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Effects of Stem Cuttings and Growing Media on Vegetative Growth of Cassava *(Manihot esculenta Crantz)*

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Abstract. Cassava (*Manihot esculenta* Crantz) leaves are widely utilized as a leafy vegetable due to their high protein and bioactive compound content. However, information regarding suitable planting materials and planting media composition for optimizing cassava leaf production is still limited. This study aimed to determine the appropriate planting material and planting media composition to improve the growth and yield of cassava leaf shoots. The experiment was conducted from July-August 2024 at the Experimental Field, Faculty of Agriculture, Universitas Sriwijaya. This study used a factorial Randomized Block Design consisting of two factors: planting material (three levels: upper stem, middle stem, and lower stem) and planting media composition (three levels: soil, soil + cattle manure, and soil + goat manure). Each treatment combination was replicated 3 times, and each experimental unit consisted of 3 plants, resulting in 9 treatment combinations × 3 replications × 3 plants per unit, for a total of 81 plants in the experiment. The results showed that the use of middle-stem cuttings combined with soil + cattle manure resulted in higher sprout growth, number of leaves, SPAD index, and leaf-shoot harvest compared to other treatments. Regular leaf shoot pruning increases the number of edible leaf shoots. The selection of planting material with the right composition of planting medium can sustainably increase the productivity of leafy vegetables in cassava.

Keywords: manure; maturity; perennial vegetable; shoots; stem cuttings

1. Introduction

Cassava *(Manihot esculenta Crantz)* is one of important crops that are widely cultivated in tropical and subtropical regions around the world (Harlina et al., 2023). Leaves of cassava are increasingly utilized as a leafy vegetable due to their high protein content 20-27% and bioactive compounds such as flavonoid and saponins, which have anti-inflammatory and antibacterial properties (Mohidin et al., 2023; Riyanti & Nur Aini, 2022). Cassava leaves are widely consumed in many tropical regions and represent a potential alternative vegetable source (Lakitan et al., 2023). However, cassava tubers are a source of carbohydrates for food and feed (Krajang et al., 2021) and are also used as raw materials for agroindustry (Zoungranan et al., 2020). Ravi et al. (2021) noted that cassava serves as a staple food source for more than 800 million people worldwide. Cassava has important prospects as a substitute for staple foods, so its production needs to be increased (Harlina et al., 2023). In addition, cassava leaf production has gained attention as an alternative vegetable source. Despite this potential, research on optimizing cassava leaf production, particularly through appropriate planting materials and planting media composition to optimize leaf shoot production remains limited.

Cassava is commonly propagated vegetatively using stem cutting to maintain genetic uniformity and ensure rapid establishment (Gustiar et al., 2024; Susiyanti et al., 2022). This method is widely applied in cassava cultivation for tuber production. However, for a leaf-oriented production system, the selection of cutting source (upper, middle, or lower stem) becomes more critical, as it may influence sprouting capacity and

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leaf biomass rather than root yield. Cuttings guarantee the purity of planting material with more uniform plant growth, sturdy roots and faster production time compared to generative propagation (Simanjuntak & Wardani, 2021). The upper, middle, and lower stems can be used as cutting material (Pakpahan et al., 2021). Differences in stem position may influence carbohydrate reserves and physiological maturity, which subsequently affect sprouting ability and early plant growth

Previous studies have shown that the success of plant cuttings is supported by several factors such as physiological age, environment (including sunlight, humidity, and temperature), planting medium (Sandhya et al., 2022) and availability of nutrients (Fauza et al., 2016). Organic fertilizers such as cattle and goat manure have been reported to improve soil fertility and plant growth due to their nutrient content and ability to enhance soil physical and biological properties. However, most studies have evaluated these factors separately, with limited attention to their combined effects on cassava leaf production. In particular, comparative information on the interaction between cutting position and organic based planting media for optimizing leaf shoot yield is still lacking. Organic fertilizers that are easy to obtain are cattle and goat manure. The nutritional content of cattle manure is 0.24% N, 0.09% P, and 0.35% K (Barłóg et al., 2020). Goat manure contains 1.34% N, 0.54% P2O5, 3.67% K2O, and 31% organic matter (Batubara et al., 2021). The high nitrogen content of manure plays an important role in the vegetative growth of plants (Dewi, 2018; Hali & Telan, 2018). In this study, a soil–manure ratio of 4:1 was selected because this proportion has been reported to provide sufficient organic matter while maintaining adequate soil structure and aeration for root development in vegetative propagation systems.

In addition, basal NPK fertilizer was applied uniformly to all treatments to ensure that differences in plant growth were primarily influenced by planting material and planting media composition rather than by unequal nutrient supply. Therefore, this study was aimed to evaluate the effect of different sources of planting material and planting media compositions on the growth and yield of cassava leaf shoots, rather than tuber yield.

2. Materials and Methods

This research was conducted at the Experimental Field of the Faculty of Agriculture, Sriwijaya University (104°39′7′′E; 3°12′57′′S), North Indralaya District, Ogan Ilir Regency, South Sumatra, Indonesia, with a maximum temperature of ± 32.4°C and a relative humidity of ± 83°C (BMKG Agroclimatology Station South Sumatra). The research was carried out from July to August 2024. This period corresponds to the dry season in South Sumatra, which is characterized by relatively stable rainfall, adequate solar radiation, and moderate humidity that support sprouting and early vegetative growth of cassava cuttings while minimizing excessive soil moisture that may inhibit root establishment.

Planting media on each polybag (35 x 40 cm) consisted of a mixture of soil and manure at a ratio of 4:1 (v/v). This ratio was selected to provide sufficient organic matter and nutrients from manure while maintaining adequate soil structure, aeration, and drainage for optimal root development of cassava cuttings. The manure used in the media consisted of either cattle manure or goat manure, depending on the treatment. Each plant was fertilized with 5 g of NPK fertilizer (16:16:16) at 24 days after planting (DAP), and the fertilizer was applied uniformly to all treatments to avoid confounding effects caused by unequal nutrient supply.

The experimental design used a Factorial Randomized Block Design (RBD) with 3 replicates. The first factor is planting material, namely the upper stem (B1), middle stem (B2), and lower stem (B3). The second factor is the composition of planting media, namely soil (P1), soil mixture: cattle manure [4:1 v/v] (P2), and soil mixture: goat manure

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[4:1 v/v] (P3). The experiment consisted of 9 treatment combinations (3 planting materials × 3 planting media), each replicated 3 times, for a total of 27 experimental units. Each plant with the experimental unit was considered as a sampling unit, and observations were recorded from all three plants and then averaged per experimental unit. Although organic manure was used as part of the planting media, potential nutrient carryover effects between treatments may still occur due to differences in nutrient release rates between cattle and goat manure. In addition, the use of polybags may limit root expansion and does not fully represent field condition, which could influence plant growth and biomass accumulation. However, this approach was selected to ensure controlled growing conditions and uniform treatment application across experimental units.

Growth data collected included the number of new shoots, length of shoots (cm), diameter of shoots (mm), number of leaves, and chlorophyll index of leaves. The leaf chlorophyll index was measured using a Soil Plant Analysis Development meter (SPAD-502 Plus, Konica Minolta, Japan). Harvesting was carried out three times at 42, 63, and 77 days after planting (DAP). The data measured at harvest time included number of shoots harvested, leaf canopy area (cm2), fresh and dry leaf weight (g), fresh and dry weight of non-consumption leaves (g), fresh and dry weight of petiole (g), fresh and dry weight of stems (g), fresh and dry weight of roots (g), and length of roots (cm). The leaf canopy area was measured using Easy Leaf Area software. Measurements related to biomass weight were carried out at the Plant Physiology Laboratory, Faculty of Agriculture, Sriwijaya University.

Analysis of Variance (ANOVA) was performed using Microsoft Excel and RStudio software version 4.2.1. The significant difference between the treatments was tested using the Least Significant Difference (LSD) test at $P \leq 0.05$.

3. Results and Discussion

Shoot growth is a vegetative growth stage that reflects the ability of cassava stem cuttings to initiate new meristematic tissues and establish early plant development. The different origins of planting material affect the number of shoots. The middle and upper stems have a higher number of shoots than the rootstock, as can be seen from the number of shoots at the age of 7 to 70 days after planting (DAP). This difference is related to the physiological condition and carbohydrate reserves of the stem segments, which influence sprouting ability and early vegetative growth (El-sharkawy, 2012; Otiende & Maimba, 2020). Planting material derived from the middle stem has better growth potential because it has an active shoot growth point (Ratnasari, 2014). Previous studies reported that stem segments with balanced physiological maturity tend to produce more vigorous shoots because they contain adequate stored assimilates and active buds. Cuttings at the base of semi-woody plants will be harder, softer the tip of the branch (Gustiar et al., 2024). The number of shoots increases after the harvest of the tip (Figure 1). This happened after harvesting the tip on 42 DAP. Removal of the apical shoot reduces apical dominance and stimulates the development of lateral buds, leading to the formation of additional shoots (Taiz et al., 2015).

The increased number of shoots is supported by planting media that affect the growth and development of cuttings (Figure 1). Application of manure improves soil physical and chemical properties, enhances nutrient availability, and supports root establishment, thereby promoting shoot and leaf development (Situmeang et al., 2019; Gustiar et al., 2025). The right composition of planting media can improve cassava grafting (Yelli et al., 2021). Similar results have been reported in cassava cultivation systems where improved soil fertility significantly enhances vegetative growth and biomass accumulation (Kaluba et al., 2021).

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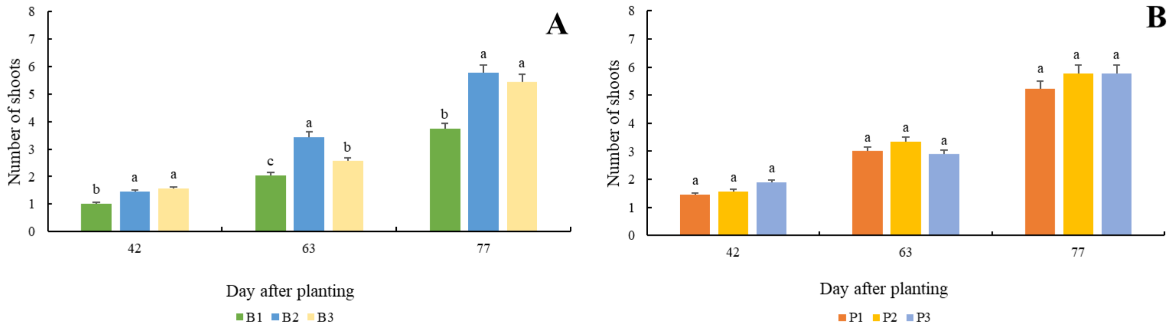

Figure 1. Effect of planting material [A] and composition of planting media [B] on the number of shoots

This study showed that the different origins of planting material affect the number of leaves. Use of rootstocks showed the highest number of leaves compared to the upper stem (Figure 2). Upper stem cuttings tend to have fewer leaves than middle and lower stems. The middle stem has an optimal hormonal balance with active meristem tissue and better structural strength (Anggara et al., 2023), so it can affect the number of shoots, number of leaves, height of shoots and weight of roots. However, the differences among stem positions may also be explained by variations in physiological maturity and internal nutrient reserves of the cuttings. An increase in leaf number enhances the photosynthetic surface area and supports carbohydrate production for plant growth (Sari & Arifandi, 2019). The use of the middle and lower stems is suitable as vegetative propagation material to increase cassava leaf vegetable yields. Meanwhile, high-N manure plays an important role in the vegetative growth of plants (Hali & Telan, 2018). Nitrogen availability supports chlorophyll formation and leaf expansion, which are essential for vegetative biomass production.

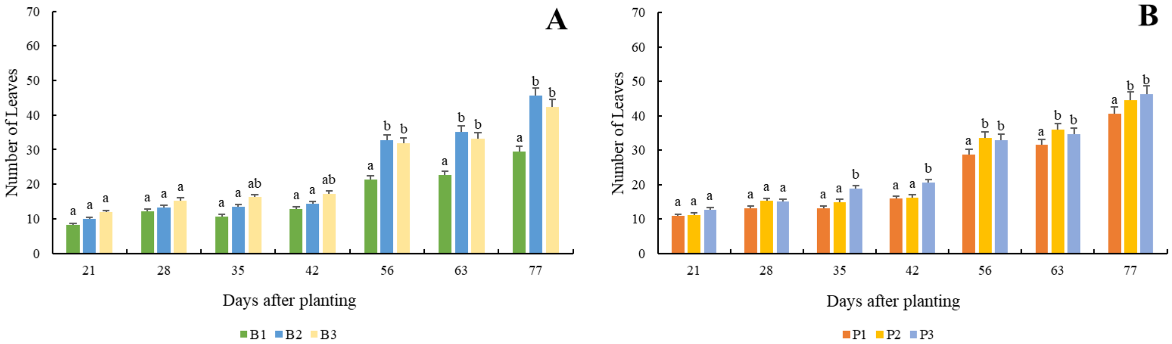

Figure 2. Effect of planting material [A] and composition of planting media [B] on the number of leaves

In 24 DAP, cassava plants were fertilized using 5 g of NPK. The application of fertilizer has an effect on SPAD value which increases from 25-41 DAP. The highest increase occurred at 29-33 DAP (Figure 3). SPAD measurements were carried out to determine the concentration of chlorophyll based on optical principles, so that it could not distinguish between chlorophyll a and b (Fadilah et al., 2022). SPAD meter is also widely used as an indicator of leaf nitrogen status (Rongting et al., 2020), in order to determine the right fertilization time. Therefore, the increase in SPAD value after

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fertilization indicates improved nitrogen availability for chlorophyll synthesis. The origin of stem cuttings shows differences in SPAD values, especially upper stem cuttings and middle stem cuttings (Figure 3). Middle stem cuttings have a higher nitrogen content than other stem cuttings (Simatupang et al., 2020).

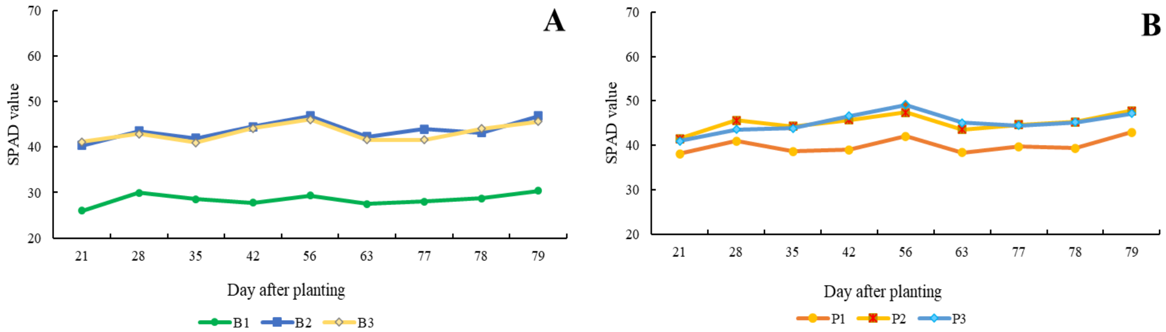

Figure 3. Effect of planting material [A] and composition of planting media [B] on SPAD value

The results of this study showed that cuttings on the upper stem had a smaller diameter than the middle and lower stems. The shoot on the upper stem is shorter than the middle and lower stems (Table 1). Smaller diameter in younger stem tissue (Gustiar et al., 2024). Younger tissues generally contain less lignified vascular structures and lower carbohydrate reserves, which may limit early shoot growth. Shoot growth supported by respiratory activity in decomposing nutrients in stem cuttings (O'Leary et al., 2019). The canopy area was measured before destructive observations were made at 77 DAP. The middle stem has a larger canopy area than the upper and lower stems (Table 1). A larger canopy area indicates greater leaf development and improved interception of solar radiation for photosynthesis. The results of Gustiar et al. (2024) indicated a consistent increase in crown area at 21-35 DAP. At the age of 77 DAP, there was an increase in the percentage of overlapping leaves in the crown, so there was no significant increase in canopy area.

Table 1. Effect of planting material and planting media on the diameter and length shoots

	Shoot diameter (mm)	**Length shoot (cm)**	**Leaf Canopy Area (cm^2)**
Planting Material			
B1	6.13 ± 1.18 b	16.60 ± 3.33 b	1023.68 ± 371.17 b
B2	8.38 ± 0.27 a	23.09 ± 2.29 a	1559.82 ± 338.92 a
B3	8.51 ± 0.29 a	25.67 ± 2.02 a	1095.93 ± 179.90 b
BNT $_{0.05}$	**0.99**	**2.81**	804.79
Planting Media			
P1	8.24 ± 0.40 a	22.16 ± 1.91 b	649.06 ± 111.99 b
P2	8.42 ± 0.25 a	23.94 ± 2.12 a	1775.68 ± 326.39 a
P3	8.89 ± 0.14 a	23.26 ± 1.48 a	1701.82 ± 328.55 a
BNT $_{0.05}$	**0.99**	**2.81**	**804.79**

Note: Numbers with different letters in the same column show a significant difference based on the LSD test at the level of 5%

Cassava leaves, especially the shoots, are consumed as leafy vegetables. The edible part is limited to the young stem that can be broken up to the apical meristem of the shoot (Gustiar et al., 2024). Harvesting of cassava shoots is carried out in 3 stages, with the yield

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continuing to increase (Figure 4). This increase occurs because harvesting stimulates the formation of new shoots from axillary buds, resulting in more shoots than before pruning. To increase the yield of cassava leaves, harvest shoots regularly. This phenomenon is commonly observed in leafy cassava production systems where repeated harvesting promotes continuous vegetative regrowth (Ravi et al., 2021). The harvest weight of cassava leaf tips experienced a significant increase at 63 DAP. This is clearly seen in the treatment of B2 and P2 (Figure 5). The use of the middle stem as planting material, combined with a mixed planting medium of cattle manure, increases the number of cassava shoots. The results in this study are in line with the research of Ratnasari (2014), which states that the middle stem cuttings have the potential to provide better growth. In planting media, use of cattle manure contains high N nutrients that play a role in vegetative plant growth (Hali & Telan, 2018).

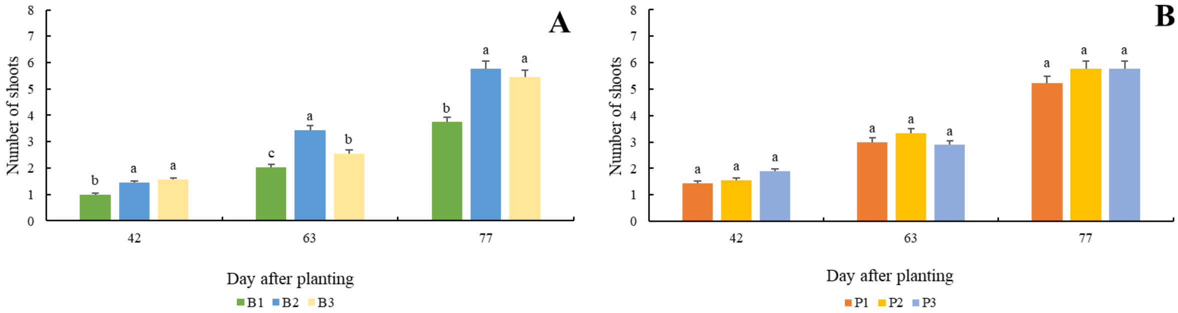

Figure 4. Effect of planting material [A] and composition of planting media [B] on the number of shoots

Table 2. Effect of planting material and planting medium on fresh weight and dry weight of non-edible leaves, petiole, and stem

	NLFW (g)	NLDW (g)	PFW (g)	PDW (g)	SFW (g)	SDW (g)
Planting Material						
B1	16.50 ±2.90 b	3.81±0.65 b	8.87 ±2.20 b	1.34 ±0.29 b	22.84 ±3.90 b	6.14 ±0.97 b
B2	39.87 ±11.69 a	8.61±2.67 a	26.14 ±7.91 a	3.33 ±1.06 a	69.25 ±20.14 a	10.83 ±2.63 a
B3	21.85 ±3.96 b	6.49 ±1.09 ab	11.64 ±3.59 b	1.82 ±0.45 b	42.83 ±8.41 b	8.73 ±1.04 ab
$LSD_{0.05}$	**12.99**	**3.56**	**10.91**	**1.26**	**22.30**	**3.36**
Planting Media						
P1	12.23 ±2.84 b	3.15 ±0.68 b	8.54 ±2.82 b	0.97 ±0.30 b	17.97 ±2.08 b	5.10 ±0.91 b
P2	47.05 ±10.62 a	11.04 ±2.42 a	30.11 ±7.62 a	4.12 ±0.98 a	84.28 ±18.78 a	13.28 ±2.34 a
P3	18.94 ±1.95 b	4.72 ±0.50 b	7.99 ±0.73 b	1.42 ±0.13 b	32.67 ±2.95 b	7.31±0.56 b
$LSD_{0.05}$	**12.99**	**3.56**	**10.91**	**1.26**	**22.30**	**3.36**

Note: Non-edible Leaves Fresh Weight (NLFW), Non_edible Leaves Dry Weight (NLDW), Petiole Fresh Weight (PFW), Petiole Dry Weight (PDW), Stem Fresh Weight (SFW), Stem Dry Weight (SDW). Numbers with different letters in the same column show a significant difference based on the LSD test at the level of 5%

The maturity level of cuttings and the composition of planting media affect destructive parameters, including fresh and dry weights of non-edible leaves, petioles, and stems (Table 2). Similar to the weight of shoots, B2 and P2 treatments also showed the highest leaves, petioles, stems, and root weights. Higher biomass accumulation indicates more efficient photosynthetic activity and nutrient utilization during

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vegetative growth. In cassava plants, leaves that are widely used are only leaves of tip, so in addition to leaves of tip, they are categorized as non-consumption leaves.

Meanwhile, root length showed different results. This is seen in P3, which affects longer roots (Table 3). This is supported by the research of Irawan et al. (2021), which states that goat manure contains high N, K, and C-Organic. Organic matter from goat manure improves soil structure and stimulates root development, thereby enhancing nutrient absorption (Odedina et al., 2011).

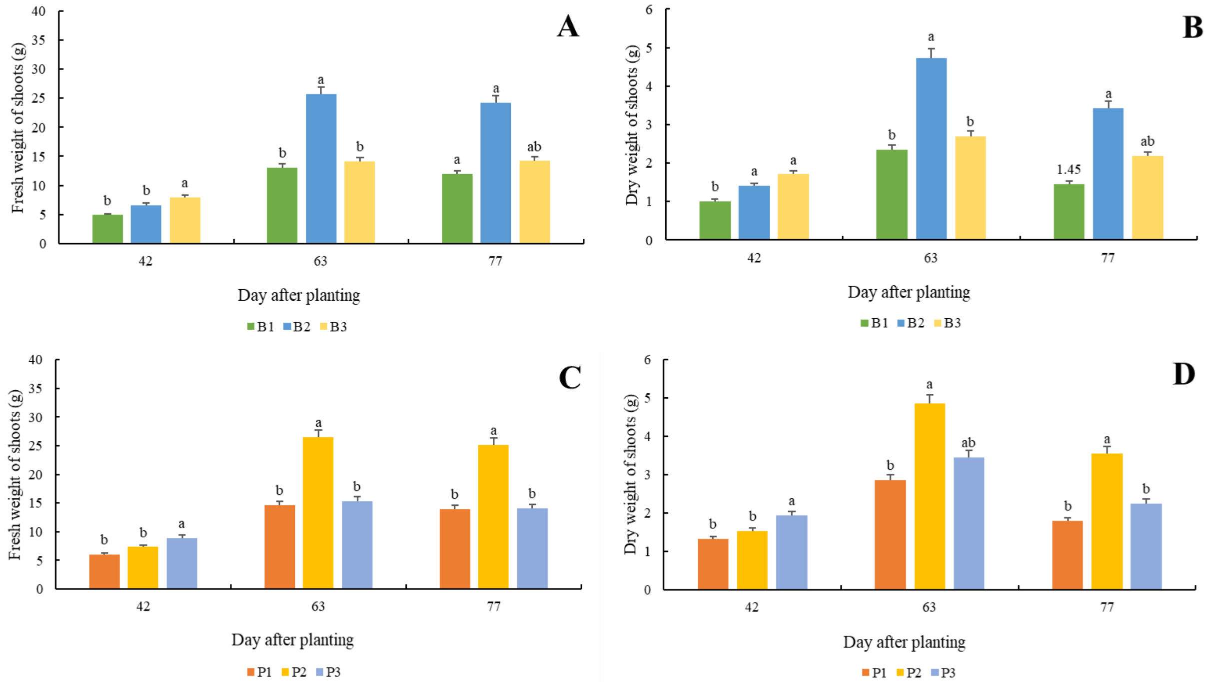

Figure 5. Effect of planting material on fresh [A] and dry [B] weight (g) of shoots; and effect of composition planting media on fresh [C] and dry [D] weight (g) of shoots.

Table 3. Effect of planting material and planting media on length, fresh weight and dry weight of root

	Root Length (cm)	Root Fresh Weight (g)	Root Dry Weight (g)
Planting Material			
B1	38.33 ± 1.93 a	12.23± 1.73 a	5.78± 0.61 a
B2	35.33 ± 1.16 a	14.12± 1.71 a	8.07± 1.67 a
B3	42.02 ± 2.54 a	11.28± 1.48 a	6.75± 0.79 a
LSD 0.05	**7.11**	**5.79**	**4.21**
Planting Media			
P1	37.90 ± 2.50 a	10.30± 1.77 a	5.87± 0.76 a
P2	38.15 ± 2.24 a	12.77± 1.34 a	6.12± 0.32 a
P3	39.63 ± 1.49 a	14.56± 1.65 a	8.60± 1.71 a
LSD 0.05	**7.11**	**5.79**	**4.21**

Note: Numbers with different letters in the same column show a significant difference based on the LSD test at the level of 5%

4. Limitations and Future Directions

This study provides useful insights into the effects of planting material and growing media on cassava leaf production; however, several limitations should be acknowledged. The experiment was conducted over a relatively short

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period, which may not fully represent long-term growth dynamics and productivity under varying environmental conditions. In addition, the study primarily focused on morphological and yield-related parameters, while physiological responses such as photosynthetic rate, transpiration, and nutrient uptake were not evaluated. Future studies are therefore recommended to extend the observation period and include a broader range of physiological parameters to better understand the mechanisms underlying cassava growth and yield responses.

5. Conclusion

This study aimed to evaluate the effects of different planting materials (stem cutting position; upper, middle, and lower) and planting media composition on the growth and yield of cassava leaf shoots cultivated as leafy vegetables. The selection of planting material and planting media significantly influenced several vegetative growth parameters of cassava under the conditions of this experiment. Cuttings derived from the middle stem tended to produce higher shoot growth and leaf production compared with upper and lower stem cuttings under the conditions of this study. Within the experimental conditions of this study, shoot pruning stimulated the formation of additional shoots and increased the harvestable cassava leaf yield. Among the planting media tested, the soil + cattle manure treatment (P2) tended to support better vegetative growth and shoot production, whereas the soil + goat manure treatment (P3) was more associated with root development.

These results suggest that using middle-stem cuttings combined with soil and cattle manure may be a promising approach for cassava leafy vegetable production under similar environmental conditions.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the author did not use AI, the author reviewed and edited the content as needed and is fully responsible for the content of the publication.

Authorship Contribution Statement

Lya Nailatul Fadilah: Methodology, Data analysis, Data curation, Writing original draft, Visualization; Fitra Gustiar: Conceptualization, Methodology, Writing (review and editing); Marlin Sefrila: Validation, Formal analysis, Writing (review and editing); Didik Wisnu Widjajanto: Validation, Writing (review and editing); Adiba Mutia Rahmah: Data collection, Writing (review and editing).

Declaration of Competing Interest

The authors declare that they have no known financial interests that could have appeared to influence the work reported in this manuscript.

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