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Effect of Long Term Manuring on Soil Carbon Stock and Some Biological Properties under Rice – Rice Cropping System in an *Inceptisol* of Bhubaneswar, Odisha, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This research was carried out to determine the effect of different manurial treatments on the quantity of carbon added to soil through stubble in rice-rice cropping system, organic carbon stock and its relation to biological properties in an *Inceptisol* of Bhubaneswar, Odisha. This has been contemplated in existing Long Term Fertilizer Experiment which is in progress since 1994 located

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in Central Research Station, OUAT with Rice-Rice cropping sequence. The experiment dealt with six treatments during the eighth crop cycle viz, 100% NPK, 100% NPK + FYM, 100% N, 100% NP, 100% NPK +Lime, control (no manuring) with 4 replications in a randomized block design. Both in the kharif and the rabi seasons, rice stubble with undisturbed roots was meticulously collected, processed, and tested for total carbon after rice harvest. The usual approach was followed when collecting and analyzing soil samples. Between 1223.5 and 2571.5 kg/ha of carbon and 2998.9 to 6330.85 kg/ha of total stubble were absorbed into the soil. After kharif and rabi, the surface carbon stock of the soil ranged from 7.41 to 12.50 Mg/ha and 7.14 to 11.76 Mg/ha, respectively. After kharif, the SOC of surface soil ranged between 3.48 and 6.51 g/kg and 3.35 and 6.13 g/kg. In 100% NPK+ FYM, the highest amounts of stubble, stubble carbon, and MBC were found. No manuring enhanced the BD (1.42 Mg/m3) but the addition of FYM and stubble decreased the BD (1.28 Mg/m3). MBC varied from 45.89 to 132.41 g of carbon per g of soil. The importance of subble addition in enhancing SOC was demonstrated by the significantly positive association between SOC and quantity of stubble addition (r = 0.85), carbon addition by stubble (r = 0.94), and carbon stock (r =0.91**). Similar to this, the MBC-SOC connection (r = 0.83**), which supported the contribution of SOC to collective formation. The strong positive link between SOC and MBC suggests that adding carbon helps to improve soil health, and rice straw is an excellent source of carbon. It needs to be suppressed in the soil.

Keywords: Carbon residues; cropping system; long term fertilizer; soil carbon stock.

1. INTRODUCTION

Soils are the largest carbon reservoirs of the terrestrial carbon cycle. Soil, if managed properly, can serve as a sink for atmospheric carbon dioxide. Worldwide about 1500 Pg carbon is stored in first 30 cm of soil [1]; for India it is only 9 Pg [2]. Soils contains 3.5% of the 66earth's carbon reserves, compared with 1.7% in the atmosphere, 8.9% in fossil fuels,1.0% in biota and 84.9% in the oceans [3]. Soil is the largest terrestrial C pool, encompassing approximately two-thirds of C in ecosystem. Also, mean residence time of soil organic carbon pools have the slowest turnover rates in terrestrial ecosystems and thus C sequestration in soil has potential to mitigate CO_2 emission to the atmosphere.

Under different crops varieties and land use pattern C sequestration in soil is different [3]. Manuring and fertilization influences soil organic carbon content.SOC content increases under inorganic fertilization, especially for inorganic(N) fertilizer [4]. Inorganic N fertilizers improve the crop residues in the soil; and thus improve the SOC. N fertilizer, however, have been shown to promote the decomposition of crop residues and soil C, a process which may offset the possible increase in C from crop residues [5].

Soil carbon stock is the product of soil organic carbon, bulk density and depth of plough horizon. Organic amendments and rice residues (rice stubble & root) are the main 'C' sources converted soil 'C' in paddy field ecosystem [6]. Many studies in sub-humid and semi-arid soils indicated strong positive relationship between the amount of carbon incorporated into soil organic matter (SOM), either from crop residues or from external sources such as manure, and the content of organic C of the soil [7]. It has also been observed that in C_{org} were linearly related to gross C input into soil.

Bhubaneswar soil is lateritic in origin, light textured, acidic and contains low carbon [8]. The hot and sub humid climatic condition with high monsoon rainfall causes the annual depletion of carbon. There is a scope to capture atmospheric carbon by different manuring practices through stubble in rice-rice cropping system. Rice-rice cropping system is a popular system prevailing in Odisha occupying about 16% of total rice area in Odisha. A substantial quantity of stubble is left in field at the time of harvest by the farmer. In this system, stubble is a good source of carbon. In Bhubaneswar soil under rice-rice cropping system, stubble is incorporated into soil. But information on how much of C is added in different type of manuring through stubble is not available.

The objective of the study is the quantification of incorporated stubble in soil by different manurial treatments, C added through stubble in different treatments, SOC and its effect on soil biological properties.

2. MATERIALS AND METHODS

The long-term fertilizer experiment at E block Central Research Station, OUAT, Bhubaneswar Odisha at ($20^0$16' - $20^0$17' N latitude and $85^0$48-'$85^0$49' E longitude) was selected for this study. The experiment was started in 1994 on Inceptisol (710 g kg^{-1} sand, 120 g kg^{-1} silt and 170 g kg^{-1} clay). The initial pH (1:2) was 5.8, electrical conductivity 0.12 dS m^{-1}, SOC: 4.3 g kg^{-1}, CEC: 3.75 c mol (P^+) kg^{-1}, Alkaline $KMnO_4$ available N: 187 kg ha^{-1}, $NaHCO_3$ extractable P: 19.4 kg ha^{-1}, NH_4OAC extractable K: 93.4 kg ha^{-1} content of soil. The field experiment was laid out in randomized block design with four replications and treatments *viz.*, T_1 (100% NPK), T_2 (100%NPK +FYM), T_3 (100% N), T_4 (100% NP), T_5 (100%NPK +Lime), T_6 (Control- no manure and fertilizer). 100% recommended dose of fertilizer 80 kg N, 40 kg P_2O_5, 60 kg K_2O was applied each year per season. Nitrogen as (Urea) was applied in three splits i.e., 25% basal, 50% at maximum tillering (MT) stage and 25% at panicle initiation (PI) stage. Total phosphorus as basal as DAP and potassium as MOP in two splits 50% as basal and 50% at panicle initiation stage was applied. Manure in the form of FYM @ 5 t ha^{-1} and lime@ 1 t ha^{-1} was applied per .cropping season. Manure with chemical composition and C: N ratio of FYM is given in Table 1.

Table 1. Quality aspect of FYM used during rabi season

Properties	Content
Carbon (%)	20.8
N (%)	0.79
P_2O_5 (%)	0.50
K_2O (%)	0.80
C: N value	26.28

2.1 Soil Sampling

Pre-rabi soil samples were taken in December 2013 and post-rabi soil samples were taken in April 2014. SOC (MBC) was measured using composite surface soil samples from each treatment that were collected at a depth of 0 to 15 cm, air dried, and then put through a 2 mm filter. For the purpose of estimating bulk density, soil cores from 0 to 15 cm of soil depth were obtained.

2.2 Collection and Processing of Stubble

1 square meter metallic frame of 10 cm height was randomly installed in the treatment plot, pressed to (1-2) cm, water was added to make the soil wet, soft and loose. Next day morning stubble was uprooted carefully so that loss of rootlets will be negligible. Root was washed with water, treatment wise stubble was made bunches and tagged, dried for a week under sun then oven dried. Stubble (both shoot and root) were chopped and used for carbon estimation in muffle furnace.

2.3 Soil Analysis

The bulk density of soil samples was determined by applying the core method, which Black (1965) described. Carbon in rice stubble were estimated by hot digestion method. The wet oxidation method devised by Walkley and Black was utilized to assess the soil's organic carbon, and the Vance et al. (1987) reported fumigation and extraction procedure was employed to estimate the carbon in the soil's microbial biomass.

2.4 Plant Analysis

For determining the organic content of root & shoot of recognizable water activity were weighed in a dry silica crucible. Heat was given slowly by raising the temperature setting in 3 steps (100, 400 & 550 ^{0}C). The final temperature setting was at 550 ^{0}C maintained for 8 hrs. Then crucible containing ash was cooled & weighed. Percentage ash and organic matter were calculated by difference between crucibles before & after combustion as follows:

$$\text{Ash (\%)} = \frac{W3 - W1}{W2 - W1} \times 100$$

And organic matter (%) = 100 – ash %

(Where W_1 = The weight of empty crucible, W_2 = The weight of dry crucible containing root & shoot, W_3 = The weight of dry crucible containing root & shoot after following ignition).

3. RESULTS AND DISCUSSION

3.1 Addition of Quantity of Rice Stubble (20 cm) in Soil

A comparison of stubble addition by different treatments stated that 100% NPK + FYM treatment helped in adding 111.10% more over control followed by 63.96 %, 51.39 %, 30.16 %, 21.55 % in 100% NPK + Lime, 100% NPK, 100%NP and 100% N treatment respectively (Table 2). Similarly, comparison of quantity of addition by different treatment over RDF it was found that in 100% NPK +FYM 39.43 % and in 100% NPK + Lime 8.29 % which was positive and in other treatments carbon is added in a drastic reduced quantity of -14.02 %,-19.70 %, -33.94 % in 100%NP,100% N and control treatment. Always in control treatment addition of stubble was the minimum irrespective of season and year. The quantity of stubble in differential treatment was maximum in 100% NPK + FYM followed by 100% NPK + Lime, 100% NPK, 100% NP, 100 %N, control. This trend of quantity of stubble added was due to the differential biomass production in their respective treatments.

3.2 Addition of Carbon in soil Through Rice Stubble

A comparison of carbon addition by different treatments stated that 100% NPK +FYM treatment helped in adding 110.17% more over control followed by 65.50 %, 50.42%, 38.12%, 28.93% in 100% NPK + Lime, 100% NPK, 100%NP and 100% N treatment respectively (Table 3). Similarly comparison of carbon addition by different treatment over RDF it was found that in 100% NPK +FYM 39.71% and in 100% NPK + Lime 10.02% which was positive and in other treatments carbon is added in a drastic reduced quantity of -8.17%, -14.28%,-33.52% in100%NP ,100% N and control treatment. The quantity of carbon added through rice stubble including root was maximum in 100% NPK + FYM followed by 100% NPK + Lime, 100% NPK, 100% NP, 100%N, control. This trend of quantity of 'C' added was due to the multiple quantity of stubble incorporated in the respective treatments [9]. Due to differential biomass production, variable quantity of stubbles and carbon were added in their respective treatments.

Table 2. Quantity of rice stubble (20 cm) added (kg/ha) in different manurial treatments

Treatment	*Kharif* 2012	*Rabi* 2012-13	*Kharif* 2013	*Rabi* 2013-14	Avg/yr	Increase over control (%)	Increase over RDF (%)
100% NPK	2172.5	2452.5	2045.3	2410.3	4540.3	51.39	-
100% NPK + FYM	3086.5	3355.2	2872.5	3347.5	6330.85	111.10	39.43
100% N	1768.4	2002.5	1542.5	1977.5	3645.45	21.55	-19.70
100%NP	1911.2	2097.5	1782.5	2015.6	3903.4	30.16	-14.02
100% NPK + Lime	2522.6	2596.4	2302.5	2412.5	4917	63.96	8.29
Control	1489.1	1597.5	1380.6	1530.6	2998.9	-	-33.94
SE(m)±	191.93	98.05	28.73	88.97			
CD(0.05)	578.45	295.52	86.58	268.15			

Table 3. Effect of long-term manuring on addition of carbon in soil through rice stubble (kg/ha)

Treatment	*Kharif* 2012	*Rabi* 2012-13	*Kharif* 2013	*Rabi* 2013-14	Avg/yr	Increase over control (%)	Increase over RDF (%)
100% NPK	866	981	858	976	1840.5	50.42	-
100% NPK + FYM	1233	1342	1229	1339	2571.5	110.17	39.71
100% N	706	881	697	871	1577.5	28.93	-14.28
100%NP	762	939	753	926	1690	38.12	-8.17
100% NPK +Lime	1008	1024	1001	1017	2025	65.50	10.02
Control	592	639	584	632	1223.5	-	-33.52
SE(m)±	28.08	57.91	25.32	28.37			
CD(0.05)	84.66	174.57	76.33	85.52			

3.3 Carbon Stock

Organic carbon stock was calculated as per the formula [(C_{stock} = SOC (%) × BD (Mg m^{-3} × soil depth (m) ×100]. Data showed that it varied from 7.41 to 12.50 Mg ha^{-1} and 7.14 to 11.76 Mg ha^{-1} of (0-15) cm soil depth post-harvest soils of *kharif* and *rabi* season respectively (Table 4). The minimum SOC stock was observed in control where as maximum was found out in 100% NPK+ FYM treatment followed by 100% NPK + Lime. The SOC stock value was in order of control< 100% N < 100% NPK< 100% NP < 100% NPK + Lime < 100% NPK+ FYM. After continuous 7 cropping cycles a good amount of organic matter in the form of in situ stubble and external FYM were added in the treatment resulting in significantly higher quantity of soil organic carbon stock than any other treatment. This type of findings corroborated using the results of [9,10].

Table 4. Effect of long-term manuring on Carbon stock (Mg ha^{-1}) of soils after harvest of *Kharif* and *Rabi* crops

Treatment	(0-15)cm	
	Kharif	***Rabi***
100% NPK	10.57	9.37
100% NPK+ FYM	12.50	11.76
100% N	10.11	9.14
100%NP	10.25	9.30
100% NPK+ Lime	10.92	9.80
Control	7.41	7.14
SE(m)±	0.44	0.43
CD(0.05)	1.31	1.30

3.4 Soil Organic Carbon

SOC value varied from 3.48 to 6.51(g/kg) and 3.35 to 6.13 (g/kg) of (0-15) cm soil during *kharif* and *rabi* respectively. Similarly, in (15-30) cm of depth SOC value for above season varied from 1.65 to 4.65 g/kg and 1.38 to 4.32 g/kg respectively. SOC value of surface soil was found to be higher than subsurface soil in respective treatments irrespective of seasons. The minimum SOC was observed in control where as maximum SOC was found out in 100% NPK+ FYM treatment followed by 100% NPK+ Lime treatment. The SOC value was in the order of control < 100% N < 100% NP< 100% NPK < 100% NPK + Lime < 100% NPK+ FYM.SOC value was found maximum in NPK +FYM treated plot followed by NPK + Lime , 100% NPK, 100% NP, 100% N control in decreasing order (Table 5). The significantly greater SOC in the NPK+ FYM treatment was caused by both the addition of more stubble and FYM. In their research on agricultural soils, they reported identical outcomes that have been amply documented by [11]. The amount of organic carbon in soil was thought to depend on the farming system's net input of organic residues [12]. The findings made it abundantly evident that the carbon store was higher in kharif than in rabi due to more SOC, a cooler environment, and more stubble addition.

Table 5. Effect of long-term manuring on SOC (g/kg) of soils after harvest of *Kharif* and *Rabi* crops

Treatment	(0-15)cm	
	Kharif	***Rabi***
100% NPK	5.34	4.73
100% NPK+ FYM	6.51	6.13
100% N	4.92	4.45
100%NP	5.10	4.63
100% NPK+ Lime	5.6	5.03
Control	3.48	3.35
SE(m)±	0.20	0.23
CD(0.05)	0.60	0.70
Initial	4.3	

3.5 Bulk Density (BD)

The BD varied from 1.28 to 1.42 Mg m^{-3} in (0-15) cm, less than the initial BD (1.55 Mg m^{-3}) and 1.32 to 1.49 Mg m^{-3} in (15-30) cm of soil (Table 6). Addition of stubble, FYM and inorganic fertilizer helped in reducing the BD. Imbalanced or no fertilization increase the BD due to comparatively less stubble addition and compaction. The BD value of subsurface soil is higher than the surface soil irrespective of treatments [13].

Table 6. Effect of long-term manuring on BD (Mg m^{-3}) of soils after harvest of *Kharif* crops

Treatment	(0-15) cm
100% NPK	1.32
100% NPK+ FYM	1.28
100% N	1.37
100%NP	1.34
100% NPK+ Lime	1.30
Control	1.42
SE(m)±	0.04
CD(0.05)	0.11
Initial	1.55

3.6 Microbial Biomass Carbon (MBC)

The data revealed that the value of MBC varied from 111.21 to 204.93 µg of C g^{-1} and 45.89 to 132.41 µg of C g^{-1} (0-15) cm soil in *kharif* and *rabi* respectively (Table 6). Similarly, in (15-30) cm depth the value of MBC for above seasons varied from 44.32 to 93.79 µg of C g-1 and 32.18 to 81.59 µg of C g^{-1} respectively. Regardless of the season, the MBC value of surface soil was found to be higher than subsurface soil in the corresponding treatments. The control had the lowest MBC value, whereas 100% NPK+ FYM therapy had the highest MBC value, followed by 100% NPK + Lime. The MBC value fell into the following categories: 100% N, 100% NP, 100% NPK, 100% NPK + Lime, and 100% NPK+ FYM. The agro-nutrient ecosystem's cycling depends greatly on the microbial biomass. The amount of microbial biomass in a soil is significantly influenced by soil management practises. In the current experiment, a number of long-term manuring practises had a considerable impact on soil MBC (Table 7). The MBC was low in the control and unbalanced fertiliser treatments, but it drastically rose after applying manure and the proper quantity of NPK. Similar findings have been reported by a number of other researchers [14-16]. The rapidly metabolizable carbon and nitrogen in organic manure, as well as growing root biomass and root exudates as a result of improved crop development, are the main contributors to the biomass rise.

3.7 Correlation between SOC with Addition of Stubble, Carbon Added, Carbon Stock

Results on Correlation study of SOC with C enhanced by stubble, C stock of soil (Figs. 1, 2, 3, 4 ,5, 6) was found to be significantly high.

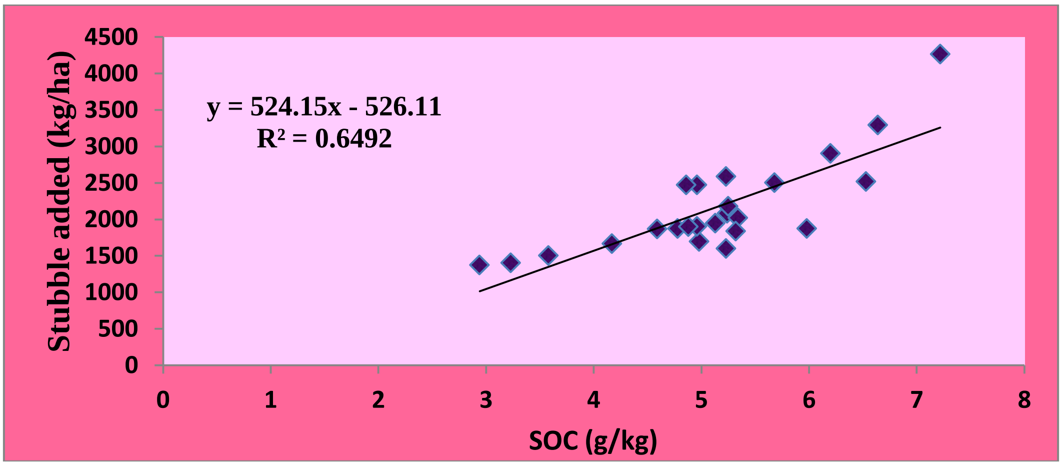

Fig. 1. Correlation between SOC (*Kharif* 2013) and addition of stubble (*Rabi* 2012-13)

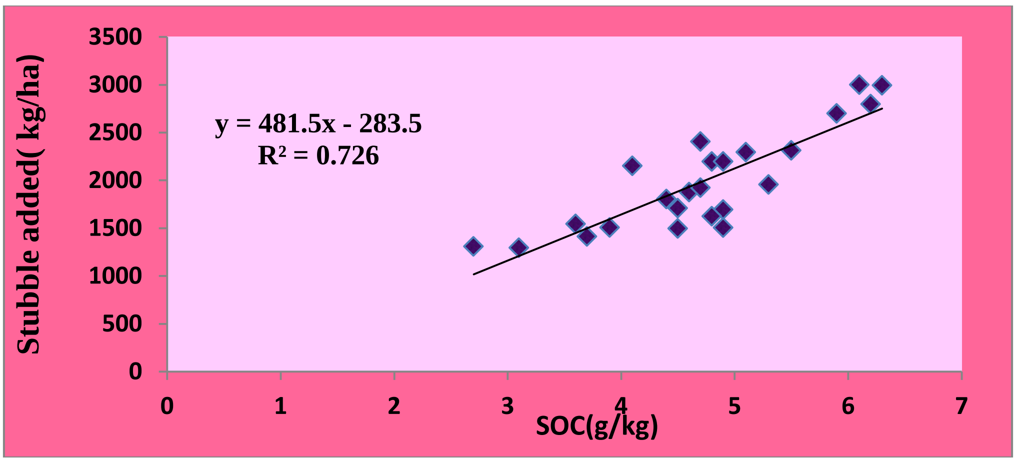

Fig. 2. Correlation between SOC (*Rabi* 2013-14) and addition of stubble (*Kharif* 2013)

Correlation between SOC (*Kharif* 2013) with addition of stubble (*Rabi* 2012-13), SOC (*Rabi* 2013-14) with addition of stubble (*Kharif* 2013) was found to be ($r = 0.80^{**}$), ($r = 0.85^{**}$) respectively. This showed contribution of stubble in SOC was more in *Rabi* 2013-14 than that of *Rabi* 2012-13 and between SOC (*Kharif* 2013) with carbon added through stubble (*Rabi* 2012-13) and SOC (*Rabi* 2013-14) with carbon added through stubble (*Kharif* 2013-14) found to be ($r = 0.94^{**}$) and ($r = 0.85^{**}$) respectively. A significant interaction across SOC (kharif) with carbon stock in *Kharif* and SOC (*rabi*) with carbon stock in *rabi* were ($r = 0.88^{**}$) and ($r = 0.91^{**}$) respectively. A substantial relationship between SOC and MBC ($r = 0.83^{**}$) (Fig. 6) were found indicating role of stubble incorporation in elevated SOC, MBC.

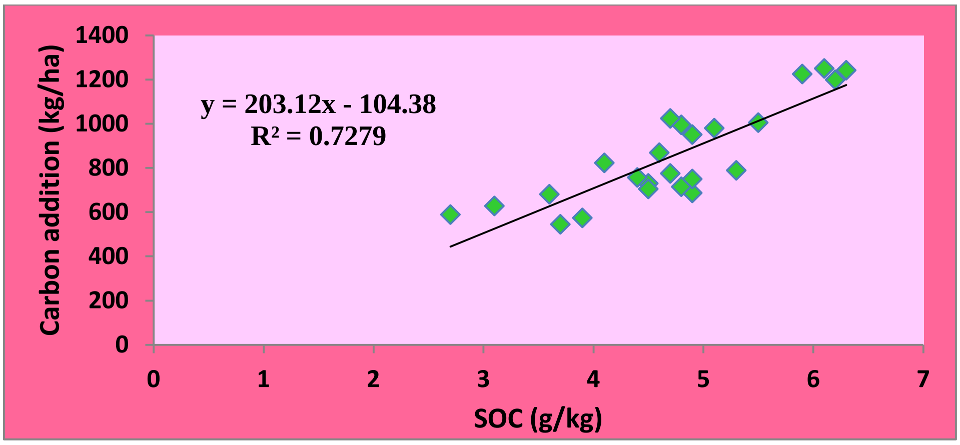

Fig. 3. Correlation between SOC (*Rabi* 2013-14) with carbon addition through stubble (*Kharif* 2013)

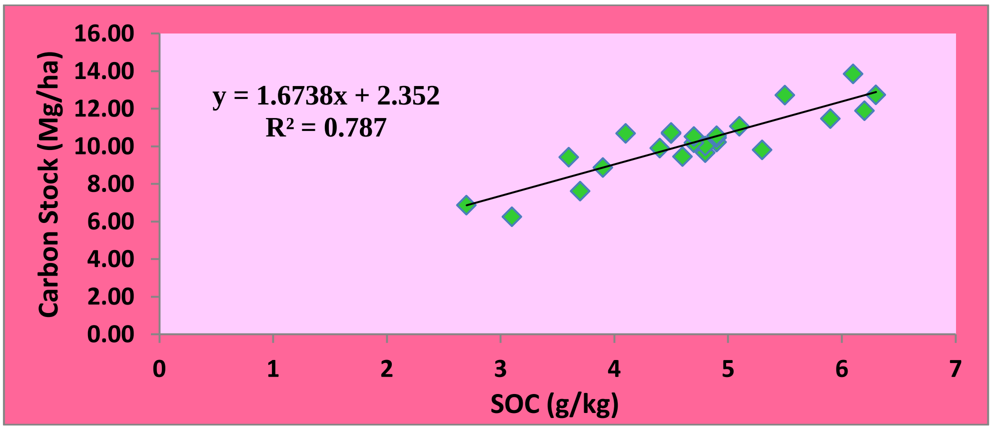

Fig. 4. Correlation between SOC and carbon stock in *Kharif*

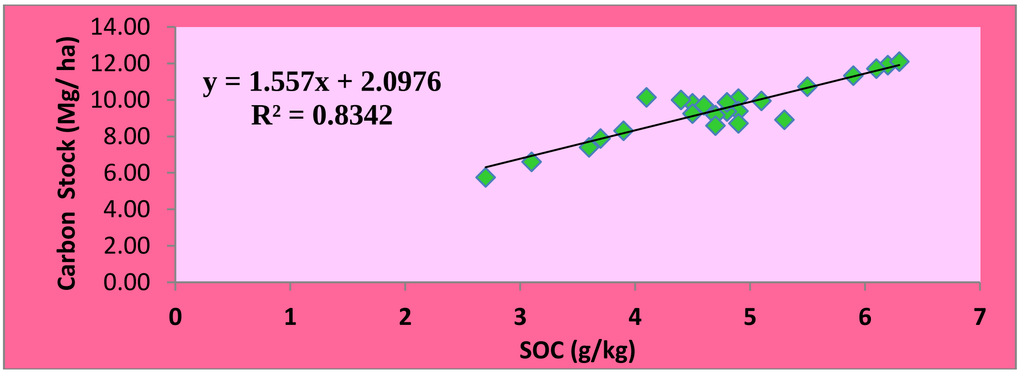

Fig. 5. Correlation between SOC and carbon stock in *Rabi*

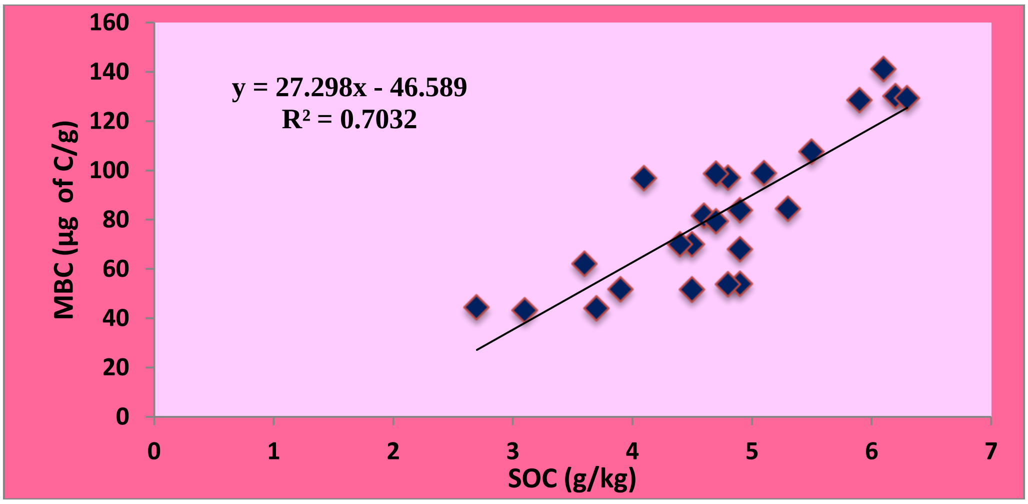

Fig. 6. Correlation between Soil organic carbon and Microbial biomass carbon

Table 7. Effect of long-term manuring on MBC (µg of C g^{-1}) of soils after harvest of *Kharif* and *Rabi* crops

Treatment	(0-15) cm	
	Kharif	***Rabi***
100% NPK	166.86	86.76
100% NPK+ FYM	204.93	132.41
100% N	126.65	55.39
100%NP	156.49	71.88
100% NPK+ Lime	184.51	100.66
Control	111.21	45.89
SE(m)±	0.81	0.54
CD(0.05)	2.46	1.68

4. CONCLUSION

In a long-term manuring experimental field under rice-rice cropping system at Bhubaneswar soil seasonally added stubble enhanced the carbon content in stubble, carbon stock in soil and soil organic carbon. The microbial population and activity of microorganisms in soil were enhanced which was indicated by higher MBC where more stubble was added. Increased soil carbon stock, SOC, and MBC were found in 100% NPK+ FYM, which was proceeded in decreasing order by 100% NPK + Lime, 100% NPK, 100% NP, 100% N, and control.

From the entire study following conclusions can be drawn:

1. Balance fertilization is good, balanced fertilizer with lime treatment in acid soil is better but integration of organic with inorganic is the best way of manuring in a light textured, low fertile acid soil at Bhubaneswar in rice-rice cropping system.
2. Recommend dose of fertilizer was better over imbalanced or no manuring where less stubble was produced and incorporated.
3. For the soil, rice straw is a good source of carbon. It has a positive effect on the condition of the soil, improving rice quality and yield. Soil has to be amended with stubble.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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