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Technology to Increase Carbon Mineralization Potential of Crop Residues under Cotton-Maize-Pulse Cropping System

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ABSTRACT

Background: Cotton, maize and pulses are widely grown crops in the western zone of Tamil Nadu, resulting in a significant accumulation of crop residues throughout the year. The persistence of these crop residues after harvest can cause problems for farmers and the soil system. Therefore, the goal of the current study is to investigate the carbon mineralization process in these residues to enrich the soil's nutrient content, turning waste into a valuable resource.

Methods: The incubation experiment comprised 13 treatments, each with three replicates. These included a control, surface residue addition, buried residue addition and various combinations of soil, residue, microbial consortia, urea and jaggery, both on the soil surface (S) and incorporated into the soil (I).

Result: The incorporation of crop residues into the soil, along with the addition of 1% microbial consortia, 2.0% jaggery and 1% urea, significantly enhanced carbon mineralization. Among the three crop residues, cowpea exhibited the highest performance, followed by cotton and maize, with values of 692, 564 and 522 µg C g^{-1} soil, respectively. This trend was further supported by the Michaelis-Menten model (V = 951.72 * x/22.13 + x), with a high goodness-of-fit represented by an R^2 value of 0.95 for cowpea. The maximum Vmax (951.72 µmol/min) further substantiates the efficient carbon mineralization achieved by utilizing allocated resources in cowpea-incorporated crop residues (CWFI).

Key words: Carbon, Cotton, Cowpea, Incorporated, Maize, Michaelis-Menten model, Surface.

INTRODUCTION

Crop residues, the remnants of plants left in fields after harvest, play a crucial role in the terrestrial carbon cycle and soil nutrient dynamics. The decomposition of these residues is a complex process influenced by various factors, including soil microbes, residue type and placement method (Wang *et al*., 2020). Each type of residue has a unique chemical composition, affecting its decomposition rate and nutrient availability. The term "residue placement" refers to how residues are introduced into the soil, either incorporated or left on the surface, impacting the physical, chemical and biological properties of the soil (Stegarescu *et al*., 2020). Soil microbes decompose organic matter in these residues, releasing nutrients and carbon dioxide (CO_2) into the soil. Managing agricultural waste, such as crop residues, is essential for ethical farming practices in India, where soil fertility is critical for millions of farmers. By recycling crop residues into the soil, farmers can retain soil organic carbon (SOC), improve soil health and fertility, reduce reliance on chemical fertilizers and sustain crop production (Sandhu *et al*., 2022).

However, despite its importance, there is a lack of research on how different crop residue types and placement methods affect CO_2 emissions and nutrient release in Indian soils. A widely used framework for assessing the rate of carbon mineralization in soil due to agricultural residues is the Michaelis-Menten equation (Al-Kaisi and Mahdi, 2011; Kaur *et al*., 2023). This model can predict how various crop residue management techniques impact soil quality and environmental sustainability. For example, it can estimate the amount and rate at which carbon is stored in the soil's organic matter pool and how crop residue management affects carbon sequestration in agricultural soils (Cooper *et al*., 2011). Furthermore, the model can evaluate nutrient uptake and release during decomposition, impacting farming efficiency and nutrient availability. It can also assess the net balance of

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greenhouse gas emissions during mineralization. Thus, the Michaelis-Menten model is a valuable tool for understanding and optimizing the outcomes of various crop residue management strategies (Turmel *et al*., 2015).

In Tamil Nadu's western region, cotton is often grown alongside maize and cowpea as part of crop rotations (Kumar *et al*., 2023). To study the carbon mineralization behaviour of these residues, incubation experiments were conducted in the lab. Various consortia combinations and placement techniques, including surface and incorporation, were assessed, monitoring CO_2 equivalent (CO_2-C) emissions during incubation. The study aims to provide insights into the complex kinetics of carbon mineralization in cotton, maize and cowpea residues, considering the combined effects of residue type and placement, with potential implications for sustainable soil management and crop productivity.

MATERIALS AND METHODS

Soil and crop residue samples for an incubation experiment were collected from the Eastern block farm of Tamil Nadu Agricultural University (TNAU), located in Coimbatore, Tamil Nadu, India, at coordinates 11°00′54″N; 76°56′16″E, 427 m above sea level. The soil is classified as Vertic ustropept, belonging to the Inceptisol order and Periyanaicken palayam soil series. It is a mixed black calcareous, fine, montmorillonitic, isohyperthermic soil. Soil samples from the 0-15 cm depth layer was collected in July 2021 using a metal core sampler, with visible crop and residue debris removed. The soil samples were sieved through a 2-mm mesh and divided into two subsamples. One subsample was used for a laboratory incubation experiment to measure carbon mineralization and the other was air-dried under shade for chemical analyses. The results of the soil analyses are presented in Table 1.

The air-dried soil samples were analyzed for pH, electrical conductivity (EC), oxidizable organic carbon, total C, available N, P, K contents. Crop residues were collected during the 2021 harvest seasons of cotton (March), maize (cowpea) and maize (September). Crop residue samples were air-dried, oven-dried at 60°C to determine moisture content and then ground for total C and N concentration analysis. The remaining ground samples were stored for the incubation experiment. The chemical compositions of the crop residues are presented in Table 2. The CHNS Vario El III analyzer (Elementar) was used to measure total C and N of both soil and crop residues. Standard methods were followed for determining soil pH and EC (soil:water ratio 1:2.5), available nitrogen (Subbiah and Asija, 1956), available phosphorus (Olsen *et al*., 1954 method) and available potassium Jackson, (1967). Soil bulk density was measured using metal cores with dimensions of 5 cm length and 5 cm internal diameter Blake and Hartge, (1986).

Incubation experiment

The incubation experiment included 13 treatments with three replicates each and the details are furnished in the Table 3. The treatments were as follows: CC- Control: This was the baseline condition with no amendments. A_S- Soil + residue (Surface): This assessed the impact of surface residues on C mineralization. A_I- Soil + Residue (incorporated): This examined how buried residues affected C mineralization. B_S to F_I: These treatments involved various combinations of soil, residue, microbial consortia, urea and jaggery, both on the soil surface (S) and incorporated into the soil (I). The microbial consortia and organic inputs (urea and jaggery) were added to stimulate microbial activity and influence C mineralization rates in the soil. The microbial consortia were prepared by isolating bacteria and fungi from native soil and growing efficient cultures separately. The cultures were then mixed to form the consortia that were used for the study.

The laboratory incubation method proceeded in this study was similar to Angers and Recous, (1997) to measure C mineralization under controlled conditions. In brief, the pre-incubated fresh soils at 25°C for 1 day to let the microbes to adapt the laboratory incubation conditions. Then, mixed one tenth of a gram of crop residue evenly into the fresh soil (equal to 20 grams oven-dried soil) or laid it as a single layer on top of the soil surface. Soils with or without residues were added in conical flasks (300 ml in volume, 12 cm in height) and kept them at a steady temperature (25°C) and a steady soil moisture content (60% of water-holding capacity) for 75 days. And attached a beaker (3 cm in diameter, 8 cm in height) with 10 ml of 1.0 M NaOH to each flask to capture the released CO_2. The traps were replaced at regular intervals (1, 3, 7, 14, 28, 42 and 56 days) to refresh the air in the flasks and avoid saturation of the NaOH solution. The CO_2 production was determined by titrating the NaOH solution with 0.5 M HCl with excess BaCl2, using phenolphthalein as an indicator. After the removal of NaOH beaker, the flasks were opened for 2 hours to refill the air. Soil moisture was regularly monitored by weighing the flasks and added distilled water when needed. The rate of C mineralization as the difference between the amount of CO_2 produced from the samples with residues and those without residues were calculated. And the amount of CO_2 measured after 1, 3, 7, 14, 28, 50 and 75 days to determine the total C mineralization for the 75-day incubation period were summed up. By dividing the values of CO_2 released by the mass of the soil samples (on an oven-dried weight soil basis) were determined and expressed in micrograms CO_2-C g^{-1} soil.

The Michaelis-Menten equation was used to describe the kinetics of carbon mineralization in crop residue (Al-Kaisi and Mahdi, 201; Rakesh *et al*., 2021). The equation is as follows:

$$V = \frac{Vmax\,[X]}{Km + [X]}$$

where,
V = Rate of carbon mineralization.
[X] = Concentration of carbon substrate.
Vmax = Maximum rate of carbon mineralization.
Km = Michaelis constant.

Which represents the concentration of substrate at which the rate of carbon mineralization is half of Vmax.

RESULTS AND DISCUSSION

The effect of different crop residues, microbial consortia, nitrogen, carbon sources and residue placement on carbon mineralization in soil was evaluated using a microcosm incubation study of 75 days. The results showed that the carbon mineralization rate varied significantly among the treatments and followed the Michaelis-Menten model (Fig 1, 2 and 3) The model fit metrics and kinetics were statistically studied and presented in tables 4, 5 and 6. The highest cumulative C mineralization and decomposition rate (Vmax) were observed for cotton residue with 1% consortia + 1% urea + 1.5% jaggery applied on the soil surface (CDS treatment), indicating the robust activity of carbon mineralization in this treatment. The effect of residue placement was significant (P<0.0001), with higher values for residues incorporated into soils than those placed on the surface, except for cowpea residue, which performed well irrespective of placement. This finding contradicts the previous study by Li *et al*. (2013), who reported higher cumulative C mineralization for maize residues placed on the soil surface.

The results suggest that the combination of crop residues, microbial consortia, nutrient sources and residue placement can influence the carbon mineralization process in soil and have implications for soil fertility and carbon sequestration. The results of carbon mineralization from different crop residues were analyzed using the Michaelis-Menten model, which can help in predicting the effects of different crop residue management practices on soil carbon sequestration (Al-Kaisi and Mahdi, 2011). The model was statistically significant (P< 0.0001) and well fitted to the data, as indicated by the high R^2 values (0.93 to 0.99) and the low RMSE values (5.67 to 50.65) for all treatments. The model parameters, Vmax and Km, revealed the rate and efficiency of substrate utilization by soil microbes (Table 4). The treatments receiving high carbon and nitrogen sources along with consortia (CFS, MFI, CWFI) recorded the maximum Vmax values (745.31, 812.71 and 951.72 µmol/min, respectively), indicating higher mineralization of carbon from cotton, maize and cowpea residues (Table 6).

Meanwhile, the treatments with incorporation of 1% consortia (CBI, MBI, CWBI) recorded the lowest Km values (15.71, 16.11 and 14.68 mM, respectively), indicating higher efficiency of substrate binding and utilization in soil. The treatments with surface placement of crop residues generally exhibited lower Vmax and higher Km values than the treatments with incorporation of crop residues, suggesting that incorporation enhances microbial activity and substrate availability Cooper *et al*. (2011). The results also showed that the addition of substrate may increase the efficiency of carbon mineralization, but over saturation

Table 1: Initial characteristics of the soil used for the incubation study.

Soil properties	Mean (values)*
pH (1:2.5 soil:water)	8.34
EC (dS m^{-1}; 1:2.5 soil:water)	0.45
Total carbon (%)	0.71
Oxidizable organic carbon (%)	0.43
Available N (kg ha^{-1})	267
Available P (kg ha^{-1})	17.54
Available K (kg ha^{-1})	356
Total N (%)	0.13
Bulk density (Mg m^{-3})	1.45

*Mean of three replications.

Table 2: Initial chemical characteristics of the crop residues used for the study.

Residue type	Total C (%)	Total N (%)	C/N ratio
Cotton	45.63	1.22	37.4
Maize	41.32	0.86	48.0
Cowpea	43.21	2.17	20.1

Table 3: Treatment details.

Mode of placement	Crop residues: Cotton (C)	Maize (M)	Cowpea (CW)	Treatment details
		CC		Control
Surface ($_s$)	CA_S	MA_S	CWA_S	Soil + residue
	CB_S	MB_S	CWB_S	Soil + residue + 1% consortia
	CC_S	MC_S	CWC_S	B_I + 0.5% Urea + 1.5% Jaggery
	CD_S	MD_S	CWD_S	B_I + 1% Urea + 1.5% Jaggery
	CE_S	ME_S	CWE_S	B_I + 0.5% Urea + 2.0% Jaggery
	CF_S	MF_S	CWF_S	B_I + 1.0% Urea + 2.0% Jaggery
Incorporated ($_I$)	CA_I	MA_I	CWA_I	Soil + residue
	CB_I	MB_I	CWB_I	Soil + residue + 1% consortia
	CC_I	MC_I	CWC_I	B_I + 0.5% Urea + 1.5% Jaggery
	CD_I	MD_I	CWD_I	B_I + 1% Urea + 1.5% Jaggery
	CE_I	ME_I	CWE_I	B_I + 0.5% Urea + 2.0% Jaggery
	CF_I	MF_I	CWF_I	B_I + 1.0% Urea + 2.0% Jaggery

Table 4: Michaelis-Menten's model metrics and kinetics for carbon mineralization in cotton crop residue.

Treatment		RMSE	R^2	V_{max} (µmol/min)	Prob> chi square	Km (mM)	Prob> chi square	Model equation
Control (CC)		5.67	0.93	120.45	<.0001*	51.00	0.0069*	V=120.45*X/51.00+X
Surface	CA_S	7.41	0.99	372.14	<.0001*	19.83	<.0001*	V=372.14*X/19.83+X
	CB_S	16.32	0.97	449.86	<.0001*	18.97	<.0001*	V=449.86*X/18.97+X
	CC_S	32.00	0.96	717.42	<.0001*	24.94	<.0001*	V=717.42*X/24.94+X
	CD_S	38.56	0.95	746.73	<.0001*	26.07	0.0002*	V=746.73*X/26.07+X
	CE_S	30.13	0.97	708.04	<.0001*	24.18	<.0001*	V=708.04*X/24.18+X
	CF_S	31.02	0.97	745.31	<.0001*	25.09	<.0001*	V=745.31*X/25.09+X
Incorporated	CA_I	7.66	0.99	370.92	<.0001*	18.05	<.0001*	V=370.92*X/18.05+X
	CB_I	22.25	0.96	426.87	<.0001*	15.71	<.0001*	V=426.87*X/15.71+X
	CC_I	33.42	0.95	660.55	<.0001*	22.58	<.0001*	V=660.55*X/22.58+X
	CD_I	35.44	0.95	692.98	<.0001*	22.01	<.0001*	V=692.98*X/22.01+X
	CE_I	32.75	0.96	649.80	<.0001*	21.03	<.0001*	V=649.80*X/21.03+X
	CF_I	32.35	0.96	690.40	<.0001*	20.97	<.0001*	V=690.40*X/20.97+X

Table 5: Michaelis-Menten's model metrics and kinetics for carbon mineralization in maize crop residue.

Treatment		RMSE	R^2	V_{max} (µmol/min)	Prob> chi square	Km (mM)	Prob> chi square	Model equation
Control (CC)		5.67	0.93	120.45	<.0001*	51.00	0.0069*	V=120.45*X/51.00+X
Surface	MA_S	9.41	0.98	363.97	<.0001*	59.64	<.0001*	V=363.97*X/59.64+X
	MB_S	20.31	0.96	437.00	<.0001*	22.67	<.0001*	V=437.00*X/22.67+X
	MC_S	28.50	0.96	606.63	<.0001*	22.60	<.0001*	V=606.63*X/22.60+X
	MD_S	32.43	0.96	656.35	<.0001*	21.78	<.0001*	V=656.63*X/21.78+X
	ME_S	23.91	0.97	598.46	<.0001*	21.74	<.0001*	V=598.46*X/21.74+X
	MF_S	28.56	0.96	644.31	<.0001*	20.11	<.0001*	V=644.31*X/20.11+X
Incorporated	MA_I	9.90	0.98	365.80	<.0001*	23.58	<.0001*	V=365.80*X/23.58+X
	MB_I	18.78	0.97	494.49	<.0001*	27.82	<.0001*	V=494.49*X/27.82+X
	MC_I	37.40	0.94	616.88	<.0001*	22.36	<.0001*	V=616.88*X/22.36+X
	MD_I	34.64	0.96	762.07	<.0001*	26.64	<.0001*	V=762.07*X/26.64+X
	ME_I	32.85	0.96	681.35	<.0001*	26.08	<.0001*	V=681.35*X/26.08+X
	MF_I	38.95	0.96	812.71	<.0001*	27.32	<.0001*	V=812.71*X/27.32+X

Table 6: Michaelis-Menten's model metrics and kinetics for carbon mineralization in cowpea crop residue.

Treatment		RMSE	R^2	V_{max} (µmol/min)	Prob> chi square	Km (mM)	Prob> chi square	Model equation
Control (CC)		5.67	0.93	120.45	<.0001*	51.00	0.0069*	V=120.45*X/51.00+X
Surface	CWA_S	12.92	0.98	388.85	<.0001*	16.59	<.0001*	V=388.85*X/16.59+X
	CWB_S	16.62	0.98	471.89	<.0001*	16.52	<.0001*	V=471.89*X/16.52+X
	CWC_S	41.39	0.96	823.55	<.0001*	21.50	<.0001*	V=823.55*X/21.50+X
	CWD_S	46.07	0.96	904.91	<.0001*	24.25	<.0001*	V=904.91*X/24.25+X
	CWE_S	43.91	0.96	881.54	<.0001*	23.20	<.0001*	V=881.54*X/23.20+X
	CWF_S	48.98	0.95	921.15	<.0001*	22.92	<.0001*	V=921.15*X/22.92+X
Incorporated	CWA_I	13.33	0.98	392.44	<.0001*	16.46	<.0001*	V=392.44*X/16.46+X
	CWB_I	16.01	0.98	456.77	<.0001*	14.68	<.0001*	V=456.77*X/14.68+X
	CWC_I	44.97	0.95	846.63	<.0001*	20.76	<.0001*	V=846.63*X/20.76+X
	CWD_I	49.06	0.95	895.71	<.0001*	21.18	<.0001*	V=895.71*X/21.18+X
	CWE_I	50.65	0.95	875.39	<.0001*	21.09	0.0003*	V=875.39*X/21.09+X
	CWF_I	49.92	0.95	951.72	<.0001*	22.13	<.0001*	V=951.72*X/22.13+X

leads to decline the mineralization rate. The lowest rate of mineralization was noted in control treatments with no additives (Rieke *et al*., 2022).

Overall, the Michaelis-Menten model provides valuable insights into carbon dynamics across different treatments and can be used to optimize crop residue management for soil health and productivity (Datta *et al*., 2019). The effects of different treatments on carbon mineralization from three crop residues (cowpea, cotton and maize) were evaluated using the cumulative mineralization values and the Michaelis-Menten model parameters (Vmax and Km). The results showed that cowpea residue exhibited the highest carbon mineralization rate, followed by cotton and maize, across all treatments. The treatments receiving consortia, urea and jaggery (CFS, MFI, CWFI) recorded the highest cumulative mineralization values and Vmax values,

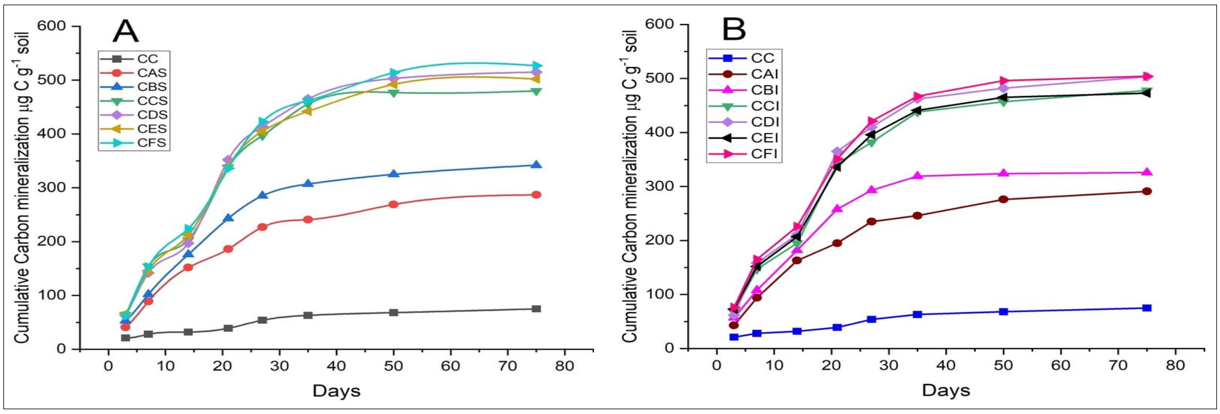

Fig 1: Rate of change in carbon content of cotton residue; surface (A) vs incorporated (B).

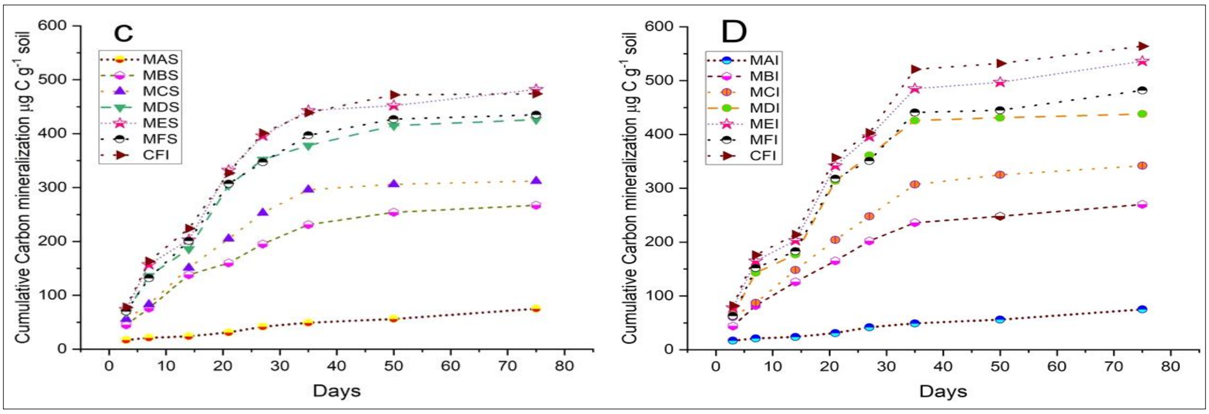

Fig 2: Rate of change in carbon content in maize residue; surface (C) vs incorporated (D).

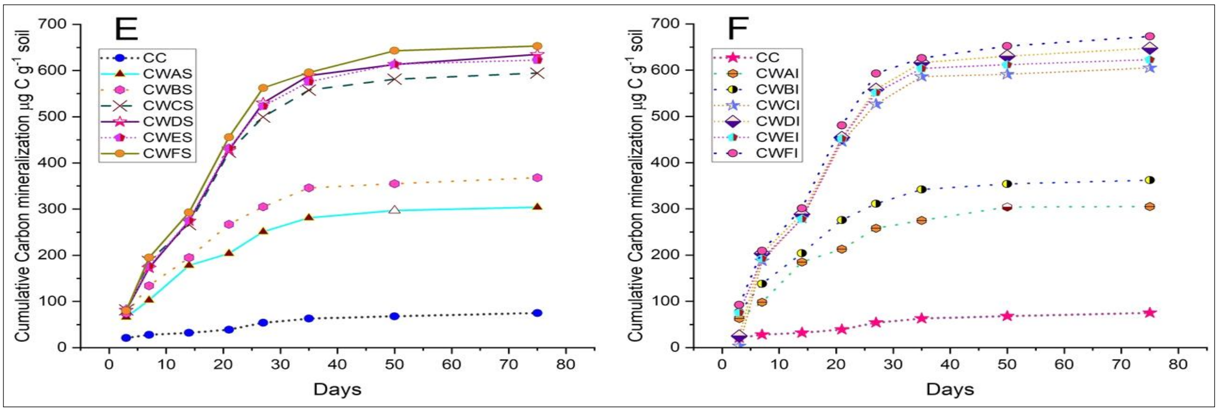

Fig 3: Rate of change in carbon content in cowpea residue; surface (E) vs incorporated (F).

indicating higher microbial activity and carbon turnover from the added substrates. The treatments with incorporation of consortia alone (CBI, MBI, CWBI) recorded the lowest Km values, indicating higher efficiency of substrate binding and utilization in soil. The treatments with surface placement of crop residues generally exhibited lower mineralization rates and Vmax values than the treatments with incorporation of crop residues, suggesting that incorporation enhances substrate availability and microbial contact.

The results also revealed that the C/N ratio of the crop residues influenced the mineralization rate and efficiency. The low C/N ratio of cowpea residue resulted in higher mineralization than the high C/N ratio of maize residue, which resulted in slower decomposition. The cotton residue had a moderate C/N ratio and recorded moderate mineralization rates. The rate of carbon mineralization increased significantly up to the 50th day of incubation and then gradually slowed down across all treatments. The results demonstrated that different crop residue management practices can affect the carbon dynamics in soil and can be optimized to improve soil health and productivity.

The decomposition of the residues was facilitated by the closer contact between soil and residue, as shown by many studies (Abiven and Recous, 2007). The residue–soil contact was influenced by the chemical characteristics (soluble compounds) and morphological features of the residues, as well as the particle size and location in the soil. The C mineralization of the residues, whether incorporated or surface-applied, was also affected by moisture content and temperature. The initial C mineralization was higher for crop residues with low C/N ratio and high N concentration than for those with high C/N ratio and low N concentration (Table 2; Fig 1 and 2). This is consistent with the findings of previous studies (Li *et al*., 2011). The substrate quality and nitrogen availability in soil affect the microbial activity (Muhammad *et al*., 2011). When residue decomposes, it releases nitrogen into the soil, which acts as an N source for the microorganisms and enhances C mineralization.

Thus, the initial N concentration might have influenced the C mineralization of the residues (Poudel *et al*., 2023). Cowpea residue, being a legume, had higher N content and lower C/N ratio than cotton and maize residues (Table 2) and therefore decomposed faster regardless of placement. In contrast, maize and cotton residues had high C/N ratio (Table 2). Furthermore, adding external nitrogen and carbon sources improved the carbon mineralization in respective treatments than in residue alone treatments (Fig 3).

CONCLUSION

The study focused on addressing the issues of crop residue accumulation in the western zone of Tamil Nadu and sought to enhance carbon mineralization as a means of converting this agricultural waste into a valuable resource for enriching soil nutrient content. In this study, we focused on addressing crop residue accumulation in Tamil Nadu's western zone by enhancing carbon mineralization to convert agricultural waste into a valuable soil enrichment resource. Results showed that incorporating crop residues into the soil, especially with 1% microbial consortia, 2.0% jaggery and 1% urea, significantly promoted carbon mineralization. Cowpea exhibited the highest performance (692 µg C g-1 soil), followed by cotton (564 µg C g-1 soil) and maize (522 µg C g-1 soil). The Michaelis-Menten model, with an R2 value of 0.95 for cowpea, supported this trend. The maximum Vmax of 951.72 µmol/min for cowpea-incorporated residues further confirms the efficiency of this approach. This study has practical implications for farmers in the region, offering a sustainable solution to improve soil nutrient content while managing crop residues responsibly.

Conflict of interest

The authors declare no competing interests.

REFERENCES

Abiven, S., Recous, S. (2007). Mineralisation of crop residues on the soil surface or incorporated in the soil under controlled conditions. Biol Fertil Soils. 43: 849-852. DOI: 10.1007/s00374-007-0165-2.

Al-Kaisi, M. (2011). Tillage and Crop Residue Effects on Soil Carbon Turnover Using the Michaelis-Menten Approach. Environmental Science, Agricultural and Food Sciences. DOI: 10.1201/b10600-15.

Angers, D.A., Recous, S. (1997). Decomposition of wheat straw and rye residues as affected by particle size. Plant Soil. 189: 197-203.

Blake, G.R. and Hartge, K.H. (1986) Bluk Density, In: Method of soil Analysis, [Klute, A. (Eds.)], Part I. Physical and Mineralogical Methods: Agronomy Monograph no.9 (2nd ed.), American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin, pp. 363-375.

Cooper, J.M., Burton, D., Daniell, T.J., Griffiths, B.S. and Zebarth, B.J. (2011). Carbon mineralization kinetics and soil biological characteristics as influenced by manure addition in soil incubated at a range of V temperatures. European Journal of Soil Biology. 47(6): 392-399. DOI: 10.1016/j.ejsobi.2011.07.010.

Datta, A., Jat, H.S., Yadav, A.K., Choudhary, M., Sharma, P. C., Rai, M. and Jat, M.L. (2019). Carbon mineralization in soil as influenced by crop residue type and placement in an Alfisols of Northwest India. Carbon Management. 10(1): 37-50. doi.org/10.1080/17583004.2018.1544830.

Jackson, M.L. (1967) Soil chemical analysis. Prentice Hall of India Pvt. Ltd. New Delhi.

Kaur, H., Kommalapati, R.R. and Saroa, G.S. (2023). Kinetics of native and added carbon mineralization on incubating at different soil and moisture conditions in Typic Ustochrepts and Typic Halustalf. International Soil and Water Conservation Research. 11(2): 365-381. DOI: 10.1016/j.iswcr.2023. 01.006.

Kumar, S., Gopinath, K.A., Sheoran, S., Meena, R.S., Srinivasarao, C., Bedwal, S. and Praharaj, C.S. (2023). Pulse-based cropping systems for soil health restoration, resources conservation and nutritional and environmental security in rainfed agroecosystems. Frontiers in Microbiology. 13: 1041124. DOI: 10.3389/fmicb.2022.1041124.

Li, L.J., Han, X.Z., You, M.Y., Yuan, Y.R., Ding, X.L. and Qiao, Y.F. (2013). Carbon and nitrogen mineralization patterns of two contrasting crop residues in a Mollisol: Effects of residue type and placement in soils. Euro J. Soil Biol. 54: 1-6.

Li, L.J., Zeng, D.H., Yu, Z.Y., Fan, Z.P., Yang, D. and Liu, Y.X. (2011). Impact of litter quality and soil nutrient availability on leaf decomposition rate in a semi-arid grassland of Northeast China. J. Arid Environ. 75: 787-792. doi.org/10.1016/j.jaridenv.2011.04.009.

Muhammad, W., Vaughan, S.M., Dalal, R.C. and Menzies, N.W. (2011). Crop residues and fertilizer nitrogen influence residue decomposition and nitrous oxide emission from a Vertisol. Biol Fertil Soils. 47: 15-23. doi.org/10.1007/s00374-010-0497-1.

Olsen, C.R., Cole, C.V., Wantanable, F.S. and Dean, L.A. (1954). Estimation of available P in soil by extraction with sodium bicarbonate. USDA Circ. No. 939. Washington, 19pp.

Poudel, P., Parajuli, B., Park, D. and Ye, R. (2023). Cover crop residues decomposition and nutrient releases in a sandy ultisols of us coastal plain: Impacts of termination timing. Communications in Soil Science and Plant Analysis. 1-18.

Rieke, E.L., Cappellazzi, S.B., Cope, M., Liptzin, D., Mac Bean, G., Greub, K.L. and Honeycutt, C.W. (2022). Linking soil microbial community structure to potential carbon mineralization: A continental scale assessment of reduced tillage. Soil Biology and Biochemistry. 168: 108618. doi.org/10.1016/j.soilbio.2022.108618.

Rakesh, S., Sarkar, D., Sinha, A.K., Shikha, Mukhopadhyay, P., Danish, S., Fahad, S. and Datta, R. (2021). Carbon mineralization rates and kinetics of surface-applied and incorporated rice and maize residues in entisol and inceptisol soil types. Sustainability. 13(13): 7212. Doi: https://doi.org/10.3390/su13137212.

Sandhu, O.S., Jat, M.L., Gupta, R.K., Thind, H.S., Sidhu, H.S. and Singh, Y. (2022). Influence of residue type and method of placement on dynamics of decomposition and nitrogen release in maize-wheat-mungbean cropping on permanent raised beds: A litterbag study. Sustainability. 14(2): 864. doi.org/10.3390/su14020864.

Stegarescu, G., Escuer-Gatius, J., Soosaar, K., Kauer, K., Tõnutare, T., Astover, A. and Reintam, E. (2020). Effect of crop residue decomposition on soil aggregate stability. Agriculture. 10(11): 527. DOI: 10.3390/agriculture10110527.

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for the determination of available nitrogen in soils. Curr Sci. 25: 259-260.

Turmel, M.S., Speratti, A., Baudron, F., Verhulst, N. and Govaerts, B. (2015). Crop residue management and soil health: A systems analysis. Agricultural Systems. 134: 6-16.

Wang, X., He, C., Liu, B., Zhao, X., Liu, Y., Wang, Q. and Zhang, H. (2020). Effects of residue returning on soil organic carbon storage and sequestration rate in China's croplands: A meta-analysis. Agronomy. 10(5): 691. doi.org/10.3390/agronomy10050691.