Tropical Agricultural Research & Extension 27 (3): 2024

RESEARCH ARTICLE

IMPACT OF DIFFERENT SOIL AMENDMENTS ON CARBON AND NITROGEN MINERALIZATION IN ULTISOLS

Amarasinghe SR*, Premanath KPSD, and Wanniarachchi SD

Department of Soil Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, 81100, Sri Lanka

Received: 23 September 2023, Accepted: 18 June 2024, Published: 30 September 2024

Abstract

Quantifying the nutrient mineralization in soils amended with different materials is vital for understanding the nutrient availability for plant uptake. It helps to improve nutrient management by minimizing nutrient loss from the soil. The present research was conducted as a laboratory incubation to assess the nitrogen (N) and carbon (C) mineralization in Ultisols amended with cattle manure, spent poultry layer litter, Gliricidia leaves (*Gliricidia sepium*), leaf litter compost, urea, and Siam weed leaves (*Chromolaena odorata*). A Completely Randomized Design (CRD) was used with four replicates, and means were compared with Duncan's multiple range test (DMRT) after analyzing the data with the SPSS 25 statistical package. CO_2-C evolution in amended soils increased up to day 14 of incubation and became stable as incubation progressed. The highest total flux of CO_2-C (171.89 g/kg) was obtained in cattle manure-amended soil. Compost-amended soil showed significantly higher (p=0.05) release of mineralized nitrogen (1530.31 mg/kg) over unamended control. The pH in all the amended soils increased over time, with the highest pH in soil amended with compost. Thus, the present study indicated rapid C and N mineralization when different amendments are integrated into the soil.

Keywords: Carbon, Incubation, Mineralization, Nitrogen, Nutrient availability, Soil amendments

INTRODUCTION

Mineralization plays a crucial role in assessing soil nutrient availability, as it determines the conversion of organic matter into essential nutrients that plants can readily absorb. Organic matter accumulates from plant, animal, and microbial residues that exist in the soil or are added as organic amendments. Compost, manure, sewage, green manure, and other organic materials can be added to soil to improve its physicochemical and biological quality and are considered organic amendments (Liyanage *et al*., 2021). Organic amendments exhibit substantial variability in their composition and stabilization levels, resulting in varying capacities for nutrient release (Sikora *et al.* 2001). Thus, identifying the mineralization patterns after applying soil amendments is essential for optimizing their nutrient release and synchronizing it with plant nutrient demand. Synchronizing the carbon (C) and nitrogen (N) release patterns with plant requirements and nutrient transformations can improve the efficiency and effectiveness of soil-plant systems, enhancing carbon mineralization, minimizing nitrogen losses, and reducing phosphorus fixation in the soil (Bai *et al.* 2020). Hence, incubation studies on incorporating soil amendments and synchronizing nutrient availability with crop demand should be conducted before amendment practices are applied in agricultural lands.

Many incubation studies have been conducted to determine the mineralization of organic amendments (Liyanage *et al*. 2021; Khalil *et*

Corresponding author: rajika@soil.ruh.ac.lk

al. 2005; Haer and Benbi 2003). An incubation study is essential to identify the temporal nutrient release pattern by incorporating different amendments into the soil (Bankole and Azeez 2024; Impraim *et al.* 2022). Furthermore, many researchers have used incubation experiments to model the mineralization kinetics of N and C (Liyanage *et al.* 2021; Moharana *et al.* 2015; Wyngaard *et al.* 2018; Stanford and Smith 1972). These studies have shown that N mineralization of various soils follows the first order (exponential) kinetics, where the constant (*k*) remains the same for most soils. At the same time, the potential mineralizable N varies significantly. Additionally, according to the kinetics of C mineralization, incorporating various organic amendments substantially boosts the amount of mineralized carbon, reaching its peak in the early stages of incubation.

Mineralization is a microbial-driven process influenced by several factors, mainly soil properties such as texture, mineralogy, acidity, biological activity, presence of other nutrients, temperature, moisture content, and characteristics of the amendments (Tian *et al.* 2010; Wang *et al.* 2018). The type and quality of organic amendments will affect the stabilization of microbial biomass (Ladd *et al.* 1996). Amendments with high nitrogen content and low carbon-to-nitrogen ratios, such as Gliricidia leaves, tend to mineralize rapidly, providing a quick release of nutrients to plants (Liyanage *et al.* 2021; Dossa *et al.* 2015; Kumar *et al.* 2016). High-quality amendments containing >2% nitrogen and C/N ratios <25 may rapidly release N when incorporated into the soil (Abbasi *et al.* 2015). Organic N goes through the mineralization process, which converts the organic N into inorganic N (NO_3^-, NO_2^- or NH_4^+) (Wang *et al.*, 2023; Chatterjee and Lal, 2022). This decomposition process drives soil microorganisms to release plant-available nutrients and CO_2. The added amendments will supply an energy source (C) to microorganisms involved in N transformations. Thus, the mineralization process can be investigated by measuring either the consumption of substrates or the production of CO_2. The release of CO_2 is directly associated with the mineralization of organic materials in the soil. In contrast, materials with higher C: N ratios, like leaf litter compost, may mineralize more slowly, offering a more prolonged nutrient release (Abbasi *et al.* 2015). However, other controlling factors such as the lignin to nitrogen ratio other than C and N ratio, effectively support nitrogen release patterns (Melillo *et al.* 1984). Further, Fox *et al.* (1990) stated that the total lignin and polyphenol to N ratio would indicate initial mineralization. Several other factors affect the mineralization, such as cellulose, hemicellulose and lignin contents of the amendments (Van *et al.* 2000; Hao and Benke 2008; Xie *et al.* 2022).

Many researchers have recognized the positive impact of using plant residues, composts, and manures as organic amendments to enhance soil fertility. Using an incubation study, Kalita et al. (2023) studied organic amendments such as farmyard manure, poultry manure, pig manure, and vermicompost. They showed that pig and poultry manure had a maximum nutrient release within 50-60 days of incubation. Liyanage *et al.* (2021) showed that Gliricidia leaves decomposed rapidly, with the highest mineral C content in the mineralization process. Incorporating 1 t of Gliricidia leaf manure adds 21 kg N, 2.5 kg P, 18 kg K, and other trace elements (Nagavallemma 2000). Furthermore, this study mentioned that Gliricidia lopping has consistently supplied N from 7 - 121 mg kg^{-1} soil in 150 days of incubation. Moreover, Siam weed has many soil nutrients, including high N content (Vineela *et al.* 2008). These residues contribute nitrogen (3.79%) to the soil and contain a total % N content of 0.6% (Murthy 2013). Stark *et al.* (2007) stated that green manure crops add labile organic matter to the soil after incorporation. In addition, manure contains a lot of N and P, and is recycled again to the soil and provides 30% of the N requirement for plants. However, aerobically decomposed manure releases less N to the soil. On the other hand, compost in a decomposed state continuously supplies nutrients (Agustina *et al.,* 2019). Poultry litter, a mixture of poultry excreta, bedding material, feathers, and ration, provides plants with 30-50% readily available N (Bittenbender *et al.* 1998). Prolonged field application of organic amendments may affect soil's organic N composition and mineralization rate (He *et al.* 2014; Nicholson *et al.* 1997). Meanwhile, several studies compare the mineralization of organic amendments and urea (inorganic fertilizer), highlighting how these treatments affect soil nitrogen dynamics compared to organic amendments (Tambone and Adani 2017; Singh *et al*. 2016; Stark *et al.* 2007). In urea, the hydrolysis converts it to ammonia and carbon dioxide in relatively fast reactions using urease enzyme by soil microorganisms (Piotrowska-Długosz, 2020). Stark *et al.* (2007) incubated soil amended with a ground legume (lupin 4.3 t/ha) as an organic form and urea (100 kg/ha) as an inorganic form.

Evaluating soil properties under consistent conditions allows for individually examining soil moisture levels, temperature, microbial interactions, and soil type using incubation studies (Stark et al., 2007). Soil pH is crucial in carbon (C) and nitrogen (N) mineralization among various soil properties. Ultisols, known for their high acidity and low organic matter content, often exhibit low fertility. Numerous studies have utilized acidic soils in incubation experiments (O'Connor, 2023; Uddin et al., 2021; Yang et al., 2021). Atoloye *et al.* (2024) investigated compost and urea mineralization and microbial activity in Ultisols. Uddin *et al.* (2021) studied the nitrogen release patterns and kinetics in acidic soils treated with compost, poultry manure, rice husk biochar, poultry manure biochar, and cow dung combined with urea fertilizer.

In Sri Lanka, common organic amendments incorporated into agricultural lands include compost, Gliricidia, Siam weed, cattle manure, and poultry litter. Researchers amended soils with different soil amendments in varying quantities and forms to investigate the impact of microbial communities on C and N mineralization using incubation studies of various soil types in Sri Lanka (Jayarathna *et al.* 2024; Liyanage *et al.* 2021; Amarasinghe and Gunawardana, 2020; Gunarathne *et al.* 2020). However, organic forms of soil amendments and urea in acidic soils have yet to be extensively studied in Sri Lanka. Therefore, this study focuses on acidic soils (Ultisols), examining the effects of the widely used soil amendments and urea. It aims to investigate the C and N mineralization dynamics during incubation to compare their effectiveness in releasing inorganic N and stimulating microbial activity.

MATERIALS AND METHODS

Soil characteristics

Soil (0 - 15 cm depth) was collected from a bare land at the Faculty of Agriculture, University of Ruhuna, Kamburupitiya (6° 3' 38.86" N and 80° 33' 50.53" E). According to the USDA soil classification, the soil belongs to the order Ultisols and Hapludults (Ju *et al.* 2006). The collected soil samples were air-dried and sieved through a 4 mm mesh. A sample was used to measure the physico-chemical properties of the experimental soil (Table 1).

Table 1: Some physicochemical properties of soil selected for the incubation study

Soil Properties	Amount in soil
Bulk density	1.5 g/cm^3
Particle density	2.5 g/cm^3
Sand %	65%
Silt %	20%
Clay %	15%
Soil Texture	Sandy loam
pH_w (1:2.5 w/v)	4.4
EC_w (1:5 w/v)	0.07 dS/m
Total organic matter	1.97%
Total nitrogen content	0.053%
Available NO_3^--N	2.74 ppm
Available Ammonium NH_4^+-N	25.08 ppm

Characteristics of soil amendments

All organic materials (cattle manure, spent poultry layer litter, Gliricidia, leaf litter compost, and Siam weed) were collected from the farm at the Faculty of Agriculture, University of Ruhuna, Sri Lanka. Urea was purchased from a fertilizer shop. The carbon percentage of all amendments was measured using the Walkley-Black method, and the organic matter percentage was calculated by applying the conversion factor of 1.72. Total nitrogen was determined using the Kjeldahl method (Velp UDK 139, Italy) (Mapa *et al.* 1999). Subsequently, the C/N ratio was calculated. The total C%, total N%, and the C ratio are presented in Table 2.

Table 2: Characteristics of the amendments used for the incubation study

Type of amendment	Total C %	Total N %	C: N ratio
Cattle manure	15.44	2.98	5.18
Spent poultry litter	24.98	3.53	7.07
Gliricidia leaves	18.30	2.80	6.54
Dry leaf litter compost	41.50	1.49	27.85
Urea	20.00*	46.00*	0.43
Siam weed leaves	18.32	1.65	11.10

*By calculation

Treatments and laboratory incubation study

The incubation study was conducted as a batch experiment with seven treatments: T1 - dry cattle manure, T2 - spent poultry layer litter, T3 - Gliricidia, T4 - leaf litter compost, T5 - urea, T6 - Siam weed, T7 - soil without any treatment. To create experimental units, air-dried and sieved (4 mm) 100 g of soil was added to clean 500 ml glass bottles. Daily monitoring and weighing of the bottles containing soil samples carefully regulated soil moisture content. If moisture levels dropped below the desired threshold, water was added to maintain 60% of the soil's field capacity, ensuring optimal soil moisture conditions throughout the experiment.

The bottles were placed in a dark room at ambient temperature and pre-incubated for two weeks. At the end of the pre-incubation period, each of the seven amendments was separately applied to the glass bottles and thoroughly mixed. Organic amendments were applied at field application rates equivalent to 10 t/ha, and urea was applied at 100 kg/ha after adjusting for the 100 grams of soil used in each bottle.

The tops of the bottles were covered with polythene film with small punctures for aeration and placed inside larger jars for sealing. The experiment was arranged in a Completely Randomized Design with batches for destructive sampling. Each treatment was replicated three times within each batch.

To measure microbial activity via CO_2-C evolution, another set of bottles was prepared and incubated in the dark at ambient temperature. During incubation, a vial of 1M NaOH and a distilled water tube were maintained inside each bottle. On the relevant day of incubation, NaOH was titrated with 0.1M HCl (McGill and Figueiredo, 1993). Samples were destructively collected from the respective batches for C and N analysis.

Soil sampling and Analysis

Soil samples were collected from the bottles on days 1, 3, 5, 7, 14, 21, 28, 35, and 42 of the incubation periods. The pH, NH_4^+-N, NO_3^--N, and CO_2-C evolution were determined using the methods and instruments described in Table 3.

Table 3: Methods and instruments used to analyze the soil samples

Parameter	Instrument and method used
pH	pH meter; 1:2.5 (w/v soil: water), (HANNA multi-parameter analyzer)
NH_4^+-N	Salicylate method by UV visible spectrophotometer (UV 160, Shimadzu, Japan) (Amarasinghe and Gunawardhana, 2020)
NO_3^--N	Salicylate method by UV visible spectrophotometer (UV 160, Shimadzu, Japan) (Amarasinghe and Gunawardhana, 2020)
Microbial activity	Titration method (CO_2-C evolution method) (Amarasinghe and Gunawardhana, 2020)

Statistical Analysis

The SPSS 25 statistical package (IBM Corp. 2017) was utilized to determine significant differences among treatments, and means were compared using Duncan's multiple range test (DMRT) at $P \leq 0.05$.

RESULTS AND DISCUSSION

Microbial activity (CO_2 evolution) in soil treated with different amendments.

The total CO_2–C evolution during the 42-day incubation period showed significant variations ($p=0.05$) among the treatments compared with the control. CO_2 evolution increased in all amended soils as incubation progressed, regardless of the type of amendment. However, the daily CO_2–C flux from different amendments decreased gradually until day 14 of incubation and remained stable, except in T2 (Figure 1). Rapid CO_2 emission was observed in Gliricidia, and similar results were seen in an incubation study for acidic tea soils (Liyanage *et al.* 2021). In the early stages, decomposition rates were high due to readily decomposable components such as sugars, amino acids, and proteins (Pitta *et al.* 2012). The decomposition rate of poultry litter was lower than other treatments due to the accumulation of recalcitrant components such as lignin, tannins, and cellulose (Pitta *et al.* 2012). The breakdown of these complex compounds may occur over a longer period, sustaining microbial activity and increasing CO_2 production.

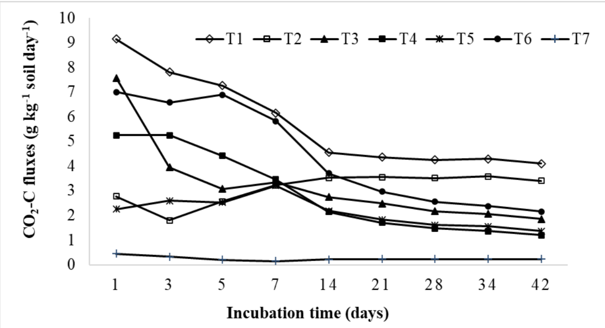

Figure 1: Evolution of daily CO_2–C fluxes during the 42-day incubation time from soils incorporated with six amendments

T1: cattle manure amended soil, T2: spent poultry layer litter amended soil, T3: Gliricidia amended soil, T4: leaf litter compost amended soil, T5: Urea amended soil, T6: Siam weed amended soil T7: soil without any treatment

Moreover, the total CO_2–C evolution was highest (171.89 g/kg) in cattle manure-amended soil, possibly due to the higher levels of microorganisms that enhance microbial activity (Figure 2). The control soil had deficient microbial activity because of the low availability of energy sources. The amount of CO_2–C in Gliricidia leaves amended soil is lower than in Siam weed leaves amended soil. The study by Kausadikar *et al.* (2020) stated that the amount of CO_2 released by Gliricidia leaves is less than other plant residues. The incorporated amendments regulated the cumulative CO_2-C evolution as cattle manure > compost > Siam weed > Gliricidia <poultry litter > urea > control soil (Figure 2). Cattle manure contains a substantial amount of organic carbon in the form of easily degradable organic matter. The high availability of this carbon can lead to rapid microbial activity, resulting in higher carbon mineralization rates. Nitrogen in cattle manure may be more readily assimilable by microbes, promoting microbial growth and activity and further driving carbon mineralization. According to Hartz *et al.* (2000), mineralization of manure C averaged higher C content in 24 weeks, while plant residue compost C mineralization averaged only a lesser amount. However, urea-amended soil showed less CO_2 evolution. Urea does not provide carbon as an energy source for soil microbes compared to compost or manure, which provide both nitrogen and carbon, supporting a higher level of microbial activity. The soil's pH is initially increased, resulting in high pH soils in the latter part of incubation, ranging from the lowest value of 4.85 to the highest value of 8.41. When ammonia is released into the soil, the pH increases due to the formation of ammonium hydroxide. Previous studies have documented the rise in soil pH due to the application of animal manure (Whalen *et al.*, 2000; Wyngaard *et al.*, 2016).

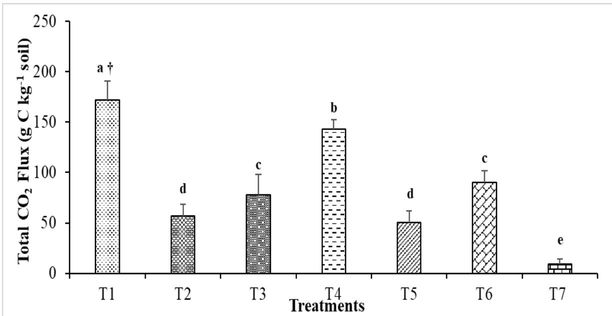

Figure 2: Total CO_2 evolution during 42-day incubation time in different amendments

T1: cattle manure amended soil, T2: spent poultry layer litter amended soil, T3: Gliricidia amended soil, T4: leaf litter compost amended soil, T5: Urea amended soil, T6: Siam weed amended soil T7: soil without any treatment. Error bars indicate ± standard deviations. †Means with the same letters are not significantly different at $p > 0.05$ by Duncan's Multiple Range Test.

Changes in pH

If the soil is initially acidic, the removal of NH_3 may lead to a slight decrease in acidity. Accordingly, the soil amendment incorporated showed a slight pH increment. The highest value of 8.41 and the lowest value of 7.28 at 42 days of incubation were observed in compost and control soil, respectively. Even without incorporating any amendments, the control soil showed a slight increase in pH, possibly due to the mineralization of organic matter in particular soil.

Changes of NH_4^+-N and NO_3-N in soils amended with different treatments

The release of NH_4^+-N and NO_3^--N (mineral N) from the soils amended with different treatments is shown in (Table 4). It showed that the NH_4^+-N decreased with the progression of incubation, regardless of the treatments. The decreasing NH_4^+-N may be due to the soil conversion of NH_4^+-N to NO_3^--N. Ammonification was rapid in the initial stage of the treatments, decreased until day 14, and became stable afterwards. Similar results were obtained by Khalil *et al.* (2005), showing initial ammonification continues until day 15 of the incubation. Later, the NH_4^+-N oxidation occurred at higher pH levels. Initially, NH_4^+-N of amendments varied from 5.41 mg kg^{-1} to 88.5 mg kg^{-1}. On day 14 of the incubation period, NH_4^+-N values ranged from 26.72 mg kg^{-1} to 139.58 mg kg^{-1}, and on day 42, they varied from 11.35mg kg^{-1} to 82.70 mg kg^{-1}. However, according to Yuan *et al.* (2011), the concentration of NH_4^+-N increased throughout the incubation, peaking at 30 days, and then began to decline. The NH_4^+-N values of all the amendments during the incubation period showed significantly higher values (p=0.05) than the control treatment, except on days 7 and 28 in cattle manure-amended soil (Table 4).

The NO_3^--N was higher in T1 (cattle manure amended soil) at the beginning of incubation until day 14, then decreased afterwards. The initial low carbon-to-nitrogen (C:N) ratio, rapid mineralization, and microbial activity may increase the NO_3^-- N content at the initial incubation stage in cattle manure-amended soil. Leaf litter compost generally has a higher

Table 4: The amount of NO_3^--N and NH_4^+-N mineralized in the soil with various amendments.

Treatments	Time of incubation (days) 1		3		5		7		14		21		28		35		42	
	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N
	mg/kg																	
T1	4.61^{a}	5.41^{g}	3.28^{bc}	201.09^{f}	4.19^{b}	280.56^{b}	18.09^{bc}	51.05^{c}	16.54^{a}	48.27^{d}	29.20^{b}	50.87^{c}	8.35^{e}	14.09^{e}	9.54^{d}	39.50^{d}	6.19^{d}	51.65^{d}
T2	0.70^{b}	46.1^{b}	3.15^{bc}	242.26^{e}	4.78^{ab}	323.96^{a}	18.60^{b}	281.67^{a}	16.41^{a}	69.47^{b}	37.02^{a}	54.98^{b}	6.53^{f}	61.80^{c}	8.91^{d}	82.76^{b}	4.57^{e}	52.65^{d}
T3	0.70^{b}	40.4^{c}	2.60^{c}	396.75^{a}	4.19^{b}	197.47^{d}	16.61^{c}	39.28^{d}	13.09^{c}	58.42^{c}	17.85^{d}	43.93^{d}	22.94^{a}	79.14^{b}	56.95^{a}	104.87^{a}	20.05^{a}	66.75^{c}
T4	0.46^{bc}	88.5^{a}	7.48^{a}	259.14^{b}	6.10^{a}	230.30^{c}	20.90^{a}	285.38^{a}	14.92^{b}	139.58^{a}	18.93^{cd}	125.09^{a}	18.73^{b}	83.90^{ab}	29.06^{b}	109.25^{a}	15.29^{b}	77.23^{b}
T5	0.74^{b}	38.48^{d}	6.18^{a}	217.65^{e}	3.64^{b}	223.25^{c}	19.49^{ab}	68.39^{b}	14.62^{b}	41.03^{e}	20.85^{c}	44.95^{d}	17.07^{c}	39.43^{d}	19.20^{c}	56.27^{c}	13.29^{c}	28.13^{e}
T6	0.74^{b}	28.56^{e}	4.13^{b}	231.13^{d}	3.30^{b}	227.70^{c}	16.47^{c}	41.13^{d}	15.22^{b}	56.88^{c}	20.97^{c}	42.39^{d}	17.20^{c}	91.59^{a}	51.64^{a}	112.49^{a}	15.28^{b}	82.70^{a}
T7	0.23^{c}	17.95^{f}	2.60^{c}	106.15^{g}	3.55^{b}	140.68^{e}	3.68^{d}	50.77^{c}	4.36^{d}	26.72^{f}	5.93^{e}	12.22^{e}	13.54^{d}	13.59^{e}	13.20^{cd}	12.67^{e}	13.07^{c}	11.35^{f}

T1: cattle manure amended soil, T2: spent poultry layer litter amended soil, T3: Gliricidia amended soil, T4: leaf litter compost amended soil, T5: urea amended soil, T6: Siam weed amended soil T7: soil without any treatment.

Mean values designated by the same letter are not significantly different at p<0.05 as determined by DMRT .

C:N ratio, thus showing less NO_3^-- N content at the beginning of the incubation. However, a significant portion of the easily decomposable carbon might have already been broken down during composting. Then, nitrogen in leaf litter compost may become more available over time as the organic matter stabilizes and decomposes, resulting in higher nitrogen mineralization rates at the end of the incubation period (42 days). When compared to the control on day 1, all treatments showed significantly higher (p=0.05) NO3- -N values except the T4 treatment. On day 3, T4, T5, and T6 treatments showed significantly higher NO_3^--N than the control treatment. However, on day 5, only the T4 treatment showed a significantly higher NO3- -N value than the control. On days 7, 14, and 21, all treatments showed significantly higher (p=0.05) values than the control. However, on day 28 of incubation, T1 and T2 showed significantly less NO_3^--N than the control, while other treatments showed significantly higher values. The rapid release of NH_4^+-N was found in urea up to day 5 (Table 4) due to hydrolysis, and it was reported in other research studies (Khalil *et al.* 2005; MacLean and MacRae 1987). Liyanage *et al.* (2014) stated that urea hydrolysis has increased pH within four days when hydrolysis is completed in urea-amended soils.

According to the results, the total mineralized N values varied as compost > poultry litter > Gliricidia > Siam weed > urea > cattle manure > control (Figures 3 & 4). Thus, it was clear that compost-amended soil had the highest plant-available N value (1530.31 mg Kg^{-1}) compared to other treatments, while the control soil had the lowest cumulative N (452.41 mg Kg^{-1}). However, the cumulative N mineralization in poultry litter-amended soil was slightly lower than in compost-amended soil. The research from a 90-day aerobic incubation study found that prolonged application of poultry litter can increase soil N mineralization in sandy loam soil (Watts *et al.* 2010). The research conducted by Wyngaard *et al.* (2018) described that cumulative N mineralization is higher in poultry litter-amended soil than inorganic N fertilizer-amended soil. According to Bittenbender *et al.* (1998), poultry litter, a mixture of poultry manure, bedding material, feathers, and feed remnants, provides plants with 30-50% readily available nitrogen (N). The Siam weed amended soil (T6) showed higher cumulative N during the incubation than T2, T5, and T7. Siam weed has many soil nutrients, including high N content (Vineela *et al.* 2008). According to Murthy (2013), Siam weed residues contribute 3.79% nitrogen to the soil.

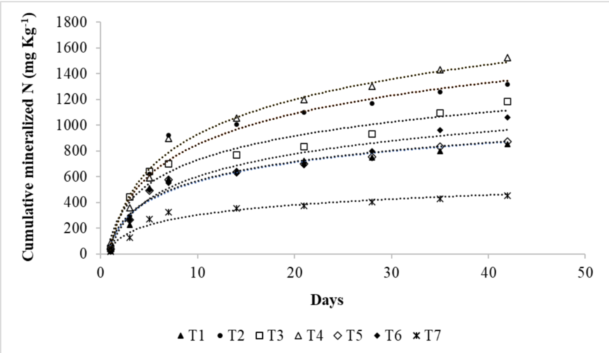

Figure 3: Cumulative amount of N mineralized by different soil amendments during incubation.
T1: cattle manure amended soil, T2: spent poultry layer litter amended soil, T3: Gliricidia amended soil, T4: leaf litter compost amended soil, T5: Urea amended soil, T6: Siam weed amended soil T7: soil without any treatment

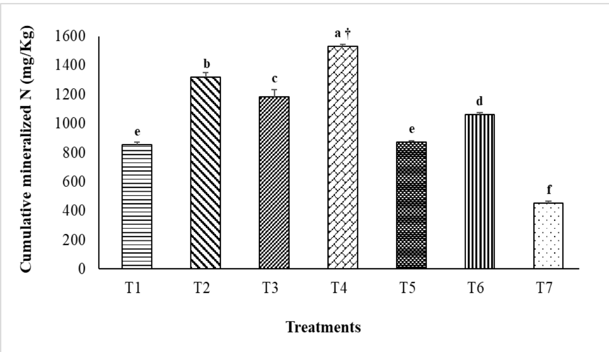

Figure 4: Cumulative mineralized N in soils amended with different amendments.
T1: cattle manure amended soil, T2: spent poultry layer litter amended soil, T3: Gliricidia amended soil, T4: leaf litter compost amended soil, T5: Urea amended soil, T6: Siam weed amended soil T7: soil without any treatment. Error bars indicate ± standard deviations. †Means with the same letters are not significantly different at p > 0.05 by Duncan's Multiple Range Test.

Net Nitrogen Mineralization

Net N mineralization is a balance between the rates of mineralization (release of inorganic nitrogen as NH_4^+-N and NO_3^--N) and immobilization (uptake of inorganic nitrogen by microorganisms), indicating the net amount of inorganic nitrogen available in the soil for plant use at the relevant incubation day 't'. It varied significantly ($p<0.05$) among the different treatments during incubation. The mineralization of soil amendments depends upon different soil factors such as pH, temperature, oxygen replacement, type of amendment, level of other nutrients, microbial quantity and diversity and water availability. Stanford and Smith (1972) stated that soil pH had little influence on mineralization. However, according to their study, in very acidic soils, the pH increased significantly due to a gradual increase of mineralization after the initial incubation period. The present study with acidic pH (Ultisols) obtained similar results. On the other hand, Khalil et al. (2005) observed that nitrification increased as the pH level increased over the incubation period. Further, the net mineralized N strongly depends upon the N level of the amendments. Total soil N and organic C quantities are basic indicators of soil N mineralization (Bengtsson *et al.* 2003; Selles *et al.* 1999). It was indicated that amendments which have a low C/N ratio improve the mineralization of N (Khalil *et al.* 2005). The net N mineralization of compost is low (Hadas and Portnoy 1994; Benitez *et al.* 1998). The mineralization rate is influenced by various compost characteristics, including the type of raw material, composting method, maturity, and carbon-to-nitrogen (C/N) ratio of the compost. Factors such as the compost application rate, soil characteristics, and climatic conditions also play significant roles (Hadas *et al.* 1996; Whalen *et al.* 2001). However, in the present incubation study, the net N mineralization of soil amendments during the 42-day incubation period varied significantly among treatments, irrespective of the C/N ratio. The reason may be ammonia volatilization or immobilization during varied microbial activities.

Further, a higher quantity of N remains in organic form in compost-treated soils, and this organic N mineralizes to a plant-available form (Moharana *et al*. 2015). Adding chemical nitrogen (N) to organic N can enhance the mineralization process due to increased microbial activity, leading to higher levels of mineral N. This approach aligns with the principles of an integrated nutrient management system. Thus, mixing chemical fertilizers may also affect the net N mineralization of organic amendments as it lessens the C/N ratio of the soil, which improves the mineralization of soil organic matter.

CONCLUSIONS

The present incubation study indicates the differences in C and N mineralization depending on the heterogeneity of amendments. The soil was amended with different amendments in the incubation study, and continuous C mineralization decline was observed until day 14 and became constant throughout the incubation period. The highest evolved CO_2-C flux was observed in amended soils of cattle manure. In the case of cumulative N mineralization, soil amended with leaf litter compost reported the highest release of nitrogen. Nitrogen release from all treatments was higher up to 21 days compared to the control soil. Urea-amended soil showed less microbial activity than the other amendments, evolving a lesser amount of CO_2 -C during incubation. Further, efforts should be made to link the findings of the incubation study to field-level implementation.

AUTHOR CONTRIBUTION

SRA and SDW designed and supervised the study. PKPSD and SRA performed the experiments and analyzed the data. SRA drafted the manuscript and critically revised it.

REFERENCES

Abbasi, M.K., Tahir, M.M., Sabir, N. and Khurshid, M., 2015. Impact of the addition of different plant residues on nitrogen mineralization–immobilization turnover and carbon content of a soil incubated under laboratory conditions. *Solid Earth*, 6

(1), pp. 197-205.
Amarasinghe, S.R. and Gunawardhana, L.A.A.S.M., 2020. Effect of vermicompost with biodynamic formulated biochar on Carbon and Nitrogen mineralization in Ultisols and Alfisols. *13th International Research Conference General Sir John Kotelawala Defence University*, pp. 40-45.
Atoloye, I., Erhunmwunse, A., Ekundayo, R. and Olayinka, A., 2024. Compost and Mineral Fertilizer Application Affects Soil Microbial Activity and Nutrient Mineralization in an Ultisol. *Communications in Soil Science and Plant Analysis*, pp. 1-10.
Bai, J., Yu, L., Ye, X., Yu, Z., Guan, Y., Li, X., Cui, B. and Liu, X., 2020. Organic phosphorus mineralization characteristics in sediments from the coastal salt marshes of a Chinese delta under simulated tidal cycles. *Journal of Soils and Sediments*, 20, pp. 513-523.
Bai, Z., Caspari, T., Eastman, A.H. and De Jonge, L.W., 2020. Soil nutrient management in sustainable agriculture. *Sustainability*, 12(9), p. 3755.
Bankole, G.O. and Azeez, J.O., 2024. Nitrogen, phosphorus, and sulphur mineralization patterns of different animal manures applied on a sandy loam soil–an incubation study. *Arabian Journal of Geosciences*, 17 (3), pp. 1-12.
Bengtsson, G., Bengtson, P. and Månsson, K.F., 2003. Gross nitrogen mineralization, immobilization, and nitrification rates as a function of soil C/N ratio and microbial activity. *Soil Biology and Biochemistry*, 35, pp. 143 -154.
Benitez, C., Bellido, E., Gonzalez, J.L. and Medina, M., 1998. Influence of pedological and climatic factors on nitrogen mineralization in soils treated with pig slurry compost, *Bio resource Technology*, 63, pp. 147-151.
Bittenbender, H.C., Hue, N.V., Fleming, K. and Brown, H., 1998. Sustainability of organic fertilization of macadamia with macadamia husk-manure compost. *Communications in Soil Science and Plant Analysis*, 29, pp. 409-419.
Chatterjee, N. and Lal, R., 2022. Nitrogen mineralization and its controlling factors in soil: A review. *Soil Biology and Biochemistry*, 169, p.108588.
Dossa, E.L., Fernandes, E.C.M., Reid, W.S. and Ezui, K., 2015. Above- and belowground biomass, nutrient and carbon stocks contrasting an open-grown and a shaded coffee plantation. *Agroforestry Systems*, 89(5), pp.857-870.
Fox, R.H., Myers, R.J.K. and Vallis, I., 1990. The nitrogen mineralization rate of legume residues in soil as influenced by their polyphenol, lignin, and nitrogen contents. *Plant and Soil*, 129, pp.251-259.
Gunarathne, V., Senadeera, A., Gunarathne, U., Biswas, J.K., Almaroai, Y.A. and Vithanage, M., 2020. Potential of biochar and organic amendments for reclamation of coastal acidic-salt affected soil. *Biochar*, 2, pp.107-120.
Hadas, A. and Portnoy, R., 1994. Nitrogen and carbon mineralization rates of composted manures incubated in soil. *Journal of Environmental Quality*, 23, pp.1184-1189.
Haer, H.S. and Benbi, D.K., 2003. Modelling nitrogen mineralization kinetics in arable soils of semi-arid India. *Arid Land Research and Management*, 17, pp.153-168.
Haer, H.S. and Benbi, D.K., 2003. Modeling nitrogen mineralization kinetics in arable soils of semiarid India. *Arid Land Research and Management*, 17 (2), pp.153-168.
Hao, X. and Benke, M.B., 2008. Nitrogen transformation and losses during composting and mitigation strategies. *Dynamic Soil Dynamic Plant*, pp.10-18.
Hartz, T.K., Mitchell, J.P. and Giannini, C., 2000. Nitrogen and carbon mineralization dynamics of manures and composts. *HortScience*, 35(2),

pp.209-212.

He, Y., Xu, X., Kueffer, C., Zhang, X. and Shi, P., 2014. Leaf litter of a dominant cushion plant shifts nitrogen mineralization to immobilization at high but not low temperature in an alpine meadow. *Plant and Soil*, 383, pp.415-426.

Hue, N., 1992. Correcting soil acidity of a highly weathered Ultisol with chicken manure and sewage sludge. *Communications in Soil Science and Plant Analysis*, 23, pp.241-264.

IBM Corp., 2017. *IBM SPSS Statistics for Windows, Version 25.0*. Armonk, NY: IBM Corp.

Impraim, R., Weatherley, A., Deli Chen and Suter, H., 2022. Effect of lignite amendment on carbon and nitrogen mineralization from raw and composted manure during incubation with soil. *Pedosphere*, 32(5), pp.785-795.

Jayarathna, M.K.N.W., Dharmakeerthi, R.S. and Igalavithana, A.D., 2024. Effects of Biochar Based N Fertilizer Application on Ammonia Volatilization from a Rice Growing Soil: A Laboratory Scale Closed Chamber Study. *Tropical Agricultural Research*, 35(1), pp.34-45.

Ju, X.T., Liu, X.J., Zhang, F.S. and Christie, P., 2006. Effect of long-term fertilization on organic nitrogen forms in a calcareous alluvial soil on the North China Plain. *Pedosphere*, 16, pp.224-229.

Kalita, L., Singh, N.J., Ray, L.I. and Singh, A.K., 2023. Incubation study of kinetics and mineralization rate of nitrogen in organic sources of Ultisol. *Current Science*, 125(7), pp.765.

Kausadikar, P.H., Patel, J., Kuchanwar, O.D., Rananavare, S. and Mairan, N., 2020. Dynamics of plant residue decomposition and availability of nutrients. *International Journal of Current Science*, 8(6), pp.07-11.

Khalil, M.I., Hossain, M.B. and Schmidhalter, U., 2005. Carbon and nitrogen mineralization in different upland soils of the subtropics treated with organic materials. *Soil Biology and Biochemistry*, 37(8), pp.1507-1518.

Kumar, K., Bhargava, R., Bhattacharyya, R., Das, T.K. and Prasad, S., 2016. Carbon and nitrogen mineralization kinetics of organic amendments applied to the rice-wheat cropping system. *Agricultural Research*, 5(2), pp.132-138.

Ladd, J.N., Jocteur Monrozier, L. and Amato, M., 1996. Carbon turnover and nitrogen transformations in an alfisol and vertisol amended with 14C (U)-glucose and 15N ammonium sulfate. *Soil Biology and Biochemistry*, 28(3), pp.323-333.

Ladd, J.N., van Gestel, M., Monrozier, L.J. and Amato, M., 1996. Distribution of organic 14C and 15N in particle size fractions of soils incubated with 14C, 15N labelled glucose/NH4, and legume and wheat straw residues. *Soil Biology & Biochemistry*, 28, pp.893-905.

MacLean, A.A. and MacRae, K.B., 1987. Rate of hydrolysis and nitrification of urea and implications of its use in potato production. *Canadian Journal of Soil Science*, 67, pp.679-686.

Mapa, R.B., Somssiri, S. and Nagarajah, S., 1999. Soils of the wet zone of Sri Lanka. *Soil Science Society of Sri Lanka*, pp.23-92.

Mary, B., Recous, S., Darwls, D. and Robin, D., 1996. Interactions between decomposition of plant residues and nitrogen cycling in soils. *Plant and Soil*, 181, pp.71-82.

McGill, W.B. and Figueiredo, C.T., 1993. Total Nitrogen. In: M.R. Carter (ed.), *Soil Sampling and Methods of Analysis*. Cana. Soc. Soil Sci. Lewis Publishers, Boca Raton, FL, USA, pp.201-211.

Melillo, J.M., Naiman, R.J., Aber, J.D. and Linkins, A.E., 1984. Factors controlling mass loss and nitrogen dynamics of plant litter decaying in northern streams. *Bulletin of Marine Science*, 35(3), pp.341-356.

Moharana, P.C., Biswas, D.R. and Datta, S.C., 2015. Mineralization of nitrogen, phosphorus and sulphur in soil as influenced by rock phosphate enriched compost and chemical fertilizers. *Journal of the Indian Society of Soil Science*, 63(3), pp.283-293.

Moharana, P.C., Biswas, D.R. and Dattawaters, S.C., 2015. Mineralization of Nitrogen, Phosphorus and Sulphur in Soil as Influenced by Rock Phosphate Enriched Compost and Chemical Fertilizers. *Journal of the Indian Society of Soil Science*, 63(3), pp.283-293.

Murthy, R.K., 2013. Evaluation of composted Chromolaena and Parthenium as a plant nutrient source on paddy. *Asian Journal of Soil Science*, 8, pp.255-259.

Naikwade, P.V., 2011. Evaluation of leaf litter compost and vermicompost on yield and nutrient uptake of Trigonella. *Indian Journal of Applied Research*, 4(2), pp.3-5.

Nicholson, F.A., Chambers, B.J., Mills, A.R. and Strachan, P.J., 1997. Effects of repeated straw incorporation on crop fertilizer nitrogen requirements, soil mineral nitrogen and nitrate leaching losses. *Soil Use and Management*, 13 (3), pp.136-142.

O'Connor, J., 2023. Interaction of Urea Ammonium Nitrate with Food Waste Organic Amendments on Gaseous Emissions, Nitrogen Dynamics and Soil Properties. *Nitrogen Dynamics and Soil Properties*.

Piotrowska-Długosz, A., 2020. Significance of the enzymes associated with soil C and N transformation. In: Carbon and nitrogen cycling in soil, pp.399-437.

Pitta, C.S.R., Adami, P.F., Pelissari, A., Assmann, T.S., Franchin, M.F., Cassol, L.C. and Sartor, L.R., 2012. Year-round poultry litter decomposition and N, P, K and Ca release. *Revista Brasileira de Ciência do Solo*, 36, pp.1043-1053.

Schlesinger, W.H. and Bernhardt, E.S., 2020. *Biogeochemistry: An Analysis of Global Change* (4th ed.). Academic Press.

Selles, F., Campbell, C.A., McConkey, B.G., Brandt, S.A. and Messer, D., 1999. Relationships between biological and chemical measures of N supplying power and total soil N at field scale. *Canadian Journal of Soil Science*, 79, pp.353-366.

Sikora, L.J., Szmidt, R.A.K., Stofella, P.J. and Kahn, B.A., 2001. Nitrogen sources, mineralization rates and nitrogen nutrition benefits to plants of compost. In: *Compost utilization in horticultural cropping systems*, pp.287-305. Lewis Publishers.

Srivastava, P., Singh, R., Bhadouria, R., Tripathi, S., Singh, P., Singh, H. and Raghubanshi, A.S., 2016. Organic amendment impact on SOC dynamics in dry tropics: a possible role of relative availability of inorganic-N pools. *Agriculture, Ecosystems & Environment*, 235, pp.38-50.

Stanford, G. and Smith, S.J., 1972. Nitrogen mineralization potentials of soils. *Soil Science Society of America Journal*, 36, pp.465-472.

Stark, C., Condron, L.M., Stewart, A., Di, H.J. and O'Callaghan, M., 2007. Influence of organic and mineral amendments on microbial soil properties and processes. *Applied Soil Ecology*, 35(1), pp.79-93.

Tambone, F. and Adani, F., 2017. Nitrogen mineralization from digestate in comparison to sewage sludge, compost and urea in a laboratory incubated soil experiment. *Journal of Plant Nutrition and Soil Science*, 180(3), pp.355-365.

Tian, H., Chen, G., Zhang, C., Melillo, J.M. and Hall, C.A.S., 2010. Pattern and process of nitrogen dynamics in terrestrial ecosystems: modeling, empirical studies, and synthesis. *Ecological Applications*, 20(6), pp.1665-1688.

Tian, H., Lu, C., Chen, G., Tao, B., Pan, S., Del Grosso, S.J. and Xu, X., 2010. Spatial and temporal patterns of CH4 and N2O fluxes in terrestrial ecosystems of North America during 1979–2008: Application of a global biogeochemistry model.

Biogeosciences, 7(9), pp.2673-2694.

Uddin, S., Islam, M.R., Jahangir, M.M.R., Rahman, M.M., Hassan, S., Hassan, M.M., Abo-Shosha, A.A., Ahmed, A.F. and Rahman, M.M., 2021. Nitrogen release in soils amended with different organic and inorganic fertilizers under contrasting moisture regimes: A laboratory incubation study. *Agronomy*, 11(11), p.2163.

Van Kessel, J.S., Reeves, J.B. and Meisinger, J.J., 2000. Nitrogen and Carbon Mineralization of Potential Manure Components. *Journal of Environmental Quality*, 29, pp.1669-1677.

Vineela, C., Wani, S.P., Sriivasarao, C., Padmaja, B. and Vittal, K.P.R., 2008. Microbial properties of soil as affected by cropping and nutrient management practices in several long term manurial experiments in the semi-arid tropics of India. *Applied Soil Ecology*, 40(1), pp.165-173.

Wang, J., Song, C., Guo, Y., Wang, L. and Sun, Y., 2018. Soil organic carbon mineralization as affected by soil properties and land use in an agricultural region of Northeast China. *Agriculture, Ecosystems & Environment*, 251, pp.1-14.

Wang, J., Zhang, L., Wei, J., Li, H., Yang, X. and Zhao, Y., 2023. Organic amendment enhances soil nitrogen mineralization and ammonia oxidizers abundance in an agricultural soil. *Applied Soil Ecology*, 184, p.104736.

Wang, Y., Hu, N., Ge, T., Kuzyakov, Y., Wang, Z., Li, Z., and Wu, C., 2018. Soil aggregation regulates distributions of carbon, microbial community and enzyme activities after 23-year manure amendment. *Applied Soil Ecology*, 124, pp.58-68.

Watts, D.B., Torbert, H.A., Prior, S.A. and Huluka, G., 2010. Long-term tillage and poultry litter impacts soil carbon and nitrogen mineralization and fertility. *Soil Science Society of America Journal*, 74, pp.1239-1247.

Whalen, J.K., Chang, C., Clayton, G.W. and Carefoot, J.P., 2000. Cattle manure amendments can increase the pH of acid soils. *Soil Science Society of America Journal*, 64, pp.962-966.

Wyngaard, N., Cabrera, M.L. and Shober, A., 2018. Fertilization strategy can affect the estimation of soil nitrogen mineralization potential with chemical method. *Plant and Soil*, DOI: 10.1007/s11104-018-3786-3.

Wyngaard, N., Cabrera, M.L., Shober, A. and Kanwar, R., 2018. Fertilization strategy can affect the estimation of soil nitrogen mineralization potential with chemical methods. *Plant and Soil*, 432, pp.75-89.

Xie, Y., Zhou, L., Dai, J., Chen, J., Yang, X., Wang, X., Wang, Z. and Feng, L., 2022. Effects of the C/N ratio on the microbial community and lignocellulose degradation, during branch waste composting. *Bioprocess and Biosystems Engineering*, 45(7), pp.1163-1174.

Yang, Y., Liu, H., Dai, Y., Tian, H., Zhou, W. and Lv, J., 2021. Soil organic carbon transformation and dynamics of microorganisms under different organic amendments. *Science of the Total Environment*, 750, p.141719.