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Effect of biofertilizer and manure on soil characteristics under rice-rice cropping system in Sundarbans region

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Abstract: Field experiment was conducted during *kharif* and *rabi* seasons for six consecutive years from 2008 with rice-rice rotation to study the effect of long term application of inorganic fertilizer with or without biofertilizer (*Azolla*) and manure (Vermicompost) on soil properties and paddy yield. On farm experiments were laid out in Gosaba, Mathurapur II and Patharpratima blocks, south 24 Parganas, West Bengal, with three treatmentsT_1: soil test based recommended NPK,T_2: NPK + biofertilizer, and T_3: NPK + manure and soil samples were collected at the beginning of the experiment that is during 2008 and after six years of trial. Results from the study showed that the integrated use of biofertilizer and manure improved the status of organic carbon, porosity and water holding capacity of soils. These combined application of inorganic and bio-inputs recorded marked changes in soil pH, EC and bulk density over inorganic fertilizer along. Integrated use of biofertilizer and manure with inorganic fertilizer gave significantly higher values of available NPK and higher content of DTPA extractable Zn, Fe and Mn at the end of six years cycle. These combined bio-inputs treatments also enhanced the higher values of microbial population over initial as well as inorganic fertilizer treatments. Highest percentage of paddy yield and sustainable yield index were obtained with integration of inorganic and bio-inputs under rice-rice cropping system. It is concluded that integrated application of 100% NPK+ bio-inputs was the most effective treatment in meeting the nutrient requirement as well as sustainable soil health management of rice-rice cropping system.

Key words: *Long term effect, soil properties, biofertilizer and manure, sustainable yield index, paddy yield.*

Introduction

Sundarbans in India, which are extended over north and south 24 Parganas consisting 19 administrative blocks and composed with 102 islands among them 54 island support agriculture. The rice-rice sequence is a dominant cropping system which has about 16.8% of the total cropped areas under rabi cultivation and the remaining cultivable areas are monocropped *kharif* rice with poor yield of traditional varieties (Sen *et al.* 1996). The intensive system of cultivation over a period of time has set declining yield trends as well as deterioration in soil productivity even with optimum use of fertilizer. Integrated use of organic and inorganic fertilizer however exhibited steady improvement in crop yield (Nambriar 1995; Krishnaiah 1988). Low and unstable productivity of rice in Sundarban is attributed to its impoverished soils, unsound agricultural practices and climatically challenging environment (Bandyopadhyay and Sinha 1985). It has potential to give comparable yield under improved management systems. Hence for restoration of soil productivity, there is an urgent need to investigate other options of plant nutrient supply besides the use of conventional chemical fertilizers. In view of these considerations, the present investigation was undertaken to assess the long term effect of biofertilizer and manure on soil quality in rice-rice cropping system.

Materials and Methods

A long term study was started in 2008 on rice-rice cropping system at farmers' field in Gosaba, Mathurapur II and Patharprotima blocks, South 24 Parganas district, West Bengal. The experiment was conducted in five farmers' fields in each aforesaid block. Each farmer's field was divided into three equal plots of approximate size 2 kata (133 m^2) for application of three fertilizer treatments (Table 1). The soil test based recommended 100% NPK doses (T_1) were applied to both *rabi* and *kharif* paddy as urea, single superphosphate and murate of potash (Ali 2005).1/4 of N, entire dose of P and ¾ of K were applied at the time of transplanting of both *kharif* and *rabi* paddy. ½ of N at tillaring stage and remaining N and K fertilizer at flowering initiation stage were applied (Ali 2005).

Table 1. Treatment combinations used in rice-rice cropping system

Treatment number	Treatment details
T_0	Selected farmers' field before the start of the experiment
T_1	Soil test based recommended 100%NPK doses (Ali 2005)
T_2	100% NPK + 5 t ha^{-1}*Azolla* as green manuring crop incorporated every year before rabi paddy
T_3	100% NPK + 4 t ha^{-1} vermicompost incorporated every year before rabi paddy

Agronomic measures were adopted based on the needs of crops in all the treatments in three blocks. Initial composite surface (0-15 cm) soil of the undivided experimental field (T_0) and soil samples from each treated plots (T_1, T_2, T_3) after the harvest of rabi paddy as 12th crop in rice-rice rotation were collected. Soil samples were air dried and pulverized to pass through 2 mm sieve. Another soil sample was stored at low temperature in deep freezer and used for estimation of different soil biological properties. Soil samples were analyzed by using standard procedures as described for pH and EC (Jacksons 1973), organic carbon (Walkley and Black 1934), available nitrogen (Subbiah and Asija 1956), and available phosphorus (Olsen *et al*. 1954). BD, porosity, WHC were determined by Keen-Rackzowski box method (Piper 1966) and available potassium by flame photometer after extracting neutral 1N NH_4OAC solution (Schollenbeger and Simon1945). The DTPA extractable Zn, Mn and Fe were determined by AAS (Lindsay and Norvell 1978). The population of bacteria, actinomycetes and fungi in soil were determined by serial dilution pour plate using Thornton's medium for bacteria, Ken Knight and Munaier's medium for actinomycetes and Martin's Rose-Bengal streptomycin agar medium for fungi (Chhonkar *et al.* 2002)

The sustainable yield index (Singh *et al.* 1990) and percentage of soil physical value (PV), micronutrient content (MC), biological population (BP) and paddy yield (PY) were calculated as follows:

(a) Sustainable yield index (SYI) $= \dfrac{Y - \delta}{Y_{max.}}$

Y = Estimated average yield ofpaddy

δ = Estimated Standard deviation

$Y_{max.}$ =Maximum average yield in the experiment

(b) % of PV/MC/BP/PY = $\frac{Z \times 100}{Z_{max.}}$

Z = Average physical value / average micronutrient content/ averagebiological population /average paddy yield

$Z_{max.}$ = Maximum average physical value /Maximum average biological population /Maximum average paddy yield / Critical value of micronutrient

Results and Discussion

Table 2 shows that the soils of these localities were low to medium in OC content, acidic to alkaline in reaction and saline to normal in nature. The range and mean values of different soil characteristics of different treatments in three localities of Sundarban are presented in tables 2, 3, 4, 5, 6 and 7. Acid-base characteristics of the soils changed from acidic to slightly acidic in Gosaba, slightly acidic to neutral in Mathurapur II and alkaline to neutral categories in Patharprotima block when biofertilizer (T_2) and manure (T_3) were added (Table 2). Similar results were reported by Ali (2005). Similarly these treatments (T_2 and T_3) also changed soil salinity from saline to normal category and soil organic carbon from low to medium category in the above localities. On the other hand, application of chemical fertilizer along (T_1) could not maintain initial (T_0) soil EC value and OC content, though soil pH was slightly improved (Table 2). These results are in accordance with the findings of Kumar and Singh 2010.

Table 2. Change of chemical properties after 6 years application of biofertilizer and manure

Soil parameters	Treatments	Gosaba		Mathurapur-II		Patharprotima	
		Range	Mean	Range	Mean	Range	Mean
	T_0	4.75-5.73	5.27(A)	5.79-6.51	6.19(SA)	6.86-8.47	7.77(Al)
pH	T_1	4.85-5.86	5.38(A)	5.93-6.59	6.31(SA)	6.83-8.23	7.59(Al)
	T_2	5.21-5.86	5.53(SA)	6.25-6.83	6.53(N)	6.94-7.49	7.26(N)
	T_3	5.45-5.94	5.66(SA)	6.42-6.97	6.72(N)	6.98-7.14	7.18(N)
	T_0	0.98-1.21	1.13(S)	0.85-1.09	0.94(No)	1.29-1.66	1.47(S)
EC	T_1	1.10-1.31	1.20(S)	0.84-1.21	1.02(S)	1.44-1.71	1.55(S)
(dSm^{-1})	T_2	0.58-0.75	0.66(N’)	0.47-0.62	0.53(N’)	0.84-1.18	0.99(N’)
	T_3	0.56-0.70	0.64(N’)	0.46-0.60	0.52(N’)	0.79-1.11	0.97(N’)
	T_0	0.31-0.48	0.40(L)	0.43-0.61	0.52(M)	0.38-0.54	0.44(L)
OC	T_1	0.27-0.41	0.35(L)	0.36-0.54	0.44(L)	0.32-0.46	0.38(L)
(%)	T_2	0.46-0.62	0.52(M)	0.52-0.71	0.63(M)	0.48-0.64	0.54(M)
	T_3	0.51-0.60	0.54(M)	0.57-0.72	0.64(M)	0.50-0.65	0.57(M

Data in parenthesis represent category of soil i.e. Acidic (A), Slightly Acidic (SA), Neutral (N), Alkaline (Al), Saline(S), Normal (N’), Low (L) and Medium (M).

Table 3 shows that application of biofertilizer (T_2) and manure (T_3) exhibited lower bulk density (decrease of 1.6-4.7 % PV), improved porosity (increase of 1.1-7.0 % PV), and higher water holding capacity (increase of 4.5-8.0 % PV) in three localities of Sundarban. Whereas treatments T_1 receiving only chemical fertilizer exhibited reverse results *i.e.* higher bulk density (increase of 0.9-1.9 % PV), lower porosity (decrease of 2.5-4.5 % PV) and water holding capacity (decrease of 2.7-5.0 % PV) in comparison with initial status (T_0). Lower bulk density is attributed to increase in water stable aggregate with addition of organic matter in soil which resulted in more pore space and good water holding capacity (Mishra and Sharma 1997).

Table 3. Change of physical properties after 6 years on application of biofertilizer and manure

Soil Parameters	Treatments	Gosaba		Mathurapur-II		Patharprotima	
		Range	Mean	Range	Mean	Range	Mean
	T_0	1.31-1.47	1.37(98.1)	1.24-1.46	1.35(97.1)	1.25-1.41	1.33(95.1)
BD	T_1	1.35-1.48	1.39(100)	1.26-1.48	1.37(98.0)	1.27-1.44	1.35(97.0)
(gm/cc)	T_2	1.29-1.41	1.33(95.4)	1.20-1.45	1.31(93.4)	1.23-1.39	1.30(93.5)
	T_3	1.27-1.42	1.33(95.1)	1.19-1.44	1.29(92.4)	1.21-1.37	1.28(91.8)
	T_0	40.5-45.6	42.9(85.9)	42.1-50.7	46.6(93.4)	43.3-49.7	46.4(93.0)
Porosity	T_1	39.3-43.2	41.3(82.7)	41.5-48.9	45.4(90.9)	41.3-46.5	44.2(88.5)
(%)	T_2	41.2-46.2	43.5(87.0)	44.0-51.7	47.8(95.7)	45.4-50.5	48.1(96.4)
	T_3	42.4-46.5	44.1(88.4)	45.5-52.0	48.9(97.9)	46.7-52.4	49.9(100)
	T_0	27.5-42.8	35.1(84.0)	29.1-47.0	37.8(90.6)	30.2-46.7	38.9(93.1)
WHC	T_1	26.5-41.4	33.9(81.3)	27.6-45.8	36.086.2)	29.4-43.4	36.8(88.1)
(%)	T_2	32.9-44.8	37.9(90.9)	32.2-49.1	40.2(96.3)	34.1-47.7	40.7(97.6)
	T_3	33.6-45.4	38.3(91.8)	33.6-48.9	41.1(98.6)	34.2-48.7	41.7(100)

Data in parenthesis represent percentage of physical value (PV)

Table 4 shows that incorporation of biofertilizer (T_2) and manure (T_3) changed the available NPK from lower to higher category, whereas chemical fertilizer (T_1) caused change towards lower category as compared to initial status (T_0). The increase in available N may be attributed to N mineralization from bio inputs (Sharma *et al*. 2000) and increase in available P and K content may be attributed to the decomposition of organic matter which was built up in the soil (Kumar and Yadav 1995) by addition of bio inputs. The percentage of micronutrient content was calculated over critical limit (Zn = 0.6, Mn = 1.0 and Fe = 4.5 mg kg^{-1}) which is shown in table 5. Available micronutrients content, although initially they were optimum level in soil increased with application of biofertilizer (T_2) and manure (T_3) whereas chemical fertilizer alone (T_1) decreased their amount and in case of Zn, which was below critical limit. Thus, T_2 and T_3 treatments were more effective in meeting the micronutrient particularly Zn requirement of paddy in Sundarban.

Table 4. Change of soil fertility after 6 years on application of biofertilizer and manure

Para-meters	Treat-ments	Gosaba		Mathurapur-II		Patharprotima	
		Range	Mean	Range	Mean	Range	Mean
	T_0	211.4-262.4	241.0(L)	264.7-314.5	290.6(M)	251.8-277.7	265.1(L)
N	T_1	211.5-234.3	225.2(L)	211.7-247.9	235.6(L)	191.0-236.8	220.7(L)
(kg/ha)	T_2	267.5-315.8	285.4(M)	436.2-504.2	471.0(M)	309.5-348.5	325.7(M)
	T_3	293.2-313.6	300.1(M)	453.8-517.5	485.3(M)	339.7-362.3	350.1(M)
	T_0	27.2-52.4	40.7(L)	17.6-50.8	32.7(L)	42.5-65.1	52.7(M)
P_2O_5	T_1	13.2-37.5	26.4(L)	08.7-31.6	21.3(L)	30.1-52.3	39.1(L)
(kg/ha)	T_2	39.6-65.6	55.5(M)	39.5-61.7	49.9(M)	61.4-83.2	70.1(M)
	T_3	41.5-66.3	56.5(M)	34.2-70.0	52.8(M)	64.0-81.7	72.4(M)
	T_0	290.3-427.2	345.8(H)	197.4-350.4	279.4(M)	327.3-513.2	402.2(H)
K_2O	T_1	228.7-348.3	288.8(M)	157.4-284.6	231.9(M)	275.4-456.6	351.9(H)
(kg/ha)	T_2	322.2-416.1	379.6(H)	273.8-486.5	335.5(M)	379.2-562.3	469.1(H)
	T_3	345.2-431.6	394.5(H)	268.8-485.3	342.1(H)	349.2557.6	454.0(H)

Data in parenthesis represent category of soil i.e. Low (L), Medium (M) and High (H)

Table 5. Change of micronutrients after 6 years on application of biofertilizer and manure

Micro-nutrients	Treat-ments	Gosaba		Mathurapur-II		Patharprotima	
		Range	Mean	Range	Mean	Range	Mean
	T_0	0.57-0.96	0.77 (127.7)	0.43-0.82	0.66(109.3)	0.33-0.66	0.51(085.3)
Zn	T_1	0.41-0.67	0.57(095.3)	0.33-0.64	0.51(084.3)	0.27-0.52	0.40(067.3)
(ppm)	T_2	0.62-1.06	0.85(141.7)	0.54-0.89	0.75(124.3)	0.51-0.74	0.63(105.7)
	T_3	0.71-0.97	0.82(137.3)	0.52-0.93	0.74(124.0)	0.52-0.78	0.64(106.3)
	T_0	11.8-38.6	24.7(2474)	6.41-28.3	16.1(1606)	4.21-13.8	9.16(916)
Mn	T_1	08.9-32.7	18.8(1879)	3.75-22.5	12.4(1236)	2.15-10.4	6.64(664)
(ppm)	T_2	14.2-43.5	30.2(3016)	9.12-30.3	18.4(1835)	7.21-16.8	12.9(1286)
	T_3	16.8-44.7	31.7(3174)	10.3-31.5	19.0(1904)	9.22-18.7	14.0(1316)
	T_0	03.7-14.5	09.1(0202)	4.13-30.7	16.3(363)	6.71-40.3	23.1(512)
Fe	T_1	02.6-09.7	05.8(0129)	2.41-19.7	10.0(222)	3.94-32.5	16.9(376)
(ppm)	T_2	08.8-19.5	14.2(0316)	6.57-38.4	21.3(473)	12.4-47.5	28.7(638)
	T_3	10.9-20.7	16.0(0354)	8.73-40.7	22.9(509)	11.5-49.4	29.0(644)

Data in parenthesis represent percentage of micronutrient content (MC)

Table 6 shows that both treatments of biofertilizer (T_2) and manure (T_3) maintained significantly higher value of bacterial population (BP > 77.7%), actinomycetes population (BP > 71.3%),) and fungi population (BP >81.4%), whereas chemical fertilizer (T_1) exhibited lower percentage of BP *i.e.* percentage of bacterial population varies from 12.8 to 15.6, percentage of actinomycetes population ranged from 12.8 to 15.6 and percentage of fungi population lies from 18.9 to 34.6. Initially (T_0) the percentage of biological population varied from 45.8 to 49.2 for bacteria, from 23.8 to 34.1 for actinomycetes and from 30.0 to 37.0 for fungi. It could be attributed to greater availability of higher amount of biofertilizer and manure derived carbon and energy to the soil microbes resulting into multiplication of biological population (Patil and Varade 1998). Further biological population was also enhanced by improvement of soil physico-chemical characteristics and better availability of nutrients by addition of bio inputs (Sinde and Banger 2003).

Table 6. Change of biological properties after 6 years on application of biofertilizer and manure

Population	Treat-ments	Gosaba		Mathurapur-II		Patharprotima	
		Range	Mean	Range	Mean	Range	Mean
	T_0	12.0-17.0	16.8(46.9)	08.0-27.0	17.6(49.2)	12.0-21.0	16.4(45.8)
Bacteria	T_1	04.0-07.0	05.4(15.1)	04.0-08.0	5.6(15.6)	04.0-06.0	4.6(12.8)
(X $10^5 g^{-1}$ dry	T_2	20.0-37.0	29.2(81.6)	17.0-41.0	30.0(83.8)	17.0-34.0	27.8(77.7)
soil)	T_3	22.0-40.0	31.2(87.2)	22.0-48.0	35.8(100)	22.0-33.0	28.8(80.4)
	T_0	06.0-09.0	07.8(23.8)	09.0-14.0	11.2(34.1)	06.0-11.0	8.4(25.6)
Actinomycetes	T_1	02.0-05.0	03.2(09.8)	02.0-05.0	3.4(10.4)	02.0-04.0	3.0(09.1)
(X $10^5 g^{-1}$ dry	T_2	20.0-31.0	25.8(78.7)	17.0-43.0	29.2(89.0)	18.0-26.0	23.4(71.3)
soil)	T_3	21.0-32.0	27.0(82.3)	22.0-43.0	32.8(100)	20.0-28.0	24.8(75.6)
	T_0	33.0-52.0	42.0(30.0)	36.0-57.0	46.8(33.4)	43.0-62.0	51.8(37.0)
Fungi	T_1	22.0-31.0	26.4(18.9)	29.0-40.0	34.4(24.6)	26.0-40.0	32.0(22.9)
(X $10^3 g^{-1}$ dry	T_2	85.0-135.0	114.0(81.4)	105.0-157.0	129.6(92.6)	100.0-150.0	120.2(85.9)
soil)	T_3	95.0-126.0	112.8(80.6)	06.0-180.0	140.0(100)	109.0-140.0	125.2(89.4)

Data in parenthesis represent percentage of biological population (BP)

Application of both biofertilizer (T_2) and manure (T_3) increased the paddy yields in three localities of Sundarban and the gain was more than 85% in both seasons whereas chemical fertilizer (T_1) decreased the PY and the gains ranged between 64.4 and 76.2% (Table 7). Initially (T_0) the percentage of PY in Gosaba and Mathurapur II blocks were >85 (suitability class, Sys *et al*. 1993) and in Patharprotima block it was <85 in both seasons. Based on the percentage PY, all the bio input as well as initial fields (except initial field in Patharprotima which was placed in S2 suitability class after 6 years were placed in suitability class S_1. On the other hand, receiving only chemical fertilizer after 6 years, the initial S_1 fields were changed into suitability class S_2. Analysis of SYI index values in table 7, shows that sustainability of paddy yield is decreased in *kharif* season (SYI lies between 0.54-0.60) and *rabi* season (SYI lies between 0.63-0.70) on application of chemical fertilizer along (T_1) and increased yield sustainability in *kharif* season (SYI lies between 0.72-0.94) and *rabi* season (SYI lies between 0.84-0.96) on addition of bio input compared to initial status where sustainability status were recorded in *kharif* season (0.68-0.83) and *rabi* season (0.77-0.89).

Table 7. Change of paddy yield after 6 years on application of biofertilizer and manure

Para-meters	Treat-Ments	Gosaba		Mathurapur-II		Patharprotima	
		Range	Mean(PY/SYI)	Range	Mean(PY / SYI)	Range	Mean(PY/ SYI)
	T_0	2.97-4.11	3.66(85.0/0.74)	3.51-4.44	3.96(92.2/0.83)	2.79-3.99	3.42(79.5/0.68)
Kharif	T_1	2.34-3.42	2.88(67.1/ 0.57)	2.46-3.51	3.00(69.8/0.60)	2.25-3.33	2.76(64.4/0.54)
(t/ha)	T_2	3.36-4.47	3.93(91.3/ 0.94)	3.93-4.56	4.26(98.9/0.92)	2.97-4.20	3.63(84.2/0.72)
	T_3	3.51-4.44	3.96(92.1/ 0.84)	3.96-4.59	4.29(100/0.93)	3.06-4.26	3.66(85.3/0.74)
	T_0	4.53-5.25	4.92(89.0/ 0.84)	4.86-5.52	5.16(93.5/0.89)	4.14-4.92	4.59(82.9/0.77)
Rabi	T_1	3.51-4.53	4.05(73.3/0.66)	3.72-4.56	4.20(76.2/0.70)	3.36-4.50	3.93(71.1/0.63)
(t/ha)	T_2	4.83-5.43	5.13(93.0 /0.89)	5.25-5.76	5.52(100/0.96)	4.56-5.19	4.89(88.3/0.84)
	T_3	4.89-5.55	5.22(94.6/ 0.90)	5.19-5.73	5.43(98.1/0.94)	4.65-5.31	4.95(89.8/0.85)

Data in parenthesis represent percentage of paddy yield (PY) and Sustainable yield index (SYI)

Conclusions

This study clearly indicates that biofertilizer and manure application improved the physico-chemical characteristics, available NPK and micronutrients and enabled the higher microbial population and paddy yields. The results also reveal that it is possible to increase and sustain rice grain yield with use of bio inputs against the existing farmers' practices *i.e.* use of chemical fertilizer only. It can be concluded that use of bio inputs in Sundarbanis are effective in meeting the Zn requirement of rice crop.

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