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Enhancing Growth and Yield of Garuda Clone Cassava through Mukibat Grafting and Microbial-Based Fertilization

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ABSTRACT

Cassava (Manihot esculenta Crantz) is a strategic commodity in Indonesia, but the productivity (20–30 t/ha) remains far below the biological potential (>60 t/ha). Mukibat grafting, which combines rubber cassava (Manihot glaziovii) as scion onto cultivated cassava rootstock, represents an effective approach to enhance productivity. This study aimed to evaluate the effects of planting materials (Mukibat grafting vs. conventional cutting) and fertilizer types (inorganic NPK, goat manure, and microbial-based fertilizer/MBF) on the growth and yield of Garuda clone cassava. The experiment was conducted using a Strip Plot Design with a 2×3 factorial treatment structure and three replications. Results showed that grafting success rate was 100% across all treatments. Mukibat grafting significantly outperformed conventional cuttings, increasing tuber yield by 98.14% (61.70 kg vs. 31.14 kg per 3 plants) and total starch production by 102.77% (50.49 vs. 24.90 t/ha). Starch content did not differ significantly between treatments. MBF produced the highest tuber yield (52.40 kg per 3 plants) and total starch production (42.95 t/ha), representing a 31.07% and 28.81% increase over inorganic fertilizer (39.98 kg per 3 plants), respectively. These findings demonstrate that integrating Mukibat grafting with microbial-based fertilization represents an effective strategy for sustainable intensification of cassava production in Indonesia.

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is one of Indonesia's strategic food commodities, playing a vital role in supporting national food security and serving as a raw material for various starch-based industries. This crop ranks as the third source of carbohydrates after rice and maize, and is utilized not only as an alternative staple food, but also as a raw material for various processed products such as dried cassava chips, tapioca, modified cassava flour (mocaf), modified starch, bioethanol, sorbitol, biosurfactants, and cosmetic products (Utomo *et al*., 2025). This diversity of utilization positions cassava as a commodity of high strategic value, both for food security and for increasing national agroindustry added value (Waluyo, 2020).

Lampung Province is the largest cassava producer in Indonesia and one of the main centers of commodity development. The majority of cassava production in Lampung Province is utilized as raw material for the tapioca flour industry. In addition, cassava also has potential to be processed into modified cassava flour (MOCAF), which can replace

30–100% of wheat flour in various processed products such as cakes, noodles, pasta, and fermented products. The use of MOCAF not only increases the added value of cassava, but also has potential to reduce dependence on wheat imports, thus positively impacting food security and the national economy (Pusdatin Kementan, 2020; BPS, 2023).

Despite its high yield potential, cassava productivity at the farm level remains relatively low. Data from the Central Bureau of Statistics indicate that Indonesia's cassava production in 2023 reached 14.56 million tons, with Lampung Province contributing approximately 39%, or around 5.67 million tons (BPS, 2024). Nevertheless, cassava productivity at the farm level ranges only from 20–30 t/ha, far below the maximum yield potential of superior varieties, which can exceed 60 t/ha (Waluyo, 2020). This low productivity is attributable, among other factors, to the use of conventional stem cutting planting materials, declining soil fertility, and dependence on inorganic fertilizers, which in the long term have the potential to reduce soil quality.

One cultivation technology with the potential to increase cassava productivity is the Mukibat grafting technique. This technique combines rubber cassava (*Manihot glaziovii*) as scion with cultivated cassava as rootstock. The system is based on optimization of the source–sink relationship, where the vigorous canopy of rubber cassava serves as the photosynthate source, while the cassava rootstock functions as the assimilate sink stored in the form of tubers (Triana et al., 2025). Research shows that the application of Mukibat grafting can increase tuber yield by 37–100% compared to conventional cuttings (Bangthong *et al*., 2022; Radjit & Prasetiaswati, 2011).

In addition to propagation technique, proper nutrient management plays an important role in supporting productivity. Microbial-based fertilizers containing consortia of functional microorganisms, such as nitrogen-fixing bacteria, phosphate-solubilizing microbes, and plant growth-promoting rhizobacteria (PGPR), have been reported to increase nutrient availability, improve rhizosphere conditions, and stimulate plant growth through the production of phytohormones and enzymes (Shahwar *et al*., 2023; Timofeeva *et al*., 2023). Furthermore, the application of microbial-based fertilizers has potential to increase nutrient use efficiency and reduce dependence on inorganic fertilizers, thus supporting a more sustainable farming system (Hridya *et al*., 2014).

Although various studies have examined the advantages of the Mukibat grafting technique and the use of microbial-based fertilizers separately, research integrating Mukibat grafting with microbial-based fertilization in cassava has not been reported, particularly for high-yielding clones such as the Garuda clone under the agroecosystem conditions of Lampung Province. Therefore, this study was conducted to evaluate the effect of planting material origin (Mukibat grafting vs. conventional cutting) and fertilizer type (inorganic NPK, goat manure, and microbial-based fertilizer) on the growth and production of Garuda clone cassava.

The hypotheses proposed in this study are: (1) Mukibat grafting significantly improves vegetative growth and productivity of Garuda clone cassava compared to conventional cuttings; (2) microbial-based fertilizer (MBF) produces the best growth and yield response compared to inorganic fertilizer and goat manure; and (3) no significant interaction exists between planting material origin and fertilizer type on the growth and production of Garuda clone cassava.

2. MATERIALS AND METHODS

The experiment was conducted at Rara Estate complex in Rajabasa Raya, Bandar Lampung (5.3565° S, 105.2492° E), from December 2024 to September 2025.

2.1. Materials and Equipment

Materials included Garuda clone cassava seedlings (rootstock), rubber cassava (*Manihot glaziovii*) stems as scion, NPK Pusri 17-6-25 fertilizer, goat manure, and microbial-based fertilizer (MBF) consisting of Solid Microbial Consortium (KMP) and Liquid Microbial Consortium (KMC), products of Ghaly Tech. Equipment used included a tractor, hoe, grafting knife, saw, vernier calipers, analytical balance, measuring tape, and stationery.

2.2. Experimental Design

The experiment used a Strip Plot Design with a factorial treatment structure (2×3), yielding 6 treatment combinations and 3 replications (18 experimental units). Each experimental unit consisted of 20 plants with a spacing of 100×100 cm, giving a total of 360 plants. The selection of 100×100 cm spacing was based on several scientific considerations: first, Saleh *et al*. (2016) recommend 100×100 cm spacing (equivalent to 10,000 plants/ha) for Garuda clone under intensive cultivation; and second, the Mukibat system produces a wider canopy, requiring adequate growing space to avoid inter-plant light competition. This spacing is consistent with Bangthong *et al*. (2022), who used a similar plant density. For comparison, the spacing commonly used by farmers in Lampung ranges from 80×100 to 100×100 cm (BPS, 2024), making the spacing chosen in this study still relevant to field conditions. The additive linear model used was as follows:

$$Y_{ijk} = \mu + \alpha_i + \gamma_k + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk} \quad (1)$$

where Y_{ijk} is the observed value at the i-th level of cutting material factor (B), j-th level of fertilizer factor (P), and k-th replication; μ is the general mean; α_i is the effect of the planting material factor; β_j is the effect of fertilizer type; γ_k is the replication effect; $(\alpha\beta)_{ij}$ is the interaction effect of cutting material and fertilizer type; and ε_{ijk} is the experimental error. The error for the main plot factor (planting material) was computed from the planting material × replication interaction, while the error for the sub-plot factor (fertilizer type) and its interaction was computed from the residual error following the rules of the Strip Plot Design.

The first factor was planting material origin (B), consisting of: B1 = Mukibat grafting, and B2 = Conventional cutting. The second factor was fertilizer type (P), consisting of: P1 = Inorganic NPK Pusri 17-6-25 (350 kg/ha, applied twice at 14 and 56 days after planting (DAP), equivalent to N 59.5 kg/ha, P_2O_5 21 kg/ha, and K_2O 87.5 kg/ha); P2 = Goat manure (2 kg/plant equivalent to 20 t/ha at 1×1 m spacing. Based on average goat manure composition (N 1.5%, P_2O_5 0.9%, K_2O 1.8% (Dalorima *et al*., 2021), this dose is equivalent to N approximately 300 kg/ha, P_2O_5 180 kg/ha, and K_2O 360 kg/ha on a fresh matter basis); and P3 = Microbial-Based Fertilizer (MBF) comprising KMP (1 t/ha) + KMC (250 ml per 15 liters of water). Stem length of cutting material was 40 cm.

2.3. Experimental Procedure

Land preparation was carried out using a tractor, followed by the creation of plots measuring 5×4 m with planting holes spaced 1×1 m apart. Fertilization was performed according to treatment type with the following procedures. Goat manure (2 kg/plant) was applied one week before planting directly into the planting holes to allow complete decomposition before planting. For the MBF treatment, KMC was sprayed at 250 ml per 15 liters of water one week before planting on the planting hole area to neutralize chemical residues and colonize microbes in the soil; spray equipment used must be free from chemical residues. After planting, KMP was applied around the plant stems at 1 t/ha, followed by re-spraying of KMC at the same dose (250 ml per 15 liters of water) onto the entire plant and surrounding area. Inorganic NPK Pusri 17-6-25 (350 kg/ha) was applied in two stages, at 14 and 56 DAP.

Prior to the experiment, chemical soil analysis was carried out for composite soil samples collected at a depth of 0–20 cm from the experimental site. Analysis was conducted by two accredited laboratories: (1) the Academic Support Unit of the Integrated Laboratory (UPA LT) at the University of Lampung for pH and K-total parameters, and (2) the Polinela Analysis Laboratory for N-total, P-available, and C-organic parameters. Soil analysis results were used as the basis for determining fertilizer doses and interpreting plant responses to the various fertilization treatments. Climate data during the experimental period (December 2024-September 2025) were obtained from the nearest Meteorological, Climatological, and Geophysical Agency (BMKG) weather station. Monthly average rainfall during the experiment ranged from 120–380 mm/month, with wet months (rainfall >200 mm) occurring from December 2024 to March 2025, and dry months (rainfall <100 mm) in August–September 2025. Average air temperature ranged from 27–29 °C with relative humidity of 75-85%, conditions suitable for optimal cassava growth in the tropics.

The grafting method used was splice grafting. Rubber cassava scion stems (40 cm length, 1–2 cm diameter) were grafted onto Garuda clone rootstocks aged 2–3 months. The tip of the rootstock was cut to a depth of approximately 1 cm over a length of approximately 10 cm, then the base of the scion was similarly cut and joined to the rootstock, before being tied tightly with plastic rope. Rootstock stem cuttings (Garuda clone) were planted immediately after preparation (same day). The rootstock stem cuttings of Garuda clone were planted vertically (90°), inserted into the soil to a depth of 7 cm at a spacing of 100×100 cm. Maintenance included daily watering, weeding, removal of rootstock buds, and pruning of rubber cassava flowers. Harvesting was performed manually at 8 months after planting (MAP).

2.4. Observed Variables

Vegetative growth variables observed included shoot height (cm), number of leaves, stem diameter (cm), number of branches, and fresh shoot biomass weight (kg). Vegetative growth observations were conducted periodically every two weeks from 1 to 4 MAP (8 observation times); however, data used for statistical analysis and presented in the results are from 8 MAP as the final vegetative growth data before harvest. Yield variables observed at harvest (8 MAP) included: number of productive roots per plant, total number of roots per plant, productive root length (cm), root span (cm), tuber diameter (cm), tuber weight per 3 plants (kg), tuber production (t/ha), and starch content (%). Starch content was measured using the gravimetric method with a starch content analyzer scale, where the starch content percentage was read directly from the instrument scale. Each treatment was observed on 3 sample plants.

2.5. Data Analysis

Data were tested for normality using the Shapiro-Wilk test and homogeneity of variance using the Bartlett test. Analysis of variance (ANOVA) was subsequently performed at 5% confidence level, and differences between treatments were tested using the Least Significant Difference (LSD) test at the 5% level. Data analysis was performed using Microsoft Excel, Minitab, and R Studio software.

3. RESULTS AND DISCUSSION

3.1. Initial Soil Chemical Characteristics of the Experimental Site

Results of initial soil chemical analysis of the experimental site are presented in Table 1. The experimental site soil exhibited an acidic pH (5.63), low N-total content (0.92%, db), very low P-available (<2.06 ppm, db), low C-organic (1.34%, db), and moderate K-total (103.7 mg/kg). The acidic soil conditions (pH 5.63) at the experimental site have direct implications for nutrient availability to plants. Within this pH range, phosphorus availability is generally very limited due to fixation by Al and Fe, which are active under acidic conditions (Bhatt *et al*., 2019). This is confirmed by the analysis results showing very low P-available (<2.06 ppm), far below the optimal requirement for cassava, which ranges from 15–25 ppm (Saleh *et al*., 2016). The low C-organic content (1.34%) indicates that soil biological activity and nutrient retention capacity are relatively limited, which is commonly found on intensively cultivated tropical agricultural lands due to continuous harvesting without adequate organic matter return (Purwanto & Alam, 2020).

These nutrient-poor soil conditions provide an important background explaining the superiority of MBF and goat manure in this study. On soils with very low P-available, phosphate-solubilizing microbes in MBF (such as *Penicillium* sp. and *Bacillus megaterium*) are capable of dissolving P fixed by Fe and Al through the production of organic acids and phosphatase enzymes, thereby significantly increasing P availability to plants (Kaul *et al*., 2019; Timofeeva *et al*., 2023). The low Total-N (0.92%) also explains the important role of nitrogen-fixing bacteria in MBF (*Azotobacter* and *Azospirillum*), which are capable of providing additional N through biological nitrogen fixation from the atmosphere, reducing dependence on synthetic chemical fertilizers (Shahwar *et al*., 2023). Meanwhile, goat manure contributes to improving the low Organic-C content of the soil, thereby increasing cation exchange capacity, aeration, and soil water-holding capacity, all of which support the growth and development of the root system (Dalorima *et al*., 2021). Thus, the initial acidic and nutrient-poor soil characteristics contextually reinforce the relevance of using microbial-based organic fertilizers compared to inorganic fertilizers alone at this experimental site. Figure 1 shows profile of cassava plants from this experiment plot at age of 2 MAP (month after planting). The Mukibat grafting plant (left) shows more vigorous canopy development due to the larger leaf area of the *Manihot glaziovii* scion, while the conventional cutting plant (right) displays typical growth pattern of single-stem cassava at the same age.

Table 1. Initial soil chemical analysis results of the experimental site at Rara Estate Rajabasa, Bandar Lampung

Parameter	Unit	Value	Category*	Laboratory / Method
Soil pH	-	5.63	Acidic	UPA LT Unila / SNI 6989.11-2019
Total-K	mg kg^{-1}	103.7	Medium	UPA LT Unila / EPA 200.7 Rev.5 2001
Total-N	% adbk	0.92	Low	Lab. Polinela / Eviati *et al.* (2023)
Available-P	ppm adbk	<2.06	Very Low	Lab. Polinela / Eviati *et al.* (2023)
Organic-C	% adbk	1.34	Low	Lab. Polinela / Eviati *et al.* (2023)

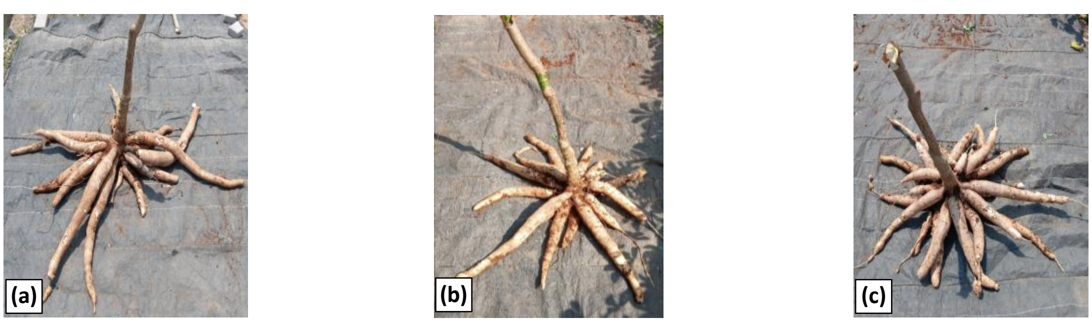
* Assessment criteria were based on the technical guidelines described by Eviati *et al.* (2023).

Figure 1. Planting position of Mukibat grafting (left) and conventional stem cuttings (right) of Garuda clone cassava at 2 months after planting (MAP), planted vertically (90°) at a depth of 7 cm with a spacing of 100×100 cm.

3.2. Result

Visually, the tubers of Garuda Clone cassava harvested at 8 months after planting (MAP) showed distinct differences in appearance between the Mukibat grafting system and conventional stem cuttings, as well as among fertilizer treatments. In the conventional stem cutting system, the tubers produced tended to be fewer, shorter, and smaller in diameter compared to the Mukibat grafting system. In the Mukibat grafting system, the tubers appeared larger, longer, and more numerous per plant, reflecting an increased sink capacity due to higher photoassimilate supply from the *Manihot glaziovii* canopy. Regarding fertilizer treatments, plants treated with microbial-based fertilizer (MBF) and goat manure generally produced larger tubers compared to inorganic fertilizer, both in the conventional stem cutting and Mukibat grafting systems. The tuber appearance of each treatment combination is presented in Figure 2. The average tuber weight of the stem cutting system was 10.37 kg/plant with a starch content of 24.00%. The average tuber weight of the Mukibat Grafting system was 20.56 kg/plant with a starch content of 24.55%.

Figure 2. Cassava tuber formation of Garuda clone (conventional stem cutting) at harvest 8 MAP under three fertilizer treatments: (a) Inorganic NPK, (b) Goat Manure, and (c) Microbial-Based Fertilizer (MBF).



(a) (b) (c)

Figure 3. Cassava tuber formation of Garuda clone (Mukibat grafting) at harvest 8 MAP under three fertilizer treatments: (a) Inorganic NPK Fertilizer, (b) Goat Manure, and (c) Microbial-Based Fertilizer (MBF).

3.2.1. Summary of ANOVA

Table 2 presents the ANOVA results evaluating the effects of planting material origin, fertilizer type, and their interaction on the growth and yield of Garuda clone cassava at 8 months after planting (MAP). The results indicate that planting material origin significantly affected most growth and yield variables, including shoot height, number of leaves, stem diameter, branching level, number of productive roots, total number of roots, tuber diameter, root span, productive root length, tuber weight, and fresh shoot biomass ($p < 0.05$ or $p < 0.01$). However, it did not significantly influence starch content ($p > 0.05$). Fertilizer type significantly affected the number of leaves, stem diameter, tuber diameter, productive root length, and tuber weight, while its effects on the other variables were not significant. Furthermore, no significant interaction between planting material origin and fertilizer type was observed for any of the measured variables ($p > 0.05$), indicating that the response to fertilizer was consistent regardless of the planting material origin.

Table 2. Summary of ANOVA: Effects of treatment factors on the growth and yield of Garuda clone cassava at age of 8 MAP.

No	Variable	Planting Material (B)		Fertilizer (P)		Interaction B×P	
		***p*-value**	**Sig**	***p*-value**	**Sig**	***p*-value**	**Sig**
1	Shoot height	0.0243	*	0.1665	ns	0.2010	ns
2	Number of leaves	0.0017	**	0.0173	*	0.3556	ns
3	Stem diameter	0.0238	*	0.0130	*	0.3414	ns
4	Branching level	0.0017	**	0.7901	ns	0.3922	ns
5	Number of productive roots	0.0080	**	0.4723	ns	0.9653	ns
6	Total number of roots	0.0269	*	0.5467	ns	0.9983	ns
7	Tuber diameter	0.0095	**	0.0186	*	0.8161	ns
8	Root span	0.0174	*	0.0874	ns	0.0900	ns
9	Productive root length	0.0131	*	0.0085	**	0.2145	ns
10	Tuber weight	0.0309	*	0.0331	*	0.5094	ns
11	Starch content	0.5765	ns	0.4512	ns	0.6989	ns
12	Fresh shoot biomass	0.0028	**	0.4006	ns	0.2795	ns

Note: ** = Significant at α = 1%; * = Significant at α = 5%; ns = Not significant

Table 3. Effect of planting material origin on shoot height, number of leaves, stem diameter, branching level, and fresh shoot biomass weight of Garuda clone cassava at 8 MAP

Treatment	Shoot Height (m)	Number of Leaves	Stem Diameter (cm)	Branching Level	Fresh Shoot Biomass (kg)
Convensional Cutting	3.79 a	331.33 b	4.04 b	3.17 b	8.33 b
Mukibat Grafting	3.69 b	1126.22 a	4.23 a	6.78 a	13.92 a
LSD 5 %	0.07	139.57	0.12	0.63	1.26

Note: Mean values followed by the same letter do not differ significantly based on the LSD test at 5%.

3.2.2. Vegetative Growth of Cassava

All vegetative growth variables of Garuda clone cassava at 8 MAP were significantly affected by the planting material origin treatment (Table 3). Cassava plants derived from the Mukibat grafting method showed a significantly higher number of leaves (1,126.22 leaves, $p = 0.0017$), larger stem diameter (4.23 cm, $p = 0.0238$), higher branching level (6.78 branches, $p = 0.0017$), and greater fresh shoot biomass weight (13.92 kg, $p = 0.0028$) compared to plants derived from conventional cuttings. Conversely, shoot height of plants from conventional cuttings (3.79 m) was significantly taller than those from Mukibat grafting (3.69 m; $p = 0.0243$) based on the LSD test at the 5% level.

Number of leaves and stem diameter of Garuda clone cassava at 8 MAP were significantly affected by fertilizer type treatment, while shoot height, branching level, and fresh shoot biomass did not show significant differences among treatments (Table 4). MBF treatment produced a significantly higher number of leaves (792.67 leaves, p = 0.0173) than inorganic fertilizer (608.00 leaves), but did not differ significantly from goat manure. In addition, MBF treatment also produced a significantly larger stem diameter (4.28 cm, p = 0.0130) than inorganic fertilizer (3.98 cm). Goat manure treatment produced significantly higher number of leaves (785.67 leaves) and stem diameter (4.15 cm) than inorganic fertilizer. Meanwhile, fertilizer type had no significant effect on shoot height (p = 0.1665), branching level (p = 0.7901), or fresh shoot biomass (p = 0.4006) based on the LSD test at the 5% level. Analysis of variance showed that no significant interaction existed between planting material origin and fertilizer type on any vegetative growth variable of Garuda clone cassava at 8 MAP.

Table 4. Effect of fertilizer type on shoot height, number of leaves, stem diameter, branching level, and fresh shoot biomass weight of Garuda clone cassava at 8 MAP

Treatment	Shoot Height (m)	Number of Leaves (leaves)	Stem Diameter (cm)	Branching Level (branches)	Fresh Shoot Biomass (kg)
Inorganic NPK	3.51	608.00 b	3.98 b	4.83	10.13
Goat Manure	3.74	785.67 a	4.15 a	5.00	11.30
MBF	3.97	792.67 a	4.28 a	5.08	11.95
LSD 5%	ns	113.01	0.15	ns	Ns

Note: Mean values followed by the same letter do not differ significantly based on the LSD test at 5%. "ns" = not significant.

3.2.3. Root and Tuber Characteristics

All root and tuber characteristic variables of Garuda clone cassava at harvest were significantly affected by planting material origin treatment (Table 5). Plants derived from Mukibat grafting showed a significantly higher number of productive roots (20.11 tubers/plant, $p = 0.0080$) compared to plants from conventional cutting (16.05 tubers/plant). In addition, total number of roots in grafted plants (24.16 tubers/plant) was also significantly higher than in cutting plants (20.67 tubers/plant, $p = 0.0269$). Mukibat grafting produced a significantly wider root span and longer productive root length than the cutting method, with values of 170.98 cm ($p = 0.0174$) and 95.44 cm ($p = 0.0131$), respectively. Furthermore, tuber diameter of grafted plants (7.75 cm) was significantly larger than that of cutting plants (6.72 cm; $p = 0.0095$) based on the LSD test at the 5% level.

Table 5. Effect of planting material origin on number of productive roots, total root number, root span, productive root length, and tuber diameter of Garuda clone cassava at age of 8 MAP

Treatment	Productive Roots (tubers)	Total Roots (tubers)	Root Span (cm)	Productive Root Length (cm)	Tuber Diameter (cm)
Conventional Cutting	16.05 b	20.67 b	132.28 b	73.00 b	6.72 b
Mukibat Grafting	20.11 a	24.16 a	170.98 a	95.44 a	7.75 a
LSD 5%	1.56	2.52	22.26	11.41	0.43

Note: Mean values followed by the same letter do not differ significantly based on the LSD test at 5%.

Table 6. Effect of fertilizer type on number of productive roots, total root number, root span, productive root length, and tuber diameter of Garuda clone cassava at age of 8 MAP

Treatment	Productive Roots (tubers)	Total Roots (tubers)	Root Span (cm)	Productive Root Length (cm)	Tuber Diameter (cm)
Inorganic NPK	17.25	20.75	141.91	78.91 b	6.77 b
Goat Manure	18.58	22.83	148.17	81.50 b	7.38 a
MBF	18.41	20.75	164.80	93.00 a	7.56 a
BNT 5 %	ns	ns	ns	6.64	0.45

Note: Mean values followed by the same letter do not differ significantly based on the LSD test at 5%. "ns" = not significant.

Productive root length and tuber diameter were significantly affected by fertilizer type, while number of productive roots, total root number, and root span did not show significant differences among treatments (Table 6). MBF treatment produced significantly longer productive roots (93.00 cm, p = 0.0085) compared to inorganic fertilizer (78.91 cm) and goat manure (81.50 cm). In addition, MBF also produced a significantly larger tuber diameter (7.56 cm, p = 0.0186) than inorganic fertilizer (6.77 cm), but did not differ significantly from goat manure. Goat manure produced a significantly larger tuber diameter (7.38 cm) than inorganic fertilizer. Meanwhile, fertilizer type had no significant effect on number of productive roots (p = 0.4723), total root number (p = 0.5467), or root span (p = 0.0874) based on the LSD test at the 5% level. Analysis of variance showed that no significant interaction existed between planting material origin and fertilizer type on any root and tuber characteristic variable.

3.2.4. Tuber Yield and Starch Content

Tuber weight per three plants was significantly affected by planting material origin (p = 0.0309), while starch content showed no significant difference among treatments (p = 0.5765; Table 7). Plants from Mukibat grafting produced a tuber weight of 61.70 kg per 3 plants, while plants from conventional cutting produced 31.14 kg per 3 plants, representing a difference of 30.56 kg per 3 plants or a 98.14% increase. This value represents the total tuber weight from 3 sample plants, not the average per plant. Meanwhile, starch content did not differ significantly between grafting (24.55%) and conventional cutting systems (24.00%; p = 0.5765).

Although starch content did not differ significantly among treatments, calculation of total starch per unit area revealed a marked difference. Based on tuber weight obtained, the Mukibat grafting system produced a total starch of 50.49 t/ha, while the conventional cutting system produced 24.90 t/ha. Thus, a 102.77% increase in total starch was achieved in the Mukibat grafting system compared to the cutting method.

Table 7. Effect of cutting origin on tuber weight, starch content, and starch yield of Garuda clone cassava at 8 MAP

Treatment	Tuber Weight (kg/3 plants)	Starch Content (%)	Starch Production (t/ha)
Conventional Cutting	31.14 b	24.00	24.90 b
Mukibat Grafting	61.70 a	24.55	50.49 a
LSD 5%	23.60	ns	26.54

Note: Mean values followed by the same letter do not differ significantly based on the LSD test at 5%. "ns" = not significant.

Table 8. Effect of fertilizer type on tuber weight, starch content, and starch production of Garuda clone cassava at 8 MAP

Treatment	Tuber Weight (kg/3 plants)	Starch Content (%)	Starch Production (t/ha)
Inorganic NPK	39.98 b	25.02	33.34 b
Goat Manure	47.88 ab	23.30	37.18 ab
MBF	52.40 a	24.59	42.95 a
LSD 5%	8.94	ns	8.62

Note: Mean values followed by the same letter do not differ significantly based on the LSD test at 5%. "ns" = not significant.

Tuber weight per three plants was significantly affected by fertilizer type (p = 0.0334), while starch content showed no significant difference among treatments (p = 0.4512; Table 8). MBF treatment produced the highest tuber weight of 52.40 kg per 3 plants, compared to inorganic fertilizer at 39.98 kg per 3 plants, representing an increase of 12.42 kg per 3 plants or 31.07%. Goat manure treatment produced tuber weight of 47.88 kg per 3 plants, a 19.76% increase over inorganic fertilizer. Meanwhile, starch content did not differ significantly among fertilizer treatments (p = 0.4512), with values of 25.02% for inorganic fertilizer, 23.30% for goat manure, and 24.59% for MBF.

Based on tuber weight and starch content obtained, calculation of total starch per hectare showed that inorganic fertilizer produced 33.34 t/ha, goat manure produced 37.18 t/ha, and MBF produced 42.95 t/ha. Thus, a 28.81% increase in total starch production was achieved with MBF compared to inorganic fertilizer. Analysis of variance showed no significant interaction between planting material origin and fertilizer type on tuber weight or starch content based on the LSD test at 5%.

3.3. Discussion

The superiority of vegetative growth in Mukibat grafted plants, particularly in terms of number of leaves, stem diameter, branching level, and fresh shoot biomass, is inseparable from the physiological mechanisms underlying the source–sink system in the interspecific graft union between *Manihot glaziovii* (scion) and Garuda clone (rootstock). The canopy of *M. glaziovii* possesses a larger leaf area and longer leaf lifespan than cultivated cassava, resulting in a higher total CO_2 assimilation capacity per unit canopy area (Chiewchankaset *et al*., 2022). Mechanistically, sucrose synthesized in the mesophyll cells of *M. glaziovii* is loaded into the phloem via the symplastic pathway, then translocated through the vascular tissue formed at the graft union toward the Garuda clone root system as the primary sink. The successful formation of phloem connectivity across the graft union is supported by the 100% grafting success rate achieved across all treatments, indicating good anatomical compatibility between the two species within the genus Manihot (Opoku-Agyemang *et al*., 2024). The increased carbon supply flowing from this stronger source directly supports cell division and expansion in lateral vegetative organs, resulting in higher number of leaves, stem diameter, and branching level compared to cuttings. The slightly shorter shoot height in grafted plants is a logical consequence of photoassimilate redistribution that is more dominant toward lateral growth than apical growth, consistent with the concept of inter-organ sink competition proposed by Cock *et al*. (1979).

The significant effect of MBF on number of leaves and stem diameter can be explained through three mechanistic pathways operating synergistically. First, phosphate-solubilizing bacteria in MBF (such as *Bacillus megaterium* and *Penicillium* sp.) excrete organic acids and phosphatase enzymes that dissolve P fixed by Fe and Al in the acidic soil (pH 5.63) at the experimental site, thereby significantly increasing P availability to plants (Timofeeva *et al*., 2023; Zhang *et al*., 2019). Available phosphorus plays a crucial role in ATP synthesis as the primary energy source for cell division and in the composition of phospholipid membranes, directly determining the rate of leaf cell expansion and stem tissue formation. Second, *Azotobacter* and *Azospirillum* in MBF fix atmospheric N2 and produce endogenous phytohormones, particularly indole-acetic acid (IAA) and cytokinin, which stimulate lateral root formation, increase the nutrient absorption surface area, and promote cell division and differentiation of vegetative organs (Aasfar *et al*., 2021; Pii *et al*., 2023). Third, improvement of the rhizosphere microbial community by MBF increases the availability of N and essential micronutrients for chlorophyll biosynthesis, thereby enhancing photosynthesis capacity per unit leaf area (Cai *et al*., 2021). The superiority of MBF over inorganic fertilizer under initially nutrient-poor soil conditions (Total-N 0.92%; available-P <2.06 ppm) reflects the ability of microbial consortia to mobilize nutrients from unavailable fractions, a capacity that single inorganic fertilizers do not possess.

The superiority of Mukibat grafting across all root characteristic parameters (number of productive roots, length, span, tuber diameter) reflects the synergy between increased carbon supply from the *Manihot glaziovii* canopy and the genetic sink capacity of Garuda clone. Mechanistically, higher sucrose flux from source to the root zone drives increased activity of key starch biosynthesis enzymes, particularly ADP-glucose pyrophosphorylase (AGPase), which catalyzes the rate-limiting step in converting glucose-6-phosphate to ADP-glucose as the substrate for starch synthesis (Fu, 2024). This explains why number of productive roots, length, and tuber diameter in grafted plants were consistently superior: the high sink strength of Garuda clone tubers actively draws sucrose supply from the stronger source, resulting in greater starch accumulation per unit root. The wider root span in grafted plants (170.98 vs. 132.28 cm) also indicates more intensive soil exploration, supported by greater carbon availability for new root growth.

The Mukibat grafting system produced a tuber weight of 61.70 kg per 3 plants, a 98.14% increase over cuttings (31.14 kg per 3 plants). This result falls within the upper range reported by Bangthong *et al*. (2022), who documented a 37-100% increase across various planting seasons in Thailand. The difference in magnitude between studies can be biologically attributed to two main factors: (1) the genetic superiority of Garuda clone, which has a high tuber sink strength compared to the local Thai cultivars used by Bangthong *et al*. (2022), and (2) the initially nutrient-poor soil conditions at the experimental site, which received intensive management with microbial-based fertilizer proven to increase P availability and rhizosphere activity. Compared to Radjit & Prasetiaswati (2011), who reported 37-70% increases under East Java conditions, the tuber weight in this study reaching 61.70 kg per 3 plants under the Mukibat system was considerably higher, indicating that the combination of a superior genotype (Garuda clone) with the Mukibat system and MBF can approach the maximum biological potential of cassava. These results also exceed the national average cassava productivity (20-30 t/ha), demonstrating that the yield gap between biological potential and farm-level productivity remains large and can be addressed through cultivation technology innovation.

The stability of starch content (±24%) across all treatments despite nearly doubled tuber weight in the grafting system is an important finding reflecting tight genetic regulation of the starch biosynthesis pathway in Garuda clone. The absence of a dilution effect in grafting indicates that key starch biosynthesis enzymes, particularly granule-bound starch synthase (GBSS) for amylose synthesis and soluble starch synthase (SS) for amylopectin, continued to operate at full capacity proportional to the increased substrate (sucrose) supply (Fu, 2024). In other words, the sink strength of Garuda clone is not limited by the enzymatic capacity of starch biosynthesis, but rather by substrate availability from the source, so that when the source is strengthened through grafting, starch accumulation increases proportionally without concentration dilution. Starch content stability was also maintained across fertilizer treatments, showing that nutritional manipulation affects tuber size (through nutrient availability for cell growth) but does not alter the expression of starch biosynthesis genes genetically controlled by the genotype.

MBF produced a tuber weight of 52.40 kg per 3 plants, a 31.07% increase over inorganic fertilizer (39.98 kg per 3 plants). This increase is larger than the findings of Otaiku (2019) on cassava in Nigeria, who reported 15–20% increases with single biofertilizer. The MBF used in this study employed a multi-microbe consortium (KMP + KMC) providing a more complete ecosystem service: N fixation, P solubilization, phytohormone production, and rhizosphere structure improvement simultaneously (Giri *et al*., 2025). Goat manure produced 47.88 kg per 3 plants, higher than inorganic fertilizer, which can be explained through improvements in soil physical and biological properties: organic matter from manure increases cation exchange capacity, macropore aeration, and water retention, all of which expand root exploration zones and increase nutrient uptake efficiency (Dalorima *et al*., 2021). The increase in total starch weight under MBF treatment (42.95 t/ha) compared to inorganic fertilizer (33.34 t/ha) is a direct consequence of increased tuber weight, not changes in starch content, confirming that MBF operates through the pathway of increasing sink biomass rather than modifying the starch biosynthesis pathway.

The absence of significant interaction between planting material origin and fertilizer type ($p > 0.05$ for all variables) has important mechanistic implications. The Mukibat system operates at the level of increasing source capacity (leaf area and photosynthetic efficiency of the *M. glaziovii* canopy) and optimizing vascular source-sink connectivity, while fertilizer type operates at the level of mineral ion availability in the rhizosphere and hormonal activity in the root zone. Since both factors intervene in different physiological pathways and are not mutually limiting, their effects are additive and independent. This simultaneously shows that Garuda clone responds consistently to increased nutrient availability from MBF in both grafting and cutting systems, without limitations arising from interactions between the two technologies. Practically, this finding implies that adoption of either technology alone (grafting or MBF) already provides significant benefit, and their combination provides additive benefits without requiring complex interaction optimization at the farm level. Although the Mukibat grafting system has been proven to significantly increase productivity, its adoption at the farmer level faces several practical challenges: (1) High technical grafting skill requirements farmers require intensive training, as the grafting failure rate among beginners can reach 20–40%; (2) Limited availability of *M. glaziovii* rootstock in many production centers; (3) Higher seedling production costs (2–3× compared to conventional stem cuttings), necessitating a supportive benefit-cost (B/C) ratio analysis; and (4) Longer seedling preparation duration (3-4 months versus 1 month for stem cuttings). To promote adoption, the following measures are required: development of simplified grafting procedures, organized supply of *M. glaziovii* rootstock, and seedling subsidies or credit access. On the other hand, these challenges also present medium-scale business opportunities for the production and distribution of ready-to-plant Mukibat grafting seedlings, which, if standardized, could become a high-value commodity in the national cassava seed supply chain.

The results of this study provide relevant insights for farmers and agricultural practitioners regarding the actual yield potential achievable under field conditions. When tuber weight is converted to tons per hectare using a planting population of 10,000 plants/ha (spacing of 100×100 cm), the Mukibat grafting system has the potential to yield approximately 205.67 t/ha, while conventional stem cuttings yield approximately 103.80 t/ha. With respect to fertilizer treatments, the application of MBF has the potential to yield approximately 174.67 t/ha, goat manure approximately 159.60 t/ha, and inorganic fertilizer approximately 133.27 t/ha. These figures far exceed the average cassava productivity of farmers in Indonesia (20-30 tons/ha) and even surpass the maximum biological yield potential threshold of improved varieties previously used as a reference (>60 t/ha), thereby providing a strong indication that the implementation of Mukibat grafting combined with MBF can serve as a measurable and practical intensification strategy to increase the income of cassava farmers. It should be noted that the ton/ha conversion values presented here represent projected estimates calculated based on the weight of 3 sample plants, rather than the total harvest weight of the entire plot population; therefore, confirmation through total harvest in subsequent studies remains necessary for further validation.

The novelty of this study lies in integrating source–sink optimization through Mukibat grafting with microbial-based fertilizer (MBF) management in a high-yielding Garuda cassava clone, an approach that rarely been evaluated under

Indonesian agroecosystem conditions. Previous studies have investigated Mukibat grafting (Bangthong *et al*., 2022; Radjit & Prasetiaswati, 2011) and biofertilizer application (Hridya *et al*., 2014; Otaiku *et al*., 2019) separately, with limited information on their combined application in a superior cassava genotype under acidic, nutrient-poor tropical soils. Beyond demonstrating substantial improvements in tuber yield and starch productivity, this study shows that both technologies act through independent physiological pathways without significant interaction, providing new insights into their complementary roles in sustainable cassava intensification. The findings provide practical evidence that integrating source–sink optimization through Mukibat grafting with biologically enhanced nutrient management represents a promising and sustainable strategy to narrow the cassava yield gap and support environmentally friendly production systems.

4. CONCLUSION

Based on the results of this study, it can be concluded that Mukibat grafting technique significantly improves the growth and productivity of Garuda clone cassava compared to conventional cutting. Tuber weight in the Mukibat system reached 61.70 kg per 3 plants, a 98.14% increase over the cutting method (31.14 kg per 3 plants). Although starch content did not differ significantly among treatments (±24%), the substantial increase in tuber weight in the Mukibat system resulted in a 102.77% increase in total starch production per hectare, from 24.90 t/ha (conventional cutting) to 50.49 t/ha (Mukibat). This study also confirmed that Microbial-Based Fertilizer (MBF) produced significantly better growth and yield responses than conventional inorganic fertilizer. Tuber weight under MBF treatment reached 52.40 kg per 3 plants, a 31.07% increase over inorganic fertilizer (39.98 kg per 3 plants). Although fertilizer type had no significant effect on starch content, the increase in tuber weight under MBF contributed to a 28.81% increase in total starch production per hectare, from 33.34 t/ha to 42.95 t/ha. No significant interaction was observed between seed cutting origin and fertilizer type across all observed variables, indicating that plant responses to fertilizer type were consistent and independent in both Mukibat grafted and conventionally cut plants.

AUTHOR CONTRIBUTION

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Ari	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	
SDU	✓	✓		✓	✓		✓			✓		✓	✓	✓
Yus	✓	✓		✓						✓		✓		
FY		✓		✓						✓		✓		
KS					✓					✓				
WAZ							✓						✓	
Kha							✓							✓

C: Conceptualization; M: Methodology; So: Software; Va: Validation; Fo: Formal Analysis; I: Investigation; D: Data Curation; R: Resources; O: Writing - Original Draft; E: Writing - Review & Editing; Vi: Visualization; Su: Supervision; Fu: Funding Acquisition; P: Project Administration

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DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE MANUSCRIPT PREPARATION

Not applicable. The authors did not use any generative AI tools or services in the preparation of this manuscript. All content is entirely the intellectual work of the authors.

REFERENCES

Aasfar, A., Bargaz, A., Yaakoubi, K., Hilali, A., Bennis, I., Zeroual, Y., & Kadmiri, I.M. (2021). Nitrogen fixing *Azotobacter* species as potential soil biological enhancers for crop nutrition and yield stability. *Frontiers in Microbiology,* ***12***, 628379. https://doi.org/10.3389/fmicb.2021.628379

Bangthong, P., Vuttipongchaikij, S., Kongsil, P., Ceballos, H., & Kittipadakul, P. (2022). Evaluation of *Manihot glaziovii* scion-cassava understock grafting for cassava growth and root yield during rainy and dry seasons. *Journal of Crop Improvement,* ***36***(2), 193–206. https://doi.org/10.1080/15427528.2021.1931609

Bhatt, M.K., Labanya, R., & Joshi, H.C. (2019). Influence of long-term chemical fertilizers and organic manures on soil fertility: A review. *Universal Journal of Agricultural Research,* ***7***(5), 177–188. https://doi.org/10.13189/ujar.2019.070502

BPS (Badan Pusat Statistik). (2024). *Statistik Pertanian 2024* (Agricultural Statistics 2024). Pusat Data dan Sistem Informasi Pertanian, Kementerian Pertanian Republik Indonesia, Jakarta. ISBN: 978-602-6726-68-8.

Cai, J., Zhang, J., Ding, Y., Yu, S., Lin, H., Yuan, Z., Li, K., Ou, W., & Chen, S. (2021). Different fertilizers applied alter fungal community structure in rhizospheric soil of cassava (*Manihot esculenta* Crantz) and increase crop yield. *Frontiers in Microbiology,* ***12***, 663781. https://doi.org/10.3389/fmicb.2021.663781

Chiewchankaset, P., Thaiprasit, J., Kalapanulak, S., Wojciechowski, T., Boonjing, P., & Saithong, T. (2022). Effective metabolic carbon utilization and shoot-to-root partitioning modulate distinctive yield in high yielding cassava variety. *Frontiers in Plant Science,* ***13***, 832304. https://doi.org/10.3389/fpls.2022.832304

Cock, J.H., Franklin, D., Sandoval, G., & Juri, P. (1979). The ideal cassava plant for maximum yield. *Crop Science,* ***19***(2), 271–279. https://doi.org/10.2135/cropsci1979.0011183X001900020025x

Dalorima, T., Sakimin, S.Z., & Shah, R.M. (2021). Utilization of organic fertilisers: A potential approach for agronomic crops: A review. *Plant Science Today,* ***8***(1), 190–198. https://doi.org/10.14719/pst.2021.8.1.1045

Eviati, Sulaeman, Herawaty, L., Anggria, L., Usman, Tantika, H.E., Prihatini, R., & Wuningrum, P. (2023). *Petunjuk Teknis Analisis Kimia Tanah, Tanaman, Air dan Pupuk* (Edisi ke-3). Balai Pengujian Standar Instrumen Tanah dan Pupuk, Bogor. https://repository.pertanian.go.id/handle/123456789/24650

Fu, J. (2024). Biochemical pathways of starch synthesis in cassava: Genetic bases and breeding implications. *Plant Gene and Trait,* ***15***(3), 108–117. https://doi.org/10.5376/pgt.2024.15.0012

Giri, A., Verma, R., & Mehta, S. (2025). Biofertilizers: A sustainable solution for enhanced crop yield and soil health in modern agriculture. *International Journal of Plant & Soil Science,* ***37***(8), 562–576. https://doi.org/10.9734/ijpss/2025/v37i85656

Hridya, A.C., Byju, G., & Misra, R.S. (2014). Effects of microbial inoculations on soil chemical, biochemical and microbial biomass carbon of cassava (*Manihot esculenta* Crantz) growing Vertisols. *Archives of Agronomy and Soil Science,* ***60***(2), 239–249. https://doi.org/10.1080/03650340.2013.791023

Kaul, S., Sharma, S., Apra, & Dhar, M.K. (2019). Phosphate-solubilising fungi and their potential role in sustainable agriculture. In B. Giri, R. Prasad, Q.S. Wu, & A. Varma (Eds.), *Biofertilizers for sustainable agriculture and environment* (pp. 371–393). Springer. https://doi.org/10.1007/978-3-030-18933-4_17

Opoku-Agyemang, F., Amissah, J.N., Owusu-Nketia, S., Ofori, P.A., & Notaguchi, M. (2024). Optimization of cassava (*Manihot esculenta* Crantz) grafting technique to enhance its adoption in cassava cultivation. *MethodsX,* ***13***, 102904. https://doi.org/10.1016/j.mex.2024.102904

Otaiku, A.A., Mmom, P.C., & Ano, A.O. (2019). Biofertilizer impacts on cassava (*Manihot esculenta* Crantz) rhizosphere: Crop yield and growth components, Igbariam, Nigeria – Paper 1. *World Journal of Agriculture and Soil Science,* ***3***(5), 000575. https://doi.org/10.33552/WJASS.2019.03.000575

Pii, Y., Penn, A., Terzano, R., Crecchio, C., Mimmo, T., & Cesco, S. (2015). Plant-microorganism-soil interactions influence the Fe availability in the rhizosphere of cucumber plants. *Plant Physiology and Biochemistry,* ***87***, 45–52. https://doi.org/10.1016/j.plaphy.2014.12.014

Purwanto, B.H., & Alam, S. (2020). Impact of intensive agricultural management on carbon and nitrogen dynamics in the humid tropics. *Soil Science and Plant Nutrition*, *66*(1), 50–59. https://doi.org/10.1080/00380768.2019.1705182

Pusdatin Kementan (Pusat Data dan Sistem Informasi Pertanian, Kementerian Pertanian RI). (2020). *Outlook Komoditas Ubi Kayu 2020*. Kementerian Pertanian RI, Jakarta.

Radjit, B., & Prasetiaswati, N. (2011). Potensi hasil umbi dan kadar pati pada beberapa varietas ubikayu dengan sistim sambung (Mukibat). *Buana Sains, **11***(1), 35–44.

Saleh, N., Taufiq, A., Widodo, Y., Sundari, T., Gusyana, D., Rajagukguk, R.P., & Suseno, S.A. (2016). *Pedoman budi daya ubi kayu di Indonesia*. IAARD Press.

Shahwar, D., Mushtaq, Z., Mushtaq, H., Alqarawi, A.A., Park, Y., Alshahrani, T.S., & Faizan, S. (2023). Role of microbial inoculants as bio fertilizers for improving crop productivity: A review. *Heliyon, **9***(6), e16134. https://doi.org/10.1016/j.heliyon.2023.e16134

Timofeeva, A.M., Galyamova, M.R., & Sedykh, S.E. (2023). Plant growth-promoting soil bacteria: Nitrogen fixation, phosphate solubilization, siderophore production, and other biological activities. *Plants, **12***(24), 4074. https://doi.org/10.3390/plants 12244074

Triana, M., Yusnita, Y., Utomo, S. D., Hapsoro, D., & Yelli, F. (2025). Effect of Indole Butyric Acid (IBA) application and spliced grafting on the growth of garuda clone cassava. *Jurnal Teknik Pertanian Lampung*, ***14***(6), 2046–2056. https://doi.org/10.23960/jtepl.v14i6.2046-2056

Utomo, S.D., Laksmana, D., & Edy, A. (2025). Cassava cultivar development toward attainment of zero hunger: Variation of morphological and agronomic characters and selection on F1 population. *SDGs Review, **5***(6), e06928. https://doi.org/10.47172/2965-730X.SDGsReview.v5.n06.pe06928

Waluyo, T. (2020). Pemanfaatan hormon tumbuh organik untuk meningkatkan produktivitas singkong hasil eksplorasi seleksi bibit unggul. *Jurnal Ilmu dan Budaya, **41***(70). https://doi.org/10.47313/jib.v41i70.923

Zhang, J., Liu, Y.-X., Zhang, N., Hu, B., Jin, T., Xu, H., Qin, Y., Yan, P., Zhang, X., Guo, X., Hui, J., Cao, S., Wang, X., Wang, C., Wang, H., Qu, B., Fan, G., Yuan, L., Garrido-Oter, R., Chu, C., & Bai, Y. (2019). NRT1.1B is associated with root microbiota composition and nitrogen use in field-grown rice. *Nature Biotechnology, **37***, 676–684. https://doi.org/10.1038/s41587-019-0104-4