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Research Paper

Influence of long-term organic nutrient management on soil quality and crop productivity in rice (*Oryza sativa*)–potato (*Solanum tuberosum*)–okra (*Abelmoschus esculentus*) cropping system under irrigated condition

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ABSTRACT

A long-term field experiment was conducted during 2006–07 to 2014–15 on organic nutrient management in rice (*Oryza sativa* L.)–potato (*Solanum tuberosum* L.)–okra (*Abelmoschus esculentus* L.) cropping system under irrigated conditions in the coastal alluvial sandy loam soil having *p*H 5.8 and organic carbon 0.62% at Bhubaneswar, Odisha. Eight treatments comprising of five organic, two integrated and one inorganic of nutrient management were tested with three replications in randomized block design. Organic sources of nutrient supply reduced the system yield by 7.6 to 9.7% over the inorganic source in the first year. However, the mean system yield of 'conversion period' (first three cropping system cycles) with organic nutrient management comprising of supply of one-third N each through farm yard manure (FYM), green manuring of *dhaincha* (*Sesbania cannabina*) or vermicompost and neem (*Azadirachta indica*) oilcake + *Azospirillum* or *Azotobacter* + phosphate solubilizing bacteria (PSB) was on par with inorganic approach. The mean system yield from fourth to ninth cropping system cycles ('after conversion period') with organic sources of nutrient supply, i.e. FYM + green manuring or vermicompost + neem oilcake + *Azospirillum* or *Azotobacter* + PSB was significantly higher (11.1%) than that of with inorganic source of nutrient supply *i.e.*, 100% NPK + $ZnSO_4$ @ 25 kg/ha to rice and 100% NPK + gypsum @ 110 kg/ha + borax @ 10 kg/ha + ammonium molybdate @ 0.8 kg/ha to both potato and okra. The organic nutrient management package increased the soil organic carbon and available N, P and K at the end of ninth cropping system cycle over the initial and the build-up was maximum in the soil applied with one third N each through FYM, *dhaincha*/vermicompost and neem oilcake + *Azospirillum*/*Azotobacter* + PSB. The microbial population in terms of colony forming units increased in a higher rate in soils with organic nutrient supply system (bacteria 36.5 to 39.4%, fungi 33.0 to 38.2% and actinomycetes 36.0 to 37.3%) compared to the inorganic source of nutrient supply system (bacteria 5.6%, fungi 10.3% and actinomycetes 12.7%) after ninth cropping system cycle over initial status. The microbial biomass carbon of the soils with organic sources of nutrient supply was enhanced considerably (57.7% to 66.8%) over the initial level (98.7 to 107.4 μg C/g). Application of one-third N each through FYM, green manuring of *dhaincha* and neem oilcake + *Azospirillum* + PSB to rice followed by similar combination of FYM, vermicompost, neem oilcake + *Azotobacter* + PSB to both potato and okra was the best organic nutrient management practice for rice–potato–okra cropping system for improving soil health and productivity. However, this system can be profitable under organic farming only when on-farm generated organic manures are used.

Key words : Cropping system, Microbial biomass carbon, Nutrient uptake, Organic sources of nutrient supply, Soil microbial population, System yield

Rice based cropping systems form an integral part of agriculture in coastal Odisha. Though rice–groundnut is the predominant cropping system under irrigated ecosystem, farmers grow various field crops and short duration vegetables in small patches after rice with limited irrigations. Inclusion of vegetables in the rice-based cropping systems has been suggested for higher productivity and profitability (Kachroo *et al.*, 2014). Rice–potato–okra has been identified as one of the most productive and profitable cropping systems for coastal Odisha under irrigated conditions (OUAT, 2005). Promotion of organic farming is being viewed as farming practice with distinct advan-

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tages of sustainability of crop production. Organic farming also permits the recycling of organic wastes, disposal of which could be difficult and expensive (Manjunatha *et al*., 2012). Though positive role of organic residues, including green manures on soils and crops has been well documented (Rupela *et al*., 2006), information on their use in location specific cropping systems is lacking to understand the role of organic farming on soil health, crop productivity and sustainability. It is a common belief that yields of several crops are reduced during the initial years under organic farming, but many experiments were conducted only for three or four years consecutively and often only with a specific crop; rather than in a well defined high productive cropping system (Rao *et al*., 2014). In view of this an experiment was conducted at Bhubaneswar on rice–potato–okra cropping system with various organic and integrated nutrient management practices consecutively for nine years to find out the impact of various nutrient management practices on system productivity and soil properties.

MATERIALS AND METHODS

A long-term field experiment was conducted from 2006–07 to 2014–15 (nine years) on organic nutrient management in rice–potato–okra system under irrigated condition at Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha situated at 20° 26' N, 85° 81' E, 34 m above mean sea-level having hot humid climate with mean annual rainfall of 1482 mm. The annual mean maximum and minimum temperature were 31.5 and 22.3°C respectively. The soil of the experimental site was sandy loam (68% sand, 15% silt and 17% clay) having *p*H 5.8, organic carbon 0.62%, available N, P and K of 262.2, 19.1 and 170.8 kg/ha, respectively. The experiment was laid out in randomized block design with eight treatments (detailed in Table 1) replicated thrice.

The organic sources of nutrients used in the experiment were farmyard manure (FYM) (N, P, K 0.56, 0.28, 0.64%), vermicompost (N, P, K 1.62, 1.00, 1.54%), neem (*Azadirachta indica*) oilcake (N, P, K 4.48, 0.92, 1.32%)

Table 1. Details of organic nutrient management treatments in rice–potato–okra system

Treatment	Rainy season (rice)	Winter season (potato)	Summer season (okra)
T_1	50% RDF + 50% N as FYM (8 t/ha)	50% RDF + 50% N as FYM (15 t/ha)	50% RDF + 50% N as FYM (8 t/ha)
T_2	Different organic sources equivalent to one-third of recommended N (one-third N as FYM @ 5.5 t/ha, one-third N as green manuring of *dhaincha* (*Sesbania cannabina*), one-third N as neem (*Azadirachta indica*) oilcake)	Different organic sources equivalent to one-third of recommended N (one-third N as FYM @ 10 t/ha, one-third N as vermicompost, one-third N as neem oilcake)	Different organic sources equivalent to one-third of recommended N (one-third N as FYM @ 5.5 t/ha t/ha, one-third N as vermicompost, one-third N as neem oilcake)
T_3	Same as T_2	Same as T_2	T_2 + cowpea (*Vigna sinensis*) as a trap crop (1: 1) in additive series
T_4	T_2 + manual weed control + biopesticides (neem oil and pot manure[*])	T_2 + manual weed control + biopesticides (neem oil and pot manure[*])	T_2 + manual weed control + biopesticides (neem oil and pot manure[*])
T_5	50% N as FYM + *Azospirillum* + RP + PSB (soil application)	50% N as FYM + *Azotobacter* + RP + PSB (soil application)	50% N as FYM + *Azotobacter* + RP + PSB (soil application)
T_6	T_2 + *Azospirillum* + PSB	T_2 + *Azotobacter* + PSB	T_2 + *Azotobacter* + PSB
T_7	100% NPK + 25 kg $ZnSO_4$ /ha	100% NPK + gypsum @ 110 kg + borax @ 10 kg + ammonium molybdate @ 0.8 kg/ha	100% NPK + gypsum @110kg + borax @ 10 kg/ha + ammonium molybdate @ 0.8 kg/ha
T_8	T_7 + crop residue recycling[**]	T_7 + crop residue recycling[**]	T_7 + crop residue recycling[**]

RDF, recommended dose of fertilizers; FYM, farmyard manure; RP, rock phosphate; PSB, phosphate solubulizing bacteria; RDF (N-P-K in kg/ha): rice, 80–17.5 –33; potato, 150 –33–82.5; okra, 80 –17.5–33

[*] Pot manure or *handi khata* as locally called is prepared with karanja (*Pongamia pinnata*) leaves 0.5 kg, bel (*Aegle marmelos*) leaves 0.5 kg, arakha (*Calotropis* sp.) leaves 1 kg, neem (*Azadirachta indica*) leaves 1 kg, jaggery 0.2 kg, cow urine 2 liters and fresh cow dung 1 kg. All the materials and chopped leaves are kept inside an earthen pot and thoroughly mixed. Then the mouth of pot is covered and kept under shade. After a week, another 2 liters of cow urine is poured inside the pot. In 3 weeks, the manure is ready to use in crop fields. The liquid extract is diluted with water and sprayed on the plants; [**]after harvest the total quantity of crop residue were incorporated in the soil of the respective plots. On an average, rice straw 2.8 t, potato plant residue 3.6 t and okra plant residue 4.1 t/ha were available for recycling. Average nutrient content, rice straw N 0.42, P 0.25, K 1.35%, potato plant residue N 3.29, P 0.21, K 3.29% and okra plant residue N 1.91, P 0.39, K 2.54%

and green manuring of *dhaincha* (*Sesbania cannabina*) (N, P, K 2.82, 0.58%, 1.18%) and biofertilizers such as *Azotobacter*, *Azospirillum* and phosphate-solubilizing bacteria (PSB). In case of organic nutrient management, all manures were applied before final land preparation for transplanting of rice and at planting of potato and okra in furrows. The inorganic sources used were urea, single super phosphate and muriate of potash to supply N, P and K, respectively, zinc sulphate (21% Zn) for zinc, gypsum (21% Ca, 17% S) for calcium and sulphur, borax (10% B) for boron and ammonium molybdate (52% Mo) for molybdenum. In case of inorganic nutrient management, full quantity of P and K were applied as basal in all the crops and N was applied in split doses. In rice, 25% of N was applied as basal, 50% top dressed at tillering and rest 25% was applied at panicle initiation stage. In potato and okra 50% of N was applied as basal and rest N was applied in 2 equal splits at 25 and 45 days after planting. The test varieties for rice, potato and okra were 'Lalat', 'Kufri Jyoti' and 'Utkal Gourav', respectively. Standard agronomic management practices were followed for all crops. Crop yields were recorded at the end of each season and rice equivalent yield (REY) was computed at the end of each cropping cycle. System yield was obtained by adding REY of component crops and prices were used from ninth cycle for all the years. The first three cropping cycles were taken as 'conversion period' and the next six years' yields were taken as 'after conversion period' and the mean yields of 'conversion period' and 'after conversion period' were calculated. Overall mean yield was also calculated taking yields of all the nine years. The treatment with recommended dose of inorganic nutrients (100% NPK + $ZnSO_4$ @ 25 kg/ha to rice and 100% NPK + gypsum @ 110 kg + borax @ 10 kg + ammonium molybdate @ 0.8 kg/ha to both potato and okra) was taken as reference treatment and increase or decrease in system yield was calculated for the 'conversion period', 'after conversion period' and 'overall mean' over this treatment for comparison. Economic efficiency in terms of ₹/ha/day was worked out by net returns of the system divided by 365 days. For economic analysis (cost of cultivation and gross returns) cost of inputs and price of outputs were used from ninth cycle (2014–15) for all the years. Statistical analyses were carried out using standard methodology of randomized block design.

Soil samples were drawn at initial and at the end of each cropping cycle (up to ninth cropping cycle) from a depth of 0–15 cm from each treatment and soil organic carbon (SOC), N, P and K content were analysed using standard procedures (Jackson, 1973). A portion of fresh soil samples were passed through a 2-mm sieve and stored at 4° C for determination of microbial population (Dhingra and Sinclair, 1993) and soil microbial biomass carbon (MBC) (Vance *et al*., 1987). The MBC was estimated from the equation, MBC = 2.64 Ec, where Ec is the difference between organic carbon extracted from the K_2SO_4 extract of fumigated and non-fumigated soils.

RESULTS AND DISCUSSION

Yield

The individual crop yields and system yield in terms of rice-equivalent yield (REY) during the first cropping system cycle were the highest with the recommended dose of fertilizers (RDF) including secondary and micro nutrients (zinc sulphate to rice, gypsum, borax and sodium molybdate to potato and okra), which was closely followed by 50% of the RDF + 50% of N as FYM. The treatment with 50% of N as FYM + *Azospirillum* + RP + PSB recorded the the lowest yield during the first year and the reduction in system yield was 13.5% compared to inorganic sources (Table 2). Organic treatments reduced the system yield by 7.6–9.7%. The lower yield in organic treatment might be related to the continuing phase of transition from conventional to organic agriculture (Surekha and Satishkumar, 2014). After four years of experiments in rice, Rao *et al*., (2014) also concluded that though organic farming had an edge over inorganic farming to sustain the soil health and grain quality, it was less productive as compared to inorganic or integrated nutrient management practices.

Reduction in yields due to replacement of chemical fertilizers with organics decreased during the 'conversion period'. After first three cropping system cycles, the mean system yield with organic treatment FYM + green manuring or vermicompost + neem oil cake + *Azospirillum* or *Azotobacter* + PSB was almost the same as that of inorganic treatment. But application of 50% RDF + 50% of N as FYM increased the mean system yield marginally by 1.7% over the inorganic treatment; however, the other organic treatments without biofertlizers were low yielders than the inorganic treatment.

After conversion period (fourth to ninth cropping system cycles), all the organic nutrient management practices except 50% N as FYM + *Azospirillum* + RP + PSB increased the individual mean crop yields and mean system yields over the inorganic treatment (Table 2). The increase in mean system yield was the highest (9.8%) in the treatment with FYM + green manuring or vermicompost + neem cake + *Azospirillum* or *Azotobacter* + PSB. The trend was also same for the overall mean yield (first to ninth cropping system cycle). Presence of organic matter improved the physico-chemical properties of soil (Table 5) which might have resulted in increased productivity by increasing availability of plant nutrients. Further, organic matter also maintained regular supply of macro and micro-

Table 2. Effect of nutrient management packages on crop yield (t/ha) in rice–potato–okra cropping system

Treatment	Initial yield level (first year)				Mean yield of 'conversion period' (first–third cropping system cycles)				Mean yield of 'after conversion period' (fourth–ninth cropping system cycles)				Overall mean yield (first–ninth cropping system cycles)			
	Kharif	*Rabi*	Summer	REY	*Kharif*	*Rabi*	Summer	REY	*Kharif*	*Rabi*	Summer	REY	*Kharif*	*Rabi*	Summer	REY
T_1	4.30	7.38	4.60	13.78	4.75	8.83	4.66	15.16	4.25	13.48	7.13	20.16	4.41	11.93	6.31	18.49
T_2	3.98	6.62	4.10	12.46	4.82	7.96	4.53	14.57	4.12	13.56	6.82	19.73	4.36	11.70	6.05	18.01
T_3	3.92	6.60	4.20	12.50	4.93	7.65	4.67	14.65	4.31	13.43	6.85	19.87	4.51	11.51	6.12	18.13
T_4	4.00	6.78	4.12	12.60	4.91	8.10	4.47	14.68	4.10	13.53	6.78	19.65	4.37	11.72	6.01	17.99
T_5	3.64	6.49	4.00	11.93	4.60	7.26	4.35	13.74	3.85	12.49	6.54	18.52	4.10	10.75	5.81	16.93
T_6	4.05	7.00	4.10	12.75	4.80	8.72	4.46	14.92	4.53	14.15	7.70	21.47	4.62	12.34	6.62	19.28
T_7	4.28	7.40	4.62	13.80	4.74	8.51	4.61	14.91	3.90	13.26	6.81	19.32	4.18	11.68	6.08	17.85
T_8	4.00	7.25	4.46	13.25	4.67	8.51	4.51	14.72	3.92	13.30	6.78	19.33	4.17	11.71	6.02	17.79
SEm±	0.08	0.14	0.09	0.27	0.04	0.21	0.04	0.18	0.08	0.18	0.11	0.32	0.06	0.18	0.07	0.24
CD (P=0.05)	0.23	0.41	0.26	0.80	0.12	0.62	0.11	0.54	0.22	0.53	0.32	0.94	0.17	0.53	0.21	0.71

REY, rice equivalent yield; *Kharif*, rainy seson; *Rabi*, winter season; Details of treatments is given in Table 1.

nutrients in soil resulting in higher yields (Sharma and Subehia, 2014).

Economics

Application of one-third N each through FYM, green manuring of *dhaincha* and neem oilcake + *Azospirillum* + PSB to rice followed by FYM + vermicompost + neem oilcake + *Azotobacter* + PSB to both potato and okra recorded the highest mean (first to ninth cropping system cycles) gross returns ₹2,65,919/ha (Table 3). However, the highest system net returns ₹1,03,025 with the highest benefit: cost ratio 1.72 and economic efficiency ₹282/ha/day was realized with application of 100% NPK + $ZnSO_4$ @ 25 kg/ha to rice and 100% NPK + gypsum @ 110 kg/ha + borax @ 10 kg/ha + ammonium molybdate @ 0.8 kg/ha to potato and okra. This was due to higher cost of cultivation in case of organic treatment which also include transportation cost of huge quantity of organic manure. Organic treatment incurred ₹42,686/ha more cost than the inorganic treatment, which restricted the net returns/ha. The same trend was also maintained till the ninth cropping system cycle.

Nutrient uptake

The pattern of total nutrient uptake (Table 4) followed almost the same trend as that of the system yield in the first year as well as after conversion period. The maximum uptake of 284.4 kg N, 53.3 kg P and 368.9 kg K/ha was obtained in the inorganic treatment in the first year and 360.4 kg N, 62.6 kg P and 438.3 kg K/ha in the organic treatment involving biofertilizers, when averaged over the nine cropping system cycles. On an average, the organic treatment removed 30.9, 7.3 and 33.4 kg more N, P and K/ha, respectively than the inorganic treatment. The same treatment also recorded the highest increase in system nutrient uptake (32.9, 24.7 and 26.5% higher for N, P and K, respectively) at end of the ninth cropping system cycle over first cropping system cycle. Higher availability of nutrients under organic sources might have improved the physiological and metabolic activities in crops leading to higher biomass production and higher uptake (Shalini Pilai *et al*., 2007).

Soil organic carbon

The initial status of soil organic carbon (SOC) of the experimental site was medium (0.62%). The final status of the soil organic carbon after ninth cropping system cycle was in the range 0.61 to 0.88% (Table 5). The organic carbon contents of soil in all the treatments increased by 19.4% to 41.9% over the initial at the end of ninth cropping system cycle except the treatment applied with 100% RDF through inorganic fertilizers. The treatments with organic nutrient management package registered significant increase in SOC (24.4 to 41.9%) and the build-up was maximum in the soil applied with one-third N each through FYM, green manuring and neem oilcake + *Azospirillum* + PSB to rice followed by similar combination with FYM, vermicompost, neem oilcake + *Azotobacter* + PSB to both potato and okra. Addition of organic nutrient sources might have created environment conducive for formation of humic acid, stimulated the activity of soil microorganisms resulting in an increase in organic carbon contents (Prasad *et al*., 2010). The higher build-up of SOC in the organic sources applied plots may be attributed to slower break down rate (less and constant mineralization rate) and increased above and below ground organic residues due to enhanced crop growth (Moharana *et al*., 2012).

Available N, P and K

The initial status of available N, P and K of the soil were 262.2, 19.1 and 170.8 kg/ha, respectively (Table 5). The increase in available N, P and K in the soils under organic inputs was to the tune of 18.9 to 35.2%, 1.6 to 8.4% and 1.9 to 14.9%, respectively over the initial contents after ninth cropping system cycle. The available N, P and K content in soils under inorganic inputs decreased by 7.6, 22.5 and 17.0%, respectively over the initial contents. Increase in available nitrogen with organics was due to increase in SOC and slow release of N from organics (Yadav *et al*., 2000). The lower nutrient content in soils under inorganic treatment was a result of mining of available N with continuous cropping over a long period of time. Build-up of available P in soils under organics might be due to the release of organic acids during decomposition, which in turn helped in releasing phosphorus through solubilizing action of native phosphorus in the soil (Urkurkar *et al*., 2010).

Soil microbial population

The population of bacteria, fungi and actinomycetes in the soils receiving nutrients from various organic sources

Table 3. Economics of rice–potato–okra cropping system

Treatment	Ninth cropping system cycle					Mean of first to ninth cropping system cycles				
	Gross returns ($\times 10^3$ ₹/ha)	Total cost ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Economic efficiency (₹/ha/day)	Benefit: cost ratio	Gross returns ($\times 10^3$ ₹/ha)	Total cost ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Economic efficiency (₹/ha/day)	Benefit: cost ratio
T_1	255.9	155.4	100.5	275	1.65	254.9	155.4	99.5	273	1.64
T_2	244.7	181.9	62.8	172	1.35	248.5	181.9	66.6	183	1.37
T_3	243.2	179.9	63.3	173	1.35	250.3	179.9	70.4	193	1.39
T_4	238.6	184.9	53.7	147	1.29	248.3	184.9	63.4	174	1.34
T_5	227.6	146.0	81.6	223	1.56	233.6	146.0	87.5	240	1.60
T_6	274.3	185.8	88.5	243	1.48	265.9	185.8	80.2	220	1.43
T_7	245.5	143.1	102.4	281	1.72	246.1	143.1	103.0	282	1.72
T_8	232.0	147.6	84.4	231	1.57	245.2	147.6	97.6	267	1.66

Sale Price (₹/t); rice grain, 13500; rice straw, 1000; potato, 800; okra, 15,000; Details of treatments is given in Table 1.

Table 4. System nutrient uptake (kg/ha) under various nutrient management practices in rice–potato–okra cropping system

Treatment	System nutrient uptake by first cropping system cycle			System nutrient uptake by ninth cropping system cycle			Mean system nutrient uptake (first to ninth cropping system cycles)		
	N	P	K	N	P	K	N	P	K
T_1	279.3	51.2	360.4	328.0	56.7	406.7	333.6	55.7	409.3
T_2	253.4	45.1	330.4	318.0	52.8	397.2	319.9	51.4	392.6
T_3	258.7	49.1	337.9	320.8	56.0	398.2	327.8	56.0	401.5
T_4	263.2	49.7	338.3	329.7	57.3	403.1	329.1	55.7	399.3
T_5	245.5	43.5	323.6	297.4	49.9	371.5	307.8	50.0	382.7
T_6	271.3	53.0	350.2	358.6	66.1	443.0	360.4	62.6	438.3
T_7	284.4	53.3	368.9	323.2	56.8	404.0	329.5	55.3	404.9
T_8	273.4	50.0	357.3	326.7	55.6	407.7	322.8	52.8	398.6
SEm±	5.03	1.32	5.96	6.23	2.02	4.88	5.68	1.45	6.13
CD (P=0.05)	15.05	3.91	17.78	18.67	6.05	14.53	16.84	4.31	18.32

Details of treatments is given in Table 1.

increased by 36.5 to 39.4%, 33.0 to 38.2% and 36.0 to 37.3%, respectively after ninth cropping system cycle over the initial status as against the respective increases of 5.6, 10.3 and 12.7% in the soils receiving nutrients through chemical fertilizers (Table 6). Increased organic carbon content of the soil due to application of various organic nutrients over the years served as a source of energy for biological activity, thereby enhancing the density of microbes (Moharana *et al*., 2012). Further, most of the soil microorganisms are chemo-autotrophs, which require organic source of carbon as food and oxidation of organic substances provides energy which might be the reason in improving microbial population in soils applied with organics (Ingle *et al*., 2014).

Microbial biomass carbon

The microbial biomass carbon in the soils under organic nutrient practices was enhanced considerably (57.7 to 66.8%) over the initial (97.6 to 108.6 μg C/g) (Table 6). The soils with inorganic fertilization on the other hand registered the minimum gain (8.7%) in soil microbial biomass carbon over the initial (83.1 μg C/g). The higher MBC in soils receiving organics is related to higher microbial population due to balanced supply of nutrients and carbon (Basak *et al*., 2012). The good quality organic inputs in the soil have a potential to augment soil enzymatic activities and improve the microbial biomass carbon and organic carbon (Nath *et al*., 2012).

Application of one-third N each through farmyard manure, green manuring of *Sesbania cannabina* and neem (*Azadirachta indica*) oilcake + *Azospirillum* + phosphate solubulizing bacteria to rice followed by similar combination of farmyard manure, vermicompost, neem oilcake + *Azotobacter* + phosphate solubulizing bacteria to both potato and okra was found to be the best organic nutrient management practice for rice–potato–okra cropping sys-

Table 5. Changes in soil physico-chemical properties under organic nutrient management practices in rice–potato–okra cropping system (after ninth cropping system cycle)

Treatment	Bulk density (g/cm^3)	Water holding capacity (%)	Soil organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T_1	1.46	44.6	0.74	296.6	20.2	166.6
T_2	1.41	46.3	0.86	328.2	20.6	189.2
T_3	1.40	46.8	0.88	354.6	19.7	182.2
T_4	1.43	45.9	0.83	321.0	19.4	179.4
T_5	1.44	44.8	0.79	311.7	19.7	174.0
T_6	1.40	46.9	0.88	340.4	20.7	196.2
T_7	1.47	43.6	0.61	242.4	14.8	141.8
T_8	1.46	44.9	0.75	288.2	16.8	174.6
Initial	1.48	43.0	0.62	262.2	19.1	172.2

Details of treatments is given in Table 1

Table 6. Changes in microbial attributes under organic nutrient management practices in rice–potato–okra system

Treatment	Initial				After ninth cropping system cycle			
	Microbial population in colony forming units/g dry soil			Microbial biomass carbon in soil (μg C/g)	Microbial population in colony forming units/g dry soil			Microbial biomass carbon in soil (μg C/g)
	Bacteria ($\times 10^7$)	Fungi ($\times 10^4$)	Actinomycetes ($\times 10^6$)		Bacteria ($\times 10^7$)	Fungi ($\times 10^4$)	Actinomycetes ($\times 10^6$)	
T_1	18.4	11.4	10.2	94.3	22.3	13.2	12.6	124.1
T_2	19.7	10.9	11.4	102.4	26.9	14.5	15.5	167.3
T_3	19.2	10.7	11.7	108.6	26.4	14.3	15.8	171.3
T_4	18.7	11.2	10.6	98.7	25.8	15.1	14.5	161.7
T_5	18.1	11.6	10.9	97.6	25.1	15.8	14.8	158.3
T_6	18.8	11.0	11.0	107.4	26.2	15.2	15.1	179.1
T_7	19.8	10.7	10.2	83.1	20.9	11.8	11.5	90.3
T_8	19.6	10.9	10.4	94.6	23.4	12.9	12.5	120.3
SEm±					0.82	0.51	0.61	11.80
CD (P=0.05)					2.41	1.52	1.81	34.36

Details of treatments is given in Table 1 tem for improving soil health and productivity under irrigated condition of coastal zone of Odisha. The same system can be profitable under organic farming only when on-farm generated organic manures are used.

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