided into 40 paddocks with electrical fence, with an average size of 0,2412 ha. The trial was carried out in an area of 8,40 ha, divided into 24 paddocks, of 0,35 ha as average, during the period between April, 2019, and February, 2020.

Soil and climate of the experimental area. The soils of the farm are yellowish brown, with a sandy loam texture (sand, 64 %; silt, 24 % and clay, 12 %). During the research period, rainfall was 1 491 mm, with the highest accumulated rain in September and October. Dominguez-Escudero *et al*. (2021) reported the results of the chemical composition of the soil, as well as the climate characteristics of the farm.

Pastures. The pastures were managed under the principles and concepts of the VRG, developed by Pinheiro-Machado (2015). According to this method, the paddocks were not grazed in chronological order, but the optimum resting point was determined, as recommended by Pinheiro-Machado (2016) through weekly walks in the grazing area. The days of occupation and resting of the grazing paddocks, as well as the grazing intensity and pressure, were managed by considering the pasture availability and paddock size, which is described in a previous paper by Domínguez-Escudero *et al*. (2021).

The prevailing cultivated pastures in the systems were the grasses *Cynodon dactylon* L. Pers cv. Alicia, *Digitaria didactyla* Willd cv. Swazi, *Urochloa arrecta* Morrone & Zuloaga cv. Tanner, *Megathyrsus maximus* (Jacq.) B. K. Simon & S. W. L. Jacobs cv. Tanzania, *M. maximus* cv. Mombaza, *M. maximus* x *M. infestum* cv. Massai, *U. brizantha* R. D. Webster cv. CIAT-6780, *U. brizantha* cv. CIAT-26110, *U. decumbens* R. D. Webster cv. CIAT-606, *U. humidicola* Morrone & Zuloaga cv. CIAT-679, *U. humidicola* cv. CIAT-6133, *U. híbrido* CIAT-36087, and the legume *Arachis pintoi* Krapovickas & Gregory cv. CIAT-18744.

Animals. Fifty-three non-castrated steers based on Zebu and its F1 and F2 crossings (Zebu x Holstein), of unknown ages were used, divided into two fattening groups. Initial weights were 369 and 401 kg for the first and second group, respectively. The first fattening period (with 27 animals) lasted 150 days (May 10 to October 7). Before the beginning of this fattening cycle, during March-April, grazing animals from other areas of the system were used to increase the consumption of lignified pastures, from the dry season, with the subsequent increase in the effective stocking rate. Towards the end of this cycle, follower animals (13) were also used, after the grazing of the experimental leading animals. The second cycle (26 animals) began on November 1, 2019, and lasted 79 days (until January 19, 2020). The animals were weighed individually every 30 days, to determine the increase in LW per period, the individual daily gains and the gain per ha, with the use of a digital scale, trademark Tru-Test Ezi Weigh 7i.

The animals grazed the 24 hours of day, with access to drinking water in the drinking troughs placed in the paddocks, and to rustic feeding troughs, with commercial mineral salts from the region.

Statistical analysis. The data was grouped by two-month periods, for a better understanding of the dynamics of animal management in the farm. A specific experimental design was not used, but for a better analysis and understanding of the results and the dynamics of farm animal management, the data were processed through a simple classification variance analysis, after verifying whether they met the assumptions of variance homogeneity by Levene's test and normality of errors by the Shapiro-Wilk test. In cases where significant differences were found among the selected indicators, Duncan's multiple comparison test was used, with 95 % confidence. The analyses were performed using the statistical package IBM® SPSS® Statistics version 22.

Results and Discussion

Table 1 shows some of the main indicators of paddock management during the research period, which included two fattening cycles. These and other related indicators were analyzed and discussed in more depth in a previous work conducted by Domínguez-Escudero *et al*. (2021).

The offer of pastures and the grazing pressure per two-month periods were below the recommendations

Table 1. Performance of some management indicators in the Voisin rational grazing system.

Indicator	Production two-month period						SE ±
	March-April, 2019	May-June	July-August	September-October	November-December	January-February, 2020	
ESR, LAU/ha	6,0[a]	4,0[b]	2,6[b]	3,7[b]	2,7[b]	2,8[b]	0,341**
FS, kg DM/animal/day	-	19[d]	31[b]	24[c]	34[a]	31[b]	2,804***
GP, kg DM/100 kg/LW/day	-	3,8[b]	6,2[ab]	4,8[ab]	6,8[a]	6,2[ab]	0,631**

ESR: effective stocking rate; FS: forage supply, GP: grazing pressure
a, b, c, d: Values with different superscripts in the vertical differ at $p < 0,05$, according to Duncan (1955)
*$p < 0,05$; **$p < 0,01$; *** $p < 0,001$
Source: adapted from Domínguez-Escudero *et al*. (2021)

for growing-fattening animals (Queirolo-Aguinaga *et al*., 2015) in the periods May-June and September-October. In the first case (19 kg DM/animal/day and 3,8 kg DM/100 kg LW), it was related to the strategy of using follower animals (which increased the stocking rate in the system) to decrease pasture height, very lignified due to the dry season, and increase its intake. The other aspect that had incidence was the almost zero rainfall in the previous two-month period (March-April), which limited the growth of new pasture regrowth in this two-month period (Sánchez-Vélez, 2018).

In the second case (24 kg DM/animal/day and 4,8 kg DM/100 kg LW), the reason was also the introduction of extra animals to the system (follower lot + lot two, which was gradually incorporated for the next fattening cycle), with the subsequent increase in the effective and instantaneous stocking rate.

In the other two-month periods, forage availability and grazing pressure were above 30 kg DM/animal/day and 6,0 kg DM/100 kg LW, respectively, which is related to the increased yield of the pastures and stability in the stocking rate.

Figure 1 shows the average daily gain of the animals per month and the beef production/ha per fattening period of the two evaluated lots, which are analyzed separately.

There were significant differences ($p < 0,001$) among the different months of the year for lot I, with the best gain in July (1,136 kg), associated with a better pasture supply (table 1) and better nutritional value in that period (Domínguez -Escudero, 2020).

The lowest gains were obtained in May and June, which did not differ from each other. Even those of May differ from the ones of August and September, which exceeded 0,600 kg per day. Several factors combined to decrease gains during the May-June period. In this stage (table 1), the stocking rate was high (4,0 LAU/ha), which caused the pasture supply to be low (only 19,0 kg/animal/day), with high grazing pressure. (3,8 kg DM/100 kg LW/day), below 5,0 kg DM/100 kg LW/day, value reported by Cedeño-Vera and Loor-Loor (2017), as a limit grazing pressure for pastureland systems.

In the studies conducted by Domínguez-Escudero (2020), in the same areas of this research, average CP values of only 4,0 % were found, which is related with pasture quality. These protein contents were associated with the hydric stress experienced by pastures during the dry season and the increase of the lignocellulosic structure (neutral detergent fiber values over 740,0 g/kg DM), which caused the dilution of nutrients (Anele et al., 2009), possible limitations in the voluntary intake of ruminants and, thus, that during April-May the bulls lost weight. In general, the gain of this lot during the fattening cycle of 150 days averaged 0,653 kg/day; while live beef production/ha was 336,6 kg.

In lot II, the average was 0,670 kg per day during the period; while the production of live beef/ha was 145,6 kg. Significant differences ($p < 0,001$) were found between weighing results, with the best daily gain (1,224 kg) recorded in November, when the pasture offer was high (35 kg DM/animal/day). However, in subsequent months, the gain was below 0,600 kg per day, despite the acceptable daily availability (30 kg), although in this stage the dry

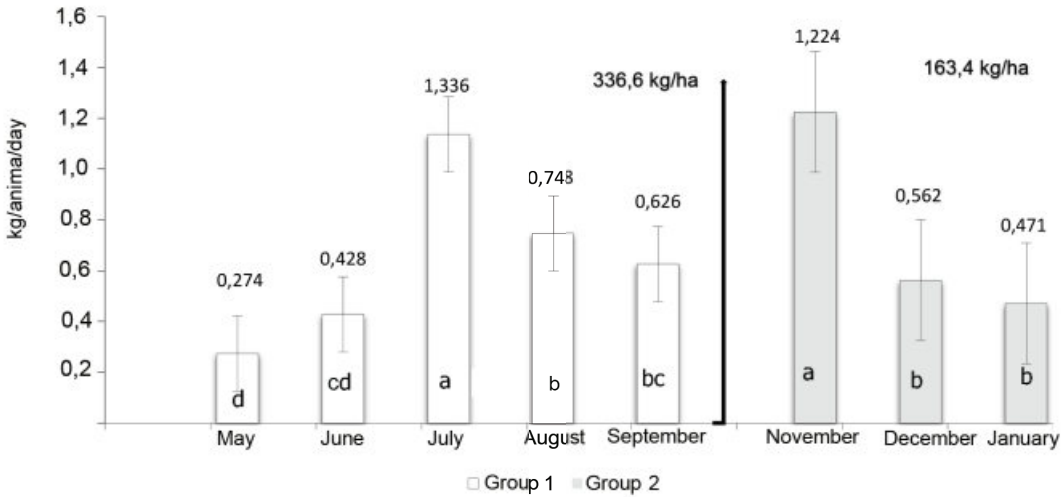

Figure 1. Average daily gain of the animals (kg/animal/day) and production/ha (kg/ha) in the two evaluated lots. $p < 0,001$

season was starting, with the consequent decrease in the quality of the available pasture.

It could be observed (fig. 2) that, although the animals did not lose weight in the two fattening periods, there was a trend to decrease the increase in gross weight among weighing times, as the bulls reached a LW above 420 kg.

This is related to the report by Fernández-Mayer (2011). This author indicated that adult animals have a lower protein synthesis and degradation rate than young animals, that is, the rate of protein turnover and protein retention decrease proportionally, as weight gain and age of the animal increase, as a consequence of a reduction in the total amount of ribonucleic acid (RNA) per unit of muscle protein. This lower turnover rate makes them grow more slowly and require higher energy intake per kg of gain (by retaining more fat than protein), with lower conversion efficiency than young animals (Dimarco, 1998; Miller, 2004). This occurs until reaching an adult gain or weight, after which the accumulation of protein tissue becomes almost null (degradation equals protein synthesis), that is, at that time there would only be retention of fatty tissue.

To reverse this situation, Casagrande *et al*. (2013) suggest energy-protein supplementation to grazing animals in the post-weaning phase, and confinement in the final fattening phase, which allows to obtain animals of lower age at slaughter and, in addition, freeing grazing areas earlier for the introduction of new lots of animals (Poppi *et al*., 2018).

Similar results to those of this research (daily gain between 0,700 and 0,800 kg) were obtained in intensive rotational grazing systems, developed by the Institute of Animal Science, in Cuba (Díaz, 2010), with modules of 90 ha, made up by star grass (67 ha, 33 paddocks) and CT-115 (22 ha, 22 paddocks) and energy-protein supplementation in both seasons. This proved that rational grazing is a productive and economical alternative for beef cattle farmers in Panama.

They were also similar to the daily gains (0,649 and 0,769 kg) reported by Iraola *et al*. (2015) in Cuba, when they evaluated cattle fattening in an agroecologically transformed rational grazing system, which involved cultivated pastures [*Cynodon nlemfuensis* Vanderyst, *Cenchrus purpureus* (Schumach.) Morrone cv. CT-115 and hybrid *Brachiaria* cv. Mulato], natural pastures [*Paspalum notatum* Alain ex Flügé, *Sporobolus indicus* (L.) R. Br., *Dichantium* sp.], herbaceous legumes [*Neonotonia wightii* (Wight & Arn.) J.A. Lackey, *Teramnus labialis* (L.F.) Spreng and *Centrosema pubescens* Benth] and *Leucaena leucocephala* (Lam) de Witt, as a protein bank in 20 paddocks. However, they were lower than those obtained (0,865 kg/animal/day) by Cruz and Pereda (2015), when evaluating different introduced grasses (*C. dactylon* cv Tifton 85, *Urochloa decumbens* (Stapf) R.D. Webster cv. Basilisk, *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster cv. Marandú, and hybrid *Brachiaria* cv. Mulato) in animal husbandry areas of the Jimaguayú municipality, in the Camagüey province, in

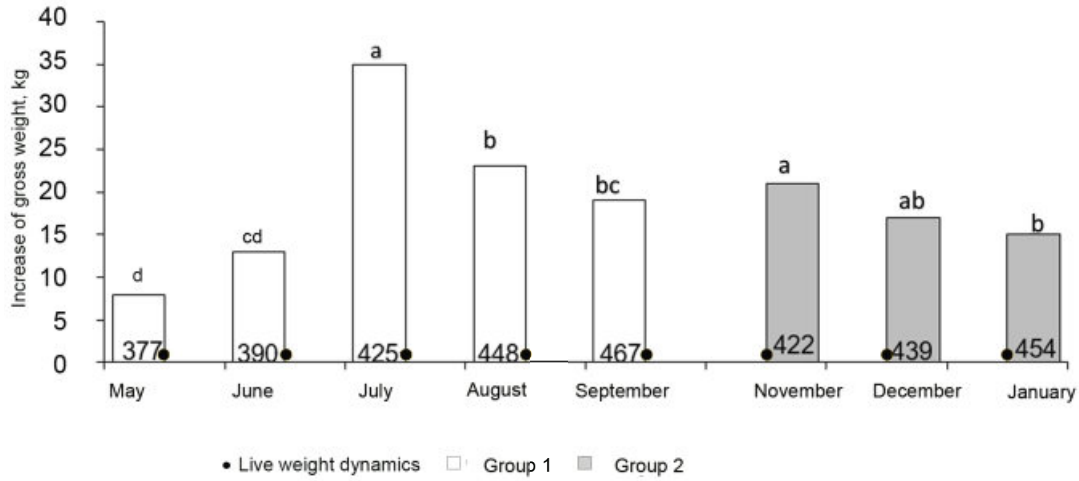

Figure 2. Live weight dynamics of the animals (kg) and increase of gross weight among weighing times.

Cuba. Although it should be noted that the animals were supplemented with molasses/urea and Norgold, at a rate of 1 kg of each feedstuff/animal/day.

Also, Canudas-Lara (2018) reported better results in Mexico, when carrying out three cattle fattening cycles in two intensive rational grazing systems, one on 9,2 ha of Taiwan grass (*C. purpureus* Schum.), with fertigation and, another on 12 ha of rain-fed Guinea grass [*Megathyrsus maximus* (Jacqs.) B.K. Simon & S.W.L. Jacobs]. In these grazing systems, the average daily gain of the animals throughout the year was 1,09 kg with the Taiwan grass and 1,05 kg with the Guinea grass; while the beef production per ha per year was 2,766 and 1,017 kg, respectively. In this investigation, the animals received 1,5-3,0 kg DM/day of whole sugarcane with 3 % urea.

However, the results obtained here exceed those obtained by Euclides *et al.* (2016) in Brazil, with two varieties of *Brachiaria brizantha* (cv. Piatã and cv. Paiaguás) under rotational grazing. In this case, the gains in the dry season did not exceed 0,350 kg per day, and were 0,640-0,690 kg in the rainy season. These authors ascribe the low profits to the poor structure of the pastureland (between 21,7 and 31,5 % of leaves only and a leaf: stem ratio of 1,50 or less), and not to the nutritional value of the pastures, because the average percentage of CP and *in vitro* dry matter digestibility (IVDMD) were 8,8 and 55,3 %, respectively.

With the brachiaria cultivars Ipyporã and Marandu, Euclides *et al.* (2018) had lower average daily weight gains than those of this study (0,675 and 0,580 kg, respectively), when the stocking rates were 3,0 and 3,6 AU/ha for Ipyporã and Marandu, respectively. The cultivar Ipyporã showed a higher percentage of leaves, a better leaf: stem ratio (2,4 *vs.* 1,7), as well as a higher CP content and IVDMD, which resulted in higher individual weight gains.

In general, the gains in this rational grazing system can be classified as good, considering the low yields obtained in Central America, when fattening is carried out on native or cultivated pastures, without supplementation, and without irrigation. There, the permissible stocking rates cannot exceed 1,5-2,0 animals, the gains/ha reach up to 90-120 kg, with individual gains rarely exceeding 0,300 kg/animal/day (Pérez-Infante, 2013). If the system is analyzed during the year, with the results of the two evaluated lots, the total beef production/ha was 477,4 kg (24,4 t throughout the system), while the average gains were very close to 0,700 kg.

Conclusions

The fattening of Zebu bulls and their F1 and F2 crossings in a Voisin rational grazing system is feasible, because average gains close to 0,700 kg/animal/day are obtained, without weight loss at times of higher feed scarcity.

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Conflict of interests

The authors declare that there is no conflict of interest among them.

Authors' contribution

- Jesús Manuel Iglesias-Gómez. Design of the research, data analysis and interpretation, manuscript writing and revision.
- José Miguel Alejandro Domínguez-Escudero. Design and setting up of the research, data analysis and interpretation, manuscript writing and revision.
- Yuseika Olivera-Castro. Data analysis and interpretation and manuscript revision.
- Hilda Beatriz Wencomo-Cardenas. Data analysis and interpretation and manuscript revision.
- Milagros de la Caridad Milera-Rodríguez. Data analysis and interpretation, technical advice.
- Odalys Caridad Toral-Pérez. Data analysis and interpretation and manuscript revision.

Bibliographic references

Anele, U. Y.; Arigbede, O. M.; Südekum, K.-H.; Oni, A. O.; Jolaosho, A. O.; Olanite, J. A. *et al.* Seasonal chemical composition, *in vitro* fermentation and in sacco dry matter degradation of four indigenous multipurpose tree species in Nigeria. *Anim. Feed Sci. Technol*. 154 (1-2):47-57, 2009. DOI: https://doi.org/10.1016/j.anifeedsci.2009.07.007.

Canudas-Lara, E. G. Producción y rentabilidad: pastoreo racional intensivo. En: G. Halffter, Magdalena Cruz y Carmen Huerta, comps. *Ganadería sustentable en el Golfo de México*. Veracruz, México: Instituto de Ecología, A. C. p. 115-129. https://bosquedeniebla.com.mx/wp-content/uploads/2019/09/Libro-Ganaderia-sustentable-eISBN-2018-1.pdf, 2018.

Casagrande, D. R.; Azenha, Mariana V.; Vieira, B. R.; Resende, F. D. de; Faria, M. H. de; Berchielli, Telma T. *et al.* Performance and carcass quality of feedlot- or pasture-finished Nellore heifers according to feeding managements in the post-weaning phase. *R. Bras. Zootec*. 42 (12):899-908. https://www.scielo.br/j/rbz/a/G5QcsKHxKqg7MskCXZfNJBk/?format=pdf&lang=en, 2013.

Cedeño-Vera, Mayra L. & Loor-Loor, A. A. *Influencia de la carga instantánea en los indicadores de producción de leche (UDIV) del hato bovino pasto y forraje ESPAM, UDFL*. Tesis previa a la obtención del título de Médico Veterinario. Calceta, Ecuador: Escuela Superior Politécnica Agropecuaria de Manabí Manuel Félix López. https://repositorio.espam.edu.ec/bitstream/42000/528/1/TMV106.pdf, 2017.

Cruz, Madelin & Pereda-Mousso, J. Evaluación agroproductiva de gramíneas bajo condiciones edafoclimáticas del municipio Jimaguayú. Su utilización en la ceba vacuna. *XXIV Reunión de la Asociación Latinoamericana de Producción Animal. XL Congreso de la Sociedad Chilena de Producción Animal*. Puerto Varas, Chile. p. 205. https://ojs.alpa.uy/index.php/ojs_files/article/download/2652/1067/, 2015.

Díaz, A. Producción de carne en pastoreo con gramíneas tropicales. San José de Las Lajas, Cuba: Instituto de Ciencia Animal, 2010.

Dimarco, O. N. *Crecimiento de vacunos para carne*. Buenos Aires, 1998.

Domínguez-Escudero, J. M. A. *Manejo del pastoreo racional Voisin con novillos de engorde en el trópico húmedo de Panamá*. Tesis presentada en opción al título académico de Master en Pastos y Forrajes. Matanzas, Cuba: EEPF Indio Hatuey, Universidad de Matanzas, 2020.

Domínguez-Escudero, J. M. A. Producción de carne mediante pastoreo racional y el PRV, su implementación en las tierras altas de Los Santos, Panamá *Cadernos de agroecología*. 14 (2). http://cadernos.aba-agroecologia.org.br/cadernos/article/view/2515/2273, 2019.

Domínguez-Escudero, J. M. A. Proyecto de transformación agropecuaria de Agro Ganadera del Sur, S. A. Ganado de leche Grado A, Consultoría de Ley 25. Panamá, 2015.

Domínguez-Escudero, J. M. A.; Iglesias-Gómez, J. M.; Olivera-Castro, Yuseika; Milera-Rodríguez, Milagros de la C.; Toral-Pérez, Odalys C. & Wencomo-Cárdenas, Hilda B.. Caracterización del pastizal y su manejo en un sistema de pastoreo racional Voisin en Panamá. *Pastos y Forrajes*. 44:e19. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942021000100019&lng=es&tlng=es, 2021.

Duncan, D. B. Multiple range and multiple F tests. *Biometrics*. 11 (1):1-42, 1955. DOI: https://doi.org/10.2307/3001478.

Euclides, Valéria P. B.; Montagner, Denise B.; Barbosa, R. A.; Valle, Cacilda B. do & Nantes, Nayana N. Animal performance and sward characteristics of two cultivars of *Brachiaria brizantha* (BRS Paiaguás and BRS Piatã). *R. Bras. Zootec*. 45 (3):85-92, 2016. DOI: https://doi.org/10.1590/S1806-92902016000300001.

Euclides, Valéria P. B.; Nantes, Nayana N.; Montagner, Denise B.; Araújo, A. R. de; Barbosa, R. A.; Zimmer, A. H. *et al.* Beef cattle performance in response to Ipyporã and Marandu brachiariagrass cultivars under rotational stocking management. *R. Bras. Zootec*. 47:1-10, 2018. DOI: https://doi.org/10.1590/rbz4720180018.

Fernández-Mayer, A. *Contribución a la viabilidad de los sistemas de producción de carne bovina en la región subhúmeda y semiárida de la República Argentina. Estrategias de mejora*. Tesis presentada en opción al grado de Doctor en Ciencias Veterinarias. San José de las Lajas, Cuba: Instituto de Ciencia Animal. https://repositorio.inta.gob.ar/xmlui/bitstream/handle/20.500.12123/5132/INTA_CRBsAsSur_EEABordenave_FernandezMayer_A_Contribucion_viabilidad_sistemas_produccion_carne_bovina.pdf?sequence=1&isAllowed=y, 2011.

IICA. *Programa de cambio climático, recursos naturales y gestión de riesgos productivos*. Costa Rica: Instituto Interamericano de Cooperación para la Agricultura. http://repositorio.iica.int/bitstream/handle/11324/7972/BVE19040249e.pdf;jsessionid=57A0E07174C9E556B4CD74A-3C48AF3D1?sequence=1, 2019.

Iraola, J.; García, Yenny; Muñoz, E.; Fraga, L. M.; Barros-Rodríguez, M.; Hernández, J. L. *et al.* Modeling of live weight per age in fattening bovines under a silvopastoral system with *Leucaena leucocephala*. *Cuban J. Agric. Sci*. 49 (3):307-315. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2079-34802015000300005&lng=es&tlng=en, 2015.

Milera-Rodríguez, Milagros de la Caridad; Machado-Martínez, R. L.; Alonso-Amaro, O.; Hernández-Chávez, Marta B. & Sánchez-Cárdenas, Saray. Pastoreo racional intensivo como alternativa para una ganadería baja en emisiones. *Pastos y Forrajes*. 42 (1):3-12. http://scielo.sld.cu/scielo.php?script=sci_abstract&pid=S0864-03942019000100003, 2019.

Miller, E. L. Protein nutrition requirements of farmed livestock and dietary supply. *Protein sources for the animal feed industry*. Bangkok: FAO. p. 29-75. https://www.fao.org/3/y5019e/y5019e06.htm, 2004.

Pérez-Infante, F. *Ganadería eficiente. Bases fundamentales*. La Habana: Asociación Cubana de Producción Animal, 2013.

Pinheiro-Machado, L. C. *Pastoreo racional Voisin. Tecnología agroecológica para el tercer milenio*. Buenos Aires: Hemisferio Sur, 2015.

Poppi, D. P.; Quigley, S. P.; Silva, T. A. C. C. da & McLennan, S. R. Challenges of beef cattle production from tropical pastures. *R. Bras. Zootec*. 47:1-10, 2018. DOI: https://doi.org/10.1590/rbz4720160419.

Queirolo-Aguinaga, A. J.; Nabinger, C.; Carvalho, P. C. de F. & Muliterno-Thurow, Juliana. Manipulação estacional da oferta de forragem para otimizar a produtividade da pastagem natural. *Memorias del Congreso de Producción Animal ALPA*. Puerto Varas, Chile. p. 369. http://dspace.utb.edu.ec/bitstream/handle/49000/5187/TE-UTB-FACIAG-ING%20AGROP-000028.pdf?sequence=1, 2015.

Sánchez-Vélez, E. V. *Determinación de la época de corte del pasto Toledo (Brachiaria brizantha) mediante la cuantificación de proteínas en la hoja*. Trabajo experimental presentado como requisito previo a la obtención del título de Ingeniero Agropecuario. Babahoyo, Ecuador: Facultad de Ciencias Agropecuarias, Universidad Técnica de Babahoyo. http://dspace.utb.edu.ec/bitstream/handle/49000/5187/TE-UTB-FACIAG-ING%20AGROP-000028.pdf?sequence=1&isAllowed=y, 2018.