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Agronomic and bromatological characteristics of Cassava cultivars

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Abstract. The aim of this study was to evaluate the potential of the aerial part of cassava, analyzing its development and nutritional value, in addition to the production of biomass at different times and with different management. A randomized complete block design was used, with six cassava varieties (BRS Formosa, BRS Mulatinha, Eucalyptus, BRS White Pot, BRS Kiriris and BRS New Horizon) and five replicates, harvested six and twelve months after planting, with and without pruning. To evaluate the amount of biomass produced by the aerial part of cassava and the production of roots, a 6×2 factorial scheme in randomized complete blocks design was conducted. Six cassava varieties were tested, each with five replicates. The plants were harvested at two different times: with pruning (harvesting at six and twelve months after planting) and without pruning (single harvest at twelve months). There was an effect for the characteristics plant height, stem diameter, number of stems, number of leaves, lobe length, lobe width and petiole length, however when they were evaluated at twelve months, there was no effect, only for the characteristics lobe length and petiole length. It was found that there was an effect for dry matter, ether extract, hemicellulose and ADF. The BRS White Pot variety presented a higher concentration of non-fibrous carbohydrates. Differences were observed for neutral detergent fiber corrected for ash and protein and lignin. For the values of total digestible nutrients, the cultivars BRS White Pot, BRS New Horizon and BRS Formosa stood out in relation to the others. There was a difference in the protein fractionation of the different cassava cultivars for total nitrogen fraction, fraction A and fraction C when they were harvested six months after planting. However, when they were evaluated at twelve months, there was only an effect for fraction C. There was an effect for CT, fraction A+B1, fraction B2 and fraction C when they were evaluated six months after planting. However, when they were evaluated twelve months after planting there was no difference for total carbohydrates and fraction B2. The interaction was not significant between the different cultivars and pruning management for the production of green matter, dry matter, crude protein, total digestible nutrients of the aerial part and green matter and dry matter of the roots. In management without pruning, there was an increase in the variables PGMPA, PDMPA, PCPPA and PTDNPA. The cultivars BRS Mulatinha and BRS New Horizon are recommended as they present greater leaf retention and number of stems, providing greater biomass production when managed without pruning.

Key words: aerial part, *Manihot esculenta*, productivity, varieties.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) stands out as one of the staple crops in tropical and subtropical regions, playing a fundamental role in global food security. Currently, it is estimated that more than 800 million people depend on cassava as their main source of income, predominantly in developing countries (FAO, 2023). Cassava's wide geographic distribution is a direct reflection of its unique agronomic characteristics. Its hardiness, which gives it resistance to challenging environments, combined with its remarkable adaptability to diverse soil and climate conditions, allows it to establish itself in regions where other crops would have difficulty. Furthermore, its ability to produce reasonable yields in low fertility soils and reduced demand for agricultural inputs are factors driving its widespread adoption (Amelework et al., 2022).

Considered a strategic crop for rural subsistence, cassava is mostly cultivated by small producers, especially in regions such as the Brazilian Northeast, where the comprehensive use of the roots and aerial parts is made for both human and animal consumption (Borku et al., 2025). This versatility, which minimizes waste, is amplified by the growing recognition of the potential of the aerial part as forage. Forage production from cassava has gained relevance due to its ability to supply animal feed in periods of pasture scarcity, in addition to transforming previously underutilized byproducts into a valuable resource (Kongsil et al., 2024).

In addition to the direct consumption of its roots, cassava has great industrial versatility, being a raw material for the production of starch, flour, modified starches, paper, cardboard, biofuels, alcohol, and adhesives, among others (Brunerová et al., 2018). This diversification of uses reinforces its economic and social importance, promoting the development of regional production chains.

Traditionally, only a fraction of the aerial part of the plant is used for the production of cuttings, intended for vegetative propagation, while the remainder is often discarded, representing a potential for use in animal feed and biomass production. Recent studies highlight the high protein content of cassava leaves, ranging from 23.2 to 35.9% crude protein, which justifies their inclusion in animal diets, especially in integrated production systems (Tinini et al., 2021).

Morphoagronomic characterization and plant growth monitoring are essential tools for the identification and selection of promising genetic materials, contributing to the decision-making of farmers and researchers in choosing more productive and adapted cultivars (Pinheiro et al., 2021).

Although pruning in cassava crops can temporarily reduce root production and carbohydrate content, it is a viable strategy for obtaining propagation material and forage production, especially when carried out in appropriate periods and conditions (Schoffel et al., 2024). Factors such as pruning season, climatic conditions, cultivar type and production purpose must be carefully evaluated to maximize the benefits of this technique (Schoffel et al., 2024). Therefore, this study aimed to evaluate the agronomic and bromatological characteristics of cassava cultivars.

MATERIALS AND METHODS

The experiment was conducted at Fazenda Bela Vista, in the municipality of Encruzilhada, Brazil - Bahia, located at 15°31'53" south latitude, 40°34'54" west longitude, at an altitude of 840 m, lasting twelve months (November 16, 2016 to November 16, 2017).

An area of 1,000 m^2 was delimited, where 20 composite soil samples were taken from a depth of 20 cm, and after homogenization, one sample was used for analysis (Table 1).

Table 1. Soil chemical analysis

	mg dm^{-3}				Cmol$_c$ dm^{-3} of soil				%
pH	P	K	Ca	Mg	Al	H	SB	T	V
4.7	1.0	0.1	1.0	0.8	0.8	5.6	1.9	6.5	23.0

SB: Sum of bases; T: pH cation exchange capacity; V: base saturation.

Based on the soil analysis, a recommendation was made for liming and fertilization, with 300 kg of limestone being added and, after 60 days, at planting, fertilization with 30 g of simple superphosphate + ½ L of cattle manure per hole. And as a top dressing, another ½ L of cattle manure per hole plus 24 g of potassium chloride.

Each plot measured 5.0 m long by 4.0 m wide. The plots corresponding to each block were demarcated in the experimental area. The planting spacing used was 0.90 m between rows and 0.80 m between plants, with 5 plants/row, 25 plants per plot, totaling 750 plants.

The soil was plowed, harrowed, and the cuttings were obtained from healthy plants, originating from the National Center for Cassava and Fruit Research of the Brazilian Agricultural Research Corporation, located in Cruz das Almas, BA, aged approximately 18 months and planted immediately after collection and distributed in holes. The cassava cuttings were planted on November 16, 2016, and weed control was carried out by manual weeding whenever necessary. The following cultivars were evaluated:

BRS Kiriris; BRS Mulatinha; BRS White Pot; BRS Formosa: Eucalyptus; BRS New Horizon.

Morphometric characteristics

To evaluate the morphometric characteristics of the aerial part of cassava, a randomized block design (RBD) was used, consisting of six cultivars (BRS Formosa, BRS Mulatinha, Eucalyptus, BRS White Pot, BRS Kiriris and BRS New Horizon) and 5 replicates, with only the Eucalipto and Kiriris cultivars being considered as table cassava (soft) harvested six and twelve months after planting.

The following variables were evaluated for three plants per plot of each cultivar marked with three different colored cords (red, blue and brown) from the useful area drawn within each treatment for evaluation of morphometric measurements:

a) Plant height: from ground level to the tip of the plant using a tape measure;

b) Stem diameter: measuring the diameter of the stem at 20 cm from the ground in, using a graduated caliper;

c) Number of stems per plant: count the number of stems per plant;

d) Number of leaves: count the number of leaves per plant;

e) Number of lobes: counting the number of lobes per plant;
f) Lobe length: from the insertion point of the central lobe using a graduated ruler;
g) Lobe width: from the widest part of the central lobe
h) Petiole length: from the middle third of the plant.

At six months (May 16, 2017) and twelve months (November 16, 2017), the aerial part was pruned to 10 cm from the ground and the roots of all cultivars were harvested, however, only from 15 plants in each plot. The samples were weighed and approximately 300 grams of the aerial part were obtained and then crushed and homogenized.

Production of biomass from aerial parts and roots

To evaluate the biomass production of the aerial part of cassava and root production, a 6×2 factorial scheme in randomized blocks was used, with six cultivars (BRS Formosa, BRS Mulatinha, Eucalyptus, BRS White Pot, BRS Kiriris and BRS New Horizon) and two harvest times: with pruning (harvested six and twelve months after planting) and without pruning (a single pruning harvested twelve months) and 5 replicates.

After harvesting, the following characteristics of the aerial part and roots of the different cassava cultivars were evaluated:

a) green matter production (t ha^{-1}) of the aerial part
b) Dry matter production (t ha^{-1}) of the aerial part
c) Crude protein production (t ha^{-1}) of the aerial part
d) Total digestible nutrient production (t ha^{-1}) of the aerial part
e) e) Tuberous root productivity – weight of all tuberous roots produced, expressed in t ha^{-1};
f) Productivity of aerial part – weight of the entire plant;
g) g) Dry mass of roots: obtained by weighing 300 grams of fresh roots, subjected to a temperature of 60 °C in an oven for 72 hours (until the dry weight stabilizes)
h) Dry mass productivity: obtained by multiplying the percentage of dry mass by the productivity of tuberous roots.

Chemical analysis bromatological composition

The samples of the aerial part and roots of cassava were identified, weighed and placed in an oven with forced ventilation at (55 °C for 72 h) to determine the pre-dry matter. After pre-drying, the samples of the aerial part were ground in a Willey type mill on sieves with 2 mm screens.

The analyses of the aerial part of cassava were determined according to the methodologies described by Detmann et al. (2021). The analysis of dry matter (DM; INCT-CA Method g-003/1), crude protein (CP; 152 (total nitrogen x 6.25) (INCT-CA Method N-001/1), neutral detergent fiber (NDF) (INCT-CA Method F-002/1), acid detergent fiber (ADF) (INCT-CA Method F-004/1), lignin (H_2SO_4 72% w/w) contents was performed. For NDF analysis, samples were treated with thermostable α-amylase without the use of sodium sulfite, corrected for ash residue (CIDN; INCT-CA Method M-002/1) and nitrogen compounds (NIDN; INCTCA Method N-004/1).

For protein fractionation, the components were obtained through the methodologies described by Licitra et al. (1996) and Fox et al. (2004), aiming to obtain the following fractions: non-protein nitrogen (A), true protein with rapid and intermediate enzymatic degradation (B1 + B2), true protein that presents slow enzymatic degradation (B3) and indigestible protein (C), comprised of the nitrogen determined in the acid detergent fiber (ADF) residue and multiplied by the correction factor 6.25.

The methodology for determining total carbohydrates (TC) was that of Sniffen et al. (1992), according to the formula: CHT = 100 – (PB + EE + MM); non-fibrous carbohydrates (NFC) corresponding to fractions 'A + B1' were estimated by the formula: NFC = 100 – (PB + NDFcp + EE + MM), in which NDFcp corresponds to the NDF corrected for ash and protein content; fraction B2 was the result of the difference between NDFcp and the indigestible fiber fraction (C); fraction C, which represents indigestible fiber, was estimated by multiplying the percentage value of the lignin fraction by a factor of 2.4.

The observed total digestible nutrient content (TDN) was obtained from the summative equation: TDN = PBD + 2.25 · EED + DNFcpD + CNFD, where PBD, EED, DNFcp and CNFD mean, respectively, digestible crude protein, digestible ether extract, digestible neutral detergent fiber (free of ash and protein) and digestible non-fibrous carbohydrates according to NRC (2001).

Statistical analysis

The data were subjected to analysis of variance and *Tukey's test* with the critical level of probability of type I error set at 0.05.

RESULTS AND DISCUSSION

Growth characteristics

There was a significant difference ($P < 0.05$) between cultivars in several characteristics evaluated at six months: plant height, stem diameter, number of stems, number of leaves, lobe length, lobe width and petiole length. However, at 12 months, only the lobe and petiole length maintained significant differences between cultivars (Table 2).

The cultivar BRS New Horizon stood out in plant height, reaching 2.2 m at six months and 2.3 m at twelve months, surpassing the other cultivars (Table 2). The ideal height of cassava plants is a complex factor, influenced by the cultivar and favorable climatic conditions. Taller plants, although they facilitate management and cultural treatments, are more susceptible to lodging, which can make harvesting difficult, as pointed out by Martins & Archangelo (2023). It is worth mentioning that there is still no consensus in the literature on the ideal size of cassava plants (Gomes et al., 2007).

Furthermore, the BRS New Horizon cultivar demonstrated a larger stem diameter ($P < 0.05$), with 1.8 cm at 6 months and 1.93 cm at 12 months, standing out from the others (Table 2). A larger stem diameter is related to plant growth and variety type (Costa et al., 2022). Cultivars with larger diameters may indicate that their stem cuttings have larger nutrient reserves, which favors a more robust initial plant development.

Additionally, BRS New Horizon also stood out in the number of stems and number of leaves per plant ($P < 0.05$), presenting higher values than the other cultivars at both 6 and 12 months (Table 2).

The cultivars that presented a greater number of leaves are probably related to the greater accumulation of starch in the roots and the decrease in leaves during the colder months, resulting in the fall of existing leaves. According to Rós et al. (2011), cassava cultivars that have only one stem and do not branch facilitate implantation in smaller spacings, which increases yield and reduces the time for crop closure. Cultivars that have only one stem and branch have low yields and require denser spacing. Therefore, the greater the spacing, the greater the ease with which they develop their branches and demonstrate their capacity to produce photoassimilates.

There was no difference ($P > 0.05$) for the number of lobes characteristic when evaluated at six months, presenting an average of 4.7 cm; however, when evaluated at twelve months, there was an effect ($P < 0.05$) and the BRS Kiriris cultivar presented the highest value of 5.3 cm, differing from the other cultivars evaluated (Table 2). According to Alves et al. (2021), the cassava leaf blade is split, originating from three to eleven lobes, with this number varying mainly due to environmental factors, especially humidity.

Table 2. Growth characteristics of different cassava cultivars in the Encruzilhada region, Bahia

Variables	Cultivars BRS New Horizon	Eucalyptus	BRS Formosa	BRS Kiriris	BRS Mulatinha	BRS White Pot	Average	CV %
6 months								
Height (m)	2.2 a	1.8 b	1.4 c	1.9 ab	1.8 ab	1.8 b	1.8	9.7
Diameter (cm)	1.8 a	1.1 bc	1.1 bc	1.3 bc	1.3 bc	1.4 b	1.3	12.3
Nº of rods	11.4 a	2.7 c	2.7 c	3.7 bc	7.1 b	0.8 c	4.3	14.3
Nº of leaves	66.2 a	19.7 c	19.7 c	29.7 bc	44.0 b	20.6 c	32.7	25.4
Nº of lobes	3.9 a	4.8 a	4.8 a	4.9 a	4.7 a	4.7 a	4.7	14.5
Lobe length (cm)	19.0 ab	15.6 bc	15.6 bc	18.7 ab	13.6 c	19.8 a	17.6	10.7
Lobe width (cm)	4.6 b	3.7 b	3.7 b	5.7 a	4.2 b	5.8 a	4.7	9.8
Petiole length (cm)	24.8 b	18.9 b	27.8 ab	23.4 b	20.5 b	35.8 a	25.2	20.4
12 months								
Height (m)	2.3 a	1.8 bc	1.6 c	2.1 ab	1.9 abc	2.1 ab	1.9	11.7
Diameter (cm)	1.9 a	1.5 b	1.5 b	1.6 ab	1.7 ab	1.7 ab	1.6	10.7
Nº of rods	13.8 a	8.3 ab	6.2 b	8.3 ab	8.8 ab	5.0 b	8.4	41.9
Nº of leaves	105.2 a	46.8 b	41.7 b	50.4 b	67.7 ab	52.9 b	60.8	41.9
Nº of lobes	3.1 b	3.7 b	3.5 b	5.3 a	3.7 b	3.3 b	3.8	19.5
Lobe length (cm)	13.7 a	15.5 a	16.5 a	15.3 a	14.4 a	13.4 a	14.8	11.8
Lobe width (cm)	3.8 bc	2.8 c	3.7 bc	5.2 a	3.8 bc	4.1 ab	3.9	14.1
Petiole length (cm)	17.4 a	19.6 a	22.6 a	20.1 a	20.2 a	18.5 a	19.9	12.8

Averages, in the same row, followed by different letters, differ from each other by the *Tukey test* at 5% probability.

For the lobe length characteristic, when evaluated at six months, the cultivars that presented the greatest lengths were BRS White Pot with 19.8 cm, BRS New Horizon with 19.0 cm and BRS Kiriris 18.7 cm, standing out among the other cultivars evaluated. However, when they were evaluated at twelve months, there was no effect ($P > 0.05$) for lobe length, considering all cultivars equal (Table 2).

For the lobe width characteristic when evaluated at six months, the cultivars that presented the greatest width were BRS White Pot (5.8 cm) and BRS Kiriris (5.7 cm), being superior to the other cultivars (Table 2). At twelve months, the cultivar that presented the highest value ($P < 0.05$) was BRS Kirirs with 5.2 cm and the lowest was observed for the cultivar Eucalyptus with 2.8 cm (Table 2). The values of this characteristic may have increased due to the correlation between lobe length and width, as they can directly influence the photosynthetic rate of the plant.

The highest value ($P < 0.05$) for the petiole length characteristic was observed for the BRS White Pot cultivar with 35.8 cm, followed by BRS Formosa with 27.8 cm when evaluated at six months, differing from the others. At twelve months, there was no effect ($P > 0.05$) among the cultivars, presenting an average value of 19.9 cm. According to Tomich et al. (2008), the ideal petiole length of a leaf can reach up to 40 cm.

Bromatological composition

There was an effect ($P < 0.05$) for the contents of DM, CP, NFC, NDFcp, cellulose, lignin, ADF, ash and TDN when evaluated at six months. When evaluated at twelve months, there was an effect ($P < 0.05$) for the contents of DM, EE, NFC, hemicellulose, lignin, ADF and TDN (Table 3).

Table 3. Bromatological composition of cassava cultivars harvested at six and twelve months in the Encruzilhada-BA region

Variables	Cultivars						Average	CV %
	BRS New Horizon	Eucalyptus	BRS Formosa	BRS Kiriris	BRS Mulatinha	BRS White Pot		
6 months								
Dry matter (%)	18.4 ab	18.2 ab	17.1 b	20.5 a	18.1 ab	16.4 ab	18.1	7.5
Crude protein[1]	21.2 c	15.8 d	27.5 a	21.7 c	22.6 c	24.8 b	22.3	5.9
Ethereal extract[1]	5.1 a	4.4 a	5.5 a	5.1 a	5.1 a	4.9 a	5.0	10.1
CNF[1]	7.4 ab	6.7 ab	7.7 ab	6.2 ab	5.1 b	8.4 a	6.9	21.8
NDFcp[1]	59.9 b	65.3 a	51.7 c	60.9 ab	60.8 ab	54.4 c	58.8	4.3
Cellulose [1]	40.9 a	40.8 a	33.4 c	36.9 abc	39.6 ab	35.4 bc	37.8	6.9
Hemicellulose [1]	13.1 a	13.8 a	14.8 a	15.1 a	14.8 a	15.9 a	14.7	11.8
Lignin[1]	9.4 c	12.1 ab	10.3 abc	12.3 a	10.1 bc	8.6 c	14.1	10.5
ADF[1]	54.9 b	58.9 a	48.6 c	55.4 ab	54.7 b	48.1 c	53.4	3.7
Gray[1]	6.3 ab	7.7 a	7.6 ab	6.2 b	6.5 ab	7.5 ab	6.9	10.7
NDT[1]	59.1 a	50.7 c	58.1 a	53.1 bc	57.6 ab	60.7 a	56.8	3.9
12 months								
Dry matter (%)	24.8 a	21.2 ab	22.0 ab	24.8 a	24.6 a	19.3 b	22.7	8.3
Crude protein[1]	15. 8 a	16.5 a	17.7 a	17.1 a	14.7 a	16.6 a	16.4	12.0
Ethereal extract[1]	2.1 ab	2.1 ab	2.5 a	1.6 b	2.4 a	2.2 ab	2.1	19.2
CNF[1]	12.2 ab	11.7 ab	14.1 ab	10.6 b	15.6 a	14.2 ab	13.1	16.1
NDFcp[1]	64.9 a	63.4 a	60.5 a	65.6 a	62.6 a	61.5 a	63.1	5.6
Cellulose [1]	35.6 a	38.9 a	33.6 a	40.1 a	32.8 a	38.5 a	36.6	12.8
Hemicellulose [1]	18.7 a	13.4 bc	18.2 ab	11.4 c	15.1 abc	13.3 bc	15.0	18.0
Lignin[1]	16.6 ab	18.5 a	16.1 ab	18.5 a	15.7 ab	15.3 b	16.8	9.2
ADF[1]	53.7 a	58.9 a	50.9 a	61.6 a	53.6 a	55.7 a	55.7	5.8
Gray[1]	4.9 a	6.2 a	5.3 a	5.2 a	4.8 a	5.5 a	5.3	14.4
NDT[1]	50.9 ab	48.1 b	52.1 a	48.1 b	53.6 a	53.4 a	51.2	3.5

Means, in the same row, followed by distinct letters, differ from each other by the *Tukey test* at 5% probability; CNF[1]: non-fibrous carbohydrates; NDFcp[1]: neutral detergent fiber corrected for ash and protein; ADF[1]: acid detergent fiber; TDN1: total digestible nutrients;

The percentage of DM found in the present study was reduced due to the age of the plants, as they were pruned six months after planting, being in full development, presenting a higher moisture content, thus reducing the DM content. Moreira et al. (2017), working with different cassava cultivars with pruning performed six months after planting, found 21.07% for the dry matter variable in the municipality of Vitória da Conquista.

For the PB variable, the BRS Formosa cultivar presented 27.5%, being higher ($P < 0.05$) than the other cultivars, followed by BRS White Pot with (24.8%) when evaluated at six months (Table 3). At twelve months there was no difference ($P > 0.05$) between the cultivars evaluated, obtaining an average of 16.4% CP.

The higher PB content for BRS Formosa can be explained by the higher leaf/stem ratio in relation to the other cultivars. And it was precisely in the leaves where the highest crude protein content was observed throughout the plant (Table 3). Moreira et al. (2017) working with different cassava cultivars obtained 19.4% crude protein from the aerial part with pruning performed six months after planting. While Fernandes et al. (2016), working with eight genotypes in the municipality of Planaltina-DF, found an average of 10.9% PB for the aerial part, with pruning performed at 18 months.

No difference ($P > 0.05$) was observed for ethereal extract when evaluated at six months, presenting a general average of 5% (Table 3). However, at twelve months differences were observed ($P < 0.05$) where the cultivars BRS Formosa and BRS Mulatinha presented higher percentages of 2.5 and 2.4%, respectively (Table 3). Curcelli (2013) also did not find differences between cultivars, however they obtained values lower than 1.8. According to this author, this result may be due to the extraction method, since when using petroleum ether, compounds such as vitamins A and D, waxes, and chlorophyll are present in the leaves and are censored when extracted, which may overestimate the values. The cultivars BRS Mulatinha and BRS Formosa showed good leaf production, which increases the percentage of ethereal extract due to the greater amount of waxes and pigments.

For the non-fibrous carbohydrates variable, the BRS White Pot cultivar presented the highest content ($P < 0.05$) with 8.4%, followed by BRS Mulatinha with 5.1% when evaluated six months after planting (Table 3). For plants evaluated twelve months after planting, the cultivar BRS Mulatinha presented 15.6% (Table 3). These variations are due to environmental differences, varieties and the time of harvesting of the material.

Differences ($P < 0.05$) were observed for neutral detergent fiber corrected for ash and protein for the cultivars evaluated six months after planting, where Eucalyptus, BRS Kiriris and BRS Mulatinha presented higher values (Table 3). When evaluated at twelve months, there was no difference ($P > 0.05$) between cultivars, with an average of 63.1% (Table 3). It can be seen that fiber contents increase with the increase in the interval between pruning, due to plant development and greater concentration of lignin in the stems.

For cellulose content, the cultivars BRS New Horizon and Eucalyptus were superior ($P < 0.05$) with 40.9 and 40.8%, respectively, in relation to the other cultivars when evaluated six months after planting. Twelve months after planting, there were no differences, with an average of 36.6% (Table 3).

No differences ($P > 0.05$) were observed for hemicellulose, with an average of 14.7% when evaluated six months after planting (Table 3). However, when they were evaluated at twelve months, they presented differences ($P < 0.05$) and the cultivar BRS New Horizon presented 18.7% (Table 3).

For the lignin variable, differences ($P < 0.05$) were observed between the cultivars evaluated at six months and twelve months after planting, where 12.3% was obtained for the BRS Kiriris cultivar at six months and 18.5% for the Eucalyptus and BRS Kiriris cultivars (Table 3).

For the variable acid detergent fiber (ADF), a difference ($P < 0.05$) was observed between the cultivars, and the Eucalyptus cultivar presented 58.9% when evaluated six months after planting (Table 3). The cultivars evaluated at twelve months did not show differences ($P > 0.05$) with an average value of 55.7% (Table 3). Moreira et al. (2017), evaluating the chemical-bromatological composition of cassava as a function of the interval between prunings, working with different cultivars, reported values of 51.4% when the plants were pruned after twelve months, values close to those found in the present work. The increase in ADF promotes a reduction in the energy value and lower digestibility of the food, since acid detergent fiber is a direct indicator of forage quality.

For ash content, six months after planting, the Eucalyptus cultivar presented the highest ($P < 0.05$) percentage with 7.7%, being higher than the Kiriris variety with 6.2% (Table 3). Curcelli (2013) evaluated cassava plant pruning times for use in animal feed and obtained an average of 6.94%, that is, he found no differences for the ash variable when evaluating the aerial part of the cassava. No differences were observed ($P > 0.05$) when they were evaluated at twelve months, with an average of 5.3% (Table 3). Thus, this difference can be explained by the increased interval between pruning, probably related to the greater accumulation of dry matter in these plants, resulting from the dilution effect caused by the accumulation of starch.

For NDT values, the cultivars BRS White Pot, BRS New Horizon and BRS Formosa stood out in relation to the others with percentages of 60.7, 59.1 and 58.1% respectively, six months after planting. When the cultivars were evaluated twelve months after planting, BRS Mulatinha, BRS White Pot and BRS Formosa stood out in relation to the others with 53.6, 53.4 and 52.1% (Table 3). The higher value found in cultivars is due to the fact that cultivars present a higher concentration of ether extract (EE). Curcelli (2013) obtained an average of 52% NDT when the plants were harvested seven months after planting, a value close to that found in the present study. However, when they were evaluated 14 and 15 months after planting, the values were higher with 58.2 and 57.9% NDT.

Protein fractionation of the aerial part

There was a difference in the protein fractionation of the different cassava cultivars ($P < 0.05$) for total nitrogen fraction (TN), fraction A and fraction C when they were harvested six months after planting. However, when they were evaluated twelve months later, there was only an effect ($P < 0.05$) for fraction C (Table 4).

For the NT variable, a difference ($P < 0.05$) was observed between the cultivars, where the BRS Formosa cultivar presented 4.4%, followed by BRS Mulatinha with 3.6% and BRS White Pot with 3.1% when evaluated six months after planting (Table 4). However, when they were evaluated at twelve months, they showed no differences ($P > 0.05$) with an average value of 2.6% (Table 4). NT values followed those of PB, with the BRS Formosa cultivar presenting the highest concentration among the other cultivars.

Fraction A is represented by non-protein nitrogen (NNP) from the aerial part of cassava. It was found that there was a difference ($P < 0.05$), with the cultivar BRS Mulatinha standing out among the others with 38.4%, followed by BRS White Pot with 38.1% and BRS Kiriris with 36.2%. However, when they were evaluated at twelve months, no differences were found ($P > 0.05$), an average of 36.2% was obtained (Table 4). Fraction A is considered the largest fraction in relation to the other fractions, this result can be explained by ruminal nitrogen losses, if there is no synchronization between this fraction and available carbohydrates. These values are similar to those found by Azevedo et al. (2006), Modesto et al. (2004) and Peripolli et al. (2007) with 36.55, 34.9 and 36.66%, respectively.

No differences ($P > 0.05$) were observed for fraction B1+B2, when they were evaluated six months and twelve months after planting, obtaining an average of 29.4 and 24.8% respectively (Table 4). Fractions B1 and B2 were considered a single fraction according to Pires et al. (2009). The results found in the present study highlight BRS New Horizon with the highest portion of true protein (B1 + B2) in (%NT).

Table 4. Protein fractionation of the aerial part of cassava harvested six and twelve months after planting

Variables	Cultivars: BRS New Horizon	Eucalyptus	BRS Formosa	BRS Kiriris	BRS Mulatinha	BRS White Pot	Average	CV %
6 months								
NT (%DS)	3.4 c	2.5 d	4.4 a	3.5 c	3.6 bc	3.1 b	3.6	5.9
A (%NT)	31.9 ab	28.5 b	34.8 ab	36.2 a	38.4 a	38.1 a	34.7	10.1
B1+B2(%NT)	33.3 a	32.8 a	25.1 a	25.9 a	25.9 a	28.8 a	29.4	13.4
B3 (%NT)	14.5 a	15.9 a	15.6 a	14.1 a	14.4 a	13.3 a	14.7	14.6
C (%NT)	20.2 ab	22.7 a	23.7 a	23.7 a	17.7 b	19.8 ab	21.3	11.1
12 months								
NT (%DS)	2.5 a	2.6 a	2.8 a	2.7 a	2.4 a	2.7 a	2.6	12
A (%NT)	33.4 a	37.1 a	35.3 a	35.1 a	34.9 a	40.2 a	36.2	12.8
B1+B2(%NT)	26.5 a	19.4 a	21.8 a	28.7 a	29.9 a	22.5 a	24.8	22.1
B3 (%NT)	11.9 a	11.6 a	14.2 a	12.2 a	10.7 a	14.8 a	12.6	20.9
C (%NT)	28.2 ab	31.9 a	28.6 ab	23.1 b	24.5 b	22.6 b	26.5	12.5

DM = dry matter; NT = total nitrogen; B1+B2 = soluble protein of rapid ruminal degradation, peptides and oligopeptides; B3 = proteins of slow ruminal degradation; C = undegradable fraction. Means, in the same row, followed by different letters, differ from each other by the *Tukey test* at 5% probability

Fraction B3 showed no difference ($P > 0.05$) between the cultivars evaluated six and twelve months after planting, with an average of 14.7 and 12.6% respectively (Table 4). The low content of fraction B3 is explained by the early cutting of the plants, at this time the plant is still young, so the content of true slow-degrading protein is low, as this fraction is directly linked to the cell wall.

For the values of fraction C that is considered indigestible, the cultivars BRS Formosa, BRS Kiriris and Eucalyptus stood out in relation to the others with percentages of 23.7, 23.7 and 22.7% respectively six months after planting. When the cultivars were evaluated twelve months after Eucalyptus planting, BRS Formosa and BRS New

Horizon stood out in relation to the others with 31.9, 28.6 and 28.2% (Table 4). The higher value of fraction C can be explained by the higher lignin content in the cultivars, as the cultivars that presented higher values in this fraction will be highly resistant to microbial enzymes and indigestible throughout the gastrointestinal tract.

Carbohydrate fractionation of the aerial part

There was a difference ($P < 0.05$) for total carbohydrates (TC), fraction A + B1, fraction B2 and fraction C when they were evaluated six months after planting (Table 5). However, when they were evaluated twelve months later, there was no difference ($P > 0.05$) for TC and fraction B2 of TC (Table 5).

For the TC variable, a difference ($P < 0.05$) was observed between the cultivars, with the Eucalyptus cultivar presenting the highest value of 72.1% compared to the other cultivars when evaluated six months after planting. However, when evaluated twelve months later, there were no differences ($P > 0.05$), presenting an average of 76.2% (Table 5). The results obtained in this study are consistent with those observed by Novaes et al. (2016), which varied from 66.2% to 73.6% among cultivars. Although the carbohydrate percentages are similar after twelve months, during fractionation, the low lignin content of the Eucalyptus and BRS Formosa cultivars can positively influence the quality of the B2 fraction of the cultivars.

Table 5. Carbohydrate fractionation of the aerial part of cassava harvested six and twelve months after planting

Cultivars								
Variables	BRS New Horizon	Eucalyptus	BRS Formosa	BRS Kiriris	BRS Mulatinha	BRS White Pot	Average	CV %
6 months								
CT (%DM)	67.4 b	72.1 a	59.4 d	67.1 b	65.9 b	62.8 cd	65.8	2.1
A+B1(%CT)	11.1 a	9.3 ab	13.0 a	9.3 ab	7.8 b	13.4 a	10.7	22.6
B2 (%CT)	55.6 a	50.3 ab	45.1 b	46.5 ab	55.3 a	53.5 ab	51.1	10
C (%CT)	33.3 b	40.4 ab	41.9 ab	44.2 a	36.9 ab	33.1 b	38.3	11.8
12 months								
CT (%DM)	77.1 a	75.2 a	74.6 a	76.1 a	78.2 a	75.7 a	76.2	3.5
A+B1(%CT)	15.9 ab	15.6 ab	18.9 ab	13.9 b	19.9 a	18.7 ab	17.2	16.7
B2 (%CT)	47.8 a	43.1 a	44.7 a	45.3 a	46.4 a	47.3 a	45.7	11.6
C (%CT)	36.3 abc	41.3 a	36.4 abc	40.8 ab	33.7 c	34.0 bc	37.1	9.6

DM = dry matter; CT = total carbohydrates; A+B1 = simple sugars (starch and pectin), rapidly degradable; B2 = potentially degradable fibrous carbohydrates; C = non-degradable fibrous carbohydrates. Means, in the same row, followed by different letters, differ from each other by the *Tukey test* at 5% probability.

For the variable A+B1, there was a difference ($P < 0.05$) between the cultivars evaluated at six and twelve months after planting, where the cultivars BRS White Pot and BRS Formosa presented the highest results with 13.4 and 13.0%, respectively, and when analyzed at twelve months, the cultivar that stood out among the others was BRS Little mulatto girl with 19.9% (Table 5). In this situation, the sugars, starch and pectins present in the aerial part of cassava may have contributed to the increase in the A + B1 fraction. Souza et al. (2011) evaluated the aerial part of four cassava varieties and found values for fraction A + B1 that varied from 25.1 to 27.6%. According to Carvalho et al.

(2007), foods with high A+B1 levels are considered energy sources, which supply the ruminal microorganisms in the animal, synchronizing with the digestion of proteins and carbohydrates, having a great effect on animal performance.

A difference ($P < 0.05$) was observed for the B2 fraction of carbohydrates, when they were evaluated at six and twelve months after planting and the BRS New Horizon cultivar presented higher values than the other cultivars with 55.6% when they were evaluated at six months and 47.7% at twelve months. The higher value of this fraction in the aerial part of cassava is mainly due to the greater contribution of stem in the plants, thus, it can be justified that the intermediate production cultivars BRS New Horizon and BRS Mulatinha will be able to provide more energy for the microorganisms, which ferment the fibrous carbohydrates, if the B2 fraction has enough time to be degraded.

For fraction C, represented by indigestible neutral detergent fiber (NDFi), which includes the portion of the cell wall not digested in the gastrointestinal tract, there was a difference ($P < 0.05$) where the cultivar that presented the highest content of this fraction was BRS Kiriris with 44.2%, standing out among the other cultivars evaluated six months after planting. When evaluated twelve months after planting, the Eucalyptus cultivar presented the highest concentration among the cultivars with 41.3%. Values found in the present study can be justified by the high lignin contents in the BRS Kiriris and Eucalyptus cultivars. These values are lower than those of the aerial part of cassava from four cassava cultivars of 21.05; 24.18; 18.83 and 17.79% described by (Souza et al., 2011.)

Productive characteristics

The interaction was not significant ($P > 0.05$) between the different cultivars and pruning management for the production of green matter, dry matter, crude protein, total digestible nutrients of the aerial part and green matter and dry matter of the roots (Table 6).

In management without pruning, there was an increase in the variables production of green matter of the aerial part (PGMPA), production of dry matter of the aerial part (PDMPA), production of crude protein of the aerial part (PCPPA) and production of total digestible nutrients (PTDNPA), 26.5, 6.11, 0.98, 3.15, 11.19 and 3.80% respectively, the values found for these variables with pruning were 20.1, 3.71, 0.86, 2.18, 8.18 and 2.66%, respectively (Table 6).

Regarding the cultivars, BRS Mulatinha and BRS New Horizon stood out compared to the others, as they presented a high production of leaves and a greater number of stems (Table 2), when compared to the other cultivars, resulting in more robust and, consequently, heavier plants, these characteristics being possibly related to their genetics, allowing these cultivars to have greater adaptation to the edaphoclimatic conditions. BRS Eucalyptus and BRS Formosa presented lower percentages for the PGMPA variable, this result can be justified by climatic conditions and genetic characteristics, which obtained a smaller number of leaves and a smaller number of stems, resulting in the green matter and dry matter contents. Management without pruning provided a greater number of leaves, number of stems and greater plant height (Table 2) compared to management with pruning, which was responsible for a greater production of green matter and dry matter.

Table 6. Productive characteristics of green matter, dry matter, crude protein, total digestible nutrients of the aerial part, production of green matter and dry matter of the root (t ha^{-1})

Variable (t ha^{-1})	Cultivars						Pruning		CV	*Value - P*		
	BRS New Horizon	Eucalyptus	BRS Formosa	BRS Kiriris	BRS Mulatinha	BRS White Pot	With pruning	No pruning		Cultivate	Pruning	Cult x Pruning
PGMPA	30.0 ab	14.4 d	15.1 d	20.3 cd	36.0 a	24.0 bc	20.1 B	26.5 A	24	0.0001	0.0001	0.2195
PDMPA	6.52 a	2.8 b	3.0 b	4.5 b	8.00 a	4.4 b	3.7 B	6.11 A	28.3	0.0001	0.0001	0.1195
PCPPA	1.23 ab	0.5 d	0.6 cd	0.9 bc	1.35 a	0.8 c	0.86 B	0.98 A	26.2	0.0001	0.0659	0.5917
PTDNPA	3.55 a	1.4 c	1.6 bc	2.3 bc	4.43 a	2.5 b	2.18 B	3.15 A	27.7	0.0001	0.0001	0.1206
PGMSOURCE	6.25 b	3.0 c	15.9 a	11.2 b	11.11 b	10.5 b	8.18 B	11.19A	29.5	0.0001	0.0002	0.082
PDMSOURCE	2.28 b	0.9 c	4.9 a	3.8 a	3.88 a	3.47 a	2.66 B	3.80 A	33.2	0.0001	0.0001	0.0913

Means followed by the same lowercase letter in the row and uppercase letter in the column do not differ from each other by the *Tukey test* at 5% probability PGMPA: production of green matter of the aerial part; PDMPA: production of dry matter of the aerial part; PCPPA: production of crude protein of the aerial part; PTDNPA: production of total digestible nutrients; PGMSOURCE: production of dry matter of the root; PDMSOURCE: production of dry matter of the root With pruning: harvested at six and twelve months after planting Without pruning: a single pruning harvested at twelve months.

The higher PCPPA of the BRS Mulatinha and BRS New Horizon cultivars is related to the higher dry matter production, greater number of leaves and high crude protein content (Table 2) in management without pruning. The lowest production of PCPPA was for the cultivars Eucalyptus, BRS Formosa, BRS Kiriris and BRS White Pot, which is also related to a lower production of dry matter, green matter, and a lower number of leaves, resulting in a lower production of crude protein from these cultivars.

In relation to PTDNPA, the cultivars BRS New Horizon and BRS Mulatinha also showed the highest production among the cultivars, being better in management without pruning (Table 6). This result can be explained by the higher TDN content, higher dry matter production and higher ethereal extract content in these cultivars (Table 2). The Eucalyptus cultivar showed the lowest production among these cultivars due to these factors, lower dry matter production and aerial part productivity and lower NDT content in the bromatological composition.

For PPGMSOURCE and PDMSOURCE, regardless of the cultivar, a reduction in the green matter and dry matter contents was observed in pruning management due to the consumption of carbohydrates by new shoots at the beginning of the second vegetative cycle, extracted by removing the aerial part with the new shoots in full development harvested after six months. These results are in agreement with Andrade et al. (2011), who observed that pruning performed after the beginning of the second cycle promoted a reduction in the levels of green matter and dry matter of the roots. In management without pruning, there was greater productivity of dry matter and green matter due to the total restructuring of the aerial part. Thus, the percentage of root production, in relation to the total biomass produced by the plant, was higher when pruning was not performed; management without pruning accumulated more in the root in relation to the total biomass produced.

Among the cultivars, the one that presented the highest root production of both green matter and dry matter was the cultivar BRS Formosa, followed by BRS Kiriris, BRS Mulatinha and BRS White Pot (Table 6). According to Fukuda et al. (2006), the BRS Formosa cultivar is a cultivar recommended for industrial use, as it has high resistance to bacterial disease, higher dry matter content in the roots and tolerance to drought, which is essential for high root productivity. This behavior of the BRS Formosa cultivar was conditioned by the climatic conditions of the region where it was planted, favored by the rise in temperature and rainfall during the period.

CONCLUSIONS

The cultivation of cassava cultivars BRS Mulatinha and New Horizon is recommended because they present higher root and aerial part production, for the production of biomass in management systems without pruning. Making them promising alternatives for the intensification of biomass production in a sustainable and efficient way.

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