# CASSAVA (MANIHOT SCULENTA CRANTZ) AERIAL PARTS TRAITS FOR RUMINANT FEED

*(CARACTERIZAÇÃO DA PARTE AÉREA DE MANDIOCA PARA ALIMENTAÇÃO ANIMAL)*

**Abstract:** The objective of this research was to quantify and study chemical composition and digestibility of aerial part and cuttings of five cassava cultivars grown in five different levels of fertilization and three plant densities, in order to use these crop residues in ruminant feed. The experiment was conducted using a randomized complete block design, in strip-split-plot scheme, with four replications. The plots were composed of IAC14, IAC15, IAC90 and Cascuda cultivars; the subplots consisted of five categories, one with fertilization from poultry litter (3000 $kg.ha^{-1}$) and four with chemical fertilization rates (0, 150, 450, 900 $kg.ha^{-1}$) of NPK 4-20-20, and all categories with densities of 7,500, 12,500, 17,500 $plants.ha^{-1}$. During the experiment aerial part and cuttings were sampled for chemical and *in vitro* digestibility analyzes. There were differences among cassava cultivars and fertilization treatments for nutrients values and $DM.ha^{-1}$ from aerial part samples ($P<0.05$). There were differences among cuttings samples cultivars and fertilization treatments for nutrients values and $DM.ha^{-1}$ ($P<0.05$). Cassava aerial part and cuttings have considerable amounts of nutrients that can be used for ruminant feed on small farms and for animal categories with low nutritional requirements. From all treatments, variety IAC15 with chemical fertilization of 900 $kg.ha^{-1}$, as well as fertilization with poultry litter, with the highest plant density were those with better nutritional composition and greater amount of nutrients available.

**Keywords:** Digestibility. Ingredient. Nutrient. Residue. Ruminants

**Abbreviations:** crude protein (CP), crude fiber (CF), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare ($DM.ha^{-1}$)

**RESUMO:** O objetivo desta pesquisa foi de quantificar e estudar a composição bromatológica e a digestibilidade da parte aérea e da maniva-mãe de cinco cultivares de mandioca, cultivadas sob cinco diferentes níveis de adubações e três densidades de plantio, com a finalidade de utilização destes coprodutos na alimentação animal. O experimento foi realizado no Pólo Regional de Desenvolvimento do Médio Paranapanema utilizando o delineamento experimental em blocos casualizados, em esquema de parcelas sub-subdivididas, com quatro repetições. As parcelas foram compostas pelas cultivares IAC 14, IAC 15, IAC 90 e Cascuda; as subparcelas compostas por doses de 4-20-20 (0, 150, 450, 900 kg/ha); e adicional (3.000 kg/ha de cama de frango) e densidades de plantio de 7.500, 12.500, 17.500 plantas/ha. Foram feitas amostragens de parte aérea e maniva-mãe e realizadas análises bromatológicas e digestibilidade *in vitro* destas. Houve diferença entre as variedades de mandioca nas frações da fibra; na composição bromatológica; digestibilidade in vitro; nutrientes digestíveis totais (NDT), e no rendimento de matéria seca (kg/ha) da parte aérea ($P<0,05$) e da maniva-mãe ($P<0,05$) e entre as diferentes adubações para a maniva-mãe ($P<0,05$). A parte aérea e a maniva-mãe oriundas das sobras da colheita de variedades de mandiocas selecionadas para a produção de raiz possuem consideráveis quantidades de nutrientes que podem ser aproveitados para a alimentação animal em pequenas propriedades. Dos tratamentos estudados a variedade IAC15, a adubação química de 900 kg/ha, bem como adubação com cama de frango e a maior densidade populacional/há foram os que apresentaram melhor composição nutricional e maior quantidade de nutrientes disponíveis por hectare.

**Palavras-chave:** Digestibilidade. Ingrediente. Nutriente. Resíduo. Ruminantes

## INTRODUCTION

Cassava production has an important role in food security specially for populations located in the tropics, for example some countries in Africa, America and Asia. According to Faostat (2014) the world production of cassava in the year of 2012, was higher than 269 million tons of roots. The cassava production area is concentrated in Africa (56,3%), Asia (32,5%) and America (11,1%). Among the main producers, Brazil is located in the fourth position with 23 million tons of roots, surpassed only by Nigeria, Thailand and Indonesia with approximately 54, 29 and 24 million tons of roots, respectively (FAOSTAT, 2014).

In Brazil the production of cassava is found throughout the country, but the states of São Paulo, Parana and Mato Grosso do Sul are the largest cassava production centers, and the roots are used for the production of starch and flour.

The cassava production generates some residues in the crop field after the harvest, consisting of leaves, stems and cuttings (cassava foliage). From all cassava cuttings produced, only 20% are used for replanting, leaving the rest on the field, which can be considerate a product of great value for ruminant feed (LEONEL, 2002). The lack of knowledge about the importance of its use in animal feed has contributed to the low utilization of this nutrient source by farmers, especially during the dry season (MOURA and COSTA, 2001). However, the presence of leaves is required so that the residue has protein value.

The harvest in regions with cassava-processing industries is usually done in the dry periods, between the rainy seasons, because the roots have desirable qualities for processing. The most favorable harvest season is when cassava plants are at dormancy period, or when weather conditions and growth stage have decreased the number and size of leaves and leaf lobes which is indicative of maximum production of roots with high starch concentration (FUKUDA & OTSUBO, 2003). However, in different environment conditions can be found higher percentage of leaf retention, indicating better nutritional characteristic of the residue. In addition, currently, the harvest of cassava can be extended depending on the demand of processing industries and selling price.

Thus, the harvest of cassava coincides with the period of lower nutritional value of pastures and with supplementation needed to avoid a decrease in animal productivity.

These factors indicate that the aerial part of cassava plant, after roots harvested, can be a good alternative to reduce the cost of ruminant feed for this critical period.

Several parts of cassava plant, including leaves, stems and roots, can be processed to produce a valuable source of energy for the dairy cows diet (ANJOS et al., 2014). Cultivars, plant density, fertilization and harvest season are characteristics that can influence the amount and chemical composition of cassava crop residues.

Although research indicates the feasibility of using cassava aerial parts for ruminant nutrition due to great value of protein and vitamins, this residue has been poorly exploited, usually being wasted in crop field (CARVALHO, 1983, cited by MOURA & COSTA, 2001). During the roots harvest, aerial part and cuttings are disregarded, which can be used in ruminant feeding.

According to Marques et al., (2000), several factors may explain why aerial part and cuttings are considered disposal in cassava production. In particular can be highlighted the lack of information about the production and use of cassava residue in ruminant feed. The other aspect is the in homogeneity of the few values of chemical composition and digestibility that can be found in the literature.

The objective of this research was to quantify and study the chemical composition and in vitro digestibility of aerial part and cuttings of five cassava cultivars grown under five different levels of fertilization and three planting densities, with the purpose of utilization in ruminant feed.

## MATERIAL AND METHODS

### Location of the experiment

The experiment was conducted at APTA Regional Médio Paranapanema (22°40'S and 50°26'W, altitude of 563m and humid subtropical climate Cwa) in the city of Assis, State of São Paulo, Brazil, in dark Haplorthox soils of medium texture. The result of the chemical analysis from soil samples (0-20 cm) showed OM (g $dm^{-3}$) = 18; P (Resin, mg $dm^{-3}$) = 9; pH ($CaCl_2$) = 4.6; K, Ca, Mg, H + Al, BSR and CEC (mmol $dm^{-3}$) = 2.8; 11; 8; 31; 13.8 and 50.8, respectively, and V (%) = 39. Before the experiment, 2 $t.ha^{-1}$ of dolomitic limestone was applied and incorporated by harrowing.

### Experimental design and treatments

The experimental design was a randomized complete block, in strip-split-plot scheme, with four replications. The plots were composed of cultivars; subplots consisted of five fertilization rates and sub-subplots consisted by the densities of plants (Figure 1).

Chemical analysis of poultry litter revealed 24.4% of humidity; N, P, K, Ca, Mg and S ($g.kg^{-1}$) respectively 22.7; 21.9; 28.6; 91; 6.2 and 4.2; Zn, Cu, Fe, Mn and B (mg $dm^{-3}$) respectively 340; 505; 8150; 536 and 32.7. The planting was done with 18 cm stem cuttings in minimum tillage system, on intercropping with oats at the stage of panicle emergence started, after the use of glyphosate as a desiccant. The fertilizers were distributed at planting time and mixed with soil. The samples of aerial part and cuttings were made 12 months after planting.

All aerial parts of each experimental unit were taken (20 cm above ground) and weighed. Also in the field, a sample of approximately five kilograms was collected and wrapped in plastic bags and subsequently taken to the laboratory for processing. Besides the plant aerial part, also sets cuttings composites of each experimental unit were weighed. After the weighing process, a sample of three cuttings was reserved to be processed in the laboratory.

In the laboratory, the samples of aerial parts and cuttings were fully chopped, homogenized and sub-sampled. The final samples of aerial parts had about one kilogram and for stem samples about 500 grams.

**Analytical determination**

Samples were dried at 65°C, placed in paper bags and processed to estimate the chemical composition by AOAC (1995). Dry matter (DM) was obtained in an oven at 103-105°C; crude protein (CP) by micro Kjeldahl method; ether extract (EE) was extracted and calculated using petroleum ether as the solvent; and mineral matter was calculated using an oven at 500-550°C. The acid detergent fiber (ADF) and neutral detergent fiber (NDF) were analyzed through procedure described by Van Soest et al. (1991). The hemicellulose (HEM) were obtained using the formula HEM = NDF - ADF. The contents of cellulose (CEL) and lignin (LIG) were determined by Van Soest & Robertson methodology (Van Soest and Robertson, 1980). In vitro dry matter digestibility (IVDDM) was determinate using the two-stage technique proposal from "Tilley and Terrey", presented by Campos et al. (2004).

**Statistical design**

The experimental design was a randomized block, split plot with four replications, totaling 240 experimental units. Due to non-randomization of sub-subplots, the results were adjusted by the model: $y = a * bx$, chosen to be closest to the biological behavior of cassava production. After adjustment, all data were subjected to analysis of variance, using the Statistical Analysis System program (SAS Inst. Inc., Cary, NC) for the model in strip-split-plot. In first moment was made the contrast between the control (no fertilizer) and fertilized treatments, followed by contrast between chemical x organic fertilizers. In the sequel, new analysis of variance was performed without organic fertilization, which applied the unfolding of the sum of squares for the factors of fertilization rates and planting density and their interactions, including the cultivars. For these analyzes was applied to the test at 5% probability and for fertilization rate and plant density was performed a regression analysis.

## RESULTS AND DISCUSSION

Cassava aerial part used in animal feed can be defined as the last third part of the plant, including stems and leaves, and its composition depends on plant age, cultivar, fertilization and environment (CAMPOS NETO et al., 1995). Leonel (2002) described that chemical composition and nutritional value of aerial part were influenced by the harvest season. Some of his experiments recommend the best harvest season is obtained from plants with 12 and 18 months old, even so, there is variation among cultivars.

Differences were found among cassava cultivars for CP, CF, EE, NFE, MM, TDN, ADF, NDF, CEL, LIG, IVDDM, CHT, DM and $DM.ha^{-1}$ ($P< 0.05$, Table 1). Among fertilization rates, there were differences in CF, NFE, MM, TDN, ADF, CEL, LIG, IVDDM, CHT, DM and $DM.ha^{-1}$ in aerial part samples ($P<0.05$, Table 1).

MM ($P<0.05$) and $DM.ha^{-1}$ ($P<0.01$) increased linearly in aerial part with the increase of fertilization. Total dry matter decreases linearly with the increase of fertilization rate ($P< 0.01$, Table 2).

In this study with cassava cultivars (CASCUDA, IAC14, IAC15 and IAC90) in different densities and fertilization rates, it was observed that IAC14 cultivar had higher amounts of $DM.ha^{-1}$, higher values of CHT, CEL, NDF and ADF, the lowest IVDDM and TDN and higher content of LIG. The cultivar with higher IVDDM and TDN was IAC90, but it presented lower production ($DM.ha^{-1}$). CASCUDA and IAC15 cultivars had higher CP and EE. On the ratio between production of $DM.ha^{-1}$ and TDN decreasing values in sequence were found for all cultivars starting with IAC14, followed by IAC15, IAC90 and CASCUDA cultivar (3.64, 2.83, 1.6 and 1.44 $NDT.ha^{-1}$ respectively).

Modesto et al. (2002) studied the chemical composition of leaves from five cassava cultivars at different harvest times, and found that earlier harvest (at 12 months) promoted higher digestibility of cell wall (90%) due to lower lignification of leaves.

When harvested at 21 months age, the leaves showed digestibility of 77%, also occurring decrease in CP content. In the present experiment, all cassava cultivars were harvested at 12 months age and showed satisfactory average values of IVDDM (54.90, 52.24, 51.24 and 44.12% for IAC90, IAC15, CASCUDA and IAC14, respectively).

Wanapat et al. (1997) showed the usefulness from cassava aerial part as good quality forage for ruminants feeding due to availability during the critical season of the year that is in the dry season. The main advantage is related to production of 10,200 $kg.ha^{-1}$ of DM and the capacity to produce 20,400 $kg.ha^{-1}$ and 5,102 $kg.ha^{-1}$ of protein, after the second and third harvest. According to Vidigal Filho et al. (2000), cultivars IAC12, IAC13 and IAC14 can produce 11.91 to 31.65 $t.ha^{-1}$ of aerial part that can reach up to 2.47 m of height. In the current experiment, the cultivar with the highest production was IAC14 (6,420 $kg.ha^{-1}$), but it was also the one with lower protein content. From all studied cultivars, IAC15 showed the highest protein production, followed by IAC14, CASCUDA, IAC90 (389.28, 365.94, 210.32 and 209.33 kg of $protein.ha^{-1}$, respectively).The percentage of protein found by Wanapat et al. (1997) was higher than the values found in the current experiment (24.9 vs 7.49% CP in DM, respectively). Wanapat et al. (1997) aimed to study cassava cultivars with aerial part high production for use in animal feeding for production system in Thailand. The cultivars studied in the current experiment were selected for root production, so it shows lower nutrient values.

Additionally, the harvest was done when the plants showed a small amount of leaves and theoretically the maximum starch accumulation in roots. In cassava crops for the production for animal feed, the crops are done when the plants have maximum quantity of leaves, which justifies the higher percentage of protein found by Wanapat et al. (1997). Thus, the purpose of this study was to take advantage in ruminant nutrition with the nutrients present in cassava aerial part from cultivars selected for root production. It is estimated that about 14 to 16 million tons of cassava aerial part are left over the harvest when it could be useful for animal nutrition, with benefit in the production of meat, milk and eggs (CARVALHO, 1994).

Most research involving the use of cassava aerial part for ruminant feed uses the plant last third part, which has a larger amount of leaves and smaller amount of stems, therefore has higher concentration of protein and higher digestibility. According to Leonel (2002), the cassava aerial part has high nutritional value and good acceptability by animals and their nutritional value can show variations due to the ratio between leaves and stems. Even so, the aerial part shows satisfactory chemical composition as forage, with the following values of chemical-bromatological analysis: 25.95% DM, 14.99% CP, 42.53% NDF and 2.66% of EE for the fresh aerial part. In this study the composition of the whole aerial part was analyzed, showing average bromatological values of 30.06% DM, 7.49% CP, NDF 66.76% and 0.87% of EE. Thus, it can be shown that due to the lower percentage of CP and higher NDF, the material sampled had proportionally greater amount of stems than leaves. This was expected since it was not only used the last third of cassava aerial part in the process, but the whole plant.

Modesto et al. (2004) studied the silage from the last third of cassava aerial part characterized through bromatological analysis, and concluded that it has good nutritional qualities, with adequate protein levels, moderate NDF content (50.75%), satisfactory fractions of non-protein nitrogen and acid detergent insoluble protein. Moreover, with a high lignin content and low tannin, which suggests the need for further studies on the use of this silage for animal feed.

The condensed tannins contained in cassava foliage hay have demonstrated an important role as a tannin-protein complex to increase protein bypass in the rumen and to reduce nematode egg counts in gastrointestinal tract (WANAPAT, 2003). Modesto et al. (2008), replacing corn silage by cassava foliage silage in the proportions of 0, 20, 40 and 60%, concluded that the substitution can be made in up to 60% for feeding non-lactating cows, it does not change feed intake, digestibility and ruminal parameters, except in CP digestibility and ruminal ammonia nitrogen in the time of 8 postprandial hours. Branco et al. (2006) studying the protein digestibility of various feed ingredients reported that cassava foliage silage showed a high ruminal degradation (50.51%) but low true intestinal digestibility (39.94%) when compared with others roughages.

Wanapat et al. (1997) described a digestibility of 71% DM, where DM digestibility of carbohydrate was relatively high and for protein was lower, which indicates that this residue is a good source of non-degradable protein. These authors also studied the whole plant, but the experiment was conducted and analysed with plants up to three months of age. In the current experiment, average values of 50.94% for IVDDM were found, but the plants were harvested at 12 months old and already had high lignin percentages (average of 16.98%). Onwuka et al. (2011) studied the nutritional value of the leaves from four cultivars of cassava in Nigeria and found an average value of 17.7 to 24.0% CP, 59.6 to 66.2% NDF, 41.8 to 54.6% FDA and 58.5 to 86.7% DM. These nutrients were positively correlated to volatile fatty acids produced in vitro with production of up to 50.5 mL/200mg DM, demonstrating that serve as supplements to ruminants fed with poor roughages.

There was little variation in nutrients of cassava aerial part due to the different fertilization. The results showed that treatments with higher values of DM.ha$^{-1}$, IVDDM and lower lignin percentage were associated with higher mineral fertilizer level (900 kg.ha$^{-1}$) and poultry litter use (Table 1). According to Souza and Fialho (2003) cassava plants presents satisfactory response to the application of organic fertilizers (manure, cakes, organic compounds, green manure and other), which should be preferred as a nitrogen source for this agricultural crop.

CP, CF, NFE, MM, CEL and DM.ha$^{-1}$ from cassava aerial part had quadratic effect with planting densities ($P<0.05$). DM increased linearly with the increase of plant density per hectare ($P<0.05$, Table 3). The regression equations are presented in Table 4 with their respective $R^2$.

Assessing the chemical fertilizer levels, linear increase in amount of mineral matter and DM.ha$^{-1}$ were found and also a linear decrease in DM, due to the increase of fertilizer levels respectively. Thus it was possible to observe that the best fertilization level showed a higher amount of material available to be used as ruminant feed. It was also observed that with the increase of plant density per hectare, an increase in the production of dry matter was found, with an average value of 810 kg DM.ha$^{-1}$ (Table 3).

Souza and Fialho (2003) report that the spacing of cassava depends on soil fertility, size of cultivar, aim of production (roots or foliage), management practices and harvesting type (manual or mechanized). In this study, the largest production of DM.ha$^{-1}$ is related to treatments with higher level of chemical fertilizer (900 kg ha$^{-1}$), organic fertilization by poultry litter and higher population density plants / ha (17,500). Cassava absorbs large amounts of nutrients and exports almost of all that was absorbed, returning to soil a little amount of nutrient through the crop residue. As an example of nutrient export may be cited the tuberous roots that are intended for the flour production, starch and other products for human and animal consumption; and also the aerial part (leaves and cuttings), for new plantings and human and animal nutrition (SOUZA & FIALHO, 2003).

Despite the cassava root is widely used for human consumption, its aerial part is little utilized as roughage source for livestock production due to poor knowledge of their potential (SANTOS et al., 2001). After harvesting of cassava for human consumption, the shoot is wasted. This waste includes leaves and stems, which are liable to be utilized for ruminant feed.

The IAC15 cultivar showed greater $DM.ha^{-1}$ from harvest, greater values of IVDDM, NFE and CP, with higher percentage of TDN and lower percentage of lignin (Table 5). However, the cultivar IAC14 had higher amounts of CHT due to the higher levels of structural carbohydrates (higher NDF, ADF and cellulose) and was also the cultivar that had the highest percentage of lignin in comparison the other cultivars.

There were differences between cassava cultivars in values of CP, CF, NFE, MM, TDN, ADF, NDF, CEL, LIG, IVDDM, CHT, HEM, DM and $DM.ha^{-1}$ from cuttings samples ($P<0.05$, Table 5).

From cuttings samples, differences were also found in CP, CF, EE, NFE, TDN, ADF, CEL, LIG, IVDDM, CHT, DM and $DM.ha^{-1}$ for fertilization variable ($P<0.05$, Table 5). NFE ($P<0.01$) and DM ($P<0.05$) decreased linearly with the increase of fertilizer level. ADF ($P<0.05$) and CEL ($P<0.01$) increased linearly with the increase of fertilizer level. The levels of CP ($P<0.01$), IVDDM ($P<0.05$) and CHT ($P<0.01$) had quadratic effect with different fertilization levels (Table 6).

For TDN and amount of DM.ha$^{-1}$ ($P<0.05$) a linear increase was observed and for DM ($P<0.01$) a decreased was observed with the increase of plant density per hectare (Table 7).

The regression equations are presented in Table 8 with their respective $R^2$.

Little variation of nutrients from fertilization treatments was observed for cuttings samples, as also observed in aerial part analysis. The application of 450 kg ha$^{-1}$ was the treatment that showed the highest percentage of CP and high value of IVDDM, but it was not the treatment with the highest DM yield ha$^{-1}$. However, fertilization with poultry litter had the highest values of DM.ha$^{-1}$ and CP.ha$^{-1}$, even not having the highest percentage of CP (186.18 vs 180.50 kg CP.ha$^{-1}$ for fertilization treatments with poultry litter and 450 kg.ha$^{-1}$, respectively, Table 5).With the increase of chemical fertilization the increase in amount of protein and structural carbohydrates (cellulose and ADF), and the decrease in percentages of NFE from cuttings samples were found (Table 6). For plant density, it was observed that the increase in density increased the concentration of nutrients in plants, with higher value of DM.ha$^{-1}$ from cuttings (Table 7).

The results of CP in this study are noteworthy. The cuttings had higher average values of CP (8.82%) than the aerial part of studied cultivars. The cassava root is classified as an energetic ingredient for ruminant feed because of its high energy and low protein (CARVALHO, 1994). Cuttings showed lower values in quimical-bromatological analysis, but very similar to corn meal that is widely used in animal feed. Valadares Filho et al. (2006) reported that corn meal has averaged 8.50% CP, 75.40% NFE, 7.83% NDF and 64.70% IVDDM. Cuttings from studied cultivars in this present study had an average value of 8.82% CP, 52.23% NFE, 65.53% NDF and 51.40% IVDDM (Table 5).

In terms of composition and amount produced, it is not possible to effectively compare the ingredients studied in this work with other commercially produced and used for ruminant feed. But it is evident that cassava root residue, either shoots or cuttings, have considerable nutrients amounts and satisfactory digestibility, that can be included as ingredient of ruminant feed on small farms.

Cassava aerial part can be administered to ruminants in fresh, hay or silage, depending on their variety. Cultivars with low content of hydrocyanic acid can be chopped and offered directly to the ruminants, while cultivars with high content of hydrocyanic acid should be dried for at least 24 hours, to reduce the level of hydrocyanic acid (HCN) to not toxic levels to animals (CAMPOS NETO et al., 1995).

Another recommendation for cassava aerial part use would be mixture with 50% of other roughage for feeding ruminants and 80% concentrate for feeding monogastric animals (CARVALHO, 1994).

Steers performance increased when fed with rice straw treated with urea and supplemented with cassava aerial part silage (EUCLIDES et al., 1988). The authors developed a study involving replacement of 25% of rice straw by cassava hay managed to correct the nitrogen deficiency in the diet, found an increase in digestible organic matter intake, reaching steers maintenance requirements, since both ingredients provided as exclusive feed not provide the amount of nutrients needed to maintenance these animals.

The basal diet of Gamba grass (Andropogon gayanus) supplemented with wilt cassava aerial part (10-12 hours before feeding) was evaluated in growing goats up to 40% of total daily intake of 3% DM. There was an increase in dry matter intake, digestibility of nutrients, nitrogen retention, weight gain and feed conversion ratio (PHENGVICHITH & LEDIN, 2006).

Cassava aerial part hay can replace up to 750 g/kg of concentrate in diet for growing goats fed with basal diet of Guinea grass (Panicum maximum) and cassava root, with similar results to weight gain and feed conversion ratio, presenting low cost. The best results were obtained when the cassava hay replaced 250 g/kg DM of the concentrate (DUNG et al. 2005). Thang et al (2010) also found a better performance in crossed steers when cassava aerial part was offered along with grass (Stylosanthes guianensis) compared to those that received only cassava aerial part as forage. The authors reported that low value of organic matter and high level of HCN in the diet in consequence of the cassava aerial part use resulted in lower growth rates due the negative effects on intake and nitrogen retention in animals.

Thus, residues of foliage and cuttings derived from cassava root production have nutrients that can be used for ruminant feed, but the nutritional value is not the same as that cassava produced for the specific purpose as animal feed. The cultivars to animal feed have a higher quality and amount of nutrients than that provided by cassava for root production residue. Therefore, the residues from root production should be used as a supplement to other ingredients to maintain the animal performance for categories of low nutritional requirements. Wanapat (2003) reported that hay from cassava aerial part is an excellent source of many nutrients for animal nutrition, especially for dairy cattle during the long dry season, and has the potential to increase the productivity and profitability of sustainable livestock production systems in tropics.

## CONCLUSION

Cassava for root production residue, composed by foliage and cuttings, have considerable amounts of nutrients that can be used for livestock feed on small farms and for animals in categories of low nutritional requirement. From all studied treatments, the cultivar IAC15, chemically fertilized with 900 $kg.ha^{-1}$, as well as fertilization with poultry litter and the highest plant density showed the best nutritional composition and greater amount of available nutrients.


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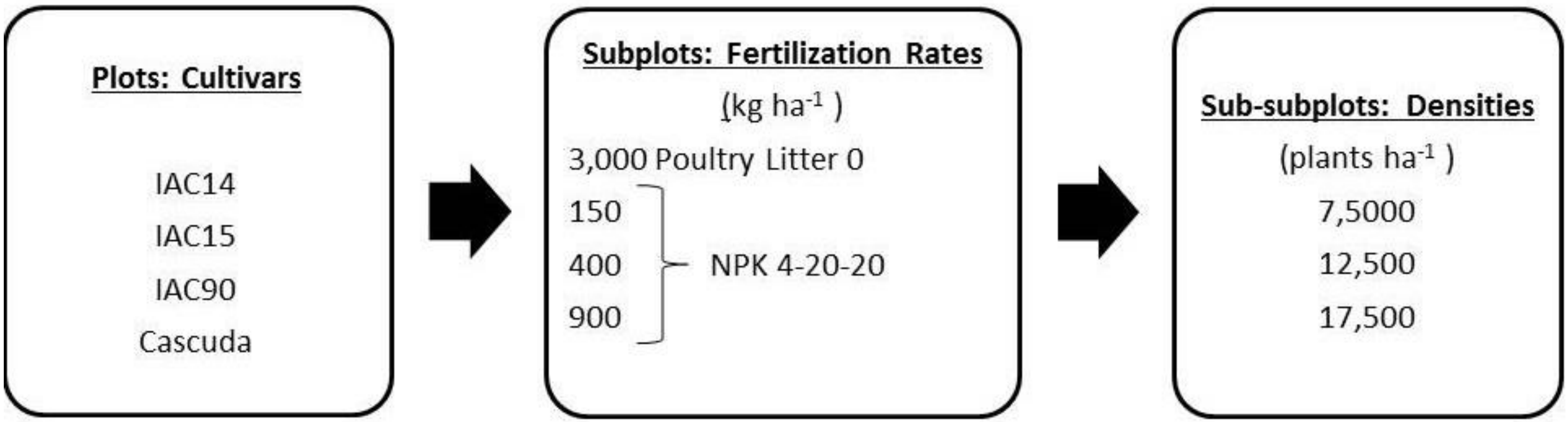


**Figure 1: Distribution of experimental treatments.**

**Table 1:** Values expressed as percentage of crude protein (CP), crude fiber (CF), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare ($DM.ha^{-1}$) for aerial part samples after harvest due to cultivars for root production and fertilization treatment.

| | **CP** | **CF** | **EE** | **NFE** | **MM** | **TDN** | **ADF** | **NDF** | **CEL** | **LIG** | **IVDDM** | **CHT** | **HEM** | **DM** | **$DM.ha^{-1}$** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cultivar** | | | | | | | | | | | | | | | |
| | | | | | | | **%** | | | | | | | | **t $ha^{-1}$** |
| CASCUDA | 8.62a | 35.56c | 0.89ab | 49.68b | 5.27a | 59.29b | 47.12b | 65.82b | 28.92c | 18.40a | 51.24b | 85.23c | 18.63 | 29.07b | 2.44d |
| IAC14 | 5.70d | 42.68a | 0.82bc | 47.23c | 3.61d | 56.72c | 51.93a | 71.90a | 34.11a | 17.93a | 44.12c | 89.87a | 19.93 | 34.13a | 6.42a |
| IAC15 | 8.11b | 36.90b | 0.97a | 49.71b | 4.33c | 59.00b | 46.52b | 65.56b | 30.06b | 16.40b | 52.24b | 86.60b | 19.01 | 29.80b | 4.80b |
| IAC90 | 7.53c | 33.93d | 0.77c | 52.97a | 4.89b | 60.52a | 44.92c | 64.49b | 29.61bc | 15.45c | 54.90a | 86.81b | 19.56 | 27.23c | 2.78c |
| Means | 7.49 | 37.09 | 0.87 | 50.07 | 4.52 | 58.98 | 47.51 | 66.76 | 30.59 | 16.98 | 50.94 | 87.13 | 19.23 | 30.06 | 4.09 |
| LSD | 0.25* | 0.92* | 0.10* | 0.91* | 0.15* | 0.74* | 1.13* | 1.54* | 0.81* | 0.56* | 1.41* | 0.37* | 1.53 | 0.74* | 0.31* |
| **Fertilization** | | | | | | | | | | | | | | | |
| | | | | | | | **%** | | | | | | | | **t $ha^{-1}$** |
| 0 | 7.41 | 37.39ab | 0.83 | 49.98abc | 4.38b | 58.85ab | 48.17a | 67.42 | 30.95a | 17.45a | 50.13b | 87.39a | 19.21 | 30.57a | 3.87bc |
| 150 kg $ha^{-1}$ (4-20-20) | 7.55 | 36.53bc | 0.86 | 50.49ab | 4.58a | 59.04ab | 47.18ab | 66.83 | 30.09b | 17.05ab | 51.10ab | 87.01b | 19.63 | 30.70a | 3.70c |
| 450 kg $ha^{-1}$ (4-20-20) | 7.48 | 37.71a | 0.90 | 49.50c | 4.55a | 59.15ab | 47.49ab | 66.65 | 30.83ab | 16.76b | 50.58b | 87.07ab | 19.07 | 30.20ab | 4.16ab |
| 900 kg $ha^{-1}$ (4-20-20) | 7.53 | 37.44a | 0.85 | 49.60bc | 4.59a | 58.50b | 47.65ab | 66.88 | 30.84ab | 16.94ab | 50.70ab | 87.04b | 19.21 | 29.49bc | 4.43a |
| 3,000 kg $ha^{-1}$ (poultry litter) | 7.46 | 36.36c | 0.89 | 50.78a | 4.53ab | 59.37a | 47.03b | 66.04 | 30.27ab | 16.72b | 52.12a | 87.13ab | 19.01 | 29.34c | 4.32a |
| Means | 7.49 | 37.09 | 0.87 | 50.07 | 4.52 | 58.98 | 47.51 | 66.76 | 30.59 | 16.98 | 50.94 | 87.13 | 19.23 | 30.06 | 4.09 |
| LSD | 0.24 | 0.91* | 0.10 | 0.91* | 0.15* | 0.70* | 1.14* | 1.46 | 0.79* | 0.60* | 1.38* | 0.35* | 1.48 | 0.83* | 0.35* |

* Statistically significant using t-test ($P<0.05$); LSD = least significance difference

**Table 2:** Values expressed as percentage of crude protein (CP), crude fiber (CF), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare (DM.ha$^{-1}$) for aerial part samples after harvest due to chemical fertilization.

| | CP | CF | EE | NFE | MM | TDN | ADF | NDF | CEL | LIG | IVDDM | CHT | HEM | DM | DM.ha$^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fertilization** | | | | | | **%** | | | | | | | | | **t ha$^{-1}$** |
| 0 (control) | 7.40 | 37.39 | 0.83 | 49.98 | 4.38 | 58.85 | 48.17 | 67.42 | 30.95 | 17.45 | 50.13 | 87.39 | 19.22 | 30.60 | 3.87 |
| 150 kg ha$^{-1}$ (4-20-20) | 7.55 | 36.53 | 0.86 | 50.50 | 4.58 | 59.04 | 47.18 | 66.83 | 30.09 | 17.05 | 51.10 | 87.01 | 19.63 | 30.70 | 3.71 |
| 450 kg ha$^{-1}$ (4-20-20) | 7.49 | 37.71 | 0.90 | 49.50 | 4.55 | 59.15 | 47.49 | 66.65 | 30.83 | 16.76 | 50.58 | 87.07 | 19.08 | 30.20 | 4.16 |
| 900 kg ha$^{-1}$ (4-20-20) | 7.53 | 37.44 | 0.85 | 49.60 | 4.59 | 58.50 | 47.65 | 66.88 | 30.84 | 16.94 | 50.70 | 87.04 | 19.21 | 29.43 | 4.43 |
| Means | 7.49 | 37.27 | 0.86 | 49.89 | 4.52 | 58.88 | 47.62 | 66.94 | 30.67 | 17.05 | 50.63 | 87.13 | 19.29 | 30.24 | 4.04 |
| **F value for regression** | | | | | | | | | | | | | | | |
| Linear | 0.25 | 1.06 | 0.16 | 1.92 | 4.32* | 1.29 | 0.11 | 0.30 | 0.37 | 2.01 | 0.11 | 1.61 | 0.11 | 11.17** | 13.80** |
| Quadratic | 0.11 | 0.05 | 1.63 | 0.10 | 2.00 | 2.34 | 1.13 | 0.71 | 0.39 | 2.53 | 0.30 | 1.31 | 0.01 | 0.44 | 0.08 |

** and * = statistical significance determined by probability of 0.01 and 0.05, respectively

**Table 3:** Values expressed as percentage of crude protein (CP). crude fiber (CF). ether extract (EE). nitrogen-free extract (NFE). mineral matter (MM). total digestible nutrients (TDN). acid detergent fiber (ADF). neutral detergent fiber (NDF). cellulose (CEL). lignin (LIG). in vitro digestibility of dry matter (IVDDM). total carbohydrates (CHT). hemicellulose (HEM). dry matter (DM) and dry matter per hectare (DM.ha$^{-1}$) for aerial part samples after harvest due to plant density.

| | CP | CF | EE | NFE | MM | TDN | ADF | NDF | CEL | LIG | IVDDM | CHT | HEM | DM | DM.ha$^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Plant Density (D)** | | | | | | **%** | | | | | | | | | **t ha$^{-1}$** |
| 7,500 plants.ha$^{-1}$ | 7.56 | 37.55 | 0.85 | 49.58 | 4.47 | 58.63 | 48.01 | 66.97 | 31.05 | 17.04 | 49.93 | 87.11 | 18.93 | 30.72 | 3.77 |
| 12,500 plants.ha$^{-1}$ | 7.30 | 36.79 | 0.83 | 50.49 | 4.60 | 59.11 | 47.14 | 66.93 | 30.14 | 17.03 | 51.28 | 87.27 | 19.76 | 29.98 | 3.77 |
| 17,500 plants.ha$^{-1}$ | 7.61 | 37.46 | 0.90 | 49.62 | 4.50 | 58.91 | 47.72 | 66.93 | 30.84 | 17.07 | 50.66 | 86.99 | 19.15 | 30.02 | 4.58 |
| Means | 7.49 | 37.27 | 0.86 | 49.89 | 4.52 | 58.88 | 47.62 | 66.94 | 30.67 | 17.05 | 50.63 | 87.13 | 19.29 | 30.24 | 4.04 |
| **F value for regression** | | | | | | | | | | | | | | | |
| Linear | 0.16 | 0.05 | 1.17 | 0.01 | 0.21 | 0.71 | 0.34 | 0.01 | 0.33 | 0.01 | 1.43 | 0.59 | 0.10 | 4.51* | 26.12** |
| Quadratic | 9.18* | 4.23* | 1.63 | 6.54* | 4.32* | 1.46 | 2.90 | 0.01 | 6.93* | 0.02 | 3.45 | 2.43 | 1.56 | 1.94 | 8.94* |

** and * = statistical significance determined by probability of 0.01 and 0.05, respectively

**Table 4:** Regression equations for mineral matter (MM), dry matter (DM) and dry matter per hectare ($DM.ha^{-1}$) of aerial part samples after harvest of cultivars for root production due to fertilization treatment and plant density.

| Variable | Regression equations | $R^2$ |
|---|---|---|
| **Fertilization** | | |
| MM | $Y = 0.0002X_A + 4.4631$ | 0.45* |
| DM | $Y = -0.0014 X_A + 30.762$ | 0.94** |
| $DM.ha^{-1}$ | $Y = 0.0007 X_A + 3.7633$ | 0.87** |
| **Plant Density** | | |
| DM | $Y = -7E\text{-}05 X_B + 31.099$ | 0.71* |
| $DM.ha^{-1}$ | $Y = 8E\text{-}05 X_B + 3.0242$ | 0.74* |

$X_A$ – fertilization rate; $X_B$ – plant density; Y – correspondent variable; ** and * = statistical significance determined by probability of 0.01 and 0.05, respectively

**Table 5:** Values expressed as percentage of crude protein (CP), crude fiber (CF), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare ($DM.ha^{-1}$) for cuttings samples after harvest due to cultivars for root production and fertilization treatment.

| | CP | CF | EE | NFE | MM | TDN | ADF | NDF | CEL | LIG | IVDDM | CHT | HEM | DM | $DM.ha^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cultivar** | | | | | | | | | | | | | | | |
| | | | | | | % | | | | | | | | | $t\ ha^{-1}$ |
| CASCUDA | 9.35b | 32.64b | 0.73 | 52.62b | 4.67a | 60.70b | 43.19b | 63.47bc | 27.57bc | 14.85b | 52.18b | 85.25c | 20.27c | 37.97b | 1.47d |
| IAC14 | 7.26c | 39.90a | 0.64 | 48.18c | 4.02bc | 57.39c | 49.87a | 72.09a | 33.25a | 15.84a | 44.17c | 88.08a | 22.23ab | 39.85a | 1.94b |
| IAC15 | 9.62a | 31.67b | 0.67 | 54.23a | 3.82c | 61.69a | 40.66c | 61.50c | 26.80c | 13.12c | 54.41a | 85.90b | 20.84bc | 37.82b | 2.59a |
| IAC90 | 9.17b | 32.43b | 0.71 | 53.46ab | 4.23b | 61.08b | 41.39c | 65.30b | 27.98b | 12.85c | 54.44a | 85.89b | 23.91a | 37.15c | 1.78c |
| Means | 8.82 | 34.09 | 0.67 | 52.23 | 4.20 | 60.23 | 47.73 | 65.53 | 28.86 | 14.13 | 51.40 | 86.32 | 21.79 | 38.25 | 1.99 |
| LSD | 0.24* | 1.07* | 0.10 | 1.01* | 0.23* | 0.53* | 1.19* | 2.10* | 0.92* | 0.41* | 1.87* | 0.38* | 1.87* | 0.60* | 0.11* |
| **Fertilization** | | | | | | | | | | | | | | | |
| | | | | | | % | | | | | | | | | $t\ ha^{-1}$ |
| 0 (control) | 8.69b | 33.47c | 0.70a | 53.08a | 4.08 | 60.68a | 42.69c | 65.06 | 28.08c | 13.96b | 51.73a | 86.55a | 22.38 | 38.58a | 1.94b |
| 150 $kg\ ha^{-1}$ (4-20-20) | 8.75b | 34.61ab | 0.66ab | 51.85bc | 4.13 | 59.94b | 44.53ab | 65.99 | 29.41ab | 14.36a | 51.48ab | 86.45a | 21.46 | 38.17ab | 1.89b |
| 450 $kg\ ha^{-1}$ (4-20-20) | 9.07a | 33.75bc | 0.72a | 52.15abc | 4.32 | 60.37sb | 42.89c | 65.01 | 28.21c | 14.03ab | 52.02a | 85.89b | 22.11 | 38.25ab | 1.99b |
| 900 $kg\ ha^{-1}$ (4-20-20) | 8.88ab | 34.82a | 0.67ab | 51.42c | 4.22 | 59.87b | 45.00a | 66.30 | 29.89a | 14.32ab | 49.97b | 86.23ab | 21.30 | 38.80b | 1.96b |
| 3,000 $kg\ ha^{-1}$ (poultry litter) | 8.70b | 33.80abc | 0.59b | 52.65ab | 4.26 | 60.28ab | 43.54bc | 65.26 | 28.71bc | 13.96ab | 51.80a | 86.46a | 21.71 | 38.45a | 2.14a |
| Means | 8.82 | 34.09 | 0.67 | 52.23 | 4.20 | 60.23 | 47.73 | 65.53 | 28.86 | 14.13 | 51.40 | 86.32 | 21.79 | 38.25 | 1.99 |
| LSD | 0.25* | 1.05* | 0.09* | 0.98* | 0.24 | 0.53* | 1.17* | 2.09 | 0.91* | 0.40* | 1.73* | 0.38* | 1.82 | 0.57* | 0.11* |

* Statistically significant using t-test ($P<0.05$); LSD = least significance difference

**Table 6:** Values expressed as percentage of crude protein (CP), crude fiber (CF), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare ($DM.ha^{-1}$) for cuttings samples after harvest due to chemical fertilization.

| | **CP** | **CF** | **EE** | **NFE** | **MM** | **TDN** | **ADF** | **NDF** | **CEL** | **LIG** | **IVDDM** | **CHT** | **HEM** | **DM** | **$DM.ha^{-1}$** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fertilization** | | | | | | **%** | | | | | | | | | **t $ha^{-1}$** |
| 0 | 8.69 | 33.47 | 0.70 | 53.08 | 4.08 | 60.68 | 42.69 | 65.06 | 28.08 | 13.96 | 51.73 | 86.55 | 22.38 | 38.56 | 1.94 |
| 150 kg $ha^{-1}$ (4-20-20) | 8.75 | 34.61 | 0.66 | 51.85 | 4.13 | 59.94 | 44.53 | 65.99 | 29.41 | 14.36 | 51.48 | 86.45 | 21.46 | 38.17 | 1.89 |
| 450 kg $ha^{-1}$ (4-20-20) | 9.08 | 33.75 | 0.72 | 52.15 | 4.32 | 60.37 | 42.89 | 65.01 | 28.21 | 14.03 | 52.02 | 85.89 | 22.11 | 38.25 | 1.99 |
| 900 kg $ha^{-1}$ (4-20-20) | 8.89 | 34.82 | 0.67 | 51.42 | 4.22 | 59.87 | 45.00 | 66.30 | 29.89 | 14.32 | 49.97 | 86.23 | 21.30 | 37.90 | 1.96 |
| Means | 8.85 | 34.16 | 0.69 | 52.12 | 4.19 | 60.22 | 43.78 | 65.59 | 28.90 | 14.17 | 51.30 | 86.28 | 21.81 | 38.25 | 1.99 |
| **F value for regression** | | | | | | | | | | | | | | | |
| Linear | 5.53* | 3.52 | 0.04 | 8.38** | 3.45 | 3.80 | 7.35* | 0.67 | 8.18** | 0.86 | 8.48** | 5.32* | 0.43 | 4.01* | 0.69 |
| Quadratic | 9.40** | 0.65 | 0.27 | 0.50 | 3.78 | 0.02 | 1.09 | 0.25 | 1.44 | 0.02 | 4.28* | 9.37** | 0.01 | 0.00 | 0.22 |

** and * = statistical significance determined by probability of 0.01 and 0.05, respectively

**Table 7:** Values expressed as percentage of crude protein (CP), crude fiber (CF), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare ($DM.ha^{-1}$) for cuttings samples after harvest due to plant density.

| | CP | CF | EE | NFE | MM | TDN | ADF | NDF | CEL | LIG | IVDDM | CHT | HEM | DM | $DM.ha^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Plant Density** | | | | | | **%** | | | | | | | | | **$t\ ha^{-1}$** |
| 7,500 $plants.ha^{-1}$ | 8.85 | 34.69 | 0.69 | 51.67 | 4.11 | 59.88 | 44.01 | 66.23 | 29.15 | 14.10 | 51.01 | 86.35 | 22.27 | 38.51 | 1.63 |
| 12,500 $plants.ha^{-1}$ | 8.89 | 33.98 | 0.63 | 52.32 | 4.19 | 60.30 | 43.71 | 65.36 | 28.85 | 14.21 | 51.56 | 86.29 | 21.65 | 38.28 | 1.89 |
| 17,500 $plants.ha^{-1}$ | 8.81 | 33.82 | 0.75 | 52.38 | 4.25 | 60.47 | 43.62 | 65.18 | 28.69 | 14.20 | 51.32 | 86.19 | 21.56 | 37.81 | 2.31 |
| Means | 8.85 | 34.16 | 0.69 | 52.12 | 4.19 | 60.22 | 43.78 | 65.59 | 28.90 | 14.17 | 51.30 | 86.28 | 21.81 | 38.25 | 1.99 |
| **F value for regression** | | | | | | | | | | | | | | | |
| Linear | 0.21 | 3.44 | 1.69 | 2.58 | 1.83 | 6.40* | 0.54 | 1.31 | 1.31 | 0.29 | 0.14 | 0.90 | 0.67 | 6.99** | 180.4* |
| Quadratic | 0.48 | 0.46 | 3.15 | 0.57 | 0.02 | 0.39 | 0.05 | 0.19 | 0.04 | 0.14 | 0.31 | 0.01 | 0.12 | 0.29 | 3.14 |

** and * = statistical significance determined by probability of 0.01 and 0.05, respectively

**Table 8:** Regression equations for crude protein (CP), nitrogen-free extract (NFE), total digestible nutrients (TDN), acid detergent fiber (ADF), cellulose (CEL), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), dry matter (DM) and dry matter per hectare ($DM.ha^{-1}$) of cuttings samples after harvest of cultivars for root production due to fertilization treatment and plant density.

| **Variable** | **Regression Equation** | **$R^2$** |
|---|---|---|
| **Fertilization** | | |
| CP | $Y = -1E\text{-}05X_F^2 + 0.0144\ X_F + 86.477$ | 0.88** |
| NFE | $Y = -0.0014\ X_F + 52.652$ | 0.63** |
| ADF | $Y = 0.0017\ X_F + 43.132$ | 0.35* |
| CEL | $Y = 0.0014\ X_F + 28.373$ | 0.39* |
| IVDDM | $Y = -5E\text{-}06\ X_F^{\ 2} + 0.003\ X_F + 51.523$ | 0.91** |
| CHT | $Y = 2E\text{-}06\ X_F^{\ 2} - 0.0025\ X_F + 86.629$ | 0.87** |
| DM | $Y = -0.0007\ X_F + 38.46$ | 0.81* |
| **Plant Density** | | |
| TDN | $Y = 6E\text{-}05\ X_D + 59.479$ | 0.94* |
| DM | $Y = -7E\text{-}05\ X_D + 39.075$ | 0.96** |
| $DM.ha^{-1}$ | $Y = 7E\text{-}05\ X_D + 1.0933$ | 0.98** |

$X_F$ – fertilization rate; $X_D$ – plant density; Y – correspondent variable; ** and * = statistical significance determined by probability of 0.01 and 0.05, respectively