Impact of Organic Amendments on Soil Organic Carbon Mineralization utilizing Kinetic Models

Abstract

This study investigates the dynamics of carbon (C) mineralization and carbon dioxide (CO_2) emissions in tropical soil treated with different organic amendments over a 120-day incubation period. The findings reveal a notable spike in CO_2 emissions during the initial three days, primarily due to the quick breakdown of easily degradable organic materials. Following this peak, emissions decreased significantly until day 24, stabilizing afterward. Among the organic amendments, cow dung manure produced the highest CO_2 emissions (129.13 mg C kg^{-1}), and maize straw yielded the lowest (98.74 mg C kg^{-1}). A combination of cow dung and rice straw resulted in substantial CO_2 production (122.66 mg C kg^{-1}). When cumulative C mineralization was modeled using first-order and second-order kinetic equations, cow dung manure showed the highest mineralization rates and maize straw the lowest due to its high lignin content. The first-order model effectively characterized long-term C mineralization dynamics, showing the strong R^2 values between 0.9198 and 0.9864. This study highlights a crucial paradox in soil management: while organic amendments like cow dung enhance short-term nutrient availability. Conversely, amendments like maize straw, despite their lower mineralization rates, foster the formation of stable C pools essential for sustainable soil health, emphasizing the importance of choosing organic amendments based on their long-term objectives for C management and climate change mitigation.

***Keywords**: Carbon mineralization; CO_2 emission; organic amendments; soil health*

1. INTRODUCTION

Soil organic carbon (SOC) is essential for terrestrial biological systems, significantly affecting soil health, fertility, and the global C cycle. SOC primarily forms from the decomposition of plant and animal residues, which enhances soil structure and nutrient availability, fostering conditions conducive to plant growth and microbial activity (Lehmann &Kleber, 2015). It serves as a key indicator of soil sustainability, with its concentration affecting various soil properties (Kuzyakov&Bol, 2006). Understanding SOC dynamics involves the process of mineralization, where microbes convert organic C into inorganic CO_2, impacting atmospheric CO_2 levels and influencing soil productivity and climate change mitigation (Schmidt et al., 2011).

Recent research emphasizes the importance of C storage and flux in soils, particularly regarding ecosystem productivity (Bernal et al., 1998, Martín et al., 2012, Ali & Nabi., 2016, Kaur, Kommalapati, &Saroa., 2023). Declines in soil fertility are often associated with reduced organic matter (OM) content (Hartemink, 2006). Consequently, organic amendments such as compost and manure have become vital for enhancing SOC levels and soil health. These amendments increase OM, stimulate microbial activity, and affect SOC mineralization rates, which are crucial for sustainable agricultural practices and improving soil resilience (Yang et al., 2021). The mineralization of crop residues is particularly important for regulating CO_2 emissions while providing essential nutrients for crops (Raiesi, 2006). Additionally, organic amendments can enhance soil structure and stability, promoting long-term C sequestration (Bationo et al., 2007).

The interaction between organic amendments and soil properties leads to varying mineralization kinetics, which can be modeled using different kinetic frameworks (Bayer et al., 2006). These models help quantify C release rates and elucidate the mechanisms of SOC mineralization (Robin et al., 2023). Among the various models, first-order and second-order kinetic models are foundational in this research area (Manzoni &Porporato, 2009). This study aims to explore the effects of different organic amendments on SOC mineralization rates using these kinetic models, and to evaluate the comparative efficacy of first-order and second-order kinetic models in forecasting SOC mineralization within the designated study area. This research not only seeks to contribute to the existing body of knowledge regarding SOC dynamics but also aspires to inform sustainable agricultural practices that align with climate resilience objectives.

2. MATERIAL AND METHODS

2.1 Experimental Site

From April to July 2024, a laboratory incubation experiment was carried out at Experiment and Lecture Building 1 (19° 50′ N, 96° 16′ E), Department of Soil and Water Science, Yezin Agricultural University.

2.2 Experimental Design and Treatments

2.2.1 Experimental Design

In the present study, four commonly utilized organic amendments were evaluated: cow dung manure, chicken manure, rice straw, and maize straw. These amendments were selected due to their prevalent availability in the study region and their recognized potential to positively influence soil health and fertility. The experimental design employed a Completely Randomized Design (CRD) with four replications for the incubation jars. Each incubation jar was comprised of 198 grams of soil and 2 grams of organic amendment, representing 1% of the total soil weight.

2.2.2 Experimental Treatments

The treatment details are as follows:

T_1	-	control
T_2	-	cow dung manure
T_3	-	chicken manure
T_4	-	rice straw
T_5	-	maize straw
T_6	-	½ cow dung manure + ½ rice straw
T_7	-	½ cow dung manure + ½ maize straw
T_8	-	½ chicken manure + ½ rice straw
T_9	-	½ chicken manure + ½ maize straw

Table 1. Characteristics of organic amendments used in this experiment

Parameters	Organic Amendments			
	Cow dung manure	Chicken manure	Rice straw	Maize straw
Total N (%)	3.37	5.09	0.73	1.19
Organic Carbon (%)	42.37	34.06	47.88	53.05
C:N ratio	12.57	6.69	65.59	44.58
pH	6.40	6.30	4.70	5.80
Lignin (%)	8.00	8.40	16.90	19.50
Total P_2O_5 (%)	1.60	2.29	0.69	1.45
Total K_2O (%)	0.69	1.93	0.80	1.20

Table 2. Physicochemical properties of experimental soil

Characteristics	Values	Rating
% sand	82.9	
% silt	8.52	
% clay	8.58	
Texture class	Loamy sand	
Bulk density (g cm^{-3})	1.3	Low
Water holding capacity (%)	46	
pH	5.75	Moderately acid
CEC (cmol$_c$ kg^{-1})	13.26	Medium
EC (dS m^{-1})	0.03	Non-saline
Organic carbon (%)	1.35	Medium
Available N (mg kg^{-1})	25.23	Very low
Available P (mg kg^{-1})	22.58	High
Available K (mg kg^{-1})	78.43	Low

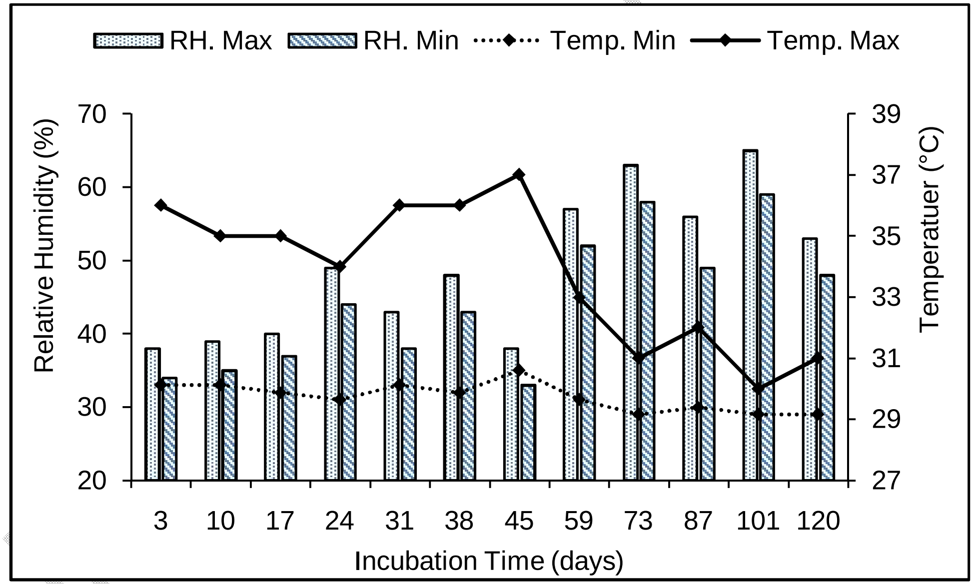

Figure 1. Room temperature and relative humidity during the period of incubation.

2.3 Incubation Experiment

Soil samples were collected from a research farm at Yezin Agricultural University, Nay Pyi Taw Territory, Myanmar. Then, these were dried in a shaded area, homogenized, and sieved to 2 mm. A total of 198 grams of prepared soil was placed into incubation jars (6.5 cm diameter, 17 cm height), and two grams of oven-dried organic amendments were ground to pass through a 2 mm sieve. The soil was mixed with the organic amendments, excluding the control treatment, and moisture levels were maintained at 60% of the water-holding capacity to optimize microbial activity. Each jar contained a centrifuge tube with 10 ml of 1 M sodium hydroxide (NaOH), sealed with a lid, and weighed for reference. The jars were incubated in darkness at room temperature for 120 days, with continuous monitoring of temperature and relative humidity. Soil moisture was regulated by weighing the jars and adding deionized water as needed. After incubation, the NaOH solution was extracted and transferred to 100 ml conical flasks, where 2 ml of barium chloride ($BaCl_2$) and phenolphthalein indicator were added, resulting in a violet coloration. This solution was titrated with 0.5 M hydrochloric acid (HCl) until a colorless endpoint was reached. To ensure oxygen replenishment, the jars were left open for three hours during and after titration, after which a fresh NaOH tube was reintroduced, and the jars resealed. Evolved CO_2 was quantified on days 3, 10, 17, 24, 31, 38, 45, 59, 73, 87, 101, and 120, respectively (Hopkins, 2008).

2.4 Carbon Mineralization Kinetics

In the first-order kinetic model, the cumulative release of CO_2 and the kinetics of C mineralization were evaluated through the analysis of CO_2-C emissions measured at various intervals across all treatments (Tian, Kang&Brussaard., 1992; Ajwa & Tabatabai, 1994; Saviozzi et al., 1997). These evaluations were conducted according to the equation outlined below.

$$\mathbf{C_{min} = C_0 (1 - e^{-kt})}$$ (De Neve, Pannier & Hofman, 1996)

and the half-life of C in soil can be calculated by

$$\textbf{Half-life} = \frac{\ln(2)}{k}$$ (Qayyum et al., 2012)

where C_{min} is the amount of cumulative mineralized organic C at time t, C_0 is the potential available Cat time zero, k is the apparent rate constant, and t is the time (days of incubation).

In a general integrated form, the second-order kinetic model is written as

$$\mathbf{C_{min} = C_1 (1 - e^{-k1t}) + C_2 (1 - e^{-k2t})}$$ (Guo et al., 2014)

where C_{min} is cumulative mineralized organic C, k_1 is a smaller and easily mineralizable C pool of higher turnover rate, k_2 is a large stable pool with a slow turnover rate, C_1 is active C pool, C_2 is resistant C pool and t is the time (days of incubation). The slow turnover rate value (k_2) was used in calculating the half-life of the most stable C fraction.

Half-life $= \frac{\ln(2)}{k2}$(Qayyum et al., 2012)

The evaluation of the two kinetic models was performed by analyzing the regression coefficients (R^2), which facilitated the identification of the most appropriate model for assessing the kinetics of carbon mineralization within the context of this research(Qayyum et al., 2012).

2.5 Statistical analysis

The collected data were analyzed using analysis of variance (ANOVA) within a Completely Randomized Design (CRD) framework, using Statistix 8 software (Analytical Software). To differentiate the means, the least significant differences were applied at a significance level of $p \leq 0.05$ (Gomez,1984).

3. RESULTS

3.1 CO_2 evolution rate

During the 120-day incubation period, CO_2 evolution rates initially surged within the first three days, followed by a significant decline that persisted until approximately day 24(Figure 2 and Figure 3). This phase of reduced emissions continued with a steady, even though the lower rate of CO_2 production until day 45. Subsequently, CO_2 evolution stabilized, with emission rates leveling off and remaining relatively constant for the remainder of the observation period.

Among the solely organic amendments assessed, T_3 exhibited the highest rates of CO_2 production during the initial observation period, specifically from days 3 to 10 (Figure 2).Following 17 days of incubation, T_2 produced significantly higher amounts of CO_2 compared to the other treatments, with T_4closely behind. In contrast, T_5 consistently demonstrated the lowest levels of CO_2 production from day 17 to day 120.

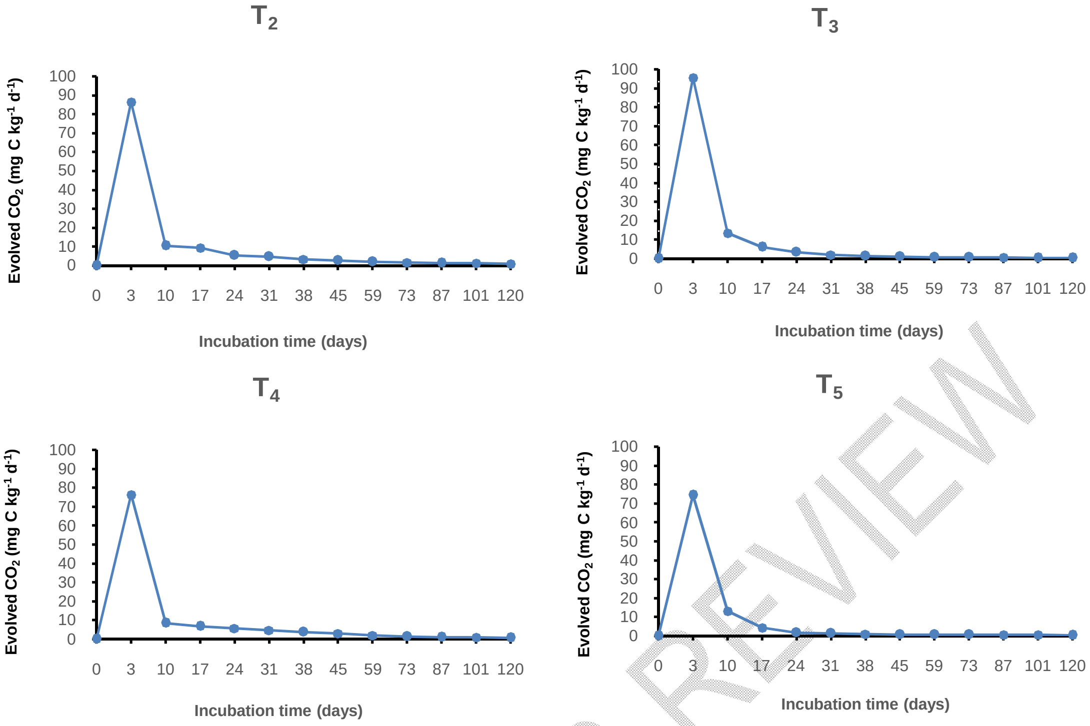

Figure 2. CO_2 evolution rate in soil amended with solely organic amendments throughout the period of incubation. T_2 = Cow dung manure, T_3 = Chicken manure, T_4 = Rice straw, T_5 = Maize straw

In the combined organic amendment treatments, T_6 exhibited the highest rates of CO_2 emissions from days 3 to 10 (Figure 3). On days 24 and 31, T_7 generated the greatest amount of CO_2. From days 38 to 120, treatment that contained T_8 consistently produced the highest levels of CO_2. Conversely, among the combined treatments, T_9 produced the lowest CO_2 emissions throughout the incubation period.

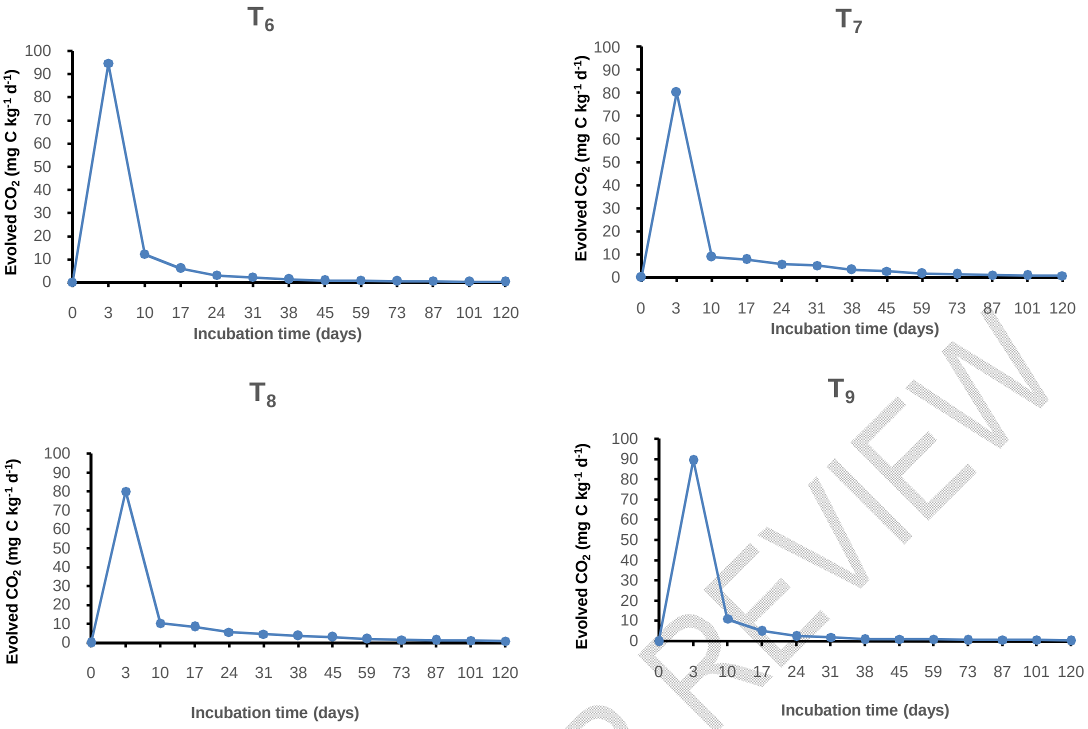

Figure 3. CO_2 evolution rate in soil amended with combined organic amendments throughout the period of incubation. T_6 = ½ Cow dung manure + ½ Rice straw, T_7 = ½ Cow dung manure + ½ Maize straw, T_8 = ½ Chicken manure + ½ Rice straw, T_9 = ½ Chicken manure + ½ Maize straw

The total CO_2 evolution observed over the 120-day incubation period exhibited significant variation among the solely organic amendments and the combined treatments (Figure 4). Notably, T_2 resulted in the highest CO_2 evolution.T_3 also demonstrated considerable CO_2 evolution, albeit at a lower rate than T_2. Treatments that combined rice straw with either type of manure (T_6 and T_8) exhibited CO_2 evolution rates that were statistically indistinguishable from those of T_3. In contrast, T_5 displayed the lowest rate of CO_2 evolution among the amendments tested. Furthermore, the control treatment (T_1), which lacked any organic amendment, significantly underperformed in terms of CO_2 evolution.

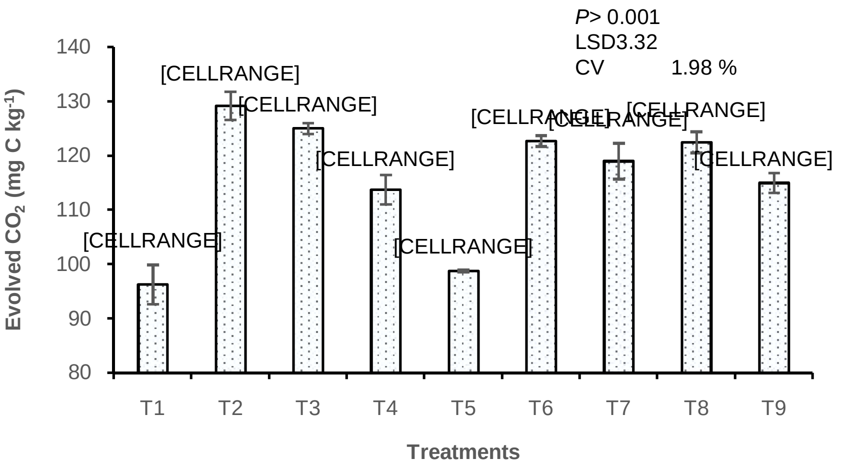

Figure 4. Total CO_2 evolution over 120 days of incubation period. T_1 = Control, T_2 = Cow dung manure, T_3 = Chicken manure, T_4 = Rice straw, T_5 = Maize straw, T_6 = ½ Cow dung manure + ½ Rice straw, T_7 = ½ Cow dung manure + ½ Maize straw, T_8 = ½ Chicken manure + ½ Rice straw, T_9 = ½ Chicken manure + ½ Maize straw. Columns with different letters indicate significant differences between treatments at P = 0.05. The values are presented as means ± SE from four replicates.

3.2 Cumulative C mineralization

During the incubation period, cumulative C mineralization was analyzed and modeled employing both first-order and second-order kinetic equations. Notably, among the treatments consisting solely of applied organic amendments, T_2 exhibited a markedly higher rate of C mineralization throughout the entire incubation duration compared to other organic amendments (Figure 5). On the other hand, T_3 demonstrated the second-highest cumulative C mineralization, suggesting its relatively effective contribution to soil fertility enhancement. In contrast, T_5 was observed as the lowest cumulative C mineralization over the complete 120-day incubation period.

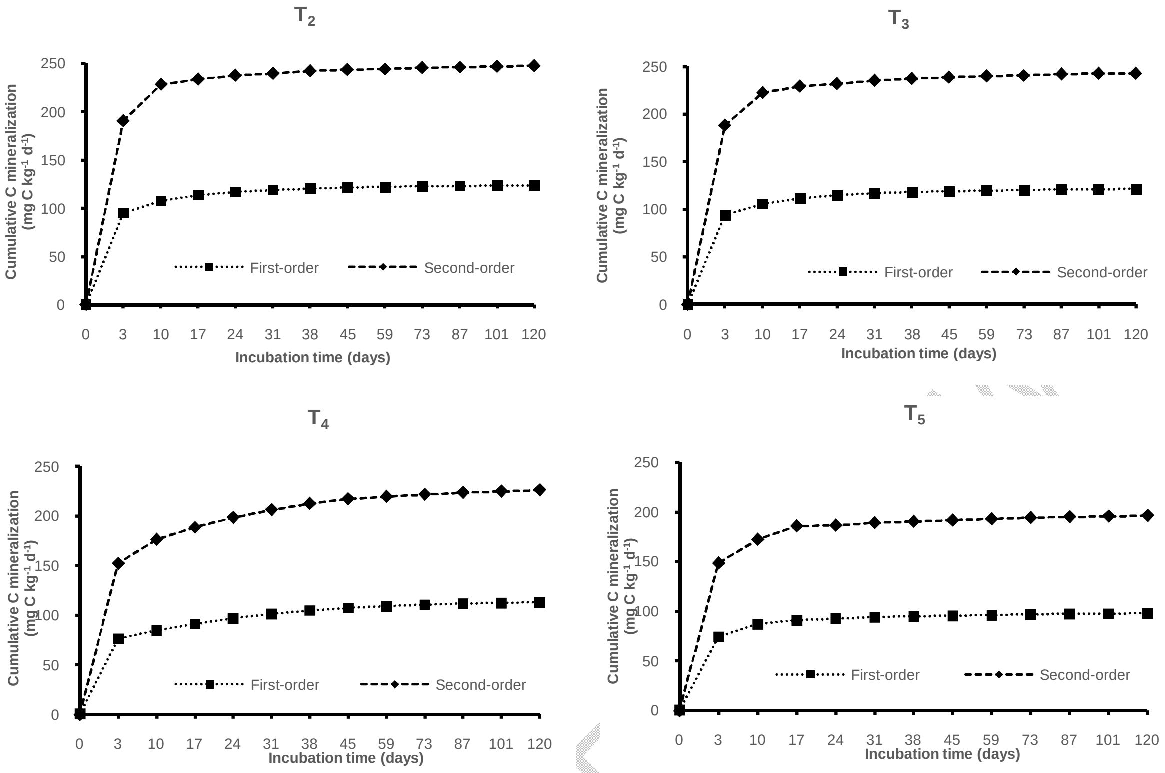

Figure 5. Cumulative total C mineralized (mg C kg^{-1} day^{-1}) in solely applied organic amendments fitted to first and second-order kinetic models. T$_2$ = Cow dung manure, T$_3$ = Chicken manure, T$_4$ = Rice straw, T$_5$ = Maize straw

In the context of the combined organic amendment treatments, T$_7$ demonstrated significantly elevated rates of cumulative C mineralization at the intervals of days 3, 10, and 17 in both first and second-order kinetic models as illustrated in Figure 6. Subsequently, from day 24 onwards, T$_6$ sustained high rates of cumulative C mineralization throughout the remainder of the incubation period. Among all the combined treatments evaluated, T$_8$ yielded the lowest cumulative C mineralization throughout the entire incubation period.

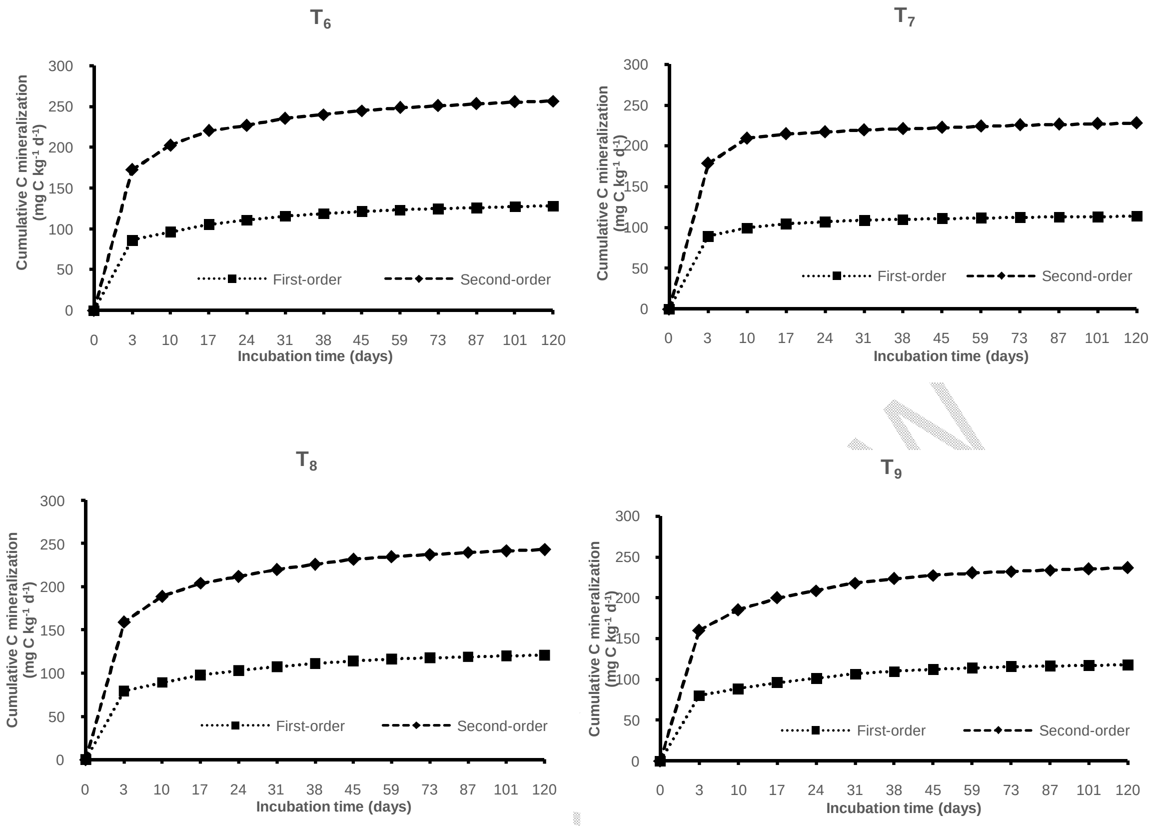

Figure 6. Cumulative total C mineralized (mg C kg^{-1} day^{-1}) in combined organic amendment treatments fitted to first and second-order kinetic models. T_6 = ½ Cow dung manure + ½ Rice straw, T_7 = ½ Cow dung manure + ½ Maize straw, T_8 = ½ Chicken manure + ½ Rice straw, T_9 = ½ Chicken manure + ½ Maize straw

In all treatments, T_2 showed the highest levels of cumulative C mineralization. This was followed closely by T_6, and T_3 (Figure 5 and 6). Throughout the entire incubation period, data demonstrated that T_5 contributed the lowest levels of cumulative C mineralization among all treatments analyzed.

3.3 Kinetics of Carbon Mineralization and ModelComparisons

The firstand second-order kinetic models were employed to elucidate the dynamics of C mineralization associated with various organic amendments. The degree of conformity between the experimental data and the validity of the models was quantified through the R² values (Table 3).

Table 3. First order and second order kinetic model fit for cumulative C mineralization under different organic amendments after 120 days of incubation.

Treatments	First-order model				Second-order model					
	C_0 (mg kg^{-1})	k (day^{-1})	half-life (year)	R^2	C_1 (mg kg^{-1})	C_2 (mg kg^{-1})	k_1 (day^{-1})	k_2 (day^{-1})	half-life (year)	R^2
T1	12.96	2.97E-04	6.39	0.9752	8.74E-02	13.22	2.96E-01	3.09E-04	6.13	0.9679
T2	17.14	3.39E-04	5.60	0.9342	1.18E-01	17.00	2.88E-01	3.50E-04	5.40	0.8975
T3	16.90	3.38E-04	5.61	0.9426	1.15E-01	16.83	2.88E-01	3.48E-04	5.42	0.9139
T4	17.46	2.73E-04	6.95	0.9804	1.01E-01	17.34	3.00E-01	2.82E-04	6.70	0.9793
T5	17.19	2.67E-04	7.10	0.9198	9.56E-02	17.17	3.01E-01	2.78E-04	6.80	0.8839
T6	18.13	2.99E-04	6.35	0.9860	1.15E-01	17.86	2.95E-01	3.10E-04	6.09	0.9636
T7	16.24	3.32E-04	5.72	0.9506	1.09E-01	16.24	2.89E-01	3.42E-04	5.53	0.9049
T8	17.66	2.86E-04	6.64	0.9864	1.09E-01	17.56	2.98E-01	2.97E-04	6.36	0.9671
T9	17.67	2.84E-04	6.70	0.9802	1.06E-01	17.57	2.98E-01	2.94E-04	6.43	0.9767

C_0 = potential available C at time zero, k = apparent rate constant, C_1 = active C pool, C_2 = resistant C pool, k_1 = smaller and easily mineralizable C pool of higher turnover rate, k_2 = large stable pool with a slow turnover rate

3.3.1 First-Order Kinetic Model

C_0:This parameter represents the initial amount of available C in each treatment, with values ranging from 12.96 to 18.13 $mgkg^{-1}$. Notably, T_6 exhibited the highest potential available C, indicating a greater initial availability of C under this treatment regime.

K:This constant reflects the rate at which C mineralizes. Higher k values, such as those observed in T_2 and T_3 (approximately 3.39E-04 day^{-1}), signify more rapid mineralization rates, whereas lower k values, represented by T_5 (2.67E-04 day^{-1}), denote slower mineralization processes.

Half-life:This metric delineates the duration required for half of the available C to mineralize. Treatments characterized by elevated k values tend to exhibit shorter half-lives, as observed in T_2 (5.60 years) and T_3 (5.61 years). Conversely, T_5, with a k value resulting in a half-life of 7.10 years, demonstrates an extended mineralization timeframe.

R^2: All treatments yielded high R^2 values, ranging from 0.9198 to 0.9864, indicating a robust fit of the first-order model to the experimental data.

3.3.2 Second-Order Kinetic Model

C_1:This parameter reflects a smaller, more readily mineralizable C pool. C_1 values range from 0.0874 $mgkg^{-1}$ (T_1) to 0.118 $mgkg^{-1}$ (T_2), with T_2 demonstrating the highest active C pool. This observation suggests that this treatment may facilitate accelerated mineralization due to an augmented availability of readily accessible C.

C_2: This component denotes a larger and more stable C pool that mineralizes at a slower rate. C_2 values exhibited slight variation across treatments, ranging from 13.22 to 17.57 $mgkg^{-1}$, with T_9 registering the highest resistant C pool, indicative of a substantial reservoir of stable C.

k_1: This parameter evaluates the rapid mineralization of the smaller C pool, where T_1 displays the highest k_1 value (2.96E-01 day^{-1}), indicative of a more expedient C release from this pool.

k_2: This parameter reflects the slower turnover of the larger, stable pool. The k_2 values were relatively homogenous across treatments, with T_2 presenting the highest k_2 value (3.50E-04 day^{-1}), thereby indicating a relatively accelerated turnover within its stable pool in comparison to the other treatments.

Half-life: The half-lives correspond with their respective k values, where higher k values are associated with shorter half-lives, thereby reflecting more rapid mineralization. Shorter half-lives were observed in T_2 (5.40 years) and T_3 (5.43 years), whereas the longest half-life was observed in T_5 (6.80 years).

R^2 : The second-order model also demonstrated high R^2 values, ranging from 0.8839 to 0.9793, signifying a strong fit to the data, albeit the values were marginally lower than those afforded by the first-order model.

Both the first- and second-order kinetic models exhibited excellent alignment with the observed data, as evidenced by high R^2 values. Specifically, T_2 and T_6 demonstrated higher potential available C and active C pools, respectively, suggesting that these conditions may facilitate elevated rates of C mineralization. The findings indicated that T_5 and T_9 appeared to possess larger stable C pools with slower turnover rates, underscoring their potential for long-term C storage. Both kinetic models adeptly captured the patterns of C mineralization. The first-order model demonstrated a marginally superior statistical fit, suggesting its preferential applicability for characterizing long-term carbon mineralization dynamics within the study area.

4. DISCUSSION

An initial surge in CO_2 emissions during the first three days indicated rapid breakdown of readily degradable organic materials. This observation was consistent with findings that organic amendments enhance soil C turnover (Wu et al., 2024). CO_2 emissions decreased from day 3 to day 24. Yang et al., 2021 demonstrated that high mineralization rates often decline as labile C sources are exhausted. Sustained CO_2 production from day 24 to day 45 suggests ongoing degradation of more resilient organic compounds, reflecting a prolonged response to organic inputs (Domouso et al., 2024). Among the different amendments, T_3 was the primary contributor to early emissions due to its nutrient-rich profile, supporting previous findings on manure's rapid decomposition (Anderson et al., 2021). In contrast, T_2showed delayed emissions starting at day 17, attributed to its complex composition and higher C:N ratio (Table 1) that slows decomposition (Liyanage et al., 2021). T_6 yielded the highest emissions from days 3 to 10, illustrating diverse nutrient sources was related to decomposition (Surigaoge et al., 2023). T_5 exhibited lower emissions due to its high lignin content(Table 1), which impedes decomposition (He et al., 2018). The control treatment underscored the essential role of organic amendments in soil C mineralization. Yang et al., 2023 and Sun et al., 2021 found that significant increases in CO_2 emissions following organic application.

During the incubation period, cumulative C mineralization was assessed using first-order and second-order kinetic models. Among the solely organic amendments tested,

T_2consistently exhibited the highest rate of C mineralization, indicating its significant potential for enhancing soil fertility and promoting C sequestration (Guo et al., 2023). T_3 followed with the second-highest mineralization rate, contributing effectively to soil fertility and C storage (Yang et al., 2024). T_5 showed the lowest cumulative C mineralization over the 120-day period, reflecting its limited effectiveness in fostering soil fertility and C retention (Zhou et al., 2024).

In mixed treatments, T_7 significantly boosted C mineralization at days 3, 10, and 17. This mixture supports both C release and nutrient availability for plant growth (Wang et al., 2024). Starting from day 24, T_6 maintained high mineralization rates, illustrating its long-term benefits for C sequestration and soil health (Singh et al., 2024). T_9 yielded the lowest C mineralization, underscoring the importance of selecting suitable organic amendments. Throughout the incubation, T_2 led in cumulative C mineralization, followed by T_6, and T_3due to their lower lignin contents (Table 1). T_5 contributed the leastcumulative C mineralization, emphasizing the need for careful selection of organic amendments to achieve sustainable soil health and optimal C storage.

The first-order kinetic model elucidates the dynamics of potential available C (C_0) across various treatments, revealing a significant range from 12.96 to 18.13 mg kg^{-1}. Notably, T_6 demonstrated the highest potential available C, highlighting its capacity to enhance C availability at the onset of mineralization. This finding suggests that specific amendments can be strategically employed to optimize C availability, with important implications for nutrient cycling in soil (Desalegn, Herrerod&Turriónb., 2019). An examination of the apparent rate constant (k) indicates substantial variation in mineralization rates across treatments. T_2 and T_3 exhibited k values of approximately 3.39E-04 day^{-1}, indicating a rapid mineralization process that facilitates the swift release of nutrients. In contrast, T_5 exhibited a notably lower k value of 2.67E-04 day^{-1}, suggesting a slower rate of C mineralization, which could affect the timing of nutrient availability in agricultural practices. This is further supported by the half-life metric, where higher k values correspond to shorter half-lives, emphasizing the connection between the rate of mineralization and the duration of C availability (Riffaldi, Saviozzi& Levi-Minzi., 1996).

The second-order kinetic model complements this analysis by introducing active (C_1) and resistant (C_2) C pools. T_2 emerged with the highest active C pool, suggesting that certain organic amendments can promote accelerated mineralization rates by providing easily digestible C sources (Da Silva et al., 2022). T_9 exhibited the highest resistant C pool, characterized by slower mineralization rates, underscoring its significance in long-term C storage (Liu et al., 2024, Chen et al., 2014). The high k_1 value in T_1 indicated rapid mineralization of the active C pool. In all treatments, T_2 showed the highest $k_2$value (3.50E-

04 day⁻¹), reflect a consistent turnover rate within the stable C pool, which is essential for sustaining soil health over time (Eleduma, Aderibigbe&Obabire., 2020).

The strength of both kinetic models is evident from the high R² values, indicating a strong fit of the models to the experimental data. The superior alignment of the first-order model suggests its applicability in characterizing long-term C mineralization dynamics within the context of this study. This finding is consistent with earlier research (Saviozzi et al., 1997; Kumar et al., 2018; Chen, Pei & Chiang., 2020; Sarkar et al., 2021). Treatments that promote higher potential available C and active C pools, such as T_2 and T_6, represent opportunities to bolster soil nutrient dynamics. Conversely, treatments with more extensive resistant C pools, such as T_5, underscore the importance of incorporating strategies that enhance long-term C storage, thereby contributing to sustainable agricultural practices and improved C management in soils.

5. CONCLUSION

The results of this study underscore a critical paradox in soil management practices: while increased C mineralization can enhance nutrient availability in the short term, it may ultimately be detrimental to long-term C sequestration efforts. Specifically, organic amendments such as cow dung and chicken manure, characterized by their rapid decomposition and high mineralization rates, facilitate a swift release of CO_2 into the atmosphere. This phenomenon, while beneficial for immediate nutrient cycling and plant growth, poses a significant challenge for sustainable C management. In contrast, amendments like maize straw, despite exhibiting lower rates of C mineralization, play a vital role in fostering the formation of resistant C pools. These resistant pools are essential for long-termC storage, as they are less susceptible to microbial degradation and can persist in the soil for extended periods. The application of kinetic models in this research, particularly the first-order model, has proven effective in elucidating the dynamics of C mineralization across various treatments. The high R² values associated with this model indicate a robust fit to the experimental data.

The study emphasizes the importance of selecting organic amendments not solely based on their immediate effects on nutrient release but also considering their long-term implications for C sequestration. Moreover, the interplay between C mineralization and sequestration presents a complex challenge for soil management. The insights gained from this study highlight the need for a strategic selection of organic amendments that optimize both nutrient availability and long-term C storage in tropical soil. By prioritizing amendments that enhance resistant C pools, such as maize straw, alongside a thorough understanding of the underlying kinetic models, agricultural practices can be aligned with the dual goals of improving soil health and mitigating climate change.

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