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Effect of integrated nutrient management on sunnhemp (*Crotalaria juncea*) and its residual effect on succeeding rice (*Oryza sativa*) in eastern Uttar Pradesh

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ABSTRACT

A field experiment was conducted during summer and rainy seasons of 2003–05 at Sunnhemp Research Station, Pratapgarh, Uttar Pradesh to find out the effect of integrated nutrient management on yield, yield attributes and nutrient uptake by sunnhemp (*Crotalariajuncea* L.), its residual effect on succeeding rice (*Oryza sativa* L.) crop and residual fertility build-up in soil. The fibre yield of sunnhemp was significantly higher (0.76 tonnes/ha) with 75% NPK + *Rhizobium* + PSB (T_5) over the control but was at par with 100% NPK & 75% NPK + *Rhizobium*, while significantly higher NPK uptake was observed with T_5 over the other treatments. On the other hand, residual effect of integrated nutrient management on rice yield was nonsignificant but 75% NPK + *Rhizobium* + PSB recorded significantly higher nutrient uptake over the other treatments except100% NPK & 75% NPK + *Rhizobium*. The maximum net returns from sunnhemp (Rs 9 822/ha) was recorded with 75% NPK + *Rhizobium* + PSB with adequate soil fertility build-up under sunnhemp–rice cropping sequence in Inceptisol of eastern Uttar Pradesh.

Key words: Integrated nutrient management, Sandy loam soil, Soil fertility, Sunnhemp–rice

Sunnhemp (*Crotalaria juncea* L.), a member of the legume family (Fabaceae) is an important multi-purpose fibre crop of India, in general and Uttar Pradesh, in particular sunnhemp (*Crotalaria juncea* L.) – rice (*Oryza sativa* L.) crop rotation is very common in eastern Uttar Pradesh during summer and rainy seasons. Integration of chemical and organic sources like manures, biofertilizers etc. and their efficient management does not only help in sustaining the productivity and physical and biological health of soil but also meets a part of the chemical fertilizer requirement of crops (Babu *et al*. 2007). Due to scarcity of organic sources of nutrients and their inability to meet the total nutrient requirements to sustain large-scale productivity goals and to meet the demands of growing population, their integrated use with chemical fertilizers is inevitable (Acharya 2002). *Rhizobium* inoculation has favourable effect on legumes. Phosphate-solubilizing bacteria improve nodulation through increased phosphate solubilization and hence, increase symbiotic nitrogen fixation (Afzal and Bano 2008). Application of *Rhizobium* and phosphate-solubilizing bacteria (PSB) in a legume–cereal cropping sequence not only fixes the biological N and solubilizes the insoluble phosphates in soil, respectively but also improves the fertilizer-use efficiency, crop productivity and lowers down the requirement of costly N and P fertilizers. Keeping these points in view, the present investigation was undertaken to study the effect of integrated nutrient management on sunnhemp and its effect on succeeding rice crop.

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MATERIALS AND METHODS

The field experiment was conducted at Sunnhemp Research Station (ICAR), Pratapgarh, Uttar Pradesh (between 25° 34 and 26° 11 latitudes and between 81° 19 and 82° 27 longitudes) during the summer and rainy (*kharif*) seasons of 2003–04 and 2004–05 on a sandy loam soil with *p*H 7.8, organic carbon 2.8 g/kg, bulk density 1.44 g/cc, $CaCO_3$ 7 to 10 g/kg and available nitrogen, phosphorus and potassium 230, 12.5 and 192 kg/ha, respectively. There were 6 treatment combinations laid out in complete randomized block design with 4 replications. The treatments were: T_1, 100% recommended dose of NPK, T_2, 50% of recommended dose + *Rhizobium*; T_3, 50% of recommended dose + *Rhizobium* + Phosphate-solubilizing bacteria (PSB); T_4, 75% of recommended dose + *Rhizobium*; T_5, 75% of recommended dose + *Rhizobium* + PSB and T_6, control. 'K-12' yellow sunnhemp was sown on 5 m × 4 m beds in rows 20 cm apart during both years with seed rate of 40 kg/ha.

The recommended doses of fertilizer N, P and K for sunnhemp and rice were 20: 40: 20 and 120: 60: 60 kg/ha, respectively. Nitrogen, phosphorus and potassium were applied respectively through urea, single superphosphate and muriate of potash. Fertilizers were applied treatment-wise at sowing. The seeds were inoculated with bacterial culture and dried in shade for 30 min. before sowing as per treatment. The crop was thinned 10 days after sowing where ever necessary to maintain a plant-to-plant spacing of 5–7 cm. Remaining package of practices were adopted as per recommendation. Nodule count was recorded at 45 days stage. Crop was harvested at 90 days stage and retted in pond. 'Sarju 52' rice was transplanted in the same layout just after harvesting of sunnhemp. The crop was transplanted at a spacing of 20 cm × 15 cm with 50% recommended dose of fertilizer during both the years. The rice crop was harvested after 90 days of transplanting. The plant samples (sunnhemp and rice) collected at harvest were dried, processed and analyzed for total N, P and K by micro-Kjeldahl, vanadomolybdate yellow colour and flame photometric methods respectively (Tandon 1993). The soil samples (0–20 cm) collected after 2 years were dried, processed and analyzed for organic carbon, available N, P and K following standard procedures (Page *et al.* 1982). The statistical analysis of the experimental data was carried out by using SPSS package (version 10.0).

RESULTS AND DISCUSSION

Nodulation and yield attributes of sunnhemp

The nodulation and yield attributes data of sunnhemp (Table 1) revealed that nodule/plant in sunnhemp increased significantly with the *Rhizobium* and PSB inoculation over un-inoculated treatments. The maximum number of nodule/plant (36) was recorded with 75% NPK + *Rhizobium* + PSB (T_5) which was significantly superior over the control (28.1) and 100% NPK (29.5).

The individual and 2 years pooled data on basal diameter, plant height and green weight of sunnhemp shows that 75% NPK + *Rhizobium* + PSB recorded highest values of basal diameter (11.25 cm), plant height (231 cm) and green weight (27.57 tonnes/ha) and the treatment was significantly superior over control, integration of *rhizobium* and PSB with 50% NPK (T_2, T_3) but was at par with 100% NPK. This favourable effect could be attributed to beneficial role of *Rhizobium* in the N nutrition through nodulation and P nutrition through P solubilization by PSB and consequently a better growth or development (Basu *et al.* 2006, Afzal and Bano 2008)).

Yield and nutrient uptake by sunnhemp

The fibre yield of sunnhemp (Table 2) increased significantly with the application of NPK fertilizer and integrated use of NPK fertilizers with biofertilizer over control. The fibre yield of sunnhemp was significantly higher (33.3%) with integration of 75% NPK with *Rhizobium* and PSB (T_5) over the control and integration of *Rhizobium* and PSB with 50% NPK (T_2, T_3) but was at par with 100% NPK. This was observed in both the years and with the 2 years pooled yield data also. However, this is clear from the data that only 25% of recommended NPK dose can be saved by integration of 75% NPK and biofertilizer (*Rhizobium* + PSB) as integration of 50% NPK with biofertilizer produced lesser fibre yield than the 100% NPK dose. This positive effect of integration of *rhizobium* and PSB with NPK on fibre yield is not only because of improvement in available N and P status by means of biological N fixation and P solubilization but also their contribution towards the maintenance of a suitable condition for favourable growth and yield. The favourable effect of integration of chemical fertilizers, *Rhizobium* and PSB on growth and yield were also reported by Laxminarayana (2005), Pattanayak *et al*. (2007) and Afzal and Bano (2008).

The nutrient uptake by sunnhemp crop responded well to integrated application of NPK with *Rhizobium* and PSB (Table 2) over control. The maxmimum N, P and K uptake

Table 1 Effect of integrated nutrient management on nodulation and yield attributes of sunnhemp

Treatment	Nodule/plant		Mean	Basal diameter (mm)		Mean	Plant height (cm)		Mean	Green weight (tonnes/ha)		Mean
	2003–04	2004–05		2003–04	2004–05		2003–04	2004–05		2003–04	2004–05	
T_1 100% NPK	28	31	29.5	12.5	9.8	11.15	227	230	228.5	29.01	24.73	26.87
T_2 50% NPK + *Rhizobium*	32	36	34.0	12.1	9.4	10.75	222	228	225.0	24.67	23.13	23.90
T_3 50% NPK + *Rhizobium* + PSB	33	36	34.5	12.2	9.5	10.85	224	229	226.5	25.80	23.40	24.60
T_4 75% NPK + *Rhizobium*	35	34	34.5	12.4	9.7	11.05	228	231	229.5	29.01	24.40	26.70
T_5 75% NPK + *Rhizobium* + PSB	35	37	36.0	12.5	10.0	11.25	229	233	231.0	30.21	24.93	27.57
T_6 Control	26	30	28.1	11.4	9.0	10.20	218	223	220.5	21.16	21.39	21.27
CD (*P*= 0.05)	3.6	4.1	3.8	0.2	0.4	0.3	2.9	4.1	3.6	2.07	1.22	1.75

Table 2 Effect of integrated nutrient management on fibre yield and nutrient uptake (2 years pooled data) by sunnhemp

Treatment	Fibre yield (tonnes/ha)		Mean	N uptake	P uptake	K uptake
	2003–04	2004–05			(kg/ha)	
T_1	0.74	0.74	0.74	220.4	24.4	127.0
T_2	0.63	0.68	0.65	200.4	21.6	115.4
T_3	0.66	0.69	0.67	208.5	23.0	120.4
T_4	0.74	0.72	0.73	214.0	25.0	128.5
T_5	0.77	0.75	0.76	228.7	30.5	135.0
T_6	0.53	0.62	0.57	185.5	18.5	95.5
CD (*P*= 0.05)	0.03	0.04	0.04	5.8	4.3	4.7

by sunnhemp crop recorded with 75% NPK + *Rhizobium* + PSB which was significantly superior over other treatments combinations including 100% NPK and was 23.3, 64.9 and 41.4% higher over respective N, P and K uptake at control. The *Rhizobium* inoculation alone and combination of *Rhizobium* and PSB has a profound influence on the uptake of N, P and K by sunnhemp. *Rhizobium* inoculation has not only influenced the N uptake but improved the P and K uptake also, similarly inoculation of PSB also increases N and K uptake along with P uptake by solubilization of insoluble organic phosphates, decomposition of phosphate rich organic compounds and production of plant growth promoting substances (Afzal and Bano 2008). The higher nutrient uptake with *Rhizobium* and PSB was also reported by Laxminarayana (2005) and Basu *et al.* (2006).

Residual effect of INM in sunnhemp on grain yield and nutrient uptake by succeeding rice

There was no significant effect of integration of NPK and biofertilizer in sunnhemp on residual grain yield of rice crop (Table 3) during both the years. In general, yield of first year was higher than the second year. The maximum grain yield of rice in both the years was recorded from the plot receiving with 75% NPK + *Rhizobium* + PSB in preceding sunnhemp. This indicates that NPK applied in previous crop in combination with PSB was not sufficient for optimum yield of rice.

However, the total nutrient uptake by rice (grain + straw) increased significantly with the applied NPK alone or in combination with *Rhizobium* and PSB in preceding crop (Table 3). The maximum N (72.5 kg/ha), P (12.5 kg/ha) and K (85.2 kg/ha) was recorded in rice grown after sunnhemp with 75% NPK + *Rhizobium* + PSB which was at par with 100% NPK but was significantly higher by 31.8, 66.6 and 24.4% over respective N, P and K uptake at control. On the other hand, nutrient uptake by rice crop grown after sunnhemp with integration of 50% NPK + *Rhizobium* + PSB (T_3) was also at par with 100% NPK. Similarly, beneficial effect of integrated nutrient management on residual wheat crop in a sunnhemp–wheat cropping sequence was also reported by Maitra *et al*. (2008).

Soil fertility status

The fertility status of soil after 2 years improved considerably by the integration of NPK, *Rhizobium* and PSB compared to control and only NPK (Table 4). The organic carbon content in the post harvest soil after 2 years increased significantly with integrated use of 75% NPK with *Rhizobium* (T_4) or *Rhizobium* + PSB (T_5) over control, initial value and 100% NPK. The maximum organic C content (4.2 g/kg) in 75% NPK + *Rhizobium* + PSB was 44.8% higher over control. The higher organic carbon content with integration of NPK, *Rhizobium* and PSB could be attributed to higher microbial population, fixation of N in organic form as organic biomass and higher left over crop residues etc. because of favourable crop growth and development. The integrated

Table 3 Residual effect of integrated nutrient management on grain yield and nutrient uptake (2 years pooled data) by rice (grain + straw)

Treatment	Grain yield (tonnes/ha)		Mean	N uptake	P uptake	K uptake
	2003–04	2004–05			(kg/ha)	
T_1	3.13	2.32	2.72	70.5	11.5	83.0
T_2	3.07	2.30	2.70	66.5	8.2	74.0
T_3	3.08	2.31	2.71	68.0	9.6	78.5
T_4	3.13	2.39	2.76	70.8	11.0	82.5
T_5	3.14	2.41	2.77	72.5	12.5	85.2
T_6	3.01	2.28	2.64	55.0	7.5	68.5
CD (*P*= 0.05)	NS	NS	NS	5.0	3.6	5.1

Table 4 Effect of integrated nutrient management on fertility status of soil (after 2 years)

Treatment	Organic C (g/kg)	Available N	Available P (kg/ha)	Available K
T_1	3.1	240.0	13.8	195.0
T_2	3.2	238.0	13.5	192.0
T_3	3.6	242.0	14.5	195.0
T_4	4.0	245.0	15.0	195.0
T_5	4.2	250.0	15.8	200.0
T_6	2.9	235.0	12.8	190.0
CD (*P*= 0.05)	0.57	5.6	0.76	7.5

effect of inorganic nutrient with biofertilizer in the improvement of organic carbon status was also reported by Majumdar *et al.* (2007).

The available N content in post harvest soil after 2 years increased substantially (Table 4) with the integrated use of NPK, *Rhizobium* and PSB. The increase in available N content in the soil with only *Rhizobium* inoculation integrated with NPK was less compared to inoculation with *Rhizobium* and PSB integrated with NPK, suggesting the fact that PSB has also helped in biological N - fixation by *Rhizobium* by adding the various plant growth-promoting substances (Afzal and Bano 2008) in the soil. The higher available N in the soil with PSB was also reported by Laxminarayana (2005). The available N status in the soil follows the same trend as that of organic carbon. The maximum available N (250 kg/ha) was recorded with 75% NPK + *Rhizobium* + PSB which was significantly higher by 6.4 and 4.2% over control and 100% NPK.

The available P status in the soil increased significantly with inoculation of *Rhizobium* and PSB with 50% and 75% NPK over control and 100% NPK (Table 4). The maximum available P content (15.8 kg/ha) in the soil was recorded with 75% NPK + *Rhizobium* and PSB which was significantly superior over all other treatments under study and was 23.4 and 14.5% higher over control and 100% NPK. This favourable effect of *Rhizobium* + PSB inoculation in the build-up of P status could be because of solubilization of insoluble P reserve of the soil as well as the favourable condition created by *Rhizobium* by adding biomass in the soil. This is in confirmatory with the findings of Laxminarayana (2005) and Basu (2006).

The available K status in the soil increased significantly with 75% NPK + *Rhizobium* + PSB (Table 4) over the control and was at par with 100% NPK. This increase in available K content with inoculation of *Rhizobium* + PSB might be because of release of exchangeable K from non-exchangeable K form by the action of organic acids released during biological N fixation, P solubilization and decomposition of organic biomass including crop residues (Pattanayak *et al* 2007 and Afzal and Bano 2008).

Gross and net returns from sunnhemp

Data pertaining to economics of sunnhemp production revealed that gross and net returns followed a similar trend during both years (Table 5). Highest gross (Rs 27 324) and net returns (Rs 10 002) were recorded with 75% of recommended dose of fertilizer coupled with *Rhizobium* and PSB closely followed by 100% of recommended dose of fertilizer, whereas lowest was observed in control. The highest returns under the treatment comprised of 75% of recommended dose of fertilizer along with *Rhizobium* and PSB were mainly due to higher yield under this treatment.

Table 5 Effect of integrated nutrient management on cost of cultivation, gross returns and net returns in sunnhemp

Treatment	2003–04			2004–05		
	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)
T_1	17 575	26 640	9 065	17 575	26 676	9 101
T_2	17 040	22 536	5 496	17 040	24 444	7 404
T_3	17 050	23 688	6 638	17 050	24 840	7 790
T_4	17 312	26 532	9 220	17 312	25 992	8 680
T_5	17 322	27 504	10 182	17 322	27 144	9 822
T_6	16 485	19 116	2 631	16 485	22 356	5 871

It can be concluded from the above study that 25% of recommended doses of chemical fertilizers may be saved by the integrated use of 75% NPK + *Rhizobium* + PSB under sunnhemp–rice crop rotation in sandy loam soil of eastern Uttar Pradesh.

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