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Soil microbial health and crop yield under organically managed rice-rice sequence

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ABSTRACT

*A field experiment was undertaken during 2013-14 in organic Block of Central Research Station, Orissa University of Agriculture and Technology. The soil of the experimental site was sandy loam in texture with pH 6.35, BD 1.58 t m^{-3}, high in organic carbon (9.4 g kg^{-1}) medium in available N (376.0 kg ha^{-1}), P_2O_5 (34.4 kg ha^{-1}) and K_2O (221.3 kg ha^{-1}). The experiment was laid out in randomized block design in rice-rice cropping sequence taking seven organic nutrient management treatments (different combinations of Dhanicha, FYM, Vermicompost and Panchagavya in kharif and same combinations of treatments except Dhanicha in summer) in three replications in two seasons. The treatment receiving Dhanicha as green manuring crop, FYM and vermicompost (split) in kharif and corresponding treatment in summer resulted the maximum average crop yield of 4.99 t ha^{-1}, straw yield of 5.60 t ha^{-1} and net profit of Rs. 26740.5 ha^{-1}. Similarly, the said treatment obtained maximum microbial population (total heterotrophic bacteria 186 CFU × 10^4 g^{-1}soil, actinomycetes 92 CFU × 10^4 g^{-1} soil, fungi 41 CFU × 10^3 g^{-1} soil, dehydrogenase activity 0.74 µg TPF g^{-1} soil hr^{-1}) and microbial biomass carbon (231.34 µg C g^{-1} soil). Rice yield of the system exhibited linear, positive and significant correlation with total heterotrophic bacteria (0.881**), actinomycetes (0.818*), microbial biomass carbon (0.907**) and organic carbon (0.816*).*

***Keywords*: Dehydrogenase activity, microbial biomass carbon, microbial population, sustainable agriculture**

An ideal agricultural system should be sustainable, maintain and improve human health, benefit the producers and consumers, protects the environment and produces enough food for an increasing world population. In this perspective, organic farming is the most appropriate agricultural system to bolster sustainable agricultural growth (Kalra *et al*., 2012). Organic agriculture has been found to enhance soil fertility and increase biodiversity (Mader *et al*., 2002). Organic residues and manuring play a pivotal role in minimizing the ill effects of intensive agriculture that has resulted in many adverse effect on natural resources such as decline in soil health, deficiency of major and micro nutrients and stagnation in yield (Viridi *et al*., 2006). Organic manures supply a natural process to seasonally strengthen the nutrient pool of soil. It steps-up the power of soil to bind soil moisture and deters insects, weeds without utilizing chemicals. Boosting yield, reducing production cost and improving soil health are three inter-linked components of the sustainability triangle (Singh *et al*., 2008). Organic amendments help in enhancing fertility and productivity of soil as a whole.

Microbial biomass is a useful indicator of soil quality. Soil microorganisms are involved in several processes that influence soil quality. Microbial biomass changes rapidly in response to changes in soil properties. Increases in microbial biomass over time are considered beneficial. They may indicate an increase in beneficial biological functions in soil.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* and summer seasons of 2013-2014 at 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 with 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 soil of the experimental site was sandy loam in texture with pH 6.35, EC 0.18 dSm^{-1}, BD 1.58 t m^{-3}, organic carbon 9.4 g kg^{-1}, available N 376.0 kg ha^{-1}, P_2O_5 34.4 kg ha^{-1} and K_2O 221.3 kg ha^{-1}. The experiment was laid out in randomized block design in three replications taking rice variety "Lalat" as test crop. Seven treatments were in combination of organic nutrient sources Dhanicha *(Sesbania aculata)*, FYM, vermicompost and panchagavya.

In *kharif* season, *Dhanicha* as a green manure crop was shown @ 25 kg seed ha^{-1} in first week of June, incorporated after 45 days after sowing then allowed to decompose *in situ* (T_1), where as in summer, same plot was kept as control without growing Dhanicha. In *kharif*,

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T_2 was supplied with Dhanicha and FYM 5 t ha^{-1} as basal. *Kharif* T_3 was raised with Dhanicha along with vermicompost 2 t ha^{-1} as basal. In k*harif* T_4 was provided with Dhanicha and vermicompost 2 t ha^{-1} as split. In same season, T_5 was grown with Dhanicha , FYM and vermicompost 2t ha^{-1} as spit. T_6 in *kharif* was grown with Dhanicha FYM and vermicompost 2 t ha^{-1} as basal. *Kharif* T_7 was raised with Dhanicha, FYM and panchagavya. In contrast to *kharif*, summer season treatments were same except raising of Dhanicha crop. Seedlings were raised in wet nursery bed and 10 days old seedlings were transplanted on 30th July, 2013@ one seedling per hill with a spacing of 25 × 25 cm in individual plot size of 12 × 6m. Vermicompost @ 2t ha^{-1} was applied either as basal or in two equal splits i.e. basally and at 20 days after transplanting (DAT). A biodynamic formulation 'Panchagavya' (a blend of milk, ghee, curd, dung and urine) was applied which improves availability of macro (N, P, K and Ca) and micro (Zn, Fe, Cu and Mn) nutrients besides total reducing sugars (glucose). The plots were kept moist all along. 'Cono weeder' was used thrice at 15 days interval starting from 10 DAT in order to manage the weed (Pradhan *et al.*, 2015). 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). Microbial population study was undertaken before *kharif* and after harvest of summer crop. Enumeration of microbial population was done by Spread Plate Technique using serial dilution method (Chhonkar *et al*., 2007). Yield attributing characters like number of panicle m^{-2}, length of panicle, number of grains panicle^{-1}, 1000 grain weight, grain and straw yield were recorded and were subjected to statistical analysis (Gomez and Gomez, 1984). Soil microbial biomass carbon (MBC) and dehydrogenase activity was estimated by the methodology as described by Vance *et al.*, (1987**)** and Casida *et al.*, (1964), Tatabai (1982), respectively.

RESULTS AND DISCUSSION

Soil microbial population study

Organic nutrient management influenced the microbial population, microbial biomass and dehydrogenase activity. The total heterotrophic bacteria population was recorded maximum in T_5 (186 × 10^4 g^{-1} soil) which was followed by T_6 (Table 1). The minimum bacterial population (93 ×10^4 g^{-1} soil) was recorded in T_1. Similar trend was also found in case of actinomycetes and fungi. The highest population of actinomycetes and fungi was observed in T_5 (92 ×10^4 g^{-1} soil and 41 × 10^{3}g^{-1} soil) respectively. The microbial biomass carbon and dehydrogenase activity was highest in T_5 (231.34 µg C g^{-1} soil and 0.74 µg TPF g^{-1} soil hr^{-1}) compared to other treatments. T_5 influenced the microbial activities significantly over other treatment due to greater soil organic carbon stock. Addition of organic inputs could have favoured microbial activity, enhanced the soil microbial biomass (SMB) and total bacterial population because of supply of organic carbon (Kenchaiah, 1997). This result was in accordance with Kar *et al*. (2013) where maximum microbial population was resulted from manure.

Table 1: Soil microbial population, biomass carbon and dehydrogenase activity in rice-rice cropping system

Treatments	Total heterotrophic bacteria	Actinomy-cetes	Fungi	Microbial biomass carbon	Dehydro-genase Activity
	CFU × 10^4 g^{-1}soil	CFU × 10^4 g^{-1} soil	CFU × 10^3 g^{-1} soil	µg C g^{-1} soil	µg TPF g^{-1} soil hr^{-1}
Initial	27	18	29	42.60	0.34
T_1: *Dhanicha*@ 25 kg ha^{-1}seed	93	63	26	86.84	0.35
T_2: T_1 + FYM 5t ha^{-1} (basal)	107	62	37	94.78	0.42
T_3: T_1 + Vermicompost 2t ha^{-1}(basal)	139	71	32	186.22	0.44
T_4: T_1 + Vermicompost 2t ha^{-1} (split)	136	73	34	187.60	0.40
T_5: T_1 + FYM + Vermicompost 2t ha^{-1} (split)	186	92	41	231.34	0.74
T_6: T_1 + FYM + Vermicompost 2t ha^{-1} (basal)	167	76	36	180.26	0.62
T_7: T_1 + FY M + *Panchagavya*	124	68	38	183.23	0.55

Studies on microbial correlation

In the present study, rice yield of the system exhibited linear, positive and significant correlation with total heterotrophic bacteria (0.881**), actinomycetes (0.818*), microbial biomass carbon (0.907**) and organic carbon (0.816*). On the other hand, rice yield was weakly correlated with dehydrogenase activity (0.768*) and fungi (0.744). Significant correlation among different microbial population and rice yield can be attributed to enhanced microbial activity and its beneficial effect on farming. The result corroborates with the findings of Kar *et al.* (2013). Total heterotrophic bacteria showed significant correlation with actinomycetes population (0.938**), MBC (0.873*), DA (0.873*) and OC (0.903**). Likewise, actinomycetes population had significant correlation with MBC (0.843*), DA (0.848*) and OC (0.933**). Fungi population also had linear, positive and significant correlation with DA (0.784*). MBC expressed significant correlation with OC (0.841*) but it was weakly correlated with DA (0.729). Significant correlation of MBC with OC implies the importance of organic inputs in nutrient cycling as well as improving soil quality. Nayak *et al.*, (2007) and Liu *et al.*, (2009) also opined correlation of MBC with OC in similar fashion. Similarly, DA was weakly correlated with OC (0.662). However, strong significant correlation between DA and rice yield implies steady biological activity and soil functioning under organic amendments (Table 2).

Table 2: Correlation coefficient between different soil chemical and biological properties and rice yield as influenced by long term organic nutrient management

	RY	THB	ACT	FUN	MBC	DA	OC
RY	1	-	-	-	-	-	-
THB	0.881**	1.000	-	-	-	-	-
ACT	0.818*	0.938**	1.000	-	-	-	-
FUN	0.744	0.653	0.595	1.000	-	-	-
MBC	0.907**	0.873*	0.843*	0.611	1.000	-	-
DA	0.768*	0.873*	0.848*	0.784*	0.729	1.000	-
OC	0.816*	0.903**	0.933**	0.537	0.841*	0.662	1.000

*Note: RY- Rice yield; THB- Total heterotrophic bacteria; ACT- Actinomycetes; FUN- Fungi; MBC- Microbial biomass carbon; DA- Dehydrogenase activity; OC- Organic carbon, *significant at $p<0.05$, **significant at $p<0.01$*

Yield and yield attributes

Similar trend was observed with respect to yield and yield attributing characters in both the seasons. The treatment receiving *Dhanicha* + FYM + vermicompost(split) in *kharif* and corresponding treatment receiving FYM + vermicompost (split) in summer (T_5) produced the highest number of panicle m^{-2} (388.3 and 382.9 in *kharif* and summer, respectively) at harvest. However, these were *at par* with those of T_4, T_6 and T_7 in both the seasons and was recorded significantly superior by 61.7 and 65.5 % over T_1 in both seasons, respectively (Table 3). Similarly the longest panicle was recorded in T_5, which were 32.7 and 31.0 cm in *kharif* and summer season, respectively. Significantly more number of filled grains per panicle (148.3 and 144.1 in *kharif* and summer seasons, respectively) was observed in T_5 and was *at par* with those of T_4, T_6 and T_7 in both the seasons. The highest test weight of 24.1 and 23.9 g was recorded for treatment T_5 and the lowest (22.5 and 22.4 g) was recorded for T_1 in *kharif* and summer seasons respectively. The average grain yield of 4.5, 4.4 t ha^{-1} and straw yield of 5.1, 4.9 t ha^{-1} was obtained for *kharif* and summer, respectively. Higher grain and straw yield was recorded in T_5, in both the seasons which were superior over T_1 by 35% each in *kharif* and 24 and 32% in summer, respectively. The average system grain yield, straw yield and net profit was found to be 8.9 t ha^{-1}, 10 t ha^{-1} and 42647.4 ' ha^{-1}, respectively and those were found maximum with T_5 (9.98, 11.19 T ha^{-1} and 53481 ' ha^{-1}, respectively).

Organic manures improve physico-chemical and biological properties of soil. It also prevent leaching and volatilization losses and its slow release pattern supply nutrients in optimal rate that congruence with crop demand improving synthesis and translocation of metabolites to various reproductive structures resulting in improvement in its yield and yield attributes (Upadhyaya *et al.*, 2000; Shanmugam *et al.*, 2001; Bhattacharya *et al.*, 2003; Raju and Sreenivas, 2008; Kumari *et al.*, 2010). 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, higher uptake and recovery of nutrients.

Soil physico-chemical properties

Much variation on nutrient availability among treatments was not observed. However the available nutrient status of N-P-K was in the optimum range due to organic nutrient management. It was due to organic manure supplies nutrients as well as solubilise the fixed forms of nutrients (Sinha 1981). Bulk density BD was almost stable. Lower BD (1.54 and 1.55 $^{-3}$ Mg m^{-3} in *kharif* and summer, respectively) was in T_5 (Table 4). It might be due to grown in organic research field rich in long term application FYM which increases in total porosity and improves soil aggregation causing decrease in BD (Rasool *et al*., 2008). Soil pH was within range of 6.34 to 6.61 that may be due to buffering property of organic matter used. Organic carbon increased in the treatments in the range of 9.4 to 13.5 g kg^{-1}. The increase in organic carbon content in the manorial treatment combinations is attributed to the direct incorporation of organic matter in the soil. Subsequent decomposition of these materials for eight years might have resulted in the enhanced organic carbon content of the soil (Singh *et al*., 2008).

In the present situation of diminishing factor productivity and escalated environmental degradation, preference is focused on organic farming to bolster sustainable agricultural growth. It is evident from the experiment that combination of organic nutrients such as *Dhanicha* + FYM + vermicompost (split) in *kharif* and FYM + vermicompost (split) in summer rice are encouraging with regards to crop growth, productivity, soil microbial activity of microorganisms which, in turn, accelerate productivity of rice and soil health. The same treatment can be advocated to be practiced in rice-rice sequence.

Table 3: Yield and yield attributing characters as influenced by organic nutrient management in rice- rice sequence (pooled)

Treatment	No. of Panicle m^{-2}		Panicle length (cm)		Filled grain per panicle		1000 grain weight (g)		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		Cost of cultivation (‘ ha^{-1})		Net profit (Rs ha^{-1})		Grain yield (t ha^{-1})	Straw yield, (t ha^{-1})	Net profit (‘ ha^{-1})
	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	Pooled		
T_1	240.1	231.4	25.8	24.3	102.8	97.5	22.5	22.4	3.73	3.64	4.52	4.18	28872	29337	15788	14094	7.37	8.70	29882
T_2	273.1	255.5	27.1	25.9	105.4	102.4	23.0	22.7	4.06	3.98	4.70	4.52	30274	30744	18148	16724	8.04	9.22	34872
T_3	291.2	290.7	27.4	27.2	113.0	110.1	23.1	22.9	4.28	4.23	4.89	4.79	31095	31595	19980	18811	8.51	9.68	38791
T_4	325.9	314.1	28.6	27.4	126.3	122.6	23.3	23.2	4.80	4.76	5.34	4.98	32222	32706	24885	23710	9.56	10.32	48595
T_5	388.3	382.9	32.7	31.0	148.3	144.1	24.1	23.9	5.05	4.93	5.64	5.55	32422	32874	27679	25802	9.98	11.19	53481
T_6	366.3	362.1	30.7	28.5	140.3	133.5	23.9	23.3	4.86	4.70	5.39	5.25	32225	32664	25582	23329	9.56	10.64	48911
T_7	358.9	350.9	26.1	27.2	138.2	128.6	23.3	22.8	4.65	4.48	5.23	5.03	32140	32575	23200	20800	9.13	10.26	44000
SEm (±)	**26.7**	**28.7**	**1.3**	**1.34**	**7.8**	**6.6**	**0.5**	**0.6**	**0.17**	**0.18**	**0.20**	**0.17**	-	-	-	-	-	-	-
LSD (0.05)	**82.4**	**88.3**	**3.9**	**4.1**	**24.0**	**20.5**	**1.6**	**2.0**	**0.53**	**0.55**	**0.62**	**0.54**	-	-	-	-	-	-	-
CV (%)	**14.4**	**15.9**	**7.6**	**8.5**	**10.8**	**9.6**	**3.6**	**4.5**	**6.73**	**7.06**	**6.90**	**6.21**	-	-	-	-	-	-	-

K- Kharif, S- Summer

Table 4: Soil physico-chemical properties as influenced by organic nutrient management in rice-rice cropping sequence

Treatment	N (kg ha^{-1})		P_2O_5 (kg ha^{-1})		K_2O (kg ha^{-1})		OC (g kg^{-1})		pH (1:2.5)		BD (Mg m^{-3})	
	K	S	K	S	K	S	K	S	K	S	K	S
Initial	376.0		34.4		221.3		9.4		6.35		1.58	
T_1	350.0	312.0	35.3	34.3	224.6	227.8	**11.4**	**10.4**	6.45	6.34	1.65	1.66
T_2	342.0	336.0	36.3	35.6	227.4	230.3	**12.5**	**10.7**	6.56	6.43	1.60	1.62
T_3	352.6	340.4	37.5	38.7	228.4	228.8	**12.6**	**11.5**	6.55	6.54	1.58	1.57
T_4	364.7	368.6	39.4	39.4	230.3	231.6	**12.9**	**11.8**	6.54	5.56	1.55	1.57
T_5	386.0	383.0	39.6	40.5	230.4	232.3	**13.5**	**12.6**	6.46	6.48	1.54	1.55
T_6	366.6	369.6	38.7	38.4	233.3	234.7	**12.3**	**11.5**	6.57	6.59	1.57	1.55
T_7	360.4	361.6	37.5	38.3	234.5	235.3	**11.5**	**10.7**	6.61	6.59	1.58	1.59
SEm(±)	**30.23**	**29.66**	**1.68**	**1.62**	**24.88**	**25.02**	**0.69**	**0.68**	**0.42**	**0.40**	**0.11**	**0.10**
LSD (0.05)	**90.92**	**89.05**	**5.06**	**4.99**	**75.64**	**77.06**	**2.54**	**2.48**	**1.257**	**1.21**	**0.32**	**0.31**

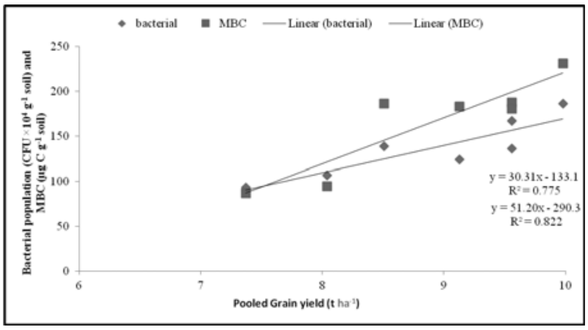

Fig.1: Relation of bacterial population and MBC to rice yield as affected by organic nutrient management

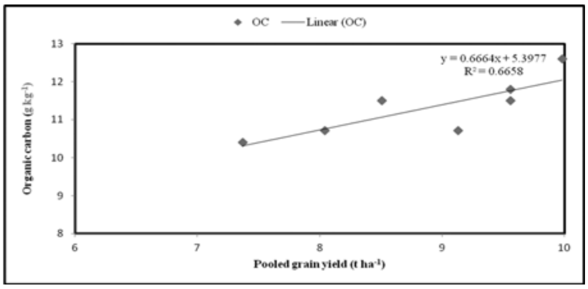

Fig. 2: Relation of actinomycetes (10^4) and Fungi (10^3) population to rice yield (t ha^{-1}) as affected by organic nutrient management

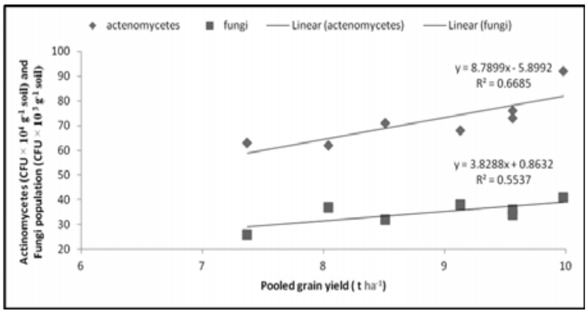

Fig. 3: Correlation of organic carbon to rice yield (pooled) as affected by organic nutrient management

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