

## APPLICATION OF LIQUID ORGANIC FERTILIZER FROM COFFEE (*Coffea canephora*) HUSK WASTE FOR CORN (*Zea mays* L.) SEED GERMINATION

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### ABSTRAK

**Kata kunci:**  
Kulit kopi  
Perkecambahan jagung  
Pertanian berkelanjutan  
Pupuk organik cair

Limbah kulit kopi merupakan salah satu produk sampingan agroindustri terbesar, yang seringkali kurang dimanfaatkan dan berkontribusi terhadap masalah lingkungan. Konversi limbah ini menjadi pupuk organik cair (POC) menawarkan solusi yang berkelanjutan untuk pengelolaan limbah dan produktivitas pertanian. Penelitian ini bertujuan untuk mengevaluasi karakteristik fisikokimia POC kulit kopi dan pengaruhnya terhadap perkecambahan dan pertumbuhan awal biji jagung. Fermentasi dilakukan secara anaerobik selama dua bulan menggunakan EM4 sebagai bioaktivator dan molase sebagai sumber nutrisi. POC yang dihasilkan menunjukkan sifat-sifat yang menguntungkan, termasuk pH netral, bau asam manis, warna coklat tua, dan viskositas yang mendekati air, sehingga mudah diaplikasikan. Analisis nutrisi menunjukkan nitrogen (1,57%), fosfor (0,14%), dan kalium (0,23%), dengan total 1,94%. Nilai-nilai ini menunjukkan bahwa kandungan N-organik yang memenuhi persyaratan minimum, sedangkan total NPK sedikit di bawah Standar Nasional Indonesia (2-6%). Penerapan POC pada konsentrasi 0,3-0,5% (v/v) secara signifikan mempercepat perkecambahan dan meningkatkan panjang akar, sementara tinggi tunas dan jumlah daun tidak terpengaruh secara signifikan. Temuan ini menunjukkan bahwa limbah kulit kopi dapat diubah menjadi POC dengan kualitas yang dapat diterima dan efek positif pada pertumbuhan awal tanaman. Optimalisasi lebih lanjut dari kondisi fermentasi dan pengayaan nutrisi direkomendasikan untuk memenuhi standar kualitas penuh dan memperluas potensi aplikasinya dalam pertanian berkelanjutan.

### ABSTRACT

**Keywords:**  
Coffee husk  
Corn  
germination  
Liquid organic fertilizer  
Sustainable agriculture

Coffee husk waste is one of the largest agro-industrial byproducts, often underutilized and contributing to environmental problems. Converting this waste into liquid organic fertilizer (LOF) offers a sustainable solution for waste management and agricultural productivity. This study aimed to evaluate the physicochemical characteristics of coffee husk LOF and its effect on corn seed germination and early growth. Fermentation was carried out anaerobically for two months using EM4 as a bioactivator and molasses as a nutrient source. The resulting LOF showed favorable properties, including a neutral pH, a sweet-acidic odor, a dark brown color, and a viscosity close to that of water, which makes it easy to apply. Nutrient analysis showed nitrogen (1.57%), phosphorus (0.14%), and potassium (0.23%), totaling 1.94%. These values indicate that the N-organic content meets the minimum requirement, while the total NPK is slightly below the Indonesian National Standard (2-6%). Application of LOF at concentrations of 0.3-0.5% (v/v) significantly accelerated germination and increased root length, while shoot height and leaf number were not significantly affected. The findings demonstrate that coffee husk waste can be transformed into LOF with acceptable quality and positive effects on early plant growth. Further optimization of fermentation conditions and nutrient enrichment is recommended to meet full quality standards and broaden its application potential in sustainable agriculture.

## INTRODUCTION

The coffee plant plays a vital role in international trade and cultural identity. Indonesia, with its favorable geography and tropical climate, is the fourth-largest coffee producer after Brazil, Vietnam, and Colombia, with an average annual yield of approximately 639,000 tons (Nugroho *et al.*, 2025). One of the largest coffee producers in Central Java is Peron Village, Limbangan District, Kendal Regency, with an annual production capacity of approximately 350 tons of fresh coffee and 87.5 tons of dried coffee (Naufal *et al.*, 2025). Nearly half of the coffee weight is fruit flesh, consisting of 42% fruit skin and 6% seed skin (Halimatusa'diyah *et al.*, 2024). As a result, a relatively large proportion of byproduct waste is produced, accounting for 50-60% of the total harvest yield. This high production volume generates a substantial amount of coffee husk waste (more than 150 tons), much of which remains underutilized in the soil. As a result, it can cause a pungent odor and contribute to degraded soil quality due to the presence of alkaloids, tannins, and polyphenols. The ongoing accumulation of coffee husk waste requires immediate management because it has the potential to cause environmental pollution.

Treating waste as a resource for value-added products opens economic opportunities, reduces costs, and sustains

the industry and environment (Andalia *et al.*, 2025). Furthermore, farmers' increasing dependence on synthetic chemical fertilizers not only increases production, but it can also lead to soil degradation, groundwater pollution, and aquatic eutrophication (Nurhidayanti, 2025). This condition indicates an urgent need to find alternative coffee waste management methods and to provide more environmentally friendly fertilizers.

Coffee husk contains high levels of organic carbon (45.30%) and essential nutrients, including nitrogen (N) (2.98%), phosphorus (P) (0.18%), and potassium (K) (2.26%) (Sidabutar *et al.*, 2024). With these nutrient contents, coffee husk has strong potential as a raw material for liquid organic fertilizer (LOF), offering a practical way to convert waste into value-added products. In addition, its use as an environmentally friendly fertilizer that can enhance plant vitality, resilience, and overall productivity (Amini *et al.*, 2025).

LOF has various advantages that support the implementation of sustainable agriculture. This fertilizer is effective in addressing plant nutrient deficiencies, is safe for repeated use, and does not damage the soil or plants, making it more environmentally friendly (Irawan *et al.*, 2021). Compared to solid organic fertilizers, LOF is absorbed more quickly by plants because its nutrient content can be adjusted flexibly. The LOF binding capacity ensures that the fertilizer solution

applied to the soil is immediately available to plants and utilized directly (Irawan *et al.*, 2021). The LOF production involves fermenting organic materials, which produces a nutrient-rich solution (Alkatiri *et al.*, 2024). This fermentation utilizes microbial consortia, including lactic acid bacteria, yeast, actinomycetes, and photosynthetic bacteria, which accelerate the decomposition of complex compounds, such as lignin and cellulose. As a result, these materials are converted into simpler compounds that are more readily available (Ziliwu & Lase, 2025).

Previous studies have discussed the use of coffee husk as organic fertilizer. Nurjakiah *et al.* (2022) processed coffee husk, converted it into liquid and solid fertilizers via one week of effective microorganism (EM4) fermentation, and applied to coffee plants in Aek Sabaon Village, thereby increasing production at a lower cost. The high K content (10.25%) was shown to stimulate faster, denser fruit growth. In addition, Saputro & Wiraguna (2025) used varying concentrations of LOF coffee husk (0-40 mL L<sup>-1</sup>) on Arabica coffee seedlings, and it was found that a concentration of 30 mL L<sup>-1</sup> gave the best results for plant height and leaf number. However, these studies have limitations, including the absence of comprehensive LOF characterization (pH, odor, color, texture) and the lack of documentation, leaving product standards undocumented. Its effectiveness has been tested only on

coffee plants, with no exploration on other crops, and applications focus on vegetative or generative phases rather than germination.

Corn (*Zea mays* L.) is a major secondary crop in Indonesia and an alternative food source after rice due to its high carbohydrate, vitamin, mineral, and fiber content (Elpira *et al.*, 2022). The germination phase greatly influences cultivation success, as it is the initial stage of young plant development and determines subsequent growth, including plant height, leaf number, and root development (Hia, 2025). Germination is a physiological process in which the embryo begins to activate and develop, influenced by humidity, temperature, oxygen (O<sub>2</sub>), and nutrient availability (Dohona, 2025).

In field practice, farmers generally treat seeds by soaking them in clean water for 6-12 h to stimulate imbibition (Waruwu & Lase, 2025). However, this treatment only increases water absorption without adding nutrients. Research shows that natural solutions, such as P and K rich banana peel soaking water, can improve viability and accelerate the emergence of corn shoots during germination (Dohona, 2025). LOF has also been shown to accelerate the initial growth and root development of corn plants during the vegetative stage. Therefore, the effect of LOF on germination remains to be studied to understand the plant's response to the

pre-planting treatment (Sahubauwa *et al.*, 2025).

Given the high volume of coffee husk waste in Peron Village and its potential for conversion into LOF. This study was conducted to produce LOF from coffee husk, analyze its physical characteristics and macronutrient content (N, P, K), and evaluate its effect on corn seed germination at various concentrations. The study addresses the role of coffee husk LOF during the physiological stage of seed imbibition, providing new insights into its use to enhance early germination.

## MATERIALS AND METHODS

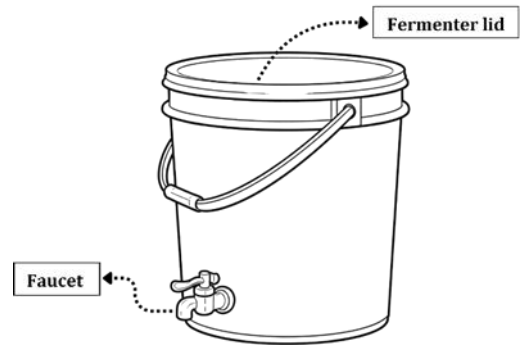
### Time and Location

The study was conducted from July 2025 to January 2026 in the Laboratory of Natural Science, Universitas Negeri Semarang, Semarang, Central Java, Indonesia. It was carried out under the student organization capacity strengthening program (PPK-ORMAWA).

### Materials

Coffee husk from a Robusta plantation in Peron Village, Semarang, Central Java, Indonesia, was used as the main ingredient. The fermentation process was conducted using EM4, yellow packaging obtained from PT. Songgolangit Persada, Jakarta, Indonesia. Molasses were purchased from a local market in Kendal, Central Java, Indonesia, as a nutrient source. Water was obtained from the local community well and used to dilute

fertilizer. A fermenter (10 L) was assembled from a plastic drum and a faucet, with a cloth filter and a wooden manual stirring rod, as shown in **Figure 1**.



**Figure 1.** Fermenter design for liquid organic fertilizer production (10 L) made from polypropylene (PP).

### Fermentation Procedure

A simple fermentation process produced LOF from coffee husk. The coffee husk (5 kg) was prepared and thoroughly washed to remove any soil or dirt. The clean coffee husk was put into a plastic gunny sack, tied, and loaded into the fermenter. Molasses and EM4 (1:1) were dissolved in 1 L and allowed to sit for 20 min. After that, the molasses and EM4 solution were added to the fermenter, and 9 L of water was subsequently added until the bag was submerged. The system was mixed thoroughly, and the fermenter was closed tightly. Molasses was added as a carbon source for microorganisms (Phibunwatthanawong & Riddech, 2019). The fermentation process was performed for 2 months in a shaded place at room temperature ( $30 \pm 5^\circ\text{C}$ ) (Mustikarini *et al.*, 2022). The fermenter was opened briefly

every 3 days for stirring to homogenize the mixture and release accumulated gas, then immediately resealed and the overall process remained under anaerobic conditions. Fermentation was complete when the mixture produced a sweet-and-sour odor.

### **LOF Characterization**

pH measurements were performed using a pH meter. The fertilizer (100 mL) was poured into a beaker, and the pH was measured three times; the results were averaged. The pH value indicates the acidity or alkalinity of the LOF solution. The viscosity of the LOF was measured using a simple viscometer. The measurement results were compared with the viscosity of water at room temperature ( $30 \pm 5$  °C) as a control. This comparison indicates the viscosity of the LOF relative to a standard liquid. The color of the LOF was recorded using a color picker application to obtain objective data on color intensity and nuance. The odor of the LOF was qualitatively assessed to characterize the fermentation product quality. This observation aimed to ensure the sweet-acidic odor. Analyses of N, P, and K were conducted in the laboratory in accordance with the Indonesian National Standard (SNI 2803:2024) to determine the potential macronutrient content.

### **Germination Experiment Design**

The germination experiment was arranged in a Completely Randomized Design (CRD) with four treatments and

three replications, resulting in 12 experimental units. The treatments were variations in LOF concentration: 0% (v/v) (C), 0.3% (v/v) (T1), 0.5% (v/v) (T2), and 0.7% (v/v) (T3). A germination experiment was conducted using soil prepared in small pots as the growing medium. The soil was collected from the local corn farm, with poor corn growth observed *in situ*. Based on its traits, the soil was categorized as low in fertility with a sandy texture with the presence of gravel, and light greyish brown color. These characteristics are consistent with previous reports that sandy soils generally exhibit low nutrient content, low cation exchange capacity (CEC), and poor fertility (Aprilia & Sukur, 2022; Yost & Hartemink, 2019; Zulkoni *et al.*, 2020).

Each treatment used 5 corn seeds planted in one pot, with 3 replications. Each pot was considered as one experimental unit. In total, there were 12 experimental units (4 treatments  $\times$  3 replications). The corn seeds used in this study were viable and healthy, obtained from a local farm with uniform size and appearance. Prior to sowing, seeds were visually inspected to ensure they were free from physical damage and disease symptoms. Corn seeds were planted at a soil depth of approximately 1-2 cm with the tops of the seeds still visible above the soil surface. Each treatment received an LOF solution at the specified concentration, while the control received

only water. All treatments were watered daily at 10.00 am to ensure equal moisture conditions. All experimental units were placed under the same conditions at room temperature ( $30 \pm 5$  °C). The observations were performed daily from the first to the seventh day after planting (DAP), or until most of the seeds had germinated.

### Parameters Observed and Data Analysis

The parameters observed included germination time and seedling (root and shoot) length for 7 days of treatment. Measurements of root length, shoot length, and leaf number were taken individually from each seedling (5 per pot). The average of the five seedlings was used to represent one pot as one experimental unit. Each treatment had three replications. However, only one replication with the highest normality value was selected for statistical analysis to ensure data validity. The observed data were tabulated and analyzed descriptively to obtain mean and standard deviation values. The data were analyzed using one-way ANOVA, followed by the post hoc Duncan multiple-comparison test. The analysis results were presented in tables and graphs to clarify interpretation.

## RESULTS AND DISCUSSION

### LOF Production and its Characteristics

Coffee husk is abundantly available as agro-industrial waste and has a high lignocellulose content, making it a

potential source of nutrients after fermentation. In this study, the LOF was produced during 1-2 month fermentation process using EM4 and molasses as supplementary nutrients. After fermentation, the product was bottled, and the presentation is shown in **Figure 2**.



**Figure 2.** Product of LOF from coffee husks after two months of fermentation.

Coffee husk contains approximately 24% cellulose, 29% hemicellulose, and 23% lignin. They also contain other nutritional components such as protein (8–11%), lipids (0.5–3%), and minerals (3–7%) (Ribeiro *et al.*, 2024), which further strengthen their potential as a raw material for LOF with added value for soil fertility and plant growth. A fermentation process by microorganisms, such as aerobic and anaerobic bacteria and fungi (Wibowo *et al.*, 2024), capable of digesting lignocellulose, is required to convert coffee husk into LOF. In this study, EM4 was added as a bioactivator to accelerate lignocellulose degradation in coffee husk.

The addition of EM4 also accelerates fertilizer formation and improves the quality of the resulting fertilizer (Mustikarini *et al.*, 2022). The microbial consortium in EM4 is expected to degrade cellulose and hemicellulose into simple sugars and soften lignin, thereby accelerating the fermentation process. EM4 is an inoculant containing selected microorganisms that enhance microbial

populations in soil and water. It comprises lactic acid bacteria such as *Lactobacillus plantarum* L. casei and *Streptococcus lactis*; photosynthetic bacteria such as *Rhodospseudomonas palustris*; yeast such as *Saccharomyces* spp.; and various types of fungi (Yuniati *et al.*, 2025). The characterization of the LOF was presented in **Table 1**.

**Table 1.** Characterization of LOF from coffee husks after fermentation for two months

Parameter	Results
pH	6.6
Odor	Sweet and sour
Color	Dark brown
Viscosity	1.74 cP (28°C)
Nitrogen	1.57%
Phosphor	0.14%
Potassium	0.23%

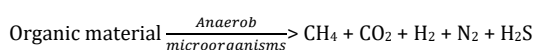
Microorganisms in EM4 work synergistically by producing enzymes to break down the complex structure of coffee husk. Enzymes that degrade complex carbohydrates and polysaccharides into simpler molecules are known as Carbohydrate-Active Enzymes (CAZymes). This group of enzymes includes the Glycoside Hydrolase (GH), Carbohydrate Esterase (CE), and enzymes with Auxiliary Activity (AA) families (Hsin *et al.*, 2025). The process of lignocellulose degradation requires the synergistic action of several enzyme types.

Endoglucanase breaks the internal  $\beta$ -1,4-glycosidic bonds in cellulose; exoglucanase breaks the bonds at the ends of the cellulose chain to produce cellobiose; and  $\beta$ -glucosidase converts

cellobiose into glucose (Hsin *et al.*, 2025; Selim *et al.*, 2025). This enzymatic degradation converts the complex structure of coffee skin into soluble nutrients, including glucose, organic acids, amino acids, and growth hormones, which are beneficial for plants. This process converts the complex structure of coffee skin into simple nutrients, such as glucose, acetic acid, propionic acid, lactic acid, and ethanol, which support plant growth (Sidabutar *et al.*, 2024).

The carbon (C) source in the form of simple sugars is required to support optimal EM4 microorganism activity. Therefore, molasses was added as a fermentation support material in this study. Sugarcane molasses is a liquid waste from the sugar industry containing

approximately 50% (w/v) total sugars (sucrose, glucose, fructose), 0.5–0.9% (w/v) nitrogen, and 10% (w/v) inorganic salts (Sun *et al.*, 2019). The addition of molasses provides nutrients and energy for microorganisms during fermentation. In this process, microorganisms decompose organic compounds into simpler compounds and produce methane gas, carbon dioxide, and low-density organic acids (Widyabudiningsih *et al.*, 2021). In general, the anaerobic decomposition reaction of organic compounds is explained by the following simple reaction:



The fermentation of LOF was carried out anaerobically for 2 months at room temperature ( $30 \pm 5$  °C), which is the optimal condition for microorganism activity in EM4. This is in line with the opinion of Mustikarini *et al.* (2022), who stated that anaerobic fermentation will proceed well if the material is maintained at 25–55 °C, a temperature range that supports bacterial growth. Generally, the LOF fermentation process from organic materials, such as vegetable or fruit waste, takes 3–4 weeks (Karyanto *et al.*, 2022; Semaun *et al.*, 2024). However, in this study, fermentation was extended to 2 months because, in the fourth week, the odor remained pungent and fermentation gas continued to form. These conditions indicate that the fermentation process is not yet complete.

This longer duration is related to the characteristics of coffee husk, which has a relatively high lignin content ( $\pm 23\%$ ), making their lignocellulosic structure more difficult to degrade than that of simpler organic materials. Lignin is complex and resistant to microbial activity, thereby slowing the formation of simple compounds needed in the fermentation process (Setyawati & Sari, 2025). A longer fermentation time allows the breakdown of cellulose, hemicellulose, and lignin. It releases more N, P, and K nutrients (Setyawati & Sari, 2025). Afa *et al.* (2024) emphasized that the LOF fermentation is indicated by the appearance of a distinctive, non-pungent fermentation odor.

A sweet-and-sour odor also characterizes LOF that has undergone complete fermentation and helps prevent foul odors (Mandamdari *et al.*, 2025). The LOF from the coffee husk fermentation process can be evaluated by characterizing the final product. LOF characterization is an important stage in determining fertilizer quality and fermentation maturity. In this study, LOF characterization includes measuring pH and viscosity, as well as observing color and odor, which are indicators of fermentation maturity.

#### **Characteristics of Coffee Husk LOF**

The degree of acidity (pH) is one of the parameters used to test the quality of LOF. The pH value of the LOF reflects the

acidity level resulting from the fermentation of organic matter into simpler molecules, which can then affect soil pH and nutrient absorption by plant roots (Chalisy & Baharudin, 2024). The results in **Table 1** show that the coffee husk liquid has a pH value of 6.6. Mature LOF has a pH characteristic close to neutral, which is in the range of 6.5–7.0 (Sulfianti *et al.*, 2021).

In the initial stage of fermentation, the pH of LOF decreases as microorganisms decompose organic matter into organic acids. It then increases again as these organic acids are converted into more neutral compounds, indicating that the LOF is approaching readiness for use. However, excessively pH level can be harmful to the environment. At the same time, a pH that is too low can reduce microorganism viability (Asad *et al.*, 2025). The resulting pH value falls within the standard range for LOF quality, as specified in the Decree of the Indonesian Minister of Agriculture No. 261/KPTS/SR.310/M/4/2019, which sets a permissible pH range of 4.0–9.0.

The LOF fermentation can also be observed through changes in odor. This study shows that the coffee husk LOF has a sweet and sour odor, indicating that fermentation has reached maturity and that the product is ready for application to plants. Odor changes during the fermentation process provide clear indications of microbial activity and the

maturity level of the LOF. A successful fermentation process is indicated by the appearance of a characteristic sour odor derived from the formation of alcoholic or lactic acid (Nada *et al.*, 2025). Microorganisms in the fermentation process can also produce odor-forming compounds that impart distinctive characteristics, including volatile compounds with positive properties (Sunaryo & Rahmatiyah, 2024).

Color is a visual indicator of the level of organic material decomposition and the fermentation maturity of the LOF. Color changes during fermentation indicate the microorganism activity as they break down complex compounds into simpler forms. The results of the color analysis using the color picker application, as shown in **Table 1**, indicate that the LOF from coffee husk is 94% dark brown, with the code #603716 and RGB values of (96, 55, 22). This value indicates a deep color intensity and low luminance (5%), indicating that the organic compound has been optimally decomposed. The result of LOF can also be assessed from its physical characteristics, including a color change to dark brown, the absence of a strong, foul odor, and the absence of excessive white mold growth (Farhamni *et al.*, 2025).

In addition, the color of fermented LOF is influenced by the raw materials used. This change occurs as microorganisms from bioactivator decompose the fertilizer material, causing

the color to shift from brown to blackish brown (Meo, 2024). The color change to dark brown not only serves as a visual indicator of maturity, but also reflects the completion of the fermentation process. This condition signifies that the LOF has become stable and high-quality.

The viscosity value obtained was 1.74 cP (28 °C), indicating that the physical characteristics of LOF from coffee husk are not too high and are close to those in water, making it easy to apply. According to Su *et al.* (2025), high viscosity can reduce fluidity in a system, thereby potentially inhibiting the application of liquid fertilizer in the field. Holifah & Ekalaturrahmah (2025) stated that the physical quality of homogeneous fertilizer with moderate viscosity and a neutral to slightly acidic pH (6.0–6.5) supports optimal availability of micro and macronutrients (NPK) for plant absorption. Thus, measuring the viscosity of the LOF from coffee husk in this study is relevant for assessing the product's physical quality and ensuring ease of application.

The N, P, K contents in LOF derived from coffee husk are presented in **Table 1**. The quality and standard of liquid organic fertilizers for macro nutrients (N + P<sub>2</sub>O<sub>5</sub> + K<sub>2</sub>O) is 2–6%, with a minimum of 0.5% N-organic. The laboratory test result showed that LOF coffee husk contained 1.57% N, 0.14% P, and 0.23% K, with a total of 1.94%. These values indicate that the N-

total meets the minimum requirement, while the total NPK is slightly below the standard range. In the previous study Karyanto *et al.*, (2022) reported that higher NPK values in vegetable waste-based (spinach) (N = 3.06%, P = 3.18%, K = 3.32%) and mustard greens LOF (N = 3.45%, P = 3.84%, K = 4.44%). Nevertheless, the NPK values of LOF in this study were lower. The difference may be attributed to the composition of the raw material, fermentation conditions, and microbial activity. The ability of coffee husk LOF to accelerate germination and enhance root length at 0.3-0.5% (v/v) demonstrates that, even with lower NPK values, the fertilizer remains effective in supporting early plant growth.

NPK are essential macronutrients required to support plant growth and productivity (Elly & Maitimu, 2025). N is an essential nutrient that plays a role in supporting plant growth and productivity. It contributes to synthesis of vital compounds, such as amino acids, enzymes, and chlorophyll (Agustina *et al.*, 2024; Elly & Maitimu, 2025). P plays a role in energy transfer and increases N absorption in the early stages of growth, accelerating root and fruit formation, and strengthening stems. Meanwhile, K regulates the carbohydrates distribution from leaves to other plant organs (Agustina *et al.*, 2024).

This study analyzed the physical characteristics and macronutrient content (NPK) of the LOF. However, measurements

of C-organic content and the C/N ratio, as important indicators of organic fertilizer standards and fermentation maturity, were not conducted due to limitations. Future studies should include these parameters to provide a more comprehensive characterization of coffee husk-based LOF.

#### **Application of Coffee Husk LOF in Corn Seed Germination**

The application of LOF at varying concentrations affected corn seed germination. On day 3, treatments T1 (0.3% (v/v)) and T2 (0.5% (v/v)) reached 100% germination, whereas the control reached only 20%. On day 7, all treatments showed high germination rates ranging from 80% to 100% (**Table 2**). The germination is presented in **Figure 3**.

The relatively low germination observed in the control treatment can be explained by the soil conditions used in this study. The soil was sandy in texture, light in color, and originally contained gravel, which reflects nutrient limitations and poor fertility. Corn plants grown in this soil *in situ* were small and weak, consistent with previous reports that sandy soils generally exhibit low nutrient content, low CEC, and poor fertility (Aprilia & Sukur, 2022; Yost & Hartemink, 2019; Zulkoni *et al.*, 2020). This condition highlights the importance of LOF application, which provides additional nutrients and bioactive compounds to support early germination.

It is also recognized that the humidity of the growing medium and seed viability are primary factors influencing germination. Nevertheless, the marked difference between the control and LOF treatments indicates that LOF application accelerated germination. The nutrients and bioactive compounds produced during fermentation likely complemented environmental factors, supporting enzyme activity and cell division during the early germination phase.

The application of LOF during corn seed germination accelerated the process, particularly on day 3, where T1 (0.3% (v/v)) and T2 (0.5% (v/v)) achieved 100% germination compared to only 20% in the control (**Table 2**). This germination rate indicates that coffee husk LOF can accelerate early plant growth processes. The nutrients (N, P, K) and bioactive compounds produced by fermentation are likely to stimulate enzyme activity and cell division during early germination. Hia (2025) stated that the germination is a critical stage in the plant life cycle because it determines the formation of young plants. This stage subsequently influences further growth, including plant height, leaf number, and root development. Thus, although Day 7 germination results were similar across treatments. The higher initial germination rate in LOF treatments shows their effectiveness in supporting corn's early growth phase.

**Table 2.** Percentage of corn seed germination within 7 days

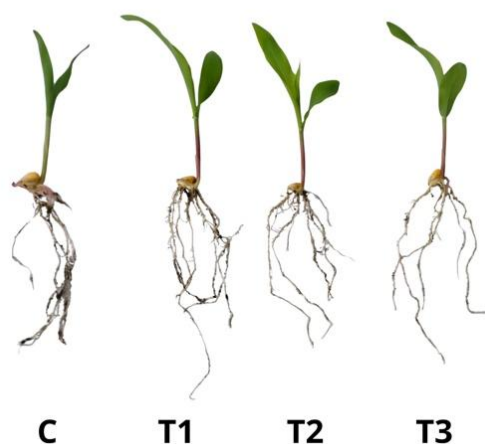
Treatment	Code	LOF Concentration % (v/v)	The day germination begins	Germination percentage on Day 3	Germination percentage on Day 7
Control	C	0	D3	20%	80%
Treatment 1	T1	0.3	D3	100%	100%
Treatment 2	T2	0.5	D3	100%	100%
Treatment 3	T3	0.7	D3	80%	100%

### Root Length

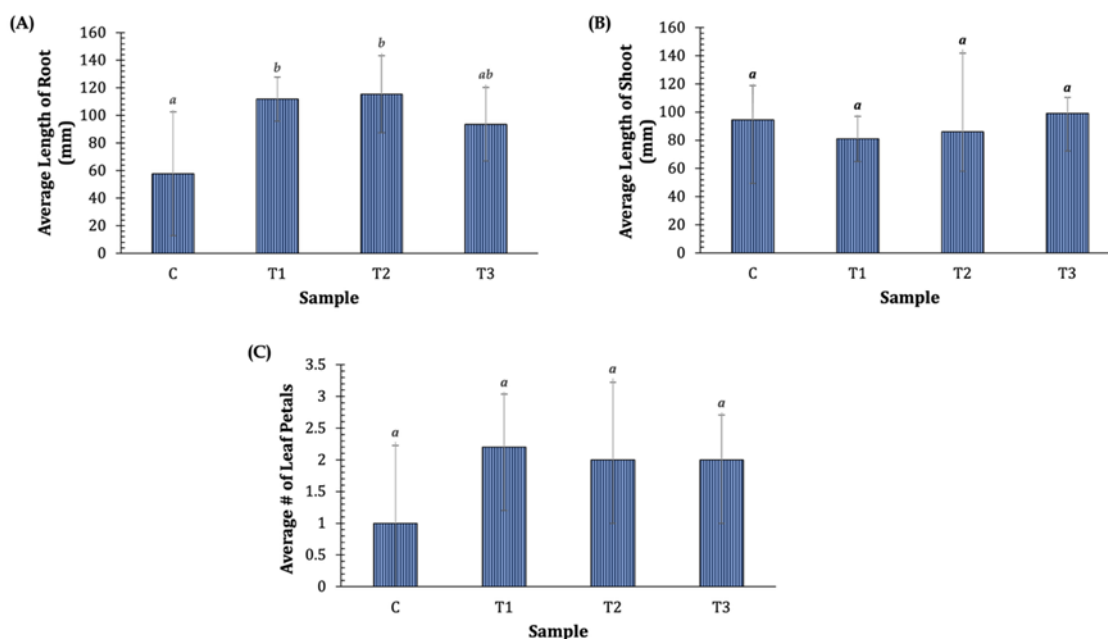
As shown in **Figure 4A**, Root length was significantly affected by LOF application ( $p = 0.033$ ). Treatments T1 and T2 produced longer roots than the control, confirming that the optimal LOF concentration is 0.3-0.5% (v/v). The increase in root length is attributed to the availability of N, P, and K. As we know that N plays a crucial role in the formation of amino acids, enzymes, and chlorophyll, which support plant growth. P helps energy transfer and increases N absorption in the early phase, while accelerating root and fruit formation and strengthening stems. Meanwhile, K regulates the carbohydrates translocation

from leaves to other organs (Agustina *et al.*, 2024).

Heryana *et al.* (2025) reported that the application of LOF from agricultural waste can significantly increase corn root growth, including length, density, and root branching. In contrast, at 0.7% (v/v) concentration (T3), root length decreased compared to 0.3% (v/v) (T1) and 0.5% (v/v) (T2), indicating that excessive LOF doses can cause suboptimal growth. Budianto *et al.* (2025) explained that excessive LOF application disrupts the nutritional balance in the growing medium and causes adverse effects due to the accumulation of unnecessary substances.



**Figure 3.** Corn seed germination samples obtained from each coffee husk liquid organic fertilizer (LOF) treatment: control (C), treatment 1 0.3% (v/v) (T1), treatment 2 0.5% (v/v) (T2), and treatment 3 0.7% (v/v) (T3) after 7 days.



**Figure 4.** Data of root **(A)** and shoot length **(B)** of corn seedlings, and number of leaf petals **(C)** under different coffee husk liquid organic fertilizer (LOF) concentrations (C, T1, T2, and T3). Values presented are mean  $\pm$  SD ( $n = 5$ ). Different letters above bars indicate significant differences (ANOVA and Duncan test at 5%).

### Shoot Length

Leaf shoot length showed an ANOVA significance value of 0.810 ( $p > 0.05$ ), indicating that treatments did not differ significantly (**Figure 4B**). This condition is likely related to environmental variations that affect plant growth. In addition, the relatively short duration of the study may have limited the full observation of the effects of LOF application (Heryana *et al.*, 2025). However, other studies have shown different results.

Mangardi *et al.* (2023) reported that applying cow manure compost significantly increased sweet corn plant height by improving soil fertility and nutrient availability. Chasanah *et al.* (2020) found that composted agricultural waste positively affected corn growth by increasing N uptake and improving soil

properties. Variations in results may be influenced by the type of organic fertilizer used (liquid vs. solid compost), environmental conditions, and the observed growth stage. Although this study did not show a significant effect on leaf buds, other literature indicates that organic fertilizers continue to play an important role in supporting vegetative plant growth under certain conditions.

### Number of Leaf Petals

Leaf number also did not differ significantly among treatments (**Figure 4C**). The low leaf number is thought to be related to the suboptimal nutrient concentrations in each treatment (Edy *et al.*, 2023). Kusuma *et al.* (2024) stated that each plant has different fertilizer requirements, so variations in nutrient content across fertilizers can affect plant

growth and development. Heryana *et al.* (2025) reported no significant differences in leaf number among treatments. This outcome is likely influenced by environmental factors and uneven nutrient availability. In addition, the relatively short duration of the study may have been insufficient to reveal the optimal effect of LOF application.

Shoot length and leaf number did not differ significantly among treatments. This result is consistent with the physiology of corn seedlings at the early growth stage. During this phase, seed reserves are primarily allocated to root elongation and embryo development rather than to shoot elongation and leaf formation. Maize growth consists of three phases, including germination (from imbibition to before the first leaf appears), the vegetative (from the opening of the first leaf to tasseling before silking), and the reproductive (after silking until physiological maturity) (Yuliana, 2024).

Due to the observation period was limited to 7 days, the plants were still in the germination phase and had not yet reached the vegetative stage where shoot and leaf growth become more pronounced. Moreover, plant height and shoot development at ages below 42 days after planting are still strongly influenced by genetic and physiological factors (Oktaviani *et al.*, 2020). Therefore, the absence of significant differences in shoot

length and leaf number is consistent with the early growth physiology of corn.

Overall, this study showed that applying LOF from coffee husks significantly increased root length at concentrations of 0.3–0.5% (v/v) but did not significantly affect shoot height or leaf number. The differences in responses across variables indicated that the effectiveness of LOF was influenced by the type of organ observed, fertilizer concentration, environmental conditions, and the duration of the study.

## CONCLUSION

Coffee husk LOF produced through microbial fermentation demonstrated good physicochemical quality, with N, P, K contents of 1.57%, 0.14%, and 0.23%, respectively. While the N-organic content met the minimum requirement, the total NPK (1.94%) was slightly below the standard range of 2-6%. Nevertheless, LOF application at 0.3-0.5% (v/v) significantly enhanced root length and accelerated corn seed germination, although shoot height and leaf number were not significantly affected. These findings indicate the potential of coffee husk LOF to support early plant growth, though further studies are needed to optimize nutrient content and evaluate performance under field conditions.

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