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Effect of debranching on sweet potato yield and quality

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Abstract

The objective of this study was to evaluate effect of branch removal on the yield and quality of sweet potato genotypes in different harvesting systems and two growing seasons. Two trials (2014 and 2016/17) were conducted in a randomized block design with three replicates in the factorial scheme composed of: three clones (Brazlândia Rosada, BD-31 TO and BD-65) and five harvesting systems (H): H1- total harvest of branch and root at 120 days after planting (DAP); H2- cut of the branches at 120 DAP, plus regrown branches and roots harvested at 210 DAP; H3 - total harvest of branches and roots at 165 DAP; H4 - cut of the branches at 165 DAP and harvest of regrown branches and roots at 210 DAP and H5- branches and roots total harvest at 210 DAP. For harvesting systems H2 and H4 the total production of branches at the end of the cycle was determined by the sum of the two cuts. The yield, dry matter of shoot and root, chemical-bromatological and nutrient quality were evaluated. The 2014 trial produced higher green mass yield of the branches, while in 2016/2017, higher root yield observed. H2 and H4 were shown to have better quality of the branches regarding the bromatological and nutrient characteristics, being recommended for animal feeding. The systems without regrowth (H3 and H5) allowed better yields and quality of roots, useful for human feeding. In general, the clone Brazlândia Rosada, produced the highest yield of roots and branches; therefore, recommended for planting.

Keywords: *Ipomoea potatoes*, Early Harvest, Harvest Systems.

Abbreviations: UFVJM_ Federal University of Jequitinhonha and Mucuri Valleys; Cl_clone; H_ harvest systems; Var_variables; DAP_days after planting; B. Rosada_Brazlândia Rosada: VC_ canonical variable; VC ac_: Cumulative canonical variable; CV_ coefficient of variation; BGMY_ branches green mass yield; BDMY_ branches dry mass yield; TRY_total roots yield; TRGMY_total roots green mass yield; MRY_ merchantable roots yield; MRDMY_ merchantable roots dry mass yield; LDM_ leaves dry mass; RDM_ roots dry mass; SDM_ stem dry mass; LDM/SDM_ ratio of the leaf dry mass to the stem dry mass; NDF_ fiber in neutral detergent; ADF_ fiber in acid detergent; CP_crude protein; TSS_ total soluble sugars; Ca_calcium; K_potassium; Mg_magnesium; N_nitrogen; P_phosphorus; Fe_iron; Co_copper; Mn_manganese; Zn_zinc; r_root; l_leaf; s_stem.

Introduction

The sweet potato (*Ipomoea potatoes*) is a tuberous root vegetable, adapted to several environments, being characterized by low production costs, rusticity and drought tolerance (Amaro et al., 2017; Andrade Júnior et al., 2012). Sweet potato plantations are being boosted due to the appreciation of the product on the market, the good quality of the product as energy and protein food, as well as a source of several minerals and the consumers' appeal for healthy foods (Anuário Brasileiro de Hortaliças, 2016).
Although it is traditionally cultivated for the production of roots for human consumption, its branches are often simply discarded as unusable waste. They can be considered as potential for animal feed such as pigs and cattle (Veiga et al., 2009, Ly et al., 2012, Pedrosa et al., 2015). Their supply is of most varied forms: *in natura*, dried or conserved, for being rich in sugars, vitamins and have high crude protein content, total digestive nutrients and digestibility (Figueiredo et al., 2012; Andrade Júnior et al., 2014; Camargo et al., 2016).
This information is relevant because the availability of fodder for grazing animals is uneven throughout the year due to the influence of climatic factors. In the dry season of several Brazilian regions, there is usually a great shortage of pastures, causing mortality of animals due to lack of food (Viana et al., 2011). This variation in forage availability during the year, coupled with the need to use lower cost food, has contributed to increase the demand for new food alternatives for ruminant animals so that their nutritional efficiency is not impaired (Ferreira et al., 2014).

Being used as an alternative source for animal feeding, the efficiency of sweet potato branches in animal feeding has already been proven in the works of Viana et al. (2011). Figueiredo et al. (2012) showed high protein content and adequate energy after fermentation for silage production. However, it is expected that the cutting and supply of the branches can be done during the roots development, considering that some genotypes have regrowth capacity. In some African countries and in Asia, the branches are harvested as a green vegetable for human and animal feeding (Nwinyi, 1992; Van An et al., 2003).

In Vietnam, Van An et al. (2003) evaluated the harvest interval of 15 sweet potato cultivars at 2 planting seasons, on dry matter yield (DMY), leaves, stems and roots at 15, 20, 30 and 120 days after planting. Furthermore, the 4, 3, 2 and 1 harvests were evaluated from the 60th DAP, and percentage of defoliation of 25, 50, 75 and 100% of the branches observed, respectively. The authors observed that the production of leaves (L), stems (S) and roots and S / L vary between cultivars and planting seasons. Root DMY was higher in the cold and wet than in the hot and dry season. Harvest at 15 and 20 day intervals favored DMY of leaves and stems, while harvest at 120 DAP provided higher DMY of roots and lower leaf yield.

Nwinyi (1992) also evaluated the impact of shoot removal at various stages of growth, 2, 4, 6, 8 and 10 weeks after planting (WAP) on total and commercial production of roots and branches of five sweet potato cultivarsfor two years. They showed that decrease in total yield was promoted by shoot removal at 2, 4, 6, 8 and 10 WAP, on average, 9.1; 13.5; 35.2; 52.5 and 57.6%, respectively. The corresponding reduction in marketable production (roots> 100 g) was 11.6, 15.9, 37.0, 56.0 and 63.3%, while for shoot production it was 13.3; 5.9; 22.1; 40.6 and 52.5%. The lowest root yield reduction (<16.0%) was occurred from 2-4 WAP, and aerial part removal was not recommended after 4 WAP. The same was happened for the production of tradable roots and branches.

However, it is necessary to study the impact of shoots removal for production of branches and roots. Dahniya et al. (1985) reported decreases in root production, from 31 to 48%, when harvesting the branches sprouts, while removing the entire branch led to a decrease of 48 to 62%. There are few studies that aim at the utilization and maximization of the sweet potato branch yield during their growing cycle for the use in animal feed, as well as the impact on yield and quality of both parts of the plant, when the shoot is removed at different times. The objective of this work was to evaluate the effect of branch removal on the yield and quality of branches and roots of sweet potato genotypes at different harvesting systems and growing seasons.

Results and discussions

Agronomic characteristics of sweet potato clones, subjected to different harvest systems

We verified the homogeneity of residual variance-ratio between highest and lowest mean squares of the residual (lower than seven) (Gomes and Garcia, 2002) for all characters. After that the joint analysis of variance was performed (Table 1). Due to the number of treatments and for better visualization, the result of each year was calculated separately.

There was a significant effect ($p \leq 0.05$) on the analysis of joint variance in most sources of interaction (Table 1). This shows that, in general, there was variability in the different clones regarding the performance in both harvesting systems and the year (time of the experiment implementation), allowing selection of superior materials. No significance was observed ($p > 0.05$) for the between clones for leaf dry mass and stem dry mass ratio (LDM/SDM), dry mass yield of branches, clone x harvesting system for root and stem dry mass; in harvest system x year for the dry mass contents of the leaf and the stem; and in the triple interaction between clone x harvesting system x year on stem dry mass content (LDM/SDM) (Table 1).

Harvesting systems that performed better on branch green mass yield (BGMY) and dry mass yield (PMR) were H2 and H5 for both two crop years (Table 1). In the harvesting system H2 (cut of the branches at 120 days after planting (DAP) and later the harvest of the roots sprouts at 210 DAP), can be explained by good development of shoot in the initial phase, due to the greater mobilization of photoassimilates for their structures, providing a greater sprouts yield. Subsequently, the tuberous roots began to develop more intensely, stronger and preferential drains of the plant assimilate, stabilizing the shoot development. In the H5 (harvesting of the branches and roots at 210 DAP), after the development of the reserve roots, a redirection of photoassimilates was occurred in the plant, investing again in the shoot development. These results corroborate with the results found by Queiroga et al. (2007).

For total roots yield (TRY), total roots green mass yield (TRGMY) (Table 2), merchantable roots yield (MRY) and dry mass yield of merchantable roots (Table 3) stood out in the H3, providing higher averages for the three evaluated clones in the two years. These results demonstrate that, when the purpose is to maximize root production, these should be harvested at 165 DAP, since there is a greater drain of photoassimilates and nutrients by the roots in this period, causing translocation of the leaves for the development of the tuberous roots (Conceição et al., 2004). These results are in agreement with Ferreira (2017) who also found higher yield of root dry mass after 165 DAP.

The lower TRGMY in H1 indicates an early harvest because roots are still in development and have not accumulated sufficient reserves. The effect of the branch removal in H2 caused redirection of the reserves, which would be used for the filling of the roots and also the emission of a new shoot, causing smaller TRGMY. According to Conceição et al. (2004), the increase of the total dry mass of the plant has a direct relation with the tuberous roots, since these represent a high proportion of the total dry mass.

The choice of the harvesting systems depends on the needs of the producers. For example, H2 more indicates the need for early harvesting of branches. Contrarily, when pastures are available, the producer can adopt the H5, which harvests the branches and roots after 210 days. Ferreira (2017) characterized growth of sweet potato in the Spanish genotype in Diamantina-MG and showed a slow initial growth of the plant, where its ideal period of harvest for the branch production was between 60 and 87 DAP, a period for maximum accumulation of dry mass.

Evaluation of performance of sweet potato genotypes in more than one agricultural year is important to measure their adaptability to the place of cultivation, since these characteristics such as branch and root yield are of quantitative inheritance and of strong environmental influence (Silva et al., 2015), small changes in the environment such as temperature, soil moisture and others may influence the expression of these characteristics. On average, clone B. Rosada excelled in two years of cultivation for yield (Tables 2 and 3) and dry mass contents (Table 3), except for roots dry mass content (RDM) in the second year, which obtained the lowest average in relation to the other clones. The early cycle of B. rosada is justified by the rapid vegetative development and higher shoot biomass gain in a shorter period of time compared to the other clones evaluated, evidencing the stability of production of this clone.

In year 1 (growing season Feb. to Sep. 2014) there were higher values for BGMY (67.53 t ha^{-1}) (Table 2) and for ratio of the leaf dry mass to the stem dry mass (LDM/SDM) (1.19) (Table 4). As for the branch dry mass yield (BDMY), there was no significant difference between the two years, with an average of 9.43 t ha^{-1}. In year 2 the highest values for TRY (31.66 t ha^{-1}) and TRGMY (9.04 t ha^{-1}) (Table 1) and MRY (23.35 t ha^{-1}) merchantable root dry mass yield (MRDMY) (6.68 t ha^{-1}), leaf dry mass (LDM) (15.92 %), root dry mass (RDM) (29.39 %) (Table 2) and the stem (SDM) (17.40 %) (Table 3) were observed, since it allowed better climatic conditions from December 2016 to July 2017 (Fig. 1). This is mainly due to root growth and its better development in average temperatures above 24ºC (Silva et al., 2008).

This differentiated performance in agricultural years and environments can be described by Viana et al. (2011), who found averages of branches yield in Diamantina-MG in 2008 in clone BD 31 TO in 2008 at different harvest times, 120, 150 and 180 days after planting. They obtained 64.52, 62.67 and 52.15 t ha^{-1} of yield, respectively. In the present study, the same clone (BD 31 TO) yield ranged from 45.09 t ha^{-1} (H1 in year 2) to 102.95 t ha $^{-1}$ (H5 and year 1).

The dry mass yield is influenced by the dry mass content and can vary among the clones due to differences in the cycle between them, whereas more mature plants have higher dry mass contents (Andrade Júnior et al., 2012). Figueiredo et al. (2012), evaluated different sweet potato clones and found that dry mass yield of branches vary from 3.05 to 4.95 t ha^{-1}. However, Andrade Júnior et al. (2014) found dry mass yield of 7.9 t ha^{-1}. In the present study, yield ranged from 5.67 to 14.04 t ha^{-1} in year 1 and 4.47 to 17.33 t ha^{-1} in year 24.47 to 17.33 t ha^{-1}. Roesler et al. (2008) found TRGMY values in the cultivar Brazlândia Rosada (6.76 t ha^{-1}) showing lower performance than the present work in the same cultivar in the two years of cultivation. Erpen et al. (2013) found averages higher than the present MRDMY study, in the Princesa cultivar (7.6 t ha^{-1}).

Leaf dry mass (LDM) in harvesting system H4 was higher at two years for all three clones, except for BD-65 in year 1 (Table 3). On average, there was no difference between the clones in the two years of culture and the LDM levels, except for the clone BD-31 TO (14.70%) in year 2, which presented the lowest average (Table 2).

Root dry mass (RDM) was affected by the branch removal in H2 and H4 (Table 3). Thus, the high values for the RDM content were observed in the harvest systems that the branch removal did not happen during the crop cycle (H1, H3 and H5). This may be related to the non-expenditure of the reserves present in the roots for the emission of a new shoot in these harvesting systems. Considering the average of all harvest systems, in year 1 the clone B. Rosada was superior (31.62%) and smaller in year 2 (26.41%) compared to the other clones. Andrade Júnior et al. (2012) observed RDM values near clone B. Rosada (27.6%) and clone BD-31 TO (28.8%).

In animal feed, it is of great importance to study the dry mass contents of the different fractions of the plant, since the elements of interest are in the dry mass, such as energy sources (sugars), fibers, minerals and protein (Van Soest, 1994). Thus, the higher the dry mass content, the higher the levels of the essential elements in animal nutrition will be, increasing its food efficiency.

The dry mass content of stem (SDM) in system H4 stood out compared to the others, providing higher levels of SDM in the two years (Table 4). High levels of SDM contributed to the increase of the yield of branches. However, it was necessary to take the relation of leaf dry mass and stem dry mass (LDM / SDM) into account, since it represents material of high protein content and higher consumption, similar to forage plants with high nutritional value to animals (Wilson, 1982). On the other hand, as the age of the plant increases, and when it reaches its physiological maturity, there is a higher fiber content, lower protein content and lower dry mass digestibility (Van Soest, 1994).

The interaction between harvesting systems and the growing seasons (year 1 and 2) can be observed, in which the lower levels of SDM and higher LDM/SDM were observed in the first year, while the reverse occurred in year 2 (Table 4). These results are explained by the greater vegetative development in year 1, as evidenced by the higher BGMY, and the higher root yield in year 2. There was no significant interaction between the sweet potato clones and the year for the SDM characteristic. It only presented the interaction of the years with the clones for the LDM/SDM ratio (Table 5). The B. rosada clone had a lower average than the BD 31 TO and BD-65 clones. In year 2, the lowest average was observed for clone BD 31 TO.

Chemical-bromatological and nutrient characteristics in sweet potato clones at different harvest systems

Besides the productive characteristics of sweet potatoes, it is of great importance to study their qualitative characteristics considering both human and animal feeding. Due to the chemical-bromatological and nutrient analyzes carried out in all parts of the sweet potato plant in each year, harvest system and genotypes, we decided to perform a multivariate analysis of the data for a better presentation of the results. Significant interactions between harvesting systems and clones were observed at the 1% level of significance (Tables 6 and 7). The canonic variables 1 and 2 (VC1 and VC2) explained 89.37 and 6.33% of the total variance of the data set in year 1, respectively. For year 2, 76.52 and 14.01% of were explained by canonical variables 1 and 2, respectively (Table 8). When the first two canonical variables explains more than 80% of the total variation, the study is feasible through the graphic dispersion of the relative scores (Cruz et al., 2012).

Table 1. Summary of the joint analysis of branches green mass yield (BGMY), total roots yield (TRY), merchantable roots yield (MRY), branches dry mass yield (BDMY), total roots green mass yield (TRGMY) and merchantable roots dry mass yield (MRDMY), of leaves dry mass content (LDM), stem dry mass content (SDM), ratio of leaves dry mass and stem dry mass (LDM / SDM) and roots dry mass (RDM) of sweet potato clones submitted to different harvest systems and growing seasons. UFVJM, Diamantina-MG, 2018.

		Estimation of the mean squares									
FV	GL	BGMY	TRY	MRY	BDMY	TRGMY	MRDMY	LDM	SDM	LDM/SDM	RDM
Block/year	4	59.09^{ns}	16.42^{ns}	12.85^{ns}	1.06^{ns}	0.48^{ns}	0.47^{ns}	1.06^{ns}	1.97^{ns}	0.02^{ns}	7.29^{ns}
Clone (Cl)	2	3362.18**	1659.85**	1980.36**	95.71**	149.85**	155.77**	15.77**	8.9**	0.004^{ns}	28.65**
Harvest System (H)	4	1058.43**	899.53**	433.19**	41.51**	105.27**	49.4**	20.6**	48.09**	0.05**	79**
Year	1	1829.52**	2327.25**	2858.01**	4.32^{ns}	210.49**	250.83**	57.87**	617.11**	1.5**	141.05**
Cl X H	8	470.37**	99.39**	111.17**	8.62**	13.85**	11.63**	3.99**	2.31^{ns}	0.01^{ns}	8.4^{ns}
Cl X Year	2	935.99**	755.42**	519.93**	26.85**	11.15**	14.24**	3.76^{ns}	1.37^{ns}	0.09**	334.68**
H X Year	4	150.27**	100.86**	81.05**	1.49^{ns}	5.82**	5.58**	9.32**	38.07**	0.07**	22.29**
Cl X H X Year	8	695.52**	73.11**	42.71**	23.92**	12.37**	6.79**	4.7**	3.45^{ns}	0.02^{ns}	11.58*
Residue	56	32.78	10.63	7.16	1.34	0.96	0.58	1.29	1.68	0.01	5.49
CV (%)		9.09	12.27	15.1	12.29	13.08	15.19	7.53	8.79	10.47	8.33
Average		63.02	26.58	17.72	9.43	7.51	5.01	15.12	14.78	1.06	28.14
[1]>MSR/<MSR		1.10	1.23	4.49	1.18	1.06	2.38	1.14	1.23	0.00	1.32

$^{ns, **, *}$ = not significant, significant at p <0.01 and p <0.05, respectively, by the F test.[1] Highest MSR / Lowest MSR = test of homogeneity of variance according to Gomes and Garcia (2002).

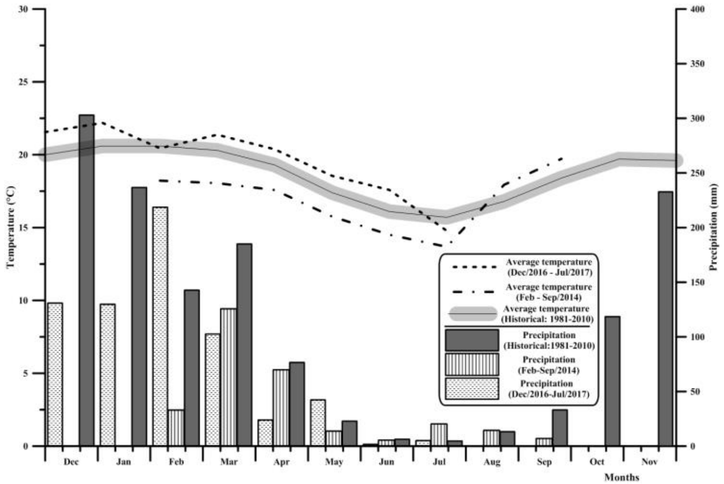

Fig 1. Climatic data collected from the experimental period 2014/2017 and historical (1981-2010). Diamantina-MG, UFVJM, 2018. Source: BDMEP - INMET.

Table 2. Variables (Var): branches green mass yield (BGMY), branches dry mass yield (BDMY), total roots yield (TRY), total roots green mass yield (TRGMY) of sweet potato clones submitted to different harvest systems (H) and growing seasons. UFVJM, Diamantina, MG, 2018.

Growing seasons									
		Year 1			Year 2			Averages	
Var	H	B. Rosada	BD-31 TO	BD-65	B. Rosada	BD-31 TO	BD-65	Year1	Year2
BGMY $t\ ha^{-1}$	1	82.38 Aa	52.53 Bc	41.35 Bb	64.56 Ab	45.09 Bb	37.43 Bbc	58.75 Ac	49.03 Bc
	2	84.68 Aa	65.00 Bbc	66.71 Ba	67.96 Ab	71.40 Aa	62.15 Aa	72.13 Aa	67.17 Aa
	3	57.11 Bb	74.74 Ab	61.55 Ba	64.80 Bb	77.00 Aa	31.90 Cc	64.46 Abc	57.90 Bb
	4	60.46 Bb	74.98 Ab	67.61 ABa	70.16 Ab	47.27 Bb	29.33 Cc	67.69 Aab	48.92 Bc
	5	58.13 Bb	102.98 Aa	62.77 Ba	92.28 Aa	68.46 Ba	47.93 Cb	74.63 Aa	69.51 Aa
	Average	68.55 A	74.05 A	59.99 B	71.95 A	61.84 B	41.75 C	67.53 A	58.51 B
BDMY $t\ ha^{-1}$	1	10.83 Aab	5.68 Bc	5.67 Bc	9.57 Ac	7.55 ABb	6.56 Bbc	7.41 Ac	7.89 Ac
	2	12.66 Aa	6.99 Bbc	10.48 Aa	11.76 Ac	10.51 Aa	9.79 Aa	10.04 Aa	10.69 Aab
	3	9.22 Ab	8.69 Ab	7.21 Abc	9.12 Ac	10.48 Aa	4.47 Bc	8.37 Abc	8.02 Ac
	4	8.53 Bb	11.43 Aa	8.63 Bab	14.45 Ab	8.64 Bab	6.07 Cbc	9.53 Aab	9.72 Ab
	5	8.66 Bb	14.04 Aa	9.48 Bab	17.33 Aa	10.40 Ba	8.10 Cab	10.73 Ba	11.94 Aa
	Average	9.99A	9.36 A	8.29 B	12.45 A	9.51 B	7.00 C	9.21 A	9.65 A
TRY $t\ ha^{-1}$	1	12.34 Ad	12.55 Ab	12.47 Ab	41.60 Abc	10.81 Cb	21.68 Bb	12.45 Bc	24.69 Ac
	2	13.13 Ad	13.36 Ab	10.97 Ab	37.13 Ac	27.73 Ba	20.00 Cb	12.49 Bc	28.29 Abc
	3	42.17 Aa	26.82 Ba	20.37 Ca	56.06 Aa	30.73 Ca	37.70 Ba	29.79 Ba	41.50 Aa
	4	21.83 Bc	29.89 Aa	21.20 Ba	46.70 Ab	29.83 Ba	19.26 Cb	24.30 Bb	31.93 Ab
	5	32.55 Ab	31.02 Aa	21.77 Ba	46.95 Ab	23.38 Ba	25.44 Bb	28.45 Bab	31.92 Ab
	Average	24.40 A	22.73 A	17.36 B	45.69 A	24.49 B	24.81 B	21.49 B	31.66 A
TRGMY $t\ ha^{-1}$	1	4.00Ad	3.40 Ab	3.09 Ab	12.28 Ab	2.90 Cc	7.40 Bbc	3.49 Bc	7.53 Ac
	2	3.32 Ad	2.77 Ab	2.96 Ab	8.13 Ac	6.96 ABb	5.13 Bd	3.02 Bc	6.74 Ac
	3	15.26 Aa	6.70 Ba	5.03 Bab	15.86 Aa	9.61 Ca	12.08 Ba	8.99 Ba	12.52 Aa
	4	6.42 Ac	6.81 Aa	5.12 Aab	12.03 Ab	8.84 Bab	5.97 Ccd	6.12 Bb	8.95 Ab
	5	11.38 Ab	7.73 Ba	5.82 Ba	12.26 Ab	7.56 Bab	8.66 Bb	8.31 Ba	9.49 Ab
	Average	8.07 A	5.48 B	4.40 C	12.11 A	7.17 B	7.85 B	5.99 B	9.04 A

Averages followed by the same capital letter in the row and lowercase in the column do not differ by the Tukey test at the 5% probability level.

Table 3. Variables (Var): merchantable roots yield (MRY), merchantable roots dry mass yield (MRDMY), leaves dry mass content (LDM), roots dry mass (RDM) of sweet potato clones submitted to different harvest systems (H) and growing seasons. UFVJM, Diamantina, MG, 2018.

Growing Seasons									
		Year 1			Year 2			Averages	
Var	H	B. Rosada	BD-31 TO	BD-65	B. Rosada	BD-31 TO	BD-65	Year1	Year2
MRY	1	8.13 Ac	5.93 ABc	2.57 Bb	36.06 Abc	5.27 Cc	14.42 Bb	5.54 Bc	18.58 Ac
t h^{-1}	2	8.66 Abc	10.06 Abc	2.44 Bb	30.47 Ac	21.43 Ba	12.73 Cb	7.06 Bc	21.54 Abc
	3	28.66 Aa	13.57 Bab	9.63 Ba	46.33 Aa	20.24 Cab	30.04 Ba	17.29 Ba	32.20 Aa
	4	14.75 Ab	18.30 Aa	7.51 Bab	33.60 Abc	22.85 Ba	11.02 Cb	13,52 Bb	22.49 Ab
	5	24.05 Aa	19.13 Aa	7.87 Bab	37.65 Ab	14.08 Bb	14.15 Bb	17.02 Bab	21.96 Abc
	Average	16.85 A	13.40 B	6.01 C	36.82 A	16.77 B	16.47 B	12.08 B	23.35 A
MRDMY	1	2.53 Ad	1.46 ABc	0.75 Bab	10.70 Ab	1.77 Cc	4.92 Bb	1.58 Bc	5.80 Abc
t h^{-1}	2	1.88 ABd	2.23 Abc	0.60 Bb	7.04 Ad	5.36 Bab	3.41 Cb	1.57 Bc	5.27 Ac
	3	10.40 Aa	3.42 Bab	2.37 Ba	13.04 Aa	6.37 Ca	9.51 Ba	5.39 Ba	9.64 Aa
	4	4.46 Ac	3.88 Aab	1.78 Bab	8.66 Acd	6.79 Ba	3.43 Cb	3.34 Bb	6.29 Ab
	5	7.65 Ab	4.76 Ba	2.09 Cab	9.89 Abc	4.54 Bb	4.80 Bb	4.83 Ba	6.41 Ab
	Average	5.36 A	3.15 B	1.52 C	9.86 A	4.97 B	5.21 B	3.34 B	6.68 A
LDM	1	14.99 Aa	13.64 Aab	15.67 Aa	17.18 Aa	14.99 Ab	17.00 Aab	14.76 Ba	16.39 Ab
%	2	15.16 Aa	12.43 Bb	15.97 Aa	17.21 Aa	13.30 Bb	14.97 Bbc	14.52 Aab	15.16 Abc
	3	12.08 Bb	12.16 Bb	15.01 Aab	14.37 Ab	13.38 Ab	13.99 Ac	13.08 Ac	13.91 Ac
	4	14.80 ABa	15.27 Aa	12.99 Bb	18.44 Aa	17.63 Aa	19.26 Aa	14.35 Bab	18.44 Aa
	5	15.27 ABa	15.84 Aa	13.54 Bab	16.28 ABab	14.23 Bb	16.66 Aab	14.88 Aa	15.72 Ab
	Average	14.42 A	13.87 A	14.63 A	16.69 A	14.70 B	16.37 A	14.32 B	15.92 A
RDM	1	31.93 Aab	24.62 Ba	24.05 Ba	29.70 Aa	33.85 Aa	34.00 Aa	26.87 Babc	32.52 Aa
%	2	26.18 ABc	21.94 Ba	26.64 Aa	22.61 Ab	25.11 Ab	26.77 Ab	24.92 Ac	24.83 Ac
	3	35.15 Aa	25.27 Ba	24.80 Ba	28.65 Aa	30.75 Aa	31.77 Aab	28.41 Aab	30.37 Aab
	4	29.71 Abc	22.59 Ba	23.67 Ba	26.64 Aab	29.72 Aab	30.71 Aab	25.32 Bbc	29.02 Ab
	5	35.10 Aab	24.73 Ba	26.88 Ba	24.45 Bab	32.24 Aa	33.92 Aa	28.90 Aa	30.20 Aab
	Average	31.62 A	23.83 B	25.21 B	26.41 B	30.33 A	31.42 A	26.88 B	29.39 A

Averages followed by the same capital letter in the row and lowercase in the column do not differ by the Tukey test at the 5% probability level.

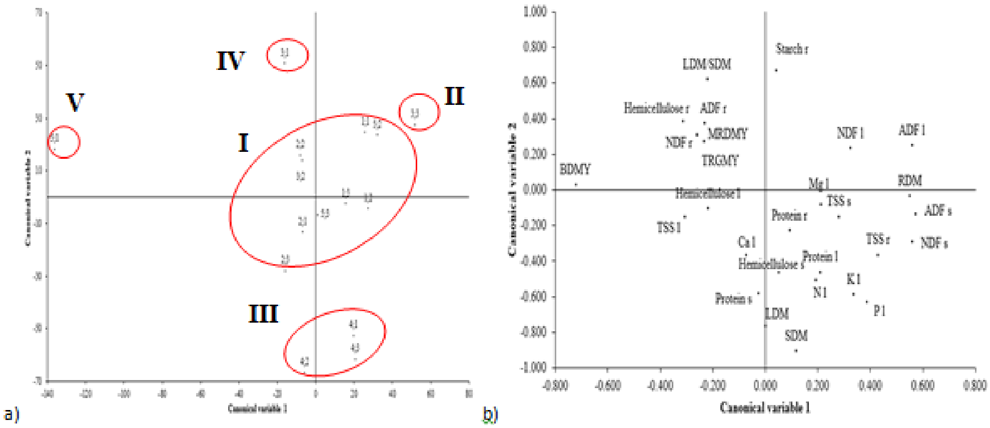

Fig 3. Graphical dispersion of the scores in relation to the first two canonical variables (VC1 and VC2) for year 2 (2016): (a) decoding of harvest system (H): clone (Cl). H ranging 1 to 5 (1: total harvest of branches and roots at 120 Days After Planting (DAP); 2: cutting of branches at 120 DAP, and harvesting of branches sprouts and roots at 210 DAP; 3: total harvest of branches and roots at 165 DAP; 4: cutting branches at 165 DAP and harvesting of branches sprouts and roots at 210 DAP; and, 5: total harvest of branches and roots at 210 DAP); and Cl ranging 1 to 3 (1: Brazlândia Rosada (B. Rosada); 2: BD-31 TO; and 3: BD-65); b) field characteristics (LDM_ leaves dry mass, SDM_ stem dry mass, LDM/SDM_ ratio of the leaf dry mass to the stem dry mass, TRGMY_ total roots green mass yield, MRDMY_ merchantable roots dry mass yield) bromatological characteristics (NDF_ fiber in neutral detergent; ADF_ fiber in acid detergent, TSS_ total soluble sugars, Protein, Starch, Hemicellulose), nutrient characteristics (Ca_calcium, K_potassium, Mg_magnesium, N_nitrogen, P_phosphorus) in each part of the plant (r_root, l_leaf, s_stem). Diamantina, UFVJM, 2018.

Table 4. Stem dry mass content (SDM) and ratio of leaves dry mass and stem dry mass (LDM / SDM) of sweet potato clones in different harvest systems (H) and growing seasons. Diamantina-MG UFVJM, 2018.

	SDM (%)		LDM/SDM (%)	
H	Year 1	Year 2	Year 1	Year 2
1	10.84 Bb	17.99 Ab	1.37 Aa	0.91 Bab
2	12.98 Ba	16.41 Ab	1.12 Ab	0.97 Bab
3	11.46 Bab	14.06 Ac	1.14 Ab	0.99 Ba
4	12.62 Ba	22.02 Aa	1.14 Ab	0.84 Bb
5	12.91 Ba	16.51 Ab	1.17 Ab	0.95 Bab
Médias	12.16 B	17.40 A	1.19 A	0.93 B

Averages followed by the same capital letter in the row and lowercase in the column do not differ by the Tukey test at the 5% probability level

Table 5. Ratio of leaves dry mass and stem dry mass (LDM / SDM) of sweet potato clones in different growing seasons. Diamantina-MG UFVJM, 2018.

	LDM/SDM (%)				
Growing seasons	B.Rosada	BD-31 TO	BD-65	CV (%)	Average
Year 1	1.14 Ba	1.25 Aa	1.18 Aba	10.47	1.06
Year 2	0.96 Ab	0.86 Bb	0.97 Ab		

Averages followed by the same capital letter in the row and lowercase in the column do not differ by the Tukey test at the 5% probability level

Table 6. Multivariate analysis of variance (MANOVA) for year 1. UFVJM, Diamantina-MG, 2018.

	Df	Pillai	approx F	num Df	den Df	Pr (>) F
R	3	2.8208	1.6867	84	9	0.200513
Cl	2	1.9901	14.4258	56	4	0.009022^{**}
H	4	3.9738	21.6775	112	16	$9.489e\text{-}09^{***}$
H x Cl	8	7.6375	6.0201	224	64	$5.720e\text{-}14^{***}$
Resíduo	28					

Table 7. Multivariate analysis of variance for year 2. UFVJM, Diamantina-MG, 2018.

	Df	Pillai	approx F	num Df	den Df	Pr (>) F
R	3	2.8713	2.3903	84	9	0.078044
Cl	2	1.9904	14.7360	56	4	0.008664^{**}
H	4	3.9773	24.9779	112	16	$3.207e\text{-}09^{***}$
H x Cl	8	7.2881	2.9252	224	64	$9.418e\text{-}07^{***}$
Residue	28					

Table 8. Estimation of eigenvalues associated with canonical variables to estimate dissimilarity between clones x harvesting systems, for year 1 and 2. Diamantina, UFVJM, 2018.

Canonical Variables	Estimates of eigen values			
	Year 1		Year 2	
	VC (%)	VC ac.(%)	VC (%)	VC ac. (%)
1	89.37	89.37	76.52	76.52
2	6.33	95.71	14.01	90.54
3	2.18	97.90	6.06	96.60
4	0.81	98.71	2.14	98.75
5	0.64	99.35	0.68	99.43
6	0.36	99.72	0.25	99.68
7	0.19	99.92	0.17	99.85
8	0.08	100.00	0.14	100.00

VC: Canonical Variable; VC ac .: Cumulative canonical variable.

From the graphical dispersion analysis for year 1 (Fig. 2a) five groups were formed by combinations of harvesting systems and clone correlating with the bromatological characteristics (Fig. 2b). In group I, most of the treatments (Fig. 2a) are present because the points are closer and; thus, greater similarity: 1: 1; 1: 2; 1: 3; 2: 2; 3: 2; 4: 1; 4: 2; 4: 3; 5: 1; 5: 2 and 5: 3. The tendency of treatments with harvesting system H3 is observed because they are displaced in the positive part of VC1 and in the negative of VC2 (Fig. 2a). Through this dispersion, groups II and III were composed respectively by the treatments 3: 1 (H3: clone B. Rosada) and 3: 3 (H3: clone BD-65). Both of which showed similarities, higher TRGMY, MRDMY, Hemicellulose (stem), and lower levels of Starch and ADF in the root; NDF and Protein in stem; NDF, Hemicellulose, Nitrogen and Protein in leaf. For group III, higher levels of TSS and lower levels of protein, ADF in the root; and, phosphorus in the leaf were observed.

Through the combined analysis of years 1 and 2 for TRGMY and MRDMY characteristics (Tables 2 and 3), H3 (total harvest of branches and roots at 165 DAP), combined with clone 1 (B. rosada) showed higher values, according to the multivariate analysis (Fig. 2a and 2b). The highest starch contents and higher TSS levels in the roots observed in group III are probably due to the fact that after the roots reach their maturation point there is a decrease in soluble sugars (Zeeman et al., 2010). The groups II and III, were composed by the treatments 3: 1 (H3: clone B. Rosada) and 3: 3 (H3: clone BD-65), respectively, which showed low levels of ADF in the root, suggesting good digestibility of the food by the animals. The higher levels of this fraction indicate a greater proportion of the fibrous components, damaging the gastric system of animals, especially microorganisms in their digestible tract (Van Soest, 1994).

In groups IV (2: 3 = H2: clone BD-65) and V (2: 1 = H2: clone B. Rosada), in contrst to groups II (3: 1 =H3: clone B. Rosada) and III (3:3=H3: clone BD-65), higher levels of reserves were observed in the shoot (Fig. 2a and 2b). It was due to the greater mobilization of reserves to regrowth, with the tendency of the treatments in the harvesting system 2 on the negative side of VC1. Group IV, formed by treatment 2:3 (H2: BD-65) presented higher levels of ADF, protein and lower TSS in the root. In group V, which was formed by treatment 2:1 (H2: B. Roosada), higher levels of NDF and protein were detected in the stem; NDF, Hemicellulose, Nitrogen and Protein in leaf; TSS, starch and protein in roots and smaller TRGMY and MRDMY. According to the joint analysis (Tables 2 and 3), the treatments with the H2 also presented smaller TRGMY and MRDMY.

The bromatological quality characteristics are: hemicellulose, nitrogen and protein in the leaf, and protein in the stem. This provides a great aptitude for use of branches of the sweet potato in the feeding ruminants. Higher hemicellulose content (integral with NDF) provides greater cellulose digestion. The higher levels of nitrogen and protein allow a greater intake of dry mass by the animals due to ruminal nitrogen deficiency, resulting in lower ruminal microbiota growth. The lack of nutritional requirements causes decrease in cell wall digestion and consumption (Wilson and Kennedy, 1996), where protein is the most required ingredient after energy for the development of metabolic functions of ruminants (Paiva et al., 2013).

As for the starch content, the mobilization of sugars from the starch reserves aims to increase the amount of soluble sugars potentially usable for cell metabolism (Zeeman et al., 2010). Thus, sugar contents are of great importance in the regrowth process (harvest system H2) and development of the buds that will give rise to new branches in the plant. The lowest TSS content in the roots in group IV is due to the later cycle of the BD-65 clone in relation to the B.Rosada clone.

For year 2, it was also possible to separate the different treatments into five groups (Fig. 3a), group I being formed by treatments 1: 1; 1: 2; 1: 3; 2: 1; 2: 2; 2: 3; 3: 2; 5: 2; 5: 3 Groups II and V presented greater dissimilarity, constituted of treatments 3: 3 and 5: 1, respectively. There was a great contribution of the highest levels of NDF and ADF in the stem; TSS and MS in the root; ADF in the leaf and lower BDMY in group II (Fig. 3b). For group V, an inverse trend of group II was observed.

These results (Figs. 3a and 3b) are in agreement with the multivariate analysis for year 1 (Fig. 2), as well as the joint analysis for years 1 and 2 (Tables 2 and 3), which obtained lower BDMY in the H3 and larger BDMY in the H5. The H3 in group II tended to be displaced on the positive side of the VC1 axis, presenting lower BDMY and higher levels of ADF in the leaf and stem, which besides diminishing the productivity of the branches, which made it less nutritious and digestible for animal feed. Thus, H3 is more recommended for the production of roots, using clones B. Rosada and BD-65, along with higher yield and bromatological characteristics quality.

Group III is more vertically displaced on the negative side of the VC2 axis and is formed by the combinations of the harvest system H4 and the BD-65 and BD-65 (4: 1; 4: 3). Of the characteristics that contributed to the formation of this group, we observed higher levels of protein in the stem; potassium and phosphorus in the leaf; smaller starch LDM/ SDM, hemicellulose in the roots. This indicates that there is a great accumulation of reserves and nutrients in the shoot in new sprouts, like in H4, after cutting the branches and when the regrowth was harvested only 45 days later (210 DAP). These results are in agreement with Ferreira (2017) who observed the growth of the sweet potato crop, where the young shoots (between 15 and 75 days) are the preferred organ of accumulation of photosynthesis and nutrients products. In group IV, which formed by the treatment 3: 1 (H3: clone B. Rosada) contrary results to group III were observed due to the greater accumulation of compound in the roots in this period.

Materials and methods

Materials (genotypes and harvest systems)

The experimental design was a randomized block design in a factorial scheme 3 (clones) x 5 (harvesting systems) with three replicates.
The studied plant materials were three clones (Cl) of sweet potato: i) Brazlândia Rosada (B. Rosada); (ii) BD-31 TO; and (iii) BD-65 from the Germoplasm Bank of the Federal University of the Jequitinhonha and Mucuri Valleys, Campus JK, Diamantina-MG.
The harvesting systems (H) were divided into five: i) H1: total harvest of branches and roots at 120 Days After Planting (DAP); ii) H2: cutting of branches at 120 DAP, and harvesting of branches sprouts and roots at 210 DAP; iii) H3: total harvest of branches and roots at 165 DAP; iv) H4: cutting branches at 165 DAP and harvesting of branches sprouts and roots at 210 DAP; and, v) H5: total harvest of branches and roots at 210 DAP. For H2 and H4 the total production of branches at the end of the cycle was determined by the sum of the two cuts.

Location and trial installation

The field trial was conducted at the Olericultura Sector of the Department of Agronomy, Federal University of Jequitinhonha and Mucuri Valleys (UFVJM), *Campus* JK, in Diamantina-MG (18º9'S, 43º21'O, 1400 m altitude) in two years (2014 and 2016). The climate of the region is mesothermic, Cwb in the classification of Köppen, with mild and humid summers, cooler and dry winters and short transitions carried out in the months of May and September. Climatic data were collected during the conduction of the trial and compared to the historical data of Diamantina (1981-2010) (Fig.1).
The plots were composed of rows of 3.0 meters in length each, spaced 1.0 m between rows and 0.30 m between plants, totaling 45 plots. In both seasons (2014 and 2016) the conduction and evaluation of the trials were the same. The soil was classified as typical Quartzianic Neosol, prepared with two gradations. The chemical and organic fertilizations were carried out according to the results of the soil analysis following the one recommended by Casali (1999) for the sweet potato crop.
The branches for seedling production of the sweet potato clones were cut into four-node cuttings, planted in styrofoam trays with 72 cells with Bioplant® commercial substrate, and kept in a greenhouse under 50% insolation and irrigation sombrite by microsprinkler twice a day for 30 days before going to the field. The transplanting of the seedlings was done manually in two seasons: February 2014 and December 2016. During the development of the plants, manual weeding was carried out to keep the area free of invasive plants. The irrigation was carried out by conventional spraying.
The branches for seedling production of the sweet potato clones were cut into four-node cuttings, planted in 72-cells styrofoam trays filled out with Bioplant® commercial substrate, and kept in a greenhouse under 50% insolation and irrigation sombrite by microsprinkler twice a day for 30 days before going to the field. The transplanting of the seedlings was done manually in two seasons: February 2014 and December 2016. During the development of the plants manual weeding was carried out in order to keep the area free of invasive plants. Some conventional spraying was also carried out.

Characteristics evaluated

The harvests were carried out according to each proposed harvesting system, and in the first season it was between the months of June, August and September of 2014 and in the second season of the trial between the months of April, June and July of 2017.
The shoots and roots were evaluated: i) branch green mass yield (BGMY), determined by weighing the branches harvested close to the soil, in the plots of each treatment, with the results expressed in t ha^{-1}; ii) total roots yield (TRY) verified by weighing all roots of each plot for each treatment and the results were expressed as t ha^{-1}; iii) merchantable roots yield (MRY), selected roots with weight between 100 and 800 grams, free of damages and with good commercial aspect, with results expressed in t ha^{-1}.
After weighing, 300 gram samples were taken from the branches, fractions, leaves, stems and roots, and the leaves and stems were separated from the same branch segment. These were pre-dried in a greenhouse with forced air ventilation at 65 ° C to constant weight for determination of: i) leaf dry mass (LDM) (%); (ii) dry mass of the stems (SDM) (%); iii) roots dry mass (RDM) (%); iv) ratio of leaf dry mass to stem dry mass (LDM / SDM) (%); v) branch dry mass yield (BDMY), obtained by the product between the yield of green mass and the dry mass content of the branches. The results were expressed in t ha^{-1}; vi) total root green mass yield (TRGMY) and vii) merchantable roots dry mass yield (MRDMY) determined by the product between the green mass yield and the roots dry mass, with the data expressed in t ha $^{-1}$.
After determination of the dry mass contents, the samples were ground in a mill (Willey) with a 1 mm sieve, to evaluate the chemical-bromatological composition: i) neutral detergent fiber (NDF), ii) acid detergent fiber (ADF) and iii)

hemicellulose fraction according to Van Soest's methodology (1994). Their values expressed as percentage of dry mass; iv) crude protein (CP) determined by the conversion of nitrogen, which was obtained through the LECO® CHNS / O elemental analyzer TruSpec Micro model and multiplied by the conversion factor 6.25; v) total soluble sugars (TSS) and vi) starch, using the methodology adapted from Mc Cready et al. (1950) with the values expressed as a percentage of dry mass.

For the determination of nutrient contents: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), copper (Co), manganese (Mn) and zinc (Zn), the quantities in the different parts of the plant, leaf (l), root (r) and stem (s) were obtained according to the methodology described by Malavolta et al. (1997).

Statistical analysis

Individual variance analyzes were performed for yield characters, in both seasons (2014 and 2016). After homogeneity, the residual variances were identified in the individual ANOVAs, by the relationship between the highest and lowest mean square of the residue (MSR) (Gomes and Garcia, 2002). Subsequently, joint analysis of variance was conducted. The experimental design was a randomized block design in a factorial scheme 3 (clones) x 5 (harvesting systems) with three replicates in two years. When the significant effect of the treatments was identified by the F test ($p \leq 0.05$), the averages of the treatments were compared by the Tukey test ($P \leq 0.05$). Due to the number of treatments and for better visualization of the results, the table was made separately per year.

Due to the large number of variables in each part of the plant for the bromatological and nutrient characteristics, the data were submitted to multivariate analysis for better interpretation, using the MANOVA function, and canonical variables through the Candisc package. The representation was by numbers as harvest system. In the harvest system ranging from 1 to 5, and clone (1 to 3) in the sequence shown in the above materials. All statistical analyzes were used with the aid of R software (R Core Team, 2017).

Conclusion

Sweet potato cultivation from February to September 2014 provided high green mass yield of the branches. For root yield the cultivation is better from December 2016 to July 2017. However, for the dry mass yield of the branches, the years did not differ from each other. Harvesting systems with branch cuts at 120 and 165 days after planting (DAP) with harvest of branches sprouts and roots at 210 DAP showed good quality of branches in terms of bromatological and nutrient aspects. The systems without regrowth with total harvest of branches and roots at 165 days DAP and with total harvest of branches and roots at 210 days DAP allowed better yields and quality of roots than the others, as well as good yields of branches. The clone Brazlândia Rosada, on average, presented the highest yields of roots and branches, and could be used as potential for planting in the region.

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References

Amaro GB, Fernandes FR, Silva GO, Mello AFS, Castro LAS (2017) Desempenho de cultivares de batata doce na região do Alto Paranaíba- MG. Hortic Bras. 35: 286-291.

Andrade Júnior VC, Viana DJS, Pinto NAVD, Ribeiro KG, Pereira RC, Neiva IP, Azevedo AM, Andrade PCR (2012) Características produtivas e qualitativas de ramas e raízes de batata-doce. Hortic Bras. 30: 584-589.

Andrade Júnior VC, Pereira, RC, Dornas MFS, Ribeiro KG, Valadares, NR, Santos, AA, Castro, BMC (2014) Produção de silagem, composição bromatológica e capacidade fermentativa de ramas de batata-doce emurchecidas. Hortic Bras. 32: 91-97.

Anuário Brasileiro de Hortaliças (2017) Batata-doce. Available in: <http://www.editoragazeta.com.br/flip/anuario-hortalicas2-2017/files/assets/basic-html/page35.html>. Acess on November, 09, 2017.

Camargo LKP, Resende JTV, Mógor AF, Camargo CK Kurchaidt SM (2016) Uso de índice de seleção na identificação de genótipos de batata doce com diferentes aptidões. Hortic Bras. 34: 514-519.

Casali VWD (1999) Batata-Doce. In: Ribeiro AC, Guimarães PTG, Alvarez VVH. In: Comissão de fertilidade do solo do estado de Minas Gerais. Recomendações para o uso de corretivos e fertilizantes em Minas Gerais: 5ª – Aproximação. Viçosa: CFSEMG 180.

Conceição MK, Lopes NF, Fortes GRL (2004) Partição de matéria seca entre órgão de batata-doce (*Ipomoea batatas* (L.) Lam), cultivares Abóbora e Da Costa. R Bras Agrociências, 10: 313-316.

Cruz CD, Regazzi AJ, Carneiro PCS (2012) Modelos biométricos aplicados ao melhoramento genético. Viçosa: UFV 4: 514.

Dahniya MT, Hahn SK, Oputa CO (1985) Effect of shoot removal on shoot and root yields of sweet potato. Exp Agric. 21: 183-186.

Silva JBCS, Lopes CA, Magalhães JS (2008) Sistemas de produção. Batata-doce (*Ipomoea batatas*). Brasília: Embrapa Hortaliças, 2008. Disponivel em: <https://sistemasdeproducao.cnptia.embrapa.br/FontesHTML/Batata-doce/Batata-doce_Ipomoea_batatas/introducao.html>. Acesso em 10/08/ 2018.

Erpen L, Streak NA, Uhlmann LO, Freitas CPO, Andriolo JL (2013) Tuberização e produtividade de batata-doce e função de datas de plantio em clima subtropical. Bragantia. 72: 396-402.

Ferreira DJ, Zanine AM, Lana RP, Ribeiro MD, Alves GR, Mantovani HC (2014) Chemical composition and nutrient degradability in elephant grass silage inoculated with Streptococcus bovisisolated from the rumen. An Acad Bras Ciênc. 86: 465-474.

Ferreira MAM (2017) Crescimento e acúmulo de nutrientes na cultura da batata-doce. Dissertação (Mestrado em Produção Vegetal) - Diamantina, Universidade Federal dos Vales do Jequitinhonha e Mucuri, 53p.

Figueiredo JA, Andrade júnior VC, Pereira RC, Ribeiro KG, Viana DJS, Neiva IP (2012) Avaliação de silagens de ramas de batata-doce. Hortic Bras. 30: 708-712.

Gomes FP, Garcia CH (2002) Estatística aplicada a experimentos agronômicos e florestais. 1. ed. Piracicaba, SP: FEALQ. 309 p.

Ly NTH, Ngoan LD, Verstegen MWA, Hendriks WH (2010) Ensiled and dry cassava leaves, and sweet potato vines as a protein source in diets for growing vietnamese large white×mong cai pigs. Asian-australas J Anim Sci. 23:1205–1212.

Malavolta E, Vitti GC, Oliveira AS (1997) Avaliação do estado nutricional das plantas: princípios e aplicações. Piracicaba: POTAFÓS 2: 319.

Mccready RM, Guggolz J, Silviera V, Owens HS (1950) Determination of starch and amylose in vegetables. Anal Chem 22: 1156^{-1}158.

Nwinyi SCO (1992) Effect of age at shoot removal on tuber and shoot yields at harvest of five sweet potato (*Ipomoea batatas* (L.) I.am) cultivars. Field Crops Res.,29: 47-54.

Paiva VR, Lana RP, Oliveira AS, Leão MI, Teixeira RMA (2013) Teores proteicos em dietas para vacas Holandesas leiteiras em confinamento. Arq Bras Med Ve. Zootec. 65: 1183-1191.

Pedrosa CE, Andrade Júnior VC, PereirA RC, Dornas MFS, Azevedo AM, Ferreira MAM (2015) Yield and quality of wilted sweet potato vines and its silages. Hortic Bras. 33: 283-289.

Queiroga RCF, Santos MA, Menezes MA, Vieira CPG, Silva MC (2007) Fisiologia e produção de cultivares de batata-doce em função da época de colheita. Hortic Bras. 25: 371-374.

R Core Team (2017). R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

Roesler PVSO, Gomes SD, Moro E, Kummer ACB, Cereda MP (2008) Produção e qualidade de raiz tuberosa de cultivares de batata-doce no Oeste do Paraná. Maringá. 30:117-122.

Silva GO, Ponijaleki R, Suinaga FA (2012) Divergência genética entre acessos de batata-doce utilizando caracteres fenotípicos de raiz. Hortic Bras. 30: 595-599.

Silva GO, Suinaga FA, Ponijaleki r, Amaro GB (2015) Desempenho de cultivares de batata-doce para caracteres relacionados com o rendimento de raiz. Rev Ceres. 62: 379-383.

Van An L, Lindberg BEF, Lindberg JE (2003) Effect of harvesting interval and defoliation on yield and chemical composition of leaves, stems and tubers of sweet potato (*Ipomoea batatas* L (Lam.)) plant parts. Field Crops Res. 82: 49-58.

Van Soest PJ (1994) Nutricional ecology of the ruminant. Ithaca: Cornell University Press 2: 476.

Veiga IRFM, Gonçalves LC, Lobato FCL, Faria Junior WG (2009) Batata-doce na alimentação de gado de leite. In: Gonçalves LC, Borges I, Ferreira PDS (eds) Alimentos para gado de leite. Belo Horizonte, FEPMVZ. 347-358.

Viana DJS, Andrade Júnior VC, Ribeiro KG, Pinto NAVD, Neiva IP, Figueiredo JA, LEMOS VT, Pedrosa CE, Azevedo AM (2011) Potencial de silagens de ramas de batata-doce para alimentação animal. Ciênc Rural. 41: 1466-1471.

Wilson JR (1982) Environmental and nutritional factores affecting herbage quality. In: Hacker JB (ed) Nutritional limits to production from pastures. Farnham Royal, CAB, 111-131.

Wilson JR, Kennedy PM (1996) Plant and animal constraints to voluntary feed intake associated with fibre characteristics and particle breakdown and passage in ruminants. Austr J Agricult Res. 47:199-225.

Zeeman SC, Kossmann J, Smith AM (2010) Starch: its metabolism, evolution, and biotechnological modification in plants. Annu Rev Plant Biol. 61: 209-234.