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ORIGINAL RESEARCH

Physiological aspects, growth, and leaf nutrient contents of sweet potato under organic management

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Abstract

Purpose: The use of mulch and organic fertilizer in semi-arid regions are ecological practices capable of promoting production and reducing pressure on agricultural production systems. The objective was to evaluate the biomass production and physiological and nutritional aspects of sweet potatoes under mulch and organic fertilization in the Brazilian semi-arid region.

Method: The experimental design was in randomized blocks, in an incomplete factorial arrangement 5 × 5 + 2 corresponding to the levels of cattle manure (CM) (0.0, 8.72, 30, 51.28, and 60 t ha^{-1}) and mulching (M) (0.0, 287.73, 989.50, 1691.27, and 1979.0 g m^{-2}), and two additional treatments (I- control; II-fertilization with NPK 40-70-90 kg ha^{-1}), with treatments obtained by the Box-Wilson Central Composite Design.

Results: Based on the results obtained, it is possible to affirm that the adoption of organic management in the sweet potato production system, with techniques such as cattle manure incorporation and mulching, is feasible from the perspective sustainable for producers in the semi-arid region of Brazil.

Conclusion: Fertilization with cattle manure and mulch increased the synthesis of photosynthetic pigments, the number of leaves, the length and diameter of the main stem, the leaf area, the fresh and dry biomass of the aerial part and the N content in potato leaves sweet. The best plant performance was provided by the interaction between CM (28.4 to 60.0 t ha^{-1}) and M (1979.0 g m^{-2}). The joint application of CM and M was more efficient than mineral fertilizer with NPK.

Keywords: Cattle manure; *Ipomea batatas*; Mulching; Organic fertilization; Sustainable technologies.

1. Introduction

The semi-arid region of Brazil is characterized by its intense climatic variability, with irregular rainfall and long and recurrent drought periods. However, the increasingly irregular rainfall events and high evaporative demand, intensified in the last few years, have necessitated the use of practices that mitigate the effects caused by these factors on agricultural crops (Silva et al., 2013; IPCC, 2020).

The use of mulching and organic fertilization in these regions are ecological technologies capable of lowering and preventing thermal fluctuations in the soil, thus reducing water evaporation and erosion, increasing nutrient input and cycling, and improving the biodiversity of the edaphic fauna, consequently resulting in better crop performance (Meneses et al., 2016; Sharma & Bhardwaj, 2017; Souza et al., 2018). The choice of materials to be used in such practices should consider factors that take into account the availability of plant residues for mulching, the carbon/nitrogen ratio, the economic viability, and the impact on natural resources and animal feeding, allowing the use of materials such as grasses, weeds, crop leaves, straw remains from different species, and different sources of animal manure (cattle, goat, swine, and sheep) (Jourgholami & Abari, 2017; Souza et al., 2018; Cavalcante et al., 2021).

Mulching and organic fertilization have been widely employed in different agricultural crops, including *Solanum Lycopersicum* L. (Osadebe et al., 2024), *Curcubita* hybrid *Tetsukabuto squash* (Pellejero et al., 2022). *Ipomoea batatas* L. (Soplanit et al., 2021), *Zea mays* L. (Deng et al., 2019), *Plectranthus ornatus,* Codd (Sousa et al., 2020), *Passiflora edulis* f. *flavicarpa* Deg. (Uchôa et al., 2018), and *Allium cepa* L. (Carvalho et al., 2018a).

Sweet potato (*Ipomea batatas* L. Lam.) is a Convolvulaceae grown in the entire Brazilian territory, showing a continuous growth in the extent of cultivated areas. The growing market demand for this crop is motivated by this plant's properties, e.g., low glycemic index, antioxidant substances, high fiber content, and a diversity of vitamins, which reflects a trend influenced by factors such as nutrition security and quality of life (Embrapa, 2021; Dinu et al., 2022).

The Northeast region of Brazil is responsible for most of the national production, amounting to 38.4%. However, the mean yield of sweet potato production in this region is low, around 12.4 t ha^{-1} (IBGE, 2021), even though the crop can produce large amounts of tuberous roots in relatively short cycles.

Sweet potato production systems in the semi-arid region of northeastern Brazil are characterized by rainfed agriculture, which is intrinsically related to rainfall variability and minimum use of crop and soil management practices (Buainain & Garcia, 2013), directly influencing the crop's yield and quality (Lamaro et al., 2022).

However, although the benefits of mulching and organic fertilization are well documented for various crops, there is a specific knowledge gap regarding how the interaction of these practices, particularly with cattle manure, influences the physiology and nutrition of sweet potatoes under the extreme soil and climate conditions of the Brazilian semiarid region. Therefore, this experiment was proposed to investigate these aspects, validating the combined effectiveness of these sustainable technologies in improving crop performance, mitigating the effects of climate variability, and, consequently, increasing productivity levels in the region. Therefore, this study aimed to analyze the biomass production and the physiological and nutritional aspects of sweet potatoes grown under mulch and livestock management.

2. Materials and methods

2.1. Site description and experimental design

The study was conducted under field conditions in a family farming production unit at the Riachão Farm, located in the municipality of Aparecida, Paraíba (06º 47'02"S, 38º 05'13"W, 214 m of elevation), in the Alto Sertão meso-region, semi-arid region of Brazil. The area was chosen because it had available resources and was lying fallow for approximately 10 years. The soil of the experimental area is a Neosol with a loam texture.

The mean monthly values of temperature, relative air humidity, and rainfall in the region during the experimental period and the normal mean of the last 30 years are shown in the ombrothermic diagram (Fig. 1) (INMET, 1988 to 2019 - São Gonçalo station - code 82689), which was used to guide the conduction of the experiment in the period that concentrates most of sweet potato cultivation in the region, with a climate characterized as As (Alvares et al., 2013). During the experimental period, the cumulative rainfall was 30.5 mm, the mean temperature was 27.8 °C, and the mean relative humidity was 69.7%.

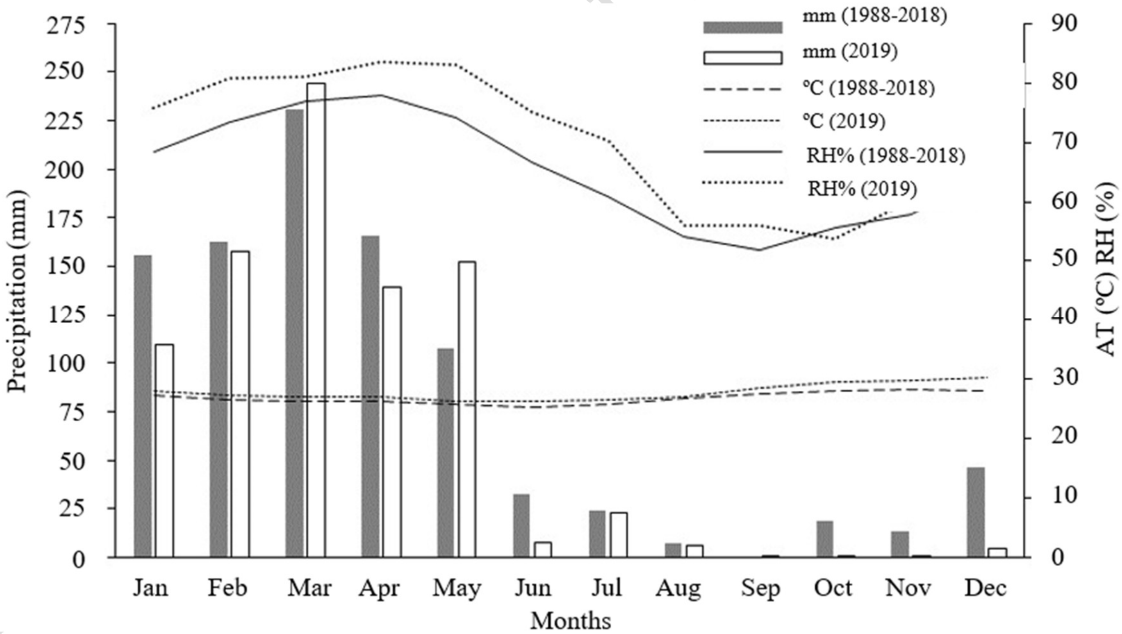

Figure 1. Average monthly values of temperature, relative humidity and rainfall variations in the region where Fazenda Riachão is located, municipality of Aparecida, Paraíba, Brazil.

The experimental design adopted was in randomized blocks with four replications. The treatments were obtained by the Box-Wilson Central Composite Design, with the treatments corresponding to cattle manure

(CM) (0.0, 8.72, 30, 51.26, and 60 t ha^{-1}) and mulching levels (M) (0.0, 287.73, 989.50, 1691.27, and 1979 g m^{-2}), plus two additional treatments (I- control; II- fertilization with NPK 40-70-90 kg ha^{-1}). The central box composite matrix was used because it provides a reduction in the number of treatments, optimizing the experimental area and reducing the standard error. The experimental plot was formed by one planting row, distanced by 0.80 m, containing eight planting holes spaced by 0.30 m, with two plants per hole, totaling 16 plants per plot and a density of 83.332 plants per hectare.

The chemical attributes of the soil in the 0-20 cm layer and the cattle manure used as organic fertilizer were determined before the experiment was set up using the methodologies contained in Embrapa (2017). The soil chemical attributes determined were: pH (H_2O) = 7.05; organic matter = 16.49 g kg^{-1}; P = 15.98 mg dm^{-3}; K^+ = 43.2 mg dm^{-3}; Na^+ = 0.13 $cmol_c$ dm-3; H^++Al^{3+}= 1.24 $cmol_c$ dm^{-3}; Al^{3+} = 0.00; Ca^{2+} = 10.12 $cmol_c$ dm^{-3}; Mg^{2+} = 3.5 $cmol_c$ dm^{-3}; sum of bases (SB) = 13.86 $cmol_c$ dm^{-3}, CEC = 15.1 $cmol_c$ dm^{-3}, base saturation (V%) = 91.75%; and exchangeable sodium percentage (ESP%) = 0.34%. The soil physical attributes were: sand = 417 g kg^{-1}; silt = 376 g kg^{-1}; clay = 207 g kg^{-1}; clay dispersed in water = 81 g kg^{-1}; degree of flocculation = 607 g kg^{-1}; soil density = 1.17 g cm^{-3}; particle density = 1.77 g cm^{-3}; total porosity = 0.34 m^3 m^{-3}; and moisture (001 Mpa) = 295 g kg^{-1} and (1.5 Mpa) = 104 g kg^{-1}.

The chemical composition of the cattle manure corresponded to: CO = 13.67%; N = 12.95 g kg^{-1}; P = 5.51 g kg^{-1}; K = 3.95 g kg^{-1}; Ca = 46.92 g kg^{-1}; Mg = 5.67 g kg^{-1}; S = 2.34 g kg^{-1}; Cu = 13.82 mg kg^{-1}; Zn = 89.98 mg kg^{-1}; Fe = 11275.11 mg kg^{-1}; Mn = 201.58 mg kg^{-1}; and B = 72.99 mg kg^{-1}.

Fertilization was based on the recommendations for sweet potato, following the guidelines of the State of Pernambuco for soil analysis (Cavalcanti, 2008). In the treatments with organic fertilization, the application of cattle manure was performed during planting. For application, a furrow was opened in the windrow using a hoe and then the cattle manure was applied, which was incorporated into the soil, preserving the structure of the windrow. Chemical fertilization was split into two applications, consisting of 50% N, 100% P, and 57.2% K at planting and 50% N plus 42.8% K 30 days after planting (DAP). Chemical fertilization was based on urea (45% N), single superphosphate (21% P), and potassium chloride (58% K).

The plant materials used were collected in the area itself, consisting of palm straw [*Copernicia prunifera* (Mill.) H. E. Moore] and the grass *Aristida longifolia* Trin. at a proportion of 1:1, recurrent species in Caatinga areas and very predominant in the study location. The application of mulching over the planting rows was performed eight days after planting. The dried, weighed, and homogenized material was applied over the entire rows, following the corresponding treatments.

Planting was preceded by manual soil preparation, followed by the raising of planting beds up to 0.30 m high. The sweet potato cultivar used the cv. Campina, which shows tubercles with an outer purple color and a white pulp. These creeper plants are vigorous, with lobate leaves with an intense green color, purple shoots, and uniform and clustered roots, with harvest 120 days after planting (Embrapa, 2021; Oliveira et al., 2021).

The shoots were removed from young plants, one day before planting, with a mean age of 75 to 80 days, and cut into pieces approximately 30 to 40 cm long containing eight internodes, on average. The material was planted manually at a depth of 10 to 12 cm.

Manual hoeing was performed twice at 25 and 55 DAP. Insect control was performed using a mixture of black pepper, garlic, and soap. Hilling was another practice employed to protect the roots, maintain the formation of the planting beds, and control the pyralid moth (*Megastes pusialis*), performed at 45 DAT.

2.2. Experiment analyses

At 65 DAT, when the plants reached their maximum growth potential, which is related to the highest biological production, the following analyses were performed by the non-destructive method, from 9:00 a.m. to 11:00 a.m.:

- Gas exchange, by evaluating the net CO_2 assimilation (A) (μmol $m^{-2}s^{-1}$), stomatal conductance (gs) (mol m^{-2} s^{-1}), transpiration (E) (mmol m^{-2} s^{-1}), and internal CO_2 concentration (Ci) (μmol mol^{-1}) with a photosynthetic photon flux of 1,200 μmol m^{-2} s^{-1}, a leaf chamber (6 cm²) coupled to a natural irradiance sensor, with air moisture values ranging from 50 to 60%, an airflow of 300 μmol s^{-1}, and atmospheric CO_2 of 400 μmol mol^{-1} determined with a portable infrared gas analyzer (IRGA) (Licor, model LI-6400XT);
- Fluorescence of chlorophyll *a*, determined by analyzing the initial fluorescence (F_0), maximum fluorescence (F_m), variable fluorescence (F_v), and the maximum quantum yield of photosystem PSII (F_v/F_m). The leaves were previously adapted to the dark using leaf clips for 30 minutes. A portable modulated fluorometer was used for these analyses (Sciences Inc.- model OS-30p, Hudson, USA);
- Contents of chlorophyll *a*, *b*, and total chlorophyll, determined with a portable chlorophyll meter (ClorfiLOG®, model CFL 1030), with results expressed as FCI (Falker Chlorophyll Index®).

The leaf contents of nitrogen (N), phosphorus (P), and potassium (K) were evaluated in the same period following the methodology of Malavolta et al. (1997). The leaf area was obtained according to Yeshitila & Taye (2016), using Equation 1 (Yeshitila & Taye, 2016).

$$AF = C * L * f \tag{1}$$

Where: AF = leaf area, in cm²;
C = Leaf length, in cm;
L = Leaf width, in cm; and
f = Correction factor for sweet potato (0.57), non-dimensional, determined by the correlation between C and L.

The number of leaves and the length and diameter of the main stem were determined, respectively, by manual counting, measurement from the base of the plant to the apex of the main stem, and measurement of the diameter at 2 cm from the soil surface.

After 120 DAT, the fresh shoot biomass was determined by weighing two plants from each treatment and replications. Next, the material was oven-dried at 65 °C for 72 h to determine the dry shoot biomass.

2.3. Statistical analyses

The data were subjected to analysis of variance, followed by polynomial regression. Next, the degrees of freedom were unfolded for the additional treatments using the following orthogonal contrasts (C): C1: NPK versus T9 (30 t h^{-1} CF + 989.50 g m^{-2} M) and C2: NPK versus T10 (Control). The statistical analyses were performed using the software R® *v.3.4.3* (R Core Team, 2020).

3. Results and Discussion

The gas exchange parameters, fluorescence of chlorophyll a, and the leaf contents of phosphorus and potassium showed no significant effects from the studied factors. The interaction between manure and mulching levels was significant for the synthesis of chlorophyll a (Chl *a*), b (Chl *b*) total chlorophyll (Chl *To*), length of the main stem (LMS), fresh shoot biomass (FSB), and leaf nitrogen contents (N). For the number of leaves (NL), diameter of the main stem (DMS), leaf area (LA), and dry shoot biomass (DSB), there was an isolated effect of the cattle manure and mulching levels (Table 1).

Table 1 - Summary of the analyses of variance of stomatal conductance (gs), net CO_2 assimilation (A), internal CO2 concentration (Ci), transpiration (E), chlorophyll *a* (CL a), chlorophyll *b* (CL b), and total chlorophyll (CL t), initial fluorescence (F_0), maximum fluorescence (F_m), and variable fluorescence (F_v) of chlorophyll *a*, quantum efficiency of photosystem II (F_v/F_m), number of leaves (NL), length of the main stem (LMS), diameter of the main stem (DMS), leaf area (LA), fresh shoot biomass (FSB), dry shoot biomass (DSB), leaf nitrogen contents (N), phosphorus (P), and potassium (K) in leaves of the sweet potato cv. Campina grown under levels of cattle manure (CF) and mulching (MC).

Sources of variation	DF	g_s	A	Ci	E	CL a	CL b	CL t	F_0	F_m	F_v	F_v/F_m
Block	3	3.35*	1.32^{ns}	10.20**	4.12*	1.31^{ns}	2.26^{ns}	1.79^{ns}	11.07**	2.38^{ns}	1.87^{ns}	6.05**
Treatment	(10)	1.70^{ns}	0.76^{ns}	1.12^{ns}	1.41^{ns}	3.17**	3.88**	4.67**	0.73^{ns}	0.33^{ns}	0.54^{ns}	0.69^{ns}
Regression analysis												
CF - L	1	0.77^{ns}	0.11^{ns}	0.87^{ns}	0.29 ^{ns}	11.70*	20.83*	23.02*	1.31^{ns}	0.03^{ns}	0.36^{ns}	0.33^{ns}
CF - Q	1	1.04^{ns}	0.23^{ns}	0.05^{ns}	0.59 ^{ns}	0.08^{ns}	0.37^{ns}	0.26^{ns}	0.92^{ns}	0.00^{ns}	0.11^{ns}	0.58^{ns}
MC - L	1	0.70^{ns}	0.03^{ns}	3.98^{ns}	0.71 ^{ns}	5.77^{ns}	0.73^{ns}	4.60**	0.19^{ns}	0.87^{ns}	1.04^{ns}	0.47^{ns}
MC - Q	1	7.34^{ns}	1.87^{ns}	0.76^{ns}	3.06 ^{ns}	0.15^{ns}	0.00^{ns}	0.08^{ns}	0.00^{ns}	0.17^{ns}	0.16^{ns}	0.04^{ns}
CF - L x MC - L	1	0.72^{ns}	0.11^{ns}	0.04^{ns}	0.03 ^{ns}	8.95**	6.17**	11.63*	0.00^{ns}	0.05^{ns}	0.04^{ns}	0.00^{ns}
Contrasts												
NPK v T9	1	0.76^{ns}	0.65^{ns}	0.52^{ns}	1.00 ^{ns}	0.02^{ns}	0.14^{ns}	0.08^{ns}	0.68^{ns}	0.27^{ns}	0.64^{ns}	0.95^{ns}
NPK v Ad. I	1	0.69^{ns}	0.48^{ns}	0.13^{ns}	1.39 ^{ns}	0.24^{ns}	0.48^{ns}	0.50^{ns}	0.00^{ns}	1.08^{ns}	0.86^{ns}	0.17^{ns}
CV (%)	-	21.2	11.4	3.7	9.10	3.60	10.40	4.10	14.90	10.70	17.10	8.50

Sources of variation	DF	NL	LMS	DMS	LA	FSB	DSB	N	P	K
Block	3	1.27^{ns}	1.20^{ns}	0.26^{ns}	0.26^{ns}	2.63^{ns}	1.75^{ns}	19.94**	4.26*	5.64**
Treatment	(10)	2.31*	5.19**	1.01^{ns}	13.21**	3.59**	2.56**	5.75**	1.13^{ns}	2.07^{ns}
Regression analysis										
CF - L	1	0.00^{ns}	8.89*	3.69^{ns}	35.33**	0.19^{ns}	0.00^{ns}	0.60^{ns}	0.27^{ns}	0.05^{ns}
CF - Q	1	4.20**	0.15^{ns}	1.02^{ns}	24.63**	5.76**	5.47**	0.42^{ns}	0.40^{ns}	3.23^{ns}
MC - L	1	4.11^{ns}	8.28*	1.30^{ns}	23.52**	5.23**	13.24*	3.97*	1.31^{ns}	1.10^{ns}
MC - Q	1	0.25^{ns}	0.32^{ns}	1.21^{ns}	11.20**	0.49^{ns}	0.01^{ns}	7.75*	0.00^{ns}	0.92^{ns}
CF - L x MC - L	1	2.66^{ns}	15.02*	4.92**	1.05^{ns}	4.30**	4.14^{ns}	8.58*	0.42^{ns}	0.03^{ns}
Contrasts										
NPK v T9	1	1.93^{ns}	15.34*	0.15^{ns}	16.63**	12.46*	0.71^{ns}	1.42^{ns}	0.79^{ns}	1.92^{ns}
NPK v Ad. I	1	0.16^{ns}	9.80*	0.01^{ns}	2.50^{ns}	0.23^{ns}	3.26^{ns}	6.52**	1.34^{ns}	0.28^{ns}
CV (%)	-	14.10	13.20	15.60	6.9	38.80	35.00	5.10	5.50	10.50

DF = degree of freedom; CV = coefficient of variation; L = Linear; Q = Quadratic; ns = not significant; * and ** respectively significant at p<0.05 and p<0.01 by the F-test.

The indices of chlorophyll *a*, *b*, and total chlorophyll of sweet potato increased as an effect of the interaction between cattle manure levels and mulching, with values of 36.95, 10.67, and 40.52, respectively, at the CM level of 60.0 t ha^{-1} and under the application of 1979.0 g m^{-2} of M (Fig. 2A, B, and C). These values represent increases of 11.1%, 28.8%, and 14.9% compared to the lowest indices quantified.

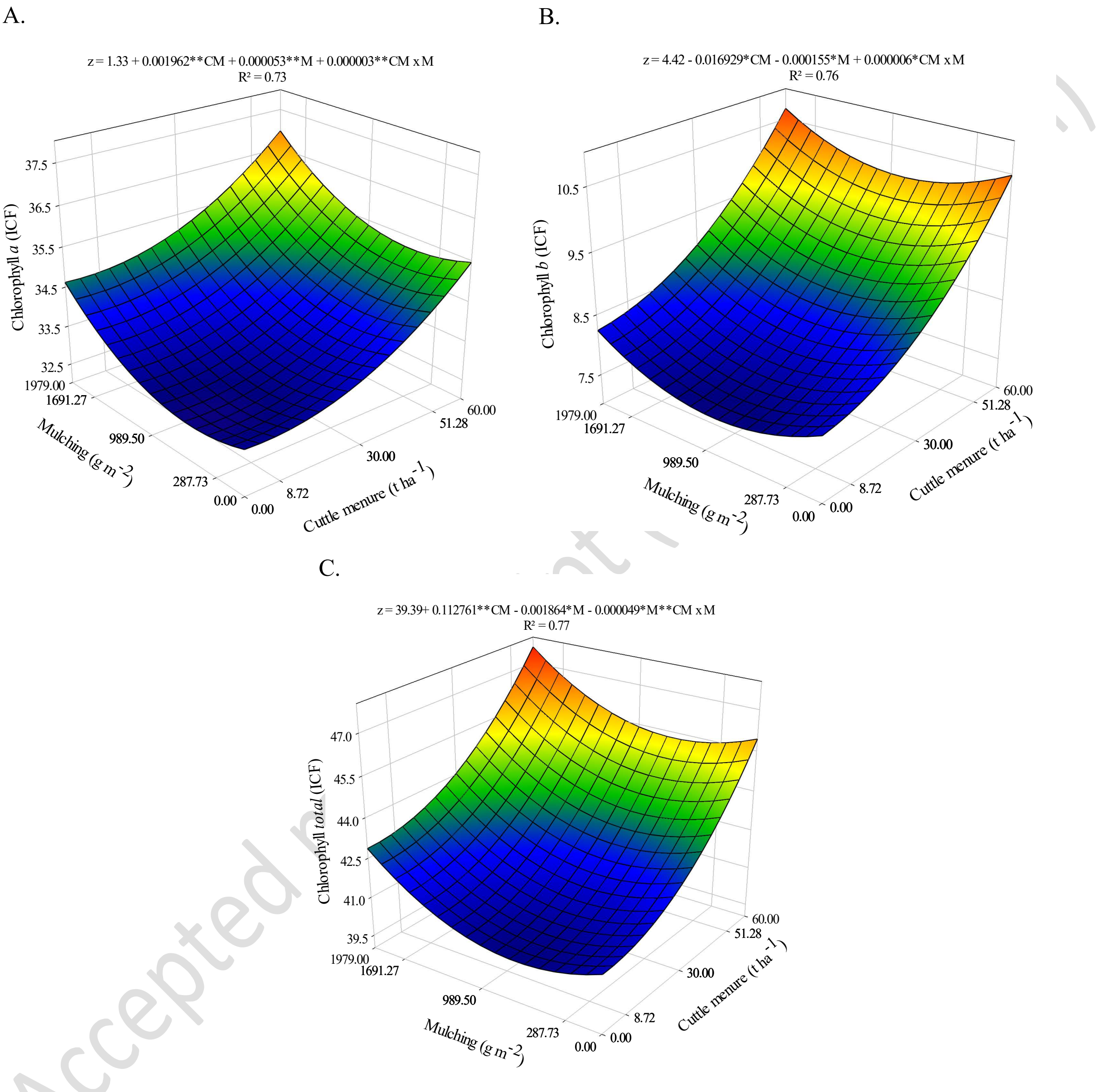

Figure 2. Chlorophyll *a* (A), *b* (B) and total chlorophyll (C) indices in sweet potato cv. Campina, as a function of mulch and cattle manure doses.

Fertilization with cattle manure and mulching improved the synthesis of photosynthetic pigments, increasing the chlorophyll indices as a result of the benefits provided by the organic matter added to the soil (Carvalho et al., 2018b). The greater nutrient input through decomposition, the maintenance of moisture, and the mitigation of temperature and thermal range favored the maintenance of the photosynthetic metabolism (Ambrosano et al., 2013; Chavarria et al., 2015; Cavalcante et al., 2016; Bassi et al., 2018).

The increase caused by the use of organic fertilization and the use of mulch in the synthesis of photosynthetic pigments was reported by Mansour (2017) when using cattle manure and by Hou et al. (2015) with mulch, obtaining increases in the chlorophyll indices of sweet potato plants of 6.1% and 9.7%, respectively.

Although no significant differences were observed in the photochemical efficiency of sweet potato plants, the F_0, F_m, F_v, and the quantum efficiency of photosystem II, showed mean values (Table 1) within the adequate range for the functioning of the photosystem since the quantum efficiency of photosystem II (from 0.67 to 0.83) is the best indicator of stress situations caused by factors such as water and nutrient availability (Krochmal-Marczak et al., 2019). Therefore, the input of organic matter and mulching improve the nutritional characteristics of the soil, increasing the nutrient supply and reducing the loss of water through evapotranspiration, thus improving water availability and regulating soil temperature (Kuts et al., 2021).

Although a significant variation was caused by cattle manure (Table 1), the data fit no model when polynomial regression was applied to the values referring to the number of leaves. However, in absolute values, the treatments under the CM level of 51.3 t ha^{-1} were higher, with a mean value of 387 leaves per plant.

The length and diameter of the main stem of sweet potato plants increased by 30.9% and 30.4% with the application of cattle manure and mulching, changing from 1.32 m to 1.91 m and from 5.5 mm to 7.9 mm, respectively, under 60 t ha^{-1} of CM and 1979.0 g m^{-2} of M (Fig. 3A and 3B).

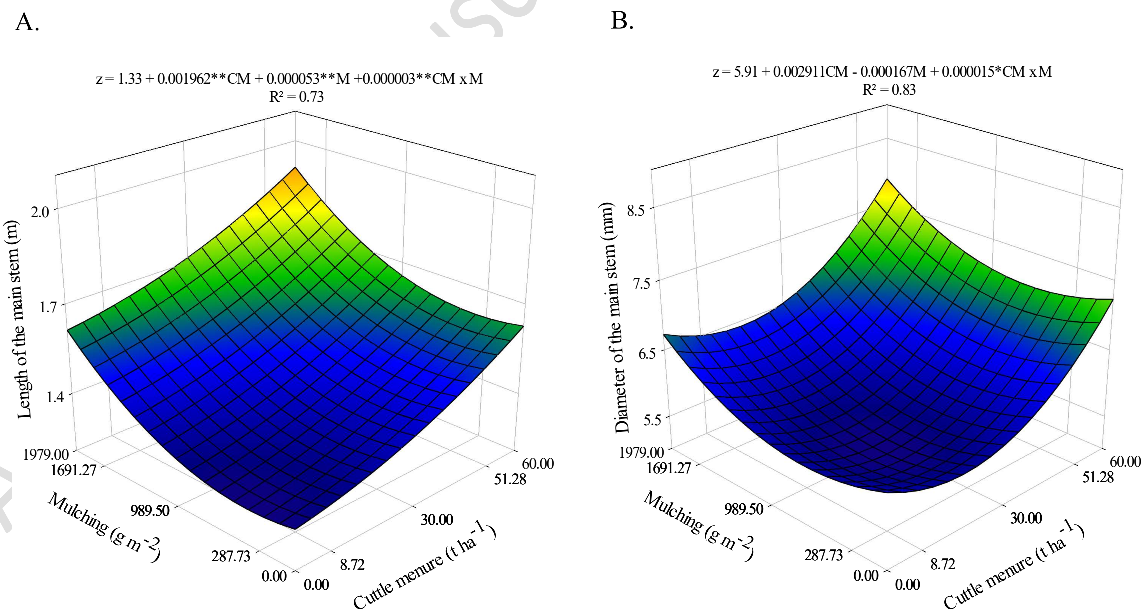

Figure 3. Length of the main stem (A) and diameter of the main stem (B) in sweet potato cv. Campina, as a function of doses of mulch and cattle manure.

Organic management with cattle manure and mulching using palm straw and grass improved the shoot growth of sweet potato, with increases in the number of leaves and in the length and diameter of the main stem. This behavior is associated with the higher nutrient availability for plants, including N, K, and P, thus improving the nutrient status and, consequently, plant development (Nóbrega et al., 2019). Furthermore, according to Oliveira et al., (2021) the sweet potato cv. Campina is singular due to the high investment in vegetative growth, as seen in the number of leaves, diameter of the main stem, and branching.

The leaf area was significantly influenced by the factors analyzed, with maximum values (5682.08 and 5567.72 cm²) achieved with the application of 1979.0 g m^{-2} of M (Fig 4A) and under the CM of 40.6 t ha^{-1} (Fig. 4B). Compared to these values, the plants under the control treatment were lower by 22% and 24%, respectively.

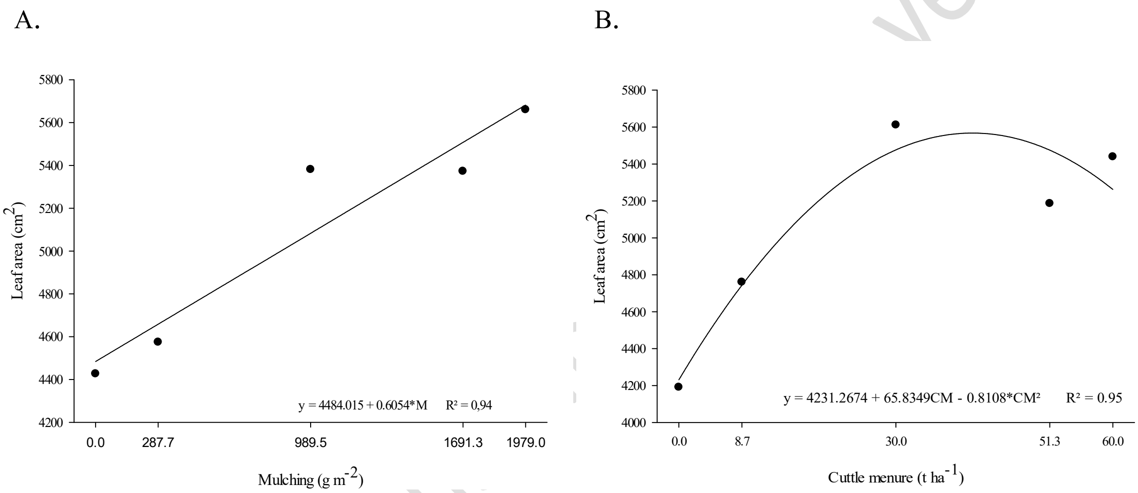

Figure 4. Leaf area (cm^2 per plant) in sweet potato cv. Campina, as a function of doses of mulch (A) and cattle manure (B).

The leaf area results were 37.2% higher than those observed by Oliveira et al., (2021) in the sweet potato cv. Campina. A study with beets (*Beta vulgaris* L.), conducted by Gadelha et al. (2021) in the State of Ceará also reported a higher leaf area index (614.06 cm²) when using mulching with the same palm species used in the present study.

The maximum efficiency of 63.9 t ha^{-1} of fresh shoot biomass (FSB) was obtained under the CM of 31.1 t ha^{-1} and 1179.9 g m^{-2} of M (Fig. 5A). In turn, the dry shoot biomass (DSB) was significantly influenced by the factors, with maximum estimated values of 8.0 t ha^{-1} and 6.7 t ha^{-1} under the application of 1979.0 g m^{-2} of M and CM level of 28.4 t ha^{-1}, respectively (Fig. 5B and 5C).

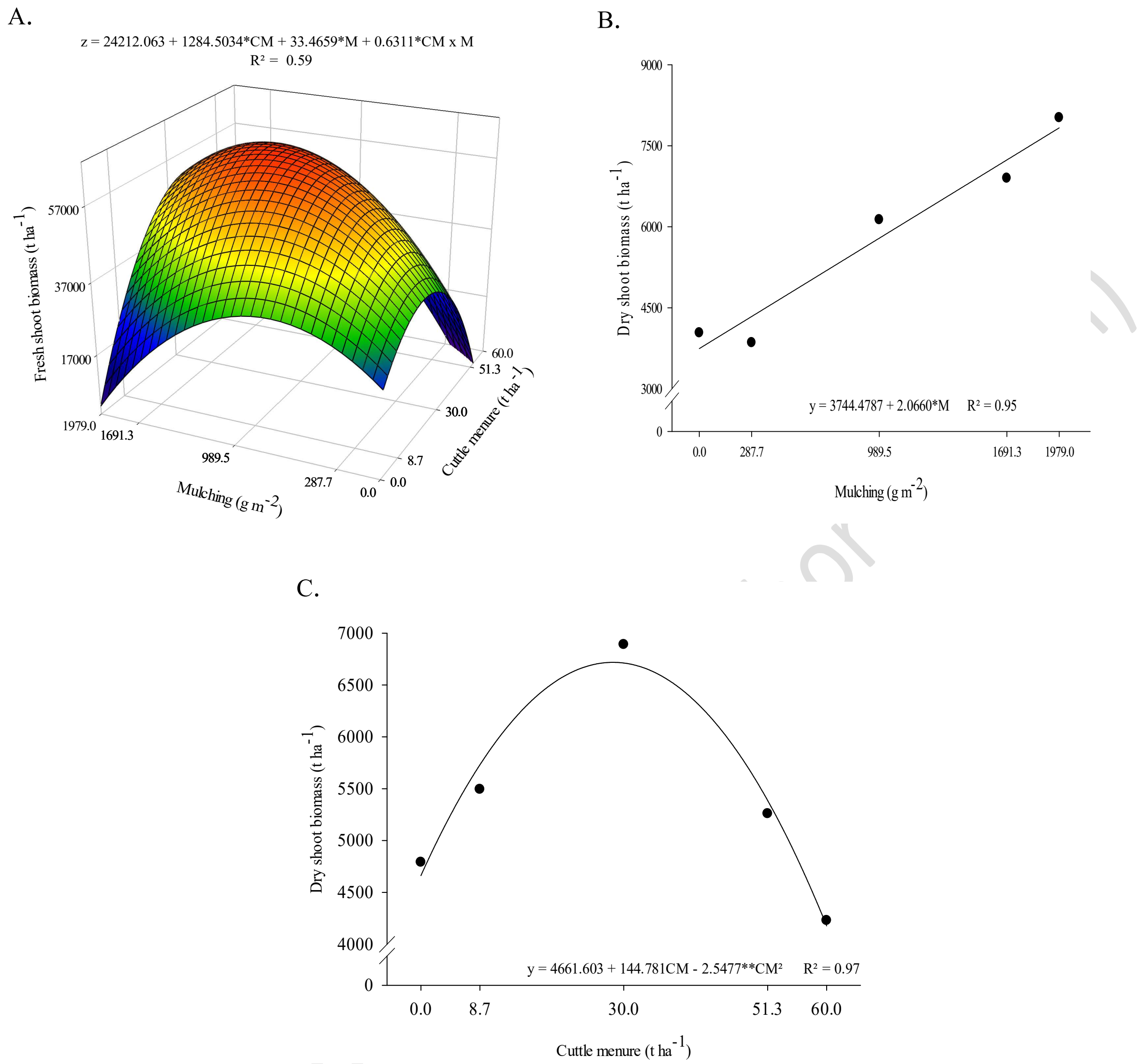

Figura 5. Green (A) and dry (B and C) phytomass of the aerial part (ton ha^{-1}) in sweet potato cv. Campina, as a function of doses of mulch and cattle manure.

The accumulation of fresh and dry shoot biomass was also favored by mulching and cattle manure application, indicating nutritional improvements with the adoption of organic management in sweet potato. The addition of these organic materials probably favored improvements in the physical, chemical, and microbiological conditions of the soil, resulting in a higher biomass production (Souza et al., 2018). Increases in the fresh and dry biomass when using palm mulch were also reported by Almeida et al., (2020) for radish (*Raphanus sativus* L.) under levels of 16 t ha^{-1} and 9.3 t ha^{-1}, respectively, and by Santos (2021) for arugula (*Eruca sativa* L.) under 30 t ha^{-1} of cattle manure and palm mulch (1:1).

The leaf nitrogen contents were significantly influenced by the CM and M (Table 1), with the maximum efficiency of 45.88 g kg^{-1} achieved under the management with 38.0 t ha^{-1} of CM and 1979.0 g m^{-2} of M (Fig. 6), an increase of 10.90% compared to the lowest indices quantified.

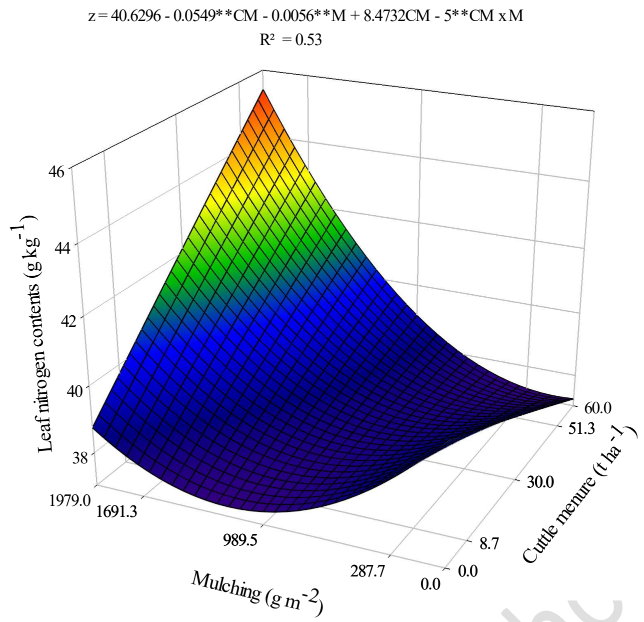

Figura 6. Leaf nitrogen content (g kg^{-1}) in sweet potato cv. Campina, as a function of mulch and cattle manure doses.

This result could be associated with the interrelation of several factors provided by cattle manure and mulching, including the higher soil microbiological activity, the supply of inorganic N, the increase in the exchange capacity between mineral ions, the gradual supply of water, and the lower moisture variation, thus favoring nutrient uptake in the soil solution (Zhang et al., 2021).

Similar results for biomass production and physiological and nutritional aspects of plants grown under fertilization with cattle manure and mulching were also reported for other vegetable species in different regions of Brazil, e.g., *Beta vulgaris* L. (Gondim et al., 2015) and *Raphanus sativus* L. (Gomes et al., 2020).

Through the application of orthogonal contrasts (NPK versus T9 (30 t h^{-1} CM + 989.50 g m^{-2} M) and NPK versus Control), it was possible to analyze that the length of the mains tem, leaf area, fresh shoot biomass, and leaf nitrogen content were significantly influenced (Table 1), with a marked superiority in the plants that received cattle manure and mulching.

In the treatments with CM and M, the values referring to the length of the main stem, leaf area, and fresh shoot biomass were 40.5%, 31%, and 57% higher than those observed in plants fertilized with NPK, respectively (Table 1). For the length of the main stem and leaf nitrogen content, there was an effect of contrasts between additional, with the values observed in the plants under NPK fertilization being 35.2% and 11% lower than those recorded in the plants under the control treatment, respectively (Table 1).

The adoption of organic fertilization and mulching with palm and grass residues showed higher efficiency compared to mineral fertilization, improving the synthesis of photosynthetic pigments and the growth of sweet potato plants. These results can be explained by the fact that these materials, when incorporated into the soil, serve as much more complex and balanced nutrient sources for plants than mineral fertilizers since their composition provides beneficial effects for the physical structure of the soil through aggregation and soil infiltration, effects that improve soil fertility with the presence of macro- and micronutrients and the microbiological quality with the increase and maintenance in biological diversity (Prosdocimi et al., 2016; Kader et al., 2019).

Based on the results obtained, it is possible to affirm that the adoption of organic management in the sweet potato production system, with techniques such as cattle manure incorporation and mulching, is feasible from the perspective sustainable for producers in the semi-arid region of Brazil. Furthermore, it confirms that an efficient combination of practices employed in this research which mitigate the effects of adverse climate conditions and promote high productivity, use, and conservation of natural resources is fundamental and indispensable for production systems in semiarid regions, where adverse soil and climate conditions intensify. Thus, the adoption of these technologies favors the continued production capacity of sweet potato systems and contributes to ensuring food security and sovereignty.

4. Conclusion

The association between mulching and cattle manure fertilization provided high values in the indices of chlorophyll *a*, *b,* and total chlorophyll and in the length and diameter of the main stem, fresh and dry shoot biomass, and the leaf nitrogen contents; The highest number of leaves per plant was obtained under fertilization with cattle manure, and the highest leaf area was obtained under mulching with palm and grass residues; The associated application of cattle manure and mulching was more efficient than mineral fertilization with NPK for sweet potato plants.

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Author contributions

MBP, MBA, and WEP conceived the study. MBP, RTF, and JTAF collected field data. MBP and WEP managed and analyzed the data. MBP wrote the manuscript with feedback from RTF and JSN.

Conflict of interest statement

The authors declare that they are no conflict of interest associated with this study.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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