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A Study on Litter Productivity and Leaf Decomposition of Robusta Coffee (*Coffea canephora* Pierre) in the Plantation Area of Politeknik Negeri Jember

Setyo Andi Nugroho[1], Eva Rosdiana[1], Rudi Wardana[1], Abdurrahman Salim[1], Fandyka yufriza Ali[1], Virman Maulana Yahya[1], Ika Lia Novenda[2], Mira Herawati Soekamto[3]
[1] Department of Agricultural Production, Politeknik Negeri Jember, Indonesia
[2] Biology Education, University of Jember, Indonesia
[3] Department of Agrotechnology, Universitas Muhammadiyah Sorong, Indonesia

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ABSTRACT
Litter productivity and decomposition are essential ecological processes influencing nutrient cycling and soil fertility in coffee-based agroecosystems. This study aimed to evaluate litter productivity and the decomposition rate of Robusta coffee (Coffea canephora) leaf litter in the plantation area of Jember State Polytechnic, East Java, Indonesia. The site is located at 89 meters above sea level, with a tropical monsoon climate, an average temperature of 26–28°C, and annual rainfall of approximately 2,200 mm. Litter was collected weekly for 12 weeks using 1 m² litter traps, while decomposition was analyzed using the litter bag method with three leaf size treatments (P1: 51–70 cm², P2: 31–50 cm², P3: 10–30 cm²) and three concentrations of EM4 (K1: 5 mL, K2: 10 mL, K3: 20 mL). The study applied a factorial Completely Randomized Design (CRD) with two factors, three levels each, and three replications. The highest litter productivity (18.07 g/m²/week) was recorded in the third week, coinciding with high rainfall and temperature. While neither leaf size nor EM4 concentration alone had a significant effect on decomposition, their interaction significantly influenced the decomposition rate, with the P3K3 treatment (smallest leaf size and highest EM4 concentration) showing the highest rate (2.3%). Compost color reached maturity (black) between the 8th and 10th week, although the C/N ratio remained above the Indonesian national compost standard (SNI 19-7030-2004), indicating incomplete decomposition. These findings highlight the importance of treatment combinations and environmental conditions in managing litter decomposition to enhance soil fertility and organic matter recycling in Robusta coffee plantations.

Corresponding Author:
Setyo Andi Nugroho,
Department of Agricultural Production, Politeknik Negeri Jember, Indonesia
Jl. Mastrip PO BOX 164, Jember - Jawa Timur, Indonesia
Email: andi1746@polije.ac.id

1. INTRODUCTION

Indonesia's national coffee production reached 1.262 million tons in 2022, showing an increase compared to the previous year, which recorded only 1.258 million tons. This upward trend in coffee production occurred during the COVID-19 pandemic. In the pre-pandemic period, specifically in early 2019, production stood at 752 thousand tons, followed by a significant rise in 2020 to 1.250 million tons, with continued growth in subsequent years. Overall, coffee production increased by 66.17% from 2019 to 2020 ((Direktorat Jenderal Perkebunan, 2022; Nugroho et al., 2022). This notable increase in coffee production has a direct impact on the volume of coffee litter generated. Litter constitutes organic material derived from plant parts that eventually return to the soil. Common components of litter include stems, roots, leaves, and twigs (Bargali et al., 2015). When managed properly, the accumulation of litter can significantly contribute to the improvement of soil physical properties. Specifically, it can enhance soil porosity and aeration, which supports increased infiltration capacity and the formation of stable soil aggregates (Fiqa & Sofiah, 2011).

The intensification of coffee cultivation is accompanied by rising quantities of organic waste, particularly leaf litter, which if unmanaged, can contribute to pest proliferation, nutrient imbalance, and reduced plantation hygiene (van Rikxoort et al., 2014). Conversely, this organic waste also holds potential as a source of soil organic matter and nutrients through natural decomposition, promoting sustainable soil fertility (Hairiah et al., 2006). The challenge lies in balancing litter accumulation with effective decomposition strategies to support nutrient cycling and minimize negative environmental impacts. Therefore, understanding the productivity and decomposition of coffee litter is crucial for developing sustainable organic waste management practices in coffee agroecosystems, particularly in areas such as the Robusta plantations of Jember State Polytechnic.

Litterfall and decomposition processes are fundamental components in nutrient cycling and carbon dynamics in agroecosystems, particularly in perennial crops such as coffee. Quantitatively, litter production in tropical plantations typically ranges from 2 to 12 Mg ha^{-1} $year^{-1}$, depending on plant species, canopy density, and management intensity (Henrique et al., 2022; Nadaf et al., 2024). In *Coffea canephora* systems, reported litter productivity values vary between 2.5 and 6.7 Mg ha^{-1} $year^{-1}$, contributing substantially to soil organic matter and nutrient replenishment (Nugroho et al., 2023). The decomposition rate of coffee leaf litter, usually represented by the decomposition constant (k), ranges from 0.003 to 0.012 day^{-1}, influenced by factors such as lignin content, moisture, and shade levels (Schmitt & Perfecto, 2021; Barreto-Garcia et al., 2024). Faster decomposition rates, often found in shaded systems, can lead to 30–50% mass loss within 60 days, enhancing nutrient availability but potentially reducing long-term carbon sequestration (Piza et al., 2021). Conversely, slower rates in full-sun plantations may prolong nutrient release but contribute to greater surface litter accumulation (Maltoni et al., 2022).

In agroecosystems, litterfall—the natural deposition of dead plant material such as leaves, branches, and reproductive parts—represents a major input of organic matter and nutrients to the soil. Litterfall rates in tropical agroforestry systems can range from 3.0 to 10.5 Mg ha^{-1} $year^{-1}$, depending on species composition, canopy structure, and management intensity (Becker et al., 2015; Oyedele et al., 2025). Once deposited, decomposition transforms this litter into forms available for plant uptake, mediated by microbial communities and macrofauna. The decomposition constant (k)—a widely used metric to describe this process—typically ranges from 0.002 to 0.012 day^{-1} in agroforestry systems. These rates determine how quickly nutrients such as nitrogen (N), phosphorus (P), and potassium (K) are mineralized and reabsorbed into the plant-soil system (Petit-Aldana et al., 2019; Oyedele et al., 2025).

Quantitatively, up to 80–95% of annual nutrient input in agroecosystems can originate from litterfall decomposition (Tangjang et al., 2015). For example, nitrogen return via decomposing litter can be up to 150 kg N ha^{-1} yr^{-1} in multi-strata coffee or cacao systems (Saj et al., 2021). Additionally, this process contributes to soil organic carbon (SOC) stocks, where litter turnover accounts for 30–60% of belowground carbon storage in well-shaded systems (Asigbaase et al., 2021). Furthermore, these processes buffer against soil erosion, improve moisture retention, and support soil biota, forming a feedback loop that enhances soil health, productivity, and resilience of agroecosystems in both lowland and upland zones (Oyedele et al., 2025).

Robusta coffee (*C. canephora*) constitutes over 40% of total coffee production in Indonesia, primarily cultivated in lowland regions with rainfall exceeding 1,800 mm annually and temperatures between 22–30°C (Nadaf et al., 2024). Despite its economic significance, site-specific data on litter input and decomposition dynamics remain scarce, particularly in educational plantations such as that of Politeknik Negeri Jember. Nugroho et al. (2023) reported leaf litter productivity values of 3.15–4.52 Mg ha^{-1} $year^{-1}$ in this area, yet decomposition data remain unquantified. Quantitative evaluation of these parameters is crucial for modeling nutrient budgets, informing compost application, and minimizing dependency on external fertilizers. In addition, empirical decomposition studies employing litterbag methodology can yield statistically valid k-values and nutrient release curves critical for agroecological planning (López et al., 2021; Schmitt & Perfecto, 2021). As educational and research-oriented plantations aim to integrate sustainability with learning outcomes, such studies also contribute to curriculum development and evidence-based training models.

This research therefore aims to quantify the annual litter productivity and calculate the decomposition constant (k) of Robusta coffee leaf litter under local conditions, using standardized litterfall collection and in situ litterbag experiments. The findings are expected to support data-driven plantation management strategies and enhance the ecological understanding of nutrient cycling within *C. canephora* systems.

2. RESEARCH METHOD

Research Design

This study adopts a quantitative descriptive design aimed at measuring litter productivity and leaf decomposition rate of *Coffea canephora* (Robusta coffee). The approach includes direct measurement of litterfall biomass and litter decomposition rates using field-based sampling and standardized litterbag techniques. Data were analyzed statistically to determine productivity rates and decomposition constants.

Research Location and Time

The research was conducted in the Robusta coffee plantation of Politeknik Negeri Jember, East Java, Indonesia. The area is characterized by tropical monsoonal climate with average annual rainfall of approximately 2,200 mm, average temperature of 26–28°C, and located at an elevation of approximately 89 meters above sea level. Here are the GPS coordinates for Politeknik Negeri Jember latitude: -8.1578024°, longitude: 113.7239999°.

The study was carried out over a period of 6 months during the dry and early rainy seasons to capture variations in litter dynamics.

Materials and Tools

1. Digital weighing scale (±0.01 g accuracy)
2. Litter traps (1 m × 1 m frames with mesh netting)
3. Litterbags (20 cm × 20 cm; 2 mm mesh)
4. Oven (for drying samples at 70°C)
5. Digital caliper and meter tape
6. GPS for plot mapping
7. Statistical software (SPSS or R)

Sampling Procedure

a. Litter Productivity Measurement

Litterfall traps (1 m²) were installed beneath the coffee canopy at 10 randomly selected locations, spaced at least 5 meters apart to reduce spatial bias. Litter was collected bi-weekly for a total of 12 collection rounds. Collected litter was sorted (leaves, branches, fruits), oven-dried at 70°C for 72 hours, and weighed. Litter productivity was expressed in g/m²/week¹, extrapolated from the cumulative dry weight. The litter productivity process was conducted over a period of 12 weeks. During the litter collection process, climate data including wind speed, humidity, and temperature were recorded. The average litter productivity per plot was calculated from each observation using the following formula:

$$x_j = \frac{\sum_{i=o}^{m} x_i}{n}$$

xj = The mean litter production per plot was recorded for each weekly interval
xi = Litter production was measured per plot for each observation period.
n = Litter traps were used to collect falling litter. (Nugroho, 2014).

b. Leaf Decomposition Rate

Freshly fallen Robusta coffee leaves were collected, cleaned, air-dried for 48 hours, and then weighed to 10 g per bag. A total of 60 litterbags were placed on the soil surface under coffee trees. The remaining mass was dried and weighed to determine the mass loss over time. The research was designed using a factorial Completely Randomized Design (CRD), consisting of two factors, each with three levels and three replications. The factors included:

The factors were as follows:

1. First Factor – Coffee Leaf Litter Fragmentation Size
   a. P1: Coffee leaves cut into 2 pieces (51–70 cm²)
   b. P2: Coffee leaves cut into 4 pieces (31–50 cm²)
   c. P3: Coffee leaves cut into 8 pieces (10–30 cm²)
2. Second Factor – Solution Concentration Ratio
   a. K1: Sugar solution (100 g sugar + 1000 mL water) with 5 mL EM4
   b. K2: Sugar solution (100 g sugar + 1000 mL water) with 10 mL EM4
   c. K3: Sugar solution (100 g sugar + 1000 mL water) with 20 mL EM4

Decomposition Result Parameters

Several observational parameters were used in this study, as described below:

- **Compost Temperature**

Temperature measurements were conducted biweekly over a 10-week period. Temperature was measured using a digital thermometer.

- **Compost pH**

pH was measured every two weeks for a duration of 10 weeks using a pH meter.

- **Decomposition Rate**

The decomposition rate was calculated at the end of the observation period, after the decomposed litter had been air-dried, using the appropriate formula.

3. RESULT AND DISCUSSION

Litter Productivity

The litter productivity assessment was conducted at the coffee plantation of Politeknik Negeri Jember. Administratively, the plantation is located in Tegal Gede, Sumbersari District, Jember Regency. Observations on litter productivity were carried out over a period of 12 weeks. A total of 12 coffee trees were selected for observation, with two litter traps installed per tree. Thus, 24 traps were used throughout the study. The results showed that the highest litter productivity occurred in the third week, reaching 18.07 g/m²/week, which coincided with the rainy season in November. The lowest productivity was recorded in the eleventh week, at 3.45 g/m²/week, which also fell within the rainy season. High litter productivity was consistently observed during the rainy season, with a notable value of 16.55 g/m²/week in the fourth week of November.

Environmental conditions influence the amount of litterfall, including factors such as temperature, air humidity, and wind speed. Temperature observations ranged from 25.5°C to 31.2°C. Temperature had a significant effect on litter productivity. As temperature increased, litter productivity also tended to rise (Nugroho, 2014). This trend was evident in the third week, where the highest productivity of 18.07 g/m²/week corresponded with the highest recorded temperature of 31.2°C. Air humidity ranged from 60% to 93.6%, and it was inversely related to temperature. As temperature increased, humidity decreased, which was associated with higher litter productivity. Wind speed observations ranged from 0.03 m/s to 0.9 m/s. Greater wind speed tended to result in higher litterfall productivity. Wind can cause adjacent leaves to rub against each other, leading to various forms of physical damage that promote litterfall. The results of litter productivity are presented in figure 4.1 as follows.

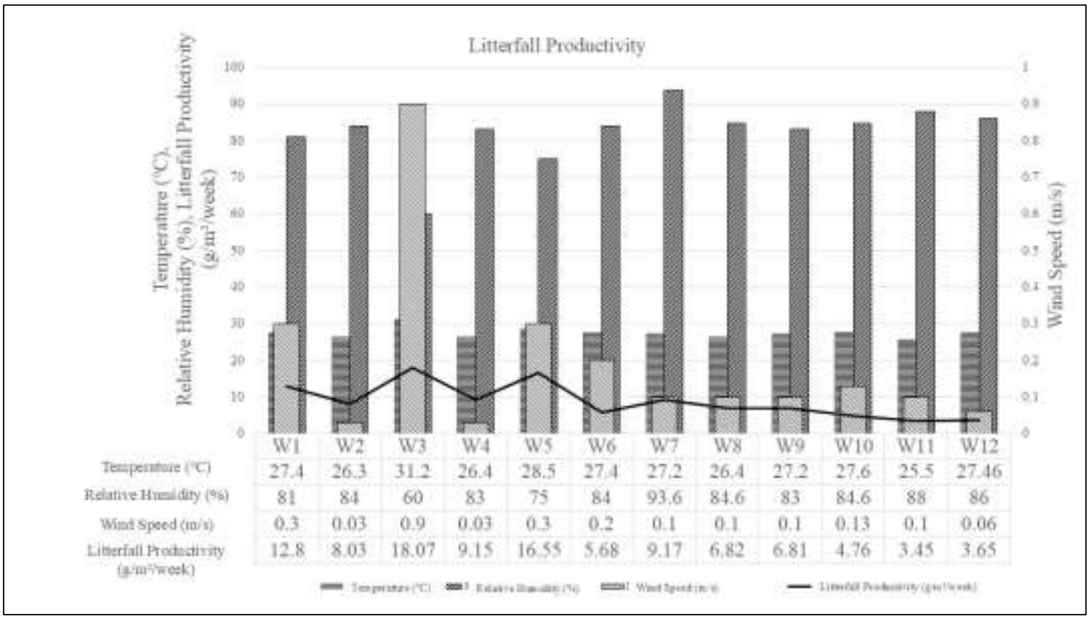

Figure 1. The Relationship Between Litter Productivity and Environmental Factors in Coffee Stands

The mechanical processes of rainfall, wind, and plant physiological responses to environmental changes influence litter productivity (Santiago & Mulkey, 2005). Based on the research findings (Figure 1), the highest litter productivity was recorded in the 3rd week, reaching 18.07 g/m²/week, which occurred during the period from October to January. The lowest productivity was observed in the 11th week, at 3.45 g/m²/week, coinciding with the peak of the rainy season. Litter productivity tends to reach its maximum during the rainy season due to increased humidity and wind speed, which cause friction between adjacent leaves, leading to physical damage. According to Luizão (1989), intense rainfall combined with strong winds and followed by short dry spells positively correlates with high litterfall rates.

Leaves are a major component of litter productivity and are particularly responsive to climate variability (Liu et al., 2004). One of the key climatic variables is temperature. Based on the research data, temperatures ranged from 25.5°C to 31.2°C. Temperature has a significant effect on litter productivity. Higher litterfall rates are associated with increased temperatures (Nugroho, 2014), as shown by the peak productivity of 18.07 g/m²/week at 31.2°C. Temperature and air humidity are interrelated in influencing litter productivity. When air temperature rises, it often causes a drop in humidity, which in turn increases plant transpiration rates. To reduce water loss, plants may shed their leaves (Zamroni & Rohyani, 2008). This is consistent with the results shown in Figure 4.1, where weeks 3 and 5 recorded the highest temperatures (31.2°C and 28.5°C, respectively), while also showing the lowest humidity levels (60% and 75%, respectively).

Litter Decomposition

One of the key components in the litter decomposition process is the breakdown of litter material, which contributes to the production of organic matter that plays a crucial role in the food chain (Widhitama et al., 2016). The parameters investigated in this study include pH, temperature, and decomposition rate, with the results presented in Table 4.1. The data show statistically significant differences, and further analysis was conducted using the Honestly Significant Difference (HSD) test at the 5% significance level.

a. Compost Temperature

Compost temperature was monitored from the second week to the tenth week. The study revealed that the temperature in week 2 was recorded at 28.87°C, followed by a decrease in week 4, and a rapid increase in week 6, reaching 30.16°C. Decomposition is a complex process influenced by various environmental factors, such as temperature (Guo & Sims, 1999). According to the results (Figure 2), the temperature increased steadily from week 1 to week 6, ranging between 27°C and 30°C. High temperatures are essential for accelerating the decomposition process, while low temperatures can slow down or even halt decomposition. This may indicate insufficient oxygen and suboptimal moisture levels, leading to reduced microbial activity (Lekasi et al., 2003).

Temperature plays a critical role in the decomposition process, particularly through the activity of microbial populations during the mesophilic phase (20°C–40°C). This phase represents the initial stage of decomposition, during which the breakdown of organic matter occurs rapidly. It is also the period when microbial growth—especially fermentative fungi and actinomycetes—is most active. Furthermore, enzyme production for organic matter degradation is most effective during this phase (Nugroho, 2014). The effects of leaf size treatment and EM4 concentration on compost temperature are presented in the following diagram:

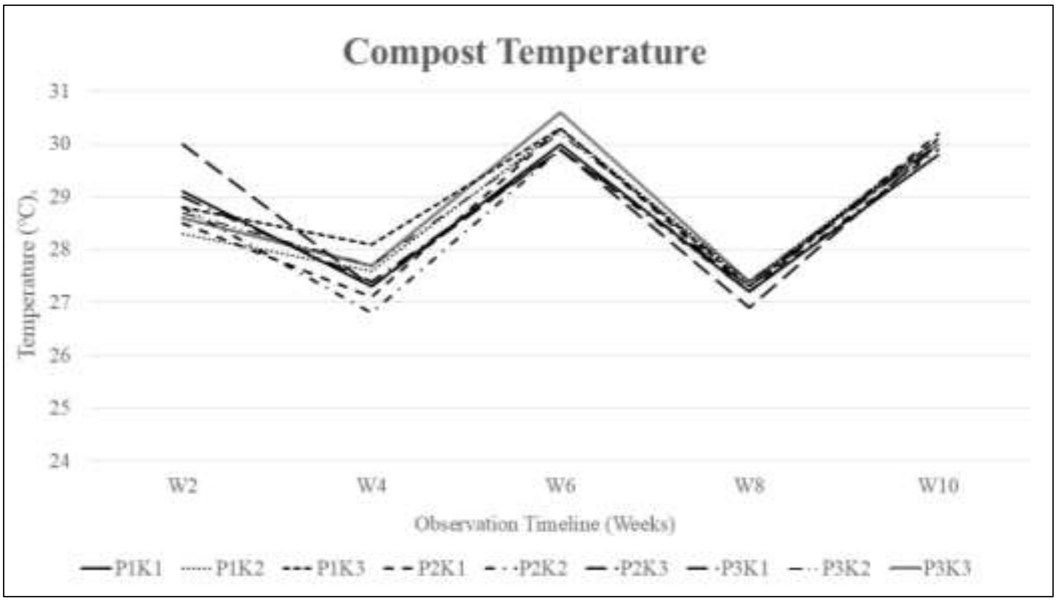

Figure 2. Monitoring of Compost Temperature in the Decomposition Process

b. Compost pH

Observation of compost pH parameters was carried out from the second week to the tenth week of the composting process. The pH of the compost was monitored from the second to the tenth week of the composting process. The initial pH measurement in week 2 was 6.63, which increased in week 4 and then gradually stabilized as the compost approached maturity. In addition to temperature, pH is a crucial factor in the decomposition process. During decomposition, pH typically ranges from 4 to 12. The metabolic activity involved in litter decomposition significantly influences pH levels. An increase in pH can result from a chemical reaction known as deamination, where amino groups are released from amino acid compounds through microbial metabolism. These amino groups are converted into ammonia. Conversely, the decomposition of carbohydrates and lipids contributes to a decrease in pH due to the production of organic acids.

The rise in pH is closely associated with the decomposition process. As organic matter breaks down, it can increase the activity of hydrogen (H^+) and hydroxide (OH^-) ions, which originate from carboxyl (-COOH) and hydroxyl (-OH) functional groups. The H^- ions help neutralize excess H^+ ions in the solution, contributing to pH stabilization. Changes in pH are primarily governed by the balance between H^+ and OH^- ions. When the concentration of H^+ increases, the pH decreases (becomes more acidic). In contrast, an increase in OH^- concentration raises the pH (more alkaline). Well-decomposed organic matter is capable of producing OH^- ions, which help neutralize H^+ ions. Therefore, an increase in pH is strongly correlated with the decomposition of organic material. Research findings indicate that compost pH typically shifts from acidic to neutral as decomposition progresses. At the beginning of the process, compost tends to be acidic, while mature compost exhibits a near-neutral pH (Nugroho, 2014). The effects of leaf size treatments and EM4 concentration on compost pH are illustrated in the following diagram:

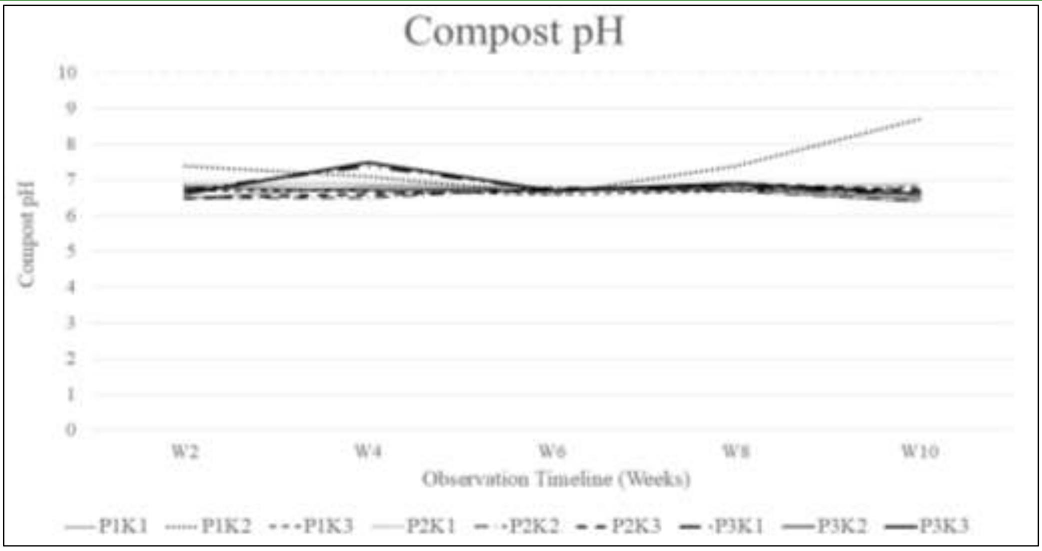

Figure 3. Monitoring of Compost pH in the Decomposition Process

c. Decomposition Rate

The fastest decomposition rate was observed in treatment P3K3, which involved the smallest leaf size category (cutting 3) with a surface area range of 10–30 cm² and the highest EM4 concentration (concentration 3), consisting of a sugar solution (100 grams of sugar dissolved in 1 liter of water) combined with 20 ml of EM4. Conversely, the slowest decomposition rate occurred in treatment P1K1, which used the largest leaf size category (cutting 1) with a surface area range of 51–70 cm² and the lowest EM4 concentration (concentration 1), consisting of a sugar solution (100 grams of sugar dissolved in 1 liter of water) combined with only 5 ml of EM4.

Table 1. The Effect of Leaf Size and EM-4 Concentration on the Decomposition Rate of Leaf Litter

Treatment	Decomposition Rate (%)	Notation
P1K1	1,2	ab
P1K2	1,3	ab
P1K3	1,6	abc
P2K1	1,3	ab
P2K2	1,7	abcd
P2K3	2,2	cd
P3K1	1,9	bcd
P3K2	2,2	cd
P3K3	2,3	d

Note: Values with the same letter in the same column are not significantly different (BNJ 5%).

Treatment P3K2 matured faster and proved more efficient compared to the other treatments. The small particle size of the litter positively influenced oxygen movement within the compost pile, which is closely related to microbial activity during the decomposition process involving enzymatic function and substrate interaction. Smaller litter particles also facilitated better carbon dioxide diffusion, thereby accelerating the decomposition and maturation process. EM-4 played a role in reducing odor during decomposition, accelerating the breakdown of organic matter, and enhancing the overall activity level of microorganisms.

The research results indicated a significant interaction between coffee litter particle size and EM-4 concentration in influencing the decomposition process. Litter decomposition is the breakdown of organic materials, such as coffee leaves, into soluble nutrients and smaller particles, characterized by a reduction in litter mass. Rapid mass loss during the early stages of decomposition is associated with the degradation of easily decomposable carbohydrates, whereas the later stages are relatively slower due to the accumulation of more recalcitrant compounds, such as lignin and cellulose (Nugroho, 2014).

d. Compost Color

Color is one of the key characteristics used to assess compost maturity and quality (Lekasi et al., 2003). Based on the results of this study, treatment P3K2 was more efficient, as the compost had already turned black by the 8th week despite requiring a lower EM4 concentration compared to treatment P3K3, which also turned black in the same week. Anaerobic decomposition was considered complete (mature) by the final week in treatments P1K1, P1K2, P1K3, P2K3, P3K1, P3K2, and P3K3, as indicated by the characteristic dark color.

The results showed that treatment P3K2 reached a black color by week 8, indicating a maturity level of 76–100%, even with a lower EM-4 concentration. This suggests that smaller litter particle size (P3) combined with a moderate concentration of EM-4 (K2) promotes a more efficient decomposition process, likely due to increased microbial accessibility and better aeration within the compost mass (Nugroho, 2014).

Interestingly, treatment P3K3, which also used fine litter particles but a higher EM-4 concentration, exhibited a similar maturity level at the same time point. This suggests that P3K2 is more resource-efficient, achieving comparable results with less input. By week 10, all treatments except P2K1, P2K2, and P2K3 had reached the black coloration stage, indicating the completion of anaerobic decomposition. These remaining treatments matured slightly slower, reaching only dark brown (score 3), which corresponds to 51–75% maturity. This pattern supports the assertion by Lekasi et al. (2003) that compost color serves as a simple but effective diagnostic tool for evaluating maturity. The transition from original leaf color to brown, dark brown, and finally black reflects the breakdown of labile compounds and the gradual accumulation of humic substances.

Table 2. Maturity Color Decomposition of Robusta Coffee (*Coffea canephora*) Leaves

Week	Treatment								
	P1K1	**P1K2**	**P1K3**	**P2K1**	**P2K2**	**P2K3**	**P3K1**	**P3K2**	**P3K3**
2	1	1	1	1	1	1	1	2	2
4	1	1	1	2	1	1	1	2	2
6	2	2	2	3	2	3	2	3	3
8	3	3	2	3	2	3	3	4	4
10	4	4	4	3	3	4	4	4	4

Notes:
Value (1): Original color (maturity level 0–25%)
Value (2): Brown (maturity level 26–50%)
Value (3): Dark brown (maturity level 51–75%)
Value (4): Black (maturity level 76–100%)

e. Nutrient Content in Coffee Leaf Litter

The most efficient C/N ratio of organic matter in coffee leaf litter was found in Treatment P3K3, which involved leaf fragments with a surface area of 10–30 cm² (Cut Size 3). This treatment yielded the lowest C/N ratio at 31.40, in contrast to other treatments that exhibited higher C/N ratios ranging from approximately 37 to 49. The principle of composting emphasizes that the C/N ratio of organic matter should approximate that of soil. A high C/N ratio indicates a low nitrogen content, which slows down the decomposition process. The C/N ratio stabilizes only when the composting process is complete and efficient (Krismawati & Hardini, 2014; Widodo et al., 2024).

Table 3. Nutrient Composition of Coffee Leaf Litter

Treatment	C (%) Organic	N (%)	C/N Ratio	P (%)	K (%)
P1K1	47,96	0,97	49,46	0,37	0,45
P1K2	47,24	1,01	46,88	0,37	0,45
P1K3	46,77	1,05	44,63	0,38	0,46
P2K1	46,17	1,09	42,27	0,38	0,46
P2K2	45,36	1,16	39,15	0,40	0,49
P2K3	44,73	1,23	36,25	0,41	0,49
P3K1	43,91	1,18	37,08	0,40	0,48
P3K2	43,00	1,28	33,71	0,40	0,48
P3K3	41,51	1,32	31,40	0,42	0,50

The C/N ratios of the compost produced in all treatments remained relatively high and did not meet the Indonesian National Standard (SNI No. 19-7030-2004), which stipulates an ideal range of 10–20. This elevated C/N ratio is likely due to a high residual carbon content, indicating that organic matter decomposition had not yet been fully achieved. Consequently, it is recommended that the composting process be extended to allow microorganisms to further break down the remaining organic material, thereby enhancing compost maturity and quality (Wahyudin & Nurhidyatullah, 2018; Nugroho et al., 2023).

The findings from this study offer valuable insights into optimizing organic waste management in large-scale Robusta coffee plantations. The observed patterns of litter productivity and the quantified effects of leaf size and EM4 microbial treatment on decomposition rates can inform practical strategies for managing coffee leaf litter more efficiently. For instance, the accelerated decomposition observed under the P3K3 treatment (small leaf size with 20 mL EM4) suggests that pre-processing litter by shredding and applying effective microbial solutions could significantly enhance nutrient release and reduce organic waste accumulation (Hairiah et al., 2006).

In large-scale plantations, such strategies could be implemented as part of an integrated litter management system to promote in-situ composting, thereby reducing the need for external inputs while maintaining or improving soil fertility (Suryanto et al., 2019). Furthermore, understanding seasonal peaks in litter fall, as indicated by this study, enables plantation managers to synchronize waste management efforts with climatic conditions that favor decomposition, maximizing microbial activity and nutrient cycling (van Noordwijk et al., 2004). Adopting these practices could contribute to a circular nutrient economy in coffee farming systems, lowering production costs, improving soil health, and aligning with sustainable agriculture principles (FAO, 2017). Ultimately, the study provides a scientific basis for scalable, eco-friendly approaches to managing organic residues in coffee agroecosystems.

4. CONCLUSION

The highest litter productivity was observed in the third week at 18.07 g/m²/week, coinciding with the rainy season (October–January). Leaf fragment size and EM4 concentration had no significant effect on the decomposition parameters individually. However, their interaction significantly influenced the decomposition rate of coffee leaf litter.

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6. REFERENCES

Asigbaase, M., Dawoe, E., Lomax, B. H., & Sjogersten, S. (2021). Temporal changes in litterfall and potential nutrient return in cocoa agroforestry systems under organic and conventional management, Ghana. *Heliyon, 7*(12), e08587. https://doi.org/10.1016/j.heliyon.2021.e08587.

Barreto-Garcia, P. A. B., dos Santos Nascimento, M., & Almeida, D. M. (2024). Carbon in soil macroaggregates under coffee agroforestry systems: Modeling the effect of edaphic fauna and residue input. *Applied Soil Ecology*. https://doi.org/10.1016/j.apsoil.2024.105643.

Bargali, S. S., Shukla, K., Singh, L., Ghosh, L., & Lakhera, M. L. (2015). Leaf litter decomposition and nutrient dynamics in four tree species of dry deciduous forest. Tropical Ecology, 56(2), 191–200.

Becker, J., Pabst, H., Mnyonga, J., & Kuzyakov, Y. (2015). Annual litterfall dynamics and nutrient deposition depending on elevation and land use at Mt. Kilimanjaro. *Biogeosciences, 12*(19), 5635–5646. https://doi.org/10.5194/bg-12-5635-2015.

Direktorat Jenderal Perkebunan. (2022). *Statistik Perkebunan Indonesia 2020-2022*, Kopi. Direktorat Jenderal Perkebunan, Jakarta, 313-331.

FAO. (2017). *The future of food and agriculture: Trends and challenges*. Food and Agriculture Organization of the United Nations. https://www.fao.org/3/i6583e/i6583e.pdf

Fiqa, A. P., & Sofiah, S. (2011). Pendugaan laju dekomposisi dan produksi biomassa serasah pada beberapa lokasi di kebun raya purwodadi. Berk. Penel. *Hayati Edisi Khusus*, 5, 17–20.

Guo, L. B., & Sims, R. E. H. (1999). Litter decomposition and nutrient release via litter decomposition in New Zealand eucalypt short rotation forests. *Agriculture, Ecosystems and Environment*, 75(1–2), 133–140. https://www.sciencedirect.com/science/article/abs/pii/S0167880999000699.

Hairiah, K., van Noordwijk, M., Cadisch, G., & Giller, K. E. (2006). Litter quality and decomposition rates of leaves from agroforestry trees in different environments in Indonesia. *Soil Biology and Biochemistry*, 38(9), 2067–2080. https://doi.org/10.1016/j.soilbio.2006.01.005.

Henrique, N. S., Maltoni, K. L., & Faria, G. A. (2022). Litterfall decomposition of coffee shaded with *Tectona grandis* or in full sun. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 26(1), 66–72. https://www.scielo.br/j/rbeaa/a/h6n753NJm6BphmW4pshhxFD/?lang=en.

Krismawati, A., & Hardini, D. (2014). Kajian Beberapa Dekomposer Terhadap Kecepatan Dekomposisi Sampah Rumah Tangga. *Buana Sains*, 14(2), 79–89. https://jurnal.unitri.ac.id/index.php/buanasains/article/view/350.

Lekasi, J. K., Tanner, J. C., Kimani, S. K., & Harris, P. J. C. (2003). Cattle manure quality in Maragua District, Central Kenya: Effect of management practices and development of simple methods of assessment. *Agriculture, Ecosystems and Environment*, 94(3), 289–298. https://www.sciencedirect.com/science/article/abs/pii/S0167880902000373.

Liu, C., Westman, C. J., Berg, B., Kutsch, W., Wang, G. Z., Man, R., & Ilvesniemi, H. (2004). Meta-Analysis Variation in litterfall-climate relationships between coniferous and broadleaf forests in Eurasia. *Global Ecology and Biogeography*, 13, 105–114. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-882x.2004.00072.x.

López, R. E. I., Navarrete, E. F. C., & Rosado, J. T. P. (2021). Soil nitrogen cycling under contrasting management systems in Amazon *Coffea canephora* agroecosystems. *Soil Science Society of America Journal*, 85(3), 771–784. https://doi.org/10.1002/saj2.20255.

Luizao, F. J. (1989). Litter production and mineral element input to the forest floor in a Central Amazonian forest. *GeoJournal*, 19(4), 407–417. https://link.springer.com/article/10.1007/BF00176910.

Maltoni, K. L., Henrique, N. S., & Faria, G. A. (2022). Litter decomposition dynamics in *Coffea canephora* plantations under different shading. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 26(5), 320–327. https://doi.org/10.1590/1807-1929/agriambi.v26n5p320-327.

Nadaf, S. A., Shivaprasad, P., & Babou, C. (2024). Coffee (*Coffea spp.*). In *Recent Advances in Research and Development of Plantation Crops* (pp. 133–154). Springer. https://doi.org/10.1007/978-981-97-0092-9_9.

Nugroho, S. A. (2014). Produktivitas Serasah dan Dekomposisi Semi Aerobik Daun Mahoni (*Swietenia macrophylla* King). *Thesis*. Institut Pertanian Bogor. Bogor. https://repository.ipb.ac.id/handle/123456789/69250.

Nugroho, S. A., Bagiatus, S., Setyoko, U., Fatimah, T., Novenda, I. L., & Pujiastuti, P. (2022). Pengaruh Zpt Nabati Dan Media Tumbuh Terhadap Pekembangan Kopi Robusta. *Jurnal Biosense*, *5*(2), 62-76. https://ejournal.unibabwi.ac.id/index.php/BIOSENSE/article/view/2279.

Nugroho, S. A., Yahya, V. M., & Setyoko, U. (2023). Produktivitas Serasah Daun Kopi Robusta (*Coffea canephora* Pierre) di Kebun Percobaan Politeknik Negeri Jember. *Agropross*, 5(1), 46–51. https://proceedings.polije.ac.id/index.php/agropross/article/view/518.

Nugroho, S. A., Al Arozi, L. N., & Novenda, I. L. (2023). Pengaruh Media Tanam dan ZPT Nabati (Air Kelapa dan Bawang merah) terhadap Pertumbuhan Setek Vanili (Vanilla planifolia Andrews). *Jurnal Biosense*, *6*(01), 83-97. https://ejournal.unibabwi.ac.id/index.php/BIOSENSE/article/view/2837.

Oyedele, O., Hougni, D. G. J. M., & Hauser, S. (2025). Macrofauna accelerates nutrient cycling through litterfall in cocoa agroforestry systems. *Nutrient Cycling in Agroecosystems*. https://doi.org/10.1007/s10705-025-10399-4.

Petit-Aldana, J., Rahman, M. M., & Park, J. (2019). Litter decomposition process in coffee agroforestry systems. *Journal of Forest and Environmental Science, 35*(2), 131–140. https://doi.org/10.7747/JFES.2019.35.2.131.

Piza, P. A., Suárez, J. C., & Andrade, H. J. (2021). Litter decomposition and nutrient release in different land uses in Valle del Cauca (Colombia). *Agroforestry Systems*, 95(2), 389–400. https://doi.org/10.1007/s10457-020-00583-6.

Santiago, L. S., & Mulkey, S. S. (2005). Leaf productivity along a precipitation gradient in lowland Panama: Patterns from leaf to ecosystem. *Trees - Structure and Function*, 19(3), 349–356. https://link.springer.com/article/10.1007/s00468-004-0389-9.

Saj, S., Nijmeijer, A., Nieboukaho, J. D. E., & Lauri, P. E. (2021). Litterfall seasonal dynamics and leaf-litter turnover in cocoa agroforests established on past forest lands or savannah. *Agroforestry Systems, 95*, 1013–1025. https://doi.org/10.1007/s10457-021-00602-0.

Schmitt, L., & Perfecto, I. (2021). Coffee leaf litter decomposition: Short-term home-field advantage in shaded coffee agro-ecosystems. *Applied Soil Ecology*, 168, 104116. https://doi.org/10.1016/j.apsoil.2021.104116.

Suryanto, P., Rahardjo, H., & Firmansyah, M. (2019). Integrated waste management in coffee agroforestry systems: A case study from East Java. *Indonesian Journal of Environmental Management*, 5(2), 112–120.

Tangjang, S., Arunachalam, A., & Arunachalam, K. (2015). Litterfall, decomposition and nutrient dynamics in traditional agro-forestry systems of northeast India. *International Journal of Environmental and Ecological Sciences, 5*(1), 1–11. https://nieindia.org/Journal/index.php/ijees/article/view/635.

van Noordwijk, M., Hairiah, K., & Palm, C. A. (2004). Decomposition and nutrient release dynamics of mulches in agroforestry systems. In G. Cadisch & K. E. Giller (Eds.), *Driven by nature: Plant litter quality and decomposition* (pp. 99–114). CABI Publishing.

Wahyudin, & Nurhidyatullah. (2018). Pengomposan sampah organik rumah tangga menggunakan mikroorganisme lokal bonggol pisang sebagai bioaktivator. Agriovet, 1(1), 19–36. https://ejournal.kahuripan.ac.id/index.php/agriovet/article/view/172.

Widodo, T. W., Muhklisin, I., Nugroho, S. A., & Lisyanto, D. A. (2024, October). Aplikasi Rhizobium Sp Dengan Penambahan Pupuk Organik Mampu Memicu Pertumbuhan Dan Umur Berbunga Sorgum (*Sorgum bicolor* L.) Pada Lahan Pasiran. In *Agropross: National Conference Proceedings of Agriculture* (pp. 755-760). https://proceedings.polije.ac.id/index.php/agropross/article/view/767.

Widhitama, S., Purnomo, P. W., & Suryanto, A. (2016). Produksi Dan Laju Dekomposisi Serasah Mangrove Berdasarkan Tingkat Kerapatannya Di Delta Sungai Wulan, Demak, Jawa Tengah. *Diponegoro Journal Of Maquares*, 5(4), 311–319. https://ejournal3.undip.ac.id/index.php/maquares/article/view/14436.

Zamroni, Y., & Rohyani, I. S. (2008). Litterfall production of mangrove forest in the beach waters of Sepi Bay, West Lombok. *Biodiversitas Journal of Biological Diversity*, 9(4), 284–287. https://smujo.id/biodiv/article/view/359.