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Quantification of soil labile carbon content in lowland rice ecology amended by different bio-wastes

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Abstract

Soil organic carbon (SOC) plays a critical role in terrestrial carbon cycling and is central to preserving soil quality. The effects of bio-wastes on soil carbon storage were investigated. The SOC has different pools and fractions including microbial biomass carbon (MBC), readily mineralizable carbon (RMC), and water soluble carbon (WSC). Each has a varying degree of decomposition rate and stability. The rice straw + RDF treatment was more effective in increasing WSC, MBC, RMC concentrations than the RDF treatment alone. Therefore, it could be the best option for improving carbon storage and soil health while emerging as best bio-waste management technology in the rice–rice cropping system.

Keywords: Rice, bio-waste amendments, carbon pools

Introduction

Soil organic carbon (SOC) is an important component for the functioning of agro-ecosystems, and its presence is central to the concept of sustainable maintenance of soil health. Soil represents the main and largest terrestrial stock of carbon with global carbon storage of 1550 Pg (Batjes, 1996) [1], and it accounts approximately for two and three times more carbon than in the atmosphere and vegetation, respectively (Scharlemann *et al*., 2014). Hence, a minor change in the terrestrial carbon pool could have a significant impact on climate change and global warming (Zhang *et al*., 2016) [25].

The soil organic matter (SOM) is considered as the most complex and least understood component of soil, because it is comprised of plant, microbial, and animal bodies in various stages of disintegration and a mixture of heterogeneous organic substances closely associated with the inorganic constituents (Christensen, 1992) [7]. The SOM is a vital indicator of soil quality and, therefore, maintaining SOM quality and quantity is important for safeguarding long-term soil fertility (Ramesh *et al*., 2013; Tisdale *et al*., 1995; Zhao *et al*., 2015) [16, 19, 26]. It has beneficial effects on soil physical (soil structural stabilization), chemical (buffering and changes in soil pH), and biological properties (substrate and supply of nutrients for microbes), and thus it influences the productive capacity of the soil (Verma *et al*., 2013; Wang *et al*., 2017a,b) [21-23]. Maintenance and improvement of SOM quality and quantity are the most essential criteria for sustainable soil management (Campbell and Paustian, 2015; Qin *et al*., 2010) [6, 15].

There is a strong need to increase SOC density to improve the quality of natural resources for sustainable crop productivity and to mitigate global warming. However, with the rapid economic and social development, tropical paddy soils are subject to degradation as characterized by low organic carbon content and low crop productivity.

Recently, a number of agricultural management strategies have been proposed, including the development of new rice varieties, as well as the selection of appropriate water management approaches, cultivation methods, and fertilisation schemes, in an attempt to boost up rice yield and soil health. Meanwhile, the application of bio/agricultural wastes, for example, rice straw incorporation and rice straw compost, is also a typical method of improving the soil quality of paddy fields.

The application of straw in combination with inorganic fertilizer is an attractive alternative to burning because it can provide essential nutrients for crops (Edmeades, 2003) [8]. To realize the vast SOC sequestration potential for national benefit, adoption of recommended management practices, including the integrated use of organic and inorganic fertilizer, is necessary.

2. Materials and methods

The study site is situated in the experimental farm of the Central Rice Research Institute, Cuttack (20º 25' N, 85º 55' E; 24 m above mean sea level) in the eastern part of India. The climate is basically tropical. The mean annual precipitation is around 1500 mm. The soil is an Aeric Endoaquept with sandy clay loam texture (28.7% clay, 17.5% silt, 53.8% sand). The experiment was started in the Kharif season, 2018 and soil of the experimental site had a bulk density 1.39 Mg m^{-3}, pH (using 1:2.5, soil: water suspension) 6.0 and soil organic carbon (SOC) 5.40 g Kg^{-1}.

The experimental setup was under lowland rice-rice system. The treatments in rice included: (i) RDF; 80:40:40 kg N: P_2O_5: K_2O ha^{-1} (ii) RDF, Ammonium sulphate (replace Urea), (iii) RDF + Rice straw incorporation (5t/ha) (iv) RDF + Rice straw compost (5t/ha).

Soil samples were collected at different crop growth stages of the rice crop by a sample probe from the depth of 0–15 cm. Individual soil cores were taken at five different growth stages: Active tillering, maximum tillering, panicle initiation, grain filling and Maturity. The fresh soil samples were kept in the refrigerator at 4^0C for biochemical analyses.

Soil microbial biomass carbon (MBC) content of the soil samples was estimated by chloroform fumigation–extraction method with fumigation at atmospheric pressure with some modification (Witt *et al*., 2000) [24]. Readily mineralizable carbon (RMC) was measured after extraction with 0.5 M K_2SO_4 (Inubushi *et al*., 1991) [10] followed by wet digestion of the soil extract with dichromate (Vance *et al*., 1987) [20]. The water soluble carbohydrate carbon (WSC) was measured by the procedure as described by Haynes and Swift (1990) [9].

3. Results

3.1 Microbial biomass carbon (MBC)

Significant ($p \leq 0.05$) increase in the MBC content was observed under bio waste amended treatments throughout the crop growth stages in the wet season (Fig.1). The maximum MBC content was observed at the panicle initiation (PI) stage. Microbial biomass carbon content was ranged from 147.5–432.0 µg C g^{-1} during wet season of *2018* (Fig.1). Highest MBC content was found under RDF+RSI. The lowest MBC content was observed at the maturity (M) stage. The lowest MBC was found under RDF + AS.

3.2. Readily Mineralizable Carbon (RMC)

Significant ($p \leq 0.05$) increase in the RMC content was observed under bio waste amended treatments throughout the crop growth stages in the wet season (Fig.2). The maximum RMC content was observed at the panicle initiation (PI) stage. Microbial biomass carbon content was ranged from 68.1–265.4 µg C g^{-1} during wet season of *2018* (Fig.2). Highest RMC content was found under RDF+RSI. The lowest RMC content was observed at the maturity (M) stage. The lowest MBC was found under RDF.

3.3. Water Soluble Carbon (WSC)

Significant ($p \leq 0.05$) increase in the WSC content was observed under bio waste amended treatments throughout the crop growth stages in the wet season (Fig.3). The maximum WSC content was observed at the panicle initiation (PI) stage. Microbial biomass carbon content was ranged from 37.5 – 117.5 µg C g^{-1} during wet season of *2018* (Fig.3). Highest WSC content was found under RDF+RSI. The lowest WSC content was observed at the maturity (M) stage. The lowest WSC was found under RDF.

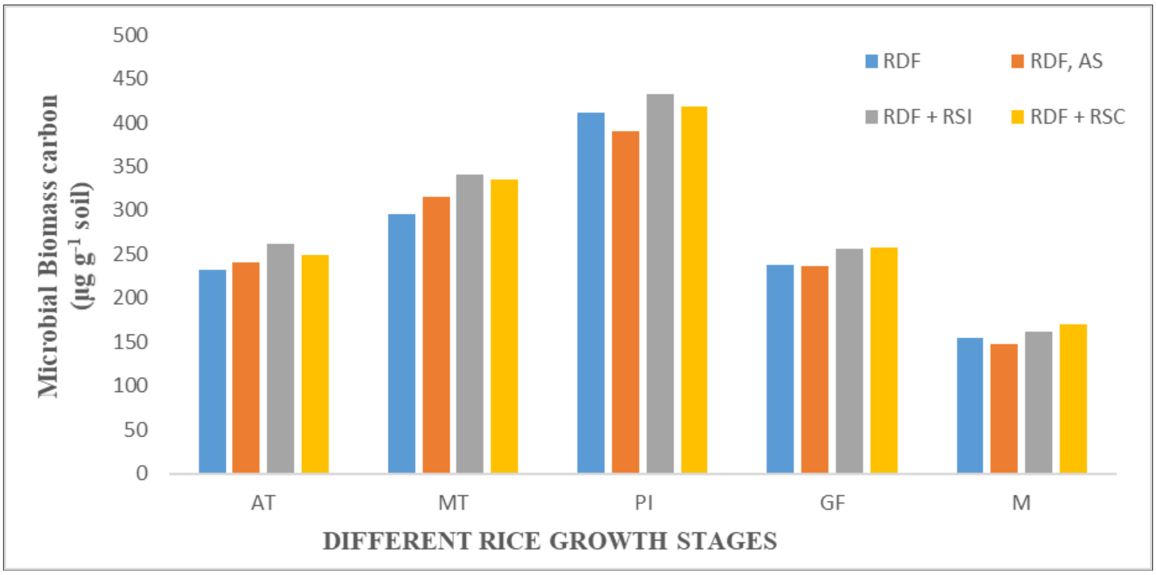

Fig 1: Microbial biomass carbon (MBC) content during various stages of plant growth under different treatments amended by bio waste amendments

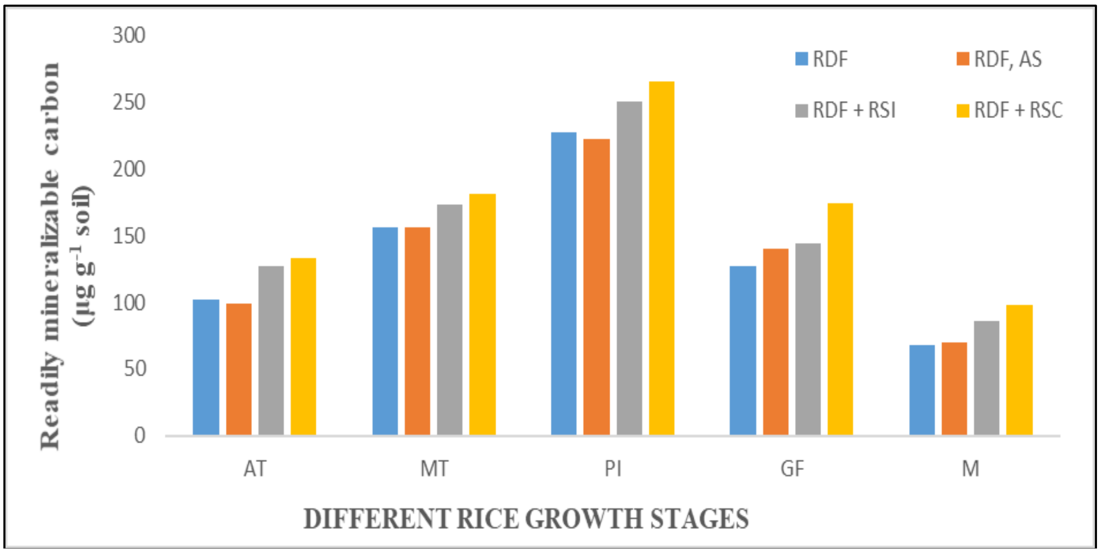

Fig 2: Readily mineralizable carbon (RMC) content during various stages of plant growth under different treatments amended by bio waste amendments

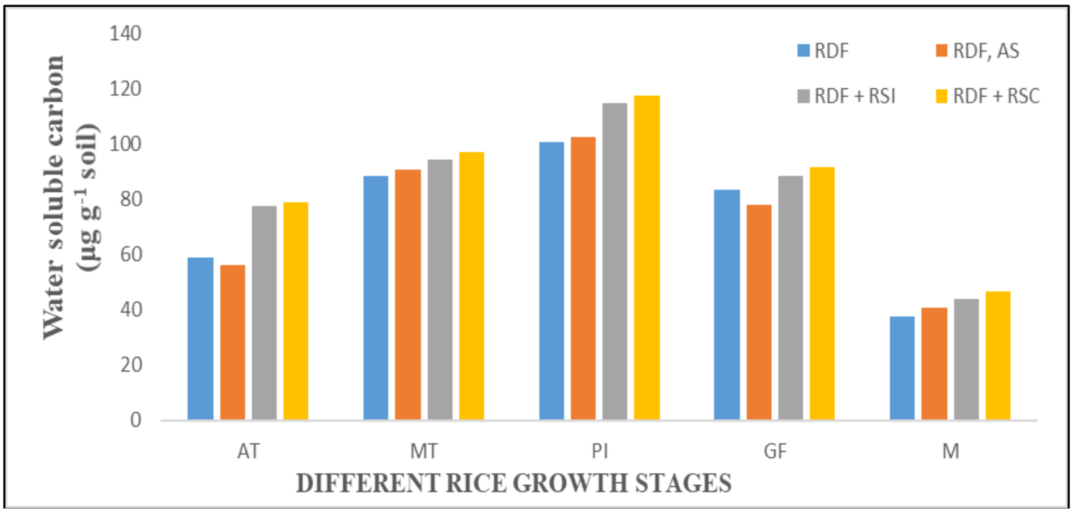

Fig 3: Water soluble carbon (WSC) content during various stages of plant growth under different treatments amended by bio waste amendments.

4. Discussion

4.1 Effect of bio waste amendments on soil carbon pool

Application of bio wastes have been reported to significantly affect soil carbon pools due to addition of C input of varying turnover rate and balanced fertilizer application. The status of MBC indicates the rate of soil organic matter decomposition and nutrient cycling in soil. It could be used as mirror of labile C fraction of soils, which is sensitive to management intervention and climate change (Pandey *et al*. 2014) [14]. Balanced fertilizer application along with different organic and inorganic amendments affect the status of MBC in the lowland flooded soil (Dash *et al*., 2017; Bhattacharyya *et al*., 2012a, 2013; Bhatt, 2017) [13, 5, 4, 2, 3]. But when rice straw incorporation is associated with recommended doses of fertilizer, the labile C and nitrogen source, supports the growth of microbial biomass, which in turn promotes the priming effect of soil organic matter resulting into higher decomposition (Dash *et al*., 2017) [13]. So soil received with this treatment would build up high labile carbon fractions in the soil, characterized by high mineralization potential. In this study also, labile C pools such as RMC, WSC and MBC in soil showed significantly higher values under bio-waste amendment treatments. The application of bio-waste amendments affect mineralization rates of soil organic matter and contribute to increase in soil organic C content by increasing residue input with increased crop production (Iqbal *et al*., 2009) [11]. In general, increase in C in lowland paddy was due to the low rate of C decomposition and higher net ecosystem production (Bhattacharyya *et al*., 2014). In some, though not all, situations this is likely to result in improved crop growth at a given level of fertilizer input. However, application of manures and other organic materials provides a means of recycling nutrients, which leads to a greater labile C pool in soil, could lead to increasing SOC.

Different treatments showed significant difference in MBC content. Dash *et al*., (2017) [13] reported that the application of inorganic fertilizers along with combination of organic manure had significant effect on SOC and its fractions including MBC due to the significant increase in carbon input after application of manure. Soil MBC regulates both soil organic matter decomposition and nutrient cycling, and also due to its immediate response and high sensitivity to management practices and environmental changes (Rudrapa *et al*., 2007). Bio-waste amendments provide a potential source of labile carbon pool and thus significantly influenced soil C pools in the present study. Similar result was reported by Bhattacharyya *et al*., (2012) [5], where application of inorganic fertilizer itself or along with green manure and rice straw had higher amount of labile carbon pool.

5. Conclusion

The application of inorganic fertilizers in combination with organic manures to a rice–rice ecosystem resulted in soil carbon build up and increase in crop productivity. However, carbon storage and carbon sequestration capacity were influenced by both the recalcitrant and labile nature of the inputs, varied significantly among the different treatments. Thus, the combination of an inorganic fertilizer along with bio-waste amendments resulted in a significant build-up of soil carbon and indirectly enhancement of crop yield.

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Reference

1. Batjes NH. Total carbon and nitrogen in the soils of the world. Eur. J. Soil Sci. 1996; 47:151-163.
2. Bhatt R. Zero tillage impacts on soil environment and properties. Environ. Agric. Sci. 2017; 10:01-19.
3. Bhatt R, Kukal SS. Tillage and establishment method impacts on land and irrigation water productivity of wheat-rice system in north-west India. Exp. Agric. 2017; 53(2):178-201.
4. Bhattacharyya P, Nayak AK, Mohanty S, Tripathi R, Shahid M, Kumar A *et al*. Greenhouse gas emission in relation to labile soil C, N pools and functional microbial diversity as influenced by 39 years long-term fertilizer management in tropical rice. Soil Tillage Res. 2013; 129:93-105.
5. Bhattacharyya P, Roy KS, Neogi S, Adhya TK, Rao KS, Manna MC. Effects of rice straw and nitrogen fertilization on greenhouse gas emissions and carbon storage in tropical flooded soil planted with rice. Soil Tillage Res. 2012a; 124:119-130.
6. Campbell EE, Paustian K. Current developments in soil organic matter modelling and the expansion of model applications: a review. Environ. Res. Lett. 2015; 10(12):123004.
7. Christensen BT. Physical fractionation of soil organic matter in primary particles and density separates. Adv. Soil Sci. 1992; 20:1-76.
8. Edmeades DC. The long-term effects of manures and fertilizers on soil productivity and quality: a review. Nutrient Cycling in Agro ecosystems 2003; 66:165-180.
9. Haynes RJ, Swift RS. Stability of soil aggregates in relation to organic constituents and soil water content. Journal of Soil Science. 1990; 41:73-83.
10. Inubushi K, Brookes PC, Jenkinson DS. Soil microbial biomass C, N and ninhydrin-N in aerobic and anaerobic soils measured by fumigation-extraction method. Soil Biology & Biochemistry 1991; 23:737-741.
11. Iqbal J, Hu R, Lin S, Hatano R, Feng M, Lu L *et al*. CO2 emission in a subtropical red paddy soil (Ultisol) as affected by straw and N fertilizer applications: a case study in Southern China. Agric. Ecosyst. Environ. 2009; 131:292-302.
12. Liang CH, Yan YIN, Qian CHEN. Dynamics of soil organic carbon fractions and aggregates in vegetable cropping systems. Pedosphere. 2014; 24(5):605-612.
13. Dash PK, Bhattacharyya P, Shahid M, Roy KS, Swain CK, Tripathi R *et al*. "Low carbon resource conservation techniques for energy savings, carbon gain and lowering GHGs emission in lowland transplanted rice", Soil and Tillage Research, 2017
14. Pandey A, Mai VT, Vu DQ, Bui TPL, Mai TLA, Jensen LS *et al*. Organic matter and water management strategies to reduce methane and nitrous oxide emissions from rice paddies in Vietnam. Agric. Ecosyst. Environ. 2014; 196:137-146.
15. Qin S, Hu C, He X, Dong W, Cui J, Wang Y. Soil organic carbon, nutrients and relevant enzyme activities in particle-size fractions under conservational versus traditional agricultural management. Appl. Soil Ecol. 2010; 45(3):152-159.
16. Ramesh T, Manjaiah KM, Tomar JMS, Ngachan SV. Effect of multipurpose tree species on soil fertility and CO2 efflux under hilly ecosystems of Northeast India. Agrofor. Syst. 2013; 87(6):1377-1388.
17. Rudrappa L, Purakayastha TJ, Singh D, Bhadraray S. Long-term manuring and fertilization effects on soil organic carbon pools in a Typic Haplustept of semi-arid sub-tropical India. Soil Tillage Res. 2006; 88:180-192.
18. Scharlemann JP, Tanner EV, Hiederer R, Kapos V. Global soil carbon: understanding and managing the largest terrestrial carbon pool. Carbon Manage. 2014; 5(1):81-91.
19. Tisdale SL, Nelson WL, Beaton JD, Havlin JL. Soil Fertility and Fertilizers, fifth ed. Macmillan Publ. Co., New York. 1995, 634.
20. Vance ED, Brookes PC, Jenkinson DS. An extraction method for measuring soil microbial biomass carbon. Soil Biology and Biochemistry. 1987; 19:703-707.
21. Verma BC, Datta SP, Rattan RK, Singh AK. Labile and stabilised fractions of soil organic carbon in some intensively cultivated alluvial soils. J. Environ. Biol. 2013; 34(6):1069.
22. Wang X, Butterly CR, Baldock JA, Tang C. Long-term stabilization of crop residues and soil organic carbon affected by residue quality and initial soil pH. Sci. Total Environ. 2017a; 587:502-509.
23. Wang Z, Liu S, Huang C, Liu Y, Bu Z. Impact of land use change on profile distributions of organic carbon fractions in peat and mineral soils in Northeast China. Catena 2017b; 152:1-8.
24. Witt C, Cassman KG, Olk DC, Biker U, Libon SP, Samson MI *et al*. Crop rotation and residue management effects on carbon sequestration, nitrogen cycling and productivity of irrigated rice system. Plant and Soil. 2000; 225:263-278.
25. Zhang L, Zhuang Q, He Y, Liu Y, Yu D, Zhao Q, Wang G. Toward optimal soil organic carbon sequestration with effects of agricultural management practices and climate change in Tai-Lake paddy soils of China. Geoderma 2016; 275:28-39.
26. Zhao YG, Liu XF, Wang ZL, Zhao SW. Soil organic carbon fractions and sequestration across a 150-yr secondary forest chronosequence on the Loess plateau, China. Catena. 2015; 133:303-308.