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Production of Green Biomass from Sugar Cane Varieties Selected for Forage

Yoslen Fernández Gálvez *, Redimio Manuel Pedraza Olivera **, Yusvel Hermida Baños *, Isabel Cristina Torres Varela *, Joaquín Montalván Delgado *, Miguel Ángel Suñet Zayas Bazán ***

***** Mid-Western Territorial Station for Sugar Cane Research. “Las Mercedes” settlement. Florida, Camagüey, Cuba.
** Centers for Animal Development and Production Studies (CEDEPA), Faculty of Agricultural Sciences, Ignacio Agramonte Loynaz University of Camagüey, Cuba. Carretera Circunvalación Norte km 5. Camagüey, Cuba.
*** Municipal University Center, Florida, Camaguey Camagüey, Cuba.
Correspondence: yoslen@eticacm.azcuba.cu

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ABSTRACT

Background: A study of green biomass production was conducted at the Territorial Sugar Cane Research Station (ETICA) in mid-eastern Camagüey province, Cuba, to evaluate the effect of variety, stump, and row spacing, based on forage-production criteria.

Methods: The plantation was made in February 2016. The experiment was set up according to a categorical multi-factorial experimental design 3^3 = 27 combinations of base design, with two replicas, and 81 observations. Row plantation spacing (0.90, 1.20, and 1.50 m), varieties (C97-366, C99-374, and My5514), and stumps (plant, ratoon, and second ratoon), were evaluated. The production of green biomass was determined at 12 months of age. A multifactorial analysis of variance was performed (Statgraphics Centurion, XVI).

Results: Statistically significant differences in the production of green biomass were detected in the interaction of stump/plantation distances between rows. The sugar cane stump planted at 0.90 m row spacing showed the best productive results, whereas no significant differences were found between cultivars.

Conclusions: The genetic potential for green biomass production was corroborated by the new sugar cane forage cultivars C97-366 and C99-374, with values above 60 t/ha^{-1}, as the average of the three harvests.

Key words: Animal nutrition, stump, Saccharum officinarum, crop plantations *(Source: DeCS)*

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INTRODUCTION

Sugar cane (*Saccharum* spp.) is an excellent source of forage during the dry season, due to its many attributes, such as easy establishment, not much management requirements, and high productivity (100 a 120 t ha^{-1}, and even higher). Additionally, the harvest season coincides with the period with the greatest shortage of grass (Vidal, 2018).

The nutritional value of sugar cane must not be considered as an isolated factor in animal nutrition, but as a complex formed by the chemical composition, and secondary components that combine to interfere with ingestion, and use of forage consumed by ruminants, in addition to other factors like age, parts of the plant, and particularly, variety (Alves *et al*., 2019).

In face of the diversity of available varieties in the industry, the selection of genotypes for the purpose of forage production is highly important. It is directly linked to the success of animal nutritional management, where the proper choice ensures high quality bulky feeds throughout the period with the highest shortages of forage (Silva, Oliveira, and Ferreira, 2018).

The main research studies in this area, regarding the use of commercial cultivars of sugar cane as animal feed in Cuba have been conducted by Franco (1981); Molina, Tuero, and Casido (1995); Milanés *et al*., (1997). Besides, Jorge *et al*. (2008) evaluated 15 features of 26 sugar cane cultivars aging 12-14 months, in brown soils with carbonates. They recommended 10 cultivars for exploitation in livestock raising areas in the country. All the genotypes evaluated and recommended were selected depending on sugar cane production criteria. According to the authors, these cultivars acquired higher added value due to a more diversified use in relation to animal nutrition and the sugar industry.

However, there are still several issues to be addressed, which are fundamental in achieving efficient use of these forage-producing cultivars, to produce large amounts of biomass for animal nutrition. Hence, the aim of this paper is to evaluate the effect of the cultivar, stump, and row plantation spacing of sugar cane varieties that produce green biomass, chosen according to criteria for forage production.

MATERIALS AND METHODS

This study was done at the Mid-Eastern Territorial Station for Sugar Cane Research (ETICA), in the municipality of Florida, Camagüey, located on 21º 30' north latitude and 78º 15' west longitude, 57.47 meters above sea level. The field experiment was conducted on mulled brown soil with carbonates, according to Hernández, Pérez, Bosch, Rivero & Camacho (2015).

The average climatic variables that prevailed during the three cycles of the study were relative humidity (76.13%), maximum, minimum, and average temperatures (31.7; 22.2; and 25.7 ^{0}C, respectively). Precipitations totaled 1 127.8 mm, with 113 rain days (Florida, Camaguey Agrometeorological Station, 2020).

Planting was made in February 2016. The experiment was established according to a categorical multifactorial design 3^3 = 27 combinations of the base design, with two replicas, and 81 observations. Plantation distances between rows (0.90, 1.20, and 1.50 m), cultivars (C97-366, C99-374, and My5514), and stumps (plant, ratoon, and second ratoon), were evaluated. Each experimental unit was made of five 7.5 m long rows, without irrigation or fertilization. Only one weed control action was made around the stump, at 90 days following manual planting in the 0.90 m row spacing choice. In addition to the manual weed control, the other distances underwent two herbicidal applications, until the field was closed. Ratoon and second ratoon also received weed control actions with herbicides.

Following plot harvesting, the material was weighed, and the amount was expressed in t of green biomass per ha^{-1}, in order to determine the production of green biomass. Each evaluation was made to the three stumps studied at 12 months of age.

Statistical processing was done according to Statgraphics Centurion XVI. A multifactorial analysis of variance was performed to the biomass production indicator, according to the cultivar, stump, and plantation distances between rows.

RESULTS AND DISCUSSION

Apart from high nutritional value and acceptability, each plant must produce high volumes of biomass to be considered appropriate for animal nutrition as forage. After removing non-significant interactions (AB, AC, and ABC) of the whole factorial model (Table 1) in a previous run, the multifactorial analysis of variance of green biomass production showed statistically significant differences in the interaction of stumps by plantation distance, whereas no significant differences were observed between cultivars (P>0.05).

Table 1. Categorical multifactorial analysis of variance green biomass production

Variation source	SC	Gl	CM	F	P
Main effects					
A: Cultivar	723.566	2	361.783	2.43	0.0954
B: Stump	21 720.9	2	10 860.5	72.97	0.0000
C: Row plantation spacing	12 870.6	2	6 435.32	43.24	0.0000
Interactions					
BC	3 819.78	4	954.944	6.42	0.0002
Error	10 418.9	70	148.842		
Total	49 553.8	80			

These results clearly show the weight of both factors in the production of green biomass from sugar cane. It is important to say that the stump is linked to the number of cuts or harvests performed to a particular crop. Therefore, it measures the second ratooning capacity and the endurance a forage-producing plant has through cutting. Most crops tend to decrease production as the number of cuts increases. Livestock production requires strong genotypes that maintain productivity levels stable, so that forage areas remain productive for as long as possible after crop establishment. Therefore, resources like seeds, and those needed for tilling can be used more rationally (Fernández *et al*., 2018 a).

In sugar cane, yields tend to decline after repeated harvests (de Oliveira Cervone *et al*., 2018). Physiologically, it can be attributed to the fact that during the initial formation of the stump, the crop reproduces by means of stems, which contain enough nutrients, and are phytosanitarily sound. However, after subsequent cuts, the plant feeds from the previously established stump. As the number of cuts increase, it becomes weaker than the stump, due to adverse factors, such as mechanical damage, soil compression, root aging, and pests, that can affect the plant, namely nematodes, borers, etc. As the number of cuts increase, the plant tends to reduce the capacity to respond to external factors of agronomic management, like fertilization, cultivation, and harvesting. The main climatic variables (precipitations, light, and temperature) also play a key role in this (Chumphu, Jongrungklang, and Songsri, 2019).

Regarding the plantation distance between furrows, several studies coincide with the opinion that lower distances increase crop yields, and biomass production by sugar cane plot (Anjum *et al*., 2015; Essam and Abd, 2016; Kumawat and Dahima, 2016; Aamer *et al*., 2017).

Table 2 shows the averages achieved in the nine combinations of stump interactions by plantation distance between furrows. In the sugar cane stump (0.90 m plantation spacing between furrows), the highest green biomass production values were observed. In this distance, the production of green biomass increased 72.77%, compared to the one used traditionally (1.50 m-1.60 m), in sugar cane plantations for the industry.

The average value of the three cuts at the 0.90 distance is over 90 t/ha^{-1}. Hence, this distance may contribute to greater durability of the stump, and lower sharp decline of yields after subsequent cuts.

Table 2. Production of green biomass (t/ha^{-1}) according to stump and plantation distance between furrows

Stump	Plantation distance between furrows		
	0.90 m	1.20 m	1.50 m
Plant	124.29^{a}	90.53^{b}	71.94^{c}
Ratoon	85.55^{b}	68.11^{cd}	58.90^{def}
2nd ratooning	62.25^{cde}	55.73^{ef}	49.64^{f}

a, b, c... f- Unequal superscripts on the biomass averages in each cell, indicate significant differences (Tukey P<0.05).

The values achieved in the 0.90 m distance are higher than the ones reported by Fernández-Gálvez *et al*. (2016) in an experiment conducted under similar edaphoclimatic conditions, using the same forage cultivars at 1.50 m spacing. Another inferior result was reported by Leyva (2012), upon evaluation of four sugar cane cultivars (C137-81, C86-503, C90-530, and B63118) as animal feed, on two locations in the province of Las Tunas. In the experiment, the plantation was made 1.60 m between furrows without irrigation and fertilization. The biomass produced on the two locations ranged between 59 and 65 t ha^{-1} at 12 months. The higher yields found in the new cultivars compared to the values published by that author, confirm their good forage potential for ruminant nutrition, particularly during the dry season in Cuba.

The results achieved in these cultivars were satisfactory, considering that the average green biomass produced following three cuts is over 70 t/ha^{-1}, which is within the 60-120 t/ha^{-1}range reported by several authors in Cuba (Franco, 1981; Molina, Tuero, and Casido, 1995; Milanés *et al*., 1997; Jorge *et al*., 2008; Leyva, 2012), only including the results from the stump of the sugar cane plant. As a result, adequate second ratooning capacity and endurance of new forage cultivars to cutting was observed, especially in cultivar My5514.

As to the stump, the previous explanation related to the effect of cutting on the decrease of green biomass production, was observed. However, it is important to highlight the results of the 2^{nd} shoots, in which cultivars produced over 55 ha^{-1}. This value may be considered good, since the study was conducted in areas without irrigation and fertilization, which are essential for proper sugar cane development (Bezerra *et al*., 2017; Costa *et al*., 2017; Alves *et al*., 2019).

Gonzales, Campero, and Campero (2016); Duarte and González (2019) corroborated the previous assertion. They noted that sugar cane has high nutritional requirements due to the high capacity to produce biomass (millable stems, foliage, stump, and roots). This productive level, associated to a prolonged duration of the cycle involves high nutrient extraction from the soil.

The behavior of these cultivars reaffirm the advantages of sugar cane compared to other forage crops, as one of the highest producer of biomass per surface area, as well as its endurance to cutting, which allows the plant to remain productive for 5-10 years, depending on handling and care, without replacing the stumps (Bastidas *et al*., 2012; Ruiz, 2012; Méndez-Adorno *et al*., 2016).

A shortened plantation distance between furrows is a viable and sustainable choice, since, otherwise, it would cause more expenses in terms of seeds compared to the other distances evaluated. A higher number of tilling actions made until the field is closed are dependent on the longer distances between furrows; costs can be compensated by comparing the shortest to the longest plantation distance (Fernández *et al*., 2018 b).

Moreover, in the shortest distance (0.90 m), cultivar harvesting is made in advance without affecting biomass production. When the field is closed earlier, weeds are controlled without herbicides, and soil erosion from direct rain exposure, and moisture loss caused by evapotranspiration, are reduced. All the above aspects make the utilization of this particular plantation row spacing for forage production feasible, producing greater system sustainability.

CONCLUSIONS

Improvements in green biomass production based on the cultivars studied can be achieved by planting sugar cane stumps at a distance of 0.90 m between furows.

The genetic potential for green biomass production by the new sugar cane forage cultivars C97-366 and C99-374, was demonstrated to have average values above 60 t/ha^{-1} in the three harvests.

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AUTHOR CONTRIBUTION

Conception and design of research: YF, RP, YH, IT, JM; data analysis and interpretation: YF, RP, YH, IT, JM, MS; redaction of the manuscript: YF, RP, YH, IT, JM, MS.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.