Pertanika J. Trop. Agric. Sci. 49 (2): 985 - 996 (2026)

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Optimising Glucomannan Production in *Amorphophallus oncophyllus* by Varying Tuber Size and Fertiliser Source

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ABSTRACT

Amorphophallus oncophyllus is widely cultivated in Indonesia to obtain starch and glucomannan content. The low productivity of the *A. oncophyllus* plant, which is only 6-12 tons ha^{-1} of fresh tubers, may be attributed to cultivation techniques that are still not intensive and remain dependent on natural harvest. The use of fertiliser type and tuber size is very important to increase production, as well as being efficient with the planting material used. The aim of this research is to evaluate the effect of inorganic fertiliser types (urea fertiliser, ammonium sulfate fertiliser and NPK fertiliser) and tuber size (whole tubers weighing 100 g, large tuber weighing 200 g (cut into 2 pieces), tuber 300 g (cut into 3 pieces) and tuber 400 g (cut into 4 pieces) on the growth and glucomannan content of *A. oncophyllus*. The results showed that statistical analysis showed no interaction between fertiliser type and tuber size treatments. Fertiliser type has an effect on stem diameter at 8 weeks after planting (WAP). Seed tuber portions influenced only the parameters of tuber number, tuber weight, and tuber diameter at the end of the observation period. The whole tuber treatment product relatively larger stem diameter at 11 weeks after planting (WAP), tuber diameter, and tuber weight compared with the half-tuber portion treatment. Our findings indicate that the whole tuber (100 g) has a relatively significant influence on tuber growth and glucomannan yield, providing important insights for commercial cultivation strategies.

Keywords: Glucomannan, inorganic fertiliser, tuber seeds

ARTICLE INFO

Article history:
Received: 20 November 2024
Accepted: 15 April 2026
Published: 30 April 2026

DOI: https://doi.org/10.47836/pjtas.49.2.26

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INTRODUCTION

Amorphophallus oncophyllus is widely cultivated in Indonesia to obtain starch and glucomannan content (Nurlela et al., 2019). It has a polysaccharide substance consisting

e-ISSN: 2231-8542

of randomly arranged α-mannose and α-glucose β-1,4. Glucomannan has broader benefits than cellulose and galactomanan. *A. oncophyllus* cultivation can be used as an alternative food and household food supply. People in mountainous areas usually plant *A. oncophyllus* under the canopy of trees or grow it wild without fertiliser input, but it is still useful for the economy.

There are fundamental things that need to be added as an effort to increase *A. oncophyllus* productivity. The average *A. oncophyllus* productivity is 6-12 tons ha^{-1} of wet tubers. Potential production can reach more than 40 tons ha^{-1} (Rahmawati 2023). The low productivity of *A. oncophyllus* plants is partly due to cultivation techniques that are still not intensive and still depend on natural harvests. *A. oncophyllus* cultivation techniques still need to be researched a lot, so agronomic improvements and planting materials still need to be reviewed, due to current conditions, the use of planting materials in farming is still inefficient.

The addition of inorganic NPK fertiliser is one way to improve agronomy in *A. oncophyllus* plants. Fertiliser dose of 50 kg N ha^{-1} and 100 kg ha^{-1} K2O to increase tuber weight 1 week after planting (Dewanti 2023). Potassium is the most important nutrient in all root crops for increasing yield and tuber quality (Torabian et al., 2025) and starch content (Berisha et al., 2014). Farmers in Amorphophallus cultivation prefer larger tubers as planting material so as to produce large tuber tillers. Plant growth is influenced by the size of the tubers, because the tuber contains food reserves that are useful for growth. Tuber planting material that is large in size can produce tuber weight and high glucomannan content.

Therefore, planting materials are used in large pieces of tubers. Planting material with the size of the whole tuber and the upper half with the main shoot produces larger tubers and plant height (Dewanti et al., 2023). However, research on different types of inorganic fertilisers and planting material sizes in Amorphophallus is still limited. The use of fertiliser type and tuber size is very important to increase production, as well as being efficient with the planting material used. The purpose of this research is to evaluate the effect of inorganic fertiliser type and tuber size on the growth and glucomannan content of *A. oncophyllus* plants.

MATERIALS AND METHODS

Experimental Site and Design

The experiment was conducted at the experimental Farm of the Faculty of Agriculture, VeteranNational Development University, East Java, Indonesia (at an altitude of 300 above sea level). Table 1 presents the set of experimental conditions used for the research. The study used a randomised complete block design (RCBD) with 2 factors (factor 1: fertiliser type and factor 2: seed tuber size) and 3 replications.

Table 1
Environmental conditions during the experiment

Variable	Environmental Conditions of Assessment
Average rainfall	255 mm
Minimum temperature	22^0 C
Maximum temperature	33^0 C
Average temperature	26^0 C
Average humidity	83%
Soil type	Lithosol
Altitude	300 asl

Note. Data are presented from the measurement results

The first factor used the types of inorganic fertiliser consisting of 3 levels: Urea fertiliser (Nitrogen 46%) 2 g/plant, Ammonium sulfate fertiliser (Nitrogen 21%, Sulfur 24%) 2 g/plant, and NPK fertiliser (Nitrogen 15%, Phosphorus 15%, Potassium 15%) 2 g/plant. Meanwhile, the second factor used tuber size of *A. oncophyllus*, namely whole tubers (100 g), large tubers weighing 200 g (cut vertically into 2 parts / 1/2 section), large tubers weighing 300 g (cut vertically into 3 parts / 1/3 section), and large tubers weighing 400 g (cut vertically into 4 parts / 1/4 section). These larger tubers are divided so that each piece weighs approximately 100 g. The data were obtained from 5 plant samples in each replication.

Planting Material and Preparation

A. oncophyllus tuber seeds were sourced from the area of Saradan Village, Madiun Regency, East Java (7°32′20″S 111°46′36″E). The tuber planting material is 1 year old (12 months). *A. oncophyllus* tuber seed used in the study consisted of whole tuber (100 g), large tubers weighing 200 g (cut vertically into 2 parts /1/2 section), large tubers weighing 300 g (cut vertically into 3 parts /1/3 section), and large tubers weighing 400 g (cut vertically into 4 parts /1/4 section). These larger tubers are divided so that each piece weighs approximately 100 g. Before planting, the part of the tuber that is split is smeared with rubbing ash from wood-burning waste to protect the exposed parts from rot caused by soil microorganisms. The way to plant tubers is to position the shoot at the top for both whole tubers and split tubers.

A. oncophyllus tubers were planted in a mixture of soil and leaf litter compost (1:1; v/v) with a polybag size of 35x35 cm filled to a maximum of ⅘ part. The planting distance between polybags was 50x50 cm with a planting depth of 15 cm. *A. oncophyllus* tubers that have been used have gone through a sorting process based on the weight of the treatment. The application of inorganic fertiliser treatments was carried out when *A. oncophyllus* had grown (at 4 and 10 weeks after planting). Fertilisation was done by placing the fertiliser in the soil around the *A. oncophyllus* stem.

Growth and Yield Observation

Observations of *A. oncophyllus* plants were carried out from 1 to 22 weeks after planting (WAP). Stem diameter variables were observed at the bottom of the plant, 5-7 cm from the soil surface (Figure 1). The number of bulbils was counted per plant manually when the bulbils had appeared. Tubers were harvested, and the weight of fresh tubers was continued to be measured at the age of 22 weeks as data on tuber growth and development. The weight of tuber flour is generated from weighing 0.5-1 g of the sample in a 250 mL glass cup. Then 50 mL of 96% alcohol was added and stirred for 1 hour.

Figure 1. Measurement of the stem diameter of *Amorphophallus oncophyllus* plants

Glucomannan Content Analysis

The glucomannan content is obtained from *A. oncophyllus* tubers, washed and cleaned of the soil attached, the skin is removed, and then shredded. Mix the grated tubers into 200 mL of 0.3% aluminum sulfate. Then stirred for 15 minutes in a water bath at 55 °C and diluted to three times the volume. Furthermore, the mixture was then centrifuged at 1500 x g for 30 minutes to produce a supernatant. The supernatant was mixed with 95% alcohol at a ratio of 1:1, and a clot was produced. Then, the clot was separated and dried in an oven at 45 °C for 24 hours. The dried clots were weighed. The ratio between the dried glucomannan lumps and the weight of the extracted *A. oncophyllus* tubers was calculated as the glucomannan yield (Wardhani et al., 2020).

Data Analysis

The data obtained were subjected to an ANOVA test. Variables that showed a significant effect due to treatment were tested using Least Significant Difference (LSD), $\alpha = 5\%$, using Microsoft Excel 2010 version.

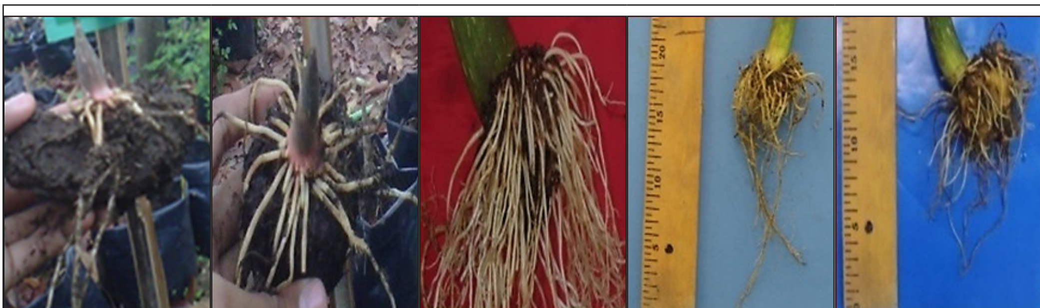
RESULTS AND DISCUSSION

Figure 2 describes the growth stages of the vegetative phase of the *Amorphophallus oncophyllus* plant. It shows the 5 stages of vegetative development of *A. oncophyllus* tuber plants to be studied. The first stage, the seedling tubers after planting began to appear, with shoot and root growth during 3 weeks after planting (WAP) (Figure 2A).

The condition of the tuber seedlings is still the same at the beginning of planting, then shoot and root elongation begin to accelerate at the age of 5 weeks after planting (Stage 2) (Figure 2B). The tubers exhibited changes in shape and size, becoming smaller due to the translocation of photosynthetate for the development of stems, leaves, and root elongation at the age of 8 weeks after planting (Stage 3) (Figure 2C). The observations have been reinforced by Yadav and Singh (2024) that 70-170 days after planting is the period of stem elongation as sink organs. It's time for the source and sink transition. Stage 4 has begun the formation of tubers from assimilate producers (leaves) at the age of 12 weeks after planting (Figure 2D). Growth and enlargement of tubers have been seen at the age of 20 weeks (Stage 5) (Figure 2E).

There was a significant effect on the stem diameter of *A. oncophyllus* plants among each tuber division treatment at the age of 7-11 weeks after planting, although at the age of 12 weeks after planting, there was no difference (Table 2). Whole tubers produced a 32% higher stem diameter compared to split tubers at the age of 7-11 weeks after planting. Without paying attention to the whole tuber treatment, there was no significant difference in stem diameter between the split tuber 2, split tuber 3, and split tuber 4 treatments at the age of 7-9 weeks after planting. Intact tubers produced a petiole diameter of 31.6% greater in *A. oncophyllus* plants than the planting material of the halved tubers; moreover, the weight of each tuber is the same at 100 g.

Table 3 shows that NPK fertiliser produced the relatively highest number of *A. oncophyllus* bulbils at 1.67 compared to urea and ammonium sulfate fertilisers at the age of 12 weeks after planting. The bulbs parameter, with the addition of NPK fertiliser treatment, increased by 89.7% from the age of 7-12 weeks after planting. This is because NPK fertiliser contains phosphorus (15%), nitrogen (15%) and potassium (15%).



(A) (B) (C) (D) (E)

Figure 2. Developmental stages of the vegetative development cycle. (A) tuber seeds have started to appear shoots and roots at the age of 3 WAP; (B) elongation of shoots and roots at 5 WAP; (C) tuber shrinkage and formation of leaves, stems and roots at 8 WAP; (D) tuber formation at 12 WAP; (E) increase and growth of tubers aged 20 WAP

Table 2
Stem diameter of Amorphophallus oncophyllus plants with different types of fertiliser and portion of tuber seeds

Treatments	Stem Diameter (mm)					
	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP	12 WAP
Inorganic Fertiliser						
Urea (P1)	2.67	3.57^{b}	3.87	4.33	4.59	4.66
Ammonium Sulfate (P2)	1.83	2.62^{a}	3.37	3.94	4.34	4.42
NPK (P3)	2.83	3.54^{b}	3.64	3.88	4.17	4.04
LSD 5%	ns	0,88	ns	ns	ns	ns
Tuber Seeds						
Whole (U1)	3.64^{b}	4.20^{b}	4.51^{b}	4.74^{b}	5.00^{b}	5.05
1/2 Section (U2)	2.31^{ab}	3.05^{a}	3.10^{a}	3.49^{a}	3.78^{a}	3.90
1/3 Section (U3)	1.68^{a}	2.68^{a}	3.28^{a}	3.94^{a}	4.20^{ab}	4.03
1/4 Section (U4)	2.15^{a}	3.05^{a}	3.62^{a}	4.02^{ab}	4.49^{ab}	4.53
LSD 5%	1.41	1.07	0.85	0.79	0.84	ns

Note. Means followed by different letters in the same column indicated significant differences at LSD 5%. ns: not significant

Table 3
Number of bulbs of Amorphophallus oncophyllus plants with different types of fertiliser and portion of tuber seeds

Treatments	Number of Bulbs		
	10 WAP	11 WAP	12 WAP
Inorganic Fertiliser			
Urea (P1)	1.06	1.46	1.66
Ammonium Sulfate (P2)	0.80	1.16	1.58
NPK (P3)	0.88	1.46	1.67
LSD 5 %	ns	ns	ns
Tuber Seeds			
Whole (U1)	1.30^{b}	1.97^{b}	1.99
1/2 Section (U2)	0.76^{a}	1.04^{a}	1.55
1/3 Section (U3)	0.89^{a}	1.14^{a}	1.39
1/4 Section (U4)	0.71^{a}	1.29^{a}	1.61
LSD 5 %	0.39	0.56	ns

Note. Means followed by different letters in the same column indicated significant differences at LSD 5%. ns: not significant

Potassium content functions in the formation of bulbils, because potassium affects K + ions to bind water in plants and accelerate the rate of photosynthesis so as to stimulate the formation of bulbs (Johnson et al., 2022). Potassium plays a role in maintaining osmotic pressure and cell turgor so that water absorption in the transpiration process runs well (Supriyono et al., 2022). The element P also plays a role in carbohydrate and protein metabolism and the transfer of energy and carbohydrates from leaves to all parts of the plant, including bulbils (Wang et al., 2021). Phosphorus has a role in stimulating root growth, helping the fruit ripening process, helping plant respiration, and forming protein (Sardans & Peñuelas, 2021).

The formation of tubers through the process of cell development and multiplication will be followed by the enlargement of cells containing starch grains. The type of fertiliser did not have a significant effect on the variables of tuber diameter and tuber weight at the age of 16-22 weeks after planting (Table 4). The results of tuber weight in urea, ammonium sulfate, and NPK fertiliser treatments were 6.70 g, 6.94 g, and 5.58 g at the age of 22 weeks after planting. This is due to the fulfilment of the needs of essential elements of phosphorus and potassium, which play a role in the formation and enlargement of tubers in the process of starch synthesis. Potassium elements act as enzyme activators and affect the metabolic process of carbohydrate formation so that carbohydrates accumulate in tubers (Simelane et al., 2023).

Table 4
Tubers' diameter and weight of Amorphophallus oncophyllus plants with different types of fertiliser and portions of tuber seeds

Treatments	**Corm Size**	
	Diameter (cm)	**Weight (g)**
Inorganic Fertiliser		
Urea (P1)	1.71	6.70
Ammonium Sulfate (P2)	1.68	6.94
NPK (P3)	1.60	5.58
LSD 5 %	ns	ns
Tuber Seeds		
Whole (U1)	1.88 ^{b}	8.45^{b}
1/2 Section (U2)	1.56 ^{a}	5.21^{a}
1/3 Section (U3)	1.54 ^{a}	5.32 ^{ab}
1/4 Section (U4)	1.67 ^{ab}	6.65 ^{ab}
LSD 5 %	0.30	3.21

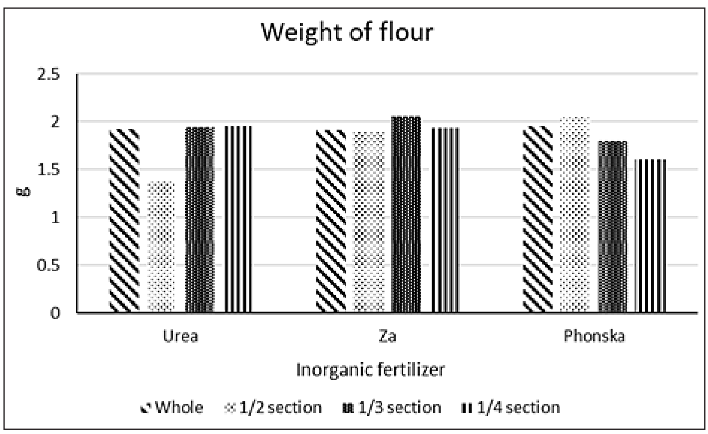
Note. Data are presented from the measurement results

The results of tuber diameter in the treatment of urea, ammonium sulfate, and NPK fertilisers were 1.71, 1.68 and 1.60 at the age of 22 weeks after planting. Tuber weight and diameter were significantly affected by the treatment of tuber division at the age of 19 to 22 weeks after planting (Table 4). Differences in weight and storage capacity of food reserves in *A. oncophyllus* tubers used as plant seeds (Soedarjo, 2021). The results of tuber weight in the whole tuber division treatment amounted to 8.45 g, quadruple division amounted to 6.65 g, and triple division amounted to 5.32 g. The rate of tuber weight gain in the whole tuber division treatment amounted to 5.32 g. The rate of tuber weight gain in the whole tuber division treatment was 26.7% at the age of 16-22 weeks after planting. The diameter of the whole tuber treatment was 1.88, which was relatively higher compared to the 1/4 section treatment, which was 1.67. The diameter of the whole tuber treatment was higher and significantly different from the two-split and three-split tubers. The increase in the diameter of the tubers from the whole tuber treatment was 11.2% higher than the rhombic treatment by 5.7% at the age of 16 to 22 weeks after planting. Whole-size tubers produced better diameter development and bulbil yield, but not significantly so at the end of the observation. Seed tuber size can affect food reserves used during early growth and embryo maturity at the point of growth. The size of the seed tuber will affect the provision of nutrients used in the formation of vegetative periods such as buds, roots, stems and subsequent growth (Triharyanto et al., 2022).

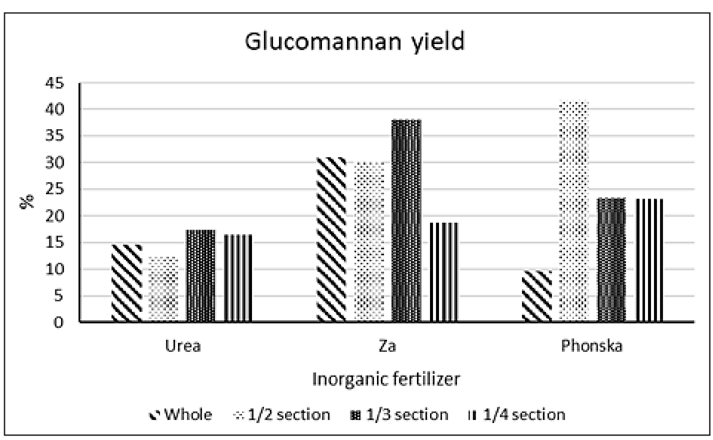
The presence of apical buds in intact tuber seedlings is important for the early emergence of buds to become leaves, stems and roots. When the apical bud of tuber seedlings is damaged, it can cause inhibition of growth and early development of stem diameter (Table 2). The presence of apical buds is very important for the initial growth of *A. oncophyllus* plants; if the buds have been damaged, it will inhibit the growth of the vegetative phase. The stem weight experienced greater enlargement in seedlings of whole tuber portions, and tuber pieces were also reported in *A. oncophyllus* plants (Dewanti et al., 2023). Moreover, research that has been conducted shows that the portion of tuber seedlings with damaged apical buds (due to splitting) produces a smaller stem diameter than intact tubers that have intact apical buds, resulting in a decrease in yield (Tables 2, 3, and 4). The results of this study are in line with Nurhalim et al., (2023) uncut or intact tubers independently produce more production than the sweet potato tuber cutting treatment. In addition, whole tubers with a weight of 100 g produce higher production compared to 100 g tuber pieces.

Utilisation of *A. oncophyllus* tubers into flour is one option to facilitate storage and further processing. Selected *A. oncophyllus* tubers are then sliced vertically as thick as (0.5-1 cm), followed by drying, which is called chip. *A. oncophyllus* flour contains a fairly high glucomannan content of 64.98%. The largest glucomannan content in *A. oncophyllus* flour ranges between 49-60% (Shi et al., 2019). Glucomannan is a polysaccharide consisting of galactose, glucose, and mannose chain bonds. The main chain bonds are glucose and mannose, while the branch is galactose (Aanisah et al., 2022). Glucomannan is a water-soluble dietary fibre that is a strong hydrocolloid and low in calories. Glucomannan also has special physical properties, namely being able to expand in water up to 138-200% (Herawati et al., 2022).

There was no interaction between the type of fertiliser and the portion of tuber seeds on flour weight and glucomannan yield (Figure 3). Figure 3 shows that *A. oncophyllus* plants produce flour weight and glucomannan yield percentage that vary between 1.6-2.05 g and 9.65-41.80%. Two-split tuber seedlings with the addition of NPK fertiliser relatively increased 48.9% in flour weight compared to the addition of urea, thus affecting the amount of glucomannan yield of 41.80%.



(A)



(B)

Figure 3. (A) Flour weight and (B) Glucomannan yield of *Amorphophallus oncophyllus* plants with different types of fertiliser and portion of tuber seeds

This shows that the two parameters are directly proportional, namely, the higher the weight of *A. oncophyllus* flour produced, will increase the amount of glucomannan yield content. Glucomannan has a strong relationship with yield (Setiavani & Suarti, 2023).This study has implications for the use of fertiliser types in order to agronomically improve the productivity of *A. oncophyllus*. Urea and NPK showed greater stem diameter growth than Ammonium Sulfate fertiliser at 8 weeks of age (Table 2). However, the application of fertiliser types showed similar results between treatments on the number of bulbils, diameter and weight of bulbs, flour weight, and glucomannan yield (Tables 2, 3, 4, and Figure 3). The application of urea fertilisers in this study relatively increased stem diameter, number of bulbs, and corm size, but the use of ammonium sulfate and NPK fertiliser relatively affected the weight of flour and glucomannan, which were higher compared to urea. It was also reinforced by Beja and Apelabi (2019) that the combination of urea, SP36, and NPK fertilisers gave the best results on the wet weight of sweet potato tubers compared to urea fertiliser alone.

Finally, the research also provides benefits in improving the cultivation of *A. oncophyllus* plants by using the portion of tuber seedlings to streamline planting materials. The use of seedling tuber portions can be recommended to produce the same flour weight and glucomannan yield as whole tuber planting material. However, the use of tuber seed portions needs to be considered again and done carefully so that the bud eyes are not damaged. In this study, the mechanisms observed due to the portion of tuber seeds, namely growth inhibition (Table 2) and reduction in crop yields (Table 4). In line with research by Hidayatullah et al., (2020) Plant morphology that has strong vigour will result in high production of taro tubers. However, the portion of tuber seeds has not been proven to produce heavy starch and glucomannan content (Figure 3). In contrast to Maretta et al., (2023) the diameter, length, and weight of taro tubers have a direct and indirect effect on glucomannan content. Further studies are needed to look at the *A. oncophyllus* plant tubers on the use of fertiliser types and portions of tuber seeds.

CONCLUSION

Portion of tuber seeds as planting material influenced only the parameters of bulb number, bulb weight and bulb diameter in the final observation. Meanwhile, the use of fertiliser types have affect to stem diameter 8 WAP. The size of the stem diameter at 11 WAP, tuber diameter and tuber weight in the whole treatment reached 89%, 21% and 62% higher than in the 1/2 section treatment. The type of fertiliser treatment showed that the stem diameter results at age 8 WAP were 36.2% better, as shown by the application of Urea fertiliser. Our results suggest that seed size significantly impacts tuber growth and glucomannan yield, providing crucial insights for commercial cultivation strategies.

ACKNOWLEDGEMENT

This research was partially supported by Dikti (Directorate General of Higher Education).

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