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Original Article

Yield and quality of sweet potato under nitrogen rates and vine cuttings densities per hole[1]

Produtividade e qualidade de batata-doce sob doses de nitrogênio e densidades de estacas por cova

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HIGHLIGHTS:

Nitrogen fertilization at 168 kg ha^{-1} achieved maximum total yield of 49 t ha^{-1} in sweet potato cv. Campina.
Single vine cutting per hole outperformed double cuttings, improving commercial yield and nitrogen use efficiency.
Plant spacing of 0.30 m combined with optimal nitrogen doses maximized both yield and starch content.

ABSTRACT: Although soil and climate conditions in Northeast Brazil are favorable for sweet potato cultivation, productivity remains below potential, likely due to inadequate management practices, particularly related to fertilization and planting density. This study aimed to evaluate the effects of nitrogen doses, plant spacing (0.30, 0.40, and 0.50 m), and the number of vine cuttings per hole (one or two) on yield components and starch content in sweet potato. A randomized blocks design with split-split plots was used. Main plots consisted of a factorial combination of five nitrogen doses (0, 60, 120, 180, and 240 kg ha^{-1}) and three spacings. At the same time, subplots corresponded to the number of vine cuttings per hole, totaling 30 treatment combinations. Single vine cutting systems reduced nitrogen requirements by 150% while maintaining superior yields compared to double vine cutting arrangements. The treatment of 168 kg ha^{-1} of N and 0.30 m spacing between plants resulted in the highest total yield (49 t ha^{-1}) when one vine cutting per hole was used, representing a 237% increase above the national average productivity. Treatments with one vine cutting per hole showed superior performance, with increases of 97.2% in foliar nitrogen, 25% in starch content, 237% in total root yield, and 76% in commercial yield. Two cuttings also showed gains, but to a lesser extent, indicating higher nitrogen use efficiency with one cutting. These findings underscore the importance of optimizing nitrogen fertilization and planting density to maximize root yield and quality under sustainable agricultural practices.

Key words: *Ipomoea batatas* L., nitrogen fertilization, plant spacing, commercial yield, starch content

RESUMO: Apesar das condições edafoclimáticas do Nordeste brasileiro serem favoráveis ao cultivo da batata-doce, sua produtividade permanece baixa, provavelmente devido a práticas inadequadas de manejo, relacionadas à adubação e à densidade de plantio. O objetivo deste foi avaliar os efeitos da adubação nitrogenada, do espaçamento entre plantas (0,30; 0,40 e 0,50 m) e do número de estacas por cova (uma ou duas) sobre a produtividade e o teor de amido em batata-doce. Utilizou-se o delineamento em blocos casualizados com parcelas subsubdivididas. As parcelas principais consistiram em cinco doses de nitrogênio (0, 60, 120, 180 e 240 kg ha^{-1}) e três espaçamentos, as subparcelas corresponderam ao número de estacas por cova, totalizando 30 tratamentos. O plantio com uma estaca por cova reduziu em 150% a necessidade de nitrogênio, mantendo a produtividade superior em comparação com duas estacas por cova. O tratamento com 168 kg ha^{-1} de N e espaçamento de 0,30 m resultou na maior produtividade total (49 t ha^{-1}) com uma estaca por cova, representando um aumento de 237% em relação à média nacional. Tratamentos com uma estaca por cova apresentaram melhor desempenho, com aumentos de 97,2% no nitrogênio foliar, 25% no teor de amido, 237% na produtividade total de raízes e 76% na produtividade comercial. O uso de duas estacas também mostrou ganhos, porém em menor escala, sendo mais eficiente o plantio com uma estaca. Esses resultados destacam a importância da adubação nitrogenada e da densidade de plantio para maximizar a produtividade e a qualidade das raízes em sistemas agrícolas sustentáveis.

Palavras-chave: *Ipomoea batatas* L., adubação nitrogenada, espaçamento, produtividade comercial, teor de amido

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Introduction

Sweet potatoes (*Ipomoea batatas* L.) are rich sources of energy, carbohydrates, minerals, vitamins C, A, and complex B. They can be used in various recipes for cakes, candies, flour, starch extraction, and even alcohol production (Alam et al., 2020). All parts of the plant can be used, for example, the roots for human consumption and the branches and/or roots to complement animals' diets (Oliveira et al., 2010; Costa et al., 2025). In addition to its use as an alternative to producing biofuels such as anhydrous alcohol or ethanol (Rizzolo et al., 2021).

In Brazil, sweet potato is cultivated in almost all states, with the greatest relevance in the South and Northeast regions, where it serves as a key food source. In 2023, production reached 847 thousand tons over 58,540 ha, with a national average yield of 14.55 t ha^{-1} (IBGE, 2023). However, this yield remains approximately 60% below the crop's potential under optimal management practices. In turn, sweet potato has the potential to reach yields of 25 to 30 t ha^{-1} easily and, in some situations, even above 40 t ha^{-1} (Oliveira et al., 2021; Mello et al., 2022).

In Northeast Brazil, where family farming predominates (Araujo et al., 2023), average yields are often lower than the national average (IBGE, 2023), reflecting both regional limitations and management constraints. These include the use of obsolete genotypes, cultivation in low-fertility soils, inadequate fertilization strategies, and limited access to appropriate agricultural technologies (Santos Junior et al., 2020; Higashikawa et al., 2024). This persistent yield gap not only hampers food security but also limits economic returns for smallholder farmers, who could double their income by adopting improved practices and site-specific fertilizer recommendations.

Nitrogen (N) is one of the most required nutrients by sweet potato (*Ipomoea batatas* L.), playing a fundamental role in determining both the yield and the nutritional composition of storage roots (Kumar et al., 2023). Studies have shown that adequate N doses promote an increase in leaf area and shoot biomass, factors directly related to photosynthetic capacity and the accumulation of reserves in the tubers, resulting in higher yields (Joko et al., 2024). However, excessive nitrogen supply can lead to excessive vegetative growth, premature senescence, imbalanced source-sink relationships, reduced storage root yield, lower nutrient use efficiency, and greater environmental risks (Oliveira et al., 2017; Du et al., 2019). Therefore, proper nitrogen fertilization is essential to optimize both yield and quality in sweet potato production (Kumar et al., 2023; Joko et al., 2024).

The sweet potato yield can also be increased with the proper spacing, density, and an adequate planting system (Dlamini et al., 2021). The ideal population of plants (density and spacing) to be adopted is that sufficient to reach the optimum leaf area index to intercept the maximum solar radiation useful for photosynthesis and, at the same time, to maximize the fraction of dry matter available for the tuberous roots (Szarvas et al., 2019). In sweet potato cultivation, planting density also causes competition for water and nutrients, which can cause low yields and poor quality due to the effects on physiological processes and storage root formation (Liang et al., 2023).

In the Northeast region of Brazil, there are variations in planting practices regarding the number of vine cuttings per hole used in sweet potato cultivation. However, the use of one vine cutting per hole is still more common among farmers; there is a noticeable lack of technical standardization (EMBRAPA, 2023). In Paraíba's Brejo region, smallholder farmers typically use 1-2 vine cuttings per hole without standardized N fertilization, resulting in yields 40-60% below potential. Therefore, this study aimed to evaluate the effects of nitrogen fertilization (0-240 kg ha^{-1}), planting spacing (0.30-0.50 m), and the number of vine cutting density (1-2 per hole) on yield components and quality of sweet potato cv. Campina.

Material and Methods

This study was carried out, in the experimental site of the Universidade Federal da Paraíba, located in Areia, Paraíba, micro-region of Brejo Paraibano, with an altitude of 574.62 m, latitude 6° 57' 46" S, and longitude 35° 41' 31" W. During the experimental period, mean temperatures ranged from 19.7 to 28.8 °C, total rainfall was 228 mm, and average relative humidity varied between 79 and 84%.

The soil in the area was classified as an Oxisol soil (Soil Survey Staff, 2022) that corresponds to a Latossolo Vermelho-Amarelo in the Brazilian Soil Classification System (EMBRAPA, 2018). Despite being pedologically classified as dystrophic, the soil showed eutrophic behavior at the time of the experiment, with a V value above 50%, likely due to liming and phosphate fertilization carried out in previous years. In the same layer, the soil had 672 and 125 g kg^{-1}, respectively, of coarse and fine sand; silt and clay = 126 and 75 g kg^{-1}; density of soil and particles = 1.28 and 2.64 g cm^{-3}; total porosity = 0.41 m^3 m^{-3}. Initially, soil samples were collected at a depth of 0-20 cm for chemical and physical analysis attributes of the soil following the methodology proposed by Teixeira et al. (2017) (Table 1). Soil P (119.3 mg dm^{-3}) was above the critical level of 60 mg dm^{-3} for sweet potato (EMBRAPA, 2023).

Plowing and harrowing were performed, and the ridges of 30 cm height were manually made with hoes. The fertilization was carried out according to the soil fertility analysis, which consisted of 10 t ha^{-1} of bovine manure, 80 kg ha^{-1} of P_2O_5 (simple superphosphate - 20% P_2O_5, 20% Ca^{2+} and 12% S), 100 kg ha^{-1} of K_2O of potassium chloride (60% K_2O) at planting. As described in the experimental design, nitrogen doses in the form of urea (18% N; 22% S) were side-dressed, split into equal parts at 30 and 60 days after planting.

Sweet potato vine cuttings of the Campina cultivar were used, collected from a field (approximately 70 - 80 days after planting), near the experimental area. The vine cuttings were taken one day before planting to facilitate handling and sectioned into 40 cm length units. Each vine cutting contained, on average, eight internodes and was buried at a depth of 10 cm.

Manual weeding was carried out with hoes during the experiment to keep the area free of weeds. Irrigation was performed using a drip irrigation system composed of drip tapes with emitters spaced at 20 cm intervals and a nominal

Table 1. Chemical and physical attributes of the soil at a depth of 0-20 cm, used in the experiment before application of the treatments

Chemical attributes								
pH H_2O 1:2.5	OM (g dm^{-3})	P (mg dm^{-3})	K^+	Na^+	Ca^{2+}	Mg^{2+} (cmol$_c$ dm^{-3})	Al^{3+}	SB
4.93	9.3	119.3	67	0.04	2.5	0.75	0.20	1.02

Chemical attributes		Physical attributes					
CTC (cmol$_c$ dm^{-3})	V (%)	Particle-size fraction (g kg^{-1}) Fine Sand	Coarse Sand	Silt	Clay	Density (g dm^{-3})	Porosity (%)
4.44	70.03	125	672	126	77	1.28	52.6

pH - Hydrogen potential; OM - Organic Matter: P - Phosphorus, K^+ - Potassium; Na^+ - Sodium; Ca^{2+}- Calcium; Mg^{2+} - Magnesium; Al^{3+}- Aluminum; SB-Sum of bases; CTC- Cation exchange capacity; V - Base saturation

flow rate of 1.6 L h^{-1} per emitter. The system was operated with a two-day irrigation interval during periods without rainfall, and the water volume applied was adjusted based on crop needs and local evapotranspiration estimates, ensuring soil moisture remained near field capacity. Phytosanitary control was not performed since the plants did not show any symptoms of attack by pests or diseases.

The experiment was arranged in a randomized block design with split-split plots and four replicates. The main plots consisted of a factorial combination of five nitrogen doses (0, 60, 120, 180, and 240 kg ha^{-1}) and three plant spacings (0.30, 0.40, and 0.50 m), while the subplots comprised the number of vine cuttings per hole (one or two) (Sulnman et al., 2001; Oliveira et al., 2006ab), totaling 30 treatment combinations. Each experimental unit (subplot) consisted of four ridges, each 4.0 m long and spaced 0.80 m apart, for a total area of 12.8 m^2. All ridges in the subplot were used for data collection. The number of plants per hectare varied according to the plant spacing and the number of vine cuttings per hole, corresponding to 41,660, 31,250, and 25,000 plants ha^{-1} for spacings of 0.30, 0.40, and 0.50 m, respectively, when using one vine cutting per hole, and doubled when using two vine cuttings per hole.

The harvest occurred 75 days after planting. To determine leaf N content (g kg^{-1}), one leaf was collected from the middle third of ten plants within the functional area of each treatment (Tedesco et al., 1995). Starch content (%) was determined from 1.0 kg samples of commercial roots, randomly collected in each treatment and transported to the Biochemistry Laboratory of CCA/UFPB. The root pulp was extracted, homogenized, and subsequently analyzed according to the methodology described in the Analytical Standards of the Instituto Adolfo Lutz (IAL, 2005).

At 120 days after planting, the harvest was performed and the following variables were evaluated: mean mass of commercial roots (g per plant), production of roots (g per plant), total and commercial productivities of roots (t ha^{-1}), all determinations followed the methodology described by EMBRAPA (2023). Yield was determined from the central 8 m^2 of each subplot, excluding border rows. The mean mass of commercial roots was quantified by dividing the total root production per plot by the number of commercial roots. The production of commercial roots per plant was determined by weighing and counting all commercial roots and dividing the total weight by the number of evaluated plants. Total and commercial root productivities were obtained by weighing all harvested roots; commercial productivity was based on roots weighing between 80 and 400 g.

Data were submitted to analysis of variance and polynomial regression for nitrogen doses and spacing at $p \leq 0.05$ and $p \leq 0.01$ by F test. The vine cutting per hole was compared by F-test at $p \leq 0.05$. The SAS software (SAS, 2011) was used for the analysis.

Results and Discussion

The baseline application of 10 t ha^{-1} bovine manure provided approximately 70 kg N ha^{-1} equivalent, explaining why significant responses occurred only above 60 kg mineral N ha^{-1}. This baseline effect was consistent across all treatments and did not affect treatment comparisons.

The analysis of variance revealed that nitrogen doses had a significant effect ($p \leq 0.01$) on all yield and quality parameters, including the starch content, mass of commercial roots per plant, production of roots per plant, total yield, and commercial yield. However, nitrogen did not significantly affect the leaf nitrogen content.

Planting spacing significantly influenced ($p \leq 0.05$ or $p \leq 0.01$) all production variables and starch content, but not leaf N content. The variable number of vine cuttings per hole had a highly significant effect ($p \leq 0.01$) on all evaluated parameters, especially total and commercial yield, which showed the highest F-values, indicating a strong influence of this factor. Among the interactions, Nitrogen × Vine cutting per hole had a significant effect ($p < 0.01$) on all yield and quality parameters. In contrast, the N × S interaction was not significant for any of the evaluated characteristics. Spacing × Vine cutting per hole was significant for total and commercial yield. The triple interaction between nitrogen dose, plant spacing, and number of vine cuttings per hole (N × S × V) was significant for commercial yield and starch content ($p \leq 0.05$) (Table 2). This result indicates that the response of these variables to nitrogen fertilization depends on the specific combination of spacing and cutting density.

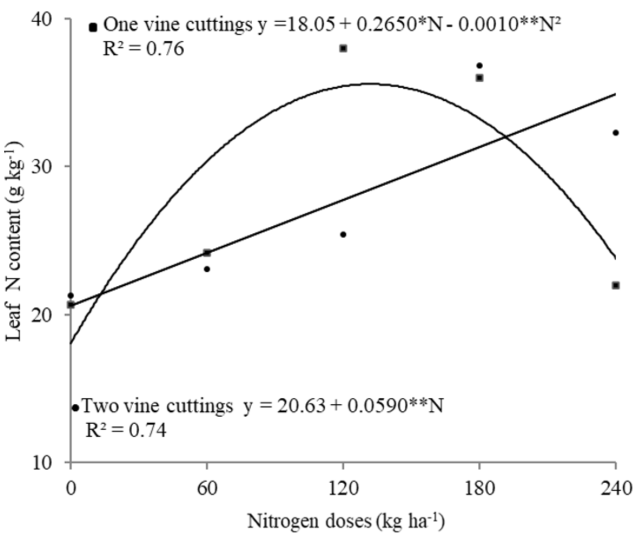
The coefficient of variation was relatively low for the yield-related traits, indicating good experimental precision, with values of 29.44% for total yield and 29.70% for commercial yield. The mean total yield was 31.06 t ha^{-1}, while the mean commercial yield was 24.16 t ha^{-1}. The mean starch content was 21.4%, with a CV of 2.42%, suggesting high experimental accuracy for this variable.

For leaf nitrogen content, an increase was observed with rising nitrogen doses (Figure 1). In treatments with one vine cutting per hole, the leaf N content increased from 18.05 to 35.6 g kg^{-1}, reaching this maximum value at an estimated nitrogen

Table 2. Summary of variance analysis for the traits observed in sweet potatoes as a function of nitrogen doses, spacing between plants and vine cuttings per hole

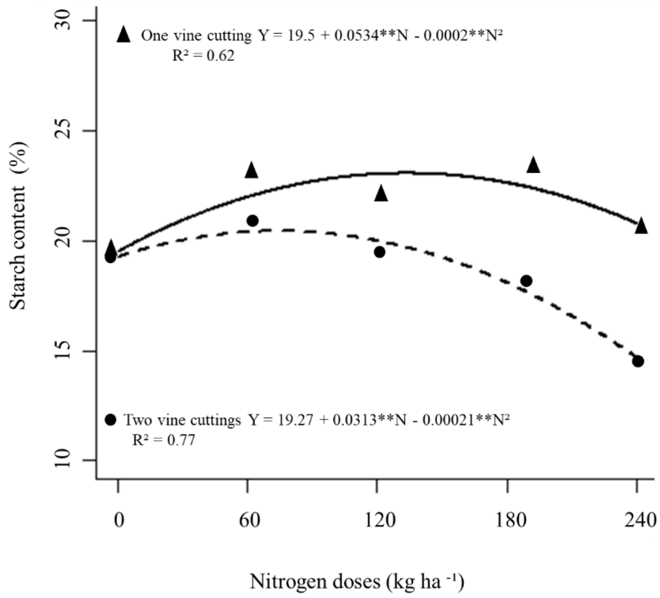
Source of variation	DF	LN	SC	MCR	PR	TY	CY
Nitrogen	4	16.6135ns	11.9514**	0.0399**	0.3465**	581.8714**	355.1397**
Spacings	2	21.6823ns	110.6367**	0.0146*	0.5320**	538.4969**	329.5083**
N × S	8	25.4321ns	26.1331ns	0.0088ns	0.0749ns	145.2938ns	88.8052ns
Error (a)	42	8.0351	0.2677	0.0044	0.0046	83.59	51.06
Vine cutting per hole	1	107.58*	36.4333**	0.0798**	3.2442**	5,727.0127**	3,498.2831**
N × V	4	31.026*	35.0861**	0.0084ns	0.0958*	125.8332*	76.9084*
S × V	2	27.7210ns	20.6214ns	0.0053ns	0.0644ns	202.6010*	123.8790*
N × S × V	8	5.4558ns	23.3928ns	0.0079ns	0.0666ns	105.3246*	64.3635*
Error (b)	45	9.9601	0.2626	0.0034	0.0026	48.74	29.73
CV(a)		11.97	2.42	31.29	28.31	29.44	29.70
CV(b)		13.32	2.56	28.84	21.22	22.48	22.57

* , ** - Significant at $p \leq 0.05$ and 0.01 respectively, and ns - Not significant by the F test. N - Nitrogen; S - Spacings; V - Vine cuttings; DF - Degrees of freedom; CV(a) - Coefficient of variation of the main plot; CV(b) - Coefficient of variation of the subplot; LN - Leaf N content; SC - Starch content; MCR - Mass of commercial root; PR - Production of roots per plant; TY - Total yield; CY - Commercial yield



N - Nitrogen Doses. *,** - Significant at $p \leq 0.05$ and 0.01 by F test

Figure 1. Leaf N content in sweet potato plants under nitrogen doses and with one (▪) and two (●) vine cuttings per hole



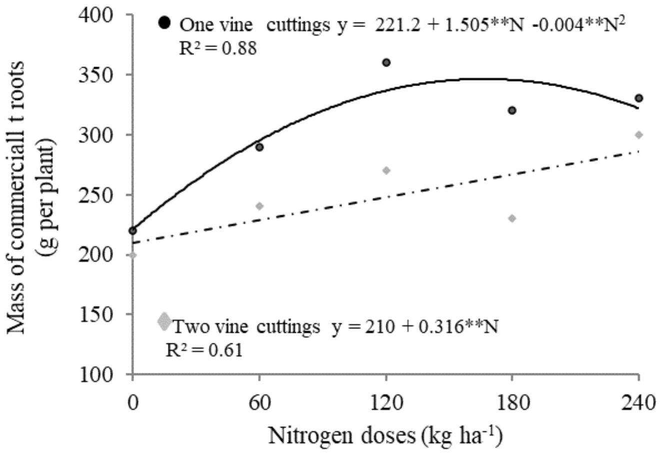
N - Nitrogen doses, ** - Significant at $p \leq 0.01$ or not significant by F test

Figure 2. Starch content in sweet potato plants under nitrogen doses and with one (▲) and two (●) vine cuttings per hole

dose of 133 kg ha^{-1}. With two vine cuttings per hole, a linear increase was also observed, ranging from 20.63 to 34.8 g kg^{-1}, when comparing unfertilized plants to those receiving the maximum nitrogen dose of 240 kg ha^{-1}. The relative increases were 97.2 and 68.7% for one and two vine cuttings per hole, respectively (Figure 1). Despite the linear behavior observed with two vine cuttings per hole, the highest tested nitrogen dose (240 kg ha^{-1}) did not lead to a plateau in leaf N content, suggesting that the maximum productive potential was not reached under this condition. In contrast, the dose of 133 kg ha^{-1} for one vine cutting per hole corresponded to a maximum estimated total yield of 36.74 t ha^{-1}. According to Rodrigues et al. (2024), the adequate range of leaf nitrogen content for sweet potato is between 33 and 45 g kg^{-1}, indicating that all treatments remained within or near this optimal range.

The starch content in sweet potato under the nitrogen doses and planting with one and two vine cuttings per hole was 25 and 23%, at doses of 125 and 142 kg ha^{-1} of nitrogen (Figure 2). This shows the greater efficiency of nitrogen accumulation in the roots. Similar results were reported by Oliveira et al. (2010), Duan et al. (2019), and Wu et al. (2022), who observed an increase in the starch content in sweet potatoes under nitrogen fertilization supplied in top-dressing. However, the percentages obtained in this study fall within the range reported in recent studies for this crop, where starch represents approximately 17.5% of the fresh weight of sweet potato roots (Leonel et al., 2021; Santos et al., 2023). In addition to the nitrogen fertilization, the starch increase was because sweet potatoes were harvested when they reached their physiological maturity at 110 days. Oliveira et al. (2010) and Silva et al. (2022) observed that maturity influences the starch content in the tuberous roots, with maximum accumulation occurring when the roots reach full maturity.

The production of commercial sweet potato roots responded to the increase in N with higher values with two vine cuttings per hole (Figure 3). However, the highest values were observed in the treatments or doses with one vine cutting per hole. For two vine cuttings, the highest value was 282 g at the rate of 240 kg ha^{-1} (Figure 3). Specifically, the treatment with one vine cutting per hole and the dose of 189 kg ha^{-1} of nitrogen resulted in the highest mean production of root mass with 362.76 g per plant. The addition of N above 188 kg N caused a slight decrease to 352 g in the mean mass of sweet



N- Nitrogen Doses. *,** - Significant at $p \leq 0.05$ and 0.01 by F test

Figure 3. Mass of commercial roots, under nitrogen doses, with one (●) and two (♦) vine cuttings per hole

potato roots, equivalent to 3.0% (Figure 3). Additionally, a linear increase from 210 to 285.84 g per plant was observed, increasing by 36.1% the production of commercial roots compared to plants that did not receive a nitrogen supply and those under the highest dose of this nutrient (Figure 3). For the commercialization of sweet potato tubers, the total root production is as important as the production of commercial roots, which must weigh more than 80 g per plant (Oliveira et al., 2022).

The results indicate that nitrogen fertilization, regardless of the number of vine cuttings per hole, increases the average mass of commercial sweet potato roots (Leonardo et al., 2014). It was observed that, in the absence of nitrogen application, the average root mass was around 200 g per plant (Figure 3).

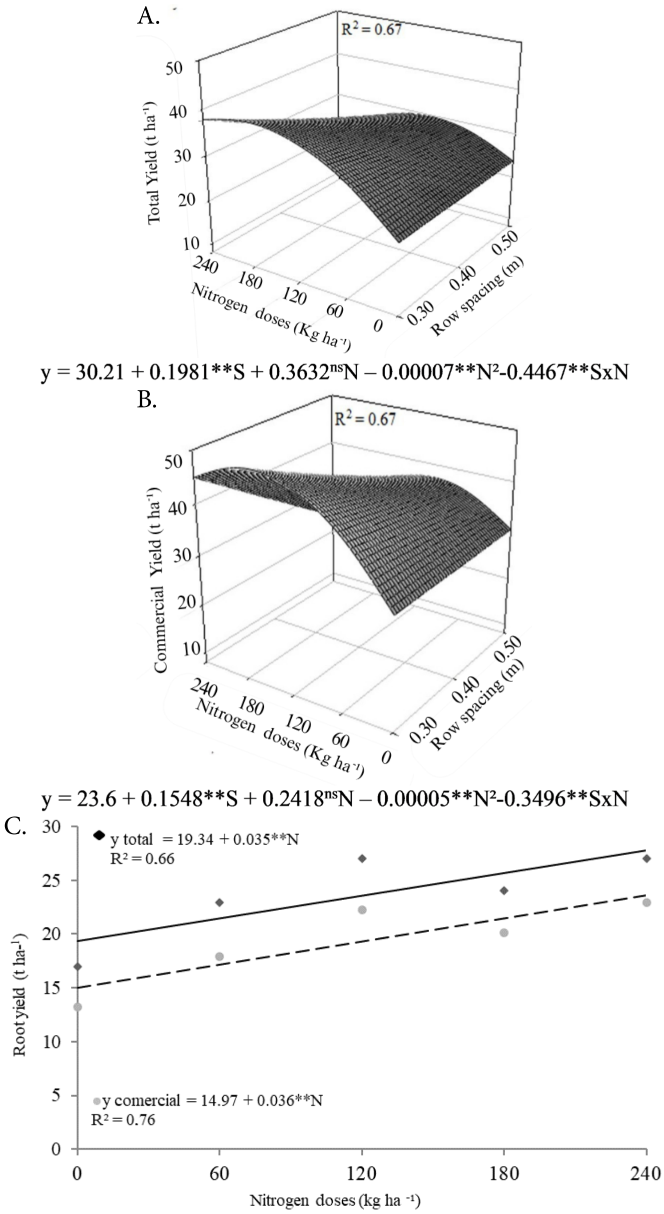
The production of commercial roots per plant responded to nitrogen doses and plant spacing, in both cultivation systems (with one or two vine cuttings per hole). However, the coefficients of determination (R^2) for the fitted models were below the threshold of 0.60 (one cutting $y = -0.14 + 2.244^{**}S + 0.008^{ns}N - 0.000^{**}N^2 - 0.009^{**}S \times N$, $R^2 = 0.57$ and two cuttings $y = -0.01 + 1.210^{*}S - 0.001^{**}N$, $R^2 = 0.58$). The highest individual production of roots per plant was 1.27 g per plant under the combination of one vine cutting per hole, in the 0.50 m spacing between plants, with an estimated nitrogen dose of 96 kg ha^{-1}. In the same spacing, in the treatment with two vine cuttings per hole, the highest value observed was 0.4 g per plant with an estimated nitrogen dose of 240 kg ha^{-1}.

Based on the results, the increase of one to two vine cuttings per hole in the planting resulted in two undesirable problems: an increase in nitrogen consumption by 150% and a loss of plant yield of 68.5%. Similar behavior was reported by Szarvas et al. (2019) when they found that the reduction in planting density increased the yield of sweet potatoes.

At the 0.30 m spacing between plants, the lowest production observed was 600 g per plant, regardless of whether one or two vine cuttings per hole were used, and occurred in the absence of nitrogen fertilization. It is known that when the plant density is increased, individuals compete for nutrients, water, and light (Szarvas et al., 2018). Therefore, when the space between plants is increased, there are gains in plant development and production.

The increase in sweet potato production under conditions of lower plant density may be a response to leaf expansion provided by nitrogen in the planting with one vine cutting per hole compared to cultivation with two vine cuttings per hole under no nitrogen fertilization, resulting in loss of root formation due to low levels of organic matter, phosphorus and potassium (Pushpalatha et al., 2018). The production of roots per plant was positively influenced by the plant spacing, probably due to less competition between plants influencing the size of the roots. On the other hand, plant density in sweet potatoes, above the ideal, negatively affects the production of roots (Oliveira et al., 2010).

The total and commercial yield of sweet potato roots responded to the interaction between plant spacing and nitrogen doses when one vine cutting per hole was planted (Figure 4). The highest total yield of 49 t ha^{-1} corresponded to



S - Spacing, N - Nitrogen doses, *,**,ns - Significant at $p \leq 0.05$ and 0.01 or not significant by F test

Figure 4. Total (A) and commercial yield (B) of sweet potato roots under nitrogen doses, spacing between plants with one vine cutting per hole; (C) Total ( ) and commercial (●) root yield of sweet potato, under nitrogen doses with two vine cuttings per hole

the combination of the 0.30 m spacing between plants fertilized with 168 kg ha^{-1} of nitrogen (Figure 4A). At the same planting density with 144 kg ha^{-1} of nitrogen fertilization, the maximum yield of commercial roots observed was 33.9 t ha^{-1} (Figure 4B). These results indicate that the nitrogen supplied adequately significantly increases the yield of sweet potatoes. Similarly, Freitas et al. (2023) also reported commercial sweet potato yields above the national average when one vine cutting per hole was used under nitrogen fertilization combined with green manure.

A yield decrease of commercial roots was verified in the nitrogen doses above 144 kg ha^{-1} (Figure 4B), which indicates that the excess of nitrogen fertilization negatively affected the formation of commercial roots, possibly due to the high green mass production and formation of adventitious roots (Joko et al., 2024). Additionally, there may have been a toxic effect of ammonium and a low nitrification rate or the indirect effect of ammonium in reducing the absorption of K^+, Ca^{+2}, and Mg^{+2} by the plants.

When only two vine cuttings per hole were considered relative to plant spacing and different nitrogen doses, the data did not fit any regression model. However, when considering only nitrogen doses with two vine cuttings per hole, total and commercial root yields showed a linear regression adjustment, increased linearly with the nitrogen doses 19.34 to 27.74 t ha^{-1} and from 14.97 to 23.61 t ha^{-1}, respectively (Figure 4C). This represents increments of 43.4 and 58.5% between plants without nitrogen and with the maximum of the fertilizer dose. The commercial yield exceeded the national average of 14.55 t ha^{-1} (IBGE, 2023).

Based on the results shown in Figures 5A, B, and C, the estimated coefficients between total and commercial yields with one and two vine cuttings per hole indicate gains of 76.6 and 43.6%, respectively. When comparing commercial and total yields, losses of 30.8 and 14.9% of the total yield were observed for one and two vine cuttings per hole, respectively. The higher yields observed with one vine cutting per hole are attributed to reduced competition for water, light, nutrients, and air circulation, which results in greater productive efficiency of sweet potato plants. These results highlight the importance of proper plant spatial arrangement as a key factor for maximizing commercial root yield and minimizing total yield losses (Liang et al., 2023).

The balance between essential elements is more important in the yield increase than high dosages of nitrogen alone (Jiang et al., 2017), and the nitrogen is essential for promoting plant growth (Guo et al. 2020), increasing the yield and nutritional composition of the root in sweet potato (Kumar et al., 2023). Therefore, an efficient planting arrangement combined with moderate nitrogen fertilization emerges as a key strategy to optimize sweet potato production, supporting sustainable and regionally adapted agricultural practices.

Conclusions

1. Nitrogen fertilization significantly increased sweet potato productivity, with optimal doses of 168 kg ha^{-1} for total yield (49 t ha^{-1}) and 144 kg ha^{-1} for commercial yield (33.9 t ha^{-1}), representing 237 and 133% increases above unfertilized controls, respectively.

2. Single vine cutting per hole outperformed double cuttings by 43.6%, demonstrating superior nitrogen use efficiency and reduced competition effects under optimal spacing of 0.30 m.

3. Starch content reached maximum values of 25% at 125 kg N ha^{-1} in single-cutting systems, indicating efficient carbohydrate partitioning to storage roots.

4. For commercial production in Northeastern Brazil, 144 kg N ha^{-1} with 0.30 m spacing and single vine cuttings provides optimal economic returns while maintaining sustainability under baseline organic matter applications.

Contribution of authors: A. K. H. Bezerra: conceptualization of the research, methodology, data acquisition, data analysis, manuscript writing, and literature review. N. F. F. Nascimento, A. P. Oliveira, E. U. Alves, and R. R. Rolim: data analysis, research conceptualization and supervision, and manuscript editing. K. B. Silva, J. M. F. L. Cruz, and A. L. L. Souza: assisted in conducting the experiments and contributed to manuscript editing.

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