

# Planting material and irrigation regimes in cassava root and cutting production

## Material de plantio e regimes de irrigação na produção de raízes e manivas de mandioca

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### ABSTRACT

The quality of planting material plays a key role in the sustainability and profitability of cassava cultivation. This study evaluated how different planting materials and supplemental irrigation affect cassava growth, yield, and the quality of harvested cuttings. The experiment took place at the State University of Southwest Bahia, in Vitória da Conquista from March 2024 to March 2025. We used a randomized block design in a split-plot arrangement with three replications. Irrigation (with and without) was the main plot treatment, and the subplot treatment was the type of planting material (conventional cuttings, micropropagated plantlets, and mini-cuttings derived from etiolated plantlets). Irrigation increased plant height by 37% and tuberous root yield by 70%. The type of planting material had no significant effect on root yield, but it did influence stems characteristics and cutting quality. Under irrigation, plantlets and mini-cuttings produced plants with thicker stems, whereas conventional cuttings produced more stems. Irrigated cuttings had more buds but lower dry matter content. Plants grown from plantlets and mini-cuttings had greater weight and diameter compared to those from conventional cuttings. In conclusion, irrigation increased cassava root yield, and modern planting materials such as plantlets and mini-cuttings improve the quality of cuttings for future propagation.

**Index terms:** *Manihot esculenta* Crantz; vegetative propagation; water stress; micropropagated plantlets; productivity.

### RESUMO

A qualidade do material de plantio desempenha um papel fundamental na sustentabilidade e rentabilidade do cultivo da mandioca. Este estudo avaliou como diferentes materiais de plantio e a irrigação suplementar afetam o crescimento, produtividade e a qualidade das manivas colhidas. O experimento foi conduzido na Universidade Estadual do Sudoeste da Bahia, em Vitória da Conquista, de março de 2024 a março de 2025. Utilizamos um delineamento em blocos ao acaso em esquema de parcelas subdivididas com três repetições. A irrigação (com e sem) foi o tratamento da parcela principal e o tipo de material de plantio (manivas convencionais, mudas derivadas de micropropagação in vitro e miniestacas derivadas de mudas estioladas) foi o tratamento das subparcelas. A irrigação aumentou a altura das plantas em 37% e o rendimento de raízes tuberosas em 70%. O tipo de material de plantio não teve efeito significativo sobre a produtividade de raízes, mas influenciou as características do caule e a qualidade das manivas. Sob irrigação, mudas e miniestacas produziram plantas com caule mais grossos, enquanto as manivas convencionais resultaram em maior número de hastes. As manivas obtidas de plantas irrigadas apresentaram maior número de gemas, porém menor teor de matéria seca. Plantas oriundas de mudas e miniestacas produziram tiveram maior massa e diâmetro em comparação às provenientes de manivas convencionais. Em conclusão, a irrigação aumentou o rendimento de raízes de mandioca e materiais de plantio modernos, como mudas micropropagadas e miniestacas, melhoraram a qualidade das manivas para propagação futura.

**Termos para indexação:** *Manihot esculenta* Crantz; propagação vegetativa; estresse hídrico; mudas micropropagadas; produtividade.

## Introduction

Cassava (*Manihot esculenta* Crantz) is a major food source for over 800 million people, especially in tropical regions where it serves as an affordable source of energy (Sessou et al., 2020). Domesticated in Brazil, cassava holds strong cultural and social significance in the country. It is cultivated in nearly all regions and supports the livelihoods of smallholder farmers while being deeply rooted in the food culture of many ethnic groups (Maciel et al., 2024). Beyond human consumption, cassava is used for animal feed and as a raw material in the food industry (flour, starch, tapioca), bioenergy (ethanol), and cellulose production, reflecting its wide economic importance (Lobo, Santos Júnior, & Nunes, 2018).

Despite its potential, the average cassava yield in Brazil is 14.70 t ha<sup>-1</sup>, far below the 27.50 t ha<sup>-1</sup> achieved by improved varieties in a single annual cycle (Oliveira et al., 2022). This low productivity is attributed to several limiting factors, including cultivation in lowfertility soils, inadequate management, and, above all, the use of

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low-quality planting material and dependence on rainfed systems, especially in semi-arid regions (Rivera et al., 2021; Conceição et al., 2023; Rodriguez-Sandoval, Mejia-Villota, & Hernández, 2025).

One of the main bottlenecks in the cassava production is the low vegetative multiplication rate, which ranges from 1:5 to 1:10 using conventional stem cuttings (Souza, Fialho, & Oliveira, 2010). This limits the adoption of new cultivars that are more productive and disease-resistant. Farmers often use propagation material with poor phytosanitary and physiological quality, a problem recognized by both researchers and producers (Barandica et al., 2016; Schoffel et al., 2023). The spread of systemic diseases through vegetative propagation is one of the greatest threats to cassava cultivation. Cassava Witches' Broom Disease (*Ceratobasidium theobromae*) is a prominent example. This disease is spreading in several producing regions, mainly through infected cuttings. Factors such as geographical location, socioeconomic conditions (Delaquis et al., 2024), education level (Nguezet et al., 2025), and access to information (Msami et al., 2025) influence farmers' ability to obtain high-quality planting material.

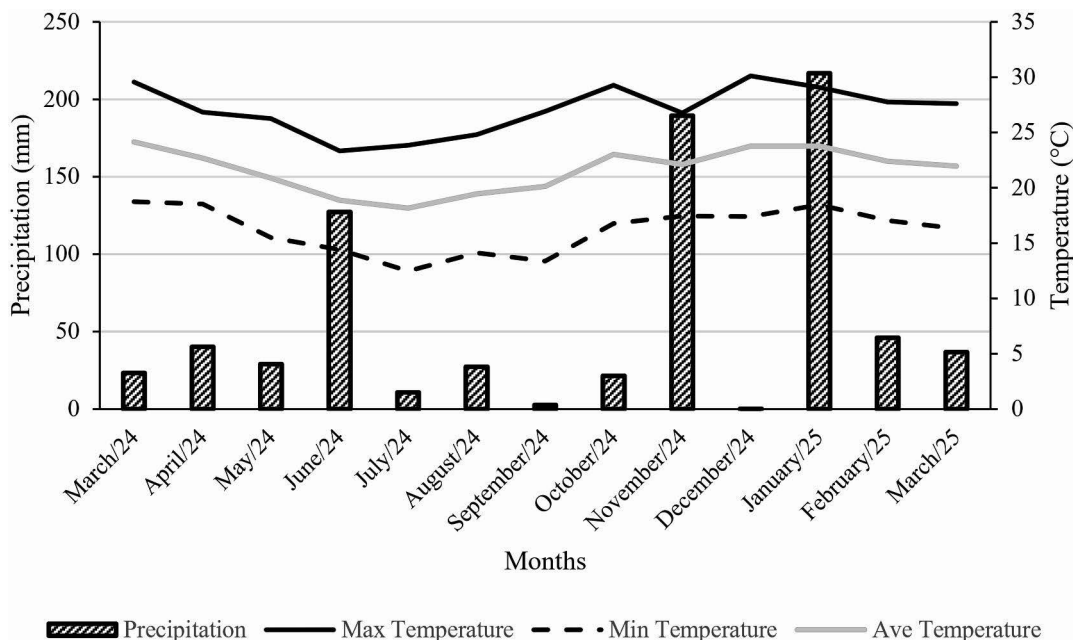
To overcome these barriers, techniques like leaf bud cuttings (Meibuko, Mtui, & Baltazari, 2025; Neves, Souza, & Oliveira, 2019), micropropagated plantlets, woody mini-cuttings (NurulNahar & Tan, 2012), and herbaceous cuttings (Otoo, 1994) offer strategic alternatives. These methods enable large-scale production of planting material with high sanitary quality, vigor, and uniformity (Seka et al., 2025). The initial plant vigor depends on the reserve potential of the cuttings, which in turn is influenced by the nutrition of the mother plant (Molina

& El-Sharkawy, 1995). Water availability is one of the main factors affecting cassava growth, especially in the early stages (El-Sharkawy & Cadavid, 2002), and the planting position also influences initial development (Mbise, Sibuga, & Mtui, 2024).

Although the individual effects of irrigation and the type of planting material are known, how these factors interact is still poorly understood. This study aimed to evaluate the combined effects of irrigation and types of planting material on cassava agronomic traits and on the quantitative and qualitative aspects of the resulting propagation material.

## Material and Methods

The field experiment was conducted from March 2024 to March 2025 at the experimental area of the State University of Southwest Bahia (UESB), in Vitória da Conquista, Bahia, Brazil. The city is located in the southwestern region of the state at 14°51' 58" S and 40°50' 22" W, with an average altitude of 941 m. According to the Köppen classification, the climate is Cwb (highland tropical), with an average annual precipitation of 717 mm, mostly between November and March. The average annual temperature is 19.6°C, with average maximum and minimum temperatures of 23.5°C and 15.1°C, respectively. The local vegetation is classified as Montane Semideciduous Seasonal Forest, also known as "Mata de Cipó" (SEI, 2023). Meteorological data were recorded by the National Institute of Meteorology (INMET)-UESB weather station during the experiment and are shown in Figure 1.



**Figure 1:** Monthly averages of rainfall and maximum, minimum, and mean temperatures during the experimental period (March 2024 to March 2025) in Vitória da Conquista, Bahia, Brazil.

The soil at the experimental site was classified as a Dystrophic Yellow Latosol. For chemical characterization, a composite sample was collected from the 0-20 cm soil layer that showed the following properties: pH (H<sub>2</sub>O) = 5.8; P = 18 mg dm<sup>-3</sup> (Mehlich<sup>-1</sup>); K<sup>+</sup> = 0.2 cmolc dm<sup>-3</sup> (Mehlich<sup>-1</sup>); Ca<sup>2+</sup> = 1.6 cmolc dm<sup>-3</sup>; Mg<sup>2+</sup> = 0.7 cmolc dm<sup>-3</sup>; Al<sup>3+</sup> = 0.2 cmolc dm<sup>-3</sup>; H<sup>+</sup> + Al<sup>3+</sup> = 2.3 cmolc dm<sup>-3</sup>; Sum of Bases (SB) = 2.5 cmolc dm<sup>-3</sup>; Cation Exchange Capacity (CEC) at pH 7.0 = 4.8 cmolc dm<sup>-3</sup>; Base Saturation (V%) = 52%; and Organic Matter (O.M.) = 16 g dm<sup>-3</sup>.

The cassava variety ‘Sergipe’ was used in this study. It is known in the southwest region of Bahia for its hardiness and high dry matter content, although recent reports indicate a decline in its vigor (Guimarães et al., 2017; Soares et al., 2016; Moreira et al., 2017; Prates et al., 2019). Three types of planting material were evaluated:

1. Conventional cuttings (manivas): 20 cm long, with 7 to 10 healthy buds, sourced from Fecularia Conquista in Vitória da Conquista, Bahia.
2. Micropropagated plantlets: Supplied by the Biofactory Institute of Bahia, in Ilhéus.
3. Mini-cuttings: 15 cm long, 0.7 to 1.0 cm in diameter, with 3 to 4 buds, obtained from etiolated micropropagated plantlets, also supplied by the Biofactory Institute of Bahia.

The experiment followed a randomized block design in a split-plot arrangement with four replications. The main plots consisted of two water regimes (irrigated and rainfed), and the subplots included three types of planting material (conventional cuttings, micropropagated plantlets, and mini-cuttings).

Soil preparation consisted of plowing and harrowing. Planting was carried out on March 14, 2024, with a spacing of 1.0 m between rows and 0.60 m between plants. Cuttings were planted horizontally, while plantlets and mini-cuttings were planted vertically. At planting, 10 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub> was applied as single superphosphate, and 10 kg ha<sup>-1</sup> of K<sub>2</sub>O as potassium chloride. Topdressing was performed with 30 kg ha<sup>-1</sup> of nitrogen at 60 and 120 days after planting, using urea (Borges et al., 2021).

Each experimental plot consisted of six rows with 13 plants, totaling 45 m<sup>2</sup>. The harvested area was the central row, which contained 11 plants (6.6 m<sup>2</sup>). In the irrigated plots, a drip irrigation system was installed, with emitters delivering 2.2 L h<sup>-1</sup>, operating twice daily. Weed control was performed manually.

Harvesting was carried out 12 months after planting. The following variables were evaluated: a) Growth and architecture: Plant height (m), stem diameter at 20 cm above ground level (mm), number of shoots, number of branches, height of the first branch (cm), and leaf area (cm<sup>2</sup>).

b) Productivity: Final number of plants, shoot biomass yield (t ha<sup>-1</sup>), and root yield (t ha<sup>-1</sup>).

c) Root quality: Dry matter content (%).

d) Quality of propagation material: Number of cuttings per plant, cutting diameter (cm), pith diameter (cm), number of buds per cutting, fresh mass weight (g), and dry mass weight (g).

The data were subjected to analysis of variance (ANOVA). Means of the irrigation treatments were compared using the F-test, while means of planting material types and interaction effects were compared using the Tukey test at 5% probability (SAEG, version 9.1).

## Results and Discussion

During the experimental period (March 2024 to March 2025), total precipitation was 769 mm, with irregular distribution. Periods of water deficit occurred, highlighting the importance of supplemental irrigation. Average temperatures remained around 21.6°C, which is considered adequate for cassava growth (INMET-UESB, 2025).

A significant interaction ( $p < 0.05$ ) was found between irrigation and planting material for stem diameter at 20 cm above ground (D20) and the number of stems per plant (NS) (Table 1). This indicates that shoot morphological responses to water availability depended on the type of propagation material.

**Table 1:** Summary of the analysis of variance for number of plants per hectare (NPH), stem diameter at 20 cm above ground (D20), number of stems per plant (NS), number of branches per plant (NB), and height of the first branch (HFB) as affected by water regimes and types of planting material. Vitória da Conquista, Bahia, 2025.

Source of Variation	df	NPH	D20	NS	NB	HFB
Irrigation (I)	1	43,421.98	559.60*	0.003	8.461	4331.98
Blocks	3	13,309.77	2.60	0.107	1.135	515.39
Residue (a)	3	10,586.79	8.71	0.030	2.406	979.75
Planting material (PM)	2	24,040.68	9.02	2.503*	3.284	475.84
I x PM	2	10,589.18	88.26*	0.956*	0.758	75.29
Residue (b)	12	9,229.90	19.13	0.055	1.476	475.04
CV % I		25.68	11.10	10.66	67.37	104.27
CV % PM		23.98	16.46	14.41	52.77	72.61

\*Statistical differences (F-test,  $p < 0.05$ ) are indicated by an asterisk.

When the interaction for stem diameter was analyzed (Table 2), irrigated plants from plantlets and mini-cuttings showed significantly larger stem diameters than those under rainfed conditions. In contrast, plants from conventional cuttings showed no difference between water regimes. These results suggest that planting materials with higher physiological quality, such as plantlets and mini-cuttings, are better able to convert increased water availability into stem growth. Irrigation helps maintain cell turgor, which drives cell expansion and division, key processes that contribute directly to stem thickening (Larcher, 2003; Taiz et al., 2017). The lack of response in plants from conventional cuttings may indicate that, under adequate moisture, photoassimilates were allocated to other growth processes rather than stem development.

**Table 2:** Stem diameter (mm) at 20 cm above ground in cassava plants from different types of planting material grown under irrigation and rainfed conditions.

Irrigation	Plantlets	Mini-cuttings	Conventional Cuttings
With	31.39 Aa	35.22 Aa	27.59 Aa
Without	23.76 Ba	18.15 Ba	23.33 Aa

Statistical differences (F-test,  $p < 0.05$ ) are indicated by letters: uppercase letters compare columns, and lowercase letters compare rows.

The interaction analysis for the number of stems per plant showed an opposite pattern to that observed for stem diameter (Table 3). Under irrigation, plants from conventional cuttings produced the highest number of stems (2.62), significantly more than those from plantlets and mini-cuttings. This suggests distinct resource allocation strategies. Cuttings, which have multiple buds along their length, respond to favorable moisture by activating more growth points, resulting in a multi-stem architecture. In contrast, plantlets and mini-cuttings, which develop from a single apical bud, tend to allocate resources toward reserve accumulation and thickening of the main stem, as previously shown in Table 2. Under rainfed conditions, the number of stems did not significantly vary among planting materials. When each planting material was evaluated separately, we observed contrasting responses to irrigation. Irrigated plants from conventional cuttings produced a higher number of stems, while those from micro-cuttings produced fewer. Plants from plantlets maintained a consistent number of stems under both water regimes.

The analysis of variance revealed a significant effect of irrigation ( $p < 0.05$ ) on plant height (PH), total leaf area (TLA), and tuberous root yield (RY) (Table 4). In contrast, the type of planting material had no significant effect on any of these variables, indicating that all propagation materials performed similarly under the conditions of this study. It should be noted, however, that micropropagated plantlets and mini-cuttings were specifically developed for producing high-quality planting material. Their use provides vigorous, pathogen-free plants for subsequent cycles, helping to reduce losses from pests and

diseases. Furthermore, these materials allow for faster, large-scale multiplication and more efficient logistics.

**Table 3:** Number of stems per cassava plant from different types of planting material grown under irrigation and rainfed conditions

Irrigation	Plantlets	Mini-cuttings	Conventional Cuttings
With	1.12 Ab	1.19 Bb	2.62 Aa
Without	1.19 Aa	1.81 Aa	1.88 Ba

Statistical differences (F-test,  $p < 0.05$ ) are indicated by letters: uppercase letters compare columns, and lowercase letters compare rows.

The comparison of means (Table 5) highlights the positive effect of irrigation on cassava performance. On average, irrigated plants were 37% taller and had nearly twice the total leaf area compared to rainfed plants. The most expressive effect was on root yield, which increased by 70% (from 8.50 t ha<sup>-1</sup> under rainfed conditions, a value close to the municipal average of 9.37 t ha<sup>-1</sup> (Instituto Brasileiro de Geografia e Estatística - IBGE, 2025), to 14.47 t ha<sup>-1</sup> with irrigation). These results indicate that, although cassava is drought-tolerant, water restriction remains a major factor limiting productivity in semi-arid regions like Southwest Bahia. Greater water availability enhances key physiological processes, such as photosynthesis, by sustaining high stomatal conductance. This, in turn, increases the production and translocation of photoassimilates to the roots, the main sink organ (Alves & Setter, 2004; Silva et al., 2021). Similar productivity gains of 50% to 167% with irrigation have been reported in other studies (Silva et al., 2022; Silva et al., 2023).

The quality of the cuttings produced was influenced by both irrigation and the type of planting material (Table 6). Irrigation significantly affected the number of buds per cutting (NBC) and dry matter content (DM). The type of planting material also influenced NBC, as well as pith diameter (PD), cutting diameter (CD), fresh mass weight (FMW), and the dry matter content (DM).

Cuttings harvested from irrigated plants had a higher average number of buds (13.57) compared to those from rainfed plants (11.80) (Table 7). The number of viable buds is an important indicator of the quality of the planting material, as it is directly related to sprouting potential and stand establishment (Neves, Souza, & Oliveira, 2020). The more vigorous vegetative growth promoted by irrigation results in more developed stems with a greater number of nodes, where buds are located. However, these same cuttings had lower dry matter content (21.85%) than those from rainfed plants (23.53%). This suggests that the rapid, continuous growth under irrigation leads to more hydrated, less lignified tissues, with lower concentrations of solutes and carbohydrate reserves per unit of mass, a phenomenon known as the “dilution effect” (El-Sharkawy, 2004). Although cuttings from irrigated plants are superior in quantity (more buds), they may be qualitatively more sensitive to storage and adverse planting conditions due to their reduced energy reserves.

**Table 4:** Summary of the analysis of variance for plant height (PH), shoot biomass yield (SY), total leaf area (TLA), dry matter content of tuberous roots (DMC), and root yield (RY).

Source of Variation	df	PH	SY	TLA	DMC	RY
Irrigation (I)	1	1.972*	615.37	14.594*	17.826	213.69*
Blocks	3	0.108	38.82	815.054	17.826	25.89
Residue (a)	3	0.043	168.27	816.073	4.369	16.13
Planting material (PM)	2	0.190	69.43	349.028	0.867	32.84
I x PM	2	0.040	114.96	156.705	6.982	22.15
Residue (b)	12	0.061	47.60	665.706	3.136	10.72
CV % I		11.46	55.97	17.14	7.17	34.97
CV % PM		13.67	29.77	35.86	6.07	28.51

\*Statistical differences (F-test,  $p < 0.05$ ) are indicated by an asterisk.

**Table 5:** Means of plant height (PH), total leaf area (TLA), root yield (RY), dry matter content of tuberous roots (DMC), and shoot biomass yield (SY) in cassava as affected by irrigation.

Irrigation	PH (m)	TLA (cm <sup>2</sup> )	RY (t.ha <sup>-1</sup> )	DMC (%)	SY (t.ha <sup>-1</sup> )
With	2.10 a	31.450 a	14.47 a	30.01 a	26.57 a
Without	1.53 b	15.860 b	8.50 b	28.29 a	18.29 a

\*Statistical differences (F-test,  $p < 0.05$ ) in each column are indicated by letters.

**Table 6:** Summary of the analysis of variance for quality characteristics of harvested cuttings: number of cuttings per plant (NC), number of buds per cutting (NBC), pith diameter (PD), cutting diameter (CD), fresh mass weight (FMW), and dry matter content (DM).

Source of Variation	df	NC	NBC	PD	CD	FMW	DM
Irrigation (I)	1	0.893	22.815*	0.0376	0.072	94.96	11.070*
Block	3	0.695	1.429	0.0273	0.189	666.28	1.306
Residue (a)	3	0.300	0.616	0.0216	0.111	767.26	2.013
Planting material (PM)	2	4.459	8.175*	0.061*	0.438*	3855.7*	8.338*
I x PM	2	1.359	3.684	0.018	0.057	1064.29	2.975
Residue (b)	12	1.313	1.536	0.014	0.096	736.84	2.091
CV % I		54.43	6.21	21.97	16.34	26.27	1.84
CV % PM		91.92	9.80	17.80	15.22	25.75	1.87

\*Statistical differences (F-test,  $p < 0.05$ ) are indicated by an asterisk.

The quality of the harvested cuttings (Table 8) varied according to the type of planting material. Cuttings from plants grown from plantlets and mini-cuttings were significantly heavier (both fresh and dry mass) and had a larger stem and pith diameter than those from plants grown from conventional cuttings. Cutting diameter is a key trait, as it correlates with the amount of nutrient and water reserves available to support sprouting and early plant development (Fialho, Vieira, & Paula-Moraes, 2000; Souza, Williams, & Williams, 2006). Investing in high-quality propagation material (such as pathogen-free, vigorous plantlets and mini-cuttings), leads to the production of a subsequent generation of superior quality conventional cuttings. This is particularly important in the context of witches'

broom disease. The main advantage of using micropropagated plantlets and mini-cuttings is not their potential to achieve yields comparable to conventional systems within a single cycle, as shown in this study, but also their role in breaking the disease cycle. Starting the cultivation with healthy material allows producers to establish a robust crop and harvest disease-free cuttings for future use. This creates a sustainable multiplication system for high-phytosanitary-quality material. As such, this strategy is the most effective for revitalizing areas affected by systemic diseases like witches' broom and for ensuring long-term production sustainability. It offers a viable alternative to conventional cuttings from unknown origin, which are often the main vector of disease spread.

**Table 7:** Means of number of buds per cutting (NBC) and dry matter content (DM) of cassava cuttings under irrigated and rainfed conditions.

Irrigation	NBC	DM (%)
With	13.57 a	21.85 b
Without	11.80 b	23.53 a

\*Statistical differences (F-test,  $p < 0.05$ ) in each column are indicated by letters.

**Table 8:** Characteristics of cassava cuttings as affected by the type of planting material: fresh mass weight (FMW), dry mass weight (DMW), cutting diameter (CD), pith diameter (PD), number of buds per cutting (NBC), and percentage of dry mass (DM).

Planting material	FMW (g)	DMW (g)	CD (cm)	PD (cm)	NBC	DM (%)
Seedlings	119.42 a	27.72 a	2.24 a	0.74 a	13.8 a	23.38 a
Mini-cuttings	116.76 a	26.94 a	2.10 ab	0.70 ab	12.19 ab	23.07 ab
Cuttings	80.13 b	17.33 b	1.79 b	0.57 b	11.94 b	21.60 b

\*Statistical differences (F-test,  $p < 0.05$ ) in each column are indicated by letters.

## Conclusions

Irrigation increased cassava root yield by 70% in the Southwest region of Bahia and improved the quality of the propagation material. Although final yields were similar across planting materials, micropropagated plantlets and mini-cuttings under irrigation produced cuttings with greater mass and diameter. This approach supports phytosanitary management by mitigating the spread of pathogens and contributes to the long-term sustainability of cassava cultivation. Continued monitoring of second- and third-generation cuttings is recommended to validate yields under rainfed conditions in commercial fields.

## Author contributions

Conceptual idea: Viana, A. E. S.; Rocha, H. S; Methodology design: Viana, A. E. S, Siteo, A. R. N.; Data collection: Siteo, A. R. N; Data analysis and interpretation: Cruz, P. G.; and Writing and editing: Viana, A. E. S.; Matsumoto, S. N.; Silveira, H. F.

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## Data availability statement

Data available upon request to authors.

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