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Integrated nutrient management for sustainable yield in rice-potato-groundnut cropping system

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Abstract
The effect of seven different organic treatment in combination with inorganic fertilizer on crops in rice-potato-groundnut cropping sequence from an ongoing long-term fertility experiment at *Gayespur* (Central Research Farm, BCKV).The experimental conditions of different treatment combinations allowed building up the organic matter status and different nutrient levels with addition of different organic and inorganic sources of nutrients and bio-fertilizers. The present study has taken advantages of an established experimental set up and selected some relevant portions rice-potato-groundnut crop rotation. The objective of the present set of experiment is to study the combined effect of inorganic N, P, K fertilizer and FYM as organic source along with $ZnSO_4$ and bio fertilizer *(Azospirillum, Azotobacter* and PSB) on the status of organic carbon, total nitrogen and availability of N, P, K, Zn and S in soil.

Keywords: Integrated nutrient management, sustainable yield, rice-potato-groundnut, cropping system

Introduction
In the present world, most important challenges is to protect natural resources, including soil and water, for increasing food production while we have to protect the environment. Long-term food security will maintain a proper balance in-between the increasing crop production, maintaining of soil health and environmental sustainability. Decreasing soil fertility is a major constraint for higher crop production in West Bengal due to lower organic matter content as well lower application of organic matter in intensively cultivated soils. The increasing uses of high analysis NPK fertilizers have no doubt remarkably increased the food production but it has also brought with it problem particularly those of sulphur and zinc in soils.

Besides nitrogen, phosphorus, potassium fertilizer elements, deficiencies of zinc and sulphur is very common in rice, potato and groundnut crops in many parts of West Bengal as well as in India (Tandon, 1991) [12]. Nambiar (1997) [9] viewed that integrated use of organic manure and chemical fertilizers would be quite promising not only in providing greater stability in production, but also maintaining better soil fertility status.The long-term research of Bangladesh Rice Research Institute (BRRI) also revealed that the application of dung manure @ 5 t ha^{-1} y^{-1} improved soil resources from degradation (Bhuiyan *et al*., 1994) [1].

Materials and Methods
In order to develop nutrient management package in rice based cropping system in alluvial soils (Entisols), soil and plant samples were periodically collected from experimental sites of the Central Research Farm, Gayeshpur, Nadia. The period of investigation for the present study was Kharif and Rabi season of 2012 and summer 2013. There were seven treatment combinations consisting with inorganic fertilizer (Urea, SSP, MOP, Zinc Sulphate) applied with or without organic manure / crop manure (FYM, Vermicompost, Neem cake, *Dhaincha* as green manure, burning of crop residue after harvesting each crop) and bio fertilizer (*Azospirillum, Azotobacter* and PSB). The treatment details are given in (Table 1).

The fertilizer were use as per recommended dose for rice (*Gobinobhog*): 80 – 40 – 40, potato (*Kufri Jjyoti*): 200 – 150 – 150, groundnut (TAG - 24): 20 – 40 – 40. Soil samples were analysed for the determination of organic carbon, total nitrogen and available potassium as described by Jackson (1973) [5], available nitrogen by Bremner and Keeney (1966) [6], available phosphorus by Hesse (1971) [4], available sulphur (Tabatabai and Brmner, 1972)[10] and DTPA – extractable zinc by Lindsay and Norvall (1978) [8]. Plant samples were analysed for the determination of total nitrogen, total phosphorus and total potassium as described by

Black (1965) [2, 3], and Hesse (1971) [4], total sulphur by Tabatabai (1974) and total zinc by Black (1965) [2, 3].

Table 1: Details of different treatment used in the field experiment

Treatments	Details of treatments
T_1	50% of recommended NPK (Inorganic) + 50% of NPK as FYM (+$ZnSO_4$ to scented rice @ 20kg/ha)
T_2	1/3 of recommended N each from FYM, Vermicompost & Neem cake.
T_3	T_2 + intercropping of coriander with potato(1:1) + intercropping of okra with groundnut (2:3)
T_4	T_2 + black polythene mulch to potato & groundnut, dhaincha green manuring in rice for weed management + burning of crop residues after harvesting of each crop.
T_5	50% N as FYM + rock phosphate to all crops (Rice@6.66 Kg/200Sqm., potato@16.66 Kg/200 Sqm., groundnut@6.66 Kg/200Sqm.,) + Azospirillum @ 20 kg/ha N (Equivalent) & PSB to winter rice& Azotobacter @20 kg/ha N (Equivalent) & PSB to potato & Rhizobium & PSB to groundnut.
T_6	T_2 + Bio-fertilizer containing N & P carriers (same as T_5)
T_7	100% NPK by chemical fertilizer + $ZnSO_4$ @ 20 kg/ha

Result and Discussion

The present study is initiated to develop some ideas with regard to the availability of nitrogen, phosphorus, potassium, sulphur and zinc in a long term experimental plot in the Central Research Farm of BCKV at Gayeshpur, Nadia. The present long-term experiment with additions of different organic manures, bio-fertilizers along with nitrogen, phosphorus, potassium and $ZnSO_4$ etc. in different treatment combinations has been conducted with a rice based cropping system.

Total available nitrogen (kg/ha) which includes ammonical nitrogen as well as nitrate nitrogen, available phosphorus (expressed as kg of P_2O_5/ha), available potassium (expressed as kg of K_2O/ha), available sulphur (expressed as kg of SO_4^{2-}/ha) and available Zinc (DTPA extractable Zn in mg/kg) are presented (results presented as mean of three replications).

Relevant Physico-Chemical Properties and Nutrient Status of the Soil before initiation of the present experiment

In order to estimate the relevant soil data for the present study, soil samples from each of the seven treatment combinations were collected before the harvest of rice crop (2012) under the present experiment set up, is considered as the initial soil sample (according to the AICRP on Integrated Farming System) before start the present experimental set up.Soil reaction, EC, organic carbon (%), available nitrogen (ammonical plus nitrate nitrogen), available phosphorus, and available potassium are presented in Table 2.

Result in Table 2 indicates that the pH of the soil under study is slightly alkaline in respect to different treatments and varies within 7.59 to 8.06 average being7.83. The soluble salt content of the soil under different treatment combination is very low and ranging from 0.40 to 0.73 dsm^{-1}. Organic carbon content of the soil is found to vary from 0.99 to 1.22 %. Variations in organic carbon content in different treatment combination are possibly due to addition of different sources of organic manure to such treatments. Highest amount of available nitrogen was found in the treatment no.1 (50% of recommended NPK inorganic and 50% of NPK as farm yard manure). Whereas the lowest amount of available nitrogen is recorded in treatment no. 7 [100% of recommended NPK as inorganic source and $ZnSO_4$ @20 (kg/ha)]. In case of available phosphorus there was no appreciable variation with respect to different treatment except treatment no. 7 (100% of recommended NPK as inorganic source and $ZnSO_4$ @20 kg/ha). Available potassium content was found to vary from 129.98 to 159.23 kg/ha and average being 147 kg/ha.

Table 2: Relevant Physico-chemical Properties and Nutrient status of the soil before the rice crop

Treatment	pH (1:2.5)	EC (dSm^{-1})	Organic Carbon (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
T_1	7.80	0.40	1.10	148.53	44.93	129.98
T_2	7.76	0.49	1.02	137.12	43.14	145.09
T_3	7.59	0.69	1.22	134.13	45.21	158.79
T_4	7.89	0.48	1.03	134.73	40.73	132.74
T_5	7.84	0.50	1.03	125.77	42.84	145.68
T_6	8.06	0.73	1.07	122.72	35.02	157.47
T_7	7.85	0.56	0.99	122.11	54.00	159.23
SEm	0.09	0.09	0.08	1.48	1.53	1.77
CD (5%)	0.19	0.19	0.17	3.23	3.33	3.85

Changes in the soil reaction, EC and nutrient status of soils under different treatment combinations after harvest of kharif rice

The results (mean of three replications) of pH, EC, organic carbon (%), total nitrogen (%) and C: N ratio of soil after harvest of rice is presented in table 3. The mean pH value of different treatments is found to vary from 7.35 to 7.86 in different treatment combination with an average of 7.63 indicating little change in the mean value after rice crop.The soil under different treatment combinations (irrespective of addition different inorganic fertilizer) indicates low total soluble salt content. Addition of organic manure in different doses as vermicompost, FYM, neem cake in different treatments, the organic carbon content of the soil did not vary appreciably. The average value of mean organic carbon content is 1.02 %. However, wider variations in the mean values of total nitrogen content (maximum 61.5% increase) in different treatments (T_4 and T_5) were recorded.

The C: N ratio calculated from the mean organic carbon content (%) and mean total nitrogen content of the soil in different treatment combinations are presented in table 3.The results indicates a very narrow C: N ratio indicating high accumulation of total N in all treatment combinations. Since this is a long term experiment and continuing for the last 10

years in the same experimental plot, chances of accumulation of nitrogen in available form may be possible.

Total available nitrogen status of the soil after harvest of rice crop showed appreciable variation from 22.07 to 44.80 kg/ha (Table 4). This variability is possibly due to wide variation in ammonical nitrogen content. Which shows approximately 3 fold increase from 12.50 (T_1) to 34.00 (T_5) kg/ha. Similar types of results also reported by Tiwari *et al*. (2002). In case of nitrate nitrogen the variation in different treatment combination was not appreciable (8.25 to 10.80 kg/ha). Available phosphorus (P_2O_5) content was found to vary from 23.25 to 46.04 kg/ha with an average of 36.07 kg/ha. Available potassium (K_2O) content of the seven different treatments under study were found to vary between 145.04 to 173.48 kg/ha and the average being 160.78 kg/ha. Available sulphur content of the soils of different treatments under study were found to vary between 8.23 to 12.71 kg/ha with an average of 9.81 kg/ha. Thus available sulphur content of most (80%) of the soils are and below the critical value where sulphur fertilizer was not added. DTPA extractable Zn (available Zn) were found to be within the range of 4.25 to 7.28 mg/kg with an average of 5.56mg/kg (Table 4). The result also indicate higher amount of DTPA extractable Zn in T_1 and T_7 where Zn was added as $ZnSO_4$ @ 20 kg/ha.

Table 3: Changes in pH, EC, organic carbon (%), total nitrogen (%) and C: N ratio after harvest of rice

Treatments	PH	EC (dSm^{-1})	Organic Carbon (%)	Total Nitrogen (%)	C:N Ratio
T_1	7.70	0.45	1.02	0.19	5.32:1
T_2	7.86	0.53	0.99	0.18	5.37:1
T_3	7.77	0.70	1.05	0.15	7.16:1
T_4	7.35	0.57	1.03	0.21	4.90:1
T_5	7.67	0.52	0.99	0.13	7.82:1
T_6	7.48	0.52	1.08	0.16	6.54:1
T_7	7.61	0.56	0.95	0.17	5.50:1
SEm	0.06	0.05	0.05	0.02	-
CD (5%)	0.12	0.11	0.11	0.04	-

Table 4: NH_4^+-N, NO_3^--N, (NH_4^++NO_3^-)-N, Available P_2O_5, Available K_2O, Available S and DTPA extractable Zinc of soils after harvest of rice

Treatments	NH_4^+-N (kg/ha)	NO_3^--N (kg/ha)	(NH_4^++ NO_3^-)-N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	AvailableS (kg/ha)	DTPA extractable Zn (mg/Kg)
T_1	12.50	9.57	22.07	41.19	170.79	12.71	6.49
T_2	13.55	10.36	23.92	42.58	153.95	8.67	4.77
T_3	20.18	10.25	30.43	40.07	173.48	8.52	5.40
T_4	25.57	10.59	36.16	46.04	162.72	8.23	4.25
T_5	34.00	10.80	44.80	25.81	160.78	8.67	4.82
T_6	30.58	8.80	39.38	23.25	158.69	10.00	5.90
T_7	22.46	8.25	30.71	33.53	145.04	11.86	7.28
SEm	0.30	0.51	0.55	0.50	1.43	0.26	0.26
CD (5%)	0.66	1.12	1.19	1.10	3.11	0.56	0.56

Changes in the soil reaction, EC and nutrient status of soils under different treatment combinations after harvest of potato (Rabi season)

The mean pH value is varying from 7.35 to 7.86 in the seven different treatments. The total soluble salt content of the soils under different treatments are low.The organic carbon content of the soil did not vary appreciable in spite of application of organic manure in different doses as vermicompost, FYM, neem cake indicating rapid decomposition of added organic materials. The average value of mean organic carbon content is found to be 0.96%. Total nitrogen content of the soils under different treatment combinations after harvest of potato indicate similar values (% of total N) in most of the treatments like earlier crop i.e. kharif rice (CD is 0.04 at 5% level). The C: N ratio calculated from ratio of the mean organic carbon content (%) and mean total nitrogen content of the soil in different treatment combinations are presented in table 5. The results indicate a very narrow C: N ratio suggesting high accumulation of total N in all treatment combination (similar results were observed in earlier crop, rice).

The total available nitrogen status of the soil in different treatments after harvest of potato crop showed appreciable variation 46.49 to 60.17 kg/ha. This variability is possibly due to variation in ammonical nitrogen content. Ammonical nitrogen contents are found to vary from 36.87 to 46.65 kg/ha. In case of nitrate nitrogen the variation in different treatment combinations were not appreciable (9.61 to 13.94 kg/ha).

Available phosphorus (P_2O_5) content of different treatments after harvest of potato was found vary from 27.67 to 42.41 with an average of 35.33 kg/ha. Available potassium (K_2O) content of the soils of seven different treatments under study were found to vary between 153.71 to 201.31 kg/ha and the average being 186.67 kg/ha. Available sulphur content of the soils of different treatments under study were found to vary within a range of 8.00 to 11.87 kg/ha with an average of 9.51kg/ha. Thus available sulphur content of 80% of the soils under different treatment combinations are below the critical limit (like previous crop rice). DTPA extractable Zn (available Zn) were found to be within the range of 4.29 to 7.08 ppm with an average of 5.51 mg/kg. Similar results were also observed in earlier crop (rice) in the pre-set trend of result is similar to that of the earlier rice crop.

Table 5: Changes in pH, EC, organic carbon (%), total nitrogen (%) and C:N ratio after harvest of potato (Rabi season)

Treatments	pH	EC (dSm^{-1})	Organic Carbon (%)	Total Nitrogen (%)	C:N Ratio
T_1	7.86	0.46	0.98	0.20	5.03:1
T_2	7.72	0.55	0.93	0.14	6.79:1
T_3	7.58	0.72	1.01	0.17	5.79:1
T_4	7.62	0.63	0.91	0.24	3.85:1
T_5	7.54	0.55	0.87	0.15	5.96:1
T_6	7.35	0.53	1.03	0.14	7.34:1
T_7	7.56	0.59	0.99	0.17	5.80:1
SEm	0.06	0.06	0.06	0.02	-
CD (5%)	0.13	0.14	0.13	0.04	-

Changes in the soil reaction, EC and nutrient status of soils under different treatment combinations after harvest of groundnut (pre-kharif season)

Mean pH value is varying from 7.33 to 7.67 in different treatment combination. Values of electrical conductivity further reveal that irrespective of addition different inorganic fertilizers the soil under different treatment combination indicates low total soluble salt content. Addition of organic manure in different doses as vermicompost, FYM, neem cake the organic carbon content of the soil did not vary appreciable. The average value of mean organic carbon content is found to be 0.97. Similar average of mean organic carbon content was recorded after harvest of rice (1.02 %) and potato (0.96 %) in Table 3 and 5 respectively. Percentage of total nitrogen content in the soils of different treatment combinations after harvest of groundnut also recorded similar trend of maximum % is recorded in T_4 and minimum % is recorded in T_5 in previous two crops. The C: N ratio of the soils under different treatment combinations are also presented in Table 7. The results indicates a very narrow C: N ratio indicating high accumulation of total N in all treatment combination (similar results were observed in earlier crops rice and potato).

Results in Table 8 present the total available nitrogen status of soil under different treatments after harvest of groundnut crop showed appreciable variation (41.06 to 52.01 kg/ha). This variability is possibly due to changes in ammonical nitrogen content in different treatment varied between 31.18 to 40.15 kg/ha. In case of nitrate nitrogen the variation in different treatment combination was within a range of 9.65 to 11.87 kg/ha. Available phosphorus (P_2O_5) content was found vary between 47.25 to 30.66 kg/ha with an average of 37.55 kg/ha. Available potassium (K_2O) content of the seven different treatment under study were found to vary between 160.94 to 175.10 kg/ha and the average being 168.00 kg/ha. Available sulphur content of the soils of different treatments under study were found to vary between 7.25 to 10.71 kg/ha with an average of 8.44 kg/ha. Thus available sulphur content of most of the soils are below the critical value. DTPA extractable zinc (available Zn) was found to be within the range of 4.54 to 7.36 mg/kg with an average of 5.46 mg/kg. Results further indicate that available sulphur and zinc content of the soils of T_1 and T_7 treatments where $ZnSO_4$ @ 20 kg/ha added (before sowing of the crops) are higher.

Table 6: NH_4^+-N, NO_3^--N, (NH_4^++NO_3^-)-N, Available P_2O_5, Available K_2O, Available S and DTPA extractable Zinc of soils after harvest of potato (rabi season)

Treatments	NH_4^+-N (kg/ha)	NO_3^--N (kg/ha)	(NH_4^++ NO_3^-)-N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	AvailableS (kg/ha)	DTPA extractable Zn (mg/Kg)
T_1	42.81	13.14	55.95	41.80	186.80	11.87	7.08
T_2	46.23	13.94	60.17	27.67	178.63	8.40	5.32
T_3	40.81	12.28	53.09	34.48	199.35	8.93	4.87
T_4	46.65	12.38	59.03	30.86	185.83	9.09	5.29
T_5	40.36	12.50	52.86	38.05	153.71	8.63	5.21
T_6	36.87	9.61	46.49	32.04	201.07	8.00	4.29
T_7	38.87	10.26	49.14	42.41	201.31	11.68	6.52
SEm	0.53	0.69	0.86	0.89	1.30	0.18	0.26
CD (5%)	1.15	1.49	1.87	1.94	2.83	0.39	0.57

Table 7: Changes in pH, EC, organic carbon (%), total nitrogen (%) and C: N ratio after harvest of groundnut

Treatments	pH	EC (dSm-1)	Organic Carbon (%)	Total Nitrogen (%)	C:N Ratio
T_1	7.76	0.64	1.11	0.17	6.60:1
T_2	7.69	0.56	0.90	0.15	5.81:1
T_3	7.53	0.61	0.95	0.15	6.35:1
T_4	7.82	0.79	0.94	0.21	4.58:1
T_5	7.50	0.64	0.92	0.12	7.49:1
T_6	7.42	0.59	0.95	0.17	5.70:1
T_7	7.69	0.61	1.01	0.17	5.86:1
SEm	0.05	0.06	0.07	0.02	-
CD (5%)	0.11	0.12	0.15	0.05	-

Table 8: NH_4^+-N, NO_3^--N, (NH_4^++NO_3^-)-N, Available P_2O_5, Available K_2O, Available S and DTPA extractable Zinc of soils after harvest of groundnut (pre-kharif)

Treatments	NH_4^+-N (kg/ha)	NO_3^--N (kg/ha)	(NH_4^++ NO_3^-)-N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	AvailableS (kg/ha)	DTPA extractable Zn (mg/Kg)
T_1	40.15	11.87	52.01	43.86	162.98	10.71	6.45
T_2	34.42	10.00	44.42	30.66	167.62	7.81	5.09
T_3	31.18	9.88	41.06	36.95	168.41	7.86	4.71
T_4	34.80	10.65	45.45	31.23	171.70	7.79	4.54
T_5	37.47	9.65	47.13	39.75	160.94	7.60	4.95
T_6	39.35	10.98	50.33	33.15	169.20	7.25	5.12
T_7	31.62	9.88	41.51	47.25	175.10	10.04	7.36
SEm	0.32	0.42	0.60	0.59	1.17	0.32	0.31
CD (5%)	0.70	0.91	1.32	1.29	2.55	0.70	0.68

Conclusion

The changes in soil chemical properties observed in this study can be explained by different inputs. Results show higher availability of total available nitrogen and organic carbon in combined application of organic and bio fertilizers with inorganic fertilizer rather than inorganic treatment. Availability of sulphur and zinc is always higher in those treatments where $ZnSO_4$ applied additionally.

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