Scientific Paper

Agronomic and nutritional performance of four cultivars of *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L in the Colombian Caribbean region

José Jaime Tapia-Coronado[1] *https://orcid.org/0000- 0002-3621-5316*, Emiro Andrés Suárez-Paternina[2] *https://orcid.org/0000-0003-2271-7160*, Wilson Andrés Barragán-Hernández[3] *https://orcid.org/0000-0003-3528-4296*, Liliana Margarita Atencio-Solano[1*] *https://orcid.org/0000-0001-8425-1621*, Sergio Luis Mejía-Kerguelen[1] *https://orcid.org/0000-0003-2498-756X*

[1]*Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Centro de investigación Turipaná, Cereté, Colombia.* [2]*Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Sede El Carmen de Bolívar, Bolívar, Colombia.* [3]*Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Centro de investigación El Nus, San Roque, Colombia. E-mail: jtapia@agrosavia.co, esuarez@agrosavia.co, wbarraganh@agrosavia.co, latencio@agrosavia.co, smejia@agrosavia.co.* [*]***Corresponding author:** *latencio@agrosavia.co*

Abstract

Objectives: To evaluate the agronomic and nutritional performance of four cultivars of *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L in the Colombian Caribbean region.

Materials and Methods: The study was conducted in five localities located in the humid Caribbean and dry Caribbean subregions of Colombia. The cultivars Agrosavia Sabanera and Agrosavia Mishaya were evaluated and compared with the commercial controls Mombasa and Tanzania. Twelve 2 x 3 m plots were established in each location, distributed in a complete randomized block design with three replicas. The evaluated factors were four cultivars and two regrowth ages (21 and 28 days), during the dry and rainy seasons. Nutritional composition, dry matter yield, plant height, cover, leaf width and leaf length were evaluated.

Results: The cvs. Agrosavia Sabanera, Mishaya, Mombasa and Tanzania showed similar dry matter yields, ranging between 480,4 and 577,8 kg DM ha^{-1}. Regarding nutritional composition, cvs. Sabanera and Mishaya had the highest crude protein concentrations (11,7 and 11,0 %, respectively), which differed ($p < 0,05$) from those recorded by cultivars Mombasa (10,5 %) and Tanzania (10,8 %), respectively. Similarly, effect ($p < 0,05$) of time and age on crude protein content was found.

Conclusion: The agronomic and nutritional characteristics observed in the Agrosavia Sabanera and Agrosavia Mishaya materials compile attributes of interest for the development of sustainable animal husbandry systems.

Key words: animal husbandry, yield, forage grasses

Introduction

In Colombia, cattle raising is one of the most economically and socially relevant animal husbandry activities, since it contributes 1,4 % of the gross domestic product, concentrates 634 thousand productive units and generates more than 1,1 million direct jobs, representing 6 % of national employment and 19 % of agricultural employment (Fedegan, 2022). However, despite being a widespread activity in the country, regions such as the Colombian Caribbean stand out, where 30 % of the national cattle inventory is concentrated (ICA, 2022).

The importance of the Caribbean region in animal husbandry activity is also supported by the export projection, given its access to seaports (Fedegan, 2018). Nevertheless, the economic and social relevance of animal husbandry in that region contrasts with the productive indicators of the animal husbandry system, which show low technical and economic efficiency (Mejía-Kerguelen *et al*., 2020).

Part of the inefficiency of livestock production systems is due, among other conditions, to prolonged periods of drought and naturalized pastures, with limited productive and nutritional capacity (Tapia-Coronado *et al*., 2019; Roncallo-Fandiño *et al*., 2020). Similarly, inadequate grazing management contributes to its productive inefficiency, causing soil and pasture degradation (Mejía-Kerguelen *et al*., 2019).

One of the strategies to solve this problem of animal husbandry systems in the Colombian Caribbean region is the introduction of new forage materials, which stand out for their high yields and nutritional composition, are tolerant to periods of water deficit, pests and diseases, as well as to shade.

Mojica-Rodríguez *et al*. (2013) in the Cesar department (Colombia) reported that the establishment of forage materials such as *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs cv. Tanzania, increased forage yields in the rainy and dry seasons by 32,0 and 57,0 %,

Received: September 09, 2022
Accepted: January 20, 2023

How to cite a paper: Tapia-Coronado, José Jaime; Suárez-Paternina, Emiro Andrés; Barragán-Hernández, Wilson Andrés; Atencio-Solano, Liliana Margarita & Mejía-Kerguelen, Sergio Luis. Agronomic and nutritional performance of four cultivars of *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L in the Colombian Caribbean region. *Pastures and Forages.* 46:e05, 2023..

respectively, compared with the yields recorded by the naturalized grass [*Bothriochloa pertusa* (L.) A. Camus]. These same authors reported higher crude protein (CP) concentrations in the Tanzania cultivar, in the rainy season as well as in the dry season. Another experience reported by Reza-García *et al*. (2011) in the Colombian Caribbean region documented that the establishment of grasses such as *M. maximus* cv. Mombasa, managed with rotational grazing, allowed to increase the carrying capacity and animal response due to higher yields and its nutritional composition.

Despite the good performance of the Mombasa and Tanzania cultivars in the region, the grass breeding program of the Colombian Agricultural Research Corporation (Agrosavia) and the International Center for Tropical Agriculture (CIAT, for its initials in Spanish) has perceived the need to develop forage materials adapted mainly to the different soil and climate conditions of the Caribbean region. Therefore, the objective of this research was to evaluate the agronomic and nutritional performance of two promising *M. maximus* cultivars in the Colombian Caribbean region.

Materials and Methods

Location and climate characteristics. The study was carried out in five localities located in the humid Caribbean and dry Caribbean subregions of Colombia (table 1). The dry Caribbean subregion shows agrophysical zones of plains and a higher presence of acid/saline-sodic savannas, with an absence of hills compared with the humid Caribbean; the average annual rainfall is 1 561 mm, average temperature is 29 ºC and relative humidity is 68 %. The humid Caribbean subregion is characterized by moderate to low fertility soils and slightly undulated relief, average rainfall of 1 334 mm/year, average temperature of 28 ºC and relative humidity of 85 % (Mejía-Kerguelen *et al*., 2020; Roncallo-Fandiño *et al*., 2020).

Soil chemical characteristics. The soil of the study area in the La Paz and Agustín Codazzi localities had a sandy loam texture, pH between 6,2 and 7,5; with a low proportion of organic matter (0,1 to 1,16 %), P (10 to 15 ppm), K (0,1 ppm) and cation exchange capacity that varied between 5,0 and 8,7 cmol (+)/kg. It is characterized as a low fertility soil.

The soil of the localities located in the humid Caribbean subregion differed in texture (sandy-clay, sandy and loam for Chinú, Cereté and El Carmen de Bolívar, respectively), with pH between 5,0 and 7,0; 2,1-3,1 % organic matter, 8,9 to 26,4 ppm of P, between 0,8 and 0,9 ppm of K and cation exchange capacity of 23,6 to 42,6 cmol (+)/kg. The localities of El Carmen de Bolívar and Chinú were characterized by soils of moderate to high fertility; while Cereté was characterized by soils of low fertility. No locality showed aluminum saturation.

Area and experimental design. In each locality, an area of 144 m^2 was used and 24 plots of 2 x 3 m were established, distributed in a complete randomized block design with three replicas.

Evaluated forage materials. Cultivars Agrosavia Sabanera and Agrosavia Mishaya, originating from the germplasm bank of the International Center for Tropical Agriculture (CIAT, for its initials in Spanish), Palmira, Valle del Cauca, Colombia, were evaluated and compared with the commercial controls cv. Mombasa and Tanzania. The evaluation was carried out during 2013 and 2014.

For the establishment of the materials, soil preparation was initially carried out, which consisted of two passes of heavy harrow and one pass of polisher or rake. Planting was carried out between April and June, corresponding to the rainy season in the area. Vegetative material or tillers were used,

Table 1. Geographical location of the trials.

Subregion	Department	Municipality	Coordinates	
			Latitude North	Length East
Humid Caribbean	Córdoba	Cereté	8° 50,980’	75° 48,890’
	Córdoba	Chinú	9° 06’46,8”	75° 23’00”
	Bolívar	El Carmen de Bolívar	9° 43’39,4”	75° 09’18”
Dry Caribbean	Cesar	La Paz	10°24’58,2”	73° 10’16,8”
	Cesar	Agustín Codazzi	10°00’0,63”	73° 14’54,5”

sown at a distance of 50 x 50 cm, without fertilization. Three months after sowing, an establishment cutting was made at 20 cm from the soil.

Evaluated variables. Evaluations of the materials were carried out at 21 and 28 days of regrowth in the rainy and dry seasons. The rainy season lasted from mid-April to November, when approximately 85 % of the rainfall was recorded, and the dry season from December to mid-April. Five evaluations were made for each season. The following variables were evaluated.

Plant height (cm). It was recorded at five random points, using a ruler graduated in centimeters. It was measured from the ground to the highest point of the plant (flag leaf), without stretching it and without counting the inflorescence (Toledo and Schultze-Kraft, 1982).

Cover (%). It was estimated according to the apparent proportion in which the grass covered each area of the gauging frame (0,25 m^2 area), according to the methodology proposed by Toledo and Schultze-Kraft (1982).

Dry matter yield (DM). At each regrowth age in the different plots, the plants were cut at 20 cm height and the forage was weighed, and then converted to kg DM/cutting ha^{-1}.

Leaf width (cm). It was determined in the middle third of a fully developed leaf.

Leaf length (cm). It was measured from the base to the apex of a fully developed leaf.

Nutritional quality. Nutritional quality was calculated by considering the factors of the experiment, according to the grazing simulation methodology proposed by Mestra-Vargas *et al.* (2020). Three hundred grams of green forage were taken and placed in paper bags for drying in a forced ventilation oven (Binder-Model FED56®) at 60 °C, for 48 h. Subsequently, the samples were weighed to determine the dry weight. The DM percentage was determined by the ratio between dry and wet forage weight multiplied by 100. The samples were then ground in a Willey-type mill with a one-millimeter screen. Crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by the Kjeldahl method, according to AOAC (2002), and *in situ* DM degradability (DMDIG) using the nylon bag technique described by Ørskov *et al.* (1980). Samples were processed at the Animal Nutrition Laboratory of AGROSAVIA, located at the Turipaná Research Center.

Statistical analysis. The analysis of the information was developed under a multilocus experiment in several periods (Martínez-Martínez *et al*., 2011) using a mixed model (PROC MIXED) with cultivar, cutting age and season as fixed effects and locations and blocks in the locality as random effects. In each of the developed analyses, normality (Shapiro-Wilks) and variance homogeneity (residual versus predicted plot) in the residuals were evaluated. In case of deviation, it was adjusted with the application of correlation structures or by weighting the variance (and with both) in the factors with heterogeneity in the residuals, respectively. In this process, the best fit model was selected, based on the Akaike and Bayesian criteria. In case of rejection of the null hypothesis, Tukey's test was applied for the separation of means, considering a type I error of 0,05. For the variables CP and DM, since the assumptions in the residuals for the analysis of variance were not met, a generalized model (PROC GLIMMIX) was applied, considering a Beta distribution with log link function. The statistical analyses were performed using SAS® Enterprise Guide® version 8.3 software.

Results and Discussion

Agrosavia Sabanera, Agrosavia Mishaya, Mombasa and Tanzania showed similar DM yields ($p > 0,05$), with no effect in the interactions with cutting time and age ($p > 0,05$). Mean values in the evaluated materials ranged from 480,4 to 577,8 kg DM/ha (table 2).

These results differ from those reported by Carvajal-Tapia *et al*. (2021), who reported a similar performance in forage mass yield between the Mombasa and Tanzania materials with Agrosavia Mishaya, but different from Agrosavia Sabanera.

Forage yield at the time of maximum rainfall exceeded ($p < 0,05$) by 63,1 % that obtained at the time of minimum rainfall, which coincides with the one reported by Cajas-Girón *et al*. (2012) in *Megathyrsus* sp. for the Caribbean region. Likewise, it was observed that at 21 days of regrowth, forage mass production was 20,7 % lower than that recorded at 28 days (table 2). The interaction season x cutting age affected ($p < 0,05$) DM yield, with higher yields (kg DM/ha) during the rainy season at 28 days of regrowth (fig. 1).

For plant height, there was an effect of cultivar, age and season ($p<0.05$). Agrosavia Sabanera showed the lowest height, without affecting forage production with regards to the other pastures. These results coincide with those reported by Carvajal-Tapia *et al*. (2021), who indicated lower height

Table 2. Agronomic performance of four *M. maximus* cultivars in the Colombian Caribbean region.

Factor	Yield, kg DM/ha	Height, cm	Cover, %	Leaf width, cm	Leaf length, cm
Cultivar					
Sabanera	526,4 ± 73,69	$51,5^{b}$ ± 3,12	$27,6^{a}$ ± 3,27	$1,9^{b}$ ± 0,07	$40,8^{b}$ ± 4,11
Mishaya	503,5 ± 73,60	$54,1^{ab}$ ± 3,15	$28,0^{a}$ ± 3,27	$1,8^{b}$ ± 0,08	$43,6^{b}$ ± 4,13
Mombasa	480,4 ± 73,48	$56,5^{a}$ ± 3,23	$24,3^{b}$ ± 3,27	$1,9^{ab}$ ± 0,08	$48,2^{a}$ ± 4,19
Tanzania	577,8 ± 73,65	$57,1^{a}$ ± 3,19	$25,9^{ab}$ ± 3,27	$2,0^{a}$ ± 0,08	$47,8^{a}$ ± 4,16
Season					
Dry	281,2 ± 79,45	44,8 ± 3,04	19,7 ± 3,24	1,7 ± 0,07	36,9 ± 4,07
Rainy	762,8 ± 113,59	64,8 ± 3,11	33,2 ± 3,22	2,1 ± 0,07	53,3 ± 4,09
Age					
21	461,6 ± 71,05	52,5 ± 3,08	24,8 ± 3,23	1,9 ± 0,07	42,3 ± 4,08
28	582,3 ± 70,54	57,2 ± 3,08	28,1 ± 3,23	1,9 ± 0,07	47,9 ± 4,08
P - value					
Season	0,0100	<0,0001	<0,0001	<0,0001	<0,0001
Cultivar	0,0970	0,0005	0,0004	0,0059	<0,0001
Season x cultivar	0,2488	0,0858	0,2569	<0,0001	0,0327
Age	<0,0001	<0,0001	<0,0001	0,6684	<0,0001
Season x age	0,0045	0,9605	0,5546	0,1118	0,2157
Cultivar x age	0,8753	0,9395	0,8837	0,8661	0,7858
Cultivar x season x age	0,8844	0,8485	0,8198	0,7548	0,9726

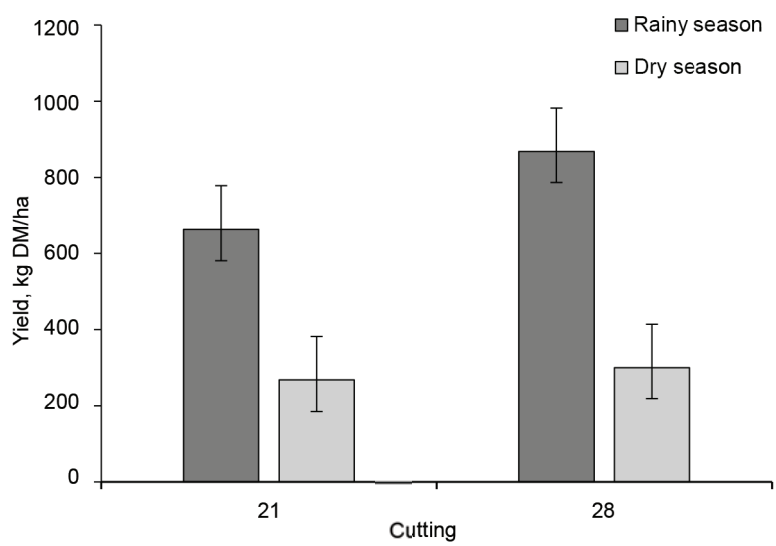

Fig. 1. Effect of the interaction season x cutting age on dry matter yield.

in this material compared with Tanzania (97 cm) and Mombasa (113,1 cm), although in their research the Agrosavia Sabanera cultivar reached 93 cm, probably due to a higher cutting age. The low plant height of Agrosavia Sabanera compared with the other taller forage materials, while retaining a similar forage mass, may favor its use in feeding, in large as well as small ruminants (Mestra-Vargas *et*

al., 2020). The greatest heights of the cultivars were evident in the period of maximum rainfall (64 *vs.* 44 cm) and at 28 days of regrowth (57 *vs.* 52 cm).

In cover, Agrosavia Mishaya and Agrosavia Sabanera stood out, showing values of 28,0 and 27,6 %, respectively, and outperformed ($p < 0,05$) Mombasa (24,3 %), which did not differ from Tanzania. Regardless of the pasture, there was greater cover ($p < 0,05$) during the period of maximum rainfall and at 28 days of regrowth, with mean values of 33,2 and 28,1 %, respectively.

With respect to leaf width and length, the analysis showed significant effects for the factors cultivar, age, season and the interaction season cultivar. The highest leaf width and length ($p < 0,05$) was recorded for cv. Tanzania during the season of maximum rainfall (fig. 2). Although the promising cultivars Agrosavia Mishaya and Agrosavia Sabanera showed the lowest leaf growth with regards to the commercial cultivars, they showed similar forage yield as the controls.

The literature review did not report any research evaluating leaf structural characteristics in cvs. Agrosavia Sabanera and Agrosavia Mishaya. For the case of Tanzania and Mombasa, the similarity in leaf length and width agrees with that reported by Fortes *et al.* (2016) and, partially, with that referred by Cedeño-Aristega *et al*. (2021), who reported similar length, but different leaf width in Tanzania and Mombasa. Discrepancies in the results are probably ascribed to different sampling times, locations and cutting days, factors that affect the morphological development of tropical pastures (Bernal, 1991).

Regarding nutritional characteristics, DM content did not differ among cultivars (table 3). However, this variable was influenced ($p < 0,05$) by the interaction of season and age. The highest DM proportions were recorded during the dry season, at 28 days of regrowth. Regarding nutritional composition, Agrosavia Sabanera and Agrosavia Mishaya showed the highest CP concentrations, which differed ($p < 0,05$) from those recorded by the cultivars Mombasa and Tanzania (table 3). Similarly, there was an effect ($p < 0,05$) of season and age on the CP content.

During the rainy season and at the age of 21 days of regrowth, mean protein contents (12,9 and 11,3 %) were observed that differed ($p < 0,05$) from the concentrations observed during the dry season at 28 days of regrowth with 9,45 and 10,7 %, respectively (table 3).

The four cultivars showed appropriate nutritional contents for ruminant feeding (Santana-Rodríguez *et al*., 2021). The Agrosavia Sabanera cv. stood out, with higher protein content and lower NDF compared to the Mombasa and Tanzania controls. The higher protein content can be related to the higher N uptake capacity of Agrosavia Sabanera (Villegas *et al*., 2020). Contrary to the results of this research, other authors (Carvajal-Tapia *et al*., 2021) reported lower CP content for Agrosavia Sabanera, probably due to different environmental conditions and cutting ages (Patía Valley, Colombia - 6 weeks and San Fernando de Apure, Venezuela - 9 weeks), respectively. Also, in Tanzania, compared with this study, low protein and high NDF content has been reported for dry Caribbean conditions (Cajas-Girón *et al*., 2012) and high protein and NDF for the humid Caribbean (Patiño-Pardo *et al*., 2018). In the cultivar Mombasa, similar CP contents have been reported, but with higher NDF (Patiño-Pardo *et al*., 2018; Barragán-Hernández and Cajas-Girón, 2019) at full light exposure and under humid Caribbean conditions, aged between 28 and 35 days.

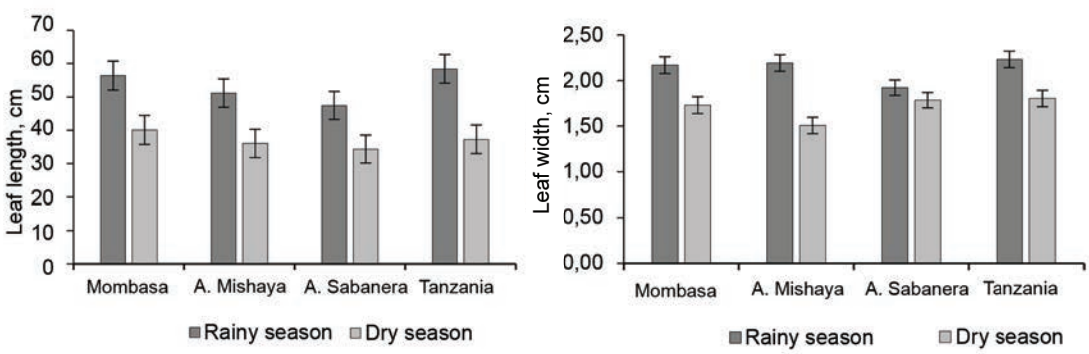

Fig. 2. Cultivar by age interaction in the variables leaf length (right) and leaf width (left).

Table 3. Nutritional performance of four cultivars of *M. maximus* in the Colombian Caribbean region.

Factor	DM	CP	NDF	ADF	Digestibility
Cultivar					
Sabanera	27,5^{a} ± 0,007	11,7 ± 0,005	55,3^{b} ± 1,07	40,8 ± 0,87	58,7 ± 1,81
Mishaya	28,3^{ab} ± 0,007	11,0 ± 0,005	58,7^{a} ± 1,08	41,5 ± 0,87	57,2 ± 1,81
Mombasa	26,9^{b} ± 0,007	10,5 ± 0,005	57,5^{a} ± 1,07	41,0 ± 0,87	58,7 ± 1,81
Tanzania	27,4^{b} ± 0,007	10,8 ± 0,005	57,1^{a} ± 1,08	41,8 ± 0,87	59,8 ± 1,81
Season					
Rainy	23,9 ± 0,006	12,9 ± 0,003	55,0 ± 1,00	41,1 ± 0,82	61,2 ± 1,70
Dry	31,5 ± 0,007	9,5 ± 0,003	59,3 ± 1,05	41,4 ± 0,74	56,0 ± 1,61
Age					
21	26,7 ± 0,006	11,3 ± 0,005	56,1 ± 1,01	39,6 ± 0,79	60,2 ± 1,67
28	28,3 ± 0,007	10,7 ± 0,005	58,2 ± 1,01	42,9 ± 0,77	56,9 ± 1,63
P - value					
Season	<0,0001	<0,0001	<0,0001	0,5294	<0,0001
Cultivar	0,1761	0,0272	<0,0001	0,5783	0,3819
Season x cultivar	0,9339	0,3411	0,5423	0,6089	0,2498
Age	0,0006	0,0412	<0,0001	<0,0001	0,0024
Season x age	0,0004	0,5550	0,0016	0,0077	0,5990
Cultivar x age	0,9628	0,9826	0,9548	0,0548	0,7394
Cultivar x season x age	0,9611	0,7047	0,1341	0,5231	0,4798

PB: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber

Among the pasture breeding plans, the aim is to ensure that the evaluated promising plants are superior to naturalized materials or, alternatively, have similar agronomic characteristics to commercial cultivars (ICA, 2020). Considering the above, cvs. Agrosavia Sabanera and Agrosavia Mishaya showed similar DM yields to those recorded by cvs. Mombasa and Tanzania, although with superior attributes, such as higher CP content and lower NDF. This condition highlights the potential of these materials for cattle feeding in the Colombian Caribbean region. In this regard, several studies have reported that the linkage of grasses of the *Megathyrsus* genus is ideal for intensifying animal husbandry systems, due to their high yields and nutritional quality for the development of sustainable systems, either in monoculture (Cajas-Girón *et al*., 2012) or in associations in silvopastoral systems (Barragán-Hernández and Cajas-Girón, 2019 and Contreras-Santos *et al*., 2021). Additionally, the agronomic and nutritional performance observed in cultivars Agrosavia Sabanera and Agrosavia Mishaya under Caribbean conditions constitutes a key element for their research and development pathway, with subsequent adoption (Enciso *et al*., 2020).

Conclusions

In morphological terms, cultivars Agrosavia Sabanera and Agrosavia Mishaya showed similar results to the commercial controls. However, their low height and shorter leaf structures, especially in Agrosavia Sabanera, characterize it as a compact material with wide coverage, a fundamental aspect in soil preservation.

The agronomic and nutritional characteristics observed in the Agrosavia Sabanera and Agrosavia Mishaya materials compile attributes of interest for the development of sustainable animal husbandry systems, which makes necessary the development of more research on zootechnical aspects and environmental impact.

Acknowledgments

The authors thank the Ministry of Agriculture and Rural Development (MADR, for its initials in Spanish) for financing the resources for the develop-

ment of the research project "Selection of pastures tolerant to water deficit as an alternative to improve the productivity of animal husbandry systems in the savannas of Córdoba, Sucre and Bolívar and Forage materials and utilization and management strategies to improve the productivity of milk and meat production systems in the humid Caribbean".

Conflict of interests

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

Authors' contribution

- José Jaime Tapia-Coronado. Data analysis and interpretation and manuscript drafting.
- Emiro Andrés Suárez-Paternina. Data analysis and interpretation and manuscript drafting.
- Wilson Andrés Barragán-Hernández. Data analysis and interpretation and manuscript drafting.
- Liliana Margarita Atencio-Solano. Data analysis and interpretation and manuscript drafting.
- Sergio Luís Mejía-Kerguelén. Data analysis and interpretation and manuscript drafting.

Bibliographic references

AOAC. *Official methods of analysis*. Gaithersburg, USA: AOAC International, 2002.

Barragán-Hernández, W. A. & Cajas-Girón, Yasmín S. Cambios bromatológicos y estructurales en *Megathyrsus maximus* bajo cuatro arreglos silvopastoriles. *Cienc. Tecnol. Agropecuaria*. 20 (2):231-244, 2019. DOI: https://doi.org/10.21930/rcta.vol20num2art:1458.

Bernal, J. *Pastos y forrajes tropicales*. Bogotá: Banco ganadero de Colombia, 1991.

Cajas-Girón, Yasmín S.; Barragán-Hernández, W. A.; Arreaza-Tavera, L. C.; Argüelles-Cárdenas, J.; Amézquita-Collazos, L. E.; Abuabara-Pérez, Y. *et al*. Efecto sobre la producción de carne de la aplicación de tecnologías de renovación de praderas de *Bothriochloa pertusa* (L.) A. Camus en la Costa Norte Colombiana. *Corpoica Cienc. y Tecnol. Agropec*. 13 (2):213-218, 2012. DOI: https://doi.org/10.21930/rcta.vol13_num2_art:259.

Carvajal-Tapia, Juliana I.; Morales-Velasco, Sandra; Villegas, D. M.; Arango, J. & Vivas-Quila, N. J. Biological nitrification inhibition and forage productivity of *Megathyrsus maximus* in Colombian dry tropics. *Plant Soil Environ*. 67 (5):270-277, 2021. DOI: https://doi.org/10.17221/445/2020-PSE.

Cedeño-Aristega, María J.; Luna-Murillo, R. A.; Espinoza-Coronel, Ana L. & Romero-Garaicoa, D. A. Producción y composición química de *Megathyrsus máximus* cultivares Tanzania y Mombasa bajo condiciones del subtrópico ecuatoriano. *Ciencia Latina*. 5 (4):6427, 2021. DOI: https://doi.org/10.37811/cl_rcm.v5i4.777.

Contreras-Santos, J. L.; Martínez-Atencia, Judith & Falla-Guzman, Cindy K. Carbono acumulado en raíces de especies vegetales en sistemas silvopastoriles en el Norte de Colombia. *Ciencias Ambientales, Heredia*. 55 (1):52-69, 2021. DOI: http://dx.doi.org/10.15359/rca.55-1.3.

Enciso, Karen; Diaz, M.; Triana, Natalia & Burkart, S. *Informe: Limitantes y oportunidades del proceso de adopción y difusión de tecnologías forrajeras en Colombia*. Colombia: Biodiversity International, CIAT, CGIAR. https://cgspace.cgiar.org/bitstream/handle/10568/111232/%5B41%5D%20Informe%20adopci%C3%B3n_JLU.pdf?sequence=1&isAllowed=y, 2020.

Fedegan. *Cifras de referencia del sector ganadero colombiano*. Bogotá: Federación Nacional de Ganaderos. https://estadisticas.fedegan.org.co/DOC/download.jsp?pRealName=Cifras_Referencia_2017.pdf&iIdFiles=641, 2022.

Fedegan. *Ganadería colombiana. Hoja de Ruta 2018-2022*. Bogotá: Federación Nacional de Ganaderos. https://www.fedegan.org.co/noticias/ganaderia-colombiana-hoja-de-ruta-2018-2022, 2018.

Fortes, Dayleni; Valenciaga, Daiky; García, C. R.; García, M.; Cruz, Ana M. & Romero, Aida. Evaluation of three varieties of *Megathyrsus maximus* in the dry period. *Cuban J. Agric. Sci*. 50 (1):131-137. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2079-34802016000100015&lng=es&nrm=iso, 2016.

ICA. *Censos Pecuarios Nacional*. Bogotá: Instituto Colombiano Agropecuario. https://www.ica.gov.co/areas/pecuaria/servicios/epidemiologia-veterinaria/censos-2016/censo-2018.aspx, 2022.

ICA. *Requisitos para la inscripción de los cultivares en el Registro Nacional de Cultivares Comerciales Resolución No. 067516*. Bogotá: Instituto Colombiano Agropecuario. https://www.ica.gov.co/getattachment/6b7dbbd1-ff9b-4eea-a936-fe57f421ea98/2020R67516.aspx, 2020.

Martínez-Martínez, M. V.; Martínez-Rueda, Nhora & Martínez-Becerra, R. *Diseño de experimentos en ciencias agropecuarias y biológicas con SAS, SPSS, R Y STATISTIX*. Bogotá: Fondo Nacional Universitario, Institución Auxiliar del Cooperativismo, 2011.

Mejía-Kerguelén, S.; Martínez-Atencia, Judith; Sánchez-López, Diana; Cuadrado-Capella, H.; Aguayo-Ulloa, Lorena; Martínez-Reina, A. *et al. Modelo productivo de carne bovina en la región Caribe colombiana*. Mosquera, Colombia: AGROSAVIA. Colección Transformación del Agro. https://repository.agrosavia.co/handle/20.500.12324/35646, 2019.

Mejía-Kerguelén, S. L.; Suárez-Paternina, E. A.; Atencio-Solano, Liliana M.; Tapia-Coronado, J. J.; Paternina-Paternina, Y. & Cuadrado-Capella, H. R. Desempeño productivo de bovinos de levante en pastoreo rotacional de *Bothriochloa pertusa* (L) A. Camus en Colombia. *Pastos y Forrajes.* 43 (4):352-360. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942020000400352&lng=es&tlng=es, 2020.

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://doi.org/10.15517/am.v31i2.38389.

Mojica-Rodríguez, J. E.; Castro-Rincón, E.; Silva-Zakzuk, J.; Hortúa-Castro, H. & García-Quintero, L. *Producción y calidad composicional de la leche en función de la alimentación en ganaderías doble propósito del departamento del Cesar.* Bogotá: CORPOICA. https://repository.agrosavia.co/handle/20.500.12324/1340, 2013.

Ørskov, E. R.; DeB-Hovell, F. D. & Mould, F. The use of nylon bag technique for the evaluation of feedstuff. *Trop. Anim. Prod.* 5 (3):195-2163. https://www.cipav.org.co/TAP/TAP/TAP53/53_1.pdf, 1980.

Patiño-Pardo, R. M.; Gómez-Salcedo, R. & Navarro-Mejía, O. A. Calidad nutricional de Mombasa y Tanzania (*Megathyrsus maximus*, Jacq.) manejados a diferentes frecuencias y alturas de corte en Sucre, Colombia. *CES Med. Zootec*. 13 (1):17-30, 2018. DOI: https://doi.org/10.21615/cesmvz.13.1.2.

Reza-García, S.; Mejía-Kerguelen, S.; Cuadrado-Capella, H.; Torregroza-Sánchez, L.; Jiménez-Mass, Nora; Espinoza-Carvajal, M. *et al. Experiencias en la implementación de modelos intensivos de producción de carne en pasturas fertirrigadas en el Valle del Sinú.* Cereté, Colombia: CORPOICA. https://repository.agrosavia.co/handle/20.500.12324/1249, 2011.

Roncallo-Fandiño, B. A.; Soca-Pérez, Mildrey & Ojeda-García, F. Comportamiento productivo de bovinos machos en desarrollo en dos explotaciones ganaderas del valle del Cesar en Colombia. *Pastos y Forrajes.* 43 (3):220-228. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942020000300220&lng=es&tlng=es, 2020.

Santana-Rodríguez, Marta O.; Mestra-Vargas, Lorena I.; Flórez-Díaz, H. & Martínez-Reina, A. M. *Alimentación estratégica de bovinos de ceba en el valle del Sinú, Córdoba, Colombia*. Mosquera, Colombia: AGROSAVIA. Colección Transformación del Agro, 2021. DOI: https://doi.org/10.21930/agrosavia.nbook.7404869.

Tapia-Coronado, J. J.; Atencio-Solano, Liliana M.; Mejía-Kerguelen, 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):43-60, 2019. DOI: https://dx.doi.org/10.15517/rac.v43i2.37943.

Toledo, M. & Schultze-Kraft, R. Metodología para la evaluación agronómica de pastos tropicales. En: J. M. Toledo, ed. *Manual para la evaluación agronómica*. Serie CIAT 07sG-1 Cali, Colombia: Red Internacional de Evaluación de Pastos Tropicales. Serie CIAT 07sG-1. p. 91-110, 1982. DOI: https://doi.org/10.7910/DVN/DYR7KS.

Villegas, D.; Arevalo, Ashly; Nuñez, J.; Mazabel, Johanna; Subbarao, G.; Rao, I. *et al.* Biological nitrification inhibition (BNI): Phenotyping of a core germplasm collection of the tropical forage grass *Megathyrsus maximus* under greenhouse conditions. *Front. Plant Sci*. 11:820, 2020. DOI: https://doi.org/10.3389/fpls.2020.00820.