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Soil organic carbon health and yield sustainability under organically managed rice-rice sequence

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ABSTRACT

A field experiment was carried out at Bhubaneswar during 2008-14. The soil of the experimental site was sandy loam in texture with 6.0 pH. The values of bulk density and soil organic carbon contents in 0-15 and 15-30 cm soil depth, respectively, were 1.58 and 1.66 tm^{-3} and 5.2 and 4.0 g kg$^{-1.}$ Rice-rice sequence was taken for six consecutive years with seven organic nutrient management treatments in randomized block design. Organic nutrient management exerted significant effect on soil organic carbon status and sustainable yield index. The observed soil organic carbon stock was maximum in treatment receiving dhanicha+ FYM+vermicompost (46.29 t ha^{-1}) and highest rate of sequestration was also observed in the same treatment (4.00 t ha^{-1} year^{-1}). Maximum average grain yield & (4.47 and 4.26 t ha^{-1}) and *highest SYI (Sustainable Yield Index) was witnessed in the same treatment in kharif (0.78) and summer (0.77) seasons respectively.*

Keywords: Carbon sequestration, soil organic carbon, sustainable yield index

Soil organic matter has been associated with various soil functions like nutrient recycling, water retention and drainage, erosion control, disease suppression and pollution remediation (Cooperband, 2002). Addition of organic material is a management technique with the potential to improve soil quality and augment production. This is particularly useful option in tropical regions where the cost of inorganic fertilizers are high but organic by products are plentiful. The benefits of organic amendments have been widely demonstrated in temperate regions of the globe but their efficacy in tropical and subtropical regions is not believed to be as significant due to high temperatures and humidity which facilitate a rapid oxidation of the applied organics. Soil organic carbon (SOC) levels are directly related to the amount of organic matter contained in soil and SOC is often used to measure the SOM content. Carbon stored in soils represents the largest terrestrial carbon pool and factors affecting this will be vital in the understanding of future atmospheric CO_2 concentrations in the climate change arena. To offset deterioration of soil structure, different organic amendments such as manure (farmyard manure, green manure), compost, and crop residues (particularly rice straw) are commonly recommended and when applied, they are distributed in different SOC pools (Majumder *et al*., 2008). SOC is simultaneously a source and sink for nutrients and plays a vital role in soil fertility maintenance. Optimum management of the soil resource for provision of goods and services requires good management of organic resources, mineral inputs and the SOC pool (Vanlauwe, 2004). Addition of exogenous OM such as FYM, vermicompost results in enhancement of OC storage in addition to improvement of many other soil function related to the presence of organic matter (Yadav *et al*., 2009; Ngo *et al*., 2012). Thus, it becomes imperative to increase SOC density for improvement in quality soil for sustainable crop productivity. The enormous SOC sequestration potential of agriculture can be exploited through proper organic nutrient management options in intensive agriculture systems. According to Mahanta *et al*. (2013) the SYI of a cropping system continuously increases by repeated addition of FYM. Keeping all these in view, the present investigation was conducted to estimate SOC sequestration and SYI of organically grown rice-rice sequence.

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MATERIALS AND METHODS

A field experiment was conducted during 2008-2014 at the Organic Block of Central Research Station of Orissa University of Agriculture and Technology, Bhubaneswar located at 20^0 15' N latitude and 85^0 52' E longitude and at an altitude of 25.9 m above mean sea level. The station comes under the East and South Eastern Coastal Plain Agro-climatic Zone of Orissa. The region is characterized by a sub-tropical climate with a hot and humid summer (March-June), hot and wet monsoon (late June-mid October) and a mild and dry winter (Nov.-Feb.). The soil of the experimental site was sandy loam in texture with pH 6.0. The bulk densities were 1.58 and 1.66 t m^{-3} and soil organic carbon were 5.2 and 4.0 g kg^{-1} for 0-15 and 15-30 cm soil depth, respectively at the start of the experiment. *Kharif* rice followed by summer rice was cultivated for six consecutive years in a fixed site and layout with seven treatment combinations (Table 1).

Table 1: Treatment details

	Kharif		Summer
T_1	Dhanicha@ 25 kg seed ha^{-1}	T_1	Control
T_2	T_1 + FYM 5t ha^{-1} (basal)	T_2	FYM 5t ha^{-1} (basal)
T_3	T_1 + vermicompost 2t ha^{-1} (basal)	T_3	Vermicompost 2t ha^{-1} (basal)
T_4	T_1 + vermicompost 2t ha^{-1} (split)	T_4	Vermicompost 2t ha^{-1} (split)
T_5	T_1 + FYM + vermicompost 2t ha^{-1} (split)	T_5	FYM + vermicompost 2t ha^{-1} (split)
T_6	T_1 + FYM + vermicompost 2t ha^{-1} (basal)	T_6	FYM + vermicompost 2t ha^{-1} (basal)
T_7	T_1 + FYM + Panchagavya	T_7	FYM + Panchagavya

The experiment was laid out in a randomized block design with three replications. Rice cv. Lalat was cultivated in both the seasons in all six years. One 10 day old seedling was transplanted in each hill with a spacing of 25 × 25 cm in individual plots measuring 12 m in length and 6 m in width. Organic management options were adopted as per the treatments along with biodynamic formulation '*Panchagavya'*. The plots were kept moist all along. Vermicompost was applied in split at 20 DAS and 40 DAS. Cono weeder was used thrice at 15 days interval starting from 10 DAT in order to manage weed menace. No major incidence of disease and insect pest was noticed. However, as a prophylactic measure, pot manure (5 kg cow dung + 5 litre urine + 250 g gur + 1.0 kg each of *Azadirachta indica*, *Pongamia pinnata* and *Calotropis gigantia* leaves, fermented for 15 days) was sprayed four times at 15 days interval starting from 15 DAT in both the seasons (Bastia *et al*., 2013; Kar *et al*., 2013). Bulk density were determined for each treatment by using core sampler method (Dastane, 1972). Soil samples were collected from each plot with a post-whole auger from 0-15 and 15-30 cm soil depth. SOC stock was calculated from this depths using the following formula:

$$\text{SOC stock} = \textstyle\sum_1^n(\text{Profile volume} \times \text{Bulk density} \times \text{SOC content})$$

From total SOC stock of 30 cm profile, the SOC sequestration rate was calculated (Kundu *et al*., 2007) separately for each treatment due to six years of experimentation with the following formula:

$$\text{SOC sequestration rate} = \frac{\text{Increase in SOC stock due to treatments over the initial stock}}{\text{No. of years of experimentation}}$$

The data so obtained for each observation were analyzed using analysis of variance technique for randomized block design as described by Gomez and Gomez (1984).

The sustainable yield index of rice-rice sequence was calculated for the treatments taking into consideration the yield data for the last six years by using the following formula (Singh *et al*., 1990):

$$\text{SYI} = \frac{Y_{mean} - \sigma}{Y_{max}}$$

where Y_{mean} = mean yield of a treatment over the years; σ = standard deviation of a treatment over the years, and Y_{max} = maximum yield irrespective of treatment and year.

RESULTS AND DISCUSSION

Grain yield and SYI

The grain yield of different seasons and years were significantly different due to application of organic nutrients (Table 2). The average grain yield was found to be the highest for T_5 (4.47 and 4.26 t ha^{-1}) in *kharif* and summer seasons. The same treatment was proved to be most sustainable having highest SYI (0.78 and 0.77 in *kharif* and summer seasons respectively). Simultaneous application of organic manures (T_5, T_6 and T_7) resulted in higher yield than treatments where single manure was applied (T_1, T_2, T_3 and T_4). Integrated use of two or three sources of organic nutrients with biofertilizers has resulted in higher grain yield of rice (Yadav *et al*., 2009; Davari and Sharma, 2010; Singh *et al*., 2011). Organic manures when applied in sufficient quantity supplied all the essential nutrients in adequate amount for plant growth and development and ultimately resulted in yield. Besides, they encourage the activity of microbes which, in turn, release enzymes and hormones that promote plant growth. Mankotia (2007) reported higher yield of rice due to *in situ* green manure of dhanicha with application of FYM. Shekara *et al*. (2010) suggested that increase in the growth, yield attributes and yield of rice due to addition of various organic manures could be attributed to adequate supply of nutrients, higher uptake and recovery of applied nutrients, which in turn, must have improved synthesis and translocation of metabolites to various reproductive structures of the plant. According to Mahanta *et al.* (2013) the SYI of a cropping system continuously increases by continuous addition of FYM.

Table 2: Effect of organic nutrient management on grain yield and SYI of rice-rice sequence

Treatment	*Kharif* grain yield (t ha^{-1})						SYI	AGY	Summer grain yield (t ha^{-1})						SYI	AGY
	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14			2008-09	2009-10	2010-11	2011-12	2012-13	2013-14		
T_1	2.40	2.53	3.06	3.09	3.30	3.73	0.50	3.01	2.42	2.45	2.93	2.98	3.26	3.64	0.50	2.95
T_2	2.73	3.14	3.18	3.27	3.72	4.06	0.57	3.35	2.72	3.12	3.12	3.12	3.67	3.98	0.58	3.28
T_3	2.87	3.06	3.41	3.52	4.08	4.28	0.59	3.53	2.63	2.96	3.37	3.39	3.72	4.23	0.57	3.38
T_4	3.34	3.40	4.03	4.12	4.40	4.80	0.68	4.01	3.06	3.31	4.01	3.90	4.39	4.76	0.66	3.90
T_5	3.70	4.03	4.54	4.58	4.92	5.05	0.78	4.47	3.54	4.01	4.24	4.34	4.53	4.93	0.77	4.26
T_6	3.25	3.84	3.97	4.26	4.47	4.86	0.70	4.10	3.14	3.75	3.92	4.12	4.43	4.70	0.70	4.01
T_7	3.01	3.72	3.80	4.07	4.31	4.65	0.67	3.92	3.02	3.68	3.73	3.76	4.07	4.48	0.66	3.80
SEm(±)	**0.15**	**0.17**	**0.21**	**0.20**	**0.21**	**0.22**	**-**	**0.19**	**0.17**	**0.18**	**0.16**	**0.20**	**0.21**	**0.22**	**-**	**0.20**
LSD(0.05)	**0.46**	**0.55**	**0.66**	**0.65**	**0.64**	**0.68**	**-**	**0.60**	**0.54**	**0.57**	**0.50**	**0.66**	**0.63**	**0.68**	**-**	**0.64**

AGY - Average grain yield (t ha^{-1})

Table 3 : Effect of organic nutrient management on soil organic carbon stock and carbon sequestration rate

Treatments	Soil profile organic carbon(g kg^{-1})		Bulk density(t m^{-3})		Total soil organic carbon stock(t ha^{-1})			Soil organic carbon sequestration rate (t ha^{-1} year^{-1})
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	Total	
T_1	7.84	5.72	1.65	1.72	19.40	14.76	34.16	1.98
T_2	9.32	7.82	1.6	1.64	22.23	19.12	41.34	3.17
T_3	11.25	7.26	1.58	1.62	26.66	17.64	44.30	3.67
T_4	11.50	7.83	1.56	1.61	26.91	18.91	45.81	3.92
T_5	11.43	8.27	1.55	1.59	26.57	19.72	46.29	4.00
T_6	10.52	7.73	1.57	1.6	24.77	18.55	43.32	3.50
T_7	10.24	7.60	1.58	1.61	24.27	18.35	42.62	3.35
SEm(±)	**0.510**	**0.375**	**0.026**	**0.024**	**0.425**	**0.317**	**1.250**	**0.263**
LSD(0.05)	**1.58**	**1.13**	**0.08**	**0.08**	**1.275**	**0.96**	**3.86**	**0.81**

SOC stock and soil organic carbon sequestration rate

Soil profile organic carbon at sampling depths of 0-15 and 15-30 cm showed significant variation due to organic nutrient management and biodynamic formulation (Table 3). Total initial SOC stock was 22.28 t ha^{-1} during 2008-09. Maximum SOC stock was found in treatment T_5 (46.29 t ha^{-1}), which was *at par* with those of T_4, T_6 and T_7. Highest rate of sequestration was also resulted in T_5 (4.00 t ha^{-1} year^{-1}), which was *at par* with treatment T_3 and T_4. Lowest soil organic carbon stock and minimum SOC sequestration rate was found in treatment T_1 (34.16 t ha^{-1} and 1.98 t ha^{-1} year^{-1}). The increase in organic carbon content in the manurial treatment combinations is attributed to the direct incorporation of organic matter in the soil. Subsequent decomposition of these materials might have resulted in the enhanced organic carbon content of the soil (Singh *et al*., 2008). Highest SOC in the upper 0-15 cm soil profile was found in treatment receiving dhanicha + FYM + vermicompost (split) in *kharif* and corresponding treatment receiving FYM + vermicompost (split) in summer (T_5) which was 51 and 45 per cent higher than the treatment receiving only dhanicha@25kg ha^{-1} (T_1) after end of the rice-rice sequence in *kharif* and summer season, respectively.

Higher amount of SOC stock in T_5 can be attributed to greater carbon input through organic manures and enhanced crop productivity. Kundu *et al*. 2007 also justified increase in SOC stock in similar fashion. The use of organic amendments such as FYM, rice straw and green manure is known to improve soil productivity and has the capacity to increase SOC amount (Ghosh *et al.,* 2010). Many researchers (Lal, 2004; Mandal *et al*., 2007) have reported that application of FYM and green manure adds organic carbon in the soil. Kukal *et al.* (2009) observed a higher SOC sequestration in a rice-wheat system due to application of FYM and the cropping system had greater capacity to sequester carbon because of high carbon input through enhanced productivity. Increase in SOC status enhances soil microbial activities which, in turn, act as catalyst for soil chemical reactions resulting in higher availability of plant nutrients. Hence, the system yield increased linearly with increase in SOC stock. SOC sequestration rate was significantly different due to organic nutrient management. A positive linear relationship (R^2 = 0.548 and 0.748 in *kharif* and summer seasons, respectively) was observed between SOC and grain yield (Fig.1). For SOC sequestration rate and grain yield, the relationship (Fig. 2) was found to be positive and linear (R^2 = 0.708 and 0.768 in *kharif* and summer seasons, respectively)

The experiment concluded that application of dhanicha @ 25 kg seed ha^{-1}+ FYM @ 5 t ha^{-1} + vermicompost (split) @ 2 t ha^{-1}to *kharif* rice and FYM @ 5 t ha^{-1}+ vermicompost (split) @ 2 t ha^{-1}to summer rice can increase the grain yield and sustainability of the system. The SOC concentration, SOC stock and SOC sequestration rate also get enhanced due to the same treatment.

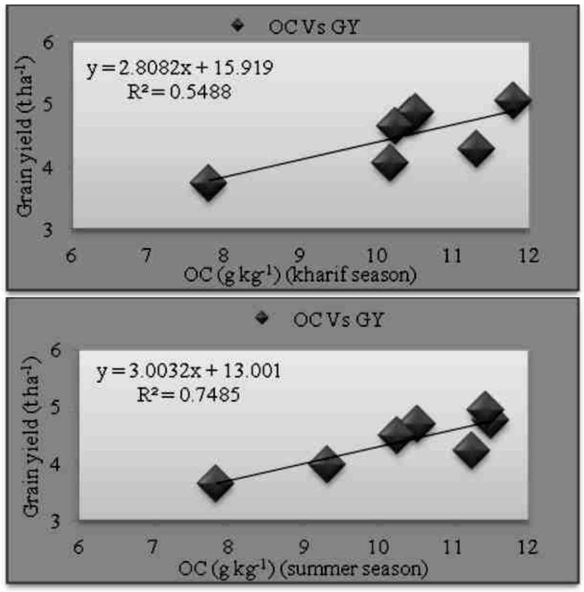

Fig 1 : Correlation of organic carbon to grain yield of *kharif* and summer rice as affected by organic nutrient management

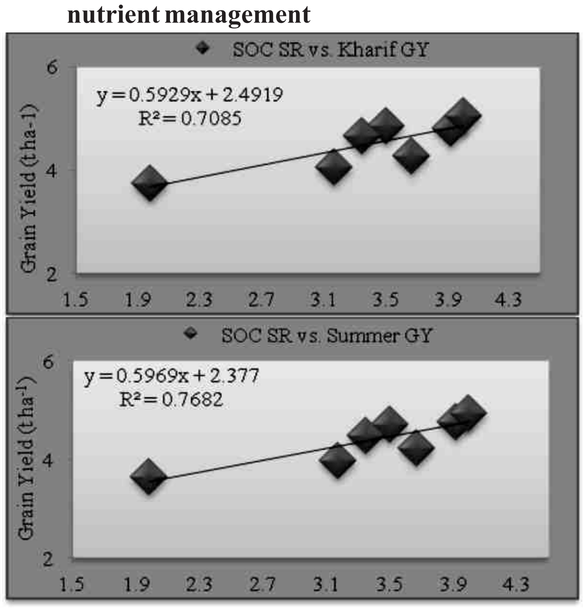

Fig 2 : Correlation of carbon sequestration rate (t ha^{-1} yr^{-1}) to grain yield of *kharif* and summer rice as affected by organic nutrient management.

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