Scientific Paper

Production and nutritional value of *Manihot esculenta* Crantz leaf residue during two production cycles

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Abstract

Objective: To characterize the production dynamics and nutritional value of fresh and dry leaf biomass resulting as agricultural residue from root production of *Manihot esculenta* Crantz.

Materials and Methods: The experimental site was the Experimental Field of the School of Agricultural Sciences of the National Northeast University in Corrientes, Argentina. The evaluated cultivars were Verde Santa Ana, Amarilla Marcelo, Palomita, Blanca de Santa Catarina, Rocha, Ramada Paso and Yerutí, each of which constituted a treatment and were distributed in randomized complete blocks with three replicas. Sampling was carried out at seven times during the 18 months of the crop cycle and in each instance the fresh and dry biomass of leaves, crude protein content and digestibility of the samples were determined. Analysis of variance and separation of means by Duncan's test (0,05 %) were performed.

Results: Average dry biomass production was 649 kg ha^{-1} and varied among harvest times, with significant reductions during the winter break. Average fresh and dry leaf biomass production at 18 months statistically exceeded all other samplings ($p \leq 0{,}0001$) and reached values of 5 390,9 and 1 240 kg ha^{-1}, respectively. Crude protein percentages and digestibility varied significantly over time, with averages of 22,5 and 47,4 %, respectively.

Conclusion: The results showed a significantly higher production of fresh and dry biomass during the months of active growth, while production was significantly reduced during winter. In addition, there were variations in crude protein concentration and leaf biomass digestibility during the experiment. The studies contribute to the understanding of biomass production dynamics in *M. esculenta*. These findings may have implications for the improvement of sustainable agricultural practices and the development of new feedstuffs derived from this plant for animal production.

Keywords: forage, nitrogen feedstuff, nutrition, yield

Introduction

A limitation of cattle raising in the northeastern region of Argentina (NEA) is the decrease in the forage production and quality in winter, which is the main cause of the low zootechnical indexes of regional cattle raising, low milk production per lactation and long intervals between calvings. This low animal productivity has a negative impact on farmers' income generation and makes the production system inefficient. The use of alternative forage crops or the use of agricultural crop residues (ACR) to compensate for the deficit in pasture availability and quality during critical periods is part of the solution to increase cattle productivity and thus improve profitability. According to Bayona-Buitrago *et al*. (2022), governments are promoting sustainable development plans worldwide, in order to safely dispose of residues such as *Manihot esculenta* Crantz husks and leaves for agro-industrial use for human and animal feeding (Díaz-Tatis *et al*., 2021; Guimarães *et al*., 2022). In this direction, *M. esculenta* leaves due to their forage potential could be integrated into the NEA agricultural production systems and framed in a circular economy system of waste reduction, suggested by the National Plan for the Reduction of Food Losses and Waste of the Ministry of Environment and Sustainable Development of the Argentine Nation (National Law 27.454/2018) in the current global socioeconomic and productive context (Secretaría de Agricultura, Ganadería y Pesca, 2018; Díaz *et al*., 2022). The reduction of waste and losses has been identified as a challenge in the 2030 Agenda among the Sustainable Development Goals (SDGs), set by the United Nations to eradicate poverty, protect the planet and ensure prosperity for all its inhabitants (FAO *et al*., 2021).

In Argentina, *M. esculenta* cultivation covers 15 000 ha exclusively for the production of roots for fresh consumption and the starch industry.

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Traditionally, leaves have been wasted as ACR, but Burgos *et al.* (2019), Porta *et al.* (2020) and Leguizamón *et al.* (2021) have conducted recent research in the NEA zone, related to their forage potential and have validated that they are a highly nutritious resource due to their protein content. Despite the multiple advantages reported for this crop (resistance to drought, pests, diseases and low fertility soils), its use as alternative forage in animal feeding, fresh or preserved, has not been generalized in the region.

There are few studies that explain the biological production and nutritional quality of foliage associated with different root harvesting dates and different cultivars of *M. esculenta*, even less under subtropical production conditions.

The objective of this work was to characterize the production dynamics and nutritional value of fresh leaf biomass resulting as agricultural residue from *M. esculenta* root production.

Materials and Methods

Experimental site. The experimental site was the Experimental Didactic Field of the School of Agricultural Sciences of the National Northeast University (UNNE, for its initials in Spanish), located in the capital department of the Corrientes province (27º28' 27.23''S; 58º47'00.6''W; 50 m.a.s.l.).

Climate characterization. The province of Corrientes is located in a subtropical region. According to the modified Köppen classification, the climate is classified as humid mesothermal, Cf w'a (h). Average annual rainfall ranges between 1 300 and 1 400 mm. The mean annual temperature is 21,6 °C, the mean minimum is less than 18 °C. The frequency of frost occurrence is 0,5 per year.

With meteorological data obtained from the Corrientes Water and Environment Institute (ICAA, 2022), climographs were prepared with rainfall (mm) and mean monthly temperatures (°C) of the agricultural seasons during which the experiment was carried out compared with historical average values for the locality of Corrientes, Argentina (figures 1 and 2).

Edaphic characterization. The soil of the experimental plot has been classified as argic Udipsamment. Regarding the genesis and taxonomy of the soil, it is classified as hyperthermic and udic. It has a sandy texture on the surface and sandy clay loam in the subsurface. The soil has no impedance in the profile for root growth of *M. esculenta*, so it offers excellent physical conditions for this crop. The results of the soil chemical analysis of the experimental site are shown in table 1.

The soil of the experiment (table 1) showed an average organic matter (OM) content of 1,02 %, which is in the range of the critical level (1 %) for the cultivation of *M. esculenta*. P content was at a moderate level (4-15 ppm), K at an adequate level (0,10-0,15 meq 100 g^{-1}), Ca at a medium level (1-5 meq 100 g^{-1}) and Mg at a very low level (<1 meq 100 g^{-1}).

Characterization of biological material. The cultivars of *M. esculenta* used in the experiment are locally recognized by their vernacular names: Verde Santa Ana, Amarilla Marcelo, Palomita, Blanca de Santa Catarina, Rocha, Ramada Paso and Yerutí.

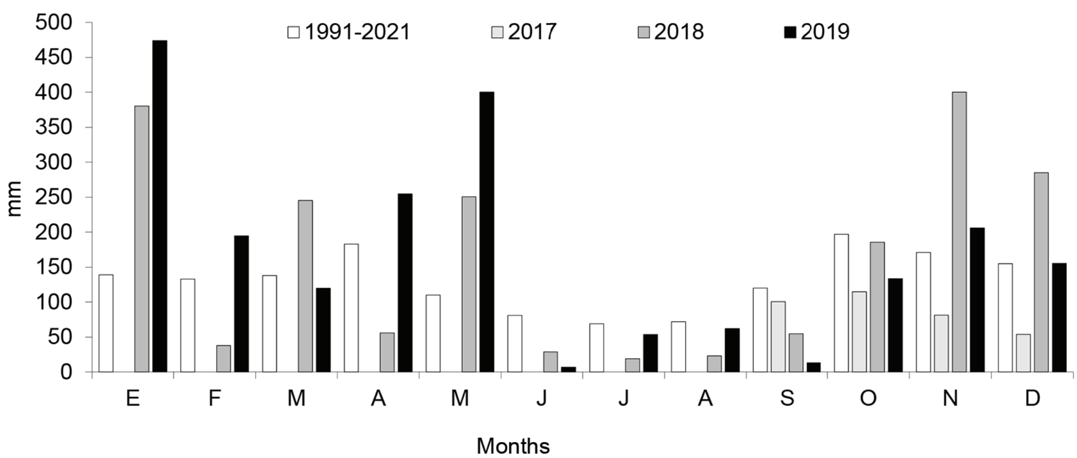


Figure 1. Distribution of average rainfall in the tested campaign (2017-2018 and 2018-2019) and its comparison with the values of the historical series for the same region (1991-2021). Corrientes, Corrientes province.

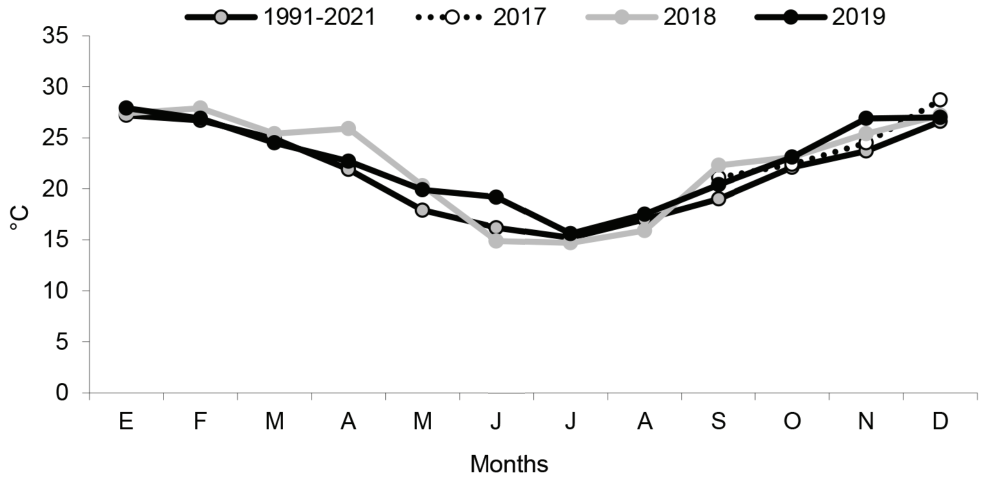


Figure 2. Climograph of mean temperature in the evaluated campaign (2017-2018 and 2018-2019) and its comparison with the values of the historical series for the same region (1991-2021). Corrientes province.

Table 1. Soil chemical analysis of the experimental site. Corrientes, Argentina 2019.

Depth, cm	pH	N	Organic matter	K	Ca	Mg	P
		%		meq/100g			ppm
0-10	5,56	0,04	1,34	0,13	1,60	0,43	9
10-20	5,57	0,04	0,70	0,14	1,49	0,11	12

Experimental design. The experimental design used was complete randomized blocks, with seven treatments (T), represented by the *M. esculenta* cultivars, with three replicas each: Verde Santa Ana (T1), Amarilla Marcelo (T2), Palomita (T3), Blanca Santa Catarina (T4), Rocha (T5), Ramada Paso (T6) and Yerutí (T7). The dimensions of the experimental units were 40 x 8 m, and each block was 8 x 12 m with a complete randomized design. Each block had 7 rows of plants and 13 plants were located in each row. A peripheral line of *M. esculenta* was established around the entire lot in order to establish a border.

Sampling was conducted at seven points in the crop cycle, from March, 6 months after pruning (map) to June (9 map), which corresponded to the first crop cycle. After the winter dormancy phase, sampling corresponding to the second cycle (post-sprouting) was carried out three more times during September (12 map), December (15 map) and March (18 map), respectively.

On each of the seven sampling dates, three plants per treatment were measured, so that each treatment consisted of 21 plants sampled over time, from 6 to 18 map.

Experimental procedure. Planting was carried out under equal conditions, density and date to standardize the conditions of the trial. Planting was carried out manually, on September 27, 2017, with the use of stem stakes, 10 to 15 cm long in horizontal position, with planting frame of 1 x 1 m. The planting depth was 8 cm.

Fertilizations were made according to the recommendations of Howeler (2014) so that the cultivars did not show nutritional restrictions. With the weighted crop requirement (WCR) data determined by Howeler (2014), the availability of the nutrient in the soil (S) (table 1) and the estimated fertilizer efficiency (E), it was necessary to apply 14 g of N per plant (30 g of urea). This dose was divided into two equivalent applications of 15 g plant^{-1} of urea each, applied 30 and 75 days after planting, respectively. Weeds were controlled by manual cleaning and timely herbicide applications. Pre-emergence chemical control was carried out with hand knapsack, using a residual herbicide Dual Gold®, at a rate of 2 L ha^{-1} at planting time. In post-emergence, Glyphosate was applied, directed with hand knapsack sprayer with screen (2 L ha^{-1})

in the inter-rows. Finally, in the row, weed control was reinforced with manual cleanings.

Measured variables. The determinations of fresh leaf biomass (FBl) and dry leaf biomass (DBl) on each of the sampling dates consisted of extracting all the leaves from different plants and weighing them on a scale to determine the weight in grams per plant (g plant^{-1}). Subsequently, they were dried in an oven at 60 °C until constant weight was reached and the dry matter percentage of the sample was determined. The weight of the FBl and DBl was multiplied by the number of plants in the hectare (10 000) and the production expressed in kg ha^{-1} was estimated.

Once the fresh material was weighed, it was quartered and three samples of FBl were separated from each treatment. They were dried in an air-forced draft oven at 60 ºC and ground to estimate:

Crude protein (CP %): this was calculated by formula from the foliar N content determined by nitric-perchloric digestion (AOAC, 2019), by multiplying it by the conversion factor CP= N (%) x 6,25. ii)

Digestibility (DIG %). This value was calculated using the formula proposed by Undersander *et al.* (1993), where: DIG = 88,9 - (% ADF x 0,779).

The acid detergent fiber content (ADF %) was determined by the method of Van Soest and Wine (1967). The obtained values are valid for comparing varieties with each other, but not as forage equivalents. All chemical determinations were made in triplicate.

Statistical analysis. Analysis of variance and mean differences were performed by Duncan's test (0,05 %). The variables associated with leaf biomass (FBl and DBl) were transformed for analysis using Log 10. The program used for statistical analysis was InfoStat version 2020 (Di Rienzo *et al*., 2020).

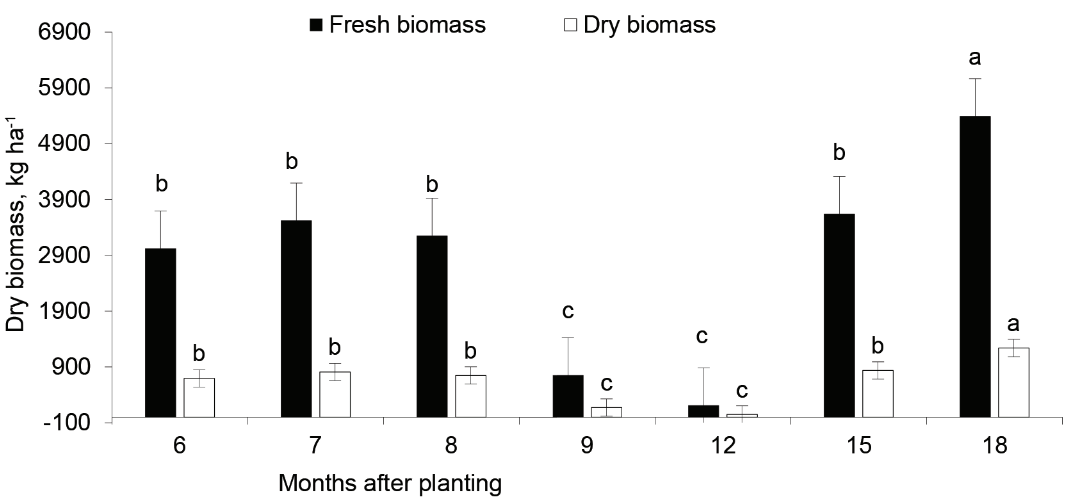
Results and Discussion

The results associated with fresh (FBl) and dry (DBl) leaf biomass of the *M. esculenta* cultivars under study, between 6 and 18 months after planting (map), are shown in figures 3 and 4.

Statistical analysis of this experiment showed that biomass (FBl and DBl) was only affected by sampling dates (figure 3, $p \leq 0,0001$), and not by cultivars (figure 4, $p = 0,7670$).

During sampling in the first quarter (months 6, 7 and 8), no significant differences in FBl and DBl production were observed. If these data were summed, they would provide a total production of 9 760 or 2 252 kg ha^{-1}, equivalent to a monthly average of 3 263 or 750 kg ha^{-1} of fresh or dry foliage, respectively, suitable for harvest (figure 3).

A significant reduction in FBl and DBl occurred between 9 and 12 map (June and September), which coincide with the entry (9 map) and exit (12 map) of the winter dormancy phase, which occurs under the subtropical agroecological conditions of Argentina (figure 3). The occurrence of winter dormancy, induced by low temperatures, divided the crop into two growth cycles. The first cycle, which occurs from planting until 9 map, and



Unequal lowercase letters indicate statistical differences among means according to Duncan $p \leq 0,05$.

Figure 3. Mean values of fresh and dry biomass of leaves at each sampling date between 6 and 18 months after planting (kg ha^{-1}).

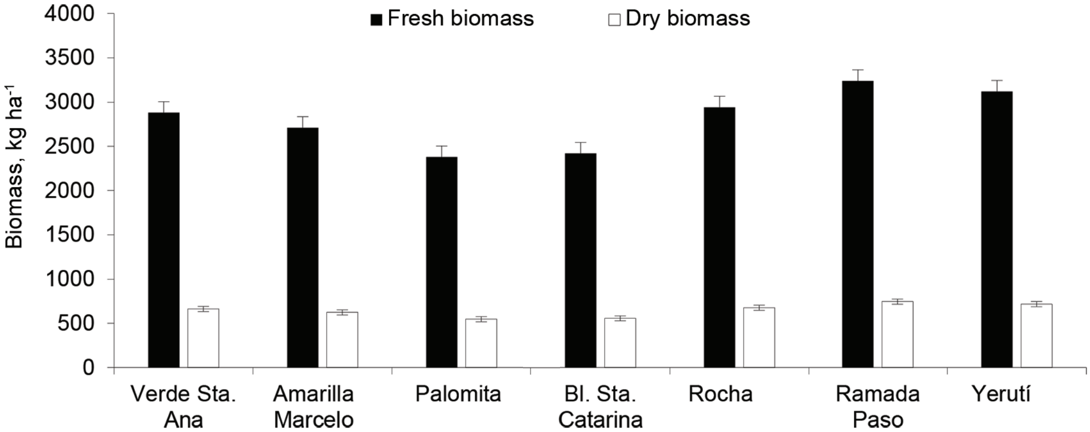


Figure 4. Mean values of fresh and dry leaf biomass of the cultivars after the seven sampling dates between 6 and 18 months after planting (kg ha^{-1}).

the second cycle, which begins with regrowth under spring 12 (map) conditions. In the first growth cycle, the plant showed physiological activity up to 8 map.

From 9 to 12 map, in mid-winter and with average temperature of 14,9 °C (June 2018, figure 2), plants in recess and with leaf abscission, showed reductions of 85,3 and 89,3 % of FBl (750 and 210 kg ha^{-1}) and DBl (142 and 48 kg ha^{-1}) production with regards to the average of the previous three months. In sampling at 9 and 12 map, there was no significant difference between them (figure 3). The average calculated FBl production was 480 kg ha^{-1} (110,4 kg ha^{-1} of DBl), which represents 10 % of the average production during the period of active growth.

After the first 8 map, when the average ambient temperature exceeds the base temperature of 15 °C, established for the cultivation of *M. esculenta*, the plant shows physiological activity. However, for regrowth to be stimulated it will need 28-30 °C and forage production will be sustained with an optimum of 20-24 °C (Chaves-Barrantes and Gutiérrez-Soto, 2017). In addition, to sustain the maximum peak of new leaf sprouting, which occurs after the dormancy period (induced by water deficit and/or low temperatures), mobilization of carbohydrate reserves from the roots occurs.

During the samplings of the second cycle, significant differences in FBl (3 640,1 and 837,2 kg ha^{-1}) and DBl (5 390,9 and 1 240 kg ha^{-1}) production were established between the 15 map and 18 map, respectively, and of this last month with respect to all other previous samplings (figure 3, $p < 0,0001$). If the collections of the last two samplings (15 and 18 map) were summed, they would reach 9 030 kg ha^{-1} in FBl or 2 077 kg ha^{-1} in DBl, an average of 4 515,5 and 1 038 kg ha^{-1}, respectively.

The dynamics of FBl and DBl production observed in the field under NEA conditions makes it clear that it could be harvested as ACR for fodder, when the roots of the plant are collected outside the winter season and preserved for later supply (Tinini *et al*., 2021).

The sum of the seven FBl collections made in this experiment reached a total of 19 750 kg ha^{-1}, which represents up to 4 600 kg ha-1 of DBl in a span of 18 months of production. Of the latter, 1 240 kg ha^{-1} would correspond to the last month of harvest at 18 map, which could be used to be supplied fresh, ensiled or hayed rather than wasted by converting the residues into animal feedstuff.

During the experiment, although there were variations in the average FBl and DBl production accumulated by each cultivar, it did not differ significantly among them (figure 4, $p = 0,7670$). The extreme values were between 2 420 and 3 240 kg ha^{-1} of FBl for cv. Blanca Santa Catarina and Ramada Paso, respectively, or their equivalent in DBl, which corresponded to 556 and 745 kg ha^{-1}. These results coincide with studies conducted in Brazil by Costa *et al*. (2022), who found no significant differences in terms of dry matter (DM) productivity of the aerial part or in the percentage of DM of the aerial part of *M. esculenta* varieties compared with 10 months after planting.

When studying the production dynamics of each cultivar in particular, significant temporal differences were observed in the construction of the accumulated FBl in all but cv. Palomita (table 2). The average BFh production was not affected by cultivar on each sampling date (table 2).

The results showed the intrinsic leaf retention capacity during the winter of the cultivars Verde Santa Ana, Amarilla Marcelo and Rocha, which allowed them to concentrate the significant reduction in FBl production in the 12 map sampling (table 2). In contrast, the cultivars Blanca Santa Catarina, Ramada Paso and Yerutí experienced significant reductions in FBl from 9 to 12 map (table 2). At 9 map, the first three cultivars mentioned (Verde Santa Ana, Amarilla Marcelo and Rocha) showed on average 1 227 kg ha^{-1} of FBl (282 kg ha^{-1} of DBl); while the other three cultivars (Blanca Santa Catarina, Ramada Paso and Yerutí) showed 330 kg ha^{-1} (76 kg ha^{-1} of DBl), almost four times less (table 2).

After the beginning of spring, 12 map, with average temperature of 22,3 °C (September, 2018, figure 2), the plants found conditions to start their second growth cycle and at 15 map (December, 2018) the plant cover was found completely restored in all cultivars with regards to the FBl values of the previous sampling at 12 map and with statistically equal values to those at 8 map, and even statistically higher in cv. Yerutí. In general terms, the cultivars maintained stable production without statistical differences in FBl at 6, 7 and 8 map, except for cv. Yerutí, which only maintained a statistically stable FBl production between 6 and 7 map. The cv. Verde Santa Ana showed a statistically stable FBl production, practically during all the months of active growth (table 2).

The average FBl production at 18 map statistically exceeded all other samplings ($p \leq 0{,}0001$) and reached 5 390,9 kg ha^{-1} (figure 3), which expressed in DBl is 1 240 kg ha^{-1}. No statistical order differences were established between 15 and 18 map in each cultivar (table 2).

Gómez *et al*. (2016), when studying the forage production of three varieties of *M. esculenta* in dry and rainy seasons, under three sowing densities and three harvest ages in the Colombian Caribbean region, found that foliage production, in the rainy season was 150 % higher than in the dry period, which highlights the incidence of climate conditions on the forage yield of *M. esculenta*. In the agroecological conditions of the NEA region, winter imposes such restrictions on the crop and on foliage production in particular.

Specifically, in May (8 map), the end of the annual production cycle is reached for the subtropical conditions of northeastern Argentina. Roots are harvested and stems are cut to keep them protected from the action of frost, which could damage their buds and leave growers without planting material for the next season. This is the right time to carefully select the cuttings to be preserved for their genetic, physiological and sanitary quality. All the remainder can be destined, at the same time, to be chopped for fresh supply for animal feeding or to be conserved as silage, microsilo or hay. Therefore, it

Table 2. Mean values of fresh leaf biomass of the seven cultivars under study during seven sampling dates between 6 and 18 months after planting (kg ha^{-1}).

Cultivar	Months after planting								
	6	7	8	9	12	15	18	CV, %	P - value
Verde Santa Ana	2 500,0^{bc}	3 333,6^{bc}	3 660,6^{bc}	1 500,6^{b}	170,6^{a}	3 500,0^{bc}	5 500,0^{c}	10,5	0,0001
Amarilla Marcelo	2 000,0^{bc}	3 160,6^{cd}	5 500,0^{d}	1 330,3^{b}	220,0^{a}	3 580,3^{d}	3 160,6^{d}	9,0	<0,0001
Palomita	1 330,3	2 330,3	2 940,3	560,0	250,6	2 500,0	6 790,3	24,9	0,0871
Blanca Sta. Catarina	4 500,0d	4 500,0d	2 220,3^{cd}	630,0^{ab}	180,6^{a}	3 400,0^{cd}	1 500,0^{bc}	13,8	0,0002
Rocha	3 000,0^{cd}	1 830,3^{bc}	3 540,0^{cd}	850,0^{b}	240,6^{a}	3 830,3^{cd}	7 330,3^{d}	10,3	0,0001
Ramada Paso	3 000,0^{b}	3 000,0^{b}	3 100,0^{bc}	170,0^{a}	250,0^{a}	4 830,3^{bc}	8 330,3^{c}	12,2	<0,0001
Yerutí	4 830,3^{c}	6 500,3^{c}	1 820,0^{b}	200,6^{a}	190,6^{a}	3 830,3^{c}	5 250,6^{c}	7,0	<0,0001
VC, %	11,4	9,4	9,8	25,5	8,6	12,6	14,2		
P - value	0,1099	0,0903	0,3162	0,0936	0,3981	0,8558	0,1715		

Different letters within each row indicate that there are statistical differences between sampling dates according to Duncan $p \leq 0{,}05$.

VC: Variation coefficient

is of particular interest to know about the FBl and DBl of the upper third of the different genetic materials specifically in May (8 map), which in general averaged 3 250,1 and 747 kg ha^{-1} respectively, but reached values of 5 500 and 1 265 kg ha^{-1} of FBl and DBl for cv. Amarilla Marcelo, 3 660,67 and 842 kg ha^{-1} for cv. Verde Santa Ana and 3540 or 814 kg ha^{-1} for cv. Rocha respectively (table 2).

Given that crop ecophysiology is strongly affected by climate conditions during the 9 and 12 map that mark the physiological rest of the subtropics, it was considered important to analyze the dynamics of FBl production among cultivars during the active growth stages of the first (6-8 map) and second cycle (15-18 map) of the crop (table 3).

During the first growth cycle, FBl and DBl production did not differ among cultivars (table 3, p-value=0,1450). During the second growth cycle and once the plant canopy was restored, at 15 and 18 map, FBl and DBl production also did not differ among cultivars (table 3, p-value=0,2277). According to what was observed, the null hypothesis can be accepted: there was no difference in FBl production among cultivars during the active growth phases of the crop.

In the first cycle, the most remarkable FBl and DBl production occurred in the cultivars Blanca de Santa Catarina and Yerutí; while that of cv. Palomita was the lowest. When analyzing the performance during the second growth cycle, the FBl and DBl production of the cv. Ramada Paso was well above the averages calculated for that period (4 515,5 and 1 038,4 kg ha^{-1}); while the cv. Blanca de Santa Catarina showed the lowest production in that same period (table 3).

While Amarilla Marcelo and Yerutí cultivars showed very similar values of FBl and DBl in the first and second growth cycles, others showed almost 100 % higher productions during the second cycle, such as Palomita, Ramada Paso and Rocha.

The FBl production of a forage crop must be analyzed in nutritional terms in order to value its contribution to the animal diet. The value of *M. esculenta* leaves is based on the protein content, which for some authors is approximately 24 %. In any case, forage nutrient content and digestibility can vary depending on crop management, tissue age at the time of cutting, environment, genetic material, soil and climate and agroecological conditions, among other factors (Sosa-Montes *et al*., 2020).

Over the course of the experiment, it was found that the average crude protein (p=0,001; VC=17,3 %) and digestibility (p<0,0001; VC=5,75 %) percentages of FBl varied across sampling dates (figure 5). Throughout the experiment, the average crude protein percentage (% CP) of leaves was found to be 22,5 % and the average digestibility (% Dig), 47,4 %.

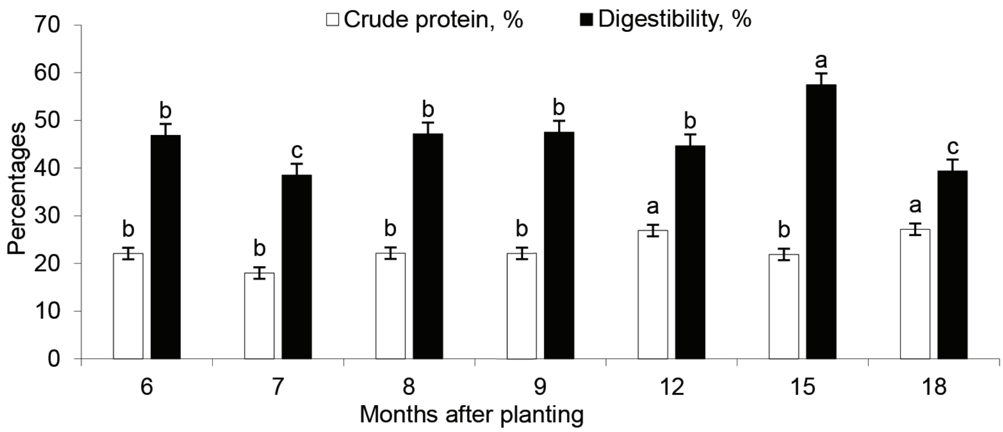
During the first growing cycle (6-9 map), there were no differences in the CP between the different sampling dates (p=0,001; VC=17,31 %) and the average value reached 20,38 % (figure 5). In the second growth cycle (12-18 map), CP concentrations were significantly higher at month 12 and 18 after planting (p=0,001; VC=17,3 %); while no statistical differences were established between them (figure 5). At 12 map, young and tender regrowth tissue showed high CP values (26,9 %), which significantly exceeded all previous sampling (figure 3), but associated with the lowest FBl and DBl production of the cycle (table 2). The results found for FBl and DBl of *M. esculenta* in September (12 map) coincide with what was postulated by Martins *et al*. (2021) in relation to the fact that tropical forages in the juvenile stage have better quality in terms of crude protein.

During the second growth cycle (12-18 map), the average CP content was 25,35 %, which represented an increase of 24,0 % with regards to the first cycle.

Table 3. Average production of fresh biomass and dry leaf biomass of cultivars during the first and second growth cycle (kg ha^{-1}).

Cycle	mdp	Variable	Cultivar							VC, %	P - value
			Amarilla Marcelo	Blanca Sta. Catarina	Palomita	Ramada Paso	Rocha	Verde Sta. Ana	Yerutí		
1st	6 to 8	FBl	3 550,1	3740,1	2 200,3	3 030,3	2 790,1	3160,7	4 380,4	11,1	0,1450
		DBl	816,5	960,2	506,0	697,0	642,0	727,0	1 000,0		
2nd	15 to 18	FBl	3 370,5	2450,0	4 640,7	6 580,3	5 580,3	4 500,0	4 500,0	13,3	0,2277
		DBl	775,2	563,5	1067,3	1 513,4	1 283,4	1 035,0	1 035,0		

FBl: fresh biomass of leaves, DBl: dry biomass of leaves



Different letters indicate statistical differences between dates according to Duncan p ≤ 0,05.

Figure 5. Mean values of crude protein content and digestibility of fresh leaf biomass throughout the *M. esculenta* crop cycle.

Forage digestibility remained relatively stable, even the first 12 map (p< 0,0001; VC=5,75 %) with an average of 45,0 % and increased 4,75 % during the second growth cycle (figure 5).

FBl production increased from 210,8 kg ha^{-1} (12 map) to 3640,1 kg ha^{-1} (15 map) within three months (table 2), when plants grew at an accelerated rate due to favorable environmental conditions. In nutritional terms, the associated changes (figure 5) showed significant increase in digestibility (57,5 %) and significant drop in CP (21,9 %), which for the latter variable can be attributed to a dilution effect as hypothesized by Howeler (2014). The increase in leaf digestibility at 15 map can be ascribed to a maximum sprouting peak on adult branches.

To conclude, at 18 map the CP content (27,2 %) increased to levels equivalent to that of tender shoots at 12 map (26,9 %), although digestibility decreased and reached its lowest expression with only 39,4 % (figure 5). The decrease in digestibility as plant age increases is associated with cell wall lignification (Soto *et al*., 2009) and an increase in structural carbohydrates.

Although protein concentrations (figure 6) did not differ among the cultivars under study (p = 0,0676; VC = 17,3 %), there were differences in digestibility (figure 7) among them (p = 0,0114; VC = 5,8 %). The average digestibility among cultivars was 45,9 % and the extreme values were between 44,0 and 48,9 % for the cultivars Yerutí and Palomita, respectively (figure 7).

Similar results were published by Tagliapietra *et al*. (2020) who found no significant differences in crude protein contents when comparing seven table and forage *M. esculenta* cultivars.

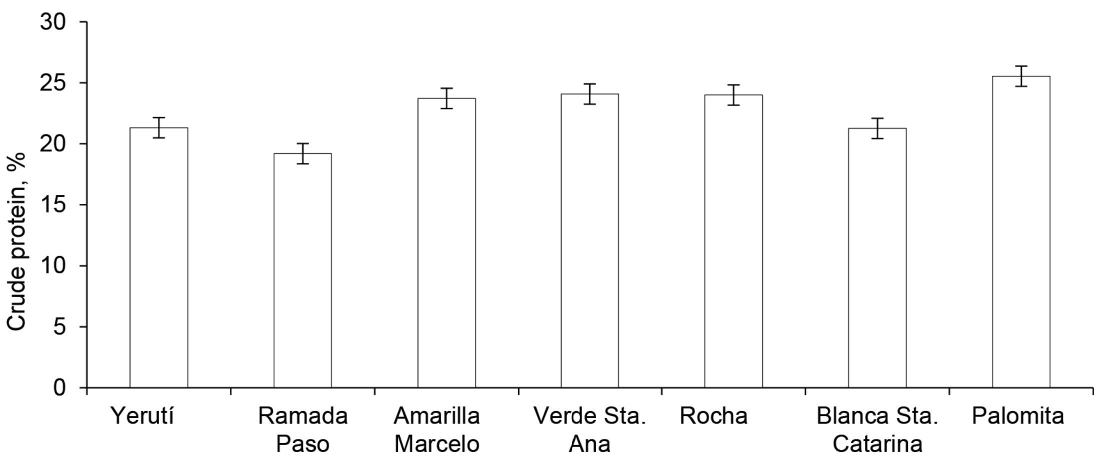
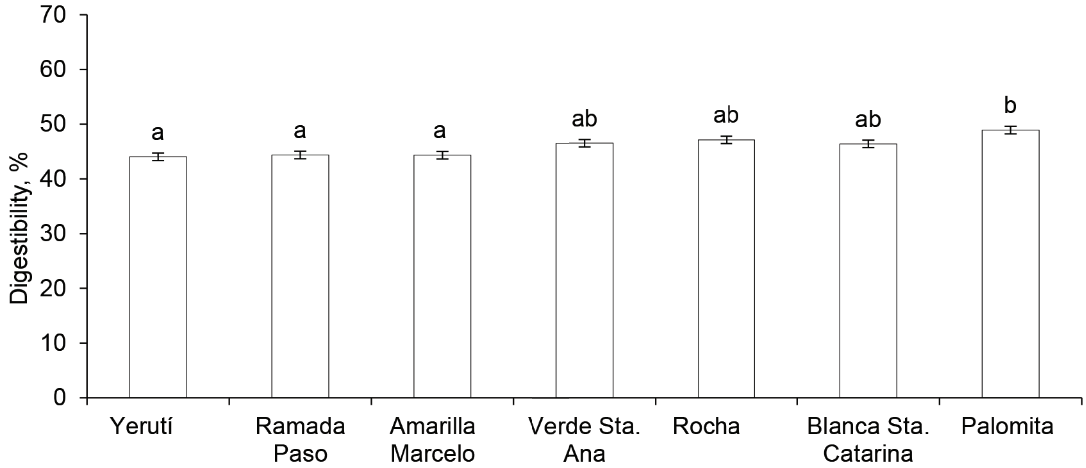


Figure 6. Average crude leaf protein content of *M. esculenta* cultivars under study (%).



Different letters indicate statistical differences between dates according to Duncan $p \leq 0{,}05$.

Figure 7. Digestibility of *M. esculenta* cultivars under study.

In this sense, the cultivars presented a mean of 22,7 % CP (figure 6), equal to the mean of 22,7 % cited by Sosa-Montes *et al*. (2020) and by Ramírez-Villalobos *et al*. (2023) for a herbaceous forage legume *Clitoria ternatea* L.

Conclusion

The dynamics of quantitative and qualitative production of fresh (FBl) and dry (DBl) biomass of cassava cultivars responds significantly to the time of harvest according to the physiological state of the crop. In the months of active growth of the first cycle, the average FBl production reaches 3263 kg ha^{-1} (750 kg ha^{-1} of DBl); while between 15 and 18 map of the second cycle it reaches 4515 kg ha^{-1} (1038 kg ha^{-1} of DBl). During the winter-induced dormancy phase, between 9 and 12 map, FBl and DBl production is significantly reduced to an average of 480 and 110 kg ha^{-1} respectively. In nutritional terms, the crude protein concentration of leaves over the 18 months is 22,7 %; while digestibility reaches values of 45,04 and 47,18 % during the first and second growth cycle, respectively.

The studies contribute to the understanding of biomass production dynamics in *M. esculenta*, filling a gap in the scientific literature on this crop. These findings may have implications for the improvement of sustainable agricultural practices and the development of new foodstuffs derived from this plant for animal production.

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Conflict of interests

The authors declare that there is no conflict of interests among them.

Authors' contribution

- Angela María-Burgos. Generated the idea, searched for bibliographic information, drafted and revised the manuscript.
- Alcides Miguel-Michellod. Performed the laboratory analyses.
- Miriam Porta. Searched for information, analyzed and critically revised the manuscript.
- Claudina M. Hack. Searched for information, analyzed and revised the manuscript.

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