Scientific Paper

Agronomic characterization of forage varieties of *Saccharum* spp. in four harvest cycles

Yoslen Fernández-Gálvez[1] *https://orcid.org/0000-0002-7824-9215*, Redimio Manuel Pedraza-Olivera[2] *https://orcid.org/0000-0002-9483-4326*, Yoslen Fernández-Caraballo[1] *https://orcid.org/0000-0002-1656-8034*, Isabel Cristina Torres-Varela[1] *https://orcid.org/0000-0001-6394-1383*, Joaquín Montalván-Delgado[1] *https://orcid.org/0000-0002-2679-4633* and Alfredo Lázaro Rivera-Laffertte[1] *https://orcid.org/0000-0001-5955-1163*

[1]*Instituto de Investigaciones de la Caña de Azúcar Florida, Batey Las Mercedes, Florida, CP 72810. Camagüey, Cuba.* [2]*Centro de Estudios para el Desarrollo de la Producción Animal, Facultad de Ciencias Agropecuarias, Universidad de Camagüey, Carretera Circunvalación Norte km. 5½, entre Camino Viejo a Nuevitas y Ave. Ignacio Agramonte. CP 70100. Camagüey, Cuba. E-mail:* yoslen@eticacm.azcuba.cu, redimio.pedraza@reduc.edu.cu, yoslenfc@eticacm.azcuba.cu, itorres@eticacm.azcuba.cu, jmontalvan@eticacm.azcuba.cu, alfredo.rivera@eticacm.azcuba.cu

Abstract

Objective: To characterize agronomic variables in forage varieties of *Saccharum* spp. in four harvest cycles.

Materials and Methods: A study was carried out in areas of the Florida Sugarcane Research Institute, Camagüey, Cuba. An experiment was planted in the spring cycle (March) under rainfed conditions, with a randomized block experimental design. Three treatments (forage varieties C97-366, C99-374 and control My5514) and three replicas were established. Agronomic variables of forage potential were evaluated at 12 months of age (March) during four harvest cycles (2015-2018). Analysis of variance and multiple mean comparison test (Duncan) were performed when there were significant differences between varieties. The statistical package STATGRAPHICS Plus®, Version 5 for Windows was used.

Results: Statistically significant differences ($p < 0,05$) were found between varieties for all variables evaluated per harvest cycles, except for stem length from the first to the third shoot. The highest productivity in the study was achieved by varieties C97-366 and C99-374 with average yields for the four cycles of 85,4 and 104,4 t ha^{-1} of green biomass and 28,9 and 32,6 t ha^{-1} of dry biomass, respectively. These yields exceeded the control, which reached 83,7 and 26,0 t ha^{-1} of green and dry biomass.

Conclusions: Varieties C97-366 and C99-374 showed great forage potential, for which their use is recommended for ruminant feeding in areas of animal husbandry farms with similar characteristics.

Keywords: adaptation, animal feeding, biomass

Introduction

The implementation of *Saccharum* spp. for forage purposes as a feeding strategy constitutes an economical and practical technology for animal husbandry farmers, who can fully utilize a resource available in the farm. In feeding systems, this crop constitutes an excellent alternative for saving inputs such as fertilizers, concentrate feed and energy in this type of exploitation.

This plant is characterized by its good adaptability to a diversity of soils, climates, topographies, fertility and production systems, as well as by its great capacity to produce green matter (more than 100 t ha^{-1} yr^{-1}) and dry matter per area unit (Lagos-Burbano *et al*., 2022). In addition, it is capable of producing more dry matter, soluble carbohydrates and forage biomass than any other tropical Poacea, which makes it the most outstanding forage of all those existing in the tropics and allows it to support a higher stocking rate (Silva *et al*., 2020).

In recent years, in Cuba, commercial varieties of *Saccharum* spp. have been recommended as animal feedstuff, obtained from criteria for the sugar industry. For their use, the *in vitro* nutritive value and their agronomic performance to produce biomass in soils with agroproductive characteristics suitable for cultivation have been considered as premise (Suárez-Benítez *et al*., 2018; Suárez-Benítez *et al*., 2023). However, the main areas destined for animal husbandry in Cuba are established on soils with low agroproductive capacity. Therefore, many of these varieties fail to express their forage potential and are demolished in a few harvest cycles. This is neither feasible nor economically sustainable for low-input ruminant production systems.

Fernández-Gálvez (2022) recommended two varieties (C97-366 and C99-374), selected based on purely forage criteria. This author carried out a detailed study, where he integrated the agronomic criteria, nutritional value and productive performance of ruminants, which allowed the regionalization of

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the new varieties of *Saccharum* spp. selected for forage purposes in the main animal husbandry areas of Camagüey province, Cuba.

To achieve efficiency and profitability in agricultural systems with the use of *Saccharum* spp. crops, varieties should be used for forage purposes, which in addition to having a good nutritional value, are capable of producing biomass in soils characteristic of animal husbandry, and that do not decline sharply in productivity with the number of cuts. For such reasons, the objective of this work was to characterize agronomic variables in forage varieties of *Saccharum* spp. in four harvest cycles.

Materials and Methods

Location. The study was established in areas of the Sugarcane Research Institute (INICA, for its initials in Spanish) in Camagüey, located in the Florida municipality, Cuba, at 21º 30' north latitude and 78º 15' west longitude, situated at 57,47 m.a.s.l.

Climate and soil. The average rainfall and temperature data were taken from the agrometeorological station, located on the institution's premises (figure 1). The recorded values were within the normal ranges for these variables for the months in which the research was carried out. The study was conducted in a grayish-brown soil (Hernández-Jiménez *et al*., 2015), with pH of 6,07 and P (mg P_2O_5) and K (mg K_2O) contents of 3,44 and 11,19, respectively. The organic matter content was 1,38 % and the cation exchange capacity was 8,32 meq/100 g soil.

Treatments and experimental design. Three varieties of *Saccharum* spp. recommended by the Sugarcane Research Institute (INICA) were evaluated: two forage varieties (C97-366 and C99-374) and one commercial variety (My5514), traditionally used as a control in animal feeding studies. The experiment was set up in a randomized block design with three replications. Planting was carried out in March, 2014. The harvests of the experiment, from the first and up to the fourth cut, were made at 12 months of age, a period that coincided with the first ten days of March, 2015 to 2018.

Experimental procedure. Planting was done manually. A total of 750 cuttings of three buds per variety were used, which were distributed at a rate of 50 per furrow. The study had a gross area of 0,12 ha. The size of each plot per variety was 80 m^2 per replica. Five rows of 10 m in length were used, with a planting frame of 1,60 x 0,60 m. The three central rows of each plot (48 m^2) per replica were considered as the experimental plot per variety. Irrigation was not used, and the crop was only fertilized in the cane plant vine. Fertilization was fractioned: one application at planting (50 % N and K, 100 % P) and 45 days later (50 % N and K) for a total of 100 kg ha^{-1} of N, 50 kg ha^{-1} of P_2O_5 and 80 kg ha^{-1} of K_2O. An initial control of the weeds was carried out in early post-emergence and a periodic manual control every 2-3 months.

Morphoagronomic and yield measurements. Twelve months after planting or cutting, during the first four harvest cycles (sugarcane plant, first, second and third shoot), the number of stems per variety was determined. For this purpose, those belonging to the three central rows of the plots were cut and the result was extrapolated to one hectare. Stem diameter measurements were made at internode + 7 with the use of a caliper, graduated in cm. To determine stem length, a 5-m tape measure, graduated in cm, was used. It was measured from the base of the soil to the first visible dewlap. For each plot, 15 representative stems were measured, belonging to the three central furrows.

For the calculation of green biomass per variety, the three central furrows of each plot were harvested. The material (whole plant) was weighed and the amount was expressed in tons of green biomass per hectare. Dry biomass production was obtained by determining DM by the gravimetric method (AOAC, 2019) of the fresh samples. It was calculated by the expression:

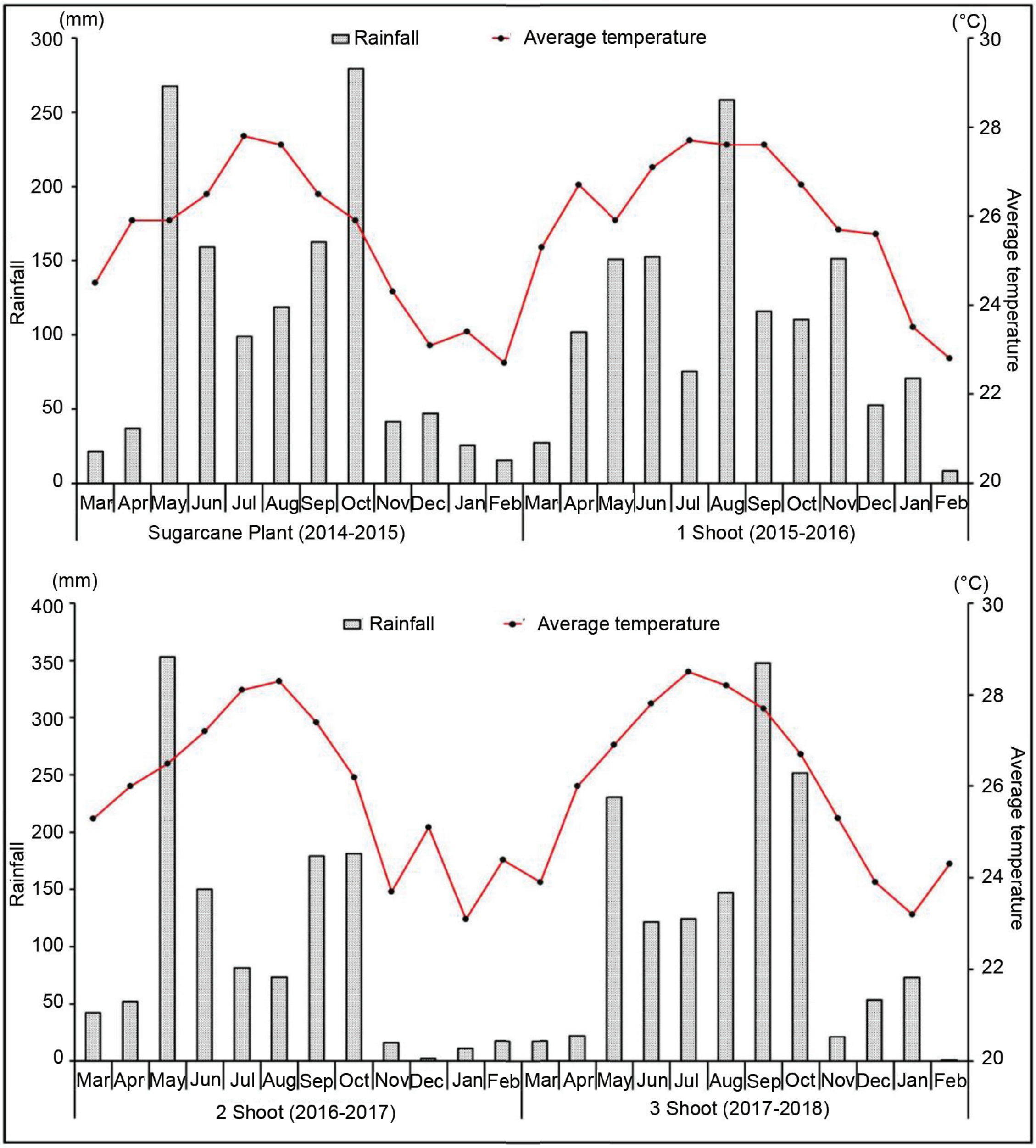
$$DBP = GBP \times DM / 100$$, where:

DBP: Dry biomass production
GBP: Production of green biomass
DM: Dry matter percentage of the fresh sample.

Statistical analysis. A simple classification analysis of variance was performed, with prior verification of the assumptions of homogeneity of variance and normality. Differences among means were contrasted using Duncan's multiple comparison test and the statistical package STATGRAPHICS Plus®, Version 5, for Windows, was used.

Results and Discussion

The production of stems per hectare is one of the most relevant indicators in the genetic improvement programs of *Saccharum* spp. It represents an important function in crop productivity (Cervantes-Preciado *et al*., 2022). In the study, statistically significant differences were observed among varieties for the variable number of stems per hectare (NSH) in the four harvest cycles (table 1).



Source: Florida Agrometeorological Station (2019).

Figure 1. Monthly rainfall and monthly average temperature by crop cycle.

The forage variety C97-366 showed the highest NSH in the study, and only showed no statistically significant differences with C99-374 in the 2R cycle. The two new forage varieties in the four harvest cycles outperformed the control My5514, proving the genetic potential of both genotypes for this important trait of great relevance in the productivity of the *Saccharum* spp. crop (Rincón-Castillo and Becerra-Campiño, 2020; Patishtan *et al*., 2023).

It is also of great importance to analyze the performance of NSH as the number of cuts of the crop increased, since it is one of the main components of yield in *Saccharum* spp. (Matoso *et al*., 2023). In addition, it is very useful for deciding whether or not to demolish the area, since a field without population is not justified from the economic and productive point of view.

The variety C97-366, in spite of showing a higher population during the four harvest cycles,

Table 1. Number of stems (x10³) per hectare per varieties and harvest cycles.

Harvest cycle	Variety			$\bar{X}$	± SE	P - value
	C97-366	C99-374	My5514			
Saccharum spp. (CP)	87,7[a]	76,9[b]	63,8[c]	76,1	3,70	0,0020
First shoot (1R)	74,9[a]	64,9[b]	60,8[b]	66,9	2,16	0,0005
Second shoot (2R)	59,0[a]	56,9[a]	51,8[b]	55,9	1,23	0,0166
Third shoot (3R)	54,4[a]	50,1[b]	45,7[c]	50,1	1,36	0,0036
Average	69,0	62,2	55,5	62,2		

Superscripts with equal letters in the same row do not differ statistically
$\bar{x}$: General mean SE: Standard error p: Significance

showed greater decrease (37,94 %), when considering the values obtained in the third shoot (3R) compared with those achieved in the cane plant (CP) strain. In contrast, My5514 showed lower values in each cycle, only decreasing NSH by 28,3 %. In turn, C99-374 showed a decrease of 34,9%.

Despite the higher reduction in the population, shown by the two forage varieties, both did not exceed 40 %, a value that can be considered acceptable, considering that the study was established under rainfed conditions in a soil with low agro-productive capacity, which was fertilized only in the CP strain. This has a direct impact on the population and, therefore, on crop productivity (Miranda *et al*., 2021).

In this regard, Chumphu *et al*. (2019) noted that water stress is the most important factor in reducing sprouting ability in *Saccharum* spp. globally. They also reported that varieties respond differently to water stress, with bud break, grindable stems, and sprouting ability being affected.

Stem diameter (SD) in *Saccharum* spp. is one of the main components analyzed for the production of agricultural potential, because it is related to productivity and is defined by the genetic characteristics of the plant (Patishtan *et al*., 2023). Variety C99-374 showed the highest mean value of this variable throughout the study. These results differed statistically in relation to variety C97-366. However, this genotype only differed from the control in strain 1R (table 2).

The three varieties showed stability of this trait, varying from 3,2 to 8,8 % from the values obtained in the 3R compared with those achieved in the CP cycle. These results coincide with those published by Bernal *et al*. (1997) and INICA (2019). Also, these three forage varieties showed similar values in experiments established in the main animal husbandry areas of Camagüey province, where they were planted on five soil types and in different environments (CITMA, 2019). Therefore, it is reaffirmed that this variable is influenced by the genetic characteristics of each particular variety, which can be a good indicator in crop improvement due to its positive correlations with regards to stem weight (Patishtan *et al*., 2023).

Stem length (SL) in *Saccharum* spp. varies considerably among varieties, even under similar soil and climate and management conditions. This trait is fundamental for crop development, which occurs mainly as a function of the genetic characteristics of the material, and can serve as a basis for the characterization and selection of promising varieties (Poudyal *et al*., 2023).

Table 2. Stem diameter of varieties per harvest cycles (cm).

Harvest cycle	Variety			$\bar{X}$	± SE	P - value
	C97-366	C99-374	My5514			
Saccharum spp. (CP)	2,7[b]	3,1[a]	3,1[a]	3,0	0,06	0,0001
First shoot (1R)	2,5[c]	3,1[a]	3,0[b]	2,9	0,08	0,0000
Second shoot (2R)	2,5[b]	2,9[a]	2,9[a]	2,8	0,07	0,0000
Third shoot (3R)	2,5[b]	2,9[a]	2,9[a]	2,8	0,06	0,0000
Average	2,6	3,0	3,0	2,9		

Superscripts with equal letters in the same row do not differ statistically
$\bar{x}$: General mean SE: Standard error p: Significance

In this study, statistically significant differences between varieties were observed only in CP. C97-366 and the control My5514 showed the highest mean SL values, results that differed statistically from C99-374 (table 3).

Similar to SD, SL variations of 3R in relation to the CP strain were low, with values between 3,6 and 8,6 %. These results, to a large extent, are ascribed to the climate conditions that prevailed in each of the harvest cycles, where rainfall and temperature (figure 1) behaved very favorably in each of the vegetative stages of the crop.

The highest rainfall and temperatures occurred from May to October (figure 1). This period coincides with the vegetative stages of tillering and maximum crop growth, where both variables have a positive effect on plant development and productivity.

Ramírez-Gonzáles *et al.* (2019) proved through a multivariate analysis that meteorological variables (rainfall, total days with rainfall, days with rainfall > 5 mm and maximum, minimum, daytime and nighttime temperatures) have the greatest influence on the phenological development of the *Saccharum* spp. crop and account for 46,4% of the total variations.

In general, the forage varieties reached very similar SL values to the control, which is of great importance because of the significance of this variable in crop productivity. In this regard, Miranda *et al.* (2021) and Patishtan *et al.* (2023) highlighted the importance of SL, because of what it can represent for forage production, since the volume of biomass that a *Saccharum* spp. variety can reach depends on NS, SD and SL.

Reis *et al.* (2019) obtained positive correlations of SL with green (r=0,80) and dry (r=0,78) biomass yield, which evidences the great importance of this morphological characteristic in the productive aspects of the varieties.

In the four harvest cycles, statistically significant differences were found between varieties for the variable green biomass yield (GBY). C99-374 reached the highest mean values in each of the strains, although in CP it did not differ from C97-366 and in 3R from the control. The average yield of the four cycles also reached the highest value (table 4).

In general, the three varieties showed a decrease in yields. It is presumed that these results are caused, to a large extent, by the low agro-productive capacity of the soil where the study was carried out, a reason that became more critical as the cuts were made due to the lack of fertilization of the area. McCray and Swanson (2020) corroborated the above, stating that soils with low organic matter content (< 2 %) have low water and nutrient

Table 3. Stem length per varieties and harvest cycles (cm).

Harvest cycle	Variety			$\bar{X}$	± SE	P - value
	C97-366	C99-374	My5514			
Saccharum spp. (CP)	267,3[a]	252,7[b]	265,9[a]	262,0	2,44	0,0254
First shoot (1R)	255,1	249,7	249,0	251,3	1,31	0,1021
Second shoot (2R)	243,7	247,3	247,0	246,0	0,82	0,1309
Third shoot (3R)	245,8	243,6	243,5	244,3	0,90	0,5882
Average	252,6	248,4	251,4	250,9		

Superscripts with equal letters in the same row do not differ statistically
$\bar{x}$: General mean SE: Standard error p: Significance

Table 4. Green biomass production per variety and harvesting cycle (t ha^{-1}).

Harvest cycle	Variety			$\bar{X}$	± SE	P - value
	C97-366	C99-374	My5514			
Saccharum spp. (CP)	131,9[ab]	146,8[a]	123,2[b]	134,0	4,24	0,0389
First shoot (1R)	87,1[b]	111,3[a]	83,5[b]	93,9	4,64	0,0017
Second shoot (2R)	72,8[b]	95,9[a]	71,2[b]	80,0	4,10	0,0002
Third shoot (3R)	49,8[b]	63,7[a]	56,8[ab]	56,7	2,49	0,0427
Average	85,4	104,4	83,7	91,2		

Superscripts with equal letters in the same row do not differ statistically
$\bar{x}$: General mean SE: Standard error p: Significance

holding capacity. Therefore, they require adequate management, irrigation, drainage and fertilization to maintain an economically sustainable level of crop production.

Another cause that could have influenced the decrease in GBP with the number of cuttings was the rainfall regime of the study (figure 1). In the four crop cycles, more than 90 % of rainfall occurred from May to October, which favored the tillering and maximum growth phase. However, in the remaining months until harvest (March), the plant experienced water stress, which affected final productivity. Figure 1 shows that the 2R and 3R strains were the most affected. In this regard, Sajid *et al*. (2023) indicated that the variability of the rainfall regime is, most of the time, responsible for the variation of production in *Saccharum* spp. either positively or negatively, which can occur due to water excesses or deficits. This is corroborated in several studies, where the positive correlation between green biomass production and the pluviometric regime is proven (Ramírez-Gonzáles *et al*., 2019).

Several authors agree that *Saccharum* spp. varieties tend to decline in productivity with the increase in the number of harvests, and that it occurs faster in soils of low fertility (Alves *et al*., 2019). From the physiological point of view, this performance can be ascribed to the fact that in the initial formation of the plant cane strain the crop is reproduced by means of a stake, which possesses sufficient nutrient reserves and good phytosanitary status. However, with the consequent cuttings, the plant is nourished by the previously established stock, and as the number of cuttings increases, it is at a disadvantage with the plant cane, as there are adverse factors that occur at harvest, such as mechanical damage, soil compaction, aging of the root system and pests that can affect it (nematodes, borers, among others). Also as the number of cuts increases, the plant tends to decrease its capacity to respond to external agronomic management factors, such as fertilization, cultivation and harvesting, as well as to the main climate variables for crop development, including rainfall, light and temperature (Chumphu *et al*., 2019).

The decrease of GBP in the study, when considering 3R with regards to the CP cycle, was in the order of 3,9 and 62,3 , values that according to the conditions under which this trial was conducted are within the range published by Kumar (2019) and Heliyanto *et al*. (2020), who estimated a reduction of productivity in *Saccharum* spp. of 60 to 70 % under rainfed conditions.

The forage varieties C97-366 and C99-374 reached mean values of 85,4 and 104,4 t ha^{-1} of green biomass in the four harvest cycles. This result was similar (C97-366) and even higher (C99-374) than the 89,3 t ha^{-1} published by Fernández-Gálvez *et al*. (2021), when evaluating 11 commercial varieties of *Saccharum* spp, recommended for animal feeding, in a soil of better agroproductive capacity.

Lagos-Burbano and Castro-Rincón (2019) propose that the production of dry biomass (DBP) in *Saccharum* spp. depends on the genetic characteristics of the variety, growth period, prevailing season of the year, introduction and timely application of inputs and crop products, and planting method.

Regarding the variable dry biomass production (DBP), statistically significant differences were found among varieties in the four harvest cycles (table 5). C99-374 reached the highest mean values of this variable per strain and also in the average of the four cycles (32,6 t ha^{-1}).

Similar to GBP, the three varieties showed a decrease in DBP as the number of harvests increased. These results are presumably caused, to a large extent, by the above-explained reasons, which have

Table 5. Dry biomass production per varieties and harvest cycles (t ha^{-1}).

Harvest cycle	Variety			$\bar{X}$	± SE	P - value
	C97-366	C99-374	My5514			
Saccharum spp. (CP)	43,4^{a}	45,0^{a}	38,9^{b}	42,4	1,08	0,0278
First shoot (1R)	30,8^{b}	35,6^{a}	28,2^{b}	31,5	1,24	0,0151
Second shoot (2R)	24,8^{b}	29,1^{a}	20,1^{c}	24,7	1,35	0,0007
Third shoot (3R)	16,5^{b}	20,5^{a}	16,9^{b}	18,0	0,77	0,0421
Average	28,9	32,6	26,0	29,2		

Superscripts with equal letters in the same row do not differ statistically
$\bar{x}$: General mean SE: Standard error p: Significance

to do with the low agroproductive capacity of the soil where the study was carried out and the water deficit present in each cycle during the last months prior to harvest (figure 1).

The forage varieties C97-366 and C99-374 reached a mean value of 28,9 and 32,6 t ha^{-1} of dry biomass in the four harvest cycles, higher than the 22,9 t ha^{-1} obtained by Fernández-Gálvez *et al.* (2021) when evaluating 11 commercial varieties of *Saccharum* spp. recommended for animal feeding in a soil of better agroproductive capacity.

Conclusions

Varieties C97-366 and C99-374 showed very similar results, and even superior to the control, with regards to the evaluated agronomic variables of forage potential, as well as a good regrowth capacity and persistence to cutting, reaching higher values than the control during the four harvest cycles. The results reaffirm the high forage potential of these genotypes, for which their use is recommended for feeding ruminants in areas of animal husbandry farms with similar characteristics.

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Conflicts of interest

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

Authors' contribution

- Yoslen Fernández-Gálvez: research planning, assembly in the template, analysis of results, writing of the paper and final revision.
- Redimio Manuel Pedraza-Olivera: research planning, analysis of results, writing of the paper and final revision.
- Yoslen Fernández-Caraballo (Junior): experimental set-up and evaluation, analysis of results, paper writing and final revision.
- Isabel Cristina Torres-Varela: set-up and evaluation of the experiment, analysis and interpretation of the results.
- Joaquín Montalván-Delgado: set-up and evaluation of the experiment, analysis of the results, writing of the paper and final revision.
- Alfredo Lázaro Rivera-Laffertte: set-up and evaluation of the experiment, analysis of results, writing of the paper and final revision.

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