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UNVEILING THE NATURE OF CARBON DECOMPOSITION ON DIFFERENT ORGANIC MANURE SOURCES: THE IMPACT OF TEMPERATURE REGIMES IN A SUBTROPICAL CLIMATE

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ABSTRACT. Organic sources are vital for crop nutrient management, but nutrient release from organic manure depends on temperature and other factors. We conducted a laboratory incubation study to investigate how temperature (15, 25, 35°C) affects the decomposition of common organic manure, which has not yet been explored in Bangladesh. The organic manures used in this study are poultry manure (PM), vermicompost (VC), bio-slurry (BS), cow dung (CD), water hyacinth compost (WHC) and rice straw compost (RSC), which were compared with a control treatment (only soil). Carbon mineralisation and CO_2 emission from microbial respiration varied among organic manures and temperature regimes. The RSC- and WHC-treated soils had a higher C mineralisation than the other manures at 35°C. The mineralisation of C among the organic manures followed the order: RSC > WHC > CD > VC > BS > PM > control. Among the temperature regimes, C mineralisation followed the order 35°C > 25°C > 15°C. Manure mineralisation was associated with mineralisable C pools (carbon availability factor, C_{af}), and 16.4–36.5% organic C was released. Irrespective of temperature regimes, the highest easily mineralisable C_{af} was recorded in PM-amended soil, followed by VC-amended soil. RSC had the lowest C_{af} under all temperature

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regimes. The C_{af} values of all incubated manures were higher under a 35°C temperature regime. Compost preparation from organic manure and its utilisation as an integrated nutrient management component can play essential roles in mitigating climate change, reducing environmental degradation, and building more sustainable and resilient agrifood systems.

Keywords: carbon cycling; climate research; eco-friendly farming; nutrient reactivity; organic carbon shifts.

INTRODUCTION

In South Asian countries, a reduction in soil fertility has become a significant biophysical barrier to crop production. Cropping intensity has been rising abnormally over the last decade to meet the rising food demand in these countries. Therefore, the dependence of agricultural production on the use of chemical fertilisers and high-yielding varieties/hybrids has increased unexpectedly (Jahiruddin and Satter, 2010). Intensifying crop production has resulted in soil nutrient depletion because crop nutrient uptake exceeds annual fertiliser replacement (Saleque *et al.*, 2004). The overuse of chemical fertilisers is linked to biodiversity loss, soil pollution with hazardous compounds and soil fertility degradation (Bisht and Chauhan, 2020). Modern agricultural practices cause soil degradation, fertility loss and nutrient depletion due to the decline in soil organic matter (SOM) (Masciandaro *et al.*, 1997).

The decline in SOM has been reported in all countries in South Asia (Jahiruddin and Satter, 2010; Sitaula, 2004). Due to rising temperatures, soil overuse, the mining of nutrients, inappropriate tillage, crop management, arbitrary fertiliser use and soil erosion, SOM is rapidly declining in South Asia (Aulakh, 2011; Zahid *et al.*, 2020). Similar to other South Asian countries, Bangladesh has a very high cropping intensity, with a rate of up to 200%. However, the organic matter (OM) content in the soil is only around 1.0% or ranges from 10 to 17 g kg^{-1} soil, which is inadequate to support crop production (BARC, 2018; Khan *et al.*, 2008). SOM depletion in different Agro-Ecological Zones of the country ranges from 9 to 62.4% over 30 years (1969–2000) (Karim *et al.*, 2004).

Consistently increasing SOM is necessary for sustainable agriculture and maintaining soil fertility for crop production (Lal *et al.*, 2013). Soil carbon cycling is crucial for plant nutrient uptake, as nitrogen and sulphur become mineralised with carbon (Gan *et al.*, 2020). Chemical fertilisers alone are unable to maintain sustainable crop production, and employing only organic manure is not a viable option for increasing crop productivity. An estimation of the possible level of organic C accumulation in soil can be obtained by determining the C mineralisation of manure (Alam *et al.*, 2018). In addition, the quality of OM is indicated by the rates of CO_2 efflux (Wagner and Wolf, 2009).

To optimise crop output without compromising soil health, it is crucial to implement an integrated organic–inorganic fertilisation approach, known as an Integrated Plant Nutrition System (IPNS) (Rahman *et al.*, 2016). However, there has been limited systematic research on the decomposition potential of organic manure sources.

According to Saha *et al.* (2007) and Poeplau *et al.* (2017), adding organic manure from animals and plants enhances the soil's organic C and nutrient content, boosting crop yields (Bhatnagar *et al.*, 1983; Piccoli *et al.*, 2020). The rate of organic material mineralisation depends on various factors, such as its chemical and physical composition, quantity, soil type and environmental conditions. Decomposition also depends on the C:N, C:P and C:S ratios of the amending materials (Cattanio *et al.*, 2008).

Elevated temperatures dramatically accelerate the decay of organic and inorganic manure (Crohn, 2004), which have multifarious implications for soil, water and the environment (including CO_2 emission). A rule of thumb is that decay rates double for every 18°F increase in temperature (Nadelhoffer *et al.*, 1991). An understanding of the effects of temperature on decomposition can help predict mineralisation during the year/crop season. Between 3 and 9°C, carbon mineralisation rates are not affected by temperature, but at temperatures between 9 and 15°C, they have an effect.

According to Nadelhoffer *et al.* (1991), changes in soil C mineralisation rates were higher than those resulting from different temperatures during incubation within the same soil. It is inconceivable to attain the goal of higher and maintained crop productivity unless the OM component is seriously considered in the cropping sequence (BARC, 2018).

To utilise manure and other organic materials to their fullest potential and to forecast the supplementation rates of inorganic fertilisers, it is necessary to understand the rate of net nutrient mineralisation.

Composting is a highly effective method for managing agricultural waste. This process involves the biological breakdown of organic waste under aerobic conditions, resulting in a valuable byproduct that can be safely used for crop cultivation or as livestock feed. Composting is a sustainable solution that not only reduces waste but also produces a useful resource for the agricultural industry. Several factors impact composting rates, including temperature, pH, moisture, oxygen, particle size, and C/N ratio. With its plethora of advantages, composting is the cornerstone of a green economy. It follows the principles of a circular economy, reducing waste and cutting greenhouse gas emissions.

Methane, a strong greenhouse gas, is released when organic materials degrade anaerobically in landfills. In contrast, composting promotes aerobic breakdown, significantly lowering methane emissions (Islam *et al.*, 2021; Yasmin *et al.*, 2022). According to the EPA (2023), composting is not only good for the environment but also stimulates the economy.

The application of compost can increase crop yields and enhance soil health, offering a sustainable substitute for mineral NPK fertilisers. By converting garbage into a useful resource, composting incorporates the core principles of a circular economy and reduces the need for resource-intensive extraction and manufacturing.

There is a lack of comprehensive and systematic research on the mineralisation and nutrient release patterns of commonly used organic manure in South Asia under incubation.

Therefore, an incubation study was conducted to evaluate the effect of temperature on the decomposition patterns of commonly used organic manure in soil and to predict annual organic C mineralisation.

MATERIALS AND METHODS

Laboratory study

The laboratory incubation study was carried out at the Micronutrient Laboratory, Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, in 2020–2021 using a Memmert incubator (GmbH+Co. KG, Germany).

Treatments and experimental design

This study was conducted to investigate the effect of temperature regimes and different sources of organic amendments on the nature of C mineralisation. This study included six organic materials: (i) poultry manure (PM), (ii) vermicompost (VC), (iii) bio-slurry (BS), (iv) cow dung (CD), (v) water hyacinth compost (WHC) and (vi) rice straw compost (RSC). A control (only soil media) treatment was also considered, and the study included seven treatments in a completely randomised (CRD) with four replications. The physical and chemical properties of the soil used in the incubation study are presented in *Table 1*.

Compost and soil collection and processing

PM, BS and CD were collected from Pazulia village, Gazipur Sador, Gazipur. VC, WHC and RSC were collected from the Soil Science Division, BARI, Joydebpur, Gazipur. The samples were cleaned and air-dried under an electric fan before being oven-dried at 60°C for 48 hours and pulverised in a steel grinding mill with a fine sieve at the BARI Soil Science Laboratory in Joydebpur, Gazipur. Before incubation, the prepared samples were stored in desiccators.

Soils were obtained from the BARI experimental field at depths ranging from 0 to 15 cm. After the weeds and stubble were removed, the soil was placed in a polythene bag and transported to the laboratory for analysis. Undecomposed plant debris was removed by hand immediately after collection, and the soil was sieved (2 mm) and covered with a polythene sheet for 24 hours after adjusting the moisture level to 40% water-holding capacity. Soils with a water retention capacity of 40% were pre-incubated aerobically at room temperature for 10 days. The microbial population was stabilised during pre-incubation in a plastic container, limiting the effects of soil handling and preparation. The soil was employed for the OM decomposition experiment immediately after conditioning.

Experiment setup and C emissions determination

Individually, 2 g of organic materials were added to 100 g of soil in a 100 mL glass container. Following the modification, glass jars were placed in 1 L dark glass bottles, sealed and incubated for 330 days at three distinct temperatures of 15, 25 and 35°C. To trap CO_2 produced by soil microbes during incubation, each glass container was filled with 20 mL of 1 M NaOH solution.

To maintain the internal humidity, 10 mL of distilled water was added to each 1 L glass bottle. The C emissions from each amendment were determined at 1, 5, 10, 15, 20, 30, 40, 60, 90, 120, 180, 240 and 330 days of incubation. The C concentration, C:N, C:P and C:S values are shown in *Table 2*.

Table 1 – Physical and chemical properties of soil used in the incubation study

Physical properties	Values
Sand (%)	27.18
Silt (%)	38.30
Clay (%)	34.52
Textural class	Clay loam
Particle density (g cm^{-3})	2.48
Bulk density (g cm^{-3})	1.42
Porosity (%)	42.74
Chemical properties	
pH	6.5
Organic C (%)	0.75
Total N (%)	0.06
Available N (μg g^{-1} soil)	50.00
Available P (μg g^{-1} soil)	12.93
Available S (μg g^{-1} soil)	15
Available Zn (μg g^{-1} soil)	0.71
Available B (μg g^{-1} soil)	0.26

Table 2 – Carbon concentration and carbon:nitrogen (C:N), carbon:phosphorus (C:P) and carbon:sulphur (C:S) ratios of the conventional composts used in the present study

Manures	C (%)	C:N	C:P	C:S
PM	25	10.8	11.5	56.8
VC	28	14.7	16.5	73.7
BS	29	20.0	23.2	93.5
CD	34	25.8	117	126
WHC	40	50.0	308	800
RSC	42	70.0	600	840

Microbial respiration measurement

After incubation for 330 days, microbial respiration was measured as CO_2 evolution from OM-added soil samples. NaOH was replaced after each sampling. Using a pH meter (WTW pH 522), the total CO_2 was titrated with standard HCl (0.02 1N). Microbial respiration was measured in terms of g CO_2-C evolved g^{-1} soil. The following reactions were expected to occur during HCl titration (Anderson, 1982):

1. $NaOH + CO_2 \rightarrow Na_2CO_3 + NaHCO_3 + H_2O$ (pH = 12)
2. $Na_2CO_3 + HCl \rightarrow NaHCO_3 + NaCl$ (pH = 8.3–12)
3. $NaHCO_3 + HCl \rightarrow H_2CO_3 + NaCl$ (pH = 3.7–8.3)

Modelling of organic C mineralisation

The mineralisation rate constants of both the labile and nonlabile carbon pools (easily mineralisable C pool (Caf); C mineralisation rate constant for easily mineralisable C pool (K_f); carbon mineralisation rate constant of resistant C pool (Ks)) were the kinetic model output parameters (as shown below) found after running data (cumulative C mineralisation data at all dates of measurement) into the SPSS platform.

$$C(t) = C_{af}\{1 - exp(-k_f t)\} + k_s t$$

where C(t) is the total amount of carbon that has been mineralised at time t, k_f is the mineralisation constant rate of the pool of carbon that is most readily broken down C_{af} and k_s is the mineralised rate constant of the resistant pool.

Predicted annual C mineralisation in organic manure-amended soils

An incubation experiment was performed for 330 days to study C mineralisation under laboratory conditions under three temperature regimes (15, 25 and 35°C). The average annual temperature in Bangladesh is 25°C. The average temperature during winter is 15°C, and the temperature with a higher ceiling during the summer and monsoon seasons is 35°C. For this reason, the data were recalculated and extrapolated to one year to determine the stable OM fraction of OM additives, which was defined as the fraction of OM that persists in soil one year after addition.

Statistical analysis

The C uptake data of different time intervals were fitted to line graphs with their standard error values to examine the treatment effects. Statistical comparison of means was done using Tukey's honestly significant difference test at 0.05 probability. The software package SPSS Inc. was used for statistical analysis and model fitting.

RESULTS

Rate of mineralisation of organic manure

Different temperature regimes and manure types greatly influenced the rate of carbon mineralisation from organic manure. Regardless of the temperature regime, all organic manures released a higher CO_2-C than the control (*Figure 1*). Regardless of the organic manure, the rate of CO_2-C evolution continuously increased with an increase in temperature throughout the incubation period.

However, regardless of the temperature, VC, CD and PM consistently demonstrated the highest mineralisation rates in compost-mixed soils, particularly during the initial sampling period.

However, at the later stage, RSC and WHC showed the highest rates of mineralisation. Different temperatures showed different rates of mineralisation.

Cumulative mineralisation of CO_2-C

The cumulative evolution of CO_2-C from manure incubated at 15°C showed the highest mineralisation (3898 µg CO_2-C g^{-1} soil) in RSC, followed by WHC, whereas the least (349 µg CO_2-C g^{-1} soil) was from the CT soil (*Figure 2*). WHC and RSC were always substantially different from the other manures used in the study when incubated at 15°C. The C mineralisation of the control (sole soil) was consistently 10 times lower than that of the other amended soils. In contrast, when the manures were incubated at 25 and 35°C, the differences in C release were small (*Figure 2*).

The initial rates of C mineralisation for organic manures PM, VC and BS were higher at 15°C but steadily decreased after 5 days of incubation, reaching their lowest rate at 330 days (*Figure 1*). However, CO_2-C evolution from CD and WHC reached a peak at 10 days of incubation.

At 25°C, except CD and RSC, the remaining four organic manures reached a peak for the CO_2-C evolution within 5 days of incubation (*Figure 1*). CD and RSC, however, reached the maximum level to release CO_2-C after 10 days of incubation.

Subsequently, the trend was similar to that at 15°C. In contrast, all tested organic manures showed the highest mineralisation at 5 days of incubation at 35°C since mineralisation declined slowly and steadily, approaching a rate at which unamended organic soil was mineralised.

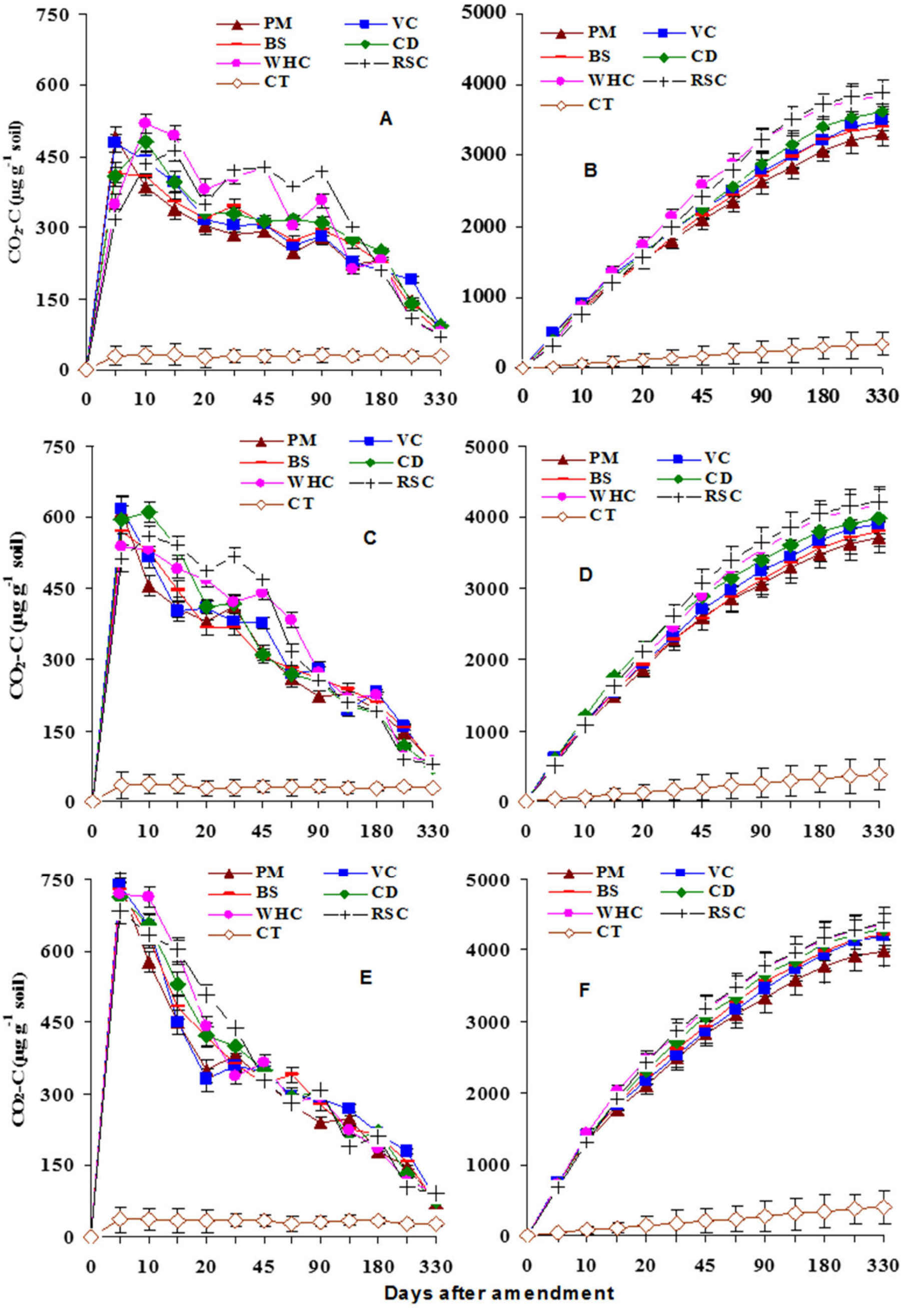

Figure 1 – CO_2-C evolution of organic manures at 15 (A = rate and B = cumulative), 25 (C = rate and D = cumulative) and 35°C (E = rate and F = cumulative) temperatures. Vertical bars indicate a standard error at 0.05 probability. PM = Poultry manure, VC = Vermicompost, BS = Bio-slurry, CD = Cow dung, WHC = Water hyacinth compost, RSC = Rice straw compost and CT = Control

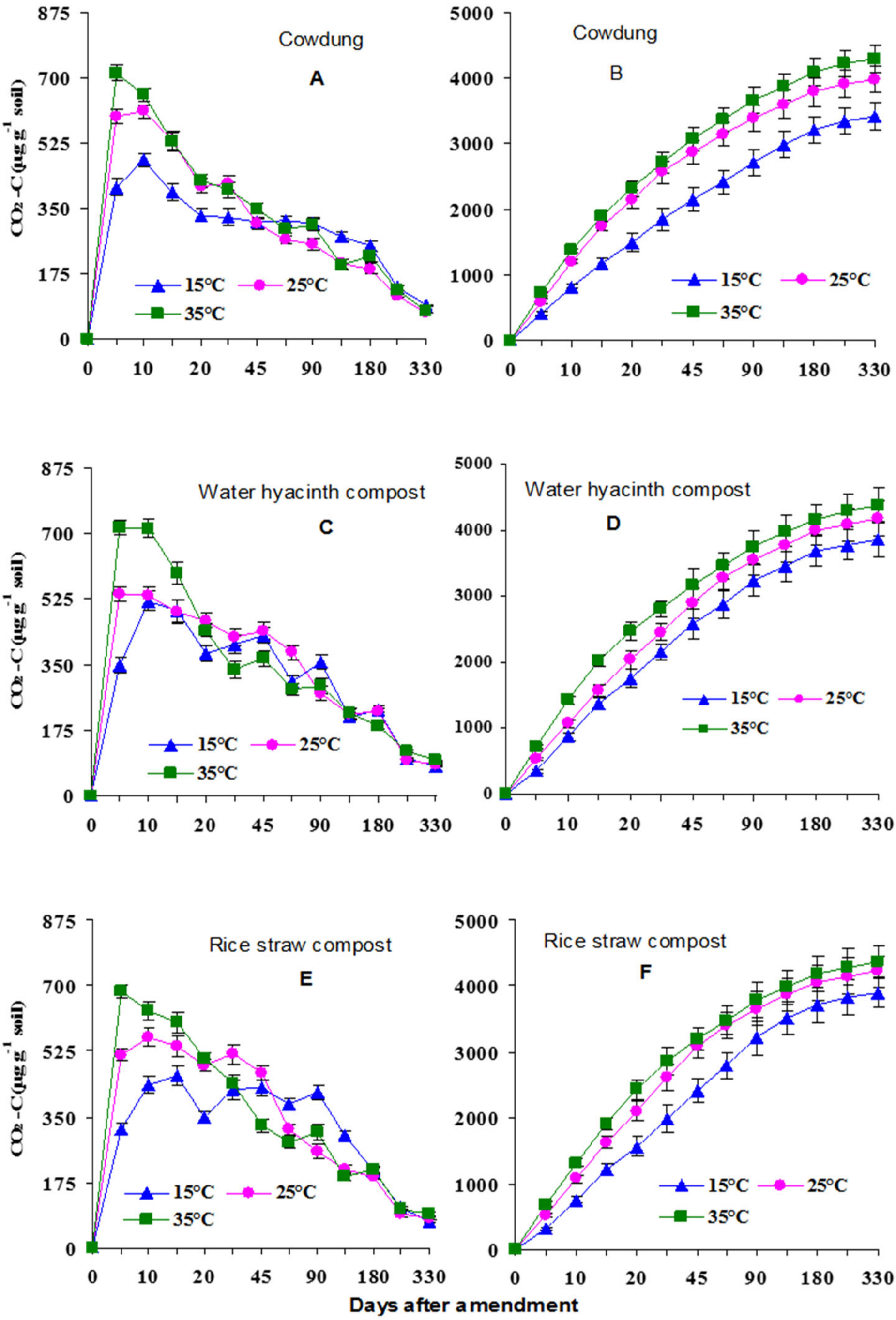

Figure 2 – CO_2-C evolution of cow dung (A = rate and B = cumulative), water hyacinth compost (C = rate and D = cumulative) and rice straw compost (E = rate and F = cumulative) at 15, 25 and 35°C. Vertical bars indicate a standard error at 0.05 probability

Prediction of C mineralisation using first- and zero-order kinetic models

The first- and zero-order kinetic models were used to estimate three parameters: C_{af} (percentage of the C pool that is easily mineralisable), K_f (mineralisation rate constant of the easily mineralisable C pool), Ks (mineralisation rate constant of the stable or resistant C pool) and R^2 (the coefficient of determination). There was no interaction between organic manure and temperature regime on C_{af}, K_f, Ks or R^2; therefore, in *Table 3*, data are presented individually.

Across temperature regimes, the C_{af} of the manure-amended soil ranged from 20.9 to 31.4%, and the organic manure PM had the highest C_{af} which was followed by soil amended with VC and BS. The lowest C_{af} was found in the organic manure RSC. Considering the temperatures, the highest temperature (35°C) had the highest mineralisable portion, and the C_{af} value decreased with the decrease in temperature.

The mineralisation rate constant of the easily degradable C pool (K_f) ranged from 10.3 to 15.9% (*Table 3*). Among the manure types, RSC-added soil had the lowest K_f, whereas the highest K_f was recorded in PM-mixed soil, followed by VC and BS.

Considering the temperature regimes, the highest K_f value was recorded from the highest temperature regime, and temperatures 15 and 25°C had similar but significantly lower K_f values than 35°C. Across temperatures, the Ks values in the manure ranged from 0.09 to 0.14% (*Table 3*). Manures PM, VC, BS and CD had similar Ks values, but were significantly higher than those of the organic manure WHC and RSC. Considering the temperature regime, the trends of Ks were similar to those of K_f.

Predicted annual C mineralisation in soils amended with organic manure

There was no interaction between organic manure and the temperature regime on annual C mineralisation; however, the individual effect was significant (*Figure 3*). Across temperature regimes, the cumulative annual C mineralisation from manure varied from 58 to 82% of total soil organic carbon (SOC), and the highest annual C mineralisation was found from organic manure PM, while the lowest was found in soil treated with organic manure RSC. Across organic manures, the highest annual C mineralisation from the organic amendment was recorded at 35°C, however, this value was significantly similar to that at 25°C. The lowest annual C mineralisation was recorded at 15°C, which was significantly lower than that at 35°C.

DISCUSSION

Carbon mineralization from organic manures

C mineralisation was greatly affected by organic amendment and temperature regime in the current study, and C mineralisation among the organic manures followed the order RSC > WHC > CD > VC > BS > PM > control. Among the temperature regimes, C mineralisation followed the order 35°C > 25°C > 15°C. Hossain *et al.* (2017) found that PM resulted in the highest CO_2-C emission rate among organic residues, followed by rice root-treated soil.

Furthermore, the study revealed that the inclusion of soil mixture in poultry litter resulted in a 121% increase in cumulative CO_2-C compared to the control, with an average CO_2-C mineralisation rate of 38%. Hossain *et al.* (2017) found that C emission loss was higher in soils treated with RSC (18.60%) and chicken manure (19.69%) than in other treatments. However, there was no significant difference between CD (12.01%) and VC (12.16%). However, Rahman *et al.* (2022) found that CD had the highest CO_2 emission levels when tested in the field.

We found that CO_2-C emission reached its peak between 7 and 15 days after incubation (DAI) and gradually decreased afterward. However, Hossain *et al.* (2017) found that CO_2 emission peaked in the fifth week of incubation and subsequently fell irregularly until the 21st week.

Hossain and Puteh (2013) recorded maximum cumulative CO_2-C emission at 120 days after incubation. The maximum CO_2-C 7–15 DAI recorded in the current study coincided with the percentage values of total organic C from manure obtained after 11 DAI.

This result can be attributed to greater C mineralisation in all organic manure-amended soils due to the larger labile C pool during the initial days. The high concentration of components that decompose quickly, such as carbohydrates, amino acids and proteins, causes rapid breakdown rates in the near term. Due to the buildup of resistant components, such as lignin, tannins and cellulose, breakdown rates tended to slow down in the later phases (Heal *et al.*, 1997; Lupwayi *et al.*, 2007).

In the present study, the higher cumulative CO_2-C evolution was recorded at 35°C (*Figure 1*). Similar to our study, Sato and Seto (1999) found that by increasing the incubation temperature from 4 to 40°C, the rates of CO_2-C evolution increased exponentially. Additionally, Chapman and Thurlow (1998) noted that a temperature increase of 5°C could result in an increase in CO_2-C emission. In areas of the world where the yearly mean temperature is 5°C, it is predicted that a temperature increase of 1°C might result in a 10% loss in SOC (Kirschbaum, 1995). A 1°C increase in temperature would result in a 3% loss of SOC in areas with a mean temperature of 30°C.

The RSC-amended soil resulted in the highest cumulative evolution of CO_2-C (*Figure 1* and *Figure 2*). According to Hossain *et al.* (2017), cumulative C emission loss was noticeably higher in soils treated with rice straw manure and chicken manure than in other treatments. According to Sylvia *et al.* (2005), increased CO_2-C emission from greater labile C-containing organic materials leads to reduced C buildup in soil. The higher cumulative CO_2-C emission from rice straw might be attributed to containing a higher amount of labile C. According to Ni *et al.* (2010) and Rahman *et al.* (2022), a higher N content and moisture in manure resulted in more rapid microbial decomposition and higher CO_2-C emission.

The declining evolution of CO_2-C over time was recorded in the present study. The soil without organic material addition evolved a very small amount of CO_2-C compared to the organic-amended soil.

Table 3 – Estimated parameters of a fitted parallel first- and zero-order kinetic model for predicting C mineralisation as affected by manure and temperature regime

Manure	C_{af} (%)†	K_f (%)δ	Ks (%)§	R^2
PM	31.43[a]	15.90[a]	0.14[a]	0.92
VC	29.17[ab]	14.83[ab]	0.14[a]	0.95
BS	27.63[ab]	13.93[ab]	0.13[a]	0.89
CD	25.30[b]	12.83[b]	0.12[a]	0.89
WHC	22.17[bc]	11.14[bc]	0.10[b]	0.90
RSC	20.87[c]	10.30[c]	0.09[b]	0.91
Temperature regime (°C)				
15	21.25[c]	11.54[b]	0.12[b]	0.92
25	26.68[b]	13.34[b]	0.13[b]	0.90
35	30.35[a]	15.59[a]	0.15[a]	0.90

*Bio-slurry, BS; Cow dung, CD; Poultry manure, PM; Vermicompost, VC; Rice straw compost, RSC and Water hyacinth compost, WHC; † Easily mineralisable C pool (C_{af}); δ C mineralisation rate constant for easily mineralisable C pool (K_f); § Carbon mineralisation rate constant of resistant C pool (Ks). R^2, regression coefficient. Different letters in a column indicate significantly different at 0.05 probability with Tukey's honestly significant difference test.

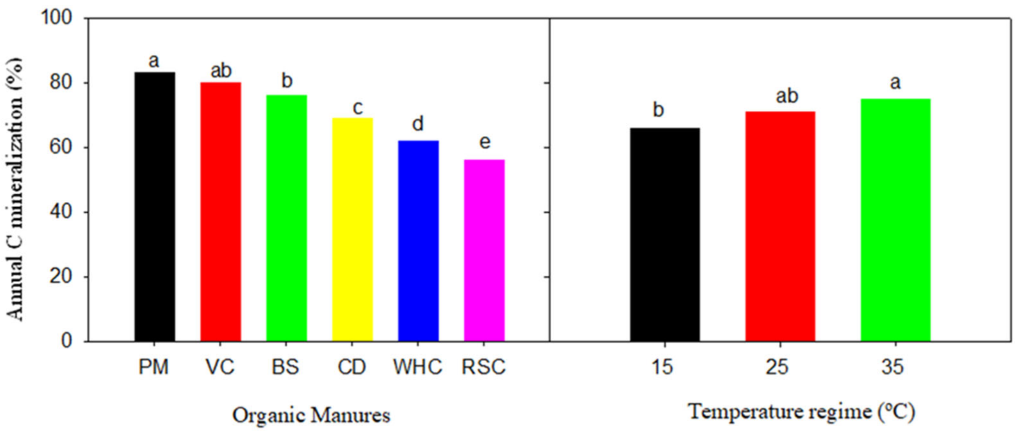

Figure 3 – Annual C mineralization rate (%) as influenced by different manures and temperature regimes

Different letters above the bars indicate significantly different at 0.05 probability with Tukey's honestly significant difference test; Poultry manure, PM; Vermicompost, VC; Bio-slurry, BS; Cowdung, CD; Water hyacinth compost, WHC and Rice straw compost, RSC

Hossain and Puteh (2013) also found similar results in the case of soil respiration (without organic manure). However, the manure C mineralisation rate declined over time and tended to reach almost zero within 330 days. One of the most accurate indicators of the breakdown of organic waste is the drop in the C:N ratio over time (Goyal *et al.*, 2005; Ranalli *et al.*, 2001). Later, a decline in manure mineralisation could mean that more organic carbon was absorbed into the microbial biomass or sequestered in the soil. Similar outcomes were observed in the study conducted by Elfstrand *et al.* (2008).

Kinetics/ prediction of C mineralisation using zero and first-order kinetic models

The parallel first- and zero-order kinetic models used for the present study to describe the C mineralisation process were typical and well-fitted for the present study. Researchers conducted similar studies to support the idea that a model can describe the C mineralisation process. Most studies claim that the first-order kinetic model accurately depicts the C mineralisation process (Alam *et al.*, 2018; Pansu and Thuries, 2003; Sleutel *et al.*, 2005). The easily mineralisable C pool in the current study ranged from 16.4 to 36.6% of total SOC, depending on the treatment. The K_f values ranged from 7.76 to 18.7% (*Table 3*). PM-treated soil at 35°C had the highest K_f value, whereas RSC at 15°C had the lowest value. The decomposition of PM-added soils incubated at 35°C was quicker, having the highest K_f and C_{af}. Even though Ks is also higher than in other organic material-added soils (Marzi *et al.*, 2020), poultry manure-added soils show a higher C_{af} than other organic material-added soils (Zaharah and Bah, 1999). Following PM-amended soil, a higher easily decomposable C pool, along with a higher decomposition rate constant, was recorded in the VC-amended soil. The regression coefficient (R^2) estimate showed that the parallel first- and zero-order models fitted well and explained C mineralisation dynamics for all tested OM. Soils with VC added at 35°C, WHC at 15°C and PM at 15°C showed the best goodness of fit, while WHC added to soil at 25 and 35°C and BS added to soil at 15°C showed the lowest goodness of fit (*Table 3*). Riffaldi *et al.* (1996) used six distinct kinetic models (first order, first order F, linearised power function, non-linearised power function, zero order and pair simultaneous reactions) during short-term laboratory incubation to determine the C mineralisation potentials of 14 agricultural soils (unamended soils). They found that a modified first-order model best described C mineralisation in soil. Islam (2012) and Ahmed (2012) found that parallel first- and zero-order kinetic models fit very well for describing and predicting annual C mineralisation.

The higher C_{af} values of PM and VC were paired with higher decay rates (K_f %), which described the higher mineralisation of PM-amended soils well (*Table 3*). However, the lowest C_{af} value in the amended soils was estimated for the RSC-added soils. The higher C_{af} values under higher temperatures dictate the relationship of temperatures with the decomposition process. The higher K_f and C_{af} values promulgated the rapid substrate availability for faster decomposition and higher CO_2-C emission. The increased decay rate for C_{af} may be related to labile C, which decomposed more quickly at the beginning. An increase in temperature shortens the duration of the decomposition phase (Hossain *et al.*, 2017).

Leveraging mineralisation studies for sustainable agriculture and a circular economy

The problem of agricultural waste is increasingly becoming a concern in the realm of agronomy (Ho *et al.*, 2022). Composting has a significant impact on overcoming this issue, which cannot be understated. The secret to turning agricultural waste and organic waste into a resource that can improve crop cultivation and soil health is composting, a biological process that converts organic waste into a valuable product under aerobic circumstances. Composting enhances soil, in addition to reducing waste and recycling nutrients since it promotes humic material development. These composting process byproducts improve the chemical, physical and biological characteristics of soil. Humic compounds improve soil quality, moisture retention and nutrient availability, which boost crop productivity (Alam *et al.*, 2018; Islam *et al.*, 2021). This is consistent with the overarching objective of sustainable agriculture, which calls for enhancing soil health to guarantee long-term food security.

The enormous volume of agricultural waste generated highlights the worldwide ramifications of successful composting. The potential for using this resource is significant. Rice straw, for example, is a common leftover with an annual production of more than 731 million tonnes worldwide (Karimi *et al.*, 2006). Alam *et al.* (2019) found that the inclusion of SOC sequestration in the life cycle assessment approach of a rice-based triple cropping system and the non-inclusion of SOC in LCA overestimated 20–30% of the LCA-based carbon footprint. The rice straw residue return or compost application has been proven to increase the SOC in soil. Unger and Razza (2018) showed that the compost scenario with SOM dynamics demonstrated a reduction in its carbon footprint of 70% when compared to the "no compost" scenario. Composting helps to increase the soil's quality, which benefits the bioeconomy. Because 58% of SOM is carbon, the use of compost also has an impact on crops' greenhouse gas balance. In landfills, the anaerobic decomposition of organic materials results in methane emissions, a potent greenhouse gas. In contrast, composting encourages aerobic breakdown and hence reduces methane emissions greatly (Islam *et al.*, 2021; Yasmin *et al.*, 2022). Composting also adheres to the principles of a circular economy while lowering trash production and addressing the environmental problems associated with garbage disposal.

Additionally, organic waste, such as cow manure, offers an undiscovered source of energy. The amount of manure produced by the world's cattle population is astounding. According to FAO data, the global cow population (141 countries) produced 66.74 billion kilograms of manure in 2017 (FAO, 2020). In addition to the production of biogas slurry and organic compost, one kilogram of fresh CD can create an estimated 0.03 m^3 of biogas per day (Olaoye *et al.*, 2018). CD can also be composted or co-composted and used in agricultural fields according to various organic use models (such as integrated nutrient management and integrated plant nutrition systems). In addition to CD and rice straw, 20,000 tonnes of chicken manure are produced annually globally for every 100,000 birds (Chastain *et al.*, 1999). The composted PM made from chicken litter has great potential for use in conjunction with inorganic fertilisers to aid the economy and ecology.

To develop efficient composting techniques for conventional waste sources, to use the compost as a nutrient source, or to ensure nutrient release in the field according to crop demand, mineralisation of manures, composts and organic resources are essential; otherwise, they can cause more environmental burdens. Organic waste, including RSC, WHC, VC, PM and CD, represents a valuable resource that, when managed effectively, can contribute to both environmental sustainability and economic growth.

CONCLUSIONS

Our investigation of the effect of temperature regimes and diverse organic sources on carbon decomposition has provided valuable insights into the dynamic processes shaping soil carbon dynamics. The observed variations in decomposition rates underscore the significance of temperature as a key driver influencing microbial activity and the enzymatic processes responsible for OM breakdown. Furthermore, our study contributes valuable information regarding the identification of optimal temperature ranges for carbon decomposition in specific organic manures. Harnessing this knowledge can not only improve nutrient cycling but also contribute to mitigating greenhouse gas emissions associated with OM decomposition.

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