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Yield and soil organic carbon sequestration under organic nutrient management in rice-rice system

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ABSTRACT

A field experiment was carried out at Bhubaneswar during 2008 - 2011. The soil of the experimental site was sandy loam in texture with 6.0 pH. 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} of soil for 0-15 and 15-30 cm soil depth, respectively. Rice-rice cropping system was taken for three consecutive years with eight organic nutrient management and biozyme application treatments in a Randomized Block Design. Grain and above-ground biomass yield increased linearly from first to third year in both the seasons. The pooled grain, straw and total biomass yields of the system were the highest (8.1, 9.0 and 18.0 t ha^{-1}, respectively) with GM + FYM + vermicompost in split dose + biozyme granule and power plus in kharif and FYM + vermicompost in split dose + biozyme granule and power plus in summer and were at par with those of all other biozyme applied treatments. In soil, organic carbon concentration, total soil organic carbon stock and soil organic carbon sequestration rates were also significantly influenced by the organic nutrient management and biozyme application treatments.

Keywords: Biozyme, nutrient management, rice, carbon sequestration

Agricultural ecosystem represent an estimated 11% of the earth's land surface which include some of the most productive and carbon-rich soils. It is widely recognized that organic matter in these soils plays an essential role in a range of soil physical, chemical and biological processes and that soil organic carbon (SOC) is one of the most important indicators of soil quality and health. Maintaining or increasing soil organic matter is critical to achieve optimum soil functions and therefore fertility and crop production. As a component of the terrestrial carbon cycle, soil can be either source or sink of atmospheric carbon dioxide (Lal, 2007). Though carbon emissions from agricultural activities contribute to the enrichment of atmospheric CO_2 (Kimble *et al*., 2002), yet carbon sequestration in agricultural soils, through adoption of improved management practices, can mitigate this trend (Lal *et al*., 1998). Conventional agriculture typically results in soil carbon depletion and reduced productivity. However, addition of organic materials is a management technique with the potential to increase SOC content and to improve soil quality. The estimated potential of agricultural intensification on SOC sequestration in soils of India ranges between 12.7 and 16.5 Tg C $year^{-1}$ (Lal, 2003). Nieder *et al*. (2003) opined that improved SOC density can improve the productivity of agricultural crops. In conformation to this, Benbi and Chand (2007) observed that each Mg of SOC in the 0-15cm soil layer increased wheat productivity by 15-33 kg ha^{-1} in semi-arid India. Thus, it becomes imperative to increase SOC density for improvement in quality of natural resources like soil, water and atmosphere, and for sustainable crop productivity. The use of crop residues and animal manures returns the much needed C back to the soil and thus results in increased SOC density and soil quality. Higher crop productivity under intensive agriculture increases plant residue input into the soils and thus, has the potential of increasing SOC level (Franzluebbers, 2005).

The enormous SOC sequestration potential of agriculture can be exploited through proper organic nutrient management options in intensive agriculture systems. Furthermore, biozyme formulations are sea weed (*Ascophyllum nodosum*) extracts which are nutrient, enzyme, hormone carriers and enhancer of chlorophyll content and also act as soil conditioners and plant capacity promoters (Wallace, 1998; Cassan *et al.,* 1992; Manna *et al*., 2012). Keeping this in view, the present investigation was conducted to estimate soil C sequestration in rice-rice sequence with organic nutrient management options and biozyme applications.

MATERIALS AND METHODS

A field experiment was carried out at the non-chemical block of Central Research Station of Orissa University of Agriculture and Technology, Bhubaneswar located at 20º 52' N latitude and 85º 15' E longitude at an altitude of 25.9 m above mean sea level during 2008-09 to 2010-11. The region is characterized by a sub-tropical climate with a hot and humid summer (March-June), hot and wet monsoon

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(late June–mid October) and a mild and dry winter (November- February).The soil of the experimental site was sandy loam in texture with pH 6.0 (1:2.5 soil to water). 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 three consecutive years in a fixed site and lay out with eight treatment combinations (Table 1).

Table 1: Treatment details

***Kharif* rice**	**Summer rice**
T_1: Control	T_1: Control
T_2: Green manuring (*Sesbania aculeata*) @ 25 kg seed ha^{-1} + FYM @ 5 t ha^{-1}	T_2: FYM @ 5 t ha^{-1}
T_3: T_2 + vermicompost @ 2 t ha^{-1} at 20 DAT	T_3: FYM + vermicompost @ 2 t ha^{-1} at 20 DAT
T_4: T_2 + vermicompost @ 1 t ha^{-1} at 20 and 40 DAT	T_4: FYM + vermicompost @ 1 t ha^{-1} at 20 and 40 DAT
T_5: T_3 + Biozyme granule @ 20 kg ha^{-1} as basal	T_5: T_3 + Biozyme granule @ 20 kg ha^{-1} as basal
T_6: T_5 + Biozyme power plus @ 15 kg ha^{-1} at 20 and 40 DAT	T_6: T_5 + Biozyme power plus @ 15 kg ha^{-1} at 20 and 40 DAT
T_7: T_4 + Biozyme granule @ 20 kg ha^{-1} as basal	T_7: T_4 + Biozyme granule @ 20 kg ha^{-1} as basal
T_8: T_7 + Biozyme power plus @ 15 kg ha^{-1} at 20 and 40 DAT	T_8: T_7 + Biozyme power plus @ 15 kg ha^{-1} at 20 and 40 DAT

The experiment was laid out in a randomized block design with three replications. Rice 'cv. Lalat' was cultivated in both the seasons in all three years. 10 days old seedlings were transplanted one seedling per hill with spacing of 25 × 25 cm in raised beds created by opening deep drains of 30cm width around beds of 15 m length and 1.5 m width. Organic nutrient management was adopted as per the treatments along with biozyme formulations which contain both macronutrient (N, P, K, Ca, Mg, S) and micronutrient (Mn, Cu, Fe, Zn, etc) and also contains plant growth hormones, organic acids, polysaccharides, amino acids, and proteins which are all very beneficial and widely used in agriculture. Water management was done by allowing water to stand in the channels only and in the process, the beds were kept moist all along. Cono weeder was worked 3 times at 15 days interval starting from 10 days after transplanting to manage the weeds. A pot manure was prepared by fermenting 5 kg cow dung, 5 litre cow urine, 1kg each of *Azadirachta indica*, *Calotropis gigantia* and *Pongamia pinnata* leaves along with 250g jaggery for 15 days. The pot manure (1:50 manure to water) was sprinkled over the crop at 15 days interval starting from 10 days after transplanting.

each depth (Majumdar *et al*., 2007) with the formula as follows;

SOC stock

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

From total SOC stocks in 30-cm profile, the SOC sequestration rate was calculated separately for each treatment over control on the basis of three years of experimentation (Kundu *et al.*, 2007) with the following formula;

SOC sequestration rate = (Increase in SOC stock due to treatments over control / No. of years of experimentation)

The *in situ* bulk density of 0-15 and 15-30 cm soil layers were determined for each treatment by using core sampler method (Dastane, 1972). The data so obtained for each observation were analyzed by analysis of variance technique for randomized block design as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Grain and straw yield

The grain and straw yields of different seasons and years had significant variation due to organic nutrient management and Biozyme application in rice-rice sequence (Table 2). Grain yield increased linearly from first to third year in both the seasons. The pooled grain, straw and total yields depicted the highest for T_8 (8.1, 9.9 and 18.0 t ha^{-1}, respectively) which were at par with those of T_7, T_6 and T_5. Split application of vermicompost (T_4, T_7 and T_8) registered 5.48, 4.45 and 4.90 % higher grain, straw and total yields over single application (T_3, T_5 and T_6). Containing water-soluble nutrients, vermicompost is an excellent, nutrient-rich organic fertilizer and soil conditioner .Advantage of split application of vermicompost on yields has been reported by Barik *et al*. (2011). Biozyme application treatments (T_5 to T_8) recorded 13.04, 13.01 and 13.02 % higher grain, straw and total yields over organic nutrient management treatments (T_3 and T_4). Biozyme formulations are reported to provide essential Soil samples were collected from each plot with a post-hole nutrients, hormones and enzymes and a better soil environment niche for the plants to express themselves to the fullest capacity (Wallace, 1998).

Soil organic carbon

Soil profile organic carbon at sampling depths of 0-15 and 15-30 cm showed significant variation due to organic nutrient management and Biozyme application (Table 3). The highest soil organic carbon status was observed for T_5 and T_6 (6.6 g kg^{-1} of soil) treatments at 0-15 cm and for T_6 (5.3 g kg^{-1} of soil) treatment at 15-30 cm depth but, in both the cases, those were at par with the SOC status due to all treatments except the control (T_1). In three years of experimentation, organic nutrient management options alone (mean of T_2 to T_4) increased the SOC by 88.0 and 64.7 % over that of the control in 0-15 and 15-30 cm soil depths, respectively. Balanced organic nutrition is expected to have increased SOC because of greater C input. Parker *et al.* (2002) reported 7-20% increase in organic C in the top 5 cm of soil in a cotton-rye cropping system with poultry litter over commercial fertilizer application. Application of biozyme formulations (mean of T_5 to T_8) over organic nutrient management options alone (mean of T_3 and T_4) increased the SOC by 3.9 and 4.2 % on 0-15 and 15-30 cm soil depths, respectively. Treatments T_5 to T_8 produced higher above ground biomass yields resulted in greater biomass of roots and rhizo-deposition leading to greater C input in the soil. Root biomass yield and rhizo-deposition in different crops have been shown to be related to the above-ground biomass harvests (Bronson *et al.*, 1998; Majumder *et al.*, 2007). Overall SOC concentration decreased by 17.2% in 15-30 cm over 0-15 cm. The decrease in SOC concentration with soil depth is well documented by Liu *et al.* (2003).

Table 2: Grain and straw yield and above ground biomass yield as influenced by organic nutrient management and biozyme applications in rice-rice sequence

Treatments	Grain yield (t ha^{-1})						*System yield (t ha^{-1})	*Straw yield (t ha^{-1})	* Total yield (t ha^{-1})
	Kharif rice			*Rabi* rice					
	2008-09	2009-10	2010-11	2008-09	2009-10	2010-11			
T_1	2.0	2.1	1.8	1.8	2.0	1.9	3.9	4.8	8.7
T_2	2.8	3.2	3.5	3.0	3.5	3.6	6.5	8.0	14.5
T_3	3.0	3.5	3.8	3.0	3.4	3.8	6.8	8.4	15.2
T_4	2.9	3.6	3.8	3.1	3.6	3.9	7.0	8.5	15.5
T_5	3.2	3.5	4.2	3.3	3.9	4.4	7.5	9.2	16.7
T_6	3.2	3.7	4.2	3.2	4.0	4.6	7.6	9.3	16.9
T_7	3.3	3.9	4.6	3.3	4.2	4.8	8.0	9.8	17.8
T_8	3.4	3.8	4.6	3.5	4.2	4.9	8.1	9.9	18.0
SEm (±)	**0.14**	**0.15**	**0.20**	**0.21**	**0.20**	**0.23**	**0.26**	**0.27**	**0.36**
LSD (0.05)	**0.42**	**0.44**	**0.58**	**0.64**	**0.60**	**0.68**	**0.78**	**0.82**	**1.07**

*Note: * pooled data*

Table 3: Effect of organic nutrients and biozyme applications on soil organic carbon (SOC) and it's sequestration rate in rice-rice sequence

Treatments	Soil profile organic carbon (g kg^{-1} of soil)		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	3.1	2.8	1.66	1.72	7.72	7.22	14.94	-
T_2	6.0	4.8	1.58	1.62	14.22	11.66	25.88	3.65
T_3	6.2	5.0	1.56	1.60	14.51	12.00	26.51	3.86
T_4	6.3	5.0	1.57	1.60	14.84	12.00	26.84	3.97
T_5	6.6	5.2	1.56	1.59	15.44	12.40	27.84	4.30
T_6	6.6	5.3	1.55	1.60	15.35	12.72	28.07	4.38
T_7	6.5	5.2	1.56	1.60	15.21	12.48	27.69	4.25
T_8	6.4	5.2	1.56	1.59	14.98	12.40	27.38	4.15
SEm (±)	**0.34**	**0.30**	**0.02**	**0.02**	**0.30**	**0.22**	**0.32**	**0.08**
LSD (0.05)	**1.01**	**0.90**	**0.06**	**0.06**	**0.89**	**0.65**	**0.96**	**0.24**

Soil organic carbon stocks and sequestration rate

Soil organic carbon stock of different depths and total SOC stock were significantly influenced by organic nutrient management and biozyme application treatments in rice-rice cropping sequence (Table 3).

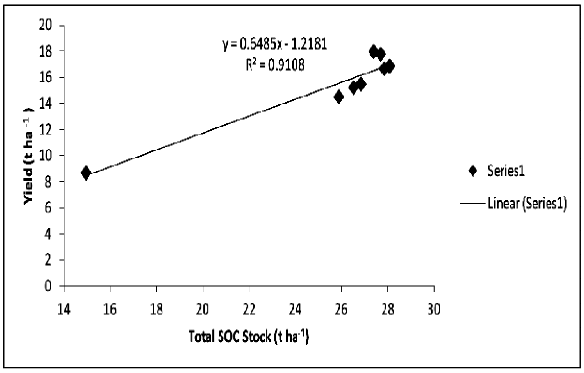

Fig. 1: Relationship between total SOC stock and grain yield of the system

Soil organic carbon stock was the maximum (15.44 t ha^{-1}) for T_5 in 0-15 cm soil depth which was at par with those of T_6, T_7, T_8 and T_4 treatments. In case of SOC stock at 15-30 cm soil depth and total SOC stock, maximum was recorded due to T6 (12.72 and 28.07 t ha^{-1} , respectively) which was at par with those of T_7, T_8 and T_5. Higher amount of SOC stock in those treatments can be attributed to greater C input through organic manures and enhanced crop productivity (Kundu *et al.*, 2007). After three years of cropping, a strong positive linear relationship (R^2=0.910) was observed between SOC stock and system yield (Fig.1). Increase in soil organic carbon enhances soil microbial activities which, in turn, act as catalyst for soil chemical reactions resulting in higher availability of nutrients to plants. Hence, the system yield increased linearly with increase in SOC stock.

SOC sequestration rate was significantly different due to organic nutrient management and biozyme application (Table 3). The highest SOC sequestration rate was recorded for T_6 ; GM + FYM + vermicompost @ 2 t ha^{-1} at 20 DAT + -iozyme granule @ 20 kg ha^{-1} as basal + -iozyme Power Plus @ 15 kg ha^{-1} at 20 and 40 DAT (4.38 t ha^{-1} year^{-1}) which was at par with those of T_5, T_7 and T_8. Mean SOC sequestration rate of biozyme application treatments (T_5 to T_8) was higher by 11.49 % over mean of organic nutrient management treatments (T_2 to T_4). Even though C input from organic manures were almost similar for above treatments, yet the root biomass production and rhizo-deposition might have been more in case of biozyme application treatments and hence the result.

The study indicated that application of GM @ 25 kg seed ha^{-1} + FYM @ 5 t ha^{-1} + vermicompost @ 2 t ha^{-1} either by single or split dose + biozyme formulations to *kharif* rice and FYM @ 5 t ha^{-1} + vermicompost @ 2 t ha^{-1} either by single or split dose + biozyme formulations to summer rice can increase the grain and starw yield of rice-rice system. The SOC concentration, total SOC stocks and SOC sequestration rate also increase due to the same treatment.

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