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Influence of Litter Quality and Mesh Size on Decomposition Dynamics and Nutrient Release Patterns of Selected Tropical Plant Residues

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Abstract

In tropical agroecosystems, the decomposition of plant residues constitutes a fundamental biogeochemical process governing soil fertility maintenance and nutrient cycling. This study quantitatively evaluated the influence of litter quality and litterbag mesh size on decomposition kinetics and nutrient mineralization patterns of selected tropical plant residues. A controlled litterbag experiment was established using six residues commonly encountered in tropical farming systems: banana leaves, *Chromolaena odorata*, *Leucaena leucocephala*, maize (*Zea mays*) stover, neem (*Azadirachta indica*) clippings, and *Panicum maximum*. Air-dried residues were placed on the soil surface within non-woven litterbags of two mesh sizes (0.5 mm and 5.0 mm) to differentiate microbial-driven decomposition from combined microbial-mesofaunal activity. Litterbags were retrieved at 7, 14, 28, 49, and 98 days after placement to determine residual mass and quantify nutrient release dynamics for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). Progressive mass loss was observed across all residues, indicating active decomposition and organic matter turnover. During the early decomposition phase (7-28 days), residue type exerted negligible influence on mass loss; however, significant differentiation emerged during the later stages (49-98 days), reflecting substrate-specific recalcitrance and lignocellulosic composition. Mesh size exerted a consistently significant control on decomposition rates, with finer mesh (0.5 mm) restricting faunal access, thereby resulting in greater litter mass retention and slower nutrient release relative to the coarser mesh (5.0 mm). Nutrient release trajectories varied systematically with litter quality. Nitrogen and phosphorus exhibited residue-dependent mineralization patterns, underscoring the role of initial nutrient content and C:N ratios. Potassium displayed rapid early-stage leaching attributable to its high solubility and weak structural binding within plant tissues. In contrast, calcium and magnesium demonstrated gradual release profiles associated with the breakdown of structural components such as cell walls. Overall, the interaction between residue quality and decomposer accessibility highlights the pivotal role of both substrate characteristics and soil biota in regulating decomposition processes and nutrient cycling, with direct implications for optimizing residue management strategies and enhancing soil productivity in tropical agroecosystems.

Keywords

Litter decomposition;
Nutrient release dynamics;
Residue quality;
Litterbag mesh size;
Tropical agroecosystems

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Introduction

The breakdown of plant residues by microorganisms and soil fauna releases vital nutrients like nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) back into the soil for plant uptake. This mechanism substantially contributes to the preservation of soil organic matter and plays an essential part in ensuring efficiency in both natural and agricultural ecosystems. Differences in the rate of breakdown can consequently profoundly affect the accessibility of nutrients and the operation of ecosystems in various environments (Singh et al., 2025; Tripathi et al., 2025).

Climate, residue chemical composition, and biological activity are some of the interconnected variables that affect how quickly plant residues break down. Among them, it is well known that one of the main determinants of decomposition kinetics is litter quality, which is defined by characteristics like nutrient concentration, lignin content, and C: N ratio. The chemical makeup of different plant species varies greatly, which causes different rates of mass loss and nutrient release during decomposition. Thus, in agroecosystems and forest systems, species variety and residue properties can have a significant impact on nutrient cycling processes (Palma et al., 2002; Cissé et al., 2021; Gupta et al., 2023).

Additionally, soil microbes are essential to the breakdown of plant wastes. While soil fauna like earthworms, arthropods, and other detritivores improve decomposition by physically altering and fragmenting plant litter, microorganisms like bacteria and fungi are principally in charge of the biochemical breakdown of organic matter. These organisms

accelerate the breakdown of litter and the release of nutrients by increasing the surface area available for microbial colonization and stimulating microbial activity. Research has shown that soil fauna plays a crucial role in controlling decomposition processes by greatly increasing litter mass loss and nutrient mobilization in soil systems (Cassani et al., 2021; Zhang et al., 2023; Shah et al., 2024).

In terrestrial ecosystems, the litterbag approach is frequently employed to study nutrient release patterns and decomposition dynamics. Researchers can assess the relative contributions of microorganisms and soil fauna to decomposition processes by controlling the availability of soil organisms to decaying residues through the use of litterbags with varying mesh sizes. While smaller mesh sizes prevent macro- and mesofauna from entering, larger mesh sizes usually permit access, allowing the evaluation of their impact on nutrient cycling and trash breakdown (Cassani et al., 2021). This method has been frequently used in ecological research to comprehend how litter properties and biological interactions affect decomposition rates.

There is little knowledge on how various plant residues that are frequently found in tropical agroecosystems differ in their decomposition patterns and nutrient release dynamics, despite the significance of plant residue decomposition in nutrient cycling. In tropical agricultural systems, where crop residues and plant biomass greatly contribute to soil fertility and sustainable nutrient management, it is especially critical to comprehend these processes. Thus, the purpose of this study was to use the litterbag approach to assess the effects of residue type and litterbag mesh size on litter mass loss and the release

dynamics of important nutrients (N, P, K, Ca, and Mg) during the decomposition of specific tropical plant residues.

Materials and Methods

Study Area

The investigation was carried out in southwest Nigeria in a tropical agroecosystem. The area is located in the humid tropical zone, which is distinguished by a bimodal rainfall pattern and an annual precipitation range of roughly 1,200 to 1,500 mm. The average yearly temperature is between 25 and 28 °C, and the year-round humidity is rather high. The majority of the region's soils come from basement complex rocks, and they are typically categorized as tropical Alfisols with well-drained profiles and moderate fertility. The region's vegetation is mostly composed of cultivated fields with annual crops and perennial tree species, as well as secondary forests.

Plant Residue Collection and Preparation

The decomposing experiment used six plant wastes that are frequently seen in tropical farming systems. Banana leaves, *Chromolaena odorata* leaves, *Leucaena leucocephala* leaves, Maize (*Zea mays*) stover, Neem (*Azadirachta indica*) clippings, and *Panicum maximum* grass leftovers were among them. Within the study region, fresh plant materials were gathered from neighboring farms and barren areas. Prior to the experiment, the residues were air-dried in the shade to a consistent weight in order to reduce microbial degradation. To guarantee consistency and make litterbag filling easier, large plant parts were chopped into smaller pieces (around 2-5 cm).

Litterbag Preparation

Two distinct mesh sizes of nylon mesh were used to create litterbags: 0.5 mm mesh size (limiting access for macrofauna). Access to macro- and mesofauna is possible with a mesh size of 5.0 mm. The dimensions of each litterbag were roughly 20 cm by 20 cm. Each litterbag was filled with a predetermined amount of air-dried plant debris (usually 20-25 g). In order to facilitate interaction with soil organisms and ambient conditions while preventing plant material loss, the bags were tightly sealed.

Experimental Design and Field Placement

A fully randomized strategy was used to arrange the litterbags on the soil's surface in the experimental field. To enable periodic sampling, litterbags with several replicates were made for both mesh sizes for each type of residue. To replicate the conditions of natural litter decomposition, the litterbags were carefully placed in touch with the soil's surface. The sacks were gently fastened to the ground with metal pins avoid shifting.

Litterbag Retrieval and Sampling

To track the dynamics of decomposition, litterbags were collected at five sample intervals: 7 days after placement (DAP), 14 DAP, 28 DAP, 49 DAP, and 98 DAP. Litterbags were meticulously gathered from the field on each sampling day and brought to the lab for examination. The dirt and soil particles that were affixed to the litterbags were carefully removed. To calculate the leftover litter mass, the remaining plant material in each bag was oven-dried at 65 °C until it reached a consistent weight.

Determination of Litter Mass Loss

Litter mass remaining was calculated as the percentage of the initial dry mass using the formula:

$$\text{Percent litter mass remaining} = \frac{\text{Dry mass after sampling}}{\text{Initial dry mass}} \times 100$$

This allowed the estimation of decomposition rates across residue types and mesh sizes over time.

Nutrient Analysis

The nutritional content of the ground subsamples of the dried residues was examined. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) are among the nutrients whose concentrations were measured. The Kjeldahl digestion method was used to measure total nitrogen, while the molybdenum blue method was used to measure phosphorus colorimetrically after acid digestion. Atomic absorption spectrophotometry (AAS) was used to determine the amounts of potassium, calcium, and magnesium following the plant samples' wet digestion. In relation to each residue's initial nutrient content, the proportion of nutrients still present in the litterbags was computed.

Statistical Analysis

The effects of residue type, litterbag mesh size, and the interaction between residue type and mesh size on litter mass remaining and nutrient dynamics during sampling intervals were assessed using analysis of variance (ANOVA). When significant differences were found, treatment means were separated at $P < 0.05$ using least significant difference (LSD) testing. To evaluate temporal trends in breakdown and nutrient release, statistical analyses were carried out independently for every sampling interval.

Results

Table 1: Summary of analysis of variance for %litter mass and nutrient remaining in litterbags

% litter/nutrient remaining	source of variation	Day after placement				
		7	14	28	49	98
		F probability				
Litter mass	Residue (R)	Ns	Ns	ns	0.008	<0.0001
	Mesh size (M)	0.0005	0.0004	0.0003	0.0002	<0.0001
	R x M	0.0084	0.0065	0.0098	0.002	<0.0001
N	R	Ns	0.02	ns	ns	<0.0001
	M	0.003	0.004	0.0011	0.04	<0.0001
	R	0.005	0.02	0.04	ns	<0.0001
P	R	<.0001	<.0001	0.05	0.0004	<.0001
	M	<.0001	0.0015	0.003	0.0005	<.0001
	R x M	0.01	ns	ns	ns	0.0005
K	R	0.002	0.0001	0.01	<.0001	<.0001

	M	Ns	ns	ns	0.01	0.0002
	R x M	Ns	ns	ns	ns	0.0017
Ca	R	0.03	<0.0001	<.0001	ns	0.0007
	M	Ns	0.005	0.04	ns	<.0001
	R x M	Ns	ns	ns	ns	Ns
Mg	R	Ns	0.04	0.0003	0.0005	0.003
	M	0.005	0.006	0.05	ns	<0.0001
	R x M	Ns	ns	ns	ns	<0.0001

Note: 'ns' represents not significant, R: Residues, M: Mesh Size

Analysis of Variance for Percent Litter Mass and Nutrient Remaining in Litterbags

Table 3 shows the analysis for percent litter mass and nutrient remaining in litterbags. There was no significance difference in residue types on 7, 14 and 28 days after placement. At 49 and 98 days after placement there was a significant difference in residue types. There was a significant difference in mesh sizes in all the sampling days. The residues in 0.5 mm mesh size had more percentage litter mass remaining compare to 5.0 mm mesh size in all sampling days. There was significant effect in interaction (Residue x mesh size) in all the sampling days.

Percent litter mass remaining in litterbags at sampling

Figure 1(a) shows the percent litter mass remaining in litterbags at sampling. Generally

the litter mass reduced as day after placement (DAP). There were no significant differences in residue types on 7, 14 and 28 days after placement. At 49 and 98 days after placement there was a significant different in residue types. Residue quality significantly influenced the percent N at 14 and 98 days after placement (Table 1).

Effect of litterbag size on percent litter mass remaining at sampling

Figure 1(b) shows the effect of litterbags size on the percent litter mass remaining in litterbags at sampling. The mesh sizes significantly affect the percent N remaining in decomposition of the residues in all sampling days. The residue of 0.5 mm mesh size had more percent litter mass remaining compared to 5.0 mm mesh size in all the sampling days (Table 1).

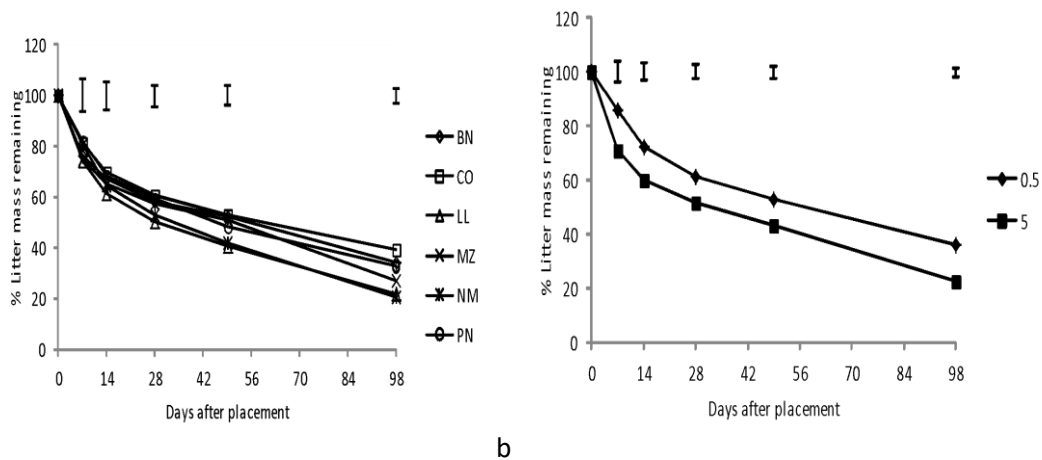


Figure 1 (a) Percent litter mass remaining in litterbags at sampling. (b) Effect of litterbag size on the percent litter mass remaining in litter bags at sampling

Note: BN = *Banana leaves*; CO = *Chromolaena odorata*; LL = *Leucaena leucocephala*; MZ = *Maize Stover*; NM = *Neem clipping*; PN = *Panicum maximum*

0.5 mesh size, 5.0 mesh size, cross bar (I) represents least significant difference (LSD)

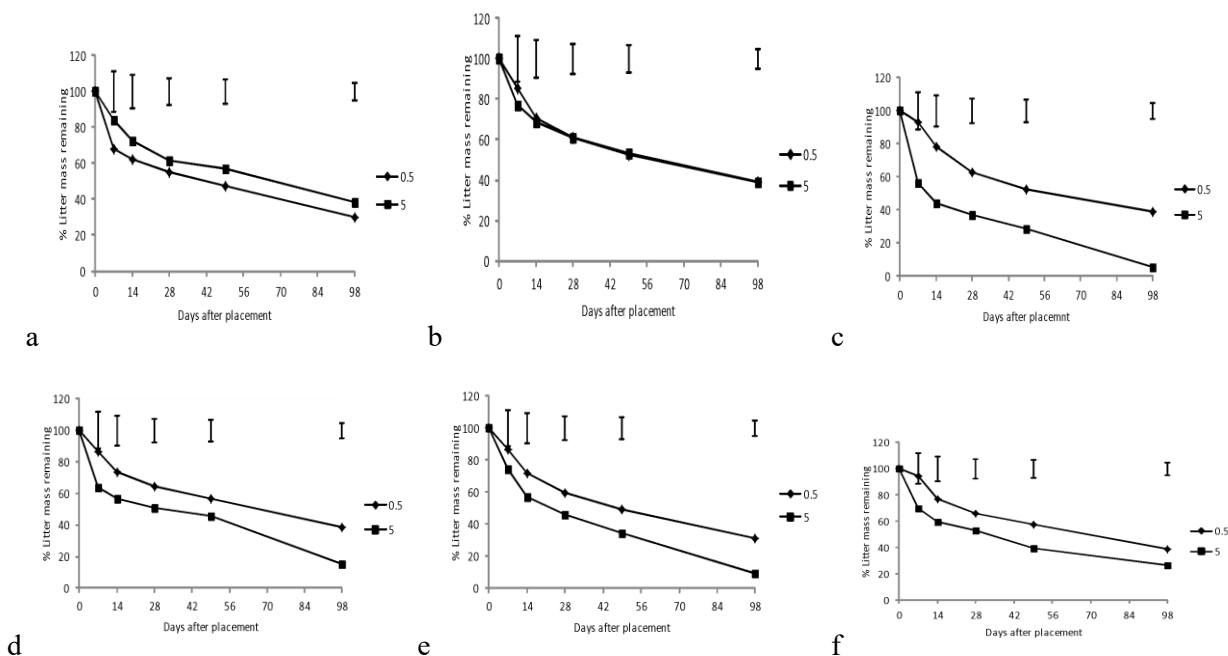


Figure 2: (a) Effect of litterbag size on the percent litter mass remaining of banana residue (b) Effect of litterbag size on the percent litter mass remaining of *Chromoleana odorata* leaves residue (c) Effect of litterbag size on the percent litter mass remaining of *Leucena leucocephala* residue (d) Effect of litterbag size on the percent litter mass remaining of maize stover residue. (e) Effect of litterbag size on the percent litter mass remaining of *Neem clippings* residue. (f) Effect of litterbag size on the percent litter mass remaining of *Panicum maximum* residue Note: 0.5 mesh size, 5.0 mesh size, cross bar (I) represents least significant difference

Effect of litterbag size on the percent residues litter mass remaining of the plant

Figure 2a shows the effect of litterbag size on the percent litter mass remaining of banana residue. There were no significant differences in percent litter mass remaining of banana residue in the two different mesh size

litterbags (0.5 mesh size and 5.0 mesh size) in all placement day. Figure 2b shows the effect of litterbag size on the percent litterbag mass remaining of *Chromoleana odorata* leaves residue.

There were no significant differences between the percent litter mass remaining of *Chromoleana odorata* leaves residue in the two different mesh size litterbags (0.5 mesh size and 5.0 mesh size) in all placement day. Figure 2c shows the effect of litterbag size on the percent litterbag mass remaining of *Leucena leucocephala* residue. The percent litter mass remaining in 0.5mm mesh size of *Leucena leucocephala* residue was significantly higher than that of 5.0mm in all placement days. Figure 2d shows the effect of litterbag size on the percent litterbag mass remaining of Maize stover residue. The percent litter mass remaining of Maize stover residue in 0.5mm mesh size was significantly higher than that of 5.0mm mesh size at 98days after placement. Figure 2e shows the effect of litterbag size on the percent litter mass remaining of Neem clipping residue. 0.5mm mesh size litterbags was significantly higher in percent litter mass remaining of Neem clipping residue than 5.0mm mesh size only at 98 days after placement.

Figure 2f shows the effect of litterbag size on the percent litter mass remaining of *Panicum maximum* residue. 0.5mm mesh size litterbag was significantly higher in percent.

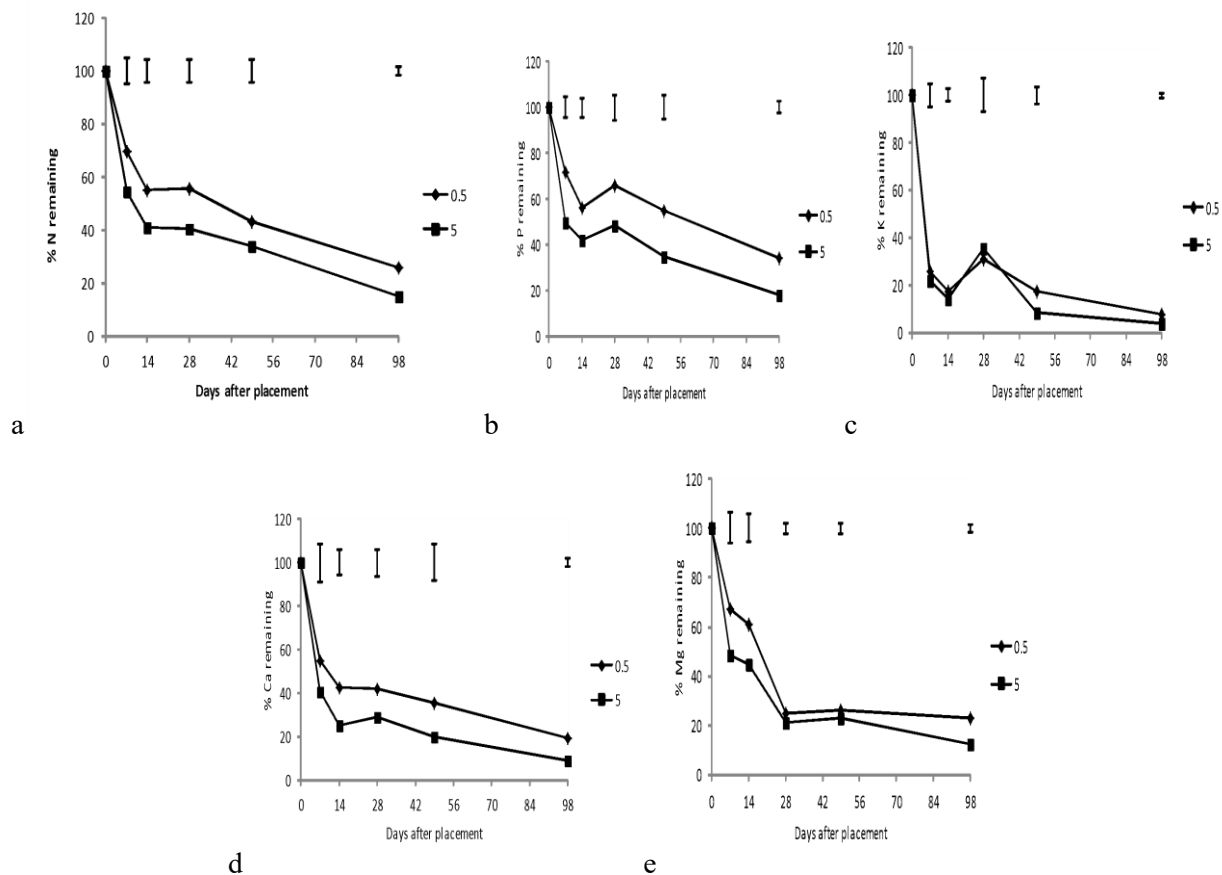


Figure 3 (a) Effects of litterbags size on Percent N remaining in the residues at sampling (b) Effect of Litterbags size on percent P remaining in the residues at sampling (c) Effect of Litterbags size on percent K remaining in the residues at sampling (d) Effect of Litterbags size on percent Ca remaining in the residues at sampling (e) Effect of Litterbags size on percent Mg remaining in the residues at sampling

Note: 0.5 mesh size, 5.0 mesh size cross bar (I) represent least significant difference (LSD)

Percentage N remaining

Figures 4 (a-f) show the release pattern of Nitrogen from different plant residue types in both litterbags size (0.5mm mesh size and 5.0mm mesh size). Residue quality significantly influenced the % N only at 14 and 98 days after placement (fig 4). However, the mesh size significantly affected the % N remaining in the decomposition of the residues in all the sampling days after placement (fig 10). At the 14 DAP, the % N remaining of the neem clipping (NM) residue (fig 4) was significantly lower compared to that of maize stover (MZ) (fig 14) while at 98 DAP, *Chromolaena odorata* (CO), Maize stover (MZ), *Panicum maximum* (PM) and Banana leave (BN) had significantly higher % N remaining than *Leucaena leucocephala* (LL) and

Neem clipping (NM). In fact *Chromolaena odorata* (CO) had more than twice % N remaining on the 98 DAP when compared to *Leucaena leucocephala* (LL) and Neem clipping (NM). On all the sampling days, the residue in 0.5 mesh size had more % N remaining compared to 5.0 mesh size. Apart from the residue from banana (fig 4), % N remaining in other residue treatments were significantly higher in mesh size 0.5 compared to mesh size 5.0. In LL, the % N remaining in the mesh size 0.5 were more than 100% higher than that of mesh size 5. The % N remaining in the bigger mesh size for *Leucaena leucocephala* (LL) and Neem clipping (NM) residue at 98 DAP were less than 10.

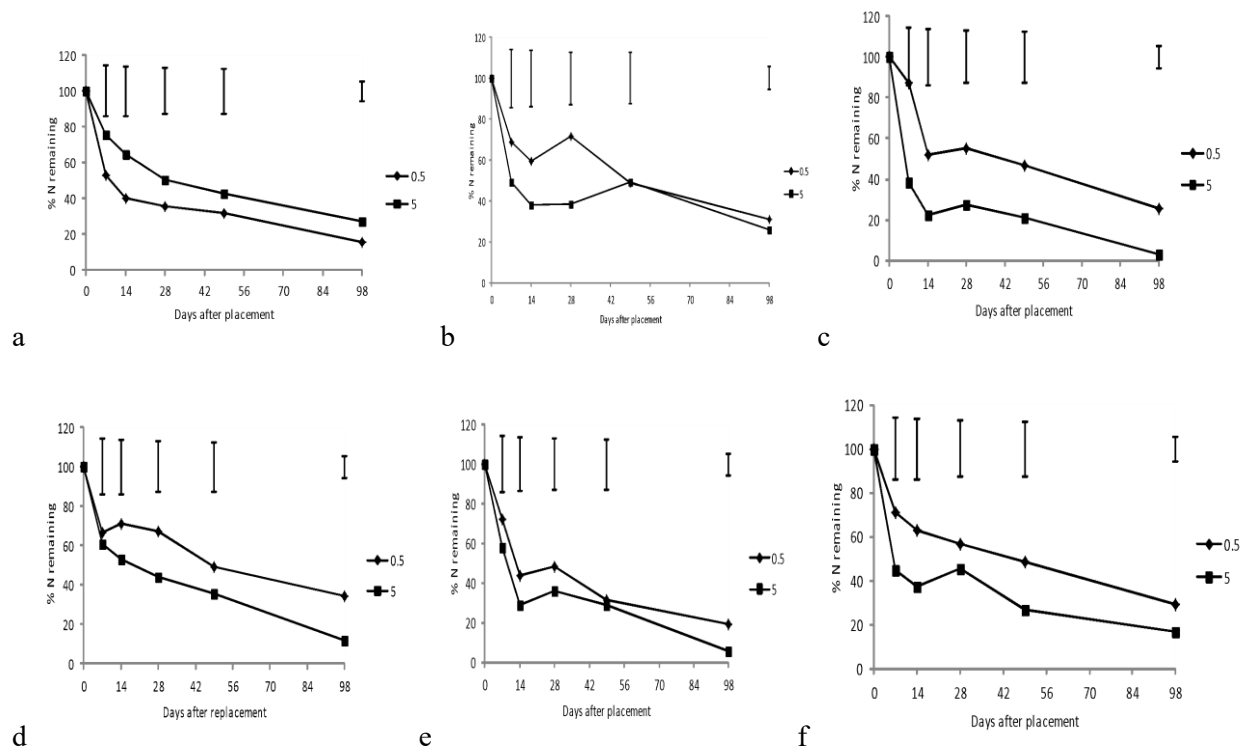


Figure 4 (a) Percent N remaining of banana leaf residue in litterbags at sampling (b) Percent N remaining of *Chromolaena odorata* residues in litterbags at sampling (c) Percent N remaining of *Leucaena leucocephala* residues in litterbags at sampling (d) Percent N remaining of maize stover residues in litterbags at sampling (e) Percent N remaining of Neem clippings residues in litterbags at sampling (f) Percent N remaining of *Panicum maximum* residues in litterbags at sampling.

Percentage P remaining

Figure 5 (a-f) shows the release pattern of Phosphorus from the different plant residue types in both litterbags (0.5mm mesh size and 5.0mm mesh size). Residue type and mesh size significantly affected ($P < 0.05$) the % P remaining in the residue after placement during the decomposition experiment. Neem clipping (NM) and *Panicum maximum* (PM) were significantly lower ($P < 0.05$) in the % P remaining compared to other residue treatment on the 7 DAP. By the 14th day after placement, the % P remaining in the Maize stover (MZ) and Banana leaves (BN) residues was significantly higher than that of *Leucaena leucocephala* (LL), Neem clipping (NM) and *Panicum maximum* (PM). Maize stover (MZ), Banana leaves (BN) and *Chromolaena odorata* (CO) residues continued to maintain significantly higher % P remaining compared to Neem clipping (NM) and

Panicum maximum (PM) in the 49 and 98 DAP. In fact the % P remaining in Neem clipping (NM) and *Panicum maximum* (PM) on the 49 and 98 DAP was about 100% lower compared to that of Maize stover (MZ), *Chromolaena odorata* (CO) and Banana leaves (BN). The % P remaining in the decomposed residues in the mesh size 0.5mm were significantly higher than that of mesh size 5.0mm. However, significant differences were not observed in the % P remaining between mesh size 0.5mm and 5.0mm when Banana leaves (BN) and *Panicum maximum* (PM) were considered. In *Chromolaena odorata* (CO), Maize stover (MZ), *Leucaena leucocephala* (LL), and Neem clipping (NM), the % P remaining in the decomposed residues of mesh 0.5mm were significantly higher than that of 5.0mm mesh size. In *Leucaena leucocephala* (LL), Maize stover (MZ) and Neem clipping (NM), the % P remaining in the mesh 0.5mm on

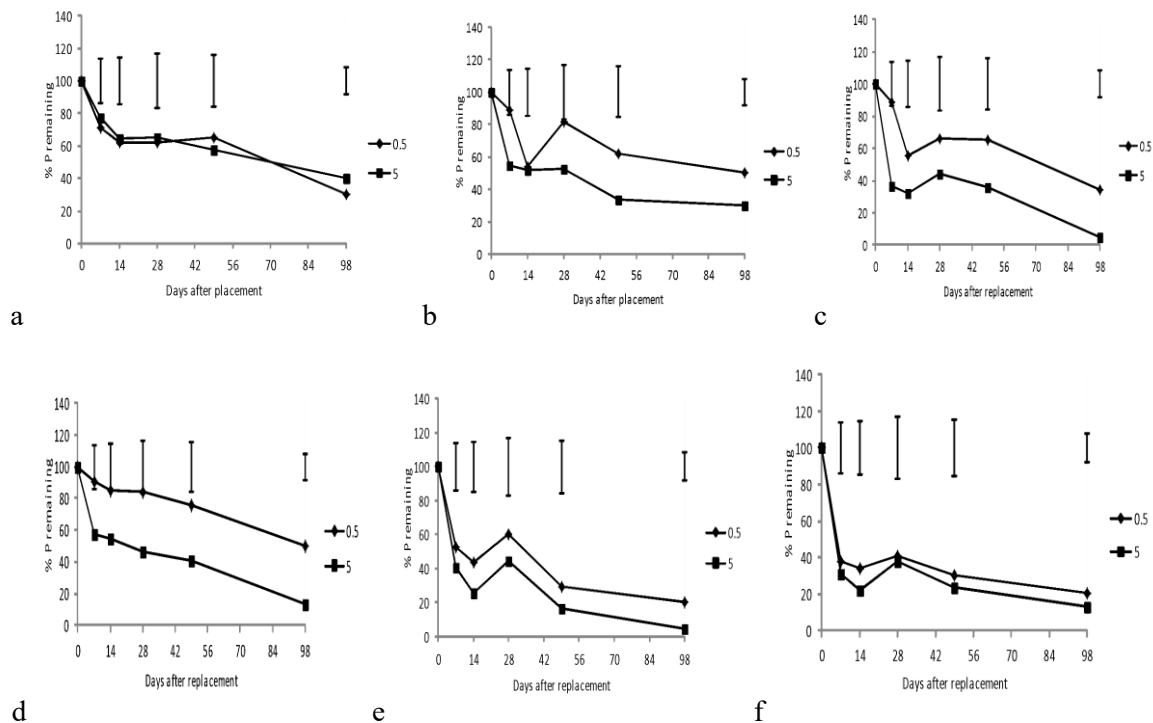


Figure 5 (a) sampling (a) Percent P remaining of banana leave residues in litterbags at sampling (b) Percent P remaining of *Chromolaena odorata* residues in litterbags at sampling (c) Percent P remaining of *Leucaena leucocephala* residues in litterbags at sampling (d) Percent P remaining of maize stover residues in litterbags at sampling (e) Percent P remaining of *Panicum maximum* residues in litterbags at sampling (f) Percent P remaining of Neem clippings residues in litterbags at sampling

Note: The last day of sampling (98 DAP) were more than two fold higher than that 5.0mm mesh size.

The Percent K remaining

Figure 6 (a-f) shows the release pattern of Potassium from different plant residue types in both litterbags. The % K remaining was significantly affected by the residue's types across the sampling dates after placements. Mesh size did not significantly affect % K remaining until 49 DAPS. Significant interaction between residue type and mesh size was observed only on the 98 DAPS. On the 7 and 14 DAP, the % K remaining in the *Leucaena leucocephala* (LL) residues was significantly higher than the other residues except Maize stover (MZ). It was more than three-fold higher than those of *Chromolaena odorata* (CO), Banana leaves (BN) and *Panicum maximum* (PM) on 7 DAP and those of Neem clipping (NM) and *Panicum maximum* (PM) on 14 DAPS. On the 28 DAP, Maize stover (MZ) had

% K remaining that was significantly higher than the other residues.

The % K remaining in Maize stover (MZ) and *Panicum maximum* (PM) residues rose by more than 100% on the 28 DAPS. On the 49 and 98 DAP, Maize stover (MZ) was still significantly higher in % K remaining than other residues types. It was the only residue that has more than 10% K remaining in the two sampling dates. The % K remaining in mesh size 0.5mm was significantly higher than that in mesh 5.0mm on the 49 and 98 DAP. The mesh size effect on each of the residues was not significantly different until 98 DAP. The mesh size 0.5mm had significantly higher % K remaining than mesh 5.0mm in *Leucaena leucocephala* (LL) and Maize stover (MZ).

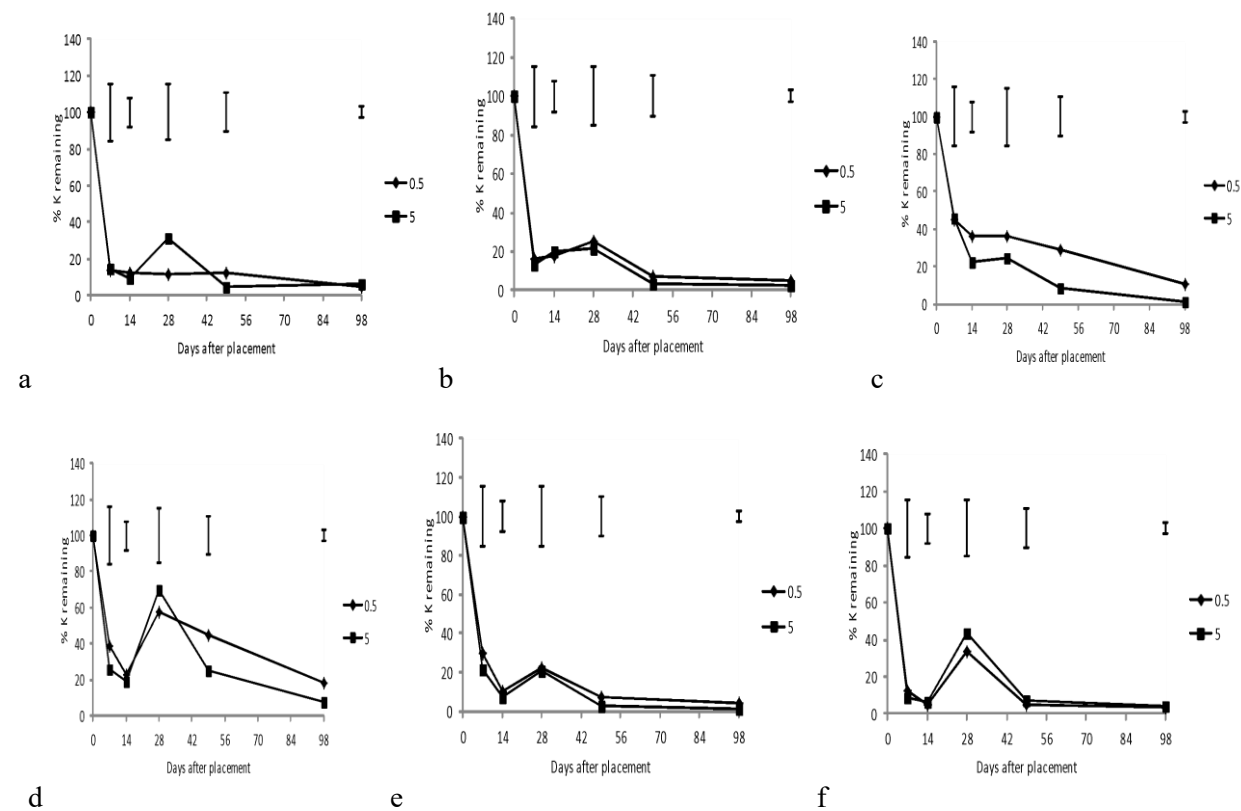


Figure 6(a) Percent K remaining of banana leave residues in litterbags at sampling (b) Percent K remaining of *Chromolaena odorata* residues in litterbags at sampling (c) Percent K remaining of *Leucaena leucocephala* residues in litterbags at sampling (d) Percent K remaining of maize stover residues in litterbags at sampling (e) Percent K remaining of Neem clippings residues in litterbags at sampling (f) Percent K remaining of *Panicum maximum* residues in litterbags at sampling.

Note: 0.5 mesh size, 5.0 mesh size cross bar (I) represent least significant difference (LSD).

Percent Ca remaining

Figure 7 (a-f) shows the release pattern of Calcium from the different plant residue types in both litterbags. The % Ca remaining was significantly affected by the residue type on all the sampling days except on 49 DAP (fig 33). Maize stover was significantly lower in % Ca remaining than all other residues in 7 DAPS except *Chromolaena odorata* (CO) and *Panicum maximum* (PM) which had the highest % Ca remaining in compared to four other residues Banana leaves (BN), Neem clipping (NM), *Leucaena leucocephala* (LL), and *Chromolaena odorata* (CO) on 14DAP. Banana leaves (BN) have significantly higher % Ca remaining than

other residues in 14 and 28 DAP. On the 98DAP, Banana leaves (BN) and *Chromolaena odorata* (CO) had significantly high % Ca remaining when compared to *Leucaena leucocephala* (LL) and Maize stover (MZ). The mesh size 0.5 had higher % Ca remaining than mesh 5.0 at all the sampling periods. Significant difference in the % Ca remaining as a result of mesh size was observed on 14, 28, and 98DAP. The mesh size effect on individual residue was not significantly different.

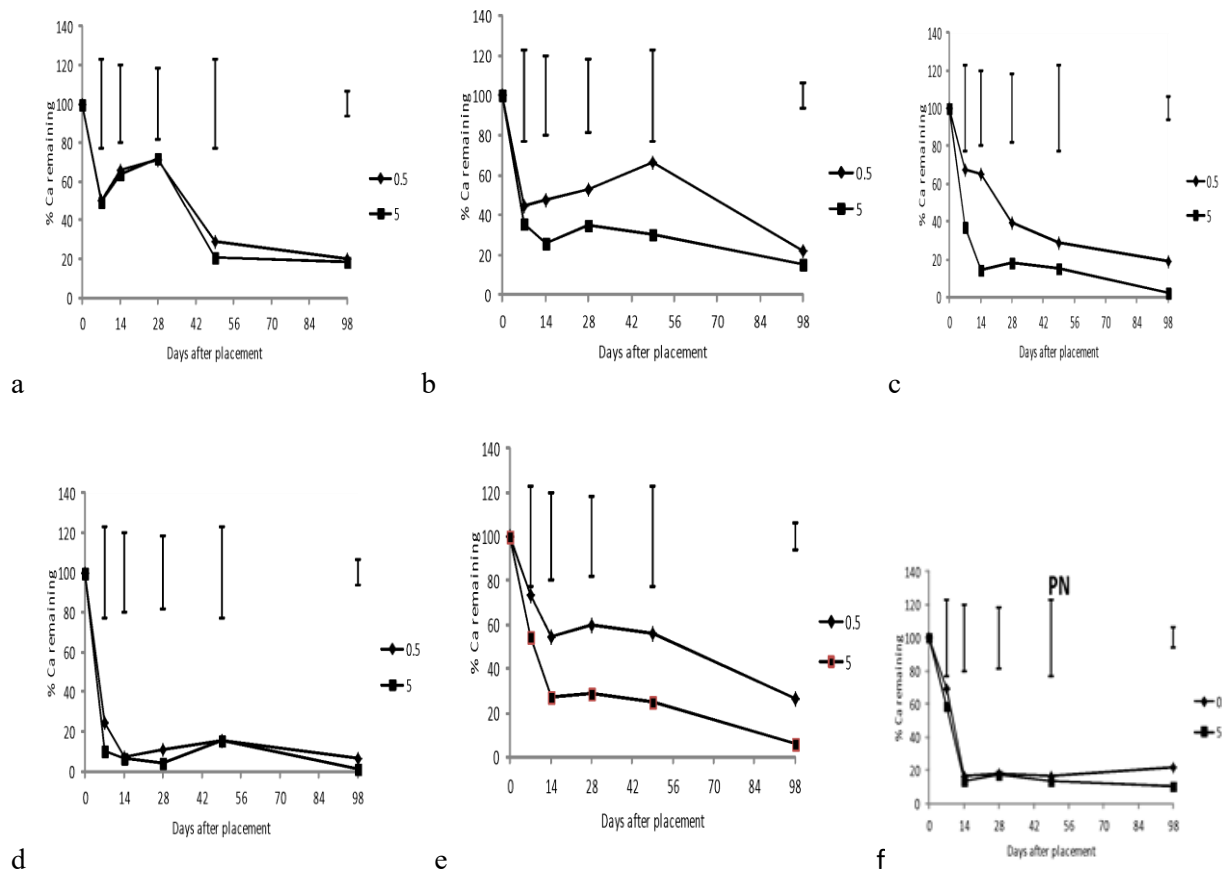


Figure 7 (a) Percent Ca remaining of banana residues in litterbags at sampling (b) Percent Ca remaining of *Chromolaena odorata* residues in litterbags at sampling (c) Percent Ca remaining of *Leucaena leucocephala* residues in litterbags at sampling (d) Percent Ca remaining of maize stover residues in litterbags at sampling (e) Figure 39: Percent Ca remaining of Neem clippings residues in litterbags at sampling (f) Percent Ca remaining of *Panicum maximum* residues in litterbags at sampling

Note: 0.5 mesh size, 5.0 mesh size cross bar (I) represent least significant difference (LSD)

Percent Mg remaining

Figure 8 (a-f) shows the release pattern of Magnesium from different plant residue types in both litterbags. Residue type significantly affected %Mg remaining from 14 to 98DAP. Percentage Mg remaining in *Leucaena leucocephala* (LL) was significantly lower than other residues except Neem clipping (NM) and *Panicum maximum* (PM) in 14 DAP. By the 28 and 49 DAP, Maize stover (MZ) was having % Mg remaining significantly higher than other

residues. At 98 DAP, *Leucaena leucocephala* (LL) residue had significantly higher % Mg remaining than *Panicum maximum* (PM) and Neem clipping (NM). The mesh size also significantly influenced % Mg remaining in all the sampling days except on 49DAP. The % Mg remaining in 0.5 mesh size litterbag were significantly higher than that of 5.0 mesh size litterbags. Significant effect of mesh size was observed on each of the residue on 98DAP.

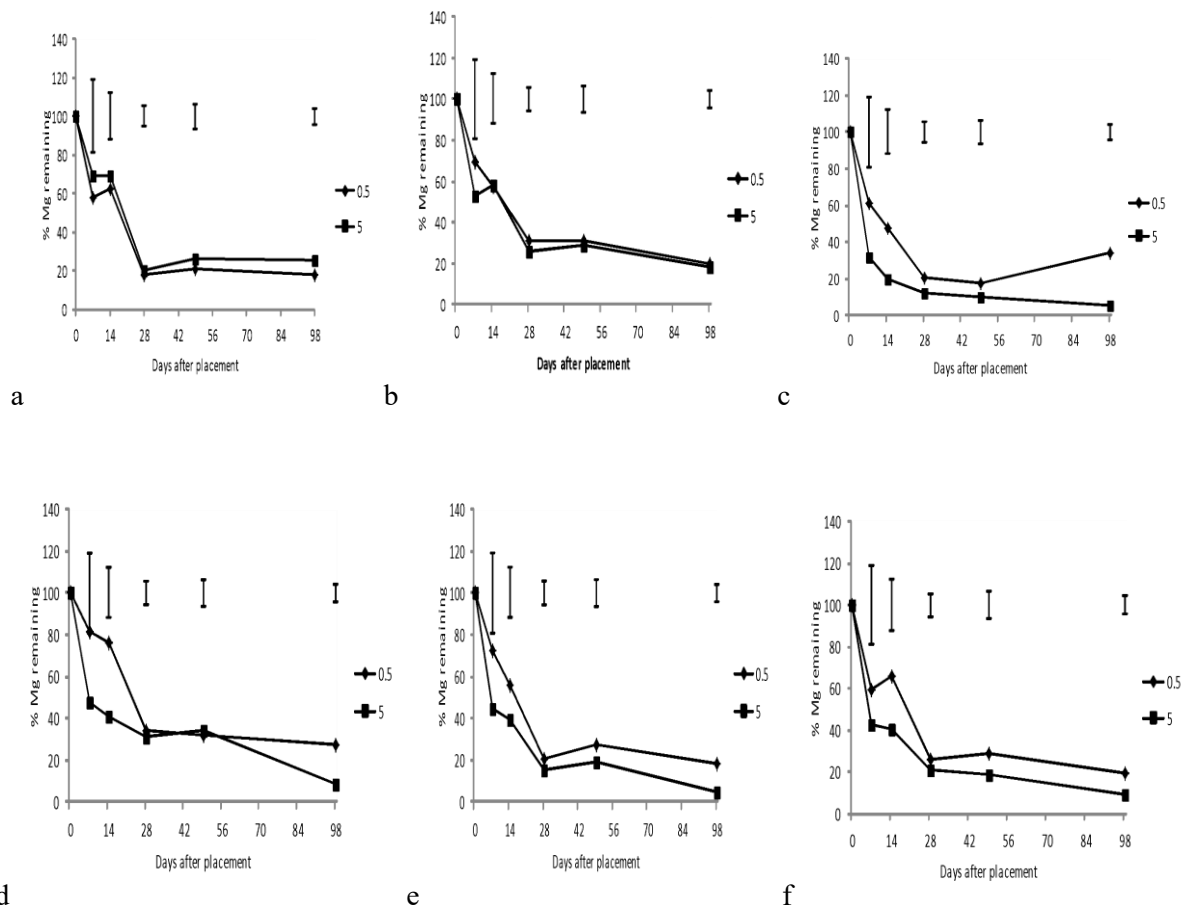


Figure 8 (a) Percent Mg remaining of banana residues in litterbags at sampling (b) Percent Mg remaining of *Chromolaena odorata* residues in litterbags at sampling (c) Percent Mg remaining of *Leucaena leucocephala* residues in litterbags at sampling (d) Percent Mg remaining of maize stover residues in litterbags at sampling (e) Percent Mg remaining of Neem clippings residues in litterbags at sampling (f) Percent Mg remaining of *Panicum maximum* residues in litterbags at sampling

Note: 0.5 mesh size, 5.0 mesh size cross bar (I) represent least significant difference (LSD)

Discussion

The normal pattern of plant residue breakdown in soil systems is confirmed by the gradual decrease in litter bulk seen with an increase in the number of days following installation. Due to the leaching of soluble chemicals and microbial use of labile substrates, litter decomposition often proceeds quickly in the early stages.

More resistant structural elements like cellulose and lignin then degrade more slowly. Studies on decomposition in tropical and agroecosystems have frequently documented comparable temporal patterns of litter mass loss (Peguero et al., 2019; Sandhu et al., 2022; Ntonta et al., 2024). The lack of discernible variations between residue types in the earliest phases (7-28 days) indicates that readily degradable substances included in the majority of plant residues were largely responsible for initial breakdown. Significant variations between 49 and 98 days, however, suggest that residue quality had a greater impact on decomposition later on. This is consistent with the widely recognized decomposition paradigm, which states that litter quality specifically, lignin content, C: N ratio, and nutrient concentration is a key factor in determining the pace of decomposition once the labile fraction is exhausted (Cheng et al., 2023; Wu et al., 2025).

The importance of soil fauna in decomposition is further demonstrated by the substantial impact of mesh size on litter mass surviving during sample intervals. Bigger mesh sizes give access to macro- and mesofauna like termites, ants, beetles, and earthworms, which break down trash more quickly by stimulating microbial activity and fragmenting it. According to studies, because of increased faunal activity and improved microbial decomposition, litterbags with wider mesh apertures usually lose more mass (Cheng et al.,

2023; Oyedele et al., 2025). The study's observations of residue-specific responses to mesh size further suggest that decomposition dynamics are influenced by the relationship between decomposer communities and residue quality. Certain leftovers, such as banana and *Chromolaena* leaves, exhibited negligible mesh size effects, indicating that microbial degradation might be enough to cause their dissolution. On the other hand, residues like *Leucaena* and maize stover showed greater mesh size effects, suggesting that faunal fragmentation played a major role in their breakdown.

Nitrogen mineralization during decomposition was greatly influenced by residue quality, as seen by the large variation in nitrogen release patterns between residues and sampling dates. Microbial immobilization activities, in which microorganisms momentarily store nitrogen to enable microbial biomass growth during the breakdown of carbon-rich substrates, may be the cause of the increased nitrogen retention seen in some residues at later stages. When microbial demand for nitrogen surpasses its supply in the substrate, such immobilization is most prevalent in the early stages of residue breakdown (Dou & Lin, 2025; Dou & Lin, 2026).

This study's findings about the impact of mesh size on nitrogen dynamics provide more evidence for the function of soil fauna in controlling nutrient cycling. Greater faunal access is usually made possible by litterbags with bigger mesh diameters, which speeds up litter fragmentation and improves microbial colonization, ultimately encouraging nitrogen release. According to earlier research, soil fauna can greatly boost rates of nitrogen mineralization by enhancing litter quality and promoting microbial decomposition processes (Zhang et al., 2023; Jayaramaiah et al., 2024). In comparison to residues like *Leucaena* and neem, residues like *Chromolaena odorata*, maize stover, and banana leaves maintained

comparatively higher nitrogen levels at later stages, indicating slower N release and greater immobilization. Variations in chemical composition, especially lignin content, polyphenols, and C: N ratios, which significantly control microbial activity and nutrient release during decomposition, may be the cause of these discrepancies.

Due to variations in residue chemistry and decomposer activity, phosphorus release during decomposition differed considerably between residue kinds and filter sizes. In comparison to neem and *Panicum* residues, the increased phosphorus retention seen in maize stover, banana leaves, and *Chromolaena* residues suggests slower phosphorus mineralization from these materials. Microbial activity and the creation of stable organic compounds have a significant impact on the dynamics of phosphorus during breakdown. Phosphorus is often momentarily retained in degrading leftovers by microbial immobilization before being progressively released into the soil.

In residues with greater structural complexity or lower initial phosphorus concentrations, this reaction is especially noticeable. Smaller mesh litterbags consistently retain more phosphorus, which may indicate that restricted faunal access slowed nutrient release and decreased litter fragmentation. Because they physically break down litter and increase the surface area accessible for microbial colonization and enzymatic breakdown, soil fauna is crucial to the phosphorus cycle. As a result, litterbags that allow more faunal access frequently release phosphorus more quickly (Oyedele et al., 2025; Nugroho et al., 2025).

Compared to other nutrients, potassium release showed a different pattern: fast early release was followed by decreased retention in subsequent sampling periods. This trend is in

line with potassium's high solubility in plant tissues. Potassium is easily leached from degrading plant wastes in the early phases of decomposition because it is not as tightly bonded to structural organic molecules as nitrogen or phosphorus. In comparison to other residues, the comparatively higher potassium that remained in the maize stover after the experiment indicated either slower leaching or stronger retention.

Such variations in potassium dynamics are frequently explained by differences in tissue structure, nutrient content, and breakdown rate among plant species. Mesh size impacts on potassium release were mostly seen in later sampling times, indicating a stronger contribution from faunal activity to potassium mobilization following the initial leaching phase. Similar findings have been documented in litterbag tests, where biological decomposition processes control the eventual release of potassium whereas leaching causes rapid potassium loss (Cheng et al., 2023).

Because calcium has a structural role in plant tissues and is involved in cell wall stabilization, its dynamics were different from those of potassium. Variations in plant tissue composition and breakdown resistance are probably the cause of the observed disparity in calcium retention among residues. At subsequent phases, residues such as banana leaves and *Chromolaena* had comparatively higher calcium retention, indicating slower release from these materials. The breakdown of structural materials like cellulose and lignin is frequently strongly linked to the release of calcium during decomposition. Calcium locked inside plant tissues gradually becomes available in the soil environment as decomposition proceeds and these compounds are progressively broken down by microbes and soil fauna. Limited faunal access slowed the fragmentation of plant residues and decreased the rate of calcium release, as seen by the

increased calcium retention seen in the litterbags with smaller mesh sizes. By physically upsetting plant tissues and promoting microbial colonization, soil fauna is essential in hastening breakdown (Peguero et al., 2019; Yue et al., 2022).

The release of magnesium during decomposition varied significantly between residues and sampling times, suggesting that residue chemistry has a major impact on magnesium dynamics. Increased immobilization within microbial biomass during the early phases of breakdown or slower decomposition could be the cause of the higher magnesium retention seen in some wastes. The substantial impact of mesh size on magnesium release implies that soil fauna had a role in this nutrient's mobilization. Soil fauna facilitates the breakdown of plant tissues and the release of nutrients like magnesium into the soil through enhanced microbial activity and litter fragmentation. Variations in tissue composition and nutrient distribution within plant organs may also be linked to disparities in magnesium release residues. Magnesium may be retained for longer during decomposition in residues with greater structural complexity or reduced microbial accessibility.

Overall, the findings show that litter decomposition and nutrient release dynamics are significantly influenced by both residue quality and litterbag mesh size. Mesh size controlled how much soil fauna contributed to decomposition processes, while residue chemical composition dictated the rate and pattern of nutrient release. These results emphasize how crucial soil biological communities are to controlling the cycling of nutrients in agroecosystems. Soil fauna improves soil fertility and nutrient availability for plant uptake by accelerating nutrient release, increasing litter fragmentation, and boosting microbial activity. Optimizing residue management techniques targeted at enhancing

soil health and sustainable crop production requires an understanding of these interactions.

Conclusion

This investigation showed that in tropical agroecosystems, plant residue decomposition behaviors and nutrient release trends are strongly influenced by litter quality and litterbag mesh size. Differences between residue types became more noticeable at later stages of decomposition, while litter mass gradually decreased over time, indicating effective decomposition mechanisms. Decomposition was consistently impacted by mesh size, with bigger mesh sizes promoting faster litter breakdown and nutrient release because soil macro- and mesofauna had easier access. Additionally, different residues had different patterns of nutrient release; potassium leached quickly in the beginning, while nitrogen, phosphorus, calcium, and magnesium leached more slowly as structural tissues broke down.

Overall, the results show how soil biological activity and residue quality work together to control organic matter turnover and nutrient cycling in tropical soils. While slower-decomposing residues may promote longer-term soil organic matter formation, residues with faster decomposition rates can contribute to nutrient availability more quickly. These findings highlight how crucial it is to choose suitable plant residues and residue management techniques in order to enhance soil fertility and maintain productivity in tropical agroecosystems.

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