Scientific Paper

Forage biomass quality of five cultivars of *Manihot esculenta* Crantz during growth

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Abstract

Objective: To evaluate the foliage quality of five cultivars of *Manihot esculenta* Crantz during the annual growing cycle of the crop in northeastern Argentina.

Materials and Methods: Five cultivars of *M. esculenta* and four cutting times (February, May, September and December) were evaluated. The experimental design was completely randomized with a 5 x 4 factorial arrangement and three replicas. The experimental plots were 5 x 5 m, with 11 rows and 11 plants per row, spaced 0,5 m apart. Digestibility, crude protein and dry matter were determined from the samples obtained from each cutting.

Results: For all evaluated variables, there was interaction between cultivars and cutting time ($p < 0,001$). The digestibility of the cultivars was higher than 50,0 %, practically all the productive cycle. In February, the lowest digestibility percentages were recorded for all cultivars, with an average of 47,0 %. In the last two cuts, the average reached 60,0 % digestibility. Crude protein content was above 20,0 %, with variations among cultivars and cutting times. Dry matter content of the genotypes varied with cutting time. Most cultivars had lower values in February and September than in May and December.

Conclusion: The results show remarkable mobility in variables related to nutritional quality of *M. esculenta* among different cutting dates and cultivars. Digestibility is closely linked to tissue age. Of all the cultivars, Paraguaya Cerro Azul (CV1) showed the lowest digestibility at most cutting dates.

Keywords: digestibility, biomass, crude protein

Introduction

Ruminant feeding in the subtropics is mostly based on the use of native pastures as a source of nutrients. In northeastern Argentina (NEA), natural fields constitute the main forage resource for animal husbandry and, to a lesser extent, planted pastures (Pizzio *et al*., 2021). A characteristic of these pastures is that they are composed of megathermal species with high photosynthetic capacity (C4) and summer growth. The growth rate of the dominant species decreases in autumn and winter, which is associated with low nutritional quality, low protein percentage and high lignified cell wall content (Porta *et al*., 2020).

The NEA is the second largest producing region in the country, with 13,2 million heads, representing 25,0 % of national production. The Corrientes province represents 3,0 % of this stock and 60,0 % of the total number of farmers have less than 100 heads (Ministry of Economy, 2023). For this group, it is particularly necessary to find economic and accessible feed sources to formulate the animals' diet, especially to cover the winter deficit.

Among the species with fodder potential that are grown in the region, *Manihot esculenta* Crantz (cassava) stands out. Although it is a species that is cultivated mainly for its starchy tuberous roots, its leaves have high potential for incorporation into cattle diets, since its nutritional value lies in its high protein content (16,0-26,0 %), much higher than that of pastures in the region (Burgos *et al*., 2019; Tinini *et al*., 2021). In addition to its high protein content, it shows good digestibility and is a considerable source of vitamins A, C and B complex. It also contains acceptable proportions of minerals such as Ca and Fe (Suárez-Paternina *et al*., 2022). The inclusion of *M. esculenta* foliage in the animal diet is an economically convenient alternative to replace the use of commercial concentrate feeds that are used in various ways: fresh, hayed, as meal and silage, together with grasses such as sugarcane, elephant grass and corn or sorghum (Burgos *et al*., 2019).

In the NEA, the agroecological characteristics are highly propitious to the cultivation of *M. esculenta* and 14 230 ha are currently planted

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(INDEC, 2021). Maximum yields of *M. esculenta* are obtained at average temperatures of 25 to 27 ºC, provided that sufficient moisture is available during the growing season. Optimum temperatures for crop development are recorded between 25 and 30 ºC. Temperatures below 16 ºC and above 34 ºC stop plant growth (Caballero-Mendoza *et al*., 2019). In the region, characterized by a mesothermal climate, M. *esculenta* shows a winter recess period, due to the low temperatures prevailing in the production areas, ending the annual growth cycle. After the winter, when temperatures exceed 16 °C, which is considered the base temperature (Tb), the plant resprouts and a new production cycle begins again (Ternes, 2002).

The research group "Production Systems and Alternative Uses of Regional Crops", of the Northeast National University, is working on the identification of *M. esculenta* cultivars with better forage potential for the Argentine subtropical region (Burgos *et al*., 2019; 2021). Detailed knowledge of the chemical composition and nutritional value of these cultivars is essential for their adequate use in agricultural production systems.

Therefore, the objective of this work was to evaluate the foliage quality of five cultivars of *Manihot esculenta* Crantz during the annual growing cycle of the crop in northeastern Argentina.

Materials and Methods

Location. The research was carried out in the northwestern part of the Corrientes province (27º28'27.23''S; 58º47'00.6''W; altitude 50 m.a.s.l.), located in northeastern Argentina. The experimental site was located at the Experimental Field of the School of Agricultural Sciences of the Northeast National University, National Route No. 12, km 1031.

Edaphic characteristics. The soil where the studied crops were located is classified as Udipsamment arganic, mixed, hyperthermic, belonging to the Ensenada Grande series. They have a coarse granulometry on the surface, with brown to reddish-brown colors in the underlying horizons. They are deep (> 100 cm), massive, very friable and medium to weakly acidic in the A horizon. The relief is gently undulating, with slopes of 1,0 to 1,5 % (table 1). These soils have excellent physical conditions for the cultivation of *M. esculenta*, but low natural fertility. They have low levels of organic matter (generally less than 1 %) and exchange bases (0,44 to 7,60 m.e.q.). Their low natural fertility and susceptibility to erosion place these soils in subclasses II e and III e (Escobar *et al*., 1994).

Climate characteristics. The climate of the area is characterized by average annual rainfall of 1 300 mm and average annual temperatures of 21,6 °C. The frost-free period is 340 to 360 days per year and the frequency of occurrence is 0,5. According to the modified Köppen classification, the climate is humid mesothermal, designated as Cf w'a (h) (SMN, 2023). In the evaluated period, mean temperatures were similar to the historical average, but rainfall was highly variable compared with the historical average (figure 1).

Experimental design and treatments. Five cultivars of *M. esculenta* and four cutting times were evaluated using a complete randomized design with a 5 x 4 factorial arrangement and three replicas. The five evaluated *M. esculenta* cultivars are locally known as Paraguaya Cerro Azul (CV1), Ramada Paso (CV2), Campeona (CV3), Amarilla (CV4) and Amarilla Molina (CV5). Cuttings were made at 5, 8, 12 and 15 months after planting (map). The first two, in February and May, with an interval of 75 days between them, and the last two after the winter break, in September and December, with the same interval.

The experimental plots were 5 x 5 m = 25 m^2, each with 11 rows of 11 plants each. The planting density of the cuttings was 0,50 m between rows and 0,50 m between plants (40,000 plants ha^{-1}), which determined a total of 121 plants per plot. Of these, only 81 were sampled, since the two perimeter rows and the first plant at the ends of each row were considered as borders. Thus, a total of 243 plants were measured per treatment.

Table 1. Soil analysis of the forage *M. esculenta* plots.

Depth, cm	pH	N, %	P, ppm	K	Ca	Mg	Na	OM, %	Density	dS/m^{-1}
				cmol(+)*kg^{-1}						
0 - 10	5,52	0,05	4,88	0,11	0,8	1,4	0,05	1,27	0,073	
10 - 30	5,59	0,03	3,8	N/D	1	0,5	N/D	2,93	0,072	

N: nitrogen, P: phosphorus, K: potassium, Ca: calcium, Mg: magnesium, Na: sodium, OM: organic matter

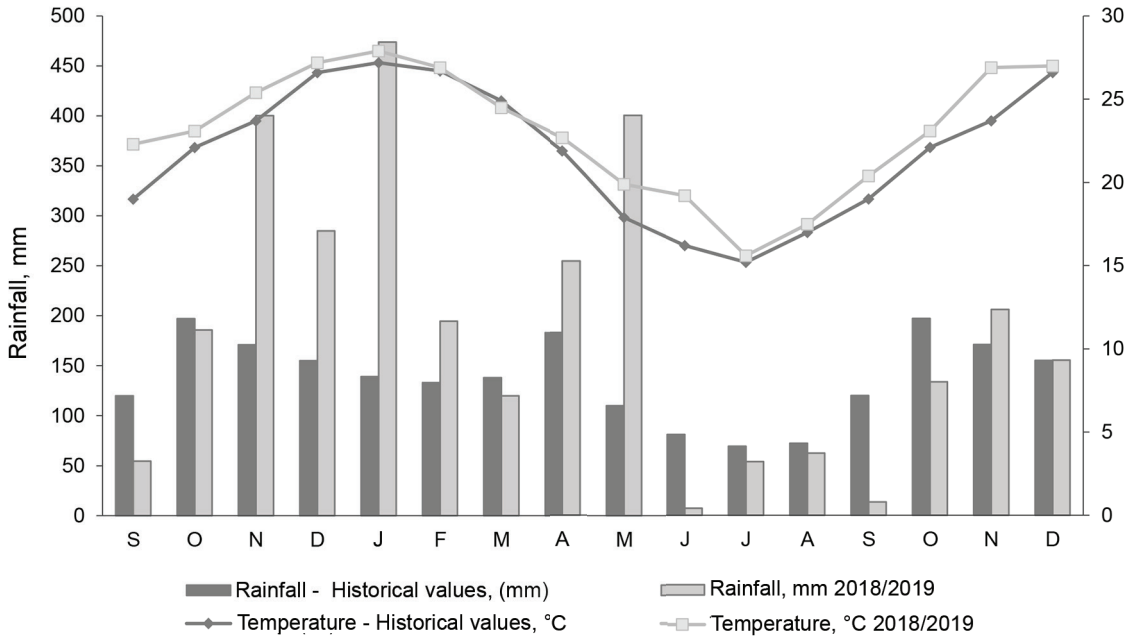


Figure 1. Monthly rainfall and mean temperatures of the study period and historical values (average period 1991-2020, SMN).

Prior to planting, the stems of *M. esculenta* were selected for uniformity and health. They were cut with a handsaw to obtain 20 cm long cuttings, with a minimum of 6 buds each, and were disinfected by immersion for 30 min. in a broth containing 15 cc of imidacloprid, 40 g of copper oxychloride and 20 g of diethyldithiocarbamate (mancozeb) per 10 L of water. After planting, in September, the crop was fertilized with nitrogen, provided in the form of granular urea (46-0-0) at a rate of 400 kg ha^{-1} divided in two moments: 50 % of the dose 45 days after planting (dap) and the remaining 50 %, 75 dap.

Sampling. For the evaluations, the foliage of each cultivar was cut. They consisted of the extraction of the upper third of the plants, including laminae, petioles and stems. For this purpose, before each cutting, the height of the plants per plot was measured with a tape measure (from the ground to the apex of the stem), the average height was established, and according to this value, the cutting height of each cultivar was determined. The cuts were made manually with pruning shears. The harvested material was weighed fresh and dried in a forced-air oven at 65 °C until constant weight was reached. Once the material was dry, it was ground and sieved for laboratory analysis.

*Evaluated variables***:**

Digestibility (DIG, %). The digestibility calculation was determined by the acid detergent fiber content (ADF) by the method of Van Soest and Wine (1967), according to the following formula:

DIG = 88,9 - (% ADF x 0,779) (Di-Marco, 2011).

Crude protein (CP, %). By means of laboratory analysis, nitrogen (N) was determined, according to the micro-Kjeldahl methodology, proposed by AOAC (2019). From N, the concentration of CP was calculated by multiplying it by the conversion factor 6,25.

Dry matter percentage (DM, %). For its determination, a percentage ratio was established between the weight of the samples dried in a forced-air oven at 65 °C until reaching constant weight and the weight of the fresh samples.

Statistical analysis. Analysis of variance was performed. The data were analyzed statistically with the Infostat® program (Di Rienzo *et al*., 2020) using the corresponding multiple comparisons test. The minimum significant difference was considered by Tukey's test ($p < 0,05$).

Results and Discussion

For all studied variables, there was interaction between factors (cultivar x cutting time, $p <$

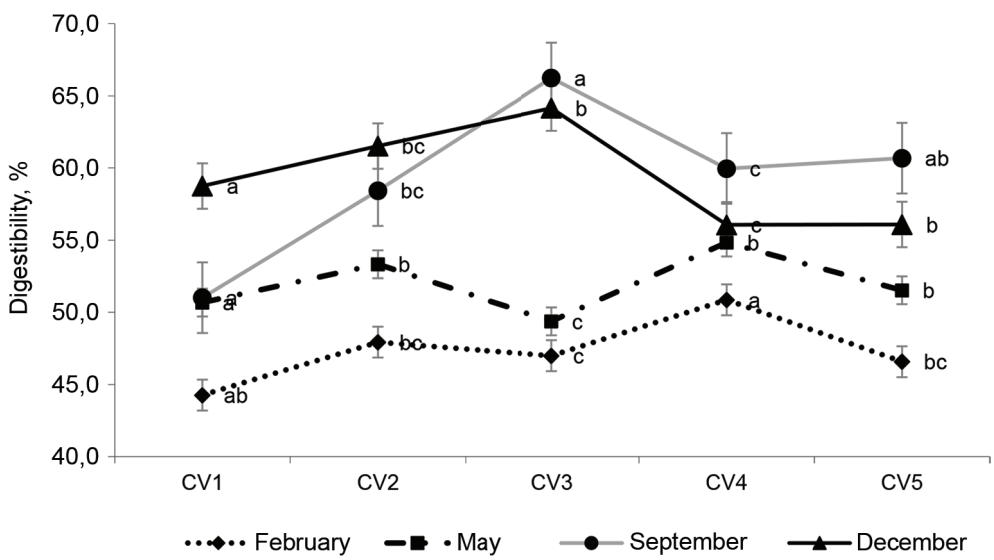
0,0001). For each variable, differences between cultivars were analyzed as a function of cutting time.

Digestibility. Differences were found for digestibility percentage among cultivars for each cutting date. The first two cuts, CV2 and CV4, showed higher % DIG, with averages of 49,4 and 54,1 % in February and May, respectively. With the September regrowth, CV3 stood out with 66,5 % and CV2, CV4 and CV5 averaged 59,9 % DIG. In December, those with the highest percentage of DIG were CV2, CV3 and CV5. Although there were no significant differences among them, CV3 showed on average 3,0 % more than the other two cultivars (figure 2). Over the course of the cycle, CV2 and CV5 progressively increased digestibility, reaching a maximum in December. In CV3, there were two periods with marked differences, the initial one with an average of 48,0 % DIG, and after the winter break, the last two cuts, with an average of 65,3 % DIG. The average digestibility values of the evaluated cultivars were similar to those obtained by Suárez-Paternina *et al*. (2022) in cuts of the upper third of the plants.

The digestibility of the cultivars was found to be above 50 %, practically throughout the entire production cycle. In February, the lowest digestibility values were recorded for all cultivars, with an average of 47,0 %. In May, the cultivars with the lowest digestibility were CV1 and CV3, with an average of 50,0 %. In the last two cuts, the average of the cultivars was 13 % higher, reaching 60,0 %.

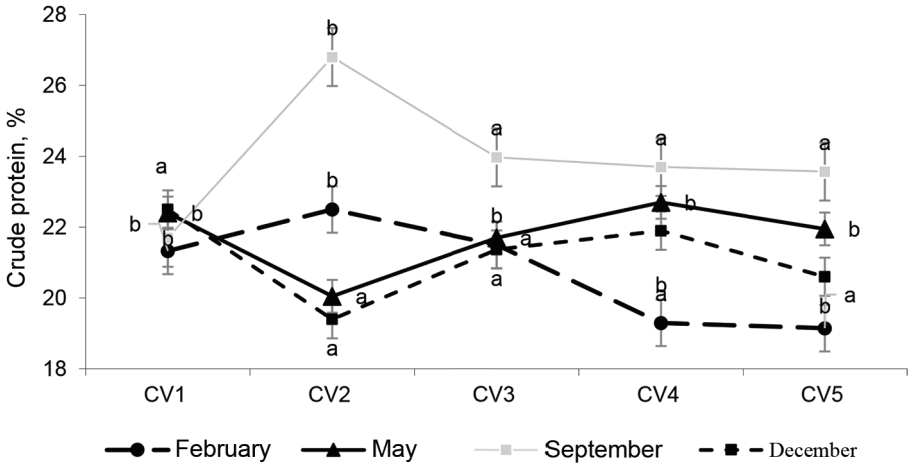
The lower digestibility of the first cut, which was made after 5 map, would be associated with tissue age. As the physiological age of the plant progresses, the percentages of cellulose, hemicellulose, and lignin increase, which reduces the proportion of potentially digestible nutrients (soluble carbohydrates, proteins, minerals, and vitamins), resulting in a sharp drop in digestibility (Fernandes *et al*., 2020). In the second cut, in May, the DIG increased 5 % on average, when the regrowth was harvested after the first pruning. After the winter break, in September, in cultivars CV2, CV3, CV4 and CV5, there was an increase compared with the first two cuts, related to spring regrowth and the presence of new tissue. In December, the digestibility of CV1, CV2 and CV5 increased as a consequence of the previously performed pruning. The practice of pruning stimulates hormonal rearrangement that causes the rupture of apical dominance and the simultaneous formation of several tender stems that have a large amount of leaves and less lignified petioles, with which it is assumed that they will have higher digestibility (Fernandes *et al*., 2020).

Crude protein. The CP content was variable in the cultivars for the different cutting times (figure 3). It should be noted that the protein concentration of all cultivars over time was high,



CV1: Paraguaya Cerro Azul, CV2: Ramada Paso, CV3: Campeona, CV4: Amarilla y CV5: Amarilla Molina
$p < 0,0001$

Figure 2. Average digestibility of five cultivars of *M. esculenta* at different cutting dates.



CV1: Paraguaya Cerro Azul, CV2: Ramada Paso, CV3: Campeona, CV4: Amarilla y CV5: Amarilla Molina
$p < 0,0001$
Figure 3. Average crude protein of five cultivars of *M. esculenta* at different cutting dates.

with values close to or above 20,0 %. CV1 did not experience variations in protein concentration at the different cutting times, with an average of 22,0 %. The remaining four cultivars had similar averages, but with fluctuations over the course of the production cycle.

In February, cultivars CV1, CV2 and CV3 differed from CV4 and CV5, averaging 21,7 and 19,2 % CP, respectively. In September, CV2 stood out for its protein content, which practically reached 27,0 % CP; while the other cultivars had 23,2 %. In this cut, cultivars CV2, CV3 and CV5 had a significant increase compared with previous months, which could be attributed to spring regrowth, a direct result of the higher proportion of young plant tissue, little lignified, which coincides with the results obtained by Fernandes *et al*. (2020).

The CP values obtained in this trial are between the ranges recorded by Utomo *et al*. (2019), with values between 22,1 and 23,2 %, with different cutting frequencies. Fernandes *et. al*. (2020) found lower average percentage of aerial parts protein (18,7 %) in pruned *M. esculenta* plants, compared with the averages recorded in this work.

It is estimated that CP concentration lower than 7,0 % in the diet could generate deficiencies in nitrogen metabolism in the rumen, which compromises its proper functioning. It should be noted that none of the evaluated cultivars showed lower CP concentrations than the cited value at any time of the year (figure 3). In general, the species that predominate in the natural field of the NEA region, reach the minimum values required by animals only in spring, with values close to 8,0 % (Pizzio *et al*., 2021). It is considered that *M. esculenta* would be a valuable resource to supplement grazing animals during periods with deficit in such environments.

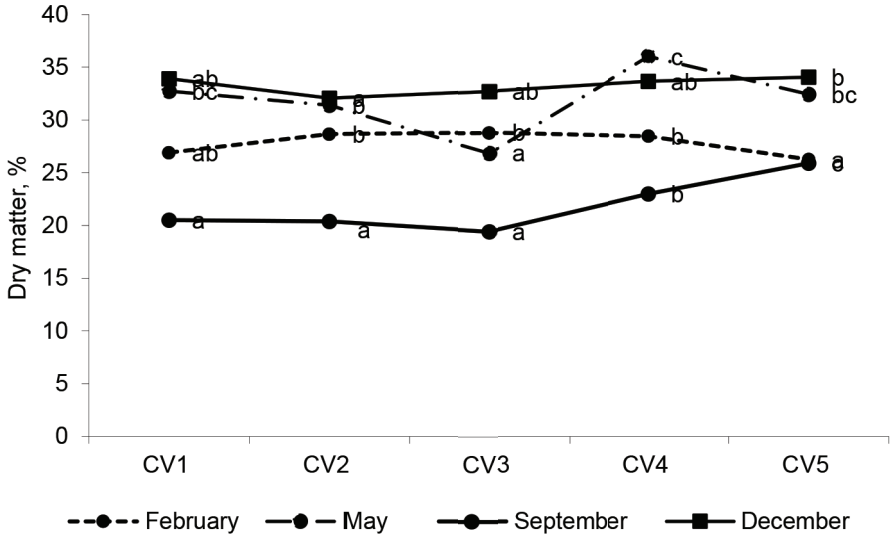
Dry matter. The evaluated genotypes had differences in DM percentage as a function of cutting time (figure 4). The differences found among cultivars over the course of the cycle agree with Fuhrmann *et al*. (2019), who suggest that the nutritional value of the shoots could be altered by genetic factors and agricultural practices, which would be given by seasonal harvests.

In the February cutting, DM percentage was less than 30 % in all cultivars. The one with the lowest DM percentage was CV5, with 26,0 %, which differed from CV2, CV3 and CV4 with 28,6 % average DM.

In the September cutting, which coincided with spring regrowth, DM percentage was the lowest of the year in all cultivars, with values below 26,0 %. At that time, CV1, CV2 and CV3 had the lowest, averaging 20,1 %, which differentiated them from other cultivars.

The months with the highest DM values were May and December, when most of the harvested material exceeded 30,0 % DM. In May, only CV3 was below this value, differentiating it from the other genotypes.

Costa *et al*. (2022) found values of 24,3 and 26,1 % DM on average for two cultivars subjected to different cutting heights. Studies conducted in Brazil by Fernandes *et al*. (2020) found average DM contents of aerial parts of 23,1 % in pruned plants,



CV1: Paraguaya Cerro Azul, CV2: Ramada Paso, CV3: Campeona, CV4: Amarilla y CV5: Amarilla Molina
$p < 0,0001$

Figure 4. Dry matter of five cultivars of *Manihot esculenta* at different cutting dates.

with a range between 22,0 and 25,5 % DM. Except for the September cutting, the DM percentages of the cultivars evaluated in this work were higher than those recorded by these authors, with values between 26,0 and 36,0 % DM.

From the combination of the studied variables, alternative uses for livestock feeding with *M. esculenta* foliage emerged at different times of the year. In May and December, the percentages of DM in the forage were high, those of DIG moderate to good and those of CP very good. At that time, the crop is at physiological maturity, and would be suitable for silage, which can be supplied during the winter, when the quality of natural pastures drops sharply and the foliage of *M. esculenta* is a highly recommended option.

The February harvest would be ideal for making hay, since it has a good DM content and 20,0 % CP, although its GFD can be low. Another advantage would be that at that time of the year the climate conditions in the region are ideal for hay making.

The September cut would be recommended to be fed fresh to animals, as it has high values of CP (23,9 %) and DIG (59,4 %), which makes it an ideal supplement at the end of winter in the NEA pastures.

Conclusions

The results show remarkable variability in variables related to the nutritional quality of *M. esculenta* among different cutting dates and cultivars.

Digestibility is closely related to tissue age. Of all the cultivars, Paraguaya Cerro Azul showed the lowest digestibility at most cutting dates.

The foliage of *M. esculenta* of all the evaluated cultivars stood out for maintaining an acceptable crude protein content throughout the year. The combination of dry matter percentage, digestibility and crude protein percentage will determine the optimal use of the harvested material at different times of the year.

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Conflict of interests

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

Authors' contribution

- Miriam Porta: Coordination of tasks, sample collection, processing and analysis, data analysis, bibliographic search and drafting of the manuscript.
- Claudina María Hack: Data analysis, literature search and participation in drafting and arranging the manuscript.
- Ángela María Burgos: Implementation, supervision of field trials and general revision of the text.

- Sebastián Carnicer: Chemical analysis and revision of the text.

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