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The Effect of Volcano Ash and Goat Manure on The Growth of Robusta Coffee (*Coffea canephora*) Seedlings

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ABSTRACT

Increasing the production of robusta coffee plants (*Coffea canephora*) can begin with selecting quality seeds. Improving seed quality can be done through fertilization using ameliorants and organic materials. Volcanic ash and goat manure are ameliorants and organic materials used in improving the planting medium. This study used a completely randomized design (CRD) with two factors: volcanic ash (25, 50, 75 *g/polybag*) and goat manure (15, 30, 45 *g/polybag*). The results of this study showed an interaction between volcanic ash and goat manure on the growth in height, shoot dry weight, and the root crown ratio of robusta coffee seedlings. The application of volcanic ash affects plant height, stem diameter, and the root crown ratio of robusta coffee seedlings. The application of goat manure affected plant height, leaf number, and the root-to-shoot ratio of Robusta coffee seedlings. The best ratio was 50 g volcanic ash per polybag and 45 *g* goat manure per polybag, which optimally increased the growth of Robusta coffee seedlings compared to other treatments. These results indicate that using volcanic ash with goat manure can be an effective alternative organic fertilizer to support coffee seedling growth and improve the fertility of the growing medium.

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INTRODUCTION

Indonesia is one of the world's major coffee-producing countries. According to data from the Directorate General of Plantations, Indonesia's coffee production in 2022 totaled 1,262,590 tons. The types of coffee widely grown in Indonesia are Arabica and Robusta. One of the provinces that produces Arabica and Robusta coffee is West Sumatra. West Sumatra Province has a higher yield of robusta coffee than Arabica coffee; robusta accounts for around 71% of the total coffee plantation area, while Arabica accounts for around 29% (Ditjenbun, 2022). Robusta coffee is more widely cultivated because it is easy to grow and less sensitive to unfavorable growing conditions (Widyasari *et al*., 2023).

Increasing robusta coffee production can be achieved by cultivating healthy plants. In this case, using high-quality coffee plant seeds can support the growth of coffee plants. Superior and healthy seeds have high vigor, are resistant to pests and diseases, and can adapt to the growing environment, thereby increasing coffee yields (Mulyani *et al.,* 2021).

Efforts to improve the quality of coffee plant seeds can be carried out through fertilization, which provides plants with sufficient nutrients. Volcanic ash and goat manure are ameliorants and organic materials that can increase the availability of macro- and micronutrients. The use of volcanic ash can also have a positive impact after a volcanic disaster, helping farmers reduce their use of chemical fertilizers. Its environmentally friendly nature prevents soil nutrient degradation.

Volcanic ash contains nutrients Ca, Na, K, and Mg, as well as other macroelements such as P and S, while microelements consist of Fe, Mn, Zn, and Cu (Anda & Wahdini, 2010). According to the study by Alviandy *et al*. (2016), administering volcanic ash at a dose of 100 g/*Polybag* can increase oil palm seedling growth in the *main nursery*, with higher plant growth and increased stem hump diameter. Although they contain soil-fertilizing nutrients, volcanic ash layers cannot be used directly for agriculture because they have not undergone complete weathering. However, a simple way to accelerate the weathering of volcanic ash is to mix it with organic matter. The organic material used is goat manure, which serves as an energy source for soil microorganisms, accelerating the decomposition of minerals in volcanic ash (Indrawan & Purwanto, 2020).

Organic matter contains compounds such as humic acid, fulvic acid, and simple organic acids, produced by microorganisms, including bacteria, fungi, and actinomycetes, during decomposition. These compounds can dissolve minerals in volcanic ash and increase nutrient availability through chelation and ion dissolution. In addition, microbial activity produces carbon dioxide (CO_2) and carbonic acid, which help dissolve silicate minerals in ash, accelerate weathering, and reduce soil acidity (Setyorini *et al*., 2018).

Goat manure functions not only as a source of nutrients such as nitrogen (N), phosphorus (P), and potassium (K), but it can also increase the content of organic matter and the cation exchange capacity (KTK) of the soil, which is important for the availability of nutrients for plants (Subowo, 2017). According to Sakirun's (2021) results, using goat manure at a dose of 31.4 g/polybag and 300 ml of onion extract can increase robusta coffee seedling growth, including plant height, stem diameter, root dry weight, and crown dry weight.

The ingredients in volcanic ash and goat manure benefit plant growth. The addition of a combination of volcanic ash and goat manure, which can be used as an option to increase the production of coffee plants, is expected to improve the chemical, physical, and biological properties of the soil and add nutrients to the planting medium of robusta coffee seedlings that can improve the quality of robusta coffee production. The objectives of this study are to: 1) Determine the interaction between the application of volcanic ash and goat manure on the growth of robusta coffee seedlings; 2) Determine the single influence of volcanic ash application on the growth of robusta coffee seedlings; 3) Determine the single effect of goat manure application on the growth of robusta coffee seedlings.

MATERIALS AND METHODS

This research was carried out at the Experimental Land of the Department of Plantation Crop Cultivation, Faculty of Agriculture, Andalas University, and at the Wiwiadi Bintang Sains Laboratory, Padang. This research started from February to June 2025. The materials used in this study are 2-month-old Hibiscus robusta coffee seeds, volcanic ash, goat manure, *ultisol* soil, and water. The volcanic ash used was 1 year old, erupted on 3 December 2023, and was collected in

Nagari Andaleh, Batupuh District, Tanah Datar Regency, West Sumatra. The tools used in this study were *a 25* x 30 cm polybag, nails, label paper, stakes, soil sieve, digital scale, hoe, 25-*mesh tylers*, *mobile phone* cameras, bars/rulers, *hand sprayers*/gembor, 75% para nets, and stationery.

This study is an experiment using the Complete Design (RAL) method with 2 factors, each with 3 levels repeated. The first factor is the application of volcanic ash (V) with 3 levels:

V1 = 25 g/*polybag* (10 ton/ha)

V2 = 50 g/*polybag* (20 tons/ha)

V3 = 75 g/*polybag* (30 tons/ha)

The second factor is the provision of goat manure (P) with 3 levels:

P1 = 15 g/*polybag* (6 tons/ha)

P2 = 30 g/*polybag* (12 tons/ha)

P3 = 45 g/*polybag* (18 tons/ha)

1. Location Selection and Cleanup of Area

The research location was chosen on a level, non-flooded area, close to a water source. The location is open and free from animal disturbances, pests, and diseases. Area cleaning is carried out two weeks before planting to clear the land of dirt such as wood, weeds, garbage, and other disturbing materials.

2. Medial Plantation Preparation

The soil used as a planting medium is ultisol soil. The soil is cleaned of roots, litter, clumps, rocks, and debris, then sifted with a 2 mm sieve to have a uniform structure. Before use, the soil is mixed with goat manure and volcanic ash according to the prescribed treatment. The mixture is watered to capacity, then incubated for 2 weeks to evenly distribute the organic matter. The planting medium is added to a 25 × 30 cm polybag in stages while shaking, ensuring it is dense and free of air cavities.

3. Seedlings

Before planting, robusta coffee seedlings are selected based on high uniformity. Seedlings that meet the criteria are planted in *polybags* measuring 25 × 30 cm. The seedlings are placed in a polybag in the planting hole, then covered with soil. Furthermore, *the polybags* are labeled with the treatment code and arranged according to the Complete Random Design (CRD).

4. Maintenance

Maintenance involves watering twice a day (morning and evening) until the soil remains moist. Weeding is done manually around the seedlings. Pest and disease control is carried out with regular observations.

A. Variable Observations

1. Volcanic Contents

The volcanic rock used in this research was obtained from Mount Marapi in Nagari Andaleh, Tanah Datar Regency, West Sumatra. The analysis carried out includes pH, Fineness, P, K, and moisture content.

2. Goat Manure Fertilizer Analysis

The goat manure used is fermented. The analysis of goat manure includes pH, N, P, K, and C-organic.

3. Soil Early and After Incubation

The soil used is a Mediterranean soil collected from the 0-20 cm *(topsoil*) layer. The analysis carried out, including pH and the elemental content of Nitrogen (N), Phosphorus (P), Potassium (K), and C-organic.

4. Seedling height (cm)

The remaining seedlings will be measured 2 weeks after planting. Measurements will be taken every two weeks using a ruler. The height of the seedlings is measured from the standard pole line to the ground surface, or from a standard 21 cm

stake using 30 cm long bamboo as a standard measurement, by lining the leaves of the Robusta coffea seedlings from bottom to top.

5. Number of leaves (leaf blade)

The number of leaves counted is defined as those that are fully opened or partially opened. Leaves are counted from the bottom to the youngest fully opened leaf. Observations will be conducted when the seedlings are 2 to 16 weeks after planting. Observations will be conducted once every two weeks.

6. Diameter batang

To measure the plant's root diameter, use a shovel to anchor, then measure the swollen soil at least 2 cm below the soil surface. Observation time is carried out for one calendar year in two weeks.

7. Luas daun (cm^2)

Leaf area was measured at the end of the study by weighing all leaves gravimetrically, then cutting and tracing them on newspaper. The resulting sheet is pulled and weighed, and the same newspaper is cut to 10 cm x 10 cm and weighed.

8. Dry weight (G)

Observation was carried out at the end of the research. The sample size is taken to be 3 per treatment.

9. Dry weight of root (g)

The root plant is weighted by separating the akarl part from the title part. Walk with a temperature of around 70°C for 48 hours after using an analytical scale. The sample size is set at 3 grams per treatment. Observation was carried out at the end of the research.

10. Root crown ratio

The root-to-crown ratio will be determined by comparing the crown dry weight to the root dry weight, cutting the root to the neck, and cleaning them until no soil/planting medium remains. The header section is also cleaned, and the root part as well as the crown are placed in separate envelopes then placed in the oven at 70°C for 2x24 hours. The dry weight of the header and dry weight of the roots.

B. Data Analysis

The observation results were statistically analyzed using multiple fingerprints (F test) at the 5% significance level. If the results of the variety analysis indicate a significant effect, further tests are carried out using *Duncan's New Range Test* (DNMRT) at the 95% significance level.

RESULTS AND DISCUSSION

A. Volcanic Ash Analysis Results

The analysis of volcanic ash carried out indicates pH within the alkaline range, nutrient content of phosphorus (P) and potassium (K), and fineness and moisture content within the met criteria, based on the Standard Testing of Soil and Fertilizer Instruments (2023) (Table 1).

Table 1. Volcanic ash analysis results

Parameter	Units	Value	Quality Standards	Criteria*
pH	-	8,34	-	Stuttgart
P	%	5,18	-	Height
K	%	13,35	-	Height
Kehalusan	%	98	Min. 80	Meet
Until air	%	1,00	Max. 5	Meet

**) Criteria Based on the Soil and Fertilizer Instrument Standard Testing Center (2023).*

Volcanic ash with alkaline pH can increase the pH of acidic soils, such as ultisols. Hardjowigeno (2010) stated that volcanic ash can increase the pH of acidic soils, thereby improving soil chemical properties and supporting the growth of plants that are not tolerant of acidic conditions. The addition of volcanic ash can increase soil pH, neutralize acidity, and create more optimal conditions for nutrient absorption by plant roots. Soil that is too acidic will inhibit the activity of

beneficial soil microbes, so the presence of alkaline pH volcanic ash can also support the life of soil microorganisms that play a role in the decomposition of organic matter and nutrient release.

The phosphorus (P) and potassium (K) content falls within the category of meeting the criteria set by the Standard Testing of Soil and Fertilizer Instruments (2023), indicating that this volcanic ash can supply essential macronutrients important for metabolic processes and plant tissue formation. The smooth texture of volcanic ash also helps it mix evenly with the soil, improving the efficiency of nutrient utilization by plant roots. In addition, the moisture content, as indicated by the criteria, indicates that this ash is relatively dry, making it easy to store and apply without the risk of clumping. The use of volcanic ash offers benefits as a soil improvement material and a source of plant nutrients, especially in sustainable agricultural systems.

B. Results of Goat Manure Analysis

The analysis of goat manure that has been carried out is known to have a pH with neutral hyteria, the content of nitrogen (N), Phosphorus (P), Potassium (K) elements that have met quality standards, and C-organic has not met quality standards based on the Soil and Fertilizer Instrument Standard Testing Center (2023), (Table 2).

Table 2. Results of goat manure analysis

Parameter	Units	Value	Quality Standards	Criteria*
pH	-	7,01	6-7	Neutral
N+P+K	%	5,55 (1,66+1, 09+2,80)	N+P+K >2	Meet
C-organic	%	8,04	>15	Not Compliant

**) Criteria Based on the Soil and Fertilizer Instrument Standard Testing Center (2023).*

Goat manure has a pH of 7.01, which is within the neutral range. pH conditions with neutral criteria are optimal conditions for plant nutrient absorption. A neutral pH increases the availability of macronutrients such as N, P, and K, which are essential for plant growth (Haryati Y, 2006). Goat manure contains a wide variety of essential nutrients and is a source of organic nutrients that are beneficial to plants. In general, the nitrogen (N) content in goat manure increases the availability of macro- and essential nutrients for plants. Goat manure provides organic nitrogen that is slowly released into the soil, thereby increasing the availability of nutrients needed for plant growth (Haidlir *et al*., 2019).

The phosphorus (P) nutrient in goat manure can be beneficial for root growth and the development of the plant's root system. Goat manure containing organic phosphorus helps increase the availability of phosphorus for plants in Ultisol soil. Potassium (K) acts as the main regulator of osmotic pressure in plant cells. This allows the plant to regulate the balance of water and nutrients that are essential for optimal growth (Fitria *et al*., 2018). organic matter that can provide nutrients to plants through the decomposition process. This process occurs gradually by releasing organic matter that is simple for plant growth. According to Styaningrum *et al.* (2013), the use of goat manure can increase soil organic matter content and cation exchange capacity, thereby improving fertilization efficiency and soil structure, enabling plants to utilize nutrients.

C. Results of Preliminary and Post-Incubation Soil Analysis

Soil analysis showed that the nutrient content in the initial soil was very low, with a pH of sour criteria, N with a value of 0.09 with a very low criterion, P-available with a value of 0.76 with a very low criterion, K-available with a value of 0.20 with a low criterion, and C-organic with a value of 0.81 with a very low criterion. After incubation,

nutrients are added to the planting medium of robusta coffee seedlings (Table 3).

Table 3. Results of soil analysis at the beginning and after incubation

Treatment	Results of incubation soil analysis*				
	pH	N (%)	P-Available (ppm)	K-Available (cmol/g)	C-organic
Early soil	4,57 M	0,09 SR	0,76 SR	0,20 R	0,81 SR
VIP1	5,00 M	0,16 R	6,87 R	0,26 R	1,96 R
V1P2	5,07 M	0,17 R	6,51 R	0,29 R	1,93 R
V1P3	5,15 M	0,18 R	6,80 R	0,28 R	1,98 R
V2P1	5,26 M	0,22 S	8,57 S	0,32 R	2,43 S
V2P2	5,38 M	0,23 S	9,08 S	0,35 R	2,46 S
V2P3	5,30 M	0,23 S	9,45 S	0,37 S	2,35 S
V3P1	5,35 M	0,26 S	11,29 T	0,46 S	2,90 S
V3P2	5,43 M	0,25 S	11,07 T	0,44 S	2,92 S
V3P3	5.55 AM	0,26 S	11,14 T	0,46 S	2,91 S

**) Criteria Based on the Soil and Fertilizer Instrument Standard Testing Center (2023).*
Q: Volcanic ash; Q: Goat manure; SR: Very low; R: Low; S: Medium; Q: High; ST: Very high; M: Sour; AM: A bit sour; N: Neutral

The initial soil analyzed has very low nutrient content for N, P, C-organic, and K. After incubation, there is an addition of nutrients N, P, K to the soil that is used as a plant medium due to the application of goat manure treatment which helps to provide nitrogen (N) nutrients and the application of volcanic ash treatment and goat manure which helps to provide phosphorus (P), potassium (K) nutrients in the planting medium so that plants are more active in absorbing the nutrients needed. According to Hidayah *et al*. (2016), nutrients N, P, and K, available in optimal and balanced amounts, can supply macronutrients for plant growth and development.

The analysis showed that the initial soil pH was among the sour criteria. After incubation, the highest soil pH was observed in the combination treatment of 75 *g/polybag* and 45 *g/polybag* of goat manure (V3P3), with a value of 5.55, within the slightly sour criterion. From these results, it can be seen that adding volcanic ash and goat manure increases soil pH. This increase in pH indicates that the addition of volcanic ash and goat manure can reduce soil acidity. Volcanic ash contains alkaline minerals such as calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na), which neutralize soil acidity (Utami *et al*., 2011). In addition, goat manure can increase soil pH because it contains organic matter that, during decomposition, produces alkaline cations that neutralize H^+ ions in the soil (Nugroho *et al*., 2017).

In the treatment with 75 *g/polybag* of volcanic ash combined with 30 *g/polybag* of goat manure, the highest C-organic content was 2.92, which falls within the moderate range, whereas in the initial soil, the C-organic content was very low. This shows an improvement after treatment. The organic matter content is one indicator of soil quality. The more organic matter there is, the higher the soil quality. This is in accordance with the opinion of Taringan *et al.* (2017), who stated that C-organic is a form of representation of organic matter in the soil; the higher the C-organic content, the better the soil quality. The addition of goat manure increases the C-organic content in the soil because it is rich in organic carbon that can be broken down by soil microorganisms, increases the content of organic matter so that it forms stable humus, and can improve soil structure.

Organic fertilizers, such as goat manure, applied to the soil can improve soil structure and increase the soil's capacity to retain calcium and magnesium

in forms available to plants. According to Sianturi *et al*. (2020), volcanic ash contains several important nutrients, especially potassium (K), phosphorus (P), and sulfur (S), as well as microelements, namely iron, manganese, zinc, and copper, which are needed by soil and plants.

D. Plant Growth Observation

1. Seedling height (cm)

Statistical analysis of the data shows an interaction between the application of volcanic ash and goat manure on the height of robusta coffee seedlings. The height of robusta coffee seedlings in the volcanic ash treatment with a dose of 75 *g/polybag*, combined with the goat manure treatment at 45 *g/polybag*, was significantly higher than in other treatments (Table 4).

Table 4. Robusta coffee seedling height (cm), age 16 MST, after applying a mixture of volcanic ash and goat manure at different doses

Volcanic Ash (g/*polybag*)	Goat Cage Fertilizer (g/*polybag*)		
	15	30	45
25	16,67 a A	18,67 from A	19,33 from A
50	17,00 from A	17,00 from A	19,33 b A
75	21,00 b B	19,67 from A	30,67 c B

KK = 11%

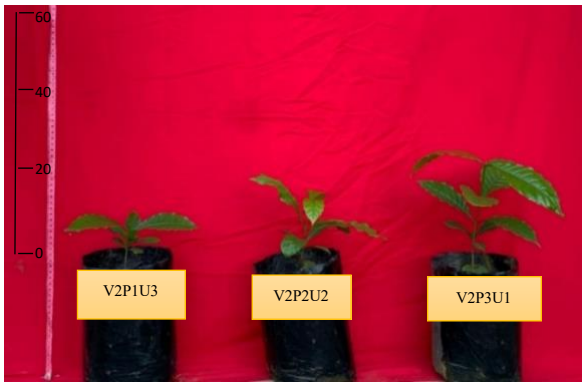
Ket: Numbers located in the same column, followed by the same uppercase letter, and in the same row, followed by the same lowercase letter, indicate different intangibles based on the DNMRT test at the 5% significance level.

The application of a combination of volcanic ash and goat manure showed that there was an interaction between the nutrient content of volcanic ash and organic elements from goat manure in increasing the growth of robusta coffee plant seedlings. Treatment of volcanic ash at a dose of 75 *g/polybag* combined with 45 *g/polybag* of goat manure (V3P3) resulted in the highest growth height of seedlings (30.67 cm), which is significantly different from other measurements (Figure 1).

The addition of volcanic ash and goat manure benefits coffee plant growth, especially during the seedling phase, which is highly dependent on the balance of macro- and micronutrients. One of the main nutrients plants need is nitrogen (N), which plays an important role in promoting vegetative growth, accelerating cell division and elongation, and providing essential nutrients, thereby supporting the tall growth of robusta coffee seedlings. Talitha (2017) stated that nitrogen deficiency can cause slow or disrupted plant growth. In line with the research of Sutanto *et al*. (2023), volcanic ash is rich in minerals such as silica, potassium, and magnesium, which can improve soil physical properties and increase nutrient absorption efficiency. Meanwhile, goat manure significantly improves soil structure and increases soil microbial activity (Prasetya & Widodo, 2022).

According to Munawar (2011), nitrogen is a very important element in supporting growth. This element is part of the constituent structure of amino acids and proteins, which play an important role in the development of the vegetative phase. In addition to nitrogen, phosphorus (P) is involved in enzyme reactions and energy metabolism, and it plays a major role in the growth of plant vegetative organs. The nutrient potassium (K) also has an important function in transporting photosynthesized compounds from leaves to meristematic tissues, supporting the formation of new tissues and strengthening plant resistance to environmental stresses.

(a)



(b)

(c)

Figure 1. Comparison of the height of robusta coffee plant seedlings 16 MST in different treatments (a) a dose of 25 *g/polybag* combined with goat manure with different doses (15, 30, 45 *g/polybag*), (b) a dose of 50 *g/polybag* of volcanic ash combined with goat manure with different doses (15, 30, 45 *g/polybag*), (c) a dose of 75 *g/polybag* combined with goat manure in different doses (15, 30, 45 *g/polybag*)

2. Diameter batang (mm)

Statistical analysis of the data showed no interaction between the application of volcanic ash and goat manure on the stem diameter of robusta coffee seedlings. The application of volcanic ash treatment has a real effect on the diameter of robusta coffee seedlings, while goat manure has a significant effect. Volcanic ash treatment shows a real effect on the growth of stem diameter because the content of nutrients P and K in volcanic ash is higher than that of goat manure, so that it can increase the growth of the stem diameter of coffee seedlings (Table 5).

Table 5. Stem diameter (mm), age 16 MST, after application of a mixture of volcanic ash and goat manure at different doses

Volcanic Ash (g/*polybag*)	Diameter Batang (mm)
25	3,44 A
50	3,56 A
75	4,22 B
Goat Manure (g/*polybag*)	Diameter Batang (mm)
15	2,44
30	2,78
45	3,11

KK = 9%

Note: Numbers in the same column and with the same letters show different intangibles based on the DNMRT test at a 5% significance level.

Analysis of volcanic ash found that the content of nutrients P and K, with values of 5.18 and 13.35, was higher than the content of nutrients P and K in goat manure, with values of 1.09 and 2.80. In line with the results of research from Alviandy *et al* (2016), the application of volcanic ash treatment affects the diameter of the stems of oil palm seedlings in the *main nursery phase*.

Stem growth is not only about height; stem diameter also increases as plants carry out their physiological functions. The application of goat manure treatment to each treatment has not shown a noticeable difference (Table 5). Leiwakabessy (1988) stated that the elements P

and K play a significant role in increasing the diameter of plant stems, especially in their role as a connecting network between roots and leaves. Nutrients P and K can improve vegetative growth, such as stem circumference. This is in accordance with Hardjowigeno's (2010) view that an increase in optimal phosphorus supply will support lateral meristem (cambium) activity in the stem, thereby accelerating cell division and cell concentration, leading to an increase in stem diameter. Lubis (2008) stated that the element potassium strengthens the rigidity of plant stems, which can affect stem diameter. Potassium activates many enzymes important for photosynthesis and respiration.

3. Number of leaves

Statistical analysis of the data showed that there was no interaction between volcanic ash and goat manure on the number of leaves on robusta coffee seedlings. The application of goat manure from the three treatments shows that the average number of coffee seedling leaves at a dose of 45 *g/polybag* is the best dose for leaf growth. This is because the nutrient content contained in goat manure, such as element N, tends to be sufficient for the growth of the leaves of robusta coffee plant seedlings (Table 6).

Table 6. The number of robusta coffee leaves (strands) aged 16 MST due to volcanic ash and goat manure at different doses.

Volcanic Ash (g/*polybag*)	Number of Leaves (helai)
25	11,33
50	12,33
75	11,44
Goat Manure (g/*polybag*)	Number of Leaves (helai)
15	10,89 A
30	11,78 B
45	12,67 B
KK = 7%	

Note: Numbers in the same column and with the same letters show different intangibles based on the DNMRT test at a 5% significance level.

Lingga and Marsono (2013) stated that sufficient nitrogen levels accelerate overall plant growth, especially in stems and leaves. Plants use nitrogen for cell division, and cell enlargement triggers the formation of plant leaves. Leaves are plant organs that determine plant survival, because in leaves, there are processes of photosynthesis, respiration, and transpiration. Phosphorus (P) functions for plants in the process of photosynthesis, energy storage, division, and cell enlargement (Winarso, 2005). According to Hendri *et al.* (2015), Phosphorus (P) is essential for protein and mineral formation in plants; it also helps circulate energy throughout the plant and stimulates root formation.

The application of volcanic ash has no real effect on the growth of the number of robusta coffee seedling leaves because the N element contained in the volcanic ash is low, so the treatment given has not been able to affect the growth of the number of robusta coffee seed leaf sheets. Gardner *et al*. (1991) stated that both genetic and environmental factors influence plant growth. Genetic factors determine the growth limits of each cell and organ, and environmental factors can affect plant growth, such as nutrient availability, which supports vegetative growth.

4. Leaf area (cm^2)

The combination treatment of volcanic ash and goat manure, as statistically analyzed, shows no interaction with the growth of robusta coffee seedling leaves. In the treatment of goat manure, it showed a real effect on the leaf area, while the application of volcanic ash treatment did not have a real effect on the leaf area of robusta coffee seedlings (Table 7).

The nitrogen (N) content in goat manure can support the vegetative growth of the coffee plant. Wijaya (2008) stated that plants with wider leaves indicate the availability of nitrogen in the planting medium, whereas those lacking nitrogen have smaller leaf areas.

Table 7. The area of robusta coffee leaves (strands) aged 16 MST due to volcanic ash and goat manure at different doses.

Volcanic Ash (g/*polybag*)	Leaf Area (cm2)
25	267,78
50	345,11
75	370,56
Goat Manure (g/*polybag*)	Leaf Area (cm2)
15	268 A
30	332,11 B
45	383, 33 B

KK = 19%

Note: Numbers in the same column and with the same letters indicate different intangibles based on the DNMRT test at a 5% significance level.

According to Lakitan (2011), plants that do not receive N in accordance with their nutrient needs will grow with dwarf and small leaves; on the other hand, plants that receive N in accordance with their nutrient needs will grow tall and form wide leaves. According to Pahan (2008), leaf area at the same age varies across regions, depending on factors such as soil fertility and moisture. An increase in leaf area, an increase in leaf seedlings, and the average size are caused by the age of the plant.

The increase in leaf area is inseparable from the influence of nutrients provided, especially nitrogen. Nitrogen nutrients affect cell division; phosphorus activates enzymes in photosynthesis; and potassium plays a role in meristem development, which can affect leaf length and width (Lakitan, 2010).

The increase in the dry weight value of the canopy occurs, due to the content of C-organic, Nitrogen (N), Phosphorus (F), and Potassium (K) contained in goat manure as well as the content of Phosphorus (F), and Potassium (K) contained in volcanic ash which has nutrient-rich nutrient content, judging from the soil analysis after incubation that the nutrient content increases to increase the availability of nutrients for plants which has a positive effect on the dry weight of the canopy of robusta coffee seedlings.

5. Dry weight title (g)

The statistical analysis of treatments involving volcanic ash and goat manure shows an interaction with the dry weight of robusta coffee seed tops (Table 8).

Table 8. The dry weight of the robusta coffee canopy was 16 MST, with and without volcanic ash and goat manure at different doses.

Volcanic Ash (g/*polybag*)	Goat Cage Fertilizer (g/*polybag*)		
	15	30	45
25	1,67 a A	2.33 from A	1,67 a A
50	2.33 from A	3,00 b B	5,00 c B
75	2,67 from A	3,00 b B	5,00 c B

KK = 18%

Note: Numbers in the same column, followed by the same uppercase letter, and in the same row, followed by the same lowercase letter, indicate different intangibles based on the DNMRT test at the 5% significance level.

Goat manure is a source of organic matter that can provide nitrogen (N), phosphorus (P), and potassium (K) needed in high amounts to support crown growth. Nitrogen is essential for the synthesis of proteins and chlorophyll, which directly increase photosynthesis rates and plant crown growth (Musdalifah *et al*., 2021). In addition, the organic matter content in manure increases the activity of soil microorganisms, which aids decomposition and nutrient mineralization (Lestari *et al*., 2020). The application of volcanic ash treatment has a positive impact on plant growth because it contains the elements Phosphorus (P) and Potassium (K), which are beneficial to plant vegetative growth. Rachman *et al*. (2022) stated

that volcanic ash also serves as a soil enhancer, improving soil structure and increasing cation exchange capacity, thereby increasing nutrient availability for plants.

Sumarsono (2010) added that the dry weight of the plant crown reflects the pattern of the plant accumulating products from photosynthesis and integrates with surrounding environmental factors. The high dry weight of plants indicates increased photosynthesis, as the necessary nutrients are readily available.

6. Dry weight of roots (g)

A statistically analyzed combination of volcanic ash and goat manure treatment showed that there was no interaction with the dry weight of robusta coffee seedlings. The application of goat manure treatment has a real effect on the dry weight of the roots, while the treatment of volcanic ash has no real effect. The 45 g/*polybag* dose yields the highest root dry weight of 1.05 g (Table 9).

Table 9. The dry weight of robusta coffee roots aged for 16 MST, treated with volcanic ash and goat manure at different doses.

Volcanic Ash (g/*polybag*)	Dry Weight Root (cm2)
25	0,73
50	0,65
75	0,82
Goat Manure (g/*polybag*)	Leaf Area (cm2)
15	0,58 A
30	0,66 A
45	1,05 B

KK = 25%

Ket: Numbers in the same column and with the same letters show different intangibles based on the DNMRT test at a 5% significance level.

The single effect of volcanic ash on root dry weight is negligible because its lack of N elements reduces nutrient absorption, which supports vegetative growth, including roots. In this case, goat manure provides nitrogen, improves soil moisture, and supports microbial activity, which is essential for nutrient mineralization. This is in accordance with Lubis (2010), who stated that root growth is stimulated by the nutrient Nitrogen, which is influenced by photosynthate supply from the leaves.

The results of photosynthesis will help support the growth of new roots, allowing them to expand the root zone and form new primary roots. The plant's dry matter level is high or low depending on the amount of nutrient absorption during growth. The more nutrients that are absorbed and overhauled, the higher the dry weight produced. According to Yuliana *et al*. (2015), during the vegetative phase, plant growth and development are highly dependent on photosynthetic efficiency, with the resulting products allocated to various plant organs during growth before being harvested as dry weight. In accordance with the opinion of Lingga (2003), the P element functions to stimulate growth, root elongation, and the formation of a good root system. According to Harahap *et al*. (2015), the N element in goat manure absorbed by plants supports vegetative growth, including roots, and element K at root tips stimulates root elongation.

7. Root header ratio

The combination treatment of volcanic ash and goat manure, statistically analyzed, shows an interaction with the root crown ratio of robusta coffee seedlings (Table 10).

The root crown ratio obtained in this study ranges from 2.00 to 8.00, indicating a value>1, suggesting that the vegetative growth of coffee seedlings is more focused on crown growth. This is in accordance with the statement of Sari (2013) that the value of the root crown ratio of >1 shows that the photosynthetic partition is more directed to plant crown growth; on the other hand, the value of the root crown ratio <1 shows that the photosynthetic partition is more directed to plant root growth.

Table 10. The crown ratio of robusta coffee roots aged 16 MST due to volcanic ash and goat manure at different doses.

Volcanic Ash (g/*polybag*)	Goat Cage Fertilizer (g/*polybag*)		
	15	30	45
25	3,00 from A	4,00 from A	2,00 a A
50	4,00 from A	5,00 b B	8,00 c C
75	4,00 from A	4,67 b B	4,33 b B

KK = 27%

Ket: Numbers located in the same column, followed by the same uppercase letter, and in the same row, followed by the same lowercase letter, indicate different intangibles based on the DNMRT test at the 5% significance level.

The root crown ratio shows how water and nutrients absorbed by the roots are translocated to the plant's crown. It is the ratio of the crown's weight to the roots' weight. Plants with a larger proportion of roots can compete more effectively for soil nutrients, while plants with a larger proportion of crowns can accumulate more energy (Allaby, 2004). Gardner (2008) stated that if the N element needed by the plant is sufficient, the plant's metabolism increases, one of which is in the process of photosynthesis, so that the translocation of photosynthate to the roots will be greater, so that the plant's root system follows the growth of the crown. Macronutrients such as N, P, and K in goat manure, as well as P and K in volcanic ash, can support plant growth.

CONCLUSIONS

1. The application of volcanic ash and goat manure showed an interaction with the parameters of seedling height, dry weight of the crown, and the crown ratio of the roots of robusta coffee seedlings.
2. The application of volcanic ash affects the height of the plant, stem diameter, dry weight of the crown, and the crown ratio of the roots of robusta coffee seedlings.
3. The application of goat manure affects the height of the plant, the number of leaves, the area of leaves, the dry weight of the crown, the dry weight of the roots, and the ratio of the root crown of robusta coffee seedlings.
4. Based on the research results, it is recommended to use 50 g of volcanic ash and 45 g of goat manure per polybag to support the growth of robusta coffee seedlings.

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