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Research Paper

Effect of organic nutrient sources on yield, nutrient uptake and soil biological properties of rice (*Oryza sativa*)-based cropping sequence

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ABSTRACT

A field experiment was carried out at Varanasi for two years (2005–2007) to study the effect of organic nutrient sources on yield, nutrient uptake and soil properties of rice (*Oryza sativa* L.) based cropping sequence. Seven rice–based cropping sequences *viz.* rice–potato (*Solanum tuberosum* L.)–onion (*Allium cepa* L.); rice–green pea (*Pisum sativum* var. *hortense*)–onion; rice–potato–cowpea (*Vigna unguiculata* subsp. *sesquipedalis*); rice–green pea–cowpea; rice–rajmash (*Phaseolus vulgaris* L.)–onion; rice–rajmash–cowpea and rice–maize (*Zea mays* L.)–cowpea were assigned to main plots and three treatments of nitrogen application *viz.* control; organic manure; organic manure + biofertilizer were allotted to sub plots. Highest rice equivalent yield (35.57 t/ha), monetary net returns (₹ 268.7×10^3/ha), production efficiency (96.81 and 98.11 kg/ha/day) and irrigation efficiency (504.8 and 511.6 kg/ha-cm) were found under rice–potato–onion cropping sequence. Among the organic treatments, the highest rice equivalent yield (35.3 t/ha), production efficiency (95.7 and 97.8 kg/ha/day), irrigation efficiency (515.7 and 527.4 kg/ha-cm) and soil biological indictors like dehydrogenase activities, urease activities, soil microbial biomass carbon and soil microbial biomass nitrogen were obtained under organic nutrient management combined with biofertilizers.

Key words: Biofertilizers, Cropping systems, Nutrient uptake, Organic manure, Soil health,

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 its place in food market in developed and developing countries (Urkurkar *et al.*, 2010). Scientists and policy-planners are, therefore, reassessing agricultural practices, which relied more on biological inputs rather than heavy usage of chemical fertilizers and pesticides. *Yadav et al*. (2013) reported that the organic production systems maintain and improve the soil health through stimulating the activity of soil organisms. *Azotobacter* naturally fixes atmospheric nitrogen in the rhizosphere, while the use of phosphate solubilizing bacteria (PSB) helpful in increasing the availability of fixed phosphorus in soil (Gaur 2006). Soil microorganisms are reliable indicators of soil quality as they respond quickly to land management practices. Soil biological properties have been extensively used as sensors in studies on influence of soil treatment on soil fertility (Gil-Sotres *et al*., 2005). Monitoring changes in various soil biological properties offers a promise for better understanding of nutrient availability and soil quality (Bending *et al*., 2004). 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. Hence N is the element to be first trust in sense of organic farming (Magar, 2004). Therefore, an investigation was under taken to study the effect of organic nutrient sources on yield, nutrient uptake and soil properties of rice based cropping sequence.

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MATERIALS AND METHODS

A field experiment was conducted during 2005–06 and 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%) and available nitrogen (185.5 kg/ha), and medium in available phosphorus (20.35 kg/ha), and potassium (210.32 kg/ha). The amount of average rainfall received during the period of investigation was 721.5 mm, major part of which was received in the month of August. 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 (green pod)] were assigned to main plots and three treatments comprising nitrogen application (control; organic manure; organic manure + bio–fertilizer) were allocated to sub plots. Gross plot size was taken as 6×3 mtr, whereas net plot size as per crops. 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 recommendations for each crop. The seed was inoculated with biofertilizers (*Azotobacter* + PSB) and sown as per treatment. Various 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 (₹10,780/t), potato (₹8,800/t), green pea (₹13,200/t), rajmash (₹15,400/t), maize (₹6,600/t), onion (₹8,800/t) and cowpea (₹17,600/t) 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. Nutrients uptake (nitrogen, phosphorus potassium and sulphur) was estimated by multiplying the nutrient content with respective yields. Surface soil samples (0–30 cm) were collected from individual plots after the harvesting of crops in both the years. The field moist soil samples were stored in plastic bags at 4°C in deep fridge. Soil dehydrogenase activity was determined by reduction of 2,3,5 triphenyl tetrazolium chloride to triphenyl formazan (TPF) by the methods of Tabatabai (1994) and soil urease activity by estimating urea hydrolysis in soils during incubation of soil with urea solution at 37^0C as described by Bremner and Douglas (1971). Soil microbial biomass carbon (SMBC) and Soil microbial biomass nitrogen (SMBN) in soil samples was estimated following chloroform fumigation extraction procedure as described by Jenkinson and Powlson (1976) using Kc value of 0.45 for SMBC (Vance *et al.*, 1987) and KN value of 0.54 for SMBN (Brookes *et al.,* 1985). Soil was analyzed at initial stage and after completion of each year cropping cycle to monitor the changes in soil properties due to different treatments.

RESULTS AND DISCUSSION

Crop productivity

Rice productivity did not differ significantly due to cropping sequence. However, application of 100% RDN through organic manure along with biofertilizers recorded the highest grain yield (4.43 t/ha) during the investigation (Table 2). This might be due to better availability of nutrients through organic manure along with biofertilizers. The maximum potato yield (20.45 t/ha) was recorded under rice–potato–cowpea sequence, which was higher than the rice–potato–onion sequence. Among the organic treatment, nitrogen application through organic manures along with biofertilizers brought about highest improvement in productivity of winter season crops *viz*., potato (27.3 t/ha), green pea (4.9 t/ha), rajmash (8.7 t/ha) and maize (16.0 t/ha) over rest of the treatments. The maximum onion yield (19.50 t/ha) was recorded under rice–green pea–onion sequence, which was slightly higher than that of the other sequences followed by the rice–rajmash–onion and rice–

Table 1. Agronomic practices followed in different crops.

Season	Crops	Variety	Seed rate (kg/ha)	Spacing (cm)	Nutrient*		
					N	P_2O_5	K_2O
Rainy	Rice	'HUBR 2–1'	30	20 × 15	120	60	80
Winter	Potato	'Kufri Badshah'	2000	50 × 25	120	60	80
Winter	Pea	'Early Apoorva'	80	30 × 10	20	10	13
Winter	Maize	'Pioneer hybrid (× 3,342)'	20	60 × 20	120	60	80
Winter	Rajmash	'HUR 137'	80	30 × 10	120	60	80
Summer	Onion	'Agrifound light red'	10	20 × 15	120	60	80
Summer	Cowpea	'Tokito hybrid'	10	50 × 20	20	10	13

*Nutrient applied on the basis of recommended dose of nitrogen (kg/ha).

potato–onion sequence due to inclusion of legume as previous crop compared to other sequences. Application of 100% recommended dose of nitrogen through organic manures along with biofertilizers recorded highest individual productivity *viz.,* onion (26.0 t/ha) and cow pea (8.9 t/ha) over rest of the treatments.

Nitrogen application through organic manures significantly augmented the crop productivity due to the continuous raising of organic crop 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). This might be due to greater availability of nutrients in soil, improved soil physical conditions and higher total uptake of nutrients because of better root penetration leading to better absorption of nutrients and moisture (Meena *et al.,* 2010). *Azotobacter* produces growth promoting substances (polysaccharides) which improve seed germination and growth of extended root system through improvement in soil aggregation, whereas PSB in the rhizosphere of crops will render insoluble soil phosphate available to plants due to production and secretion of organic acids by them (Gaur, 2006).

Rice grain equivalent yield (RGEY)

The maximum rice grain equivalent yield (35.57 t/ha) was recorded under rice–potato–onion sequence which was significantly higher than that of the other sequences followed by rice–potato–cowpea and rice–rajmash–onion, which remained statistically at par among themselves and significantly superior to others. Beside 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 system. (Debjani *et al.,* 2009)

Economics

Maximum cost of cultivation (₹19,818/ha) and net returns (₹2,68,656/ha) were recorded under system of rice–potato–onion (Table 2), which was significantly higher than that of the other system followed by system of rice–potato–cowpea and rice–rajmash–onion, which remained statistically at par among themselves and significantly superior to others. However, the benefit cost ratio was highest in the sequence rice–potato–cowpea. This was mainly

Table 2. Effect of organic nutrient and cropping system on yield of component crops and rice equivalent yield of system cost of cultivation and net returns and benefit: cost ratio (Pooled data over two years).

Treatment	Rice yield (t/ha)	Yield of potato/green pea/rajmash/maize (t/ha)				Yield of onion/cowpea (t/ha)		Rice grain equivalent yield (t/ha)	Cost of cultivation (×10^3₹/ha)	Net returns (×10^3₹/ha)	B:C ratio
Cropping sequence											
Rice–potato–onion	3.95	19.62				19.12		35.57	119.8	268.7	2.13
Rice–green pea–onion	3.98	3.88				19.50		24.65	89.5	182.2	1.94
Rice–potato–cowpea	4.04	20.45				7.00		32.17	97.0	251.9	2.51
Rice–green pea–cowpea	4.06	3.52				6.75		19.38	66.6	141.3	2.03
Rice–rajmash–onion	4.15	6.91				19.33		29.81	95.4	211.2	2.04
Rice–rajmash–cowpea	4.16	6.73				6.88		25.02	72.5	185.2	2.39
Rice–maize–cowpea	4.19	13.89				7.00		24.12	72.5	177.9	2.35
SEm±	0.11							0.49		1.5	0.08
CD (P=0.05)	NS							1.50		4.7	0.24
Organic treatment		Potato	Green pea	Rajmash	Maize	Onion	Cowpea				
Control	3.46	9.2	1.8	3.6	10.1	6.6	3.4	14.1	73.1	55.9	0.8
100% RDN through organic manure	4.34	23.2	4.2	7.9	14.9	24.8	8.1	32.3	94.4	259.5	2.8
100% RDN through organic manure + biofertilizers	4.43	27.3	4.9	8.7	16.0	26.0	8.9	35.3	95.3	292.5	3.1
SEm±	0.05							0.3		1.0	0.05
CD (P=0.05)	0.15							0.8		3.0	0.14

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 returns (₹2,92,454/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

Maximum uptake of nitrogen, phosphorus, potassium and sulphur were noticed by the rice–maize–cowpea and it 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 results are in conformity with the findings of Debjani *et al.* (2009). Among organic treatment, the highest N, P, K and S uptake were recorded under 100% RDN through organic manure along with biofertilizers and these were at par with 100% RDN through organic manure (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 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 with compare to non biofertilizers treatment. The results are in conformity with the findings of Kumar *et al*. (2011) and Raghav and Kamal (2008).

System efficiency parameters

Citation of data revealed that rice–potato–onion cropping system recorded the highest production efficiency (96.81 and 98.11 kg/ha/day), labour employment generation (454 and 484 mandays/ha/year) and irrigation efficiency (504.8 and 511.6 kg/ha-cm) followed by rice–potato-cowpea cropping system. The maximum production and irrigation efficiency were associated with higher production potential of potato and onion due to highest moisture content of their fresh produce (Singh and Bohra, 2009). Among the organic treatment, application of 100 % recommended dose of nitrogen through organic manures along with biofertilizers recorded significantly higher production efficiency (95.7 and 97.8 kg/ha/day), employment generation (404 and 434 mandays/ha/year) and irrigation efficiency (515.7 and 527.4 kg/ha-cm) followed by 100% RDN through organic manure alone over control. Consequently, increased in system efficiency through application of organic manures, enhancing the nutrient availability in soil by improving their fertility status (might be favorable improvement in soil physical, chemical and biological properties) responsible for augmentation of crop productivity as well as efficiency of system. This was mainly due to higher productivity through biofertilizers without proportionate increase in cost of cultivation.

Soil biological properties

Different cropping systems did not differ significantly

Table 3. Effect of organic nutrient and cropping system on nitrogen, phosphorus, potassium and sulphur uptake

Treatment	Nutrient uptake (kg/ha)							
	Nitrogen		Phosphorus		Potassium		Sulphur	
	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07
Cropping sequence								
Rice–potato–onion	180.7	185.5	31.9	32.7	139.9	143.8	26.3	27.0
Rice–green pea–onion	194.9	202.7	33.1	34.4	78.8	80.2	24.4	25.3
Rice–potato–cowpea	240.3	252.0	36.7	38.3	131.0	134.5	28.1	29.5
Rice–green pea–cowpea	244.0	259.2	35.6	37.7	66.5	68.0	23.7	25.1
Rice–rajmash–onion	214.1	224.2	36.7	38.6	83.3	85.4	27.7	29.2
Rice–rajmash–cowpea	267.8	284.8	40.9	43.5	69.7	71.5	28.5	30.2
Rice–maize–cowpea	403.5	371.9	68.0	60.0	179.9	135.1	41.9	37.0
SEm±	8.6	9.0	1.3	1.4	3.5	3.5	1.0	1.0
CD (P=0.05)	25.8	26.8	4.0	4.2	10.5	10.5	2.9	3.0
Organic treatment								
Control	142.7	139.6	23.3	22.6	67.9	63.3	16.3	15.8
100% RDN through organic manure	288.9	296.6	46.8	47.5	121.2	116.8	33.3	33.9
100% RDN through organic manure + biofertilizers	316.4	326.8	51.1	52.2	131.9	127.9	36.4	37.3
SEm±	4.1	4.1	0.7	0.7	1.7	1.5	0.5	0.5
CD (P=0.05)	11.8	11.8	1.9	1.9	5.0	4.4	1.3	1.3

with respect to biological properties (Table 5). However, maximum improvement in this respect was observed, where pulse crops were incorporated in the sequence. Among organic treatment, soil biological properties at the end of experiment during each year was influenced by nutrient management through organic sources (Table 5). Application of 100% recommended dose of nitrogen through organic manure in combination with biofertilizers noticed the highest improvement in biological properties of soil *viz.*, dehydrogenase activities (337.1 and 353.6 µg TPF 24/h/g soil), urease activities (8.5 and 8.9 mg urea/g soil 24/h), soil microbial biomass carbon (437and 449(µg/g soil) and soil microbial biomass nitrogen (48.5 and 50.0 µg/g soil). Soil biological properties showed significant improvement regarding enzymatic activities, SMBC and SMBN over its initial values at the end of 2 years investigation, due to supplementation of organic sources along with biofertilizers. Dehydrogenase activity is known to

Table 4. Effect of cropping sequence and organic treatment on production efficiency, employment generation and irrigation efficiency based on rice grain equivalent yield.

Treatment	System efficiency					
	Production efficiency (kg/ha/day)		Employment generation (mandays/ha/year)		Irrigation efficiency (kg/ha–cm)	
	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07
Cropping sequence						
Rice–potato–onion	96.8	98.1	454	484	504.8	511.6
Rice–green pea–onion	67.0	68.0	422	456	394.7	400.5
Rice–potato–cowpea	87.5	88.8	382	420	456.2	462.8
Rice– green pea–cowpea	52.5	53.7	361	383	309.3	315.9
Rice–rajmash–onion	80.9	82.4	432	458	422.2	429.5
Rice–rajmash–cowpea	67.8	69.3	366	388	353.3	361.5
Rice–maize–cowpea	65.4	66.8	344	374	340.8	348.4
SEm±	1.2	1.4				
CD (P=0.05)	3.9	4.3				
Organic treatment						
Control	38.6	38.7	375	405	208.1	208.7
100% RDN through organic manure	87.7	89.4	403	433	473.0	481.8
100% RDN through organic manure + biofertilizers	95.6	97.8	404	434	515.7	527.4
SEm±	0.8	0.8				
CD (P=0.05)	2.3	2.2				

Table 5. Effect of organic nitrogen sources on soil biological properties of rice based cropping system.

Treatment	Dehydrogenase activities (µg TPF/24h/g soil)		Urease activities (mg urea/g soil/24h)		SMBC(µg/g soil)		SMBN(µg/g soil)	
	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07
Cropping sequence								
Rice–potato–onion	262.4	274.2	6.8	7.3	361.4	374.2	39.8	41.1
Rice–green pea–onion	258.6	265.0	6.8	7.0	359.7	365.0	39.8	39.9
Rice–potato–cowpea	257.0	263.2	6.7	7.0	357.0	363.2	38.7	39.6
Rice–green pea–cowpea	260.4	268.1	6.8	7.0	357.0	363.6	39.3	39.6
Rice–rajmash–onion	257.3	265.0	6.7	6.7	357.3	352.7	38.8	38.0
Rice–rajmash–cowpea	257.0	264.2	6.8	6.9	361.2	362.0	39.4	39.4
Rice–maize–cowpea	259.6	265.4	6.8	7.2	359.6	371.9	39.3	41.0
SEm±	5.1	6.2	0.1	0.2	5.4	6.1	0.8	0.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Organic treatment								
Control	108.4	105.6	3.6	3.5	208.4	204.5	21.8	20.9
100% RDN through organic manure	331.2	340.2	8.3	8.7	431.7	439.6	47.6	48.5
100% RDN through organic manure + biofertilizers*	337.1	353.6	8.5	8.9	437.0	449.9	48.5	50.0
SEm±	2.4	3.6	0.1	0.1	2.6	3.9	0.4	0.6
CD (P=0.05)	7.0	10.4	0.2	0.3	7.6	11.2	1.2	1.7

have strong correlation with soil organic carbon content and thus addition of organic manure resulted in more soil dehydrogenase activity in the study (Madejon *et al*., 2007). Similarly, Liu *et al*. (2010) working on long term effects of fertilizer and organic manure treatments also proved that there was greater increase in urease activity, when organic manure was applied. The Soil microbial biomass carbon was found to increase over initial values due to application of organic materials input through manures provides organic substrates to the soil, which stimulated the microbial growth and activity (Kanchikerimath and Singh, 2001). The highest soil microbial biomass nitrogen was obtained in plot receiving 100% recommended dose of nitrogen through organic manure in combination with biofertilizers during both the years. The availability of carbonaceous materials and substrates such as sugars, amino acids and organic acids to the soil from the organic sources is responsible for supplying maintenance energy for microbial populations (Manna *et al*., 2006), which in turn increased the SMBN.

It was concluded that application of organic manure at 100% recommended dose of nitrogen through organic sources with biofertilizers (*Azotobacter* and PSB) proved optimum for higher productivity, profitability and better soil health. Among different cropping sequences rice–potato–onion gave the highest system productivity and returns.

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