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Decomposition rate and nutrient release patterns from indigenous tropical weeds during aerobic composting

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Abstract The study revealed that the decomposition rate of indigenous tropical weed biomass fluctuated during 6 weeks of incubation. During the first two weeks of the composting process, it was low at a rate of 5.78 g C day^{-1} and drastically increased by the fourth week, reaching a peak rate of 35.9 g C day^{-1}. Thereafter, it decreased at the end of the incubation period with a rate of 11.34 g C day^{-1}. Even though all weed biomasses experienced similar decomposition rate at preliminary stages, Melastoma biomass had the highest rate at the third week, surpassing Borreria and Wedelia. The study also found that organic carbon (organic-C) significantly lowered during the composting process where Melastoma compost consistently had the greatest organic-C followed by Wedelia and Borreria. On the other hand, total nitrogen (Total N) significantly increased during the incubation period, with Borreria compost consistently showing the highest content, followed by Wedelia and Melastoma. C/N ratio of all composts significantly declined during the incubation period, showing satisfying decomposing process, reducing C/N ratio of 7.25 folds at the end of the incubation period compared to initial stage. Total phosphorous (total P) and total potassium (total K) also prominently increased during the incubation period. Total P showed more than 2.4 folds increased while total K was 2.63 folds increased at the end of the incubation period compared to first stage. At the end of the composting process, Borreria had the greatest total P content, while Melastoma showed the highest total K. The study confirmed that indigenous weeds from a tropical environment have potential as substrates for organic fertilizer, supporting the development of sustainable agriculture.

Keywords: Borreria, Composting substrate, Melastoma, Tropical environment, Wedelia

Introduction

Conventional agriculture, which is accelerated by the Green Revolution, has led to a dependency on synthetic fertilizer as the main input in achieving crop productivity targets. Even though this technological intervention has significantly improved crop yield, in the long-term, intensive and prolonged use of synthetic fertilizer has degraded soil quality. Prolonged application of

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synthetic N, P, and K fertilizers has reduced soil aggregation (Huang *et al*., 2023), cation exchange capacity (Hashimi *et al*., 2020), soil pH, and increased exchangeable Al (Wang *et al*., 2019; Souza *et al*., 2023), thereby, land productivity can only be sustained by progressively increasing rates of fertilizer use.

Organic fertilizer is a keen alternative solution to reduce dependency on synthetic fertilizer and to sustainably enhance soil health. Even though this particular fertilizer does not supply nutrients instantly, such as synthetic fertilizer, it gradually provides nutrients, improves soil aggregates, increases water-holding capacity, and improves microbial activities in soil (Wang *et al*., 2023; Rivier *et al*., 2022; Pan *et al*., 2025; Muktamar *et al*., 2018). This approach offers a long-term solution because it not only provides nutrients but also rebuilds the ecological function of soil that has been degraded due to the excessive use of synthetic fertilizers. Therefore, land productivity can be sustained without continuously increasing the fertilizer rate. Organic fertilizer can be derived from various raw materials, including animal wastes, food wastes, agricultural wastes, industrial wastes, and weeds.

In recent years, weed management in sustainable agriculture has fundamentally evolved from the control approach to biomass resource use. Several studies have proven the use of weed species biomass as a raw material for compost. Invasive weeds such as water Hyacinth *(Eichornia crassipes*), which contaminate waters, can be converted to nutrient-rich compost with 1.91% N, 0.32% P, 1.77% K, and a C/N ratio of 16 (Canning, 2025). Another study indicated that compost of combined *Parthenium hysterophorus* and cow dung (2:1 ratio) has 23.2% C, 2.35% N, 2.45% P, 0.75% K, and a C/N ratio of 9.85 (Rai and Suthar, 2020). These studies indicate that final nutrient composition is dependent on weed species as raw materials.

Moreover, various studies investigate the prevalence and dominance of weed species in agricultural land and plantations. A study on weed composition suggests that weed species such as Melastoma, Wedelia, and Borreria are dominant weed species in tropical plantations (Muktamar *et al*. 2025), indicating significant availability of specific weed biomass and potential as a raw material for organic fertilizer. Most research focuses on the nutrient composition at the end of weed biomass composting and its effect on plant growth. On the other hand, research into decomposition rate and nutrient release during composting is still quite limited.

Therefore, a study on the decomposition rate and nutrient release of Melastoma, Wedelia, and Borreria biomasses is necessary to assess their potential as raw materials and final nutrient content in the compost. The research offered valuable insight into the role of weed biomass as a source of organic

fertilizer and promote sustainable weed management. It is also supported a global efforts to reduce dependency on synthetic fertilizer, thereby imposing significant economic burdens on farmers. Therefore, the study aimed to assess the decomposition rate and nutrient release pattern of tropical weed biomass during composting.

Materials and methods

Weed collection and experimental design

The study was conducted in the Composting House, University of Bengkulu, from July to September 2024. Melastoma (*Melastoma affine D.* Don) and Borreria (*Borerria alaata* Aubl.) weeds were collected from the Experimental Station, Faculty of Agriculture, University of Bengkulu, located in Medan Baru, Muara Bangkahulu District, City of Bengkulu at 3.755082°S, 102.27155 5°E. Wedelia (*Sphagneticola trilobata L.) Pruski*) was taken from Long Beach, Ratu Agung District, City of Bengkulu at 3.805000°S, 102.259117°E. Approximately 100 kg of weed biomass was collected, then air-dried for two days at the Composting House. After air-drying, the biomass was chopped to 3-5 cm using an electrical chopper. The chemical composition of weed biomass used in the study is presented in Table 1.

Table 1. Chemical composition of Melastoma, Wedelia and Borreria biomasses

Chemical Composition	Melastoma	Wedelia	Borreria
Organic-C (g kg^{-1})	505.3	446.5	427.7
Total-N (g kg^{-1})	16.7	16.6	16.3
Total-P (g kg^{-1})	1.2	2.0	1.3
Total-K (g kg^{-1})	10	30.6	18.5
Total-Ca (%)	7.8	4.2	11.8
Total-Mg (g kg^{-1})	3.6	3.5	6.9
Total-S (g kg^{-1})	3.9	3.7	7.9
Fe (mg kg^{-1})	588	545	7080
Cu (mg kg^{-1})	9.7	11.6	17.9
Zn (mg kg^{-1})	45.1	71.9	109.5
Mn (mg kg^{-1})	977	48.2	362.7
C/N	30.26	29.91	26.24
Cellulose (g kg^{-1})	80	300	40
Lignin (g kg^{-1})	700	380	740
Hemicellulose (g kg^{-1})	200	200	140

The study employed a Completely Randomized Design with the treatments of raw material compost from ingenious tropical weeds, including Melastoma (*Melastoma affine D.* Don), Wedelia (*Wedelia trilobata*), and Borreria (*Borerria*

alaata Aubl.), with 3 replicates. The variable observation was carried out over 6 weeks. Each experimental unit was randomly placed in 1.5 m-high wooden racks in the Composting House, University of Bengkulu.

Composting procedure

Aerobic composting was prepared by homogeneously mixing 3 kg of chopped raw materials (Melastoma, Wedelia, and Borreria) with 50 ml molasses, 100 ml bio-activator, and 100 ml distilled water in a plastic container. The containers were randomly placed on a 1.5 wooden rack in the Composting House. This arrangement was to minimize environmental variability, such as uneven air temperature and humidity, and to provide consistent composting conditions for all treatments. The composting ended after 6 weeks, with turning every week to ensure oxygen circulation and reduce overheating of the media. Prior to turning process, temperature measurements were carried out at the center of the media. Throughout the composting period, the media was maintained moist by watering when required.

Compost was sampled weekly for chemical analysis, starting from week 2 to the end of the incubation period. 25 g of sample was collected from 5 different points within the composting medium and thoroughly homogenized to obtain a representative sample. Prior to analysis, the sample was air-dried, gently ground, and passed through a 0.25 mm screen. The sample was analyzed for organic-C using the Walkley and Black Method, Total-N, P, and K using wet destruction, pH with pH meter using a ratio 1:5 of compost and distilled water (Balai Penelitian Tanah, 2009). The C/N ratio was determined from organic-C and total-N content of the compost. The decomposition rate was calculated using the formula suggested by Sulistyanto *et al.* (2005) as follows:

$$R = [\frac{W0-W1}{T}]$$

Where R is the decomposition rate (g day^{-1}), W0 is the initial nutrient content (g), W1 is the final nutrient content (g), and T is the incubation time (days).

Data analysis

Data were analyzed using repeated measures ANOVA at a confidence level of 95% with SAS OnDemand for Academics. Post hoc analysis was conducted using Tukey at the same confidence level.

Results

The decomposition rate and nutrient release pattern were observed throughout 6 weeks period with weekly compost sampling starting from week 2 to the end of the incubation period. The variables observed included C-organic, total N, P, and K, C/N ratio, and pH. In general, observations showed consistent trend changes during the composting period. Data analysis using repeated measures confirmed that compost raw materials from various indigenous weed biomass showed significantly different decomposition rate and nutrient content throughout the period of the incubation ($p<0.05$).

Decomposition rate

Decomposition rate indicates how fast microorganisms, such as bacteria and fungi, mineralize the organic matter. As the decomposition rate increases, the organic material converts faster into mature compost. The study revealed that in general, the decomposition rate of weeds fluctuated during the incubation period (Figure 1). At the early stage of the composting process, the rate was low with an average of 5.78 g C day^{-1}; then it significantly increased by week 4, when the decomposition reached the greatest rate (35.9 g C day^{-1}). Thereafter, the decomposition process was slower until the end of the incubation, with a rate of 11.34 g C day^{-1}. The decomposition rate was 5.2-fold higher at week 4 than at week 2. The study also showed that the decomposition rate of all weeds was similar at the early stage of decomposition, but at week 3, the decomposition rate of Melastoma surpassed Borreria, followed by Wedelia. Interestingly, by week 4, Melastoma and Wedelia experienced similar decomposition rates, indicating that during the week, Wedelia had a higher increase in decomposition rate. At the end of the incubation, the decomposition rate of all weeds was comparable.

Change in pH media

Media pH plays a significant role in the composting process, which affects the activity of microorganisms for organic matter decomposition. The study showed that pH level throughout the composting process stayed consistent across all biomasses, ranging from 6.65 to 8.24 (Figure 2). This pH range is suitable for the activity of microorganisms. Among all biomasses, Melastoma compost had the consistently lowest pH, ranging from 6.55 to 6.62, while Borreria was the greatest, varying from 8.05 to 8.13. There were no significant differences in pH between the Wedelia and Borreria composts. Upon completion of the composting process, Borreria compost showed a 24.1% higher pH than Melastoma compost.

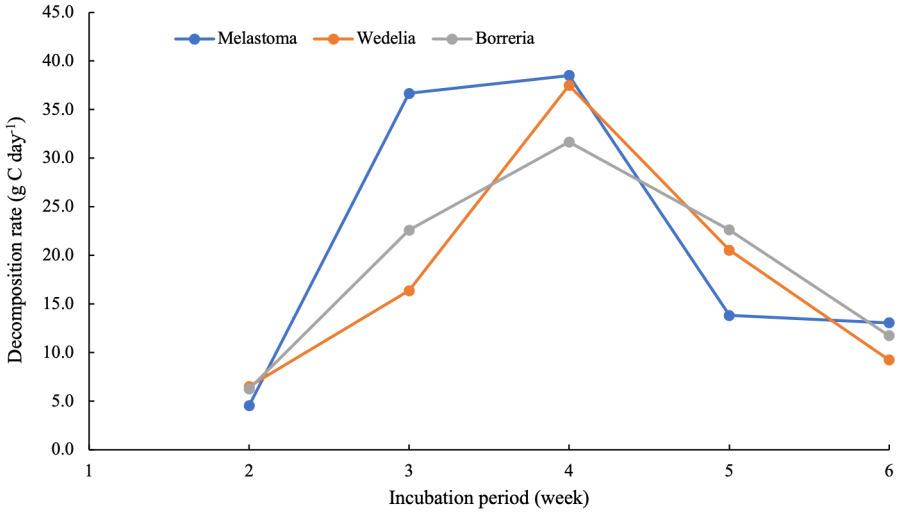


Figure 1. Decomposition rates of weed biomass during 6 weeks of aerobic composting

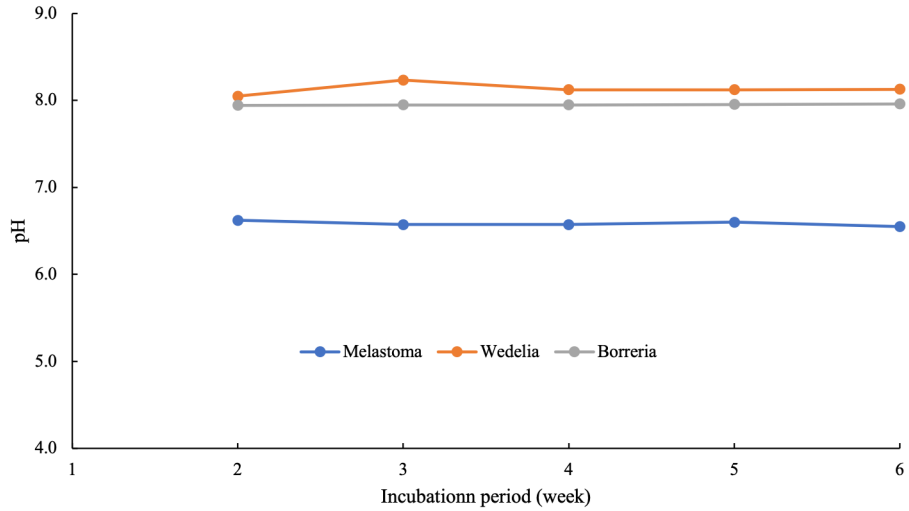


Figure 2. Changes in pH compost throughout the composting process of weed biomasses

Carbon release pattern

Organic matter has a vital role in the composting process, as the main substrate for microorganisms' activity. The study showed that during the decomposition process, organic-C content showed a significant reduction (Figure 3). It drastically declined during the first four weeks of the incubation, and by the

end of the incubation, organic-C content reduction reached 97.3%. This pattern is indicated the substantial mineralization of organic matter as composting progressed. It showed that Melastoma compost consistently had the greatest content of organic-C compared to other composts. At the end of the incubation period, Melastoma compost had 10.9% and 28.3% higher organic-C than Wedelia and Borreria composts, respectively. These differences proved the variation in carbon retention among the different biomass sources.

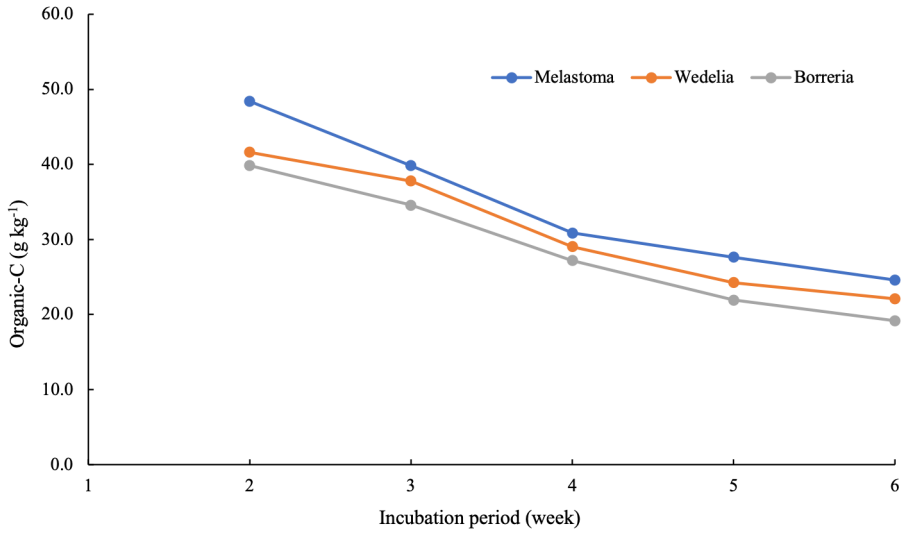


Figure 3. Organic-C changes during the incubation period of weed biomass decomposition

Nitrogen release pattern

The increase in the nutrient content was monitored throughout the six-week aerobic composting process. Data analysis using repeated-measures ANOVA showed that different weed biomasses had prominent variations in nutrient release patterns over the incubation period ($p<0.05$). Figure 4 showed that total N consistently increased throughout the composting process. On average, the increase was nearly 3.9-fold at the end of the incubation period compared to week 2. Among different indigenous weed biomasses, compost generated from Borreria consistently exhibited the highest content of total N, followed by Wedelia and Melastoma. These results indicated that nutrient content is highly dependent on the types of raw materials. At the end of the composting process, Borreria compost had 29.4% higher total N content than Melastoma and 6.1% higher than Wedelia compost.

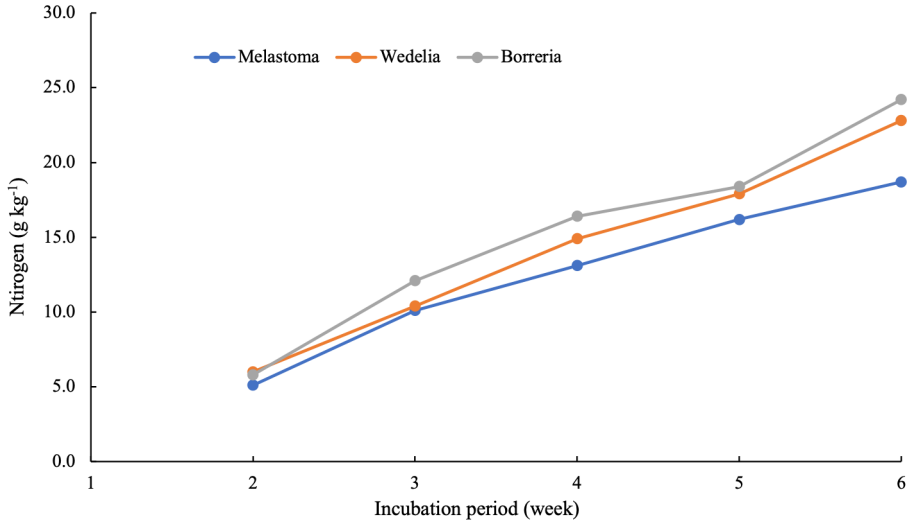


Figure 4. Total N changes throughout the composting process of indigenous weed biomasses

Change in C/N ratio

The ratio of carbon and nitrogen during the composting process is an indicator of its effectiveness. The study confirmed that the ratio steadily declined as composting progressed, showing effective organic matter decomposition and nitrogen release. C/N ratio drastically decreased during the first four weeks of the incubation period, indicating rapid organic matter breakdown and nutrient release (Figure 5). On average, the reduction of the C/N ratio reached more than fourfold in the first four weeks. The decomposition rate slowed down from week five to the end of the incubation, showing maturation of the compost. Among weed biomasses, Melastoma had the highest C/N ratio throughout the composting process, followed by Wedelia and Borreria. Melastoma had the greatest C/N ratio in the second week of the incubation period, but it approached the other two biomasses from the third week to the end of the composting process, where all compost types had comparable C/N ratios. This result proved that Melastoma exhibited the highest decomposition rate at the early composting stage, as also shown in Figure 1.

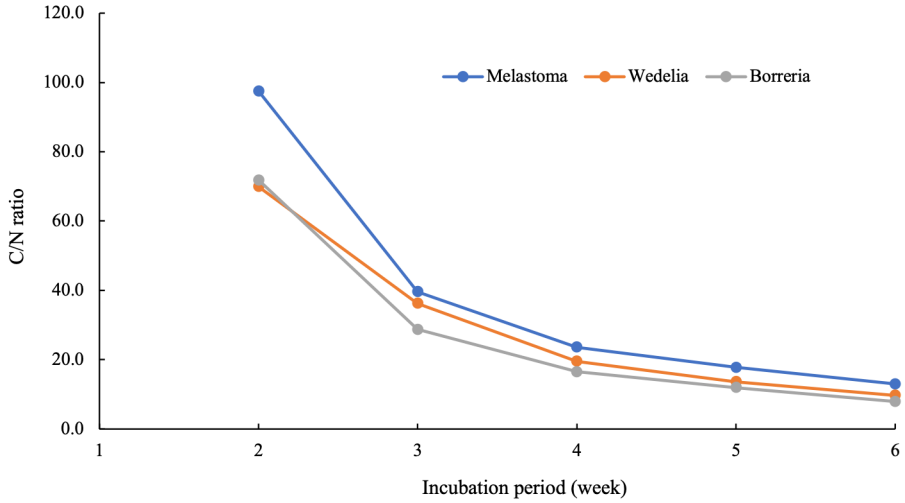


Figure 5. C/N ratio reduction during the composting of indigenous weed biomasses

Phosphorous release pattern

The release pattern of total P showed that all biomasses from indigenous weeds provided a significant increase as composting progressed (Figure 6). On average, an increase in total P was more than 4-fold at the end of the composting process compared to the second week, demonstrating the effectiveness of mineralization of organic P materials from the weed biomasses. The study also showed that Melastoma compost was superior in total P content during the first composting stage, but as composting progressed, its value declined to the lowest among biomasses by the fourth week and stayed in this position to the end of the incubation period. On the other hand, total P level in Borreria compost was the highest after the third week of the incubation until the end of the composting process.

Potassium release pattern

The study also resulted in a continuous increase in total K content throughout the incubation period (Figure 7). A significant increase was observed from the third to the fifth week, suggesting fast organic matter decomposition during this period, followed by a plateau record to the sixth week. On average, total K content increased by 2.63-fold at the conclusion of the incubation period compared to levels recorded during the second week. Furthermore, Wedelia consistently showed the greatest total K content during the composting process, followed by Borreria and Melastoma. Upon the completion of the process, total

K content in Wedelia compost was 54.4% higher than that in Melastoma compost and 40.9% higher than that in Borreria compost.

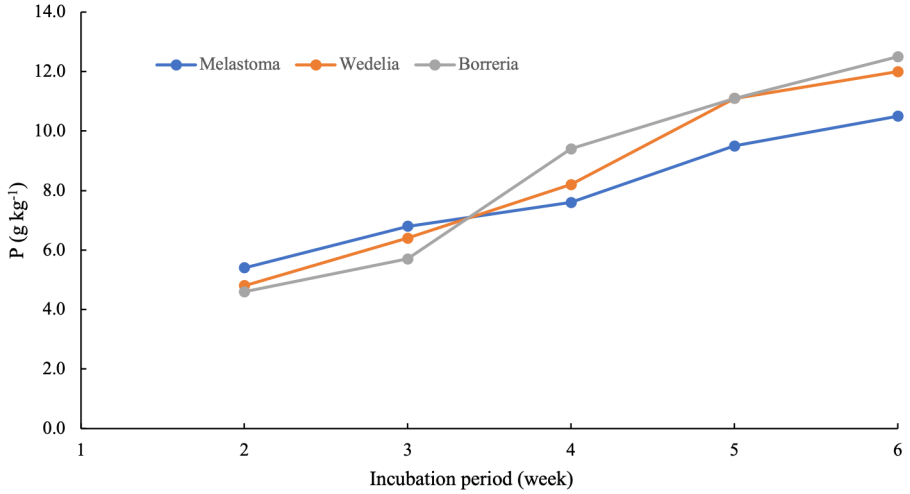


Figure 6. Total P release pattern throughout the composting process of weed biomasses

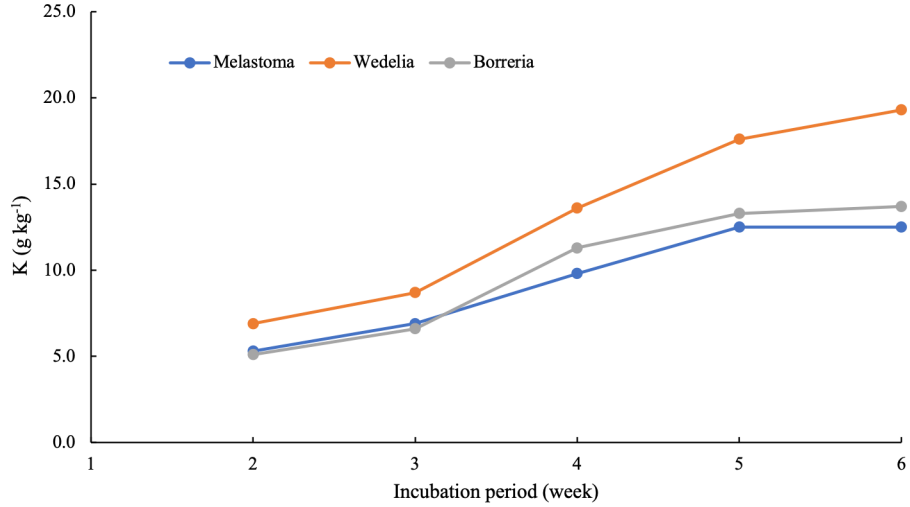


Figure 7. Release pattern of total K content throughout the composting process of weed biomasses

Discussion

The study was conducted to figure out the decomposition rate of indigenous weed biomass and major nutrient release throughout the six-week composting process. In general, during the first two weeks of the incubation, the decomposition rate was relatively low. This result suggests that microorganisms have to adapt to the environment and available substrate. Previous studies confirmed that environmental factors, including temperature, humidity, and pH of the media, influence the decomposition rate of organic material (Andriany *et al*., 2018; Nordstrom *et al*., 2022). In the initial stage, a small number of decomposing microbes requires time to reproduce and form colonies before intensively degrading organic materials. This stage is commonly called "lag phase" (Cayuela *et al*., 2009; Berg, 2000). Moreover, raw materials initially contain complex compounds such as lignin, resin, and phenol, which are resistant to degradation (Hossain and Reza, 2025; Pasquet *et al*., 2024). Decomposing microbes initially must produce specific enzymes, such as oxidative enzymes to break down these complex compounds. At the early stage of the composting process, a high C/N ratio in organic materials often causes nitrogen immobilization, a process where decomposing microbes use available nitrogen to support their growth and reproduction. According to Yang *et al.* (2021), lignocellulose lessens the decomposition rate and impedes the formation of humic substances during the composting process.

The study also showed that the decomposition rate prominently increased after the second week and reached its peak in the fourth week. The enhancement is associated with an increase in microbial populations, such as thermophilic microbes. In the initial composting process, mesophilic microbes are dominant and their activities produce heat. After the temperature rises to more than 45 ^{o}C, thermophilic microbes replace the population of mesophilic microbes (Muliani *et al*., 2022; Finore *et al*., 2023; Sobieraj, 2025). These microbes maintain very high metabolic activity and break down complex compounds such as cellulose, hemicellulose, and protein (Liu *et al*., 2025). Bernal *et al*. (1998) suggested that the greatest carbon mineralization occurred at the thermophilic stage compared to the initial or mature stages. The significant reduction in decomposition rate is related to the running out of substrate, approaching the maturation of compost. Also, the humification process is more dominant at the maturation stage, forming stable humic substances as a resistant carbon pool. Fuentes *et al.* (2020) found that at the maturation stage of the composting process, the humification process, which involves secondary biomolecule and chemical reactions, converts natural biomolecules into humic substances.

At the third week of the incubation period, Melastoma compost with a higher content of lignin exhibited a much higher decomposition rate than

Wedelia. This result might be associated with higher phenol and tannin content in Wedelia than in Melastoma biomass. Total phenol content in Wedelia extracted using distilled water is 61.05 mg GAE/g (Islam *et al*., 2021), while in Melastoma it is 47.36 mg GAE/g (Syafitri *et al*., 2014). Furthermore, Wedelia contains 7.8 mg GAE/g tannin (Langhi *et al*., 2020), while Melastoma has 1.86 mg/g (Rauf *et al*., 2023). Phenolic compounds and tannin substantially decline the decomposition rate by inhibiting microbial activity; however, as the composting process progresses, they progressively deteriorate (Zenjari *et al*., 2006; Zhang *et al*., 2020). Both total phenol and tannin contents are responsible for the lower decomposition rate of Wedelia compared to Melastoma biomass.

Throughout the incubation, organic matter mineralization resulted in a significant decline in organic-C and the C/N ratio across all composts. The reduction was specifically prominent up to the fourth week of the composting process, after which the value stayed stable to the end of the incubation period. This observed trend indicates that microbial activity reaches its peak during this stage. Microbes aggressively use easily degradable organic matter as energy sources for their growth and reproduction. Consequently, carbon dioxide is released through microbial respiration, causing a significant carbon flux from the compost. This intensified carbon release directly lowers the C/N ratio during this period. A study by Sanchez-Rosale (2024) confirmed that organic-C in compost prominently declines during the 196 days of incubation, with peak intensity mineralization at 84 days.

The study also resulted in the greatest organic-C content in Melastoma compared to other composts, suggesting that the compost retains higher organic matter. This result might be attributed to the higher initial content of lignin in Melastoma and a higher content of hemicellulose than in Borreria. According to Tuomela *et al*. (2000), lignin is not fully mineralized during the composting process; therefore, some organic C remains in the compost after the incubation ends. This incomplete lignin breakdown provides the residual organic C content in matured compost.

Release of N, P, and K content continuously increased during the incubation, with the most significant enhancement occurring within the first four weeks. These results reflect a rapid mineralization of organic N, P, and K during the period, which corresponded to the peak decomposition rate observed within this stage. Zhang *et al*. (2025) reported that rapid compost mineralization in soil occurred during the first 37 days of incubation. Notably, these results are earlier than those found by Kurniati *et al*. (2022), where peak NPK release from market organic waste occurred after 6-7 weeks of the incubation period.

The study also showed that while initial biomasses contained comparable N and P content, Wedelia biomass had the greatest K content among the weed

biomasses evaluated. At the end of incubation, the greatest N and P were found in Borreria, whereas the highest K was found in Wedelia compost. These results confirm that the final compost quality is not only dependent on its initial nutrient composition but also on the transformative process during composting. These results further suggest that all compost produced in this study is in line with the National Standard of Indonesia requirement for NPK content; therefore, these composts are suitable for agricultural use.

In summary, the study confirmed that the decomposition rate of weed biomass fluctuated through the incubation period, with the peak occurring at the fourth week, reaching 35.9 g C day^{-1}. Afterward, the rate declined to completion of the composting (11.34 g C day^{-1}). Melastoma decomposition rate was initially similar with other biomasses, but it suppressed at the third week of the composting period. Organic content and C/N ratio significantly declined within the first four weeks of the incubation period, and the reduction was lower by the completion of the composting process. Release of N, P, and K content prominently increased during the incubation period. At the end of the incubation, Borreria compost exhibited the greatest N and P content, while Wedelia compost had the highest K. All the composts evaluated in this study met the criteria of NPK requirements for Indonesian Standard. The study suggests that indigenous weed species from coastal environments have promise as compost substrates, supporting novel sustainable agricultural development.

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Conflicts of interest

The authors declare no conflicts of interest.

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