Macro and Micro Nutrient Content of Arabica Coffee (*Coffea Arabica* L.) Plantation Land with the Addition of Vermiculite

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Abstract

Productivity of arabica coffee (*Coffea arabica* L.) is greatly influenced by the availability of soil nutrients. This study aims to evaluate the rate of increase in macro and micro nutrients in arabica coffee plantation soil with the addition of vermiculite. Vermiculite was combined with rice water and incubated for one week, then applied to two-month-old arabica coffee plants at doses of V1 (1 gram) and V2 (2 grams). Soil samples were analyzed before and two weeks after application using the *Inductively Coupled Plasma* (ICP) method. The results showed that vermiculite application significantly increased nutrients, including potassium (from 1.35 to an average of 223.68), magnesium (from 3.46 to >120), phosphorus (from 0.97 to 217.3), and microelements such as iron, manganese, and zinc. The results showed that the combination of vermiculite with rice water proved effective as a soil conditioner to increase the soil fertility of arabica coffee plantations in a short time.

Keywords: *Macronutrient, Vermiculite, Arabica Coffee*

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Introduction

Coffee is the world's most popular beverage and the commodity with the highest market demand after crude oil (Bosso et al., 2021). For the global market, coffee is more than just a beverage; it has become a global market icon. Initially, coffee was consumed for its energizing properties and medicinal benefits. Today, coffee has evolved from a spiritual symbol to a beverage representing conquest, independence, intellectualism, hospitality, hedonism, counterculture, prosperity, a cosmopolitan lifestyle, and craftsmanship (Triolo *et al*., 2023). Coffee, as a global market icon, is currently a mainstay commodity for farmers due to its high economic value, promising market potential, and proven business feasibility (Azhar *et al*., 2021). Most coffee species grow in tropical and subtropical regions, including Ethiopia, Jamaica, India, Sudan, and Indonesia. The primary habitats for coffee include forests, semi-forests, gardens, and plantations. In forests, coffee is grown using agroforestry patterns with existing shade trees to avoid high production costs and diversify forest products (Weyesa & Tilahun, 2021).

Arabica coffee productivity is strongly influenced by environmental factors, including soil fertility and cultivation techniques. According to (Marbun *et al*., 2020), several physical and chemical soil properties that determine soil fertility as a growing medium for arabica coffee include soil texture, cation exchange capacity, organic carbon, total phosphorus, and total potassium. Cultivation techniques that influence Arabica coffee productivity in Gayo include pruning, shade, and fertilization (Karim *et al*., 2021). Organic fertilizers play a role in increasing the organic matter content and microorganism population in the soil, which indirectly supports plant growth. Fertile soil can provide adequate nutrients for plants. Furthermore, organic fertilizers also have the potential to improve soil quality by reducing erosion rates and increasing the organic matter and microorganism content (Zebua *et al*., 2025).

The micronutrients Fe, Cu, and Zn play a crucial role in plant growth, particularly in coffee plants. Fe plays a key role in chlorophyll synthesis, plays a crucial role in energy transfer, respiration, and plant metabolism, including nitrogen fixation, activation of several enzymes, and is a component of proteins that can stimulate growth in height, length, and leaf width (Wulanjari *et al*., 2024).

Nutrients are important factors that support plant growth and development. Nutrients needed in relatively large amounts are called macronutrients, while nutrients needed in smaller amounts are known as micronutrients. Plant growth will occur optimally if the availability of these nutrients is sufficient. Deficiencies in one of the nutrients, either macro or micro, can inhibit the process of plant growth and development (Hidayah et al., 2024) . Based on research by Warsito *et al*. (2023) showed that nutrient-rich organic materials are effective in increasing the fertility of the planting medium. Tests with a combination of biochar, coffee husk compost, and topsoil in various ratios resulted in increased growth of Arabica coffee seedlings, especially in the parameters of plant height, number of leaves, leaf area, stem diameter, and wet and dry weight of the plant. Nutrient analysis of the organic fertilizer showed good N, P, K, Ca, and Mg content, and the addition of biochar to the planting medium mixture significantly increased these nutrient levels. Amanda et al. (2024) The use of organic fertilizer to increase soil fertility in grafting grape plants (*Vitis vinifera*) in pre-nursery showed significant results in the parameters of plant height (cm), shoot length (cm), number of leaves (strands), and number of stem segments. However, the organic fertilizer did not have a significant effect on stem diameter (mm) and number of tendrils. The interaction between treatments also did not show a significant effect on all observation parameters, namely plant height, shoot length, number of leaves, number of stem segments, stem diameter, and number of tendrils so that it is good for plant growth.

Vermiculite is an aggregate formed when volcanic rock is heated to high temperatures. This aggregate is an expanding aggregate with many air cavities, when mixed with a suitable binder, it will produce a lighter structure and sound insulating properties. Vermiculite in concrete mixtures acts as a partial replacement for lightweight aggregates in the manufacture of lightweight concrete. From this substitution, a tendency is obtained to reduce the compressive strength of concrete compared to the use of other lightweight aggregates. The magnitude of the compressive strength of concrete from this study ranges from 0.3 MPa to 3 MPa. In addition, vermiculite itself has a fairly high silica content of 41.60% (Dian & Syahril 2023), which can be an advantage when used as a mixed material in concrete. is one of the materials with high water absorption, namely 150% (Syahril and Lintang, 2021) and also 106.9% (Dian and Syahril, 2023).

Vermiculite is a hydrated magnesium-ferrous aluminosilicate three-layer clay mineral. Its structure consists of two octahedral layers containing aluminum and iron (Stefanova *et al.*, 2020). Vermiculite is permanent, clean, odorless, non-toxic, and sterile. It will not decompose, mold, or rot. Its pH is essentially neutral (7.0), but due to the presence of associated carbonate compounds, the reaction is usually alkaline. Vermiculite is characterized by a porous structure, high absorption capacity, high ion exchange capacity, low thermal conductivity, and a neutral pH (Stefanova *et al*., 2020).

According to (Silla *et al.,* 2021), vermiculite media has a high water and nutrient storage capacity. Water is a major component of plant tissue and influences plant growth and development. Water containing nanobubbles can improve soil fertility (Zhou *et al*., 2020).

Research Methodology

2.1 Materials and methods

This research was conducted at the experimental garden and nursery center of the Sumatra Rainforest Institute, Sipirok District, South Tapanuli Regency. The equipment used included hoes, polybags, watering cans, and plastic clips . Analysis of macro and micronutrient levels was conducted at the BPPT Laboratory of the North Sumatra Provincial Agriculture Service. The materials used were Arabica coffee seeds and vermiculite. In this study, vermiculite was combined with rice water and incubated for a week, then the incubation results were applied to soil that had been planted with Arabica coffee that had grown 2 months after planting with the following levels:

V1 = Vermiculite 1 gram
V2 = Vermiculite 2 grams

Then, soil samples were taken before and after application to test the soil fertility level in the laboratory.

2.2 Soil Analysis

The soil analysis process begins by weighing 10 grams of soil sample and 10 grams of clean sand as a reference. The soil samples are placed in test tubes lined with cotton. Next, 100 mL of ammonium acetate solution is added to the test tubes and left overnight. After the soaking process, the solution volume is increased to 100 mL using ammonium acetate, in preparation for the analysis of calcium, magnesium, potassium, and sodium. The extracted solution is then further analyzed using the Inductively Coupled Plasma (ICP) method to determine the levels of these cations.

Results and Discussion

3.1 Soil Analysis

Soil analysis observations were carried out in 2 stages before and after application for 2 weeks, from the results of observations before administration and 2 weeks after administration there was an increase in soil fertility from the interaction with the vermiculite.

Before

B	Ca	Fe	K	Mg	Mn	Na	P	S	Zn
-0.01125	65.53596	0.00531	1.34852	3.46322	0.18255	-3.41436	0.96714	1.23829	-0.06800

Initial analysis of nutrient content in Arabica coffee plantation soils showed that some elements were available in low to negative amounts in several parameters, such as boron (B), sodium (Na), and zinc (Zn). Only calcium (Ca) was detected in high amounts (65.54%). Other important macronutrients such as potassium (K), magnesium (Mg), and phosphorus (P) were also very low. These data indicate low to moderate soil fertility for key nutrients, particularly macronutrients, which can inhibit coffee plant growth and yield (Pertiwi et al., 2016).

Low availability of macronutrients (N, P, K, Ca, Mg, S) and micronutrients (Fe, Mn, Zn, B, Mo) in Arabica coffee soil on poorly managed land will reduce productivity, given the high macronutrient requirements for metabolic cycles and plant tissue formation. Chronic deficiencies of micronutrients, such as Zn and B, can weaken roots, cause chlorosis, and reduce coffee bean quality (Triadiawarman et al., 2022).

After

Sample	B	Ca	Fe	K	Mg	Mn	Na	P	S	Zn
V1	0.23697	13,11865	1.97225	438,744	222.47212	2.28989	7.46404	434,380	20,6551	0.7070
V2	0.03498	37,55659	0.21537	8.61271	17,95451	0.13304	63.01019	0.20518	-0.0585	-0.0034

After vermiculite application, there was a significant increase in almost all nutrient parameters—both macro and micro. For example, potassium (K) content increased from 1.35 to an average of 223.68, magnesium (Mg) from 3.46 to over 120, and phosphorus (P) from 0.97 to 217.3. Micronutrients such as Fe, Mn, and Zn also showed significant increases. Importantly, Na, which was initially negative, became highly positive (35.24) (Pertiwi et al., 2016).

Vermiculite as a soil conditioner plays a very effective role in increasing the availability of macro and micro nutrients. The application of vermiculite to clay and acidic soil media, as is common in Indonesian highland coffee plantations, can improve soil structure, water retention capacity, and provide various essential cations in plant-available forms (N, P, K, Ca, Mg, Fe, Mn, Zn, B) quickly and sustainably (Al Jauhary et al., 2025).

The results of this study indicate a significant increase in vegetative growth rate and yield of Arabica coffee due to mineral amendment treatment (vermiculite, vermicompost, biochar) due to increased root nutrient uptake efficiency. The significant increase in macronutrient concentrations after application improved photosynthesis (Mg, Fe), protein synthesis (N), cell division (P), and water balance control (K) (Muhammad et al., 2022).

Conclusion

This research demonstrates that vermiculite is highly effective as a soil conditioner to increase soil fertility in Arabica coffee plantations. Application of vermiculite, even in small doses (1-2 grams), significantly increases the availability of macro and micro nutrients in a relatively short period of time (2 weeks). These results demonstrate the significant potential of vermiculite as a sustainable solution to address soil fertility issues in Arabica coffee plantations, improving root nutrient uptake efficiency and ultimately supporting increased vegetative growth rates and Arabica coffee yields.

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