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Research Paper

Evaluation of integrated nutrient management options in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system in reclaimed sodic land

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ABSTRACT

Nutrient management is one of the major problem of the sodic land due to low organic matter status and toxicity of sodium, which reduced the availability of other nutrients and affects the soil properties. A field experiment was conducted to evaluate the integrated nutrient management options in sodic soil at Shivali Village of C.S.A. University of Agriculture and Technology, Kanpur during 2005-06 and 2006-07. The physico-chemical properties of the soil were $pH_{(2.5)}$ - 8.9, $EC_{(2.5)}$ - 0.61 dS/m, organic carbon - 3.6 g/kg, $CaCO_3$-1.24%, GR-7.92 t/ha, sand-56%, silt-28%, clay-16% (sandy loam), available N-156 kg/ha, available P-25.3 kg/ha, available K-235 kg/ha and available Zn-0.78 ppm. Results indicated that plant height, fertile tillers, biomass/hill, length of ear, test weight, grain and straw yield of rice (*Oryza sativa* L.) and wheat {*Triticum aestivum* (L.) emend. Fiori & Paol} significantly increased by application of fertilizer on the soil test basis in comparison to farmers practice. Further increased the yield and yield attributing characters when organic manures (FYM, pressmud and NADEP compost) added @ 5 t/ha with the recommended doses of fertilizers. Application of organic manure (FYM) integrated with recommended dose of fertilizers and biofertilizers (PSB + BGA/ *Azotobacter*) further increased the yield and yield attributing characters of rice and wheat which was similar to 125% recommended dose of fertilizers. The maximum grain yield of rice and wheat (5.46 and 3.57 t/ha) was recorded with application of NPKZn based on soil test + FYM @ 5 t/ha + PSB + BGA. Similar trends were also recorded in case of nutrient uptake. In case of microbial populations, maximum bacterial population (94.0×10^5/g soil) and *Azotobacter* (51.5×10^2/g soil) was recorded with application of NPK Zn based on soil test + FYM @ 5 t/ha + PSB + BGA and maximum PSB count (42.0×10^2/g soil) was recorded in with application NPK Zn based on soil test+PSB+BGA. The Actinomycetes population was not affected by the different treatments. Improvement in soil properties (pH, EC, OC) and soil fertility status (NPK and Zn) was recorded when chemical fertilizers were integrated with organic manures.

Key words: *Azotobacter*, BGA, Nutrient management, PSB, Rice, Sodic soils, Wheat

Salt affected soils are estimated to 6.80 lakh ha in India and Uttar Pradesh is the largest state of the country having 2.55 lakh ha area under salinity and sodicity (NRSC, 2011). Reclamation is a major activity for crop production in sodic soil but nutrient management is also the second important process for crop production. In the reclamation process of the sodic soil, often secondary salinization is observed when integrated nutrient management is not practiced. The nature and properties of sodic soils vary considerably, which require specific approaches for their reclamation and management to maintain their sustainable productivity. Nutrient management is one of the important aspects of sodic land due to its poor fertility status and toxicity of sodium at high pH reduces the availability of nutrients and affects soil properties. The objectives of this study to find out the impact of different nutrient management options for optimum yield of rice and wheat including improvement in soil quality.

MATERIALS AND METHODS

Keeping the fact in view, the experiment was conducted to study the integrated nutrient management in sodic soil at Shivali (Kanpur Nagar) of C.S.A. University of Agriculture and Technology, Kanpur during 2005-06 to 2006-07. The geographical position of the experimental site was 26°34'35"N latitude and 80°04'40"E longitude. The physico-chemical properties of the soil were $pH_{(2.5)}$ - 8.9, $EC_{(2.5)}$ - 0.61 dS/m, organic carbon - 3.6 g/kg, $CaCO_3$-

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1.24%, gypsum requirement (GR)-7.92 t/ha, sand-56%, silt-28%, clay-16%, (sandy loam), available N-156 kg/ha, available P- 25.3 kg/ha, available K-235 kg/ha and available Zn- 0.78 ppm. Treatments of the experiment were T_1-control, T_2 - Farmers Practice (N_{100} $P_{40}K_0$), T_3-100% NPKZn soil test recommendation (STR), T_4- T_3 + FYM @ 5 t/ha, T_5- T_3 + Pressmud @ 5 t/ha, T_6-T_3+NADEP compost @ 5 t/ha, T_7- T_3+ phosphate solubilizing bacteria (PSB), T_8- T_3 + BGA/*Azotobacter*, T_9- T_3 + PSB + BGA/*Azotobacter*, T_{10}- 125% NPKZn (STR) and T_{11}- T_3 + FYM @ 5 t/ha + PSB + BGA/*Azotobacter* (The BGA was applied in rice and *Azotobacter* in wheat). The experiment was laid out in RBD design with four replications. The experiment was carried out in the same field during both the years of study. Varieties of rice and wheat were 'Usar-3' and 'Prasad (K-8434)' respectively. Gypsum @ 50% GR was applied as basal followed by leaching before layout of the experiment. Half dose of N was applied as basal and ½ N in 2 splits at tillering and panicle initiation stage through urea, phosphorus, potassium and zinc was applied as basal through single super phosphate, muriate of potash and zinc sulphate respectively. The population of bacteria, Actinomycetes, *Azotobacter* and phosphate solubilizing bacteria were analyzed by dilution plate count methods using specific media.

RESULTS AND DISCUSSION

Yield attributing characters

Rice

Plant height at 30 days after transplanting (DAT) indicated that plant height 59.5 cm was recorded in the treatment T_3 (100% NPKZn, STR) which was significantly higher than with N_{100} P_{40} K_0 showing the value of 57.9 cm. Application of organic manures (FYM, Pressmud and NADEP compost) significantly increased the plant height in the treatment T_4 (60.8 cm), T_5 (62.0 cm) and T_6 (61.5 cm) in comparison to 59.5 cm in T_3-100 % NPKZn (STR). Application of biofertilizer was also effective with maximum and significant plant height of 61.5 cm (T_9-T_3+PSB+BGA) in comparison to without application of biofertilizer in T_3. However, maximum plant height 62.1 cm was recorded in T_{11}-T_3+FYM @ 5 t/ha+PSB + BGA which was at par with T_{10}-125% NPK Zn (STR) showing the value of 62.0 cm. Similar trend was also recorded in plant height at 60 days after transplanting (Table 2). Fertile tillers at 60 DAT was also significantly higher in all the treatments over control. The maximum number of fertile tillers (11.2) was recorded in T_{10}-125% NPK Zn (STR) followed by 10.7 in T_{11}-T_3+FYM @ 5 t/ha+PSB + BGA (Table 2). Balanced fertilization effectively increased the plant biomass/hill at 60 days after transplanting. Application of organic manures in the treatment T_4, T_5 and T_6 significantly increased the fresh plant biomass 85.0 g, 87.2 g and 86.8 g which was significantly higher than 82.8 g in T_3-100 % NPK Zn (STR) without organic manure application. However, maximum biomass/hill 96.8 g was recorded in T_{10}- 125% NPKZn (STR) which was at par with T_{11}-T_3+FYM @ 5 t/ha+PSB + BGA (94.8 g). Similar trend was also observed for dry biomass. Maximum dry biomass was recorded with T_{11}-T_3+FYM @ 5 t/ha +PSB + BGA (25.7 g) which was at par with T_{10}-125% NPK Zn (25.0 g). Length of ear increased significantly by the application of 100% STR and addition of organic manures. Maximum length of ear (28.1 cm) was recorded with T_{11}-T_3+FYM @ 5 t/ha + PSB + BGA which was at par (27.7 cm) with T_{10}-125% NPK Zn (STR). Test weight also significantly affected by the application of different doses of manures and fertilizers with maximum in T_{11}-T_3+FYM @ 5 t/ha+PSB + BGA (27.7 g) which was at par with T_{10}-125% NPK Zn (STR) showing the value of 27.1 g. Harvest index showed non-significant response within the treatments. However, the maximum harvest index (41.8 %) was recorded in T_3-100 % NPK Zn when nutrients applied on the basis of soil test recommendation (Table 2).

Wheat

Plant height at 30 days after sowing (DAS) indicated that nutrient management through STR or integrated with organic manures significantly increased the plant height. Treatments T_{10}-125% NPKZn (STR) and T_{11}-T_3+FYM @ 5 t/ha+PSB + BGA were at par with the value of 17.2 cm and 17.5 cm respectively. Similar trend was also recorded at 60 days after sowing.

Fertile tillers at 60 DAS indicated a significant increase with the application of organic manures showing the value of 4.9, 5.3 and 5.2 respectively in the treatments T_4-T_3+FYM @5 t/ha, T_5- T_3+ Pressmud @ 5 t/ha and T_6-T_3+NADEP compost @ 5 t/ha. However, the maximum

Table 1. Nutrient content in organic manures applied in the experiment

Organic manures	N (%)	P (%)	K (%)	Zn (ppm)	O.C. (%)	C: N ratio
FYM	0.56	0.35	0.52	11	11.17	19.9
Pressmud	1.69	1.42	1.60	17	28.5	16.9
NADEP compost	1.62	0.85	0.67	13	29.35	18.1

number of fertile tillers was recorded with T_{11}-T_3+FYM @ 5 t/ha +PSB + BGA (5.9) followed by (5.6) in T_{10}-125% NPKZn. Biomass/hill affected significantly by the different treatments. Application of 100 % NPKZn (STR) in T_3 significantly increased fresh biomass hill^{-1} (14.2 g/hill) in comparison to farmers practice (11.6 g/hill). Application of organic manures through Pressmud or NADEP compost with 100% NPKZn (STR) significantly increased the fresh biomass (16.7 g/hill and 16.1 g/hill, respectively) in comparison to 100% NPKZn (STR) alone (14.2 g/hill). Maximum fresh biomass was recorded in the treatments T_{10} and T_{11} showing the value of 17.1 g/hill. Similar trend was also recorded in dry biomass at 60 days after sowing of wheat. Length of ear was also significantly affected by different treatments with maximum (12.3 cm) in T_{10}-125% NPK Zn (STR) & T_{11}-T_3+FYM @ 5 t/ha+PSB + BGA and minimum in control (7.1 cm). Application of organic manures significantly increased the length of the ear in the order of 11.5 cm, 12.0 cm and 11.8 cm, respectively in T_4, T_5 and T_6 over 11.1 cm in T_3-100 % NPKZn (STR). Maximum test weight was recorded (44.1 g) in the treatment T_{11}-T_3+FYM @ 5 t/ha+PSB+BGA followed by 43.9 g in T_{10}- 125% NPKZn (STR) and 43.3 g in the treatment T_5-T_3+Pressmud@ 5 t/ha. Harvest index is the indicator of the grain yield percent out of total biomass. Harvest index did not influence due to different treatments. However, the maximum harvest index (46.6 %) was obtained in control (T_1) treatment and minimum (43.5 %) in T_3-100 % NPKZn (STR) and T_{10}-125% NPKZn (STR) (Table 3).

Grain and Straw yield

Rice

Application of organic manures viz. FYM or Pressmud or NADEP compost with 100 % NPKZn (STR) significantly increased the grain yields over without organic manure application in T_3- 100 % NPKZn (STR). The positive response of organic manures due the enrichment of plant nutrients and improvement in soil quality. Pressmud and NADEP compost proved superior to FYM. Satyanarayana *et al.* (2002) reported that recommended dose of NPK along with 10 t FYM/ ha produced an optimum grain yield of rice. Yaduvanshi (2003) also reported that 100% NPK + FYM (10 t/ha) significantly increased the grain yield in comparison to 150% NPK. The addition of biofertilizer like BGA alone with 100% STR (T_8) significantly increased the grain yield of rice 5.07 t/ha in comparison to without biofertilizer application (4.73 t/ha) in T_3. However, dual inoculation of PSB + BGA with 100% NPKZn (STR) was more effective showing the grain yield of 5.16 t/ha in comparison to 4.73 t/ha with 100% NPKZn (STR) alone (T_3). PSB solubilize the unavailable/fixed phosphate in available form and BGA fixed the free environmental nitrogen in the soil, which increased the grain yield of rice. Highest grain yield 5.46 t/ha was recorded in T_{10} (125% NPKZn STR) which was statistically similar 5.46 t/ha in T_{11} (100% NPKZn+ FYM @ 5 t/ha +BGA+PSB). Tiwari *et al.* (1998) reported that the rice yield significantly increased by increasing the nitrogen level up to 125% over 100% STR. Percent increase in grain yield due to different nutrient management treatments over control and farmers practice ranged from 79.5% to 166.2% and 29.9% to 48.3% respectively. The maximum percent response in both the cases was noted in T_{10} (125% STR) and T_{11} (100% STR+ FYM 5 t/ha + BGA + PSB) (Table 4).

Like grain yield, straw yield was also significantly affected by the different treatments under study. Highest straw yield 7.87 t/ha was recorded in T_{11} (100%

Table 2. Effect of integrated nutrient management treatments on yield attributing characters of rice (mean of two years)

Treatment	Plant height (cm)		Fertile tillers hill^{-1} at 60	Biomass/hill at 60 DAT (g)		Length of ear	1000 grain weight (g)	Harvest Index
	30 DAT	60 DAT	DAT	Fresh	Dry	(cm)		(%)
T_1- Control	43.1	72.1	4.4	32.1	9.5	16.1	22.1	41.2
T_2- Farmers Practice (N_{100} P_{40} K_0)	57.9	86.8	7.1	63.4	17.5	22.8	23.1	40.9
T_3-100 % NPK Zn (STR)	59.5	91.0	8.0	82.8	21.0	24.3	25.8	41.8
T_4- T_3+ FYM @5 t / ha	60.8	93.1	9.2	85.0	23.1	26.0	26.9	41.6
T_5- T_3+ Press mud @ 5 t / ha	62.0	95.0	10.6	87.2	24.9	27.4	27.5	41.3
T_6- T_3+ NADEP compost @ 5 t/ ha	61.5	94.5	9.5	86.8	24.6	26.7	27.3	41.2
T_7- T_3+ PSB	60.5	92.0	8.6	84.8	23.6	26.0	26.1	41.3
T_8- T_3+ BGA	60.6	92.6	9.0	85.3	23.7	25.9	26.1	41.2
T_9- T_3+ PSB+BGA	61.5	95.5	9.4	85.8	24.0	26.7	26.4	41.3
T_{10}-125% NPK Zn (STR)	62.0	97.6	11.2	96.8	25.0	27.7	27.1	41.1
T_{11}-T_3+ FYM @ 5 t / ha+PSB + BGA	62.1	97.2	10.7	94.8	25.7	28.1	27.7	41.0
SEm±	0.55	1.19	0.22	1.80	0.33	0.18	0.16	-
CD (P= 0.05)	1.13	2.44	0.45	3.67	0.67	0.36	0.32	NS

STR+FYM+BGA+ PSB) followed by 7.82 t/ha in T_{10}-125% NPKZn (STR). Lowest straw yield (2.93 t/ha) was recorded in Control. Use of organic manures *viz.* FYM, Pressmud and NADEP compost alone with 100% STR significantly increased the straw yield over T_3-100% NPKZn (STR) (Table 4).

Wheat

Grain yield of wheat significantly increased by the application of 100% NPKZn (T_3) showing the value of 3.30 t/ha in comparison to 3.00 t/ha in Farmers Practice (T_2) and 1.74 t/ha in control (T_1). Highest grain yield 3.57 t/ha was recorded in T_{11}-100% NPKZn (STR) + FYM 5 t/ha +*Azotobacter* + PSB) which was at par (3.56 kg/ha) with T_{10}-125% NPKZn. Application of organic manures (FYM, Pressmud and NADEP compost) with 100% NPK Zn (STR) significantly increased the grain yield of wheat over 100% NPKZn (STR). Tiwari *et al.* (1998) reported that addition of FYM showed residual response to increasing the yield of wheat crop. Yaduvanshi (2003) observed that application of FYM (10 t/ ha) showed the residual response and significantly increased the grain yield of wheat over without organic/ green manuring with the same dose of fertilizer. Dual inoculation of biofertilizers (PSB + *Azotobacter*) with 100% NPKZn (STR) significantly increased the grain yield (3.46 t/ha) over 100% STR (T_3) alone. PSB solubilize the unavailable phosphate in available form and *Azotobacter* fixed the free environmental nitrogen in soil, which increased the grain yield of wheat. Percent increase in grain yield due to different treatments

Table 3. Effect of INM treatments on yield attributing characters of wheat (mean of two years)

Treatment	Plant height (cm)		Fertile tillers/hill at 60 DAS	Biomass/hill		Length of ear (cm)	1,000-grain weight (g)	Harvest Index (%)
	30 DAT	60 DAT		Fresh (g)	Dry (g)			
T_1- Control	11.2	44.1	2.9	5.3	1.1	7.1	37.1	46.6
T_2- Farmers practice (N_{100} P_{40} K_0)	14.3	50.0	4.0	11.6	2.1	9.9	40.7	44.3
T_3-100 % NPK Zn (STR)	15.3	53.0	4.5	14.2	2.6	11.1	42.3	43.5
T_4- T_3+FYM @5 t / ha	16.0	55.0	4.9	15.3	2.8	11.5	42.6	44.0
T_5- T_3+ Pressmud @ 5 t / ha	16.6	55.6	5.3	16.7	3.2	12.0	43.3	43.9
T_6- T_3+ NADEP compost @ 5 t/ ha	11.4	55.4	5.2	16.1	3.1	11.8	43.1	44.0
T_7- T_3+ PSB	15.2	53.2	4.7	14.4	2.7	11.3	42.4	43.8
T_8- T_3+ *Azotobacter*	15.3	53.1	4.9	14.7	2.8	11.3	42.6	43.9
T_9- T_3+ PSB + *Azotobacter*	16.0	53.5	5.0	15.8	2.8	11.5	42.8	44.1
T_{10}-125% NPK Zn (STR)	17.2	55.6	5.6	17.1	3.3	12.3	43.9	43.5
T_{11}-T_3+FYM@5t/ha+PSB+ *Azotobacter*	17.5	55.6	5.9	17.1	3.4	12.3	44.1	43.6
SEm±	0.22	1.18	0.52	1.00	0.32	.022	0.27	-
CD (P= 0.05)	0.44	2.41	1.07	2.04	0.66	0.44	0.55	NS

Table 4. Effect of INM treatments on grain and straw yield of rice and wheat (mean of two years)

Treatment	Rice (t/ha)				Wheat (t/ha)			
			% grain yield increased over				% grain yield increased over	
	Grain	Straw	Control	F.P.*	Grain	Straw	Control	F.P.*
T_1- Control	2.05	2.93	-	-	1.74	2.00	-	-
T_2- Farmers Practice (N_{100} P_{40} K_0)	3.68	5.33	79.5	-	3.00	3.78	72.5	-
T_3-100 % NPK Zn (STR)	4.73	6.58	130.7	29.9	3.30	4.28	89.7	10.0
T_4- T_3+ FYM @5 t / ha	5.11	7.16	149.3	38.9	3.48	4.44	100.0	16.0
T_5- T_3+ Pressmud @ 5 t / ha	5.38	7.64	162.5	46.2	3.56	4.56	104.5	18.6
T_6- T_3+ NADEP compost @ 5 t / ha	5.34	7.61	160.2	44.9	3.52	4.48	102.3	17.3
T_7- T_3+ PSB	5.01	7.13	144.3	36.1	3.37	4.32	93.7	12.3
T_8- T_3+ BGA/*Azotobacter*	5.07	7.24	147.3	37.8	3.41	4.363	95.7	13.3
T_9- T_3+ PSB+BGA/*Azotobacter*	5.16	7.35	151.6	40.2	3.46	4.40	98.9	15.3
T_{10}-125% NPK Zn (STR)	5.46	7.82	166.3	48.3	3.56	4.63	104.6	16.9
T_{11}-T_3+FYM @ 5 t / ha+PSB + BGA/ *Azotobacter*	5.46	7.87	166.2	48.3	3.57	4.62	105.2	18.9
SEm±	0.12	0.18	-	-	0.15	0.09	-	-
CD (P= 0.05)	0.24	0.36	-	-	0.30	0.19	-	-

*FP= Farmers Practice

ranged from 72.5% to 105.2% over control and 10.0 to 18.9% over farmer practice (Table 4).

Straw yield of wheat was also influenced by the different treatments. Highest straw yield (4.63 t/ha) was noted in T_{10}-125% NPK Zn (STR) which was similar (4.62 t/ha) with T_{11}- T_3+FYM @ 5 t / ha+PSB + BGA/*Azotobacter*.

Nutrient uptake in rice

Nitrogen

Uptake of nitrogen in rice grain ranged from 19.5 to 62.9 kg/ha with highest in T_{10}-125% NPKZn (STR) and lowest in Control (T_1). Application of organic manures like FYM, Pressmud and NADEP compost alone with 100% NPKZn (STR) significantly increased the nitrogen uptake in rice over 100% STR alone. Organic manures provided additional amounts of plant nutrients and also improved the soil quality which increased the nitrogen uptake in the plant. Pressmud and NADEP compost found alike and proved superior to FYM. The addition of biofertilizer BGA and PSB alone stimulated nitrogen uptake and dual inoculation (PSB+BGA) with 100% STR (T_9) significantly increased nitrogen uptake. PSB provided the unavailable phosphate in available form and BGA fixed the free environmental nitrogen in the soil both biofertilizer showed synergistic response and increased the nitrogen uptake in rice. Similar trend was also recorded for nitrogen uptake in the straw.

Total nitrogen uptake (grain + straw) was significantly increased by different treatments over farmers practice and control. Highest total N uptake 95.7 kg/ha and 95.6 kg/ha were recorded in T_{11} and T_{10} which was statistically at par with each other (Table 5) (Singh, 2006; Satyanarayana *et al.*, 2002).

Phosphorus

Highest P uptake (19.0 kg/ha) was recorded in T_{11} (100% STR+FYM 5 t/ha + BGA+PSB) followed by 18.8 kg/ha in T_{10} (125% STR) in grains of rice. Significant increase in P uptake was noticed by the application of organic manures, FYM, or Pressmud or NADEP compost in comparison to without organic manure application in T_3-100% NPK Zn (STR). Single or dual inoculation of biofertilizder (BGA and PSB) significantly increased P uptake in comparison to the without biofertilizer application. Integration of inorganic, organic and biofertilizer was found more effective in relation to P-uptake in rice. PSB solubilize the unavailable in available form and BGA fixed the free environmental nitrogen in the soil, which increased the phosphorus uptake in rice. P-uptake in rice straw was increased due to different treatments over control and farmers practice. P-uptake in rice straw ranged from 0.9 to 3.1 kg/ha. Application of organic manures i.e. FYM, Pressmud and NADEP compost alone with 100% STR (T_4, T_5 and T_6) significantly increased the P-uptake over without organic manure application (T_3). Single or dual inoculation of biofertilizer (PSB and BGA) significantly increased P-uptake over without biofertilization. Total P-uptake ranged from 7.6 to 22.1 kg/ha. Highest total P uptake (22.1 kg/ha) was recorded in T_{11} (100% STR+ FYM+BGA+PSB) followed by 21.8 kg/ha in T_{10}-125% NPK Zn (STR). Application of organic manure with 100% STR and single or dual inoculation of biofertilizer with 100% STR increased total P-uptake. Pressmud and NADEP compost were found superior to FYM. Dual inoculation of biofertilizer was found better in comparison to single inoculation (Table 5).

Potassium

Like nitrogen and phosphorus, K uptake in grain was also increased by the different treatments ranging from 5.7 to 17.9 kg/ha in grain and 41.6 to 128.2 kg/ha in straw, respectively. Total K uptake 145.8 kg/ha was recorded in

Table 5. Effect of INM treatments on N, P and K uptake in rice (mean of two years)

Treatment	N-uptake (kg/ha)			P-uptake (kg/ha)			K-uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1 -Control	19.5	10.7	30.2	6. 7	0.9	7.6	5.7	41.6	47.3
T_2 -Farmers Practice($N_{100}P_{40}K_0$)	39.0	20.6	59.6	12.2	1.8	14.0	10.5	83.1	93.6
T_3 -100% NPK Zn (STR)	51.9	25.8	77.7	15.9	2.4	18.3	14.3	105.5	119.8
T_4 -T_{3+} FYM @ 5 t / ha	57.6	29.3	86.9	17.4	2.6	20.0	15.9	116.1	132.0
T_5 -T_3+Pressmud @ 5 t / ha	61.3	32.3	93.6	18.4	2.9	21.3	17.2	124.8	142.0
T_6 -T_3+NADEP compost @ 5 t / ha	60.3	31.2	91.5	18.2	2.8	21.0	17.0	123.7	140.7
T_7 -T_3+PSB	55.4	28.3	83.7	17.5	2.7	20.2	15.3	114.0	129.3
T_8 -T_3+BGA	56.5	29.3	85.8	17.1	2.7	19.8	16.0	116.6	132.6
T_9 -T_3+ PSB+BGA	58.1	30.2	88.3	17.8	2.8	20.6	16.0	118.9	134.9
T_{10}-125% NPK Zn (STR)	62.9	32.7	95.6	18.8	3.0	21.8	17.9	127.7	145.6
T_{11}-T_3 + FYM @ 5 t/ha+ PSB + BGA	62.4	33.3	95.7	19.0	3.1	22.1	17.6	128.2	145.8
SEm±	1.47	0.35	1.82	0.42	0.8	0.50	0.76	2.39	3.16
CD (P=0.05)	3.00	0.71	3.71	0.86	1.6	1.02	1.56	4.89	6.45

100% STR + FYM 5 t/ha+ PSB + BGA (T_{11}) which was equal to 145.6 kg/ha in 125% STR (T_{10}). Application of organic manures in T_4, T_5 and T_6 with 100% STR significantly increased the K uptake over 100% STR alone (T_3). Pressmud and NADEP compost found alike and superior to FYM. Dual inoculation by PSB and BGA proved superior to single inoculation either by PSB or BGA (Satyanarayana *et al.*, 2002; Singh, 2006) (Table 5).

Nutrient uptake in wheat

Nitrogen

Maximum N uptake of 84.0 kg/ha in grains was recorded in T_{11} (100% STR+ FYM 5 t/ha+ *Azotobacter* + PSB) which was at par with T_{10} (125% STR). Application of all the organic manures with 100% STR (T_4, T_5 and T_6) significantly increased the nitrogen uptake by wheat in grain over 100% STR in T_3. Dual inoculation (T_9) increased N uptake over single inoculation (T_7 and T_8), though the differences were non-significant. However, it was significantly increased the nitrogen uptake in comparison to without inoculation (T_3). Similar trends were recorded in N uptake by wheat straw and total N uptake (Table 6).

Phosphorus

Application of 100% NPKZn (STR) in T_3 significantly increased the P uptake over farmers practice (T_2) and control (T_1). The P uptake by wheat grains ranged from 6.4 to 17.2 kg/ha. Application of organic manures with inorganic fertilizers (T_4, T_5 and T_6) significantly increased the P uptake over 100% STR (T_3) (Yaduvanshi, 2003). Pressmud and NADEP compost were found alike and proved superior to FYM. Dual inoculation of biofertilizer (T_9) significantly increased the P uptake over 100% STR in T_3 (Table 6). Similar trends were recorded in N uptake by wheat straw and total N uptake (Singh, 2006).

Potassium

Potassium uptake by wheat grain due to different treatments varied from 4.2 to 9.6 kg/ha. Highest K uptake in grain 9.6 kg/ha was recorded in T_{10}- 125% NPKZn (STR) followed by 9.3 kg/ha in T_{11} (100% STR + FYM 5 t/ha+ PSB + *Azotobacter*). Application of organic manures like FYM, Pressmud and NADEP compost with inorganic fertilizers (T_4, T_5 and T_6) significantly increased K uptake over T_3 -100% NPKZn (STR) (Yaduvanshi, 2003). Single or dual inoculation of biofertilizers stimulated K uptake (Singh, 2006) (Table 6).

Changes in microbial population

Microbial load of the experimental soil accelerated by the use of nutrients either through chemical fertilizer or organic manure or biofertilizers as compared to control. Spectacularly, organic manure addition with inorganic fertilizer showed a profound increase in the microbial population in comparison to use of chemical fertilizer alone. Added organic matter provides as a source of the nutrients and acts as a substrate for decomposition and mineralization of nutrients, as such it creates a favourable condition in the soil for the proliferation of microbes (Table 7).

Total bacteria

The population of total bacteria ranged from 45 X 10^5 to 94 X 10^5/g soil with maximum in T_{11}- Conjoint use of inorganic fertilizer and organic manure and dual inoculation of biofertilizer (PSB + BGA) and minimum in control (T_1). Application of inorganic fertilizer integrated with FYM and biofertizer produced favourable influences on soil bacteria and indirect effects on higher yield and nutrient uptake of rice and wheat. Application of 100% STR + NADEP compost @ 5 t/ha (T_6) also had the total bacterial population of 92 X 10^5/g soil which was at par with T_{11}, T_4, T_5 and T_6. Selvi *et al.* (2004) recorded the highest bac-

Table 6. Effect of INM treatments on N, P and K uptake in wheat (mean of two years)

Treatments	N- uptake (kg/ha)			P- uptake (kg/ha)			K- uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1 -Control	30.0	7.4	37.4	6.4	2.1	8.5	4.2	42.6	46.8
T_2 -Farmers Practice($N_{100}P_{40}K_0$)	64.9	17.6	82.5	13.2	4.3	17.5	7.5	80.6	88.1
T_3 -100% NPK Zn (STR)	76.1	21.4	97.5	15.0	5.3	20.3	8.2	92.3	100.5
T_4 -T_{3+} FYM @ 5 t / ha	81.14	22.8	103.9	16.1	5.8	21.9	9.1	95.9	105.0
T_5 -T_3+ Pressmud @ 5 t / ha	83.7	23.3	107.0	16.9	6.3	23.2	9.0	98.7	107.7
T_6 -T_3+ NADEP compost @ 5 t / ha	82.4	24.2	106.6	16.4	6.2	22.6	9.1	99.0	108.1
T_7 -T_3+ PSB	78.9	22.0	100.9	15.3	5.9	21.2	8.6	93.4	102.0
T_8 -T_3+ *Azotobacter*	79.2	22.9	102.1	16.5	6.1	22.6	8.6	94.3	102.9
T_9 -T_3+ PSB + *Azotobacter*	81.4	23.5	104.9	16.6	5.8	22.4	9.1	94.4	103.5
T_{10} -125% NPK Zn (STR)	83.9	24.8	108.7	17.2	6.4	23.6	9.6	99.8	109.4
T_{11}-T_3+FYM @ 5t / ha+ PSB+ *Azotobacter*	84.0	24.7	108.7	16.8	6.1	22.9	9.3	105.3	114.6
SEm±	2.17	1.13	3.30	0.38	0.25	0.63	0.31	2.35	2.65
CD (P=0.05)	4.43	2.31	6.74	0.78	0.51	1.29	0.63	4.79	5.42

terial counts at the end of the crop with the addition of FYM along with 100% NPK followed by 150% NPK. However, chemical fertilizer with biofertilizer (T_7, T_8 & T_9) also increased the population of total bacteria in the order of 64, 65.5 and 67 X 10^5/g soil respectively.

Azotobacter

Asymbiotic diazotrophic population of *Azotobacter* varied significantly due to INM treatments. *Azotobacter* population ranged from 22.0 X 10^2 to 51.5 X 10^2/g soil with minimum in control (T_1) and maximum in Pressmud @ 5 t/ha (T_5). It is observed that organic manure application substantially increased the population of *Azotobacter* while the increase due to the use of chemical fertilizer was nominal. Jain *et al.* (2003) reported that FYM + 100% NPK increased population of *Azotobacter* in comparison to treatments applied without FYM.

PSB

The PSB count was significantly increased with different treatment combinations over control. Maximum count 42.0 X 10^2/g soil was recorded in T_9 –T_3+ PSB+BGA followed by 40 X 10^2/g soil in T_{11}-T_3+FYM @ 5 t/ha+ PSB+BGA. Like other heterotrophs, population of PSB increased considerably due to the application of organic manures and biofertilizer. The addition of PSB with chemical fertilizer alone or together with organic manures increased the population of PSB considerably.

Actinomycetes

Although the population of 'Star fungus' actinomycetes did not differ significantly by the treatments, however, it tended to increase with fertilization. The use of organic manure showed more population. The population ranged from 10.5 X 10^5/g to 18.5 X 10^5/g soil with minimum in control and maximum in T_4, T_6 and T_{11}). Selvi *et al.* (2004) found the increased population of actinomycetes through the application of 100% NPK + FYM as compared to without FYM application treatments.

Soil properties after harvest of wheat crop

After harvest of wheat crop, the maximum reduction in pH (8.4) was recorded in T_5 (100% STR + Pressmud @ 5 t/ha) and minimum (8.8) in control (T_1). Addition of organic manures like, Pressmud, NADEP compost and FYM with chemical fertilizer reduced more pH in comparison to chemical fertilizer alone (Yaduvanshi, 2003; Singh, 2009). The maximum reduction in EC from 0.61 to 0.35 was observed with the application of Pressmud with 100% STR NPKZn (T_5). NADEP compost, FYM and biofertilizer (PSB+BGA/*Azotobacter*) with 100% STR also tended to reduce EC of the experimental field. Organic carbon improved slightly by the integrated use of organic manure with inorganic fertilizer. Singh *et al.* (2009) also reported that the addition of pressmud increased the soil organic carbon content due to increase in yield and root biomass. However, application of chemical fertilizer alone or with organic manures/ biofertilizer did not significantly improve the organic carbon content in the soil (Table 8).

Changes in fertility status

After harvest of wheat crop, available N was significantly affected by different treatments. Available N ranged from 177 to 200 kg/ha with minimum in control and maximum in T_{11} (100% STR + FYM 5 t/ha +PSB+BGA/*Azotobacter*). Balanced fertilization improved available N from its initial value. Integrated use of inorganic fertilizer and organic manure + biofertilizer was more effective for increasing the available N content. No significant variation was recorded among organic manures used in the study. Farmers practice and control (without fertilizer) reduced

Table 7. Effect of INM treatments on microbial population in soil after harvest of rice (mean of two years)

Treatment	Total Bacteria (× 10^5)	Azotobacter (×10^2)	PSB (× 10^2)	Actinomycetes (× 10^5)
T_1 -Control	45.0	22.0	12.5	10.5
T_2 –Farmers Practice ($N_{100}P_{40}K_0$)	61.0	33.5	19.5	13.0
T_3 -100% NPK Zn (STR)	63.0	33.0	21.5	14.5
T_4-T_{3+} FYM @ 5 t/ha	88.5	41.0	27.5	18.5
T_5 -T_3+Pressmud @ 5 t/ha	87.5	51.5	30.0	18.0
T_6 -T_3+NADEP compost @ 5 t/ha	92.0	50.5	35.5	18.5
T_7 -T_3+PSB	64.0	34.0	38.0	14.5
T_8 -T_3+BGA	65.5	40.0	26.0	14.0
T_9-T_3+ PSB + BGA.	67.0	36.0	42.0	15.5
T_{10} -125% NPK Zn(STR)	62.5	33.0	26.0	14.5
T_{11}-T_3+FYM @ 5t/ha+ PSB+BGA	94.0	51.0	40.0	18.5
SEm±	5.24	3.31	3.60	-
CD (P=0.05)	10.7	6.75	7.35	NS

Table 8. Changes in soil properties after harvest of wheat (mean of two years)

Treatment	pH (2.5)	EC (dS/m)	OC (g/kg)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (ppm)
T_1- Control	8.8	0.45	3.4	177	24.8	228	0.75
T_2- Farmers Practice ($N_{100}P_{40}K_0$)	8.6	0.44	3.4	184	25.8	236	0.78
T_3-100 % NPK Zn (STR)	8.6	0.41	3.3	188	26.2	239	0.82
T_4- T_3+FYM @5 t/ha	8.5	0.37	3.9	195	27.8	248	0.84
T_5- T_3+Pressmud @ 5 t/ha	8.4	0.35	3.8	198	28.6	253	0.87
T_6- T_3+NADEP compost @ 5 t/ha	8.5	0.36	3.9	196	28.1	251	0.88
T_7- T_3+PSB	8.6	0.40	3.4	187	28.6	241	0.83
T_8- T_3+ BGA/*Azotobacter*	8.6	0.38	3.5	189	26.1	244	0.84
T_9- T_3+PSB + BGA/*Azotobacter*	8.6	0.38	3.4	193	28.9	248	0.86
T_{10}-125% NPK Zn (STR)	8.6	0.36	3.3	197	29.1	252	0.91
T_{11}-T_3+FYM @ 5 t/ha+PSB + BGA/*Azotobacter*	8.5	0.36	3.6	200	29.1	254	0.91
Initial	8.9	0.61	3.6	186	25.3	235	0.78
SEm±	0.06	0.06	0.05	2.3	0.68	3.5	0.01
CD (P=0.05)	0.13	0.12	0.11	4.7	1.38	7.2	0.02

available N content in the soil (Table 8).

Available P after harvest of wheat crop ranged from 24.8 to 29.1 kg/ha under different treatments, with minimum in control and maximum in T_{10}-125% STR and T_{11}-T_3+FYM @ 5 t/ha +PSB+BGA/*Azotobacter* (Yadav *et al*., 2000; Yaduvanshi, 2002). Like nitrogen there was no significant variation among organic manures but values were significantly higher over control and farmers practice.

Available K after harvest of wheat crop ranged from 228 to 254 kg/ha being lowest in control and highest in (T_{11}-100% STR+ FYM 5 t/ha+ PSB+ *Azotobacter*). There was no significant variation among the organic manures, but the values were significantly higher than its initial value of 235 kg/ha and control value of 228 kg/ha. Yaduvanshi (2002) reported that single or combined use of inorganic fertilizers and green manuring or FYM application significantly increased the available K in the soil.

Available Zn after harvest of wheat crop ranged from 0.75 to 0.91 ppm as affected by the treatments with minimum in T_1 (control) and the higher in T_{10} T_{11}. Zinc content significantly reduced under control treatment. Application of zinc sulphate and organic manures increased available zinc content (Table- 5). Application of zinc sulphate and organic manures significantly increased the available zinc content in soil. Swarup and Yaduvanshi (2000) reported that application of NPK with FYM or GM significantly increased the available zinc over without organic treatment. Singh (2006) also reported that application of NPK with FYM increased the zinc content in soil in comparison with without FYM application.

It is concluded from this study that application of fertilizers on the basis of soil test (100% NPKZn- STR) is the more effective over farmers practice. It was more effective when 125% NPKZn- STR was applied and it was at par with integrated use of organic, inorganic and biofertilizers (100% NPKZn- STR + FYM @ 5 t/ha+ PSB + BGA/*Azotobacter*). Improvement in soil microbial population, soil properties and fertility status was recorded when chemical fertilizers integrated with organic manures and biofertilizers.

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