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System productivity and soil health in relation to microbial population in organic rice-rice sequence

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ABSTRACT

Field experiments were conducted during 2011-2013 in Organic Block of Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar. The experiment was laid out in a randomized block design with twelve treatments and three replications in kharif season and all the corresponding treatments were the same in summer season except green manuring with Sesbania aculeata. The soil of the experimental site was sandy loam with pH 6.35, BD 1.58 t m^{-3}, PD 2.65 t m^{-3}, high in organic carbon (9.7 g kg^{-1}) and medium in available N-P_2O_5-K_2O (375.0, 34.49 and 221.25 kg ha^{-1}, respectively). Microbial population was highly influenced by organic nutrient management and Biozyme formulations during the crop growing period. Maximum microbial population (Bacteria 1.1 x 10^7 and 1.08 x 10^7, Actinomycetes 9.6 x 10^6 and 9.3 x 10^6, Fungi 9.6 x 10^4 and 9.3 x 10^4 cfu g^{-1} of soil) was observed at 90 DAT of crop and decreased thereafter. The bacterial, fungal and actinomycetes population during crop growing period had strong positive linear relationship with crop yield (R^2 = 0.82 and 0.85, 0.95 and 0.95 and, 0.92 and 0.91 in kharif and summer, respectively). Organic nutrient management and Biozyme formulations expressed conspicuous effect on microbial population which, in turn, resulted in maximum rice yield for treatment receiving Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in kharif (5.09 t/ha) and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (4.95 t/ha). Soil status after system yield (N-P_2O_5-K_2O 358, 36, 229 kg ha^{-1} ; OC 12.0 g kg^{-1}; pH 6.6; EC 0.115 dSm^{-1}; BD and PD 1.54 and 2.63 t m^{-3}) was very close to or improved from those of initial status of soil.

***Key words**:* Microbial population, organic nutrient management and rice-rice sequence

An ideal agricultural system is sustainable, maintains and improves human health, benefits producers and consumers both economically and spiritually, protects the environment, and produces enough food for an increasing world population (Higa, 1991). It is evident that conventional agriculture has resulted in declining factor productivity and hence, is no more sustainable. Furthermore, it has propped up many environmental problems including soil, air and water pollution and finally human health hazards (Singh *et al*., 2011). In this context, organic farming system is adjudged to be the most viable option to sustain agricultural growth (Kalra *et al*., 2012). Moreover, this system is associated with soil health, clean environment, promotion and enhancement of agro-ecosystem services, biodiversity, biological cycles and soil biological activities.

It is widely recognized that organic matter in 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 (Majumder *et al*., 2007; Geeta Kumari *et al*., 2013). Maintaining or increasing SOM is critical to achieve optimum soil functions and thereby soil fertility and crop production.

It is important to recognize that the best soil and crop management practices to achieve a more sustainable agriculture will also enhance the growth, numbers and activities of beneficial soil microorganism that, in turn, can improve the growth, yield and quality of crops (Higa and Parr, 1994)..In essence, soil quality is the very foundation of a more sustainable agriculture (NAS, 1989; Hornick, 1992; Parr *et al*., 1992). Parr and Hornick (1992) promulgated that we must give more attention to soil biological property because of their important relationship to crop production, plant and animal health, environmental quality, and food safety and quality. Scientists have found that such problems cannot be attended to without using microbial methods and technologies in coordination with agricultural production (Reganold *et al.*, 1990; Parr and Hornick, 1992). Since microorganisms are useful in eliminating problems associated with the use of chemical fertilizers and pesticides, they are now widely applied in nature farming and organic agriculture (Higa, 1991; Parr *et al*.,1994).

Formation and re-mineralization of SOM depend on biogeochemical pathways of C and N that are governed by soil microbial biomass and soil enzymes. Mainly prokaryotic biomass constitutes the major fraction of the soil biota in flooded soils that accounts for the most labile fraction of SOM and functions simultaneously as a sink and as a source of plant nutrients. Under this circumstance, an area that appears to hold the greatest promise for technological advance in crop production, crop protection and natural resource conservation is that of beneficial and

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effective microorganism, applied as soil, plant and environmental inoculants (Higa and Parr, 2004). Keeping the importance of microorganisms for attainment of sustainable agriculture in view, it has been rightly adjudged to be the 'century of microbes'. Biozyme is a formulation of sea-weed (*Ascophyllum nodosum*) extract, which contains major and minor plant nutrients, alginic acid, vitamins, auxins, gibberellins and antibiotics (Stephenson, 2008) and is said to be a soil conditioner and enhance the inherent plant capacity to express itself with full potential (Wallace, 1998). It provides plant growth hormones which promote plant growth (Cassan *et al*., 1992) and accelerate soil biological activities (Stephenson, 2008).

Research on soil microbial study in relation to crop production and soil health is quite meagre (Higa and Parr, 1994). On this account, a research trial on 'crop productivity and soil health in relation to microbial population in organic rice-rice system' was undertaken.

MATERIALS AND METHODS

The experiment was undertaken during *kharif* and *rabi* seasons of 2011-2013 in Organic Block of Central Research Station, OUAT, Bhubaneswar (20º15' North latitude and 85 º.52' East longitude with an altitude of 25.9 m above mean sea level) taking rice variety 'Lalat' as test crop. The soil of the experimental site was sandy loam with pH 6.35, BD 1.58 t m^{-3}, PD 2.65 t m^{-3}, high in organic carbon (9.7 g kg^{-1}) and available N-P_2O_5-K_2O was in medium range (375.0, 34.49 and 221.25 kg ha^{-1}, respectively). The experiment was laid out in randomized block design with 12 treatments replicated thrice. The treatments were combination of organic nutrient sources (*Dhanicha*, FYM and Vermicompost) and Biozyme formulations (BG, BSP and BPPL) (Table 1). Seedlings were raised in wet nursery bed. Prior to sowing in nursery beds, seeds were soaked for 24 hours in water and then treated with Biozyme Seed Plus (BSP) @ 2.5ml kg^{-1} as per treatment. Twelve days old seedlings were transplanted in the main field at a spacing of 25 cm x 25 cm in both the seasons and years. The plot size was 11.25m X 1.5m and raised beds were formed by creating channels of 30cm width all around the beds. *Dhanicha* (*Sesbania aculeate*) @ 25 kg seed ha^{-1} was sown in first week of June and incorporated 7 days before main field preparation in *kharif* season FYM @ 5t ha^{-1} at final land preparation and vermicompost @ 2t ha^{-1} at 15 DAT were applied in both the seasons as per treatments. Biozyme Granule (BG)@ 15 kg ha^{-1} and Biozyme Power Plus Liquid (BPPL)@ 750 ml ha^{-1} were applied as per treatments. Mechanical weeding was done thrice with Conoweeder at 20, 30 and 40 days after transplanting. Pot manure was prepared by adding 5 kg cow dung, 5 litre cow urine, 250 g gur, 1 kg each of *Azadirachta indica*, *Pongamia pinnata* and *Calotropis gigantia* leaves in a pot and allowing that to ferment for 15 days. It was sprinkled over the crop four times at 15 days interval starting from 15 DAT with the help of a rose cane. Microbial population study was undertaken before, after and at 30 days interval during crop growing period through Microbial Enumeration by Spread Plate Technique using serial dilution method (Chhonkar *et al*., 2007). Yield attributing observations on number of panicles m^{-2}, length of panicle, number grain per panicle, 1000-grain weight, grain yield and straw yield were recorded and were subjected to statistical analysis.

Table 1: Treatment details

Treatment	*Kharif* (Rainy)	Rabi (Summer)
T_1	Dhanicha 25 kg seed ha^{-1}	Control
T_2	Dhanicha + FYM 5t ha^{-1} (Basal)	FYM 5t ha^{-1} (Basal)
T_3	Dhanicha + FYM + Vermicompost 2t ha^{-1} (20DAT)	FYM + Vermicompost 2t ha^{-1} (20DAT)
T_4	T_1 + BSP (S.T) + BG (Basal)	T_1 + BSP (S.T) + BG (Basal)
T_5	T_1 + BSP (S.T) + BPPL (Tillering + PI stage)	T_1 + BSP (S.T) + BPPL (Tillering + PI stage)
T_6	T_1 + BSP + BG + BPPL	T_1 + BSP + BG + BPPL
T_7	T_2 + BSP (S.T) + BG (Basal)	T_2 + BSP (S.T) + BG (Basal)
T_8	T_2 + BSP (S.T) + BPPL (Tillering + PI stage)	T_2 + BSP (S.T) + BPPL (Tillering + PI stage)
T_9	T_2 + BSP + BG + BPPL	T_2 + BSP + BG + BPPL
T_{10}	T_3 + BSP (S.T) + BG (Basal)	T_3 + BSP (S.T) + BG (Basal)
T_{11}	T_3 + BSP (S.T) + BPPL (Tillering + PI stage)	T_3 + BSP (S.T) + BPPL (Tillering + PI stage)
T_{12}	T_3 + BSP + BG + BPPL	T_3 + BSP + BG + BPPL

Note : S.T – Seed treatment, P.I – Panicle initiation

RESULTS AND DISCUSSION

Soil microbial population studies

Soil microbial population curve followed a parabolic trend from start to end of a season. Soil microbial population was found higher and active during crop growing period in both the seasons whereas before transplanting and after harvest the population was low. The treatment T_{12} resulted in maximum microbial population in both the seasons due to organic nutrient management and Biozyme formulations (Table 2). On the other hand, microbial population due to T_1 treatment remained low in both the seasons. A strong positive linear relationship between crop yield and bacterial population (R^2= 0.82 and 0.85 in *kharif* and summer, respectively), actinomycetes population (R^2= 0.95 and 0.95 in *kharif* and summer, respectively), and fungal population (R^2= 0.92 and 0.91 in *kharif* and summer, respectively) at 90 DAT were observed (Fig. 2 & 3). It is observed that the best organic management practices to achieve a more sustainable system production also enhanced the growth, numbers and activities of beneficial soil microorganism that, in turn, improved the growth, yield and quality of the crop. Addition of organic inputs could have favoured microbial activity and enhanced the soil microbial biomass (SMB) because of supply of organic carbon and improved soil physical properties (Kenchaiah, 1997). It was found that organic amendments can improve soil physical properties (soil moisture and structural stability), and consequently benefit soil microbial mediated processes (Liu, 2005). Higa and Parr (1994) also promulgated that predominance of microorganisms can help to improve and maintain the soil chemical and physical properties. Proper and regular addition of organic amendments are often an important part of any strategy to exercise such control. The amount of bioactive substances produced by microorganisms can be sufficient to achieve the desired positive effects on crop production and/or protection. Parr and Hornick (1992) emphasized that more attention be given to soil biological property because of their important relationship to crop production and environmental quality.

Table 2: Soil microbial population as influenced by organic nutrient management and Biozyme formulations (Pooled)

Treatment	Bacterial population				Actinomycetes population				Fungi population			
	Initial ($x10^4$ xgm^{-1} soil)	***Kharif* (90 DAT) ($x10^5$)**	**Rabi (90 DAT) ($x10^5$)**	**After system harvest ($x10^5$)**	**Initial ($x10^4$)**	***Kharif* (90 DAT) ($x10^5$)**	**Rabi (90 DAT) ($x10^5$)**	**After system harvest ($x10^5$)**	**Initial ($x10^3$)**	***Kharif* (90 DAT) ($x10^3$)**	**Rabi (90 DAT) ($x10^3$)**	**After system harvest ($x10^3$)**
T_1	53.00	60.33	58.33	39.33	44.67	69.67	66.67	38.33	42.33	61.00	58.00	36.67
T_2	52.00	73.33	70.33	37.33	46.00	73.00	70.00	42.67	44.00	71.00	69.00	38.67
T_3	53.67	82.33	80.33	42.00	44.00	82.00	79.00	46.67	44.00	73.00	70.00	42.00
T_4	53.33	83.00	79.00	40.33	44.67	75.33	72.33	42.67	46.67	68.00	64.00	39.33
T_5	54.33	83.33	80.33	43.33	43.00	75.67	72.67	45.67	46.00	71.33	67.33	41.67
T_6	52.00	91.00	89.00	39.67	46.00	79.00	76.00	46.00	42.67	69.00	66.00	40.33
T_7	53.00	93.33	90.33	44.00	45.00	82.67	79.67	51.33	43.00	81.00	79.00	41.00
T_8	54.33	99.00	95.00	46.67	49.67	85.33	82.33	54.67	47.67	82.00	77.00	40.33
T_9	54.67	98.33	96.33	48.67	49.67	88.33	85.33	50.33	45.67	92.33	90.33	43.33
T_{10}	51.33	92.00	89.00	49.33	48.00	90.67	87.67	54.33	45.00	91.67	87.67	40.67
T_{11}	53.00	97.00	93.00	53.00	48.33	90.67	87.67	53.33	46.00	91.00	89.00	46.67
T_{12}	53.33	110.00	108.00	53.67	46.00	96.33	93.33	54.00	46.00	96.33	93.33	45.33
SEm(±)	**4.169**	**6.422**	**6.422**	**4.028**	**3.413**	**6.137**	**6.137**	**4.643**	**2.952**	**5.716**	**5.716**	**2.815**
LSD(0.05)	**12.23**	**18.83**	**18.83**	**11.81**	**10.01**	**18.00**	**18.00**	**13.61**	**8.66**	**16.76**	**16.76**	**8.26**
CV (%)	**13.58**	**12.36**	**12.76**	**15.58**	**12.78**	**12.68**	**13.16**	**16.64**	**11.38**	**12.54**	**13.05**	**11.80**

Yield attributes and yield

Yield attributes and yield followed similar trend in both the seasons and years (Table 3). The average number of panicle m^{-2} was found to be 303.02 and 286.85 in *kharif* and summer, respectively. Treatment receiving *Dhanicha* + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) registered highest number of panicle m^{-2} at harvest (379.2 and 361.6, respectively), those were 68.5 and 77.0 per cent higher than the treatment producing the lowest number of panicle m^{-2} i.e. only *Dhanicha* @ 25 kg seed ha^{-1} in *kharif* and no manure application in summer (T_1). The mean of treatments receiving organic nutrient and Biozyme formulations (T_4 to T_{12}) resulted in 30.9 and 34.5 per cent higher number of panicle m^{-2} than those of treatments receiving organic sources alone (T_1 to T_3). The average filled grain was 124.62 and 120.92 in *kharif* and summer, respectively. The highest filled grain was obtained from T_{12} (145.8 and 140.8, respectively), which was 49.0 and 47.7 per cent higher than those of T_1. The mean of treatments receiving organic nutrient and Biozyme formulations (T_4 to T_{12}) resulted in 29.0 and 28.5 per cent higher filled grains in respective seasons than those of treatments receiving organic sources alone (T_1 to T_3). The 1000 grain weight were non-significant with the application of organic nutrient management and Biozyme formulations. The average grain yield and straw yield were 4.2 and 4.8; 4.1 and 4.6 t ha^{-1} in *kharif* and summer, respectively. Higher grain and straw yield were recorded in T_{12} in both the seasons, and those were 46.2 and 38.6; 48.5 and 41.1 per cent higher than T_1, respectively. The mean of treatments receiving organic nutrient and Biozyme formulations (T_4 to T_{12}) resulted in 20.6 and 18.0 and, 21.5 and 18.6 per cent higher grain and straw yield than those of treatments receiving organic sources alone (T_1 to T_3) in respective seasons. Application of Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) resulted in the highest grain yield (5.1 and 5.0 t ha^{-1} in *kharif* and summer seasons, respectively) which was at par with those of T_9 to T_{11} in *kharif* and T_8 to T_{11} in summer seasons, respectively. Treatments were unable to influence harvest index of rice which varied within a narrow range of 0.46-0.48 in both the seasons. The average system grain yield, straw yield and net profit were found to be 8.4 t ha^{-1}, 9.4 t ha^{-1} and 35341.97 respectively, and grain yield, straw yield and net profit were found to be maximum for T_{12} (10.0 t ha^{-1}, 11.1 t ha^{-1} and 52721.6, respectively)

Table 3: Yield attributes and yield of rice as influenced organic nutrient management and Biozyme formulations (pooled)

Treatment	No. of panicle m^{-2}		Filled grains per panicle		1000-grain weight (g)		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		Net profit		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Net profit
	Kharif	Rabi	*Kharif*	Rabi	*Kharif*	Rabi	*Kharif*	Rabi	*Kharif*	Rabi	*Kharif*	Rabi			
T_1	225	204	98	95	24.53	24.36	3.5	3.3	4.1	3.9	11126	10386	6.8	7.9	21513
T_2	240	221	101	99	24.87	24.72	3.6	3.4	4.2	3.9	11978	11307	7.0	8.1	23285
T_3	273	259	108	105	25.13	25.06	4.0	3.8	4.5	4.4	15900	15486	7.8	8.9	31386
T_4	241	223	111	108	24.70	24.58	3.7	3.6	4.3	4.1	11858	11254	7.3	8.5	23112
T_5	255	236	118	115	24.90	24.75	3.8	3.7	4.4	4.2	12976	12305	7.5	8.6	25281
T_6	275	261	127	123	25.33	25.26	4.1	3.9	4.7	4.5	14895	14402	8.0	9.2	29297
T_7	326	308	130	125	25.57	25.44	4.3	4.2	4.9	4.7	18208	17630	8.4	9.6	35838
T_8	330	326	136	132	25.67	25.54	4.6	4.4	5.1	4.9	21486	20910	9.0	10.1	42396
T_9	356	339	137	133	25.90	25.78	4.9	4.7	5.4	5.2	24085	23508	9.6	10.6	47594
T_{10}	364	351	141	137	25.50	25.45	4.7	4.5	5.2	5.1	22328	21955	9.2	10.3	44283
T_{11}	371	352	143	139	25.93	25.78	4.8	4.7	5.3	5.1	24034	23363	9.5	10.5	47397
T_{12}	379	362	146	141	26.07	25.94	5.1	5.0	5.6	5.4	26663	26059	10.0	11.1	52722
SEm(±)	22.354	22.3	7.978	7.68	0.768	0.768	0.17	0.18	0.21	0.23	-	-	-	-	-
LSD(0.05)	65.56	65.4	23.40	22.5	NS	NS	0.50	0.50	0.60	0.70	-	-	-	-	-
CV (%)	12.78	13.4	11.09	11.0	5.25	5.28	6.74	7.72	7.41	8.55	-	-	-	-	-

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, mineralize nutrients from the organic sources for plant availability and release enzymes and hormones that promote plant growth. 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. Organic manures besides improving the physico-chemical and biological properties of soil might have prevented leaching and volatilization losses and its slow release pattern might have supplied nutrients in optimal 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). Doan *et al*. (2013) found higher plant growth and yield and soil NH^{4+}content in soil treated with vermicompost compared to compost suggesting higher N mineralization and utilization by the plants**.** The promotional effects of Biozyme on yield and yield attributes might be because of increased root proliferation and establishment . Besides, Biozyme regulate the plant bio-physiological activities (increased chlorophyll content in leaf etc.), which collectively resulted in maintaining higher photosynthetic activity even during later period of the plant life-cycle (during grain-filling), thus the higher yield and yield attributes (Wierzbowska and Nowak, 1998).

Soil physico-chemical properties

The experimental site is organically maintained since 2003. Therefore, bulk density and particle density has almost stabilized. Soil pH was within range of (6.4 to 6.9) due to different treatments (Table 4) that may be due to the buffering property of the organic manures used. The available nutrient status of N-P-K was in the optimum range due to organic nutrient management and Biozyme formulations. Organic carbon increased according to the treatments in the range of 10.2 to 15.7 g kg^{-1}. A strong positive linear relationship (R^2 = 0.825 and 0.938 in *kharif* and summer seasons, respectively) was observed between OC and grain yield (Fig 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). The increased SOC content with the long-term application of FYM resulted in decreased soil bulk density increased total porosity as well as water holding capacity and improved soil aggregation even in the deeper soil layers (Rasool *et al*., 2008). Data on soil properties as influenced by different treatments showed that organic carbon content increased to a great extent with the addition of different organic manures. Yadav *et al*. (2009) also reported similar findings from their manorial trials. Addition of exogenous OM such like compost results in an enhancement of OC storage in addition to improvement of many other soil functions related to the presence of organic matter (Ngo *et al*., 2012). Humic substances contained in the vermicompost, are environmental friendly materials that restore the chemical and physical properties of soils and improve plant growth (Garcia *et al*., 2012). Total soil organic carbon stock and soil organic carbon sequestration rates were also significantly influenced by the organic nutrient management and Biozyme application treatments (Bastia *et al*., 2013).

Table 4: Soil physico-chemical properties as influenced by organic nutrient management and Biozyme formulations after each harvest of the crop (Pooled).

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 (t m^{-3})	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
Initial	375		34.49		221.3		9.7		6.3		1.58	
T_1	355	314	35.23	34.43	234.4	220.2	11.2	10.2	6.4	6.5	1.55	1.55
T_2	340	333	37.31	34.67	241.2	222.4	12.5	10.4	6.4	6.6	1.55	1.56
T_3	356	342	35.78	36.54	241.6	234.5	13.4	11.6	6.6	6.5	1.54	1.55
T_4	368	333	37.87	37.32	236.3	225.6	12.9	11.1	6.4	6.4	1.54	1.54
T_5	367	357	39.65	37.21	242.5	227.8	12.8	11.3	6.5	6.5	1.53	1.52
T_6	345	345	40.32	35.4	238.9	224.4	14.1	12.1	6.4	6.6	1.54	1.53
T_7	376	365	35.57	37.36	242.3	228.7	13.5	12.5	6.6	6.4	1.53	1.54
T_8	390	368	42.79	36.68	238	236.9	14.4	12.6	6.7	6.5	1.52	1.53
T_9	397	379	39.46	36.46	240.4	231.3	14.2	12.9	6.6	6.6	1.53	1.53
T_{10}	388	384	40.65	37.35	241.8	228.6	14.6	13.6	6.9	6.7	1.52	1.53
T_{11}	382	389	41.76	37.67	240.8	233.4	15.7	13.4	6.8	6.8	1.52	1.52
T_{12}	395	392	43.46	36.89	240.3	235.2	15.3	14.2	6.7	6.7	1.52	1.52

The experimental findings suggested that combination of organic nutrients with Biozyme formulations such as *Dhanicha* + FYM + Vermicompost + BSP + BG + BPPL in kharif and FYM + Vermicompost + BSP + BG + BPPL in summer rice are encouraging as regards to proliferation and activity of microorganisms which, in turn, accelerate productivity of rice and soil health.

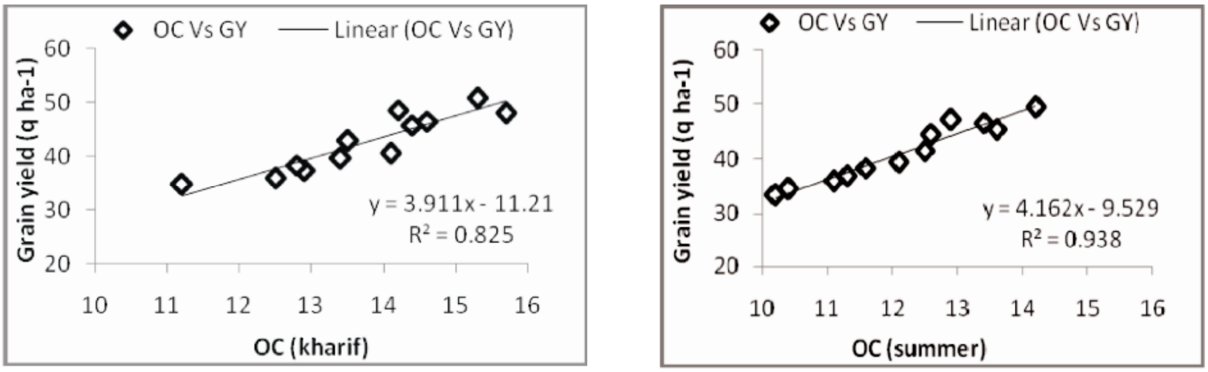

Fig 1 Correlation of organic carbon to grain yield of *kharif* and summer rice as affected by ONM and Biozyme formulations

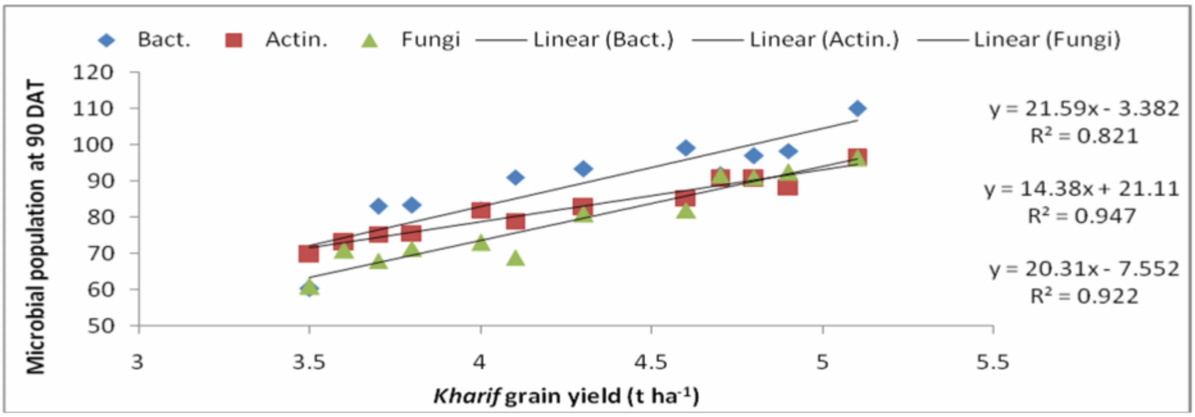

Fig 2 Relation of microbial population to grain yield of *kharif* rice as affected by ONM and Biozyme formulations

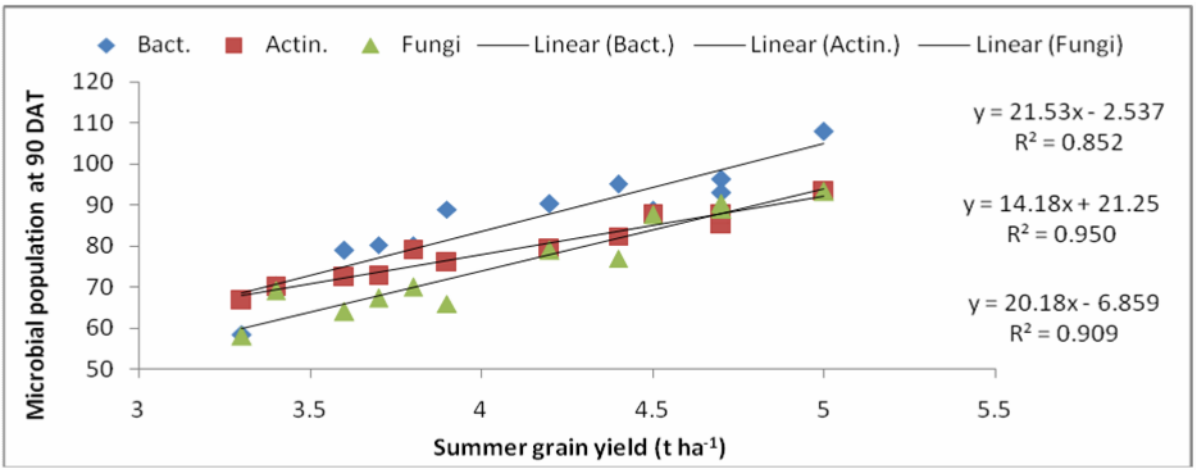

Fig 3: Relation of microbial population to grain yield of summer rice as affected by ONM and Biozyme formulations

REFERENCES

Bastia, D. K., Tripathy, S., Barik, T., Kar, C. S., Raha, S. and Tripathy, A. 2013. Yield and soil organic carbon sequestration under organic nutrient management in rice-rice system. *J. Crop Weed* **9**:52-55.

Bhattacharya, S. P., Sitangshu, S., Karimadkar, A. J., Bera, P.S., Latika, M., Sarkar, S. and Mandal, L. 2003. Effect of humic acid (earth) on the growth and yield of transplanted summer rice. *Env. Ecol.* **21**: 680-83.

Cassan, L., Jeanin, I., Lamaze, T. and Morot, G.J.F. 1992. The effect of *Ascophyllum nodusum* extract Goemar GA 14 on the growth of spinach. *Bot. Mar.* **35**: 437-39

Chhonkar, P.K., Bhadraray, S. B., Patra, A.K. and Purukayastha, T.J. 2007 *Experiments in Soil Biology and Biochemistry* Pub. Westville Publishing House, New Delhi. p 1-22.

Doan, T.T., Ngo, P. T., Rumpel, C. and Nguyen, B. V. 2013. Interactions between compost, vermicompost and earthworms influence plant growth and yield: A one-year greenhouse experiment. *Scientia Hort.* **160**: 148–54.

Garcia, A. C., Santos, L. A., Izquierdo, F. G., Sperandio, M. V. L., Castro, R. N. and Berbara, R. L. L. 2012. Vermicompost humic acids as an ecological pathway to protect rice plant against oxidative stress. *Eco. Eng.* **47**: 203–08.

Higa, T. 1991. Effective microorganisms A biotechnology for mankind. Proc. First Int. Conf. on Kyusei Nature Fmg. U.S. Department of Agriculture, Washington, D.C., USA. p. 8-14.

Higa, T. and Parr, J.F. 1994. *Beneficial and effective microorganisms for a sustainable agriculture and environment*. Int. Nature Fmg. Res. Center, Atami, Japan, p.16.

Hornick, S,B. 1992. Factors affecting the nutritional quality of crops. *Amer. J. Alternative Agric*. **7**:63-68.

Kalra, R.K., Hundal, S.S., Kaur, J. and Jassal, G. 2012. Satisfaction of the farmers regarding organic farm practices of Hoshiarpur, Punjab. *J. Eco-friendly Agric.* **7**:17-23

Kenchaiah, A. 1997. Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore, India.

Kumari, N., Singh, A.K., Pal, S.K. and Thakur, R. 2010. Effect of organic nutrient management on yield, nutrient uptake and nutrient balance sheet in scented rice. *Indian J. Agron* **55**: 220-23.

Kumari, G., Thakur, S.K., Kumar, N. And Mishra, B. 2013. Long term effect of fertilizer, manure and lime on yield sustainability and soil organic carbon status under maize-wheat cropping system in *Alfisols*. *Indian J. Agron*. **58**: 152-58.

Liu, M. 2005. Biological properties and soil organic matter physical protection of paddy soil under different organic management practices. Ph.D. Thesis. Nanjing Agriucltural University, Nanjing, China, pp. 1–219.

Majumder, B., Mandal, B., Bandyopadhaya, P.K. and Chaudhury, L. 2007. Soil organic carbon pools and productivity relationships for a 34-year-old rice-wheat-jute agroecosystem under different fertilizer treatments. *Pl. Soil*, **297** : 53-67.

National Academy of Sciences. 1989. Alternative Agriculture. Committee on the Role of Alternative Agriculture Farming Methods in Modern Production Agriculture. National Academy Press, Washington, D.C., USA. 448 p.

Ngo, P. T., Rumpel, C., Doan, T. T. And Jouquet, P. 2012. The effect of earthworms on carbon storage and soil organic matter composition in tropical soil amended with compost and vermicompost. *Soil Biol. and Biochem.* **50**: 214-20.

Parr, J.F. and Hornick,S.B. 1992. Agricultural use of organic amendments: A historical perspective. *Amer. J. Alternative Agric*. **7**:181-89.

Parr, J.F. and Hornick, S.B. 1994. Assessment of the Third Int. Conf. on Kyusei Nature Fmg. Round Table Discussion by USDA Scientists, October 7,1993. Nature Farming Research and Development Foundation, Lompoc, California, USA.

Parr, J.F., Papendick, R.I., Hornick, S.B., and Meyer, R.E. 1992. Soil quality: Attributes and relationship to alternative and sustainable agriculture. *Amer. J. Alternative Agric.* **7**:5-11.

Parr, J.F., Hornick, S.B. and Kaufman, D.D. 1994. Use of microbial inoculants and organic fertilizers in agricultural production. *In* Proc. Sem. Use of Microbial and Organic Fertilizers in Agril. Production. Food and Fertilizer Technology Center, Taipei, Taiwan.

Raju, R. A. and Sreenivas, C. 2008. Agronomic evaluation of system of rice intensification method in Godabari Delta. *Oryza* **45**: 280-83.

Rasool, R., Kukal, S.S. and Hira, G. S. 2008. Soil organic carbon and physical properties as affected by long-term application of FYM and inorganic fertilizers in maize–wheat system. *Soil Tillage Res.* **101**: 31–36.

Reganold, J.P., R.I. Papendick, and J.F. Parr. 1990. Sustainable Agriculture. *Scientific Amer.* **262**: 112-20.

Shanmugam, P. M. and Veeraputhran, R. 2001. Effect of organic and inorganic N and zinc application on soil fertility and nutrient uptake of *rabi* rice (*Oryza sativa*). *Madras Agric. J.* **88**:514-17.

Shekara, B.G., Sharnappa, S and Krishnamurthy, N. 2010. Effect of irrigation schedules on growth and yield of aerobic rice under varied levels of FYM in Cauvery Command area. *Indian J. Agron.* **55**: 35-39.

Singh, F., Kumar, R. and Pal, S. 2008. Integrated nutrient management in rice-wheat cropping system for sustainable productivity. J. *Indian Soc. Soil Sci.* **56**: 205-08.

Singh, Y.V. and Dhar, D.N. 2011. Changes in soil organic carbon and microbial population under organically managed rice (*Oryza sativa*)- wheat (*Triticum aestivum*)-greengram (*Vigna radiata*) cropping system. *Indian J Agric. Sc.* **81**:363-65.

Stephenson, W.A. 2008. Seaweeds in Agriculture and Horticulture, *Acres*. USA

Upadhyaya, S. K., Sarkar, C., Bajpai, R. K., Joshi, B. S. and Tripathi, R. S. 2000. Grain yield and N-uptake of rice as influenced by N management practices under rainfed low land. *Oryza* **37**:91-92.

Wallace, A. 1998. Some living plants and some additional products useful as soil conditioners and in various technologies (In) *Handbook of soil conditioners*, Wallace, Press lacking (Ed.), pp. 463-510.

Wierzbowska, J. and Nowak, G.A. 1998. The effect of cytokinin and auxin on yield and quality of spring wheat grain depending on NPK rates. Part I. Dynamics of plant growth and final yield formation. *Biuletyn Instytutu. Hodowli.I. Aklimatyzacji – Roslin* **208**:17-34.

Yadav, D.S., Kumar,V. and Yadav, V. 2009. Effect of organic farming on productivity, soil health and economics of rice-wheat system. *Indian J. Agron.* **54**: 267-71.