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Advancing Porang (*Amorphophallus muelleri*) Growth in Red-Yellow Podzolic Soils: An Experimental Analysis of Solid Guano and Liquid organic fertilizer Interaction

*Avanzando en el Crecimiento de Porang (*Amorphophallus muelleri*) en Suelos Podzólicos Rojo-Amarillos: Un Análisis Experimental de la Interacción entre el Guano Sólido y el Fertilizante Orgánico Líquido*

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ABSTRACT

Porang (*Amorphophallus muelleri*) represents one of Indonesia's rich tuberous biological resources, functioning as a plant that yields carbohydrates, fats, proteins, minerals, vitamins, and dietary fibers. Porang has long been employed as a raw material in the food industry, notably in konnyaku production. However, this plant's growth is often suboptimal, especially when cultivated in nutrient-poor soils like red-yellow podzolic soil. This study iaims is to understand the interaction and find the best combination of solid guano fertilizer (GF) and liquid organic fertilizer (LOF) on the growth of porang in red-yellow podzolic soil. The study was conducted experimentally using a complete randomized design (CRD) factorial comprising two factors. Factor G (GF) and factor T (LOF) had three levels. The data collected was statistically analyzed using variance analysis, followed by Duncan's new multiple range test (DNMRT) at the 5% level. The study results indicate that applying GF and LOF on porang growth significantly influences plant height, stem diameter, leaf stalk number, and lateral root number for each treatment. G2T2 (GF application of 400 g per polybag and LOF of 6 ml/l) demonstrated the best results among all treatments. Furthermore, the interaction between the two treatments significantly impacted the number of leaf stalks and lateral roots. In conclusion, this research provides compelling evidence that the combined use of GF and LOF can significantly enhance the growth of porang plants, particularly in nutrient-deficient soils.

Keywords: *Amorphophallus muelleri*, red-yellow podzolic soil, solid guano fertilizer (GF), liquid organic fertilizer (LOF), plant growth optimization.

RESUMEN

*El porang (*Amorphophallus muelleri*) representa uno de los ricos recursos biológicos tuberosos de Indonesia, funcionando como una planta que produce carbohidratos, grasas, proteínas, minerales, vitaminas y fibras dietéticas. El porang ha sido utilizado durante mucho tiempo como materia prima en la industria alimentaria, especialmente en la producción de konnyaku. Sin embargo, el crecimiento de esta planta suele ser subóptimo, especialmente cuando se cultiva en suelos pobres en nutrientes como el suelo podzólico rojo-amarillo. El objetivo de este estudio es comprender la interacción y encontrar la mejor combinación de fertilizante de guano sólido (FG) y fertilizante orgánico líquido (FOL) en el crecimiento del porang en suelo podzólico rojo-amarillo. El estudio se realizó experimentalmente utilizando un diseño factorial completamente aleatorizado (DFA), que comprende dos factores. El factor G (FG) constaba de tres niveles, y el factor T (FOL) también constaba de tres niveles. Los datos recopilados se analizaron estadísticamente mediante análisis de varianza, seguido de la prueba de rango múltiple nuevo de Duncan (DNMRT) al nivel del 5%. Los resultados del estudio indican que la aplicación de FG y FOL en el crecimiento del porang influye significativamente en la altura de la planta, el diámetro del tallo, el número de tallos de hojas y el número de raíces laterales para cada tratamiento. Entre todos los tratamientos, G2T2 (aplicación de FG de 400 g por bolsa de polietileno y FOL de 6 ml/l) demostró los mejores resultados. Además, la interacción entre los dos tratamientos influyó significativamente en el número de tallos de hojas y raíces laterales. En conclusión, esta investigación proporciona evidencia convincente de que el uso combinado de FG y FOL puede mejorar en gran medida el crecimiento de las plantas de porang, particularmente en suelos deficientes en nutrientes.*

***Palabras clave**:* Amorphophallus muelleri*, suelo podzólico rojo-amarillo, fertilizante de guano sólido (FG), fertilizante orgánico líquido (FOL), optimización del crecimiento de las plantas.*

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Introduction

Porang (*Amorphophallus muelleri*), a rich source of carbohydrates, fats, proteins, minerals, vitamins, and dietary fibers, is significant in Indonesia's tuberous biological resources (Wahidah *et al*., 2021). Its diverse nutritional content has led to its wide usage in the food industry, prominently as a raw material for glucomannan production (Pasaribu *et al*., 2020). Despite its economic potential, the cultivation of porang still needs to be developed, with farmers typically only harvesting and utilizing plants growing wild in the forest. This form of harvesting has contributed to an underdeveloped cultivation practice of porang. In reality, beginning in the early 1970s, there was an interest in farming porang due to its high economic value and potential for profitability, given that the contents of porang can be used as functional food beneficial to health (Saleh *et al*., 2015). However, the cultivation of porang poses challenges, particularly when grown in nutrient-deficient soils such as red-yellow podzolic soils (Santosa *et al*., 2016).

Podzolic soils are characterized by their nutrient impoverishment, acidity, and physical degradation, which have been recognized as significant hindrances to agricultural productivity (Al-Kaisi and Lowery, 2016). This soil type typically exhibits a high potential for aluminum toxicity and is deficient in organic matter. Moreover, it is poor in nutrient content, particularly phosphorus and exchangeable cations such as calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K), and has a high aluminum content. This leads to a low cation exchange capacity and a susceptibility to erosion (Huntley, 2023; Munawar and Wiryono, 2019). As such, efforts to enhance the growth of economically valuable plants, like porang, in such challenging conditions have centered on optimizing fertilizer application (Ho *et al*., 2022).

In recent years, the use of organic fertilizers such as solid guano and liquid organic fertilizer (LOF) has gained traction due to their environmentally friendly attributes and ability to improve soil fertility (Haryanta *et al*., 2023; Santana-Sagredo *et al*., 2021; Szpak *et al*., 2012). Guano, an organic fertilizer derived from bat or bird droppings, has contributed positively to plant growth by enriching the soil with essential nutrients (Dimande *et al*., 2023). Similarly, LOFs have been recognized for enhancing plant nutrient uptake, stimulating plant growth, and improving soil structure (Haryanta *et al*., 2023; Palm *et al*., 2014). However, the interplay between these two types of organic fertilizers, , remains relatively to be explored, especially in porang cultivation in red-yellow podzolic soils. Consequently, this study seeks to fill this knowledge gap by investigating the interaction between solid guano fertilizer and LOF, aiming to discover the best combination of these fertilizers to optimize porang growth.

Materials and Methods

Research Location and Materials

This study was conducted in the experimental garden of the Faculty of Agriculture, Universitas Lancang Kuning, Pekanbaru, Indonesia (0º34'37.6"N 101º25'31.7"E). The soil type used was red-yellow podzolic soil, sourced from the topsoil layer at 0-20 cm depth and sifted through a 20-mesh sieve. The physicochemical properties of the soil used can be seen in Table 1. The research location features a flat topography with an elevation of 16 meters above sea level, with temperatures ranging from 24-35 ºC and humidity levels between 80-95%.

The materials required for this study were porang tubers obtained from the Legumes and Tubers Crops Research Institute, Indonesia (Balai Penelitian Tanaman Aneka Kacang dan Umbi - Balitkabi). The planting material used was carefully selected tubers. Only healthy, uniformly-sized tubers weighing 5 grams were chosen, with a total of 108 tubers required for the study. The solid guano and liquid organic fertilizers used in this study were commercially available products, i.e., NaFos (Trubus Mitra Swadaya, Indonesia) and Top G2 (PT. Health Wealth International, Indonesia), respectively. The polybags used measured 30 cm × 25 cm.

Table 1. Soil physical and chemical properties.

Parameters	Value
pH (H_2O)	5.1
Organic carbon content (%)	0.86
Clay (%)	15.4
Silt (%)	9.5
Sand (%)	75.1

Research Design

This study was conducted experimentally using a 3 × 3 complete randomized design (CRD) factorial, consisting of two factors: G (GF) and T (LOF), with each having 3 repetitions. The total experimental units comprised 27 plots, each consisting of 3 plants with 2 plants serving as the sample. The first factor was GF, which had three treatment levels: G0: control, G1: guano 200 g/polybag, and G2: guano 400 g/polybag. The second factor was the application of LOF, with three treatment levels: T0: control, T1: LOF 3 ml/l of water, and T2: LOF 6 ml/l of water.

Treatment Procedure

The guano treatment was administered one week before planting the seedlings at the specified doses for each experimental unit by mixing it with the soil. LOF application was performed 30 days after the plant (DAP) by mixing the fertilizer in water at a 1 liter/plot volume and then spraying it on the plant roots using a hand sprayer. The control group was only sprayed with water without any treatment. Further treatments were carried out at 40 DAP, 50 DAP, and 60 DAP.

Seed germination was conducted for seven weeks using a 6 × 8 cm polybag filled with a mixture of soil and guano (1:1). The tuber was planted at a depth of 2 cm and placed in a shaded area that was not directly exposed to sunlight. Planting or moving porang seedlings to the research plot was done when sprouts appeared. The relocation was carried out in the late afternoon. The seedlings moved were healthy, fertile, and had solid and straight sprouts with a vegetative growth stature of 2 cm. Maintenance activities included watering, weeding, fertilization, and replanting. The data collection stage involved observation activities, followed by data processing.

Observations and Statistical Tests

The parameters observed were plant height, leaf stalk diameter, number of leaf stalks, and amount of lateral roots. The collected observational data was statistically analyzed using variance analysis followed by Duncan's new multiple range test (DNMRT) at a 5% level.

Results and Discussions

Physicochemical Properties of Soil and Fertilizers

The red-yellow podzolic soil used in this study possesses physical and chemical characteristics that can influence agricultural productivity, as displayed in Table 1. This soil has a pH of 5.1, indicating it is moderately acidic. Such a pH value is commonly found in tropical soils, including those in Indonesia (Cornelissen *et al*. 2018). The organic carbon content of this soil is 0.86%, suggesting a low level of organic matter. This level of organic matter presents a distinct challenge in podzolic soils, where organic matter content is often low and impacts soil fertility (Dymov *et al*., 2022). The soil texture is predominantly sandy (75.1%), with clay and silt percentages of 15.4% and 9.5% respectively. High sand content usually correlates with high water permeability and low water retention capacity (Brady and Weil, 2016).

Guano and liquid organic fertilizer (LOF) contain nutrients crucial for plant growth. Based on the packaging information, guano fertilizer contains 17.65% organic C, 3.85% total N, 4.92% total P_2O_5, 4.10% total K_2O, and has a pH of 7.9. Several studies have shown that guano fertilizer can enhance soil fertility and crop productivity, especially in nutrient-deficient soils (Santana-Sagredo *et al*., 2021; Szpak *et al*., 2012). Meanwhile, LOF contains 6% organic C, 5% N, 5% P_2O_5, 5.8% K_2O, and other elements such as CaO, MgO, and trace elements. LOF also contains amino acids and bioactive compounds like Gibberellins, which have been proven to promote plant growth (Gardner *et al*., 2019). Therefore, using guano and LOF in cultivating crops in red-yellow podzolic soils could enhance crop productivity through improved soil fertility and the provision of required plant nutrients.

Fertilizer Interaction on Porang Growth

Plant growth and development are greatly influenced by the availability of nutrients in the soil. These nutrients can be obtained from various sources, including fertilizer. Guano and liquid organic fertilizer (LOF) are organic fertilizers rich in nutrients and can enhance crop productivity, especially in less fertile or marginal soils. The guano used in this study originates

from bat droppings rich in nitrogen, phosphorus, and potassium, the three primary nutrients plants required. Moreover, guano fertilizer also contains various micronutrients crucial for plant growth. The LOF used in this study is nutrient-rich and organically abundant. Additionally, this LOF also contains trace elements and Gibberellin compounds that play a significant role in plant growth and development processes.

Data from this study demonstrate that applying guano and LOF, either independently or in combination, positively impacts plant growth. This growth is evidenced by the increase in plant height, stem diameter, number of leaf stalks, and the number of lateral roots in treatments using guano or LOF compared to the control, as seen in Table 2. For the single treatments, it is noticeable that the increase in guano (G1 and G2) and LOF (T1 and T2) doses correlates with the increase in plant height, stem diameter, number of leaf stalks, and lateral roots. This development suggests that both types of fertilizer can improve soil quality and provide the necessary nutrients for optimal plant growth.

Table 2. Mean observed growth results (plant height, stem diameter, number of leaf stalks, and number of lateral roots) of porang plants.

Treatments	T0	T1	T2	G average
Plant height (cm)				
G0	18.66	24.0	22.16	21.6A
G1	29.5	30.0	31.83	30.44C
G2	26.33	28.5	34.66	29.83B
T average	24.83A	27.5B	29.55C	
Stem diameter (cm)				
G0	0.52	0.56	0.62	0.55A
G1	0.75	1.04	1.06	0.95B
G2	0.95	1.01	1.1	1.02C
T average	0.74A	0.87B	0.92C	
Number of leaf stalks				
G0	1.83ab	1.83ab	1.33a	1.66A
G1	1.83ab	2.0b	1.83ab	1.88B
G2	1.83ab	2.0b	2.0b	1.94C
T average	1.83A	1.94A	1.72A	
Number of lateral roots				
G0	20.0a	31.3bcd	23.3ab	24.86A
G1	36.83cde	28.0abc	42.5e	35.77B
G2	39.66de	46.33e	42.33e	42.77C
T average	32.16	35.21	36.04	

Note: Numbers followed by upper and lower case letters in the same column and row indicate no significant difference according to the Duncan's New Multiple Range Test (DNMRT) at the 5% level.

These results are consistent with prior research suggesting that organic fertilizers, such as guano and liquid organic fertilizer (LOF), can improve soil structure, enhance nutrient availability, and promote the growth of beneficial soil microorganisms, thereby positively contributing to plant growth and development. The study by Haryanta *et al.* (2023) indicates that urban organic waste can be converted into liquid organic fertilizer (LOF) and effectively improves growth and crop yield in urban agricultural systems. LOF derived from various types of waste contains organic material, nitrogen (N), phosphorus (P), potassium (K), carbon (C), magnesium (Mg), calcium (Ca), copper (Cu), zinc (Zn), iron (Fe), and humic acid. All LOF treatments increased the growth and yield of eggplant and pak choi vegetables.

Regarding interaction effects, the results show that combining guano fertilizer and LOF can enhance plant growth more effectively than single treatments. For instance, in the G2T2 treatment (guano 400 g/polybag and LOF 6 ml/l water), plant height, stem diameter, and lateral root count achieved the highest values compared to other treatments. In a study conducted by Ojobor and Omovie-Stephen (2022), a combination of palm oil mill effluent and guano fertilizer was applied to corn plants. The study showed that this combination significantly increased corn yields and soil chemical properties, such as organic carbon content, total nitrogen, and higher available phosphorus.

Substitution of Inorganic Fertilizer

Using inorganic fertilizers such as ammonium sulfate (ZA), urea, and NPK has become integral to modern farming practices. However, excessive use of inorganic fertilizers can affect soil quality and the environment, leading to soil fertility decline and pollution of surface and groundwater (Pretty *et al.* 2001). In this context, organic fertilizers such as guano and liquid organic fertilizer (LOF) can serve as sustainable and environmentally friendly alternatives (Nannipieri *et al.*, 2003).

Guano fertilizer, derived from bird and bat droppings, is rich in essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), and

other micronutrients (Santana-Sagredo *et al*., 2021; Singh *et al*., 2020; Szpak *et al*. 2012). As a natural and slow-release source of nutrients, guano can enhance soil structure, improve microbial activity, and promote long-term nutrient availability (Singh *et al*., 2020; Szpak *et al*., 2012). A study by Ünal *et al*. (2018) indicates that guano application can boost plant growth and crop yield by providing necessary nutrients and enhancing soil health. Conversely, liquid organic fertilizer (LOF), typically produced from the fermentation of organic materials like animal manure or plant waste, is rich in essential nutrients and can be easily applied to plants through irrigation systems (Hernández *et al*., 2016). A study by Ye *et al*. (2020) found that LOF can improve soil fertility and plant growth comparably to inorganic fertilizers.

Guano and LOF can provide balanced and sustainable nutrition for plants when used in combination. For instance, a study by Yarsi (2019) showed that combining guano and LOF can enhance the growth and yield of tomato crops compared to inorganic fertilizers alone. Specifically, for porang plants, which are tropical plants requiring ample nutrients, the use of guano and LOF could be an effective solution. Although there is not much research specifically regarding these plants, a study conducted by Purnama *et al*. (2023) showed improved growth and yield of porang plants with the application of organic fertilizer. However, it should be remarked that the effectiveness of guano and LOF can vary depending on local soil and environmental conditions and the specific nutritional needs of the planted crops. Therefore, further research is needed to optimize the dosage and application methods of these fertilizers in the context of sustainable agriculture.

Conclusion

In conclusion, this study provides robust evidence that the combined application of solid guano fertilizer (GF) and liquid organic fertilizer (LOF) considerably enhances the growth of porang plants, particularly in nutrient-deficient soils such as red-yellow podzolic soil. The application of these natural fertilizers significantly influenced critical parameters of plant growth, including plant height, stem diameter, leaf stalk number, and lateral root number. The most notable results were observed with the G2T2 treatment, entailing a GF application of 400 g per polybag and LOF of 6 ml/l. Moreover, a significant interaction was found between GF and LOF treatments, further amplifying the effects on the number of leaf stalks and lateral roots. These findings highlight the potential of using natural fertilizers like GF and LOF as effective strategies to improve the growth of economically influential tuberous plants like porang, which may offer sustainable alternatives to conventional synthetic fertilizers. This approach promises to enhance the yield and quality of porang crops and also aligns with global efforts toward sustainable and environmentally friendly agriculture.

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