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Forage potential of six sugarcane cultivars for feeding ruminants

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Abstract. The study evaluated the productive, morphometric, and bromatological characteristics of six sugarcane cultivars (Regional, RB 865536, RB 867515, CTC2, CTC9001, and CTC9004M). The experiment began at UESB and continued at Fazenda Bela Vista, with evaluations conducted 3 to 18 months after planting. A randomized complete block design was used, with six cultivars per cultivar and four replicates. The cultivar CTC2 presented higher levels of lignin and indigestible neutral detergent fiber, while RB 865536 stood out for its hemicellulose content. The average contents of dry matter, crude protein, ether extract, non-fibrous carbohydrates, and corrected neutral detergent fiber did not differ between cultivars, but there was variation in carbohydrate fractions. CTC9001 presented the highest value for fraction A (68.6%), while cultivar Regional and CTC9004M stood out in fraction B1+B2, and CTC2 and CTC9004M in fractions B3 and C, respectively. In the productive characteristics, CTC9004M presented the highest values of natural matter, dry matter, soluble carbohydrates, production and juice efficiency, standing out in yield. Regarding morphometric characteristics, CTC9001 showed advantages in leaf length and diameter, stem diameter, and leaf area, although there were no significant differences in plant height, tiller number, or leaf number. The cultivars have similar chemical and bromatological composition, agronomic characteristics, and growth behavior. CTC9004M demonstrated superior production efficiency, making it the most suitable option for forage use in semiarid conditions. Future studies should evaluate animal performance directly using these cultivars in feeding trials.

Key words: adaptation, agriculture, composition, productivity, semi-arid regions.

INTRODUCTION

Grass-fed beef cattle is a pillar of Brazilian agricultural production, predominating in much of the country. However, forage production is highly seasonal: approximately 80% of dry matter is generated during the rainy season, while the dry season sees a sharp decline in both supply and pasture quality (Pereira et al., 2024). This nutritional limitation compromises animal performance and highlights the need for management strategies that minimize the effects of forage scarcity (Macêdo et al., 2022).

The use of bulky reserve feeds has proven to be an important alternative for maintaining productivity during droughts, although production costs can be high. In this scenario, sugarcane stands out as a strategic option due to its high dry matter production, ease of management, good animal acceptance, and potential to reduce supplementation costs (Cruz et al., 2023). Its carbohydrate accumulation, intensified by maturation during the dry season, reinforces its relevance as an energy source (Anjaly et al., 2024).

Selecting the appropriate variety is crucial, considering both nutritional attributes such as high sucrose content and low NDF/sucrose ratio, as well as desirable agronomic characteristics such as upright growth, stem uniformity, ease of defoliation, and absence of flowering (Arcoverde et al., 2019). This integration of nutritional and agronomic factors seeks to maximize animal productivity and the economic viability of the system.

This study aimed to compare six sugarcane cultivars in terms of productive, nutritional and morphometric characteristics to determine their forage potential for feeding ruminants in semiarid conditions.

MATERIALS AND METHODS

The experiment began with seedling production in a greenhouse, where they were developed for 36 days. The seedlings were then transported to Bela Vista Farm, where they underwent a 15-day acclimatization period in full sunlight. After this period, they were transplanted to the experimental area, marking the beginning of the evaluations. Morphological and morphometric analyses were performed every three months, totaling six evaluation periods over 18 months. The experiment was concluded at the end of this period.

To prepare the seedlings, 5 cm long sugarcane mini stalks were produced, selecting healthy stalks. Each mini stalk was carefully inspected, following the methodology of Gírio et al. (2015), to ensure the viability of the germinating bud.

Soil correction and fertilization

A total area of 1,200 m² was designated for soil sampling. Twenty composite samples were collected at a depth of 20 cm, homogenized, and a representative subsample was subsequently prepared for laboratory analysis. The corresponding results are presented in Table 1.

Table 1. Soil chemical characteristics

pH (H_2O)	P (mg dm^{-3})	K	Ca	Mg	Al	H^+	Bases sum	Eff. CEC	CEC pH 7.0	Base sat.	Al sat.
4.7	1	0.1	0.7	0.6	1.4	6	1.4	2.8	8.6	16	50

Notes: Bases sum = Ca^{2+} + Mg^{2+} + K^+; Effective CEC = bases + Al^{3+}; CEC at pH 7.0 = total capacity at neutrality; Base saturation = proportion of bases relative to CEC; Aluminum saturation = relative share of Al^{3+}.

The 1,200 m² experimental area was prepared following the CFSEMG (1999) recommendations. Initially, the soil was plowed and harrowed. Based on soil analysis, 300 kg of dolomitic limestone was applied throughout the area. At the time of planting, the seedlings were fertilized in a row, and nitrogen topdressing was applied one month after planting.

The nutrient doses used are described in Table 2.

The doses followed the recommendations of CFSEMG (1999) for an expected sugarcane yield above 120 t ha^{-1}.

Table 2. Doses of nutrients used

Application time	Product	Applied dose	Main nutrient (%)
Soil preparation	Dolomitic limestone	300 kg (total area)	-
Planting (basal fertilization)	Single superphosphate	300 g per row of plot	18% P_2O_5
Planting (basal fertilization)	Potassium chloride	113 g per row of plot	48% K_2O
Topdressing (30 days)	Urea	70 g per row of plot	45% N

Cultivars analyzed

The experiment evaluated the following sugarcane cultivars: Regional, RB 865536, RB 867515, CTC2, CTC9001 and CTC9004M. Each cultivar constituted a treatment, with four replicates per treatment.

Description of the experimental area

The experimental area totaled 1,154.40 m², with dimensions of 39 m long and 29.6 m wide, forming a rectangle. The experiment was organized into 24 plots, each measuring 9 m long and 3.6 m wide. To facilitate data collection, five 1-m-wide corridors were created between the plots. Lateral and vertical borders of 1.50 m were established. Each plot, representing a single cultivar, was replicated four times, totaling 720 plants. The plots were arranged in four blocks, with six plots per block. Each plot contained six rows of furrows measuring 3.6 m long and 30 cm deep, with 1.50 m spacing between furrows and 0.6 m between plants. Each row contained 30 pre-sprouted seedlings.

Rainfall and temperature were monitored daily on the property using a 120 mm rain gauge and a maximum and minimum thermometer. The data collected, from February 2018 to June 2019, described in Fig. 1.

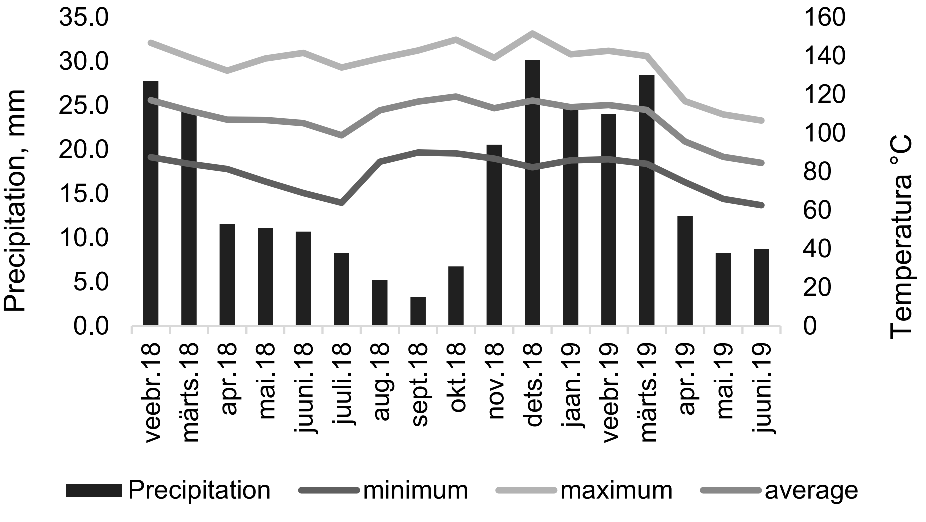

Figure 1. Precipitation and maximum, minimum and average temperatures obtained during the experimental period.

Description of the analyzed cultivars

Regional: A variety already grown at Bela Vista farm, showing good adaptation to local soil and climate conditions, with satisfactory forage and sugar productivity. Its scientific and commercial identification is still under evaluation by specialized institutions.

RB855536: Medium-sized variety with erect stalks and easy stripping, characterized by high yield, medium to late maturity, high sucrose content, and low fiber (RIDESA, 2010).

RB857515: Fast-growing and tall variety with purplish stalks, good agricultural yield, medium to late maturity, high sucrose content, and intermediate fiber levels (RIDESA, 2010).

CTC2: Rustic variety recommended for low-fertility soils, with excellent ratoon sprouting, even under unburnt harvest. It presents medium to late maturity, high yield, and long field longevity (CTC, 2018).

CTC9001: Erect stooling cultivar with good tillering, early maturity, and sucrose content around 18% (CTC, 2018).

CTC9004M: Similar to CTC9001, with erect stooling, early maturity, and sucrose content close to 18% (CTC, 2018).

Morphometric Analysis

Every three months, morphometric analyses were performed on four plants per plot. To assess yield, one central plant from each plot was collected and analyzed for green and dry matter production of leaves and stems, as well as Brix. This procedure was repeated every three months, resulting in four plants analyzed per cultivar. Morphometric analyses were conducted at 3, 6, 9, 12, 15, and 18 months after planting.

At the end of the six evaluation periods, when the plants reached 18 months of age, the lateral columns of each plot were fully harvested for final yield analysis. This harvest included the four columns that were not used in the quarterly yield collections.

Morphometric characteristics and bromatological composition

To evaluate the morphometric characteristics (Silveira et al., 2025), chemical composition and productive performance of different sugarcane cultivars, a randomized block experimental design was used. The treatments consisted of six cultivars: Regional, RB 865536, RB 867515, CTC2, CTC9001 and CTC9004M, with four replicates per treatment.

Morphometric evaluations

Table 3 presents the morphometric evaluations performed as described by Silveira et al. (2025).

Chemical analysis

Between 3 and 15 months after planting, analyses were performed focusing on the production of green and dry matter of leaves and stems, as well as on the Brix of the plants. At 18 months, analyses of chemical composition were performed. To this end, samples of each cultivar were identified, weighed, and pre-dried in a forced-air oven at 55 °C for 72 hours. After pre-drying, the aerial parts of the samples were ground in a Willey mill using 2-mm sieves.

Table 3. Morphometric evaluations performed (Silveira et al., 2025)

Evaluated parameter	Method description
Plant height	Measurement of 4 plants per plot, from soil level to the top of the plant using a measuring tape
Stalk length	Measurement of 4 plants per plot, from soil level to the top of the last internode at the sheath insertion
Stalk diameter	Measurement of 4 plants per plot, 20 cm above soil level, using a caliper
Number of tillers per plant	Counting of stalks in 4 plants per plot
Leaf length	Measurement of 4 plants per plot, from ligule insertion to the leaf tip
Leaf diameter	Measurement of 4 plants per plot, at the mid-point of the leaf, using a caliper
Number of leaves	Counting of leaves on the central stalk of 4 plants per plot
Leaf area per stalk	Determined according to Hermann & Câmara (1999)
Fresh leaf weight	All leaves from 1 plant per plot were collected and weighed on a balance (0.01 g).
Dry leaf weight	Leaves dried in an oven at 105 °C until constant weight, then weighed (0.01 g).
Fresh stalk weight	All stalks from 1 plant per plot weighed on a balance (0.01 g).
Dry stalk weight	Stalks dried in an oven at 105 °C until constant weight, then weighed (0.01 g)
°Brix (whole plant)	Determined with an analog refractometer, using juice from the central stalk region
°Brix (juice)*	Determined with an analog refractometer, using juice obtained from pressing 10 stalks
Juice yield*	Obtained from the total pressing of 10 stalks per replicate/cultivar.
Juice production efficiency (JPE)*	Ratio between fresh weight of 10 stalks and extracted juice (JPE = JC × 100 / FSW)

*(evaluated only 18 months after planting).

Chemical and Nutritional Fractionation Analyses

The sugarcane composition was determined following the standard methodologies of the INCT-CA (National Institute of Science and Technology in Animal Science) and the detailed procedures outlined by Detmann et al. (2012). The analytical determinations encompassed dry matter (DM; INCT-CA Method G-003/1), crude protein (CP, calculated as total nitrogen × 6.25; INCT-CA Method N-001/1), neutral detergent fiber (NDF; INCT-CA Method F-002/1), and acid detergent fiber (ADF; INCT-CA Method F-004/1). Lignin content was ascertained through treatment with H_2SO_4 at 72% (w/w), as per the methods described by Detmann et al. (2012).

For the NDF analysis, samples underwent treatment with thermostable α-amylase, without the inclusion of sodium sulfite. The resulting NDF values were corrected for both ash residue (aNDFom; INCT-CA Method M-002/1) and nitrogen compounds (NDFCP; INCT-CA Method N-004/1).

Protein Fractionation

The crude protein was fractionated into its distinct components using the methodologies proposed by Licitra et al. (1996) and Fox et al. (2000). This procedure yielded the following protein classes, based on their degradation rate:

• Non-protein nitrogen (A): The most rapidly degraded fraction.
• True protein of rapid and intermediate enzymatic degradation (B1 + B2): Available protein component.
• True protein of slow enzymatic degradation (B3): Fraction with gradual availability.
• Indigestible protein (C): Consisting of the nitrogen retained in the ADF residue, multiplied by the correction factor of 6.25.

Carbohydrate Estimation and Energy Content

The total carbohydrate (TCH) content was estimated following the approach by Sniffen et al. (1992), calculated using the formula: TCH = 100−(CP + EE + MM), where EE is the ether extract and mm is the mineral matter (ash).

Non-fibrous carbohydrates (NFC), corresponding to fractions 'A + B1', were estimated via the formula: NFC = 100−(CP + NDFCP + EE + MM). Here, NDFCP refers to the NDF corrected for both ash and protein. Fraction B2 (intermediate degradation carbohydrate) was determined by calculating the difference between the NDFCP and the indigestible fiber component (Fraction C). Fraction C (indigestible fiber) was estimated by multiplying the determined lignin percentage by a factor of 2.4.

The observed Total Digestible Nutrient (TDN) content was calculated using the summative equation presented by the NRC (2001):

TDN = DCP+(2.25×DEE) + DNDFCP + DNFC

where the terms represent, respectively, digestible crude protein (DCP), digestible ether extract (DEE), digestible neutral detergent fiber corrected for ash and protein (DNDFCP), and digestible non-fiber carbohydrates (DNFC).

Statistical Procedures

The data obtained were subjected to regression analysis and analysis of variance for the *Tukey test* with the aid of the Sass program (SAS), adopting 0.05 as the critical level of probability for type I error, where a mean test was performed for the bromatological and productive evaluations, and regression for the growth evaluations.

RESULTS AND DISCUSSION

At 18 months after planting, the iNDF, hemicellulose and lignin contents showed statistically significant differences ($P < 0.05$). On the other hand, the mean values of DM, CP, EE, NFC, NDFcp, NDF, ADF, cellulose, mm, TDN, BRIX and NDF/BRIX did not show significant differences ($P > 0.05$), and their mean values were consistent with the data reported in previous studies (Cruz et al., 2014; Bonomo et al., 2009; Azevêdo et al., 2003; Andrade et al., 2004) (Table 4).

The low levels of crude protein (CP) and mineral matter (MM) observed in this study are characteristic of sugarcane, corroborating the results of Cruz et al. (2014) and Bonomo et al. (2009). The variation in the average values of minerals and CP between studies is minimal, ranging from 1.7% to 3.8% (Rodrigues et al., 1997; Carvalho et al., 1998; Fernandes et al., 2001). Although CP and mm are not determining criteria for selection of varieties for animal feed, they can be corrected with mineral supplementation and low-cost non-protein nitrogen sources (Tedeschi et al., 2000; Bonomo et al., 2009; Cruz et al., 2014).

Similar to crude protein and mineral matter contents, sugarcane also has low ether extract (EE) contents. Andrade et al. (2004) highlighted that these low values limit the contribution of EE to sugarcane-based feed formulations. Furthermore, some of the EE present in sugarcane may come from the waxes that coat the stalks, which are poorly digestible for ruminants.

Table 4. Chemical composition (% DM) of sugarcane cultivars harvested 18 months after planting, in the Encruzilhada region, Bahia

Componentes	Regional	RB 85 5536	RB 86 7515	CTC2	CTC 9001	CTC 9004M	Average	CV (%)
DM (%)	25.0[a]	24.2[a]	27.4[a]	24.8[a]	26.6[a]	25.0[a]	25.5	6.5
Crude Protein	4.0[a]	3.6[a]	3.5[a]	3.3[a]	3.4[a]	3.3[a]	3.5	8.5
Ether Extract	1.9[a]	2.0[a]	2.0[a]	2.1[a]	2.3[a]	2.4[a]	2.1	8.6
Non-fibrous carbohydrates	49.9[a]	49.1[a]	53.8[a]	51.4[a]	51.2[a]	51.1[a]	51.1	5.7
NDFi[1]	18.3[b]	16.0[b]	18.5[b]	21.9[a]	17.3[b]	18.3[b]	18.4	6.6
NDFcp[2]	41.8[a]	42.7[a]	38.5[a]	40.9[a]	40.7[a]	41.2[a]	40.9	6.0
Acid detergent fiber	25.0[a]	24.5[a]	22.8[a]	25.2[a]	24,7[a]	24.2[a]	24.4	6.3
Hemicellulose	17.0[ab]	18.3[a]	15.7[b]	15.8[ab]	15.6[b]	16.9[ab]	16.5	6.7
Cellulose	19.5[a]	19.2[a]	17.3[a]	18.3[a]	18.8[a]	18.2[a]	21.0	8.0
lignin	5.3[b]	5.1[b]	5.2[b]	6.8[a]	6.1[ab]	5.8[ab]	5.7	11.2
Gray	2.7[a]	3.2[a]	2.7[a]	2.7[a]	2.9[a]	2.5[a]	2.8	18.6
TDN[3]	57.7[a]	55.0[a]	58.9[a]	58.4[a]	58.0[a]	57.7[a]	57.0	4.8
°BRIX/ Broth [4]	19.7[a]	18.2[a]	20.2[a]	19.0[a]	19.2[a]	18.7[a]	19.2	5.5
NDF/BRIX[5]	2.1[a]	2.4[a]	1.9[a]	2.2[a]	2.1[a]	2.2[a]	2.1	9.6

Significant differences between means within the same row were determined using the *Tukey test* ($P < 0.05$). NDFI: Indigestible neutral detergent fiber; NDFcp: Neutral detergent fiber corrected for both ash and protein. TDN3: total digestible nutrients; °BRIX/Broth4: soluble sugars in the broth; NDF/BRIX Neutral detergent fiber by soluble sugars (Brix).

The NDF/Brix ratio, which evaluates the energy consumed in relation to the low-ruminal degradation fiber (Gooding, 1982), is crucial to prevent high NDF levels from limiting the animals' dry matter and energy intake. To be considered suitable for animal feed, this ratio must be less than 2.7 (Rodrigues et al., 1997).

Varieties with high stalk yield are preferable, as stalk has a negative correlation with NDF/Brix ($r = -0.69$). In this study, the average NDF/Brix value was 2.1, within the limit recommended by Rodrigues et al., 1997. There was no difference ($P > 0.05$) for this component.

The cultivar CTC2 presented the highest iNDF content (21.9%), being significantly higher ($P < 0.05$) than the others. The other cultivars did not differ from each other ($P < 0.05$) (Table 4). This result can be attributed to the higher lignin content found in the cultivar CTC2 ($P < 0.05$), since lignin directly influences the digestibility of the fibrous fraction, increasing the iNDF. According to Van Soest (1994), lignin limits the digestion of the fibrous carbohydrates to which it is attached, as it is indigestible. The indigestible portion of the forage is approximately 2.4 times the lignin content of the plant.

The cultivar CTC2 presented the highest lignin content (6.75%), significantly higher ($P < 0.05$) than the other cultivars, which followed the order: CTC9001, CTC9004M, Regional, RB867515 and RB855536.

The higher lignin and iNDF content in the CTC2 cultivar may lead to lower consumption when used in cattle nutrition, due to the reduction in fiber digestibility by rumen bacteria and consequently a reduction in the passage rate, causing this food to remain retained in the rumen for longer to be degraded, leading to a limitation of physical consumption or ruminal filling.

According to Van Soest (1994), consumption limitation due to physical factors occurs when cattle exceed NDF consumption by 1.2% of their body weight. When cattle reach this limit, there is a limitation in intake, even if the animal has a greater energy need.

The average variation in fiber composition and its components observed in this study is similar to that found by Valadares Filho et al. (2002), indicating that the evaluated cultivars are representative of the sugarcane varieties used in Brazil. The authors reported an average value of 20.5% for hemicellulose in 14 observations, while the varieties in this study presented an average of 16.5%. The cultivar RB855536 had the highest hemicellulose content (18.3%), and CTC9001, the lowest (15.6%).

The A, B1+B2, B3 and C fractions differed statistically ($P < 0.05$), the total nitrogen content remained unchanged 18 months post-planting (Table 5).

Fraction A, which represents non-protein nitrogen (NPN), varied significantly among cultivars. Cultivar CTC9001 had the highest NNP content, followed by RB855536, RB867515, Regional, CTC2, and CTC9004M (Table 5). Because it is the predominant fraction, fraction A can lead to ruminal nitrogen losses if not synchronized with available carbohydrates.

Table 5. Protein fractionation of the portion of sugarcane cultivars harvested 18 months after planting, in the Encruzilhada region, Bahia

Variables	Regional	RB 85 5536	RB 86 7515	CTC2	CTC 9001	CTC 9004 M	Average	CV (%)
NT (%DM)	0.6[a]	0.6[a]	0.6[a]	0.5[a]	0.6[a]	0.5[a]	0.6	8.5
A (%NT)	62.9[abc]	64.9[ab]	64.7[ab]	60.7[bc]	68.6[a]	56.8[c]	63.1	4.6
B1+B2 (%NT)	24.0[a]	15.7[bc]	17.8[abc]	20.5[ab]	13.3[c]	23.4[a]	19.2	16.2
B3 (%NT)	5.9[b]	7.6[ab]	6.8[ab]	8.7[a]	7.8[ab]	9.0[a]	7.6	14.3
C (%NT)	7.2[b]	11.8[a]	10.7[a]	10.0[a]	10.3[a]	10.8[a]	10.1	12.0

Significant differences between means within the same row were determined using the *Tukey test* ($P < 0.05$); DM: dry matter; NT: total nitrogen; B1+B2: rapidly degrading soluble protein; B3: slowly degrading proteins; C: indigestible fraction.

For fraction B1+B2, cultivars Regional and CTC9004M obtained equal averages of 24.0 and 23.4%, respectively, and higher than the other cultivars, thus being the cultivars with the highest proportion of true protein, that is, those with the highest levels of fraction B1+B2, followed by cultivars CTC2 with an average of 20.5%, RB867515 with 17.8%, RB855536 with 15.7% and CTC9001 with 13.3%.

The true protein represented by fractions B1+B2 contains amino acids linked by peptide bonds. In the rumen, part of it is degraded by the ruminal microbiota, releasing ammonia (NH_3), peptides and free amino acids, which are used for the synthesis of microbial protein.

The fraction not degraded in the rumen (PNDR or bypass protein) escapes and is digested in the small intestine, providing amino acids directly to the animal. When balanced with fermentable energy (carbohydrates), true protein promotes maximum efficiency in microbial protein synthesis (Castro et al., 2007).

The difference observed can be attributed to the influence of Fraction A on Fraction B1+B2. Specifically, the CTC9001 cultivar supports this relationship, as it exhibited the lowest content of Fraction B1+B2 and, concurrently, the highest content of Fraction A. Thus showing the influence that one fraction exerts on the other, being that the higher the content of non-protein nitrogen (fraction A), the lower the content of true protein (fraction B1 + B2), therefore the higher the content of true protein (fraction B1 + B2), the lower the content of non-protein nitrogen (fraction A).

Significant differences ($P < 0.05$) were observed for Fraction B3 among the cultivars (Table 5). CTC9004 (9.0%) and CTC2 (8.7%) displayed statistically similar and higher mean values compared to the remaining cultivars, which were ranked as follows: CTC9001 (7.8%), RB855536 (7.6%), RB867515 (6.9%), and Regional (5.9%).

The difference that occurred can be explained by the influence of fraction B1+B2 on fraction B3, as can be seen, since the Regional cultivar that presented the lowest average for fraction B3 was the one that presented the highest average for fraction B1 + B2. Thus demonstrating that fraction B1 + B3 has an influence on fraction B3, being inversely proportional.

For the values of fraction C, which is considered the indigestible fraction of fiber, the cultivars RB855536, CTC9004, RB867515, CTC9001 and CTC were statistically equal to each other and superior to the Regional cultivar. Lignin has a direct influence on this fraction because this fraction is the fraction of the protein that is bound to lignin, thus being the indigestible fraction of the protein, having a great nutritional influence because the bound protein is not used by ruminal microorganisms, being a limiting nutritional factor in the choice of a cultivar aimed at animal nutrition.

In the carbohydrate fractionation (Table 6), significant differences ($P < 0.05$) were observed for fractions B2 and C, with no difference ($P > 0.05$) for total carbohydrates and fraction A + B1 between the cultivars, the average value obtained for total carbohydrates was 91.6%, this content is in agreement with the data obtained by (Bonomo et al., 2009; Mello et al., 2006; Azevêdo et al., 2003).

Table 6. Carbohydrate fractionation of sugarcane cultivars harvested 18 months after planting, in the Encruzilhada region, Bahia

Variables	Regional	RB 855536	RB 867515	CTC2	CTC 9001	CTC 9004M	Average	CV (%)
CT (%MS)	91.4^{a}	91.2^{a}	91.9^{a}	91.8^{a}	91.4^{a}	91.8^{a}	91.6	0.7
A+B1 (%CT)	54.6^{a}	53.8^{a}	58.6^{a}	56.0^{a}	55.5^{a}	55.7^{a}	55.7	5.2
B2 (%CT)	25.4^{ab}	28.7^{a}	21.3^{b}	20.2^{b}	25.5^{ab}	24.4^{ab}	24.3	10.2
C (%CT)	20.0^{a}	17.5^{b}	20.1^{a}	23.8^{a}	19.0^{b}	19.9^{b}	20.1	6.8

Means within the same row followed by different letters differ according to Tukey's test at a 5% probability level. CT: total carbohydrates; A+B1: soluble sugars (starch and pectin), rapidly degradable; B2: potentially degradable fibrous carbohydrates; C: non-degradable fibrous carbohydrates.

Fraction A +B1 is the fraction of carbohydrates with a high rate of ruminal degradation. The average value obtained for fraction A + B1 was 55.7, which is similar to the average value found by Mello et al. (2006), where they evaluated 9 sugarcane cultivars and obtained an average value for fraction A + B1 of 50.54%, thus corroborating the data obtained in this work.

Carvalho et al. (2007) reported that feeds with elevated levels of the A + B1 fraction are regarded as energy sources for ruminal microorganisms, promoting synchronization between protein and carbohydrate digestion and exerting a significant impact on animal performance. This is therefore an important factor in the selection of sugarcane cultivars when used for animal feed.

The B2 fraction (portion of CHOT as available fiber) of cultivar RB855536 obtained the highest content for the B2 fraction, with an average of 28.7% (Table 6). According to Azevêdo (2003), this means that the cultivar with the highest proportion of available fiber (B2) may provide more energy for microorganisms and increase the synthesis of microbial protein in the rumen. The author also reports that bulky feeds, with a higher NDF content, have a higher proportion of the B2 fraction of CHOT, which, by providing energy more slowly in the rumen, can affect the efficiency of microbial synthesis and animal performance. This study identified an average value of 24.2% for the B2 fraction, being lower than that found by Mello et al. (2006), which obtained an average of 35.4%.

A significant difference ($P < 0.05$) was detected for fraction C, represented by indigestible neutral detergent fiber (NDFi) and defined as the undigested portion of the cell wall, with cultivar CTC2 presenting the highest content.

The differences in the values of fraction C are related to the levels of lignin present in the plant. This variation provides important differences for the selection of a cultivar, since fraction C is associated with the greater or lesser digestibility of fibrous carbohydrates. Therefore, the higher the level of fraction C, the lower the digestibility of the fiber and the lower the utilization of the food, when intended for animal feed.

For the productive characteristics (Table 7), green matter production (PMV), dry matter production (PMS), broth production efficiency (EPC) and broth production (PC), a difference was observed ($P < 0.05$), with the cultivar CTC9004M presenting the best productive indices of PMV, PMS and PC, standing out compared to other cultivars in terms of forage potential and animal nutrition due to its greater production capacity.

The PMV and PMS variables are important for selecting sugarcane cultivars for animal nutrition, as they represent the amount of roughage available per area, demonstrating the productive efficiency of each cultivar. Thus, the higher the productivity of the cultivar, the greater the biomass availability, resulting in greater feed availability per area. The higher the productivity, the greater the number of animals that can be fed on the same area of sugarcane cultivation, or the greater the number of animals that can be maintained for a longer period on the same area of sugarcane cultivation. This is an advantage in the selection of the CTC9004 cultivar for ruminant nutrition.

The variables juice production efficiency (BPE) and juice production (BPP) directly affect the availability of soluble sugars, which, in turn, is the main source of energy for sugarcane, as the juice contains the soluble sugars. Thus, the CTC9004M cultivar stands out as the cultivar with the highest production efficiency among the other cultivars. This is a highly relevant factor for selecting and choosing this cultivar for production and nutritional purposes, as the higher the juice production, the greater the energy or TDN contribution to ruminant nutrition, resulting in improved animal performance.

The PMV values were lower than those of Silva et al. (2004) and Bonomo et al. (2009), who observed 122.12 t ha^{-1} and 146.15 t ha^{-1}, respectively. The average PMV value among the cultivars analyzed was 79.85 t ha^{-1}. However, these authors worked under different climate, soil, and plant density conditions. The lower values observed in the present study may be mainly due to the low rainfall that occurred during the experimental period, especially during the dry periods, and the low temperature during the coldest months of the year, which coincides with the months of lowest rainfall.

According to Conab (2019), the estimated productivity for the 2019/2020 national sugarcane harvest is 75.78 t ha^{-1}, for the Northeast region the estimated productivity for this same harvest is 58.82 t ha^{-1} and for the state of Bahia the estimated productivity is 47.00 t ha^{-1}. Thus, the productivity obtained in this work was higher than the average productivity estimated by (Conab, 2019) at national, regional and state levels.

According to Magro et al. (2011), temperature greatly influences stem growth. Growth becomes erect at temperatures below 25 °C. Below 20 °C, growth is practically non-existent. In terms of maximum temperature, growth is slow above 35 °C and non-existent above 38 °C. The optimal temperature range for stem growth is between 25 °C and 35 °C in the months of April, May, June, and July 2018 and 2019 (Fig. 5). In these months, the average temperature obtained was below 25 °C, with an average temperature of 20.1 °C, leading to a reduction in the productive potential of the analyzed cultivars.

Doorenbos & Kassam (1979) report a variation range for water demand of sugarcane crops, where they state that the crop's water requirement is between the variation range of 1,500 mm and 2,500 mm; Farias et al. (2008), evaluating the water use efficiency of sugarcane cultivated in the Tabuleiros Costeiros region, in the municipality of Capim-PB, found that maximizing the efficient use of water for the variety SP 79-1011 can be obtained with a depth of 1,276 mm per annual cycle.

Silva et al. (2011, 2012), in a study carried out on ratoon sugarcane irrigated by furrows under the semiarid conditions of the Sub-middle São Francisco Valley, found a water requirement of 1,695.1 mm for the RB92579 variety in an annual cycle. In this work, the precipitation obtained during a one-year vegetative cycle was 732 mm and during the entire 18-month vegetative cycle was 1261 mm, being lower than the precipitation recommended for the ideal development of the crop.

According to Doorenbos & Kassan (1979), sugarcane yields produced under rainfed conditions in the humid tropics range from 70 to 100 t ha^{-1}, and in the dry tropics and subtropics, with irrigation, yields between 100 and 150 t ha^{-1}, which can be considered satisfactory. According to Veiga et al. (2006), the productivity of this crop in Brazil, in the period from 1970 to 2004, increased significantly, ranging from 46.23 t ha^{-1} in the 1970/71 harvest to 73.88 t ha^{-1} in the 2004/05 harvest.

The average value obtained for the juice production efficiency was 40.09% of EPC (Table 7), this value is much lower than the juice production efficiency obtained by the industry, which reaches values close to 80%. This can be explained by the extraction process, whose technological industry for extracting sugarcane juice is advanced, where high extraction efficiency equipment is used, such as chopping knives, shredders, hoppers with several compression rollers, in addition to the use of diffusion for extracting sugarcane juice, which has an even higher extraction efficiency than the pressing process.

Table 7. Productive characteristics and production efficiency of sugarcane cultivars harvested 18 months after planting, in the Encruzilhada region, Bahia

Variables	Regional	RB 855536	RB 867515	CTC2	CTC 9001	CTC 9004M	Average	CV (%)
PMV ($t\ ha^{-1}$)	72.9^{cd}	62.1^{d}	79.4^{bc}	89.1^{ab}	81.9^{abc}	93.6 ^{a}	79.8	6.7
PMS ($t\ ha^{-1}$)	18.2^{bc}	15.0^{c}	21.8^{ab}	22.0^{ab}	21.8^{ab}	23.4 ^{a}	20.4	8.7
EPC (%)	40.5^{ab}	40.4^{ab}	34.1^{b}	42.0^{a}	41.5^{ab}	42.0^{a}	40.1	8.6
PC ($t\ ha^{-1}$)	29.4^{c}	21.2^{d}	31.9^{bc}	37.3^{ab}	33.9^{abc}	39.3^{a}	32.2	8.7

Means followed by the same lowercase letter in a row do not vary according to *Tukey's test* at the 5% probability level. PMV: green matter yield ($t\ ha^{-1}$); PMS: dry matter yield ($t\ ha^{-1}$); EPC: juice production efficiency (PC); JP: juice yield ($t\ ha^{-1}$).

In this work, the extraction process was carried out through pressing with a simple hopper that has only one compression roller, thus the extraction process becomes limited and less efficient, generating the data obtained for juice production efficiency and juice production.

There was a difference ($P < 0.05$) for the variable NDT production and for the production of non-fibrous carbohydrates $t\ ha^{-1}$, where the cultivar CTC9004M showed higher production for two variables with 13.54 $t\ ha^{-1}$ for PNDT and 12 $t\ ha^{-1}$ for the production of non-fibrous carbohydrates (Table 8).

Table 8. Productive characteristics of crude protein, total digestible nutrients and non-fibrous carbohydrates of sugarcane cultivars harvested 18 months after planting, in the Encruzilhada region - Bahia

Variables	Regional	RB 855536	RB 867515	CTC2	CTC 9001	CTC 9004M	Average	CV (%)
PPB ($t\ ha^{-1}$)	0.7^{a}	0.5^{a}	0.8^{a}	0.73^{a}	0.7^{a}	0.8^{a}	0.7	17.2
PNDT ($t\ ha^{-1}$)	9.7^{ab}	8.2^{b}	12.8^{ab}	12.9^{ab}	12.6^{ab}	13.5^{a}	11.6	18.9
PCNF ($t\ ha^{-1}$)	8.8^{bc}	7.5^{c}	11.7^{ab}	11.3^{ab}	11.1^{ab}	12.0^{a}	10.4	12.9

Means followed by the same lowercase letter in a row do not vary according to Tukey's test at the 5% probability level. PMS: dry matter production; PPB: crude protein production; PNDT: total digestible nutrient production; PCNF: non-fibrous carbohydrate production.

These components are important for the use of the crop for forage purposes, as NDT and CNF are the representation of the energy components of a food, therefore, the greater its production, the greater the energy availability is obtained, thus leading to an increase in animal production per area, that is, greater productive efficiency, with energy being one of the main constituents of animal feed and a performance limiter, therefore the CTC9004M cultivar becomes more efficient for the production of energy per area, being able to provide greater animal productivity.

No significant differences ($P > 0.05$) were observed for protein yield ($t\ ha^{-1}$). The low CP production can be explained by the low percentage of CP that the crop provides and the same applies to the PCNF, this variable in turn presents in large quantities, since the crop presents a high percentage of CNF.

Table 9 presents the data on morphometric characteristics, where the variables leaf length, leaf width, green leaf matter production, stem diameter and leaf area showed differences ($P < 0.05$). For the variables plant height, number of tillers, number of leaves per tiller, green stem matter production, °BRIX/Plant, leaf dry matter production (PMSF) and stem dry matter production, there was no difference ($P > 0.05$).

For stem diameter there was a difference ($P < 0.05$) where the cultivars CTC9001 and Regional obtained higher averages, being equal to each other and higher than the other cultivars, with averages of 31.0 mm and 30.2 mm.

Table 9. Morphometric characteristics of different sugarcane cultivars 18 months after planting, in the Encruzilhada region - Bahia

Variables	Regional	RB8 55536	RB 867515	CTC2	CTC 9001	CTC 9004M	Average	CV (%)
ALT (cm)[1]	335.9^{a}	334.06^{a}	343.2^{a}	352.8^{a}	363.7^{a}	352.9^{a}	347.1	4.1
NP[2]	8.0^{a}	9.2^{a}	9.0^{a}	10.0^{a}	9.0^{a}	9.5^{a}	9.1	11.3
NFP[3]	3.3^{a}	3.5^{a}	3.3^{a}	3.0^{a}	3.5^{a}	4.0^{a}	3.4	14.6
COMF (cm)[4]	159.9^{a}	151.2^{ab}	139.4^{b}	157.4^{a}	165.9^{a}	160.5^{a}	155.7	5.0
LF (mm)[5]	39.8^{abc}	36.3^{bc}	43.3^{ab}	35.7^{c}	44.9^{a}	41.8^{abc}	40.2	8.2
PMVF (g)[6]	329.8^{ab}	361.3^{ab}	270.0^{b}	433.0^{a}	431.5^{a}	406.8^{ab}	372.1	16.7
DC (MM)[7]	30.2^{a}	25.2^{c}	26.1^{bc}	26.8^{bc}	31.0^{a}	28.8^{ab}	28.0	5.3
PMVC (g)[8]	6,701.3^{a}	6,303.0^{a}	7,173.8^{a}	9,291.0^{a}	9,341.0^{a}	8,300.0^{a}	7851.7	17.9
°BRIX/Plant[9]	21.3^{a}	21.5^{a}	21.8^{a}	22.0^{a}	20.3^{a}	21.3^{a}	21.3	4.7
PMSF (g)[10]	129.0^{a}	117.0^{a}	122.6^{a}	128.8^{a}	156.5^{a}	134.9^{a}	131.5	18.6
PMSC (g)[11]	1,574.7^{a}	1,526.4^{a}	1,952.3^{a}	2,303.5^{a}	2,445.6^{a}	2,045.2^{a}	1,974.6	19.4
AF (cm^2)[12]	2,455.1^{bc}	2,260.5^{c}	2,373.1^{c}	2,106.2^{c}	3,079.2^{a}	3,015.5^{ab}	2,548.3	10.9

Means followed by the same lowercase letter in a row do not vary according to *Tukey's test* at the 5% probability level. ALT = plant height; NP = number of tillers; NFP = number of leaves per tiller; COMF = leaf length; LF = leaf width; PMVF = green leaf matter production; DC = stem diameter; PMVC = green stem matter production; PMSF = leaf dry matter production; PMSC = stem dry matter production; AF = leaf area.

The average values obtained for stem diameter are in agreement with Silva et al. (2004), Silva et al. (2008), and Reis (2010), who, evaluating first-cut varieties, with a spacing of 1.5 m between rows, obtained stem diameters of 25.6, 24.7 and 29.6 cm as the average of the varieties evaluated, respectively. The average value of stem diameter in this work was 28.0 cm.

The diameter of the stalk is directly related to the accumulation of sucrose. Research into sugarcane improvement has sought to produce stalks with smaller diameters and higher sucrose and soluble carbohydrate contents in cultivated varieties, to facilitate harvesting and provide high nutritional value (soluble carbohydrates) (Ripoli et al., 2006).

For the leaf length variable (COMF) there was a difference ($P < 0.05$) where the cultivars CTC9001, CTC9004M, Regional and CTC2 obtained equal averages among themselves and higher than the cultivars RB 855536 and RB 867515, where the cultivar CTC9001 had the highest average of 165.9 cm and the cultivar RB 867515 obtained the lowest average of 139.4 cm.

According to Scarpari & Beauclair (2008), the length of the sugarcane leaf in the adult phase can vary from 50 cm and reach 150 cm, data similar to those verified in this experiment, where the average leaf length among the cultivars studied was 155.7 cm.

For the leaf width variable, there was a statistical difference ($P < 0.05$), the cultivar CTC9001 obtained the highest average, being superior to the other cultivars, presenting an average of 44.9 mm. According to the authors Scarpari & Beauclair (2008), the width of the sugarcane leaf in the adult phase can vary from 25 mm and reach 100 mm, always depending on the variety, Segato & Carvalho (2018) obtained an average value of 45 mm, these data corroborate the data obtained in this work, where the average value for leaf width was 41.8 mm.

The variable production of green leaf matter showed a difference ($P < 0.05$), the cultivars CTC2 and CTC9001 obtained statistically equal averages between them 433.0 and 431.5 g, respectively, the cultivar RB 8671515 obtained a lower average of 270.0 g. These data can be explained by the possible influence of the genotype on the proportion of final leaves, where it can be observed that the cultivars CTC obtained higher averages in relation to the cultivars RB and regional, belonging to different genealogies.

Analysis of variance revealed a significant effect on leaf area ($P < 0.05$), the cultivar CTC9001 obtained a higher average, being superior to the other cultivars with an average of 3,079.2 cm^2, this data can be explained by the influence of the leaf length and leaf width on the leaf area, since the cultivar CTC9001 obtained a higher average of leaf length and leaf width, providing the same larger leaf area.

Larger leaf area provides greater light interception, greater photosynthetic capacity and greater accumulation of biomass and sugars in the stalk. Indirectly, wider and longer leaves indicate greater potential for forage production per hectare.

Correlating morphometric characteristics with nutritional composition, older leaves contain more fiber (NDF, ADF, lignin) and a lower concentration of soluble carbohydrates. Thus, more developed leaves (long/wide) can increase the share of the leaf fraction in the plant, increasing the fiber content of the forage and consequently decreasing digestibility, leading to a reduction in voluntary intake due to rumen filling, directly impacting animal performance. Stems are richer in soluble sugars, thus providing more energy.

CONCLUSIONS

The cultivars have similar chemical and bromatological composition, agronomic characteristics, and growth behavior. The CTC9004M cultivar demonstrated superior production efficiency, making it the most suitable option for forage use in semiarid conditions. Future studies should evaluate animal performance directly using these cultivars in feeding trials.

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