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Effect of organic nitrogen sources on yield, nutrient uptake and soil health under rice (*Oryza sativa*) based cropping sequence

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ABSTRACT

A two year of field experimentation was carried out at Varanasi from 2005–07 to study the effect of organic nitrogen sources on yield, nutrient uptake and soil health under rice (*Oryza sativa*) based cropping sequence. The soil was sandy clay loam in the texture with pH 7.4, moderately fertile, being low in organic carbon (0.50%), available nitrogen (185.5 kg/ha). The experiment on rice based cropping sequences with 3 organic N nutrition treatments was laid out in split plot design with three replications. Seven rice based cropping sequences [rice-potato-onion; rice-green pea-onion; rice-potato-cowpea (green pod); rice-green pea – cowpea (green pod); rice-rajmash (green pod)- onion; rice-rajmash (green pod)-cowpea (green pod) and rice-maize (green cob)-cowpea (vegetable)] were assigned to main plots and three treatments comprising nitrogen application (control; organic manure; organic manure + bio-fertilizer) were allocated to sub plots. The system productivity was the highest (355.73 q/ha) with rice–potato–onion cropping sequence under investigation. Among the manurial treatment, organic nitrogen nutrition with biofertilizers had the highest rice grain equivalent yield (353.08 q/ha) and net monetary return (₹ 292 454). The application of organic manure alone or along with biofertilizers inoculation significantly improved the N, P, K and S uptake by cropping sequence over control. However maximum improvement in soil health related to soil organic carbon, available nutrient status, soil micro-organism population were observed in organic nitrogen sources alone or along with biofertilizers.

Key words: Biofertilizers, Cropping sequence, nutrient uptake, Organic manure, Soil health

Improving global crop productivity and product quality together with taking care of environmental quality and human wellbeing are the main challenges for the immediate future. Such a goal depends on agricultural development and policy and can be achieved by providing the right nutrient source at the right rate, the right time and the right place. Food crops grown using organic inputs having less or no chemicals are being preferred over conventionally produced food by the end users. Food materials produced organically has got it place in food market in developed and developing countries (Urkurkar *et al.* 2010). Organic production systems maintained and improved the soil health through stimulating the activity of soil organisms. Organic manures are also helpful in alleviating the increasing incidence or deficiency of secondary and micronutrients and are capable of sustaining crop productivity. *Azotobacter* naturally fixes atmospheric nitrogen in the rhizosphere while the use of phosphate solubilizing bacteria (PSB) will be helpful in increasing the availability of fixed phosphorus in soil. Application of organic manure not only improves the soil organic carbon for sustaining the soil physical quality but also increases the soil nitrogen. However, nitrogen use efficiency is very low particularly in rice and is difficult to sustain in the soil system due to volatilization, leaching and denitrification losses. Hence N is the element to be first trust in sense of organic farming (Magar 2004). These evidences suggest that the use of organic manures like farmyard manure, vermicompost and poultry manure could be a key factor for achieving and maintaining high level of production in rice based cropping sequences. Therefore, an investigation was conducted to find out effect of organic nitrogen sources on yield, nutrient uptake and soil health under rice (*Oryza sativa*) based cropping sequence.

Based on a part of Ph D thesis of the first author submitted to BHU, Varanasi during 2010

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MATERIALS AND METHODS

A field experiment was conducted during 2005–06 and

Table 1 Agronomic practices followed in different crops

Season	Crops	Variety	Seed rate (kg/ha)	Spacing (cm)	Recommended dose of nitrogen (kg/ha)*
Rainy	Rice	HUBR 2-1	30	20 × 15	120
Winter	Potato	Kufri Badshah	2000	50 × 25	120
Winter	Pea	Early Apoorva	80	30 × 10	20
Winter	Maize	Pioneer hybrid (X 3342)	20	60 × 20	120
Winter	Rajmash	HUR 137	80	30 × 10	120
Summer	Onion	Agrifound light red	10	20 × 15	120
Summer	Cowpea	Tokito hybrid	10	50 × 20	20

*100% RDN through organic manures as 1/3 FYM + 1/3 poultry manure (PM) +1/3 vermicompost

2006–07 at Campus Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The soil was sandy clay loam in the texture with pH 7.4, moderately fertile, being low in organic carbon (0.50%), available nitrogen (185.5 kg/ha), sulphur (19.28 kg/ha) and zinc (0.47 ppm) and medium in available phosphorus (20.35 kg/ha), and potassium (210.32 kg/ha). The amount of total rainfall received during the period of investigation was 721.5 mm, major part of which was received in August during experimentation. The maximum temperature of 44.1^0C during the experimentation was recorded in June whereas the lowest minimum temperature remained 7.4^0C in December. The average relative humidity ranged between 49.26 to 79.04% during experimentation. The maximum relative humidity was 92% in July and the minimum relative humidity remained 14% in April. The average duration of bright sunshine day during the course of investigation was 7.5 hours. The range of maximum and minimum mean weekly bright sunshine duration was 9.5 to 1.9 hours during the period of investigation. The experiment on rice based high value cropping sequences with 3 organic N nutrition treatments was laid out in split plot design with three replications. Seven rice based cropping sequences [rice-potato-onion; rice-green pea-onion; rice-potato-cowpea (green pod); rice-green pea – cowpea (green pod); rice-rajmash (green pod)- onion; rice-rajmash (green pod)-cowpea (green pod) and rice-maize (green cob)-cowpea (vegetable)] were assigned to main plots and three treatments comprising nitrogen application (control; organic manure; organic manure + biofertilizer) were allocated to sub plots. With a view to avoid the mixing of soil in different treatments, individual plots were thoroughly prepared by power tiller in each season. The organic manures were applied as per their nutrient content on oven dry weight basis. The farmyard manure, vermicompost and poultry manure contained 0.50, 2.30 and 2.80% N, 0.20, 0.75 and 2.20% P_2O_5 and 0.50, 1.23 and 1.30% K_2O, respectively. Cultivation practices were followed as per standard recommendation for each crop. Properly decomposed organic manures were applied at 15 days before sowing the crops. The seed was inoculated with biofertilizers (*Azotobacter* + PSB) and sown as per treatment. Various growth and yield parameters were observed at harvest following the standard procedure. Prevailing market prices of inputs as per treatments of each crop was considered for working out the cost of cultivation. For working out the rice grain equivalent yield and economics the market prices of grain of rice (₹ 1 078/q), potato (₹ 880/q), green pea (₹ 1 320/q), rajmash (₹ 1 540/q), maize (₹ 660/q), onion (₹ 880/q) and cowpea (₹ 1 760/q) were considered. Grains and stover/straw/haulm of all crops in sequence were analyzed for N, P and K concentration following standard procedures and the total uptake was calculated based on grain and stover/ straw/haulm yields of these crops. Soil samples up to the depth of 30 cm were collected after completion of one year crop cycle and analyzed for the organic carbon and available nitrogen, phosphorus and potassium contents as per the standard methods. Nutrients uptake (nitrogen, phosphorus potassium and sulphur) was estimated by multiplying the nutrient content with respective yields. Soil was analyzed at initial stage and after completion of the studies to monitor the changes in nutrient status due to different treatments.

RESULTS AND DISCUSSION

Rice

In organic nitrogen sources the application of 100% RDN through organic manure along with biofertilizers recorded the highest grain yield (44.25 q/ha) during the investigation (Table 2). This might be due to better availability of nutrients through superimposition of organic manure along with biofertilizers. *Azotobacter* produces growth promoting substances which improve seed germination and growth of extended root system. It also produces polysaccharides which improve soil aggregation (Gaur 2006), whereas PSB in the rhizosphere of rice will render insoluble soil phosphate available to plants due to production and secretion of organic acids by them. Finally, it may be concluded that the improvement in the yield attributes of rice due to combined use of organic sources along with biofertilizers might be due to release of sufficient amounts of N by mineralization at constant level, which in turn resulted in better crop growth and improvement in various yield components of rice.

Potato

The maximum potato equivalent yield (204.51 q/ha) during winter season was recorded under sequence [rice-potato-cowpea (green pod)] which was significantly higher than that of the other sequences followed by sequence (rice-potato-onion) which remained statistically at par among

Table 2 Influence of organic nitrogen sources on productivity (q/ha) and economics (₹/ha) of different cropping system (Pooled data of 2 years)

Treatment	Rainy	Winter	Summer	System	System economics		
	Rice grain yield (q/ha)	Potato equivalent yield (q/ha)	Onion equivalent yield (q/ha)	Rice grain equivalent yield (q/ha)	Cost of cultivation	Net return	B:C ratio
Cropping sequence							
Rice-Potato-Onion	39.50	196.19	191.19	355.73	119818	268656	2.13
Rice-Green pea-Onion	39.84	58.13	195.03	246.50	89453	182238	1.94
Rice-Potato-Cowpea	40.40	204.51	140.05	321.67	96958	251865	2.51
Rice- Green pea -Cowpea	40.55	52.73	135.04	193.83	66594	141338	2.03
Rice-Rajmash -Onion	41.52	120.98	193.32	298.09	95366	211247	2.04
Rice-Rajmash-Cowpea	41.63	117.81	137.66	250.18	72506	185233	2.39
Rice-Maize-Cowpea	41.85	104.21	140.03	241.23	72506	177885	2.35
SEm±	1.14	6.22	4.07	4.85	N A	1522	0.08
CD (P=0.05)	NS	19.18	12.57	14.95	N A	4690	0.24
Organic treatment							
Control*	34.58	62.60	67.82	141.11	73122	55927	0.78
100% RDN through OM**	43.44	141.45	201.30	323.19	94392	259531	2.75
100% RDN through OM+ Bif***	44.25	162.20	216.16	353.08	95286	292454	3.07
SEm±	0.53	2.76	2.09	2.80	N A	1044	0.05
CD (P=0.05)	1.53	8.01	6.05	8.12	N A	3024	0.14

*No application, **100% RDN through organic manures as 1/3 FYM + 1/3 poultry manure (PM) + 1/3 Vermicompost, ***100% RDN through organic manures as 1/3 FYM + 1/3 poultry manure (PM) + 1/3 Vermicompost + *Azotobacter* + PSB

themselves and significantly superior to others in this respect. It may be emphasized here that potato equivalent yield of crops is the function of market price along with yield of particular crop. The potato itself produced higher economic yield and this accompanied with better market value as a result of potato equivalent yield were higher as compared to other sequences. Among the manurial treatment, nitrogen application through organic manures along with biofertilizers brought about significant improvement in potato equivalent yield (162.20 q/ha) over rest of the treatments. Nitrogen application through organic manures alone significantly augmented the potato equivalent yield compared to that of control. Nitrogen application through organic manures significantly augmented the potato equivalent yield due to the continuous raising of organic potato bio-dynamically on the same site which improved tuber production by enrichment of soil fertility. Soil organic matter is known to serve as soil conditioner, nutrient source, substrate for microbial activity as well as it generated essential plant nutrients, organic matter decomposition produces legends capable of complexing nutrient elements. Complexed elements remain more available to plant roots because complexion shields them against immobilization in soils (Yadav and Kumar 2009).

Onion

The maximum onion equivalent yield (195.03 q/ha) was recorded under sequence [Rice-green pea-onion] which was significantly higher than that of the other sequences followed by sequence [rice-rajmash (green pod) - onion] and sequence (rice-potato-onion) which remained statistically at par among themselves and significantly superior to others in this respect. The onion itself produced higher economic yield due to inclusion of legume as previous crop and this accompanied with better market value as a result of onion equivalent yield were higher compared to other sequences. Application of nitrogen through organic manures along with biofertilizers brought about significant improvement in onion equivalent yield over rest of the treatments. Further nitrogen application through organic manures significantly augmented the onion equivalent yield. This is due to greater availability of nutrients in soil, improved soil physical condition and higher total uptake of nutrients because of better root penetration leading to better absorption of nutrients and moisture (Meena *et al.* 2010).

Rice grain equivalent yield (RGEY)

Different crop sequences differed significantly in respect of rice grain equivalent yield. The maximum rice grain equivalent yield (355.73 q/ha) was recorded under sequence rice-potato-onion which was significantly higher than that of the other sequences followed by sequence rice-potato-cowpea and sequence rice-rajmash-onion which remained statistically at par among themselves and significantly superior to others in this respect. Besides higher production potential of potato as well as onion and better market price were instrumental for attaining higher rice grain equivalent yield by this sequence (Yadav *et al*. 2005). Application of nitrogen through organic manures along with biofertilizers brought about significant improvement in rice grain equivalent yield over rest of the treatments. Rice grain equivalent yield is directly associated with the yield of respective crops in the sequence (Table 2) and so organic manure alone or along with biofertilizers enhanced the yield potential of crops which ultimately increased the rice equivalent yield of the sequence (Debjani *et al.* 2009).

Economics

Citation of pooled data of 2 years revealed that the maximum cost of cultivation (₹ 119 818/ha) and net return (₹ 268 656/ha) were recorded under system rice-potato-onion (Table 2) which was significantly higher than that of the other system followed by system rice-potato-cowpea and system rice-rajmash-onion which remained statistically at par among themselves and significantly superior to others in this respect. However, the benefit cost ratio was highest in the sequence rice-potato–cowpea (green pod). This was mainly due to higher production potential of potato accompanied with good monetary return from onion (Singh and Bohra 2009). Highest values of cost of cultivation (₹ 95 286/ha), net return (₹ 292 454/ha) and benefit cost ratio were recorded with the application of nitrogen through organic manures along with biofertilizers. This was mainly due to higher productivity without proportionate increase in cost of cultivation.

Nutrient uptake by system

It is clear from the citation of the pooled data of both the years of experimentation that nitrogen (387.67 kg/ha), phosphorus (64.01 kg/ha), potassium (157.50 kg/ha) and sulphur (39.41 kg/ha) uptake by the system was maximum under sequence rice- maize –cowpea which was significantly superior to rest of the sequences (Table 3). Nutrient uptake by different cropping sequence is the function of crop yield and nutrient content. The increase in these factors was responsible for the increased nutrient uptake during both the years of experimentation by the system because of higher productivity potential of maize ascribed to the increase in the available nitrogen, phosphorus, potassium and sulphur, contents in grain and straw resulting from the increased availability of nutrients through organic sources particularly through organic manure along with biofertilizers. Similar findings were reported by (Debjani *et al.* 2009).

Nitrogen, phosphorous, potassium and sulphur uptake, viz 321.59, 51.63, 129.93 and 36.85 kg/ha, respectively were highest under 100% RDN through organic manure along with biofertilizers which remained statistically at par with 100% RDN through organic manure and both were significantly superior over control (Table 3). The higher nutrient uptake with organic manure application might be attributed to solubilization of native nutrients, chelation of complex intermediate organic manure molecules produced

Table 3 Effect of different treatments on nitrogen, phosphorus, potassium and sulphur uptake by the system

Treatment	Nutrient uptake (kg/ha)				Available nutrient (kg/ha)			
	N	P	K	S	N	P	K	S
Cropping sequence								
Rice-Potato-Onion	183.10	32.30	141.86	26.63	185.79	19.94	205.13	18.86
Rice-Green pea-Onion	198.79	33.75	79.49	24.86	193.33	21.74	218.43	20.12
Rice-Potato-Cowpea	246.16	37.50	132.73	28.78	190.28	21.14	212.79	20.54
Rice- Green pea -Cowpea	251.60	36.66	67.22	24.41	192.58	21.58	216.62	20.80
Rice-Rajmash -Onion	219.17	37.68	84.32	28.48	191.11	20.98	212.79	20.15
Rice-Rajmash-Cowpea	276.31	42.23	70.64	29.34	192.75	22.01	220.48	20.38
Rice-Maize-Cowpea	387.67	64.01	157.50	39.41	189.14	21.80	210.87	20.29
SEm±	8.75	1.35	3.50	0.97	5.41	0.60	6.06	0.58
CD (P=0.05)	26.26	4.05	10.48	2.89	NS	NS	NS	NS
Organic Treatment								
Control*	141.15	22.97	65.58	16.05	177.23	19.70	201.35	18.16
100% RDN through OM**	292.74	47.17	118.96	33.63	196.98	22.06	219.46	21.07
100% RDN through OM+ Bif***	321.59	51.63	129.93	36.85	197.92	22.17	220.81	21.26
SEm±	4.10	0.65	1.61	0.45	2.48	0.28	2.77	0.26
CD (P=0.05)	11.80	1.90	4.64	1.30	7.13	0.80	7.98	0.76
				Initial	185.50	20.35	210.32	19.28

*No application, **100% RDN through organic manures as 1/3 FYM + 1/3 poultry manure (PM) + 1/3 vermicompost, ***100% RDN through organic manures as 1/3 FYM + 1/3 poultry manure (PM) + 1/3 vermicompost + *Azotobacter* + PSB

Table 4 Effect of organic nitrogen sources on soil health of rice based cropping system

Treatment	Physical properties		Chemical properties			Microbial population		
	Bulk density (g/cc)	Porosity (%)	Organic Carbon (%)	Soil pH	Soil EC (dS /m)	Bacteria ($\times 10^5$)	Actino-mycetes ($\times 10^4$)	Fungi ($\times 10^3$)
Cropping sequence								
Rice-Potato-Onion	1.37	35.33	0.51	7.28	0.34	59.18	31.48	30.18
Rice-Green pea-Onion	1.39	35.09	0.52	7.29	0.33	59.76	31.31	28.10
Rice-Potato-Cowpea	1.34	35.25	0.52	7.23	0.34	59.60	31.46	28.33
Rice- Green pea -Cowpea	1.30	35.39	0.53	7.17	0.33	60.16	31.33	29.83
Rice-Rajmash -Onion	1.34	34.99	0.52	7.27	0.34	58.14	31.18	28.07
Rice-Rajmash-Cowpea	1.34	35.28	0.53	7.26	0.34	59.98	31.00	27.56
Rice-Maize-Cowpea	1.31	35.25	0.51	7.28	0.34	59.85	30.78	24.98
SEm±	0.17	1.39	0.02	0.04	0.03	1.72	0.90	0.83
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Organic treatment								
Control*	1.47	34.18	0.48	7.42	0.37	37.56	19.97	18.53
100% RDN through OM**	1.27	35.63	0.54	7.18	0.32	63.14	33.76	30.71
100% RDN through OM+ Bio***	1.29	35.86	0.54	7.17	0.31	77.88	40.02	35.13
SEm±	0.04	0.49	0.01	0.02	0.02	0.84	0.44	0.39
CD (P=0.05)	0.11	1.43	0.02	0.06	0.05	2.42	1.25	1.13
Initial value	1.44	36.38	0.50	7.4	0.35	46.10	24.37	25.19

*No application, **100% RDN through organic manures as 1/3 FYM + 1/3 poultry manure (PM) + 1/3 vermicompost; ***100% RDN through organic manures as 1/3 FYM + 1/3 poultry manure (PM) + 1/3 vermicompost + *Azotobacter* + PSB

during decomposition of added organic manures, their mobilization and accumulation of different nutrients in different plant parts. Further application of biofertilizers facilitate in increasing the availability of nitrogen and phosphorus in soil which enhanced their uptake compared to non-biofertilizers treatment.

Soil health

Different cropping system did not differ significantly with respect to soil physical, chemical and biological properties (Table 4). However, maximum improvement in this respect was observed where pulse crops were incorporated in the sequence. Application of organic manure along with biofertilizers significantly improved the physical properties of soil during investigation. Maximum decrease in bulk density an increase in porosity were recorded with application of organic manure along with biofertilizers over the initial value due to addition of large amount of bulky organic manure in the field. *Azotobacter* also produced organic compound like polysaccharides which improved soil aggregation (Gaur 2006). These parameters were indicator of a healthy soil and play important role by improving their physical environment of rhizosphere of plant for sustainable production over a longer period.

Soil pH and electrical conductivity declined over initial value during investigation after the end of experiments due to organic compounds added to the soil in form of organic manure and biofertilizers which produced more humus and organic acids on decomposition. Application of either organic manure alone or with biofertilizers significantly improved soil status related to organic carbon and nutrient under study and the highest value was associated with the application of organic manure along with biofertilizers.

At the end of 2-year cycle, the organic carbon and available nitrogen, phosphorus, potassium and secondary nutrient sulphur content of the experimental soil was found to increase over the initial value in all the manurial treatment. Continuous application of organic manures in sufficient quantities have been reported by Tiwari *et al*. (2002) to improve the soil organic carbon in soil, thereby sustaining the soil health. Increase in available nitrogen may be attributed to higher microbial activity in the manurial treatments which favoured the conversion of the organically bound nitrogen to inorganic form. Similar increase in available nitrogen in soil due to addition of organics was observed in rice (Singh *et al*. 2006). The soil available phosphorus was either maintained or slightly improved due to addition of different organic manure over the initial soil value. The organic manures, on decomposition and phosphate solubilizing bacteria (PSB), solubilize insoluble organic P fractions through release of various organic acids thus resulting into a significant improvement in available P status in soil (Laxminarayana and Patiram 2006). The available potassium content in soil was also found to increase in all the manurial treatment as compared to the initial potassium status. This increase in available potassium content in soil due to addition of organic manures might be attributed to the direct addition of potassium in the available K pool in soil and release of K due to interaction of organic matter with clay (Das *et al*. 2004). The available sulphur content of soil after the end of experiment was also improved over its initial value under manurial treatment over control.

Soil biological properties showed significant improvement in the soil microbial counts over its initial values at the end of 2-year of investigation due to supplementation of organic sources along with biofertilizers. 100% recommended dose nitrogen through organic manure along with biofertilizers was recorded best which lead into higher counts of bacteria (77.88×10^5), actinomycetes (40.02×10^4) and fungi (35.13×10^3), closely followed by the 100% recommended dose nitrogen through organic manure alone. The control treatment had relatively lower values of soil microbial count than the organic treatments. The favourable effect of organics on soil biological properties is a proven fact which helped in providing ideal conditions and presumably increased the microbial activity because of the available high organic matter. Shanmei *et al*. (2002) also reported favourable effect of organic manures on soil biological properties.

On the basis of yield economic and soil health of two years pooled data it is concluded that application of organic manure 100 % recommended dose of nitrogen through organic sources on nitrogen basis along with biofertilizers (*Azotobacter* and PSB) proved optimum for achieving long term goal of sustainable production under rice- potato- onion cropping system.

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