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Effect of Biopore Infiltration Hole on Soil Nutrient Availability and Nutrient Content of Coffee Leaves (*Coffea canephora*)

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ABSTRACT

Coffee is an important plantation commodity for the Indonesian economy. However, coffee production has decreased due to low soil fertility. One effort to increase soil fertility is by applying Biopore Infiltration Hole. This study aimed to examine the effect of biopore on nutrient availability in coffee leaves (Coffea canephora) and soil in Jatikerto Field, Malang. The experiment used a randomized block design with four treatments: control, 30 cm depth biopore, 30 cm biopore + compost, and 30 cm biopore + goat manure. Nutrient content on leaves and soil chemical properties (total N, available P, K-exchangeable) were measured. The results showed that the application of BIH 30 cm plus goat manure, was able to significantly increase the availability of N, P, K nutrients in coffee leaves and also soil total N, available P, K-exchangeable. Overall, the application of BIH was able to increase soil fertility and nutrient uptake by coffee plants.

1. INTRODUCTION

Coffee is one of the plantation crops that provides a source of foreign exchange for the country. This is because coffee has high selling value compared to other crops. Based on BPS Statistics Indonesia (BPS 2020; 2021; 2022), coffee production data during 2020-2022 experienced fluctuations. In 2020 coffee production was 762.38 thousand tons, increasing to 786.19 thousand tons in 2021 or a increase of 3.12%. In 2022 coffee production fell to 774.96 thousand tons or a decrease of 1.43%. The total volume of coffee imports over the past ten years has fluctuated. The import volume ranged from 4.20 thousand tons to 78.85 thousand tons. An increase in coffee imports accompanied the decline in coffee production. The rise in coffee imports is due to the increase in human consumption of coffee. Over the last five years, instant coffee consumption has increased significantly with an average annual growth of 9.66%. Coffee exports were recorded to be quite high, having a positive impact on foreign exchange growth. This shows that coffee has an important role in the Indonesian economy, seen from various aspects such as development financing, employment opportunities, and improving the welfare of coffee farmers. Java Island is one of the largest coffee producers in Indonesia, with East Java contributing 7.95% of the total robusta coffee production in Indonesia and average production reaching 35.93 thousand tons per year (Putra, 2021).

One of the coffee producing areas in East Java is Malang Regency, specifically in Jatikerto. Jatikerto is one of the areas in the Kromengan District that has coffee plantations which has slope 30%. The problem that occurs in Jatikerto is low soil fertility caused by low organic matter input. The results of the basic analysis showed that the soil organic carbon was 0,8% which is classified as very low. Soil organic carbon (SOC) affecting nutrient availability in soils (Krisdiati *et al*., 2022; Gerke, 2022). The availability nutrients in the soil can support high plant growth and production. Factors that affect production are genetic, environmental, and soil management factors, with fertilization an important management factor. Fertilization has an impact on the availability and absorption of nutrients by plants (Maman *et al*., 2020). Organic fertilizer can improve chemical, biological, and physical soil for sustainability agriculture. Meanwhile, inorganic fertilizer may not be sustainable in long term due to reduced soil microbas, soil acidity, and nutrient availability (Rahmah *et al*., 2022; Hanuf *et al*., 2021). Efforts to increase soil fertility by adding organic matter such as organic fertilizer. Organic fertilizer such as compost and goat manure which are abundant in the research area can be used as organic matter. However, the high slope conditions at the research location cause nutrients to be carried away by surface runoff (Mujiyo *et al*., 2021; Zhang *et al*., 2021; Wang *et al*., 2023).

Based on this description, new technology is needed, such as biopores infiltration hole. Safitri *et al*., (2019) showed that biopores are the result of the activity of microbes that creat small holes. Some benefits of biopore infiltration hole (BIH) implementation are reducing excess water, accelerate water absorption (Santosa, 2018), improve soil aeration, and increasing capacity of available soil water (Hutapea *et al*., 2018; Akbar *et al*., 2018). The result of research by Hanuf *et al*. (2021) showed that adding organic matter to biopores can improve soil physical characteristic in Bangelan Coffee Plantation. Therefore, new technology such as biopore infiltration hole as a nutrient for microbes so that they can improve chemical, physical and biological soil. Apart from that, the application of biopore infiltration holes is needed to determine the content and balance of nutrient elements.

2. IMPLEMENTATION METHOD

The research was conducted at ATP Jatikerto, Kromengan District, Malang Regency. The research implementation consisted of the following activities: 1) Location selection: The initial activity is determining the location of the observation. Location selection on coffee plantations with the slope (23-30%); 2) Making biopore: make biopore from paralon material with length of 30 cm and diameter of 15 cm. Then, 20 and 40 holes were made on the sides of the paralon with the aim of the coffee roots to enter. Next, inserted into the biopore hole that has been made using a drill. Selection of goat manure and compost as organic matters to utilize waste around the research location; 3) Soil and leaves sampling: Sampling was carried out before and after biopore application. Leaf samples were taken on the 3rd and 4th leaves located at the tips of productive branches (Figure 1). Soil samples were taken at intervals of 4 and 8 months and taken at 3 depths, that is 0-20 cm; 20-40 cm; 40-60 cm.

This research used four treatments and four replications with a Randomized Block Design (RBD). The treatments used were P1 as control (without BIH), P2 (BIH only), P3 (BIH+Compost), and P4 (BIH+goat manure). Data obtained were then analyzed using analysis of variance (ANOVA) at 5% level and then continued using the Duncan Multiple Range Test (DMRT) at the 5% level.

(a) (b)

Figure 1. a) Selection of leaf samples; b) selection of branches (Hawaiicoffee.com, 2020)

3. RESULTS AND DISCUSSION

3.1. Soil Chemical Characteristics

Analysis results show that the soil pH at the research location is slightly acidic at these three depths. The availability of nutrients in the soil can be reflected in the degree of soil acidity (pH), which is an indicator of soil fertility (Kawengian *et al*., 2021; Putri *et al*., 2019). The characteristics of soil chemical are presented in the following figure (Figure 2). The soil acidity value shows the average nutrient content in the very low-low criteria. The soil organic carbon (SOC) is classified as very low at the soil layer of 0-20 cm and 40-60 cm, while at the soil depth of 20-40 cm is classified as low. This is caused by the value of water capacity in Jatikerto is 22% which is classified as low, thus affecting SOC. The results of research of Yanti & Kusuma (2021) showed that water content affects SOC. Water content also affects soil pH. The higher the water content, the more H^+ ion release reactions, cause the soil to become more acidic (lower pH).

Nitrogen (N) is a macro nutrient for plants. Plants need nitrogen in large quantities because it is used in the vegetative phase. Total nitrogen is classified as low level in every soil depth, where the total nitrogen in 0-20 cm soil depth is 0.11%, in 20-40 cm soil depth is 0.08%, in 40-60 cm soil depth is 0.05%. The low level of total nitrogen due to high slope which is easily erotion. Furthermore, Nitrogen is mobile, easily soluble, and easily lost to the atmosphere or irrigation water. So when it rains, nitrogen nutrients can be lost from the soil (Sariyilzid *et al*., 2015; Sandhu *et al*., 2021). Available P is classified as very low in 0-20 cm soil depth is 0,9 mg/kg; in 20-40 soil depth is 0,8 mg/kg; in 40-60 cm is 0,2 mg/kg. In acidic soil, the nutrient phosphorus is more easily bound by the elements Al and Fe so it is not available to plants (Gunawan *et al*., 2019).

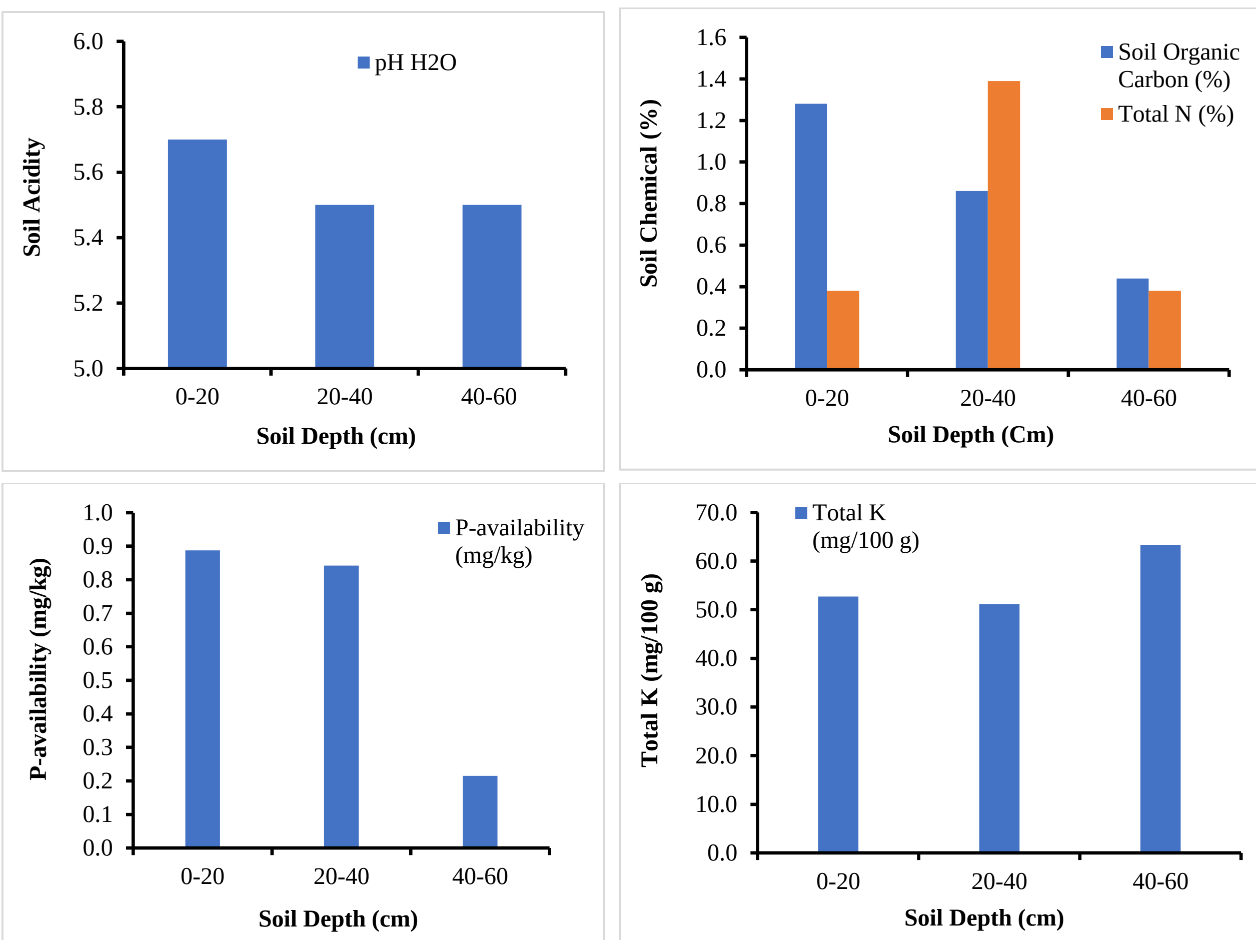

Figure 2. Soil chemical characteristics before application

3.2. Effect of Infiltration Biopore on Nutrient Status in Soil

3.2.1. Soil Total N

Table 1 shows that soil totsl N increased at 120-240 DAA. The application of BIH significantly affected the soil total N at each depth. Table 9 shows that the highest N-total value was obtained in P4 treatment 0.43% at depth of 20-40 cm on 240 DAA. The lowest value was obtained in the P1 treatment 0.05% at depth of 40-60 cm for all observations. Different types of organic matter can affect the amount of soil total nitrogen. The research by Latifah *et al*. (2018) shows that the addition of compost increased nitrogen in soil incubated for 90 days. Furthermore, the application of goat manure increased soil total nitrogen is higher than cow manure (Washaya & Washaya, 2023). Application of organic matter increasing the activity of microorganisms, especially microbiomass N and C. This activity increasing soil total nitrogen through the mineralization process (Wijanarko *et al*, 2012). The nitrogen mineralization process consist of aminization (protein becomes NH_2), ammonification (NH_2 becomes NH^{4+}, and nitrification (NH_4^+ becomes NO_3^-) (Benbi & Richter, 2002).

Table 1. Effect of biopore infiltration hole application on soil nitrogen (total N) (%)

Treatment	120 DAA			240 DAA		
	0-20 cm	20-40 cm	40-60 cm	0-20 cm	20-40 cm	40-60 cm
P1 (Control)	0.10 a	0.08 a	0.05 a	0.12 a	0.09 a	0.05 a
P2 (Biopore depth 30 cm)	0.11 a	0.15 b	0.07 a	0.12 a	0.18 a	0.09 a
P3 (Biopore depth 30 cm + compost)	0.16 ab	0.22 c	0.14 b	0.24 b	0.38 b	0.21 b
P4 (Biopore depth 30 cm + goat manure)	0.20 b	0.22 c	0.17 b	0.28 b	0.43 b	0.32 c

Note: Different letters in the same column indicate significant differences under DMRT at a level of $\alpha = 5\%$ ($p < 0.05$).

3.2.2. Available Phosphorus

One of the macro nutrient besides nitrogen (N) is phosphorus (P). The end experiments show the average soil available phosphorus ranged from 1.2 mg/kg – 3.94 mg/kg. Analysis of variance shows that BIH has significant effect on increasing soil available P at 120 and 240 DAA ($p<0.005$). The average soil available P is presented in Table 2. The highest soil available phosphorus is P4 treatment (Biopore depth 30 cm + goat manure) is 3.94 mg/kg, and the lowest is P1 treatment (control) is 1.22 mg/kg. Although P4 treatment is higher than the other treaments, but in all observations soil phosphor availability is classified "very low" level. Increasing soil available phosphorus due to input organic matter. The research by Marbun *et al*. (2024) show that giving organic matter such as vermicompost and goat manure is significantly effect on soil available phosphorus. Alfisol has characteristics low phosphorus. It caused by phosphorus nutrients easily bound by Al and Fe element. Furthermore, Alfisols is a soil that experiences a high level of weathering which causes nutrients in the soil to be leached (Arista *et al*., 2015; Sari *et al*., 2017).

Table 2. Effect of biopore infiltration hole on soil available P (mg/kg)

Treatment	120 DAA			240 DAA		
	0-20 cm	20-40 cm	40-60 cm	0-20 cm	20-40 cm	40-60 cm
P1 (Control)	1.01 a	1.08 a	1.08 a	1.26 a	1.23 a	1.22 a
P2 (Biopore depth 30 cm)	1.51 b	1.51 b	1.47 b	1.96 b	2.03 b	1.89 b
P3 (Biopore depth 30 cm + compost)	2.27 c	2.38 c	2.25 c	3.18 c	3.18 c	3.06 c
P4 (Biopore depth 30 cm + goat manure)	3.18 d	3.20 c	2.97 d	4.14 c	4.31 d	3.94 d

Note: Different letters in the same column indicate significant differences under DMRT at a level of $\alpha = 5\%$ ($p < 0.05$).

3.2.3. K-exchangeable

Potassium (K) is macro nutrients after nitrogen and phosphor nutrients. The end experiments show that BIH has significant effect on increasing soil K-exchangeable at every depth ($p < 0.005$). Table 3 show that BIH + goat manure is significantly different than P2 and P1 treatment. The average soil K-exchangeable is presented in Table 3. All experimental data are classified as very high level, where the highest soil K-exchangeable in 0-20 cm soil depth is 2.54

mg/kg; in 20-40 soil depth is 2.79 mg/kg; in 40-60 cm soil depth is 2.06 mg/kg. Soil K-exchangeable is classified very high because organic matter increasing concentration of soil nutrients and its decomposition (Sinuraya & Melati, 2019; Samndi & Jibrin, 2012). Increasing nutrients is due to the increase in biomass and microbial activity that occurs after goat manure application, which affects the availability of potassium. The input of organic matter into biopore holes can increase the availability K. Organic matter can increase soil infiltration, increase nutrient availability, and as a food source for soil microbes (Ruhimat *et al*. 2023).

Table 3. Effect of biopore infiltration on soil K-exchangble

Treatment	120 DAA			240 DAA		
	0-20 cm	20-40 cm	40-60 cm	0-20 cm	20-40 cm	40-60 cm
P1 (Control)	1.84	1.63 a	1.23 a	2.09 a	1.72 a	1.35 a
P2 (Biopore depth 30 cm)	1.95	2.19 b	1.50 b	2.00 a	2.31 b	1.67 b
P3 (Biopore depth 30 cm + compost)	2.17	2.42 b	1.71 c	2.54 b	2.79 c	2.05 c
P4 (Biopore depth 30 cm + goat manure)	2.21	2.47 b	1.72 c	2.50 b	2.76 c	2.06 c

Note: Different letters in the same column indicate significant differences under DMRT at a level of α = 5% ($p < 0.05$).

3.3. Effect of Biopore Infiltration Hole on Nutrient Content in Coffee Leaves

3.3.1. N-total

Nitrogen content on coffee leaves increased in each observation. The average nitrogen content on coffee leaves is presented in Table 4. Table 4 shows that BIH is significant by the control treatment ($p < 0.05$). On 240 DAA, the highest nitrogen content in leaves is P4 treatment, while the lowest is control treatment. Compost and goat manure addition to biopore can increase nitrogen content in coffee leaves, but it cannot be decided which organic matters is effective in increasing nitrogen content in coffee leaves. This is because the result showed that P4 and P3 treatment did not show a significant difference. In line with the result of soil total nitrogen, leaf nitrogen nutrient increased along with the addition of organic matter. Application BIH shows increasing leaf N content by increasing soil total nitrogen (Santoso & Cholid, 2021).

Table 4. Effect of biopore infiltration application on total N-coffee leaves

Treatment	Total Nitrogen (%)					
	0 DAA	Criteria*	120 DAA	Criteria*	240 DAA	Criteria*
P1 (Control)	2.12	Enough	2.61	Enough	3.28 a	Enough
P2 (Biopore depth 30 cm)	2.12	Enough	2.61	Enough	3.90 b	Enough
P3 (Biopore depth 30 cm + compost)	2.14	Enough	2.61	Enough	3.98 b	Enough
P4 (Biopore depth 30 cm + goat manure)	2.15	Enough	2.72	Enough	4.05 b	Enough

Note: Different letters in the same column indicate significant differences under DMRT at α = 5% ($p < 0.05$); *) According to Sufardi (2019).

The research of Hareesh *et al*. (2021), the robusta coffee leaf N status (2.5%) in organic fertilizer compared to control treatment. High C-organic and soil total nitrogen influence high of nitrogen content in coffee leaves (Hifnalisa *et al*., 2022). Nitrogen is one of main nutrient that needed for vegetative stage. It is component that forms various important substances such as chorophyll molecules, amino acids, enzymes, coenzymes, vitamin, hormones indolacetic acid, and zeatin (Fathi, 2022). Nitrogen defiency delays development of vegetative and generative stage (Fathi & Zeidali, 2021).

3.3.2. Total P

The analysis results of nutrient content of P in robusta coffee leaves is presented in Table 5. The coffee leaves have P nutrient content ranging 0.24%-0.26% on 240 DAA. For all time observation, it shows that BIH is not significant to nutrient content of P. Table 5 shows that BIH can increasing nutrient content of P. Biopore infiltration hole (compost and goat manure) application results in the highest P concentration of 0,26%, but P concentration is not significantly different between control treatment. The P nutrient content in robusta coffee leaves of the 0-120 DAA observation is classified as “deficient” level. This conditions due to low soil available P. Hifnalisa *et al*. (2022) found that low available

P in andisols can not provide the required amount of nutrients needed by arabica coffee. In other experiment, application NPK fertilizer did not increase P nutrient in coffee leaves (Inthasan *et al*., 2021). The soil available P will affect nutrient uptake by plants. This is because soil available P can be absorbed by plant roots (Soemarno *et al*., 2021). Adding P combined with N fertilizer can increase P uptake by plants. Plants need P nutrient in the form of $H_2PO_4^-$, HPO_4^{2-} during vegetative stage (Iswiyanto *et al*., 2023). Nutrient transformation in leaves caused by generative stage. Leaves translocate from old leaves to young leaves for fruit formation, so that the nutrient content in old leaves decreases. Furthermore, it caused by presence of mobile nutrients such as N, P, and K (Liferdi & Poerwanto, 2011).

Table 5. Effect of biopore infiltration hole application on P-total of coffee leaves

Treatment	Total Nitrogen (%)					
	0 DAA	Criteria*	120 DAA	Criteria*	240 DAA	Criteria*
P1 (Control)	0.092	Deficient	0.15	Deficient	0.24	Enough
P2 (Biopore depth 30 cm)	0.095	Deficient	0.16	Deficient	0.25	Enough
P3 (Biopore depth 30 cm + compost)	0.098	Deficient	0.18	Deficient	0.26	Enough
P4 (Biopore depth 30 cm + goat manure)	0.098	Deficient	0.19	Deficient	0.26	Enough

Note: Different letters in the same column indicate significant differences under DMRT at $\alpha = 5\%$ ($p < 0.05$); *) Based on Sufardi (2019).

3.3.3. Total K

The results of analysis of variance showed that BIH has a significant effect on total K leaf at 120 DAA observations (p<0.05), but no significant effect at 240 DAA observations (p<0.05). The average K-total value is presented in Table 6. Table 6 shows application of BIH was able to increase the total K nutrient status in coffee leaves. Total K nutrient content is classified as deficient level before application until 120 DAA. And then, classified as enough level at 240 DAA. The table shows that the application of biopore depth 30 cm + goat manure gave the highest total K is 2.56%. Meanwhile, the lowest in P2 treatment (biopore depth 30 cm) is 1.25%. Application of organic matter in goat manure or compost can improve the soil chemical properties by increasing soil acidity and availability nutrients. According to Choirina *et al*. (2013), soil pH value is an indicator of soil fertility, because it increases the soil available nutrients. The research of Hartati *et al*. (2019) showed that treatment using goat manure increased the soil pH. The optimum K nutrient in coffee leaves due to K-exchangable and C-organic in soil (Hifnalisa e al., 2022).

Table 6. Effect of biopore infiltration hole application on K-total of coffee leaves

Treatment	Total Nitrogen (%)					
	0 DAA	Criteria*	120 DAA	Criteria*	240 DAA	Criteria*
P1 (Control)	0.38	Deficient	0.26 a	Deficient	1.28	Enough
P2 (Biopore depth 30 cm)	0.35	Deficient	0.31 ab	Deficient	1.25	Enough
P3 (Biopore depth 30 cm + compost)	0.36	Deficient	0.34 ab	Deficient	1.30	Enough
P4 (Biopore depth 30 cm + goat manure)	0.37	Deficient	0.35 b	Deficient	2.56	Enough

Note: Different letters in the same column indicate significant differences under DMRT at a level of $\alpha = 5\%$ ($p < 0.05$); *) Based on Sufardi (2019).

4. CONCLUSION

Based on research results, the application of biopore infiltration hole increasing soil total nitrogen, available P, K-exchangable, nutrient conten (N, P, and K) in coffee leaves (*Coffea canephora*). Biopore with a depth of 30 cm + goat manure (P4) gave the highest results in increasing the availability of soil and leaves nutrient especially N, P, K nutrient. Furthermore, combination between biopore and compost also increasing available nutrient N, P, K. Therefore, by considering all above conclusions BIH is recommended for sustainable agriculture over the years.

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