

Effect of organic nitrogen sources and biofertilizers on production potential and energy budgeting of rice (*Oryza sativa*)-based cropping systems

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ABSTRACT

A field experiment was conducted during 2005–06 and 2006–07 at Varanasi, Uttar Pradesh, to find out the effect of organic nitrogen sources and biofertilizers on system productivity and energy budgeting of rice (*Oryza sativa* L.)-based cropping system. Rice–potato [*Solanum tuberosum* (L.)]–onion [*Allium cepa* (L.)] system recorded significantly higher production efficiency (97.5 kg/ha/day), land-utilization efficiency (91.4%), economic efficiency (₹738/ha/day), energy input (61.08×10^3 MJ/ha) and energy output (187.09×10^3 MJ/ha). The lowest (39.4×10^3 MJ/ha) energy intensiveness was recorded in rice–table pea (*Pisum sativum* var. *hortense*)–cowpea [*Vigna unguiculata* (L.) Walp.] cropping system. However, the organic nutrition with biofertilizers (*Azotobacter* and phosphate-solubilizing bacteria) had the highest rice-equivalent grain yield (35.3 t/ha), production efficiency (96.7 kg/ha/day), land utilization efficiency (89.8%), economic efficiency (803 ha/day) and energy-use efficiency (3.15) of system, followed by organic nitrogen sources alone (3.0). Recommended dose of N @ 100% through organic nitrogen sources alone was the next best treatment resulting in higher productivity and system efficiency. Rice–potato–onion cropping system was found most productive, profitable and energy efficient with application of 100% recommended dose of nitrogen through organic sources along with biofertilizers.

Key word : Biofertilizers, Crop production, Energy, Rice-based cropping systems, Organic N sources

In India agriculture not only provides food for all, but also gives employment to 50% of the total workforce. The production systems developed and adopted during green revolution were explorative and natural resources like soil and water were subjected to immense pressure beyond carrying capacity. This has led to degradation of not only crop system but also the life-supporting system as a whole Mahapatra *et al.* (2012). Generally, Indian soils are poor in organic carbon due to tropical climate. Moreover, continuous imbalanced use of fertilizers also deteriorates the soil health. This situation warrants opting to organic nutrient management for sustaining productivity of cropping system. Ultimately, energy productivity is decreasing as a consequence of escalating of inputs cost without propor-

tionate improvement in output of particular crops. The organic sources of nutrient management offer most potential measures to minimize the dependency on non-renewable energy leading to increased share of renewable energy, which will pave the way for sustainability. Organic manure influence soil productivity through correction of deficiency of secondary and micro-nutrient and their effect on soil physical, chemical and biological properties. Biofertilizers, on the other hand are cost-effective and renewable source of plant nutrients to supplement the parts of chemical fertilizers. Keeping these points in view, an investigation was undertaken to study the effect of organic nitrogen sources and biofertilizers on production potential and energy budgeting of rice-based cropping sequence.

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 (25°18' N and 83°3' E and 129.93 m above mean sea-level). The soil was sandy clay loam with pH 7.4, moderately fertile, being low in organic carbon (0.45%), available nitrogen (185 kg/ha), and medium in available P (19.27 kg/ha) and

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K (208.4 kg/ha). The amount of total rainfall received during the period of investigation was 721.5 mm, major part of which was received in the month of August during experimentation. The maximum temperature of 44.1°C during the experimentation was recorded in June, whereas the lowest temperature remained at 7.4°C in December. The highest 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 cropping systems with organic N nutrition treatments was laid out in split-plot design with 3 replications. Seven rice-based cropping sequences 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–rajma (*Phaseolus vulgaris* L.)–onion; rice–rajma–cowpea and rice–maize (*Zea mays* L.)–cowpea were assigned to main plots and three treatments, viz. control (no application of any source of nutrients), recommended dose of nitrogen (RDN) through organic manure ($\frac{1}{3}$ farmyard manure + $\frac{1}{3}$ vermicompost + $\frac{1}{3}$ poultry manure) alone and RDN through organic manure [$(\frac{1}{3}$ FYM + $\frac{1}{3}$ vermicompost + $\frac{1}{3}$ poultry manure) along with biofertilizer (*Azotobacter* + phosphate-solubilizing bacteria)] were allocated to sub plots.

To avoid the mixing of manure and soil in different treatments, individual plots were thoroughly prepared by power tiller in each season. The farmyard manure, vermicompost and poultry manure contained viz. 0.50, 2.30 and 2.80% N; 0.09, 0.33 and 0.98% P and 0.42, 1.03 and 1.08% K respectively. Cultivation practices were followed as per standard recommendation for each crop. Variety ‘HUBR 2-1’ of rice, ‘Kufri Badshah’ of potato, ‘Early Apoorva’ of green pea, ‘Pioneer Hybrid (× 3342)’ of maize, ‘HUR 137’ of rajma ‘Agrifound Light Red’ of onion and ‘Tokito Hybrid’ of cowpea were used in this experiment. Properly decomposed organic manures were applied 15 days before sowing the crops. The seed was inoculated with biofertilizers (*Azotobacter* + phosphate-solubilizing bacteria) and sown as per treatment. Rice grain equivalent yield and economics were calculated considering the prevailing market prices: rice grain (10,780/t), potato (8,800/t), green pea (13,200/t), rajma (15,400/t), maize (6,600/t), onion (8,800/t) and cowpea (17,600/t). The system productivity was calculated by dividing the total rice-equivalent yield of the system by 365. Profitability in /ha/day was worked out by dividing the average net return over years by 365. The various practices involved in

crop production and economic yield of component crops in the systems were converted into equivalent value of chemical energy (MJ/ha) for these conversions, standard values as given by Sriram *et al.* (1999) were used.

RESULTS AND DISCUSSION

Crops and system productivity

Productivity of rice did not differ significantly among different cropping systems; however, higher yield was observed in the system where legumes were included. Application of 100% recommended dose of nitrogen (RDN) through manure + biofertilizers recorded the highest productivity of rice (4.43t/ha) followed by organic manure alone (4.34 t/ha) (Table 1). Rice productivity was increased by 28% due to application of RDN through organic manure along with biofertilizers over control. Similarly, 100% RDN through organic manure alone enhanced the productivity of rice by 25.6% over the control. This might be owing to better availability of nutrients from organic manure. These results are in conformity with the findings of Gaur (2006). Further improvement in the yield of rice owing to combined use of organic manure along with biofertilizers might be because of sufficient release of N by mineralization at a desired rate, which resulted in better crop growth and improvement in various yield components of rice Babu *et al.* (2002); Chettri *et al.* (2002).

The maximum potato-equivalent yield (PEY) during winter season was recorded under system rice–potato–cowpea, which was significantly more than other cropping systems except rice–potato–onion. It may be pointed out that potato equivalent yield of crops is a function of market price and the yield of particular crop. The potato gave higher economic yield and this accompanied with better market price resulted in higher PEY. Prasad *et al.* (2011) also observed higher productivity of rice–potato–cowpea sequence over others. Among the manurial treatments, nitrogen application through organic manures alone or along with bio-fertilizers significantly improved PEY over the control. Enhancement in PEY was about 159% higher with application of nitrogen through organic manure along with biofertilizers compared with organic manure alone (126%) over the control. More than 33% increase in PEY of the winter season crop was recorded with biofertilizers. Increase in PEY might be owing to the continuous raising of organic potato bio-dynamically on the same site, which improved tuber production by enrichment of soil fertility.

The highest onion equivalent yield was recorded under rice–green pea–onion system, being significantly higher than that under all the other cropping systems and was followed by rice–rajma–onion and rice–potato–onion systems, which were statistically at par and significantly superior to the other cropping systems. The onion itself gave

higher economic yield with the inclusion of pea (a legume) as the preceding crop and this accompanied with better market value resulted in higher onion-equivalent yield compared with other cropping systems. Onion-equivalent yield of summer season crops was increased by about 219% with application of 100% RDN through organic manures along with biofertilizers, followed by 197% through organic manures without biofertilizers over the control. Therefore, about 21.9% improvement in productivity was recorded with the application of biofertilizers. Both the organic treatments along with biofertilizers or without biofertilizers brought about significant improvement in onion-equivalent yield over the control. This was owing 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).

The maximum rice grain equivalent yield was recorded under rice-potato-onion system, followed by rice-potato-cowpea and rice-rajma-onion systems, 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 these systems Yadav *et al.* (2005). Application of nitrogen through organic manures along with biofertilizers brought about significant improvement in rice-grain equivalent yield (35.31 t/ha) over the remaining treatments. Rice-grain equivalent yield is directly associated with the yield of respective crops in the systems

(Table 1) and so organic manure alone or along with biofertilizers enhanced the yield potential of crops which ultimately increased the rice-equivalent yield of the systems Debjani *et al.* (2009).

System efficiency indicators and net returns

Pooled data on system efficiency indicators as affected by different cropping systems revealed that rice-potato-onion cropping system recorded significantly maximum production efficiency, land-use efficiency economic efficiency and net return over rest of the treatments (Table 2). However, next highest production efficiency, land-use efficiency, economic efficiency and net returns were observed under rice-potato-cowpea cropping system. The maximum production, economic efficiency and net return were associated with higher production potential of potato and onion owing to the highest moisture content of their fresh produce (Singh and Bohra, 2009). The highest land-use efficiency was owing to higher duration occupied by the onion from nursery to maturity compared to the other crop in the system. Sharma *et al.* (2004) also observed higher production potential of potato accompanied with good monetary return from onion.

Among the organic treatment, application of 100% RDN through organic manures along with biofertilizers recorded significantly higher production efficiency, land-use efficiency, economic efficiency and net returns of the system, followed by 100 % RDN through organic manure alone over the control (Table 2). Consequently, increased in system indicator through application of organic ma-

Table 1. Effect of cropping sequence and organic treatment on equivalent yield (EY) of crops and system during rainy, winter and summer seasons

Treatment	Rice grain yield (t/ha)		Potato EY of <i>rabi</i> crops (t/ha)		Onion EY of <i>zaid</i> crops (t/ha)		Rice equivalent yield of system (t/ha)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
<i>Cropping sequence</i>								
Rice-potato-onion	3.98	3.92	19.47	19.77	18.94	19.30	35.34	35.81
Rice-green pea-onion	3.99	3.97	5.73	5.90	19.35	19.66	24.47	24.83
Rice-potato-cowpea	4.07	4.01	20.32	20.58	13.81	14.20	31.93	32.40
Rice-green pea-cowpea	4.08	4.03	5.20	5.35	13.30	13.70	19.18	19.59
Rice-rajma-onion	4.16	4.14	11.94	12.26	19.17	19.49	29.56	30.06
Rice-rajma-cowpea	4.18	4.15	11.61	11.96	13.57	13.96	24.73	25.30
Rice-maize-cowpea	4.21	4.16	10.25	10.60	13.82	14.19	23.85	24.39
SEm±	0.12	0.11	0.63	0.62	0.41	0.41	0.47	0.51
CD (P=0.05)	NS	NS	1.94	1.92	1.26	1.26	1.43	1.57
<i>Organic treatment</i>								
Control	3.47	3.44	6.25	6.27	6.75	6.82	14.09	14.13
100% RDN through OM	4.37	4.32	13.99	14.30	19.90	20.36	32.02	32.62
100% RDN through OM+ Biof.	4.45	4.40	15.98	16.46	21.34	21.89	34.91	35.71
SEm±	0.05	0.05	0.28	0.27	0.20	0.22	0.29	0.28
CD (P=0.05)	0.16	0.15	0.82	0.79	0.57	0.64	0.84	0.80

nures, enhancing the nutrient availability in soil by improving their fertility status (might be favourable improvement in soil physical, chemical and biological properties) responsible for augmentation of crop productivity as well as efficiency of system. Similarly, enhancement in production efficiency, land-use efficiency, economic efficiency and net return were observed with the application of 100% RDN through organic manures along with biofertilizers over 100% RDN through organic manures (Table 2). This was mainly because of higher productivity through biofertilizers without proportionate increase in cost of cultivation.

Energy budgeting of system

In general, systems involving rice, winter crops or intensification by inclusion of summer crops resulted in higher energy input. Accordingly, the maximum energy input ($61.08 \times 10^3 \text{ MJ/ha}$) was recorded under rice–potato–onion systems. The other systems that recorded higher energy input in descending order were rice–potato–cowpea, rice–rajma–onion, rice–maize–cowpea, rice–green pea–onion, rice–rajma–cowpea and rice–green pea–cowpea systems. It is evident from the Table 2 that those systems having either potato or onion recorded higher energy because of intensive input on seed in potato and irrigation in onion attributed more energy compared to the other vegetable in winter and cowpea in summer respectively. Amongst various nitrogen substitutions, application of 100% RDN through organic manures along with biofertilizers recorded the maximum ($56.89 \times 10^3 \text{ MJ/ha}$) pooled energy input, followed by same dose of nitrogen

application through organic manure ($55.30 \times 10^3 \text{ MJ/ha}$) alone over the control ($34.99 \times 10^3 \text{ MJ/ha}$). Further, the data also revealed that energy consumption was higher through organic manure (100% RDN) with biofertilizers (62.59%), followed by without biofertilizers (58.05%) over the control treatment.

Pooled data pertaining to energy output and net energy return under different cropping systems revealed marked variation in energy output and net energy return of different cropping systems (Table 2). In general, energy output and net energy return of the system remained comparatively higher during the second year than that of the first year owing to improvement in system productivity during the second year because of the improvement in soil fertility. The maximum energy output ($187.1 \times 10^3 \text{ MJ/ha}$) and net energy return ($126.00 \times 10^3 \text{ MJ/ha}$) was recorded in rice–potato–onion system, and proved significantly superior to all the other systems except rice–potato–cowpea ($177.8 \times 10^3 \text{ MJ/ha}$ and $122.99 \times 10^3 \text{ MJ/ha}$) and rice–maize–cowpea ($165.0 \times 10^3 \text{ MJ/ha}$ and $117.1 \times 10^3 \text{ MJ/ha}$) systems, which were statistically at par among them. The energy output and net energy return, however, are dependent on grain as well as straw yields under different cropping systems and higher yields associated to register greater output and net energy return. Nevertheless, the lowest energy ($110.4 \times 10^3 \text{ MJ/ha}$) output and net energy return ($71.0 \times 10^3 \text{ MJ/ha}$) was found through rice–green pea–cowpea system during both the years. Application of recommended (100%) dose of nitrogen through organic manures along with biofertilizers recorded the maximum average energy output ($180.2 \times 10^3 \text{ MJ/ha}$) and net energy

Table 2. Effect of different cropping sequence and organic treatment on system efficiency, net returns and energy budgeting (pooled data of 2 years).

Treatment	Production efficiency (kg/ha/day)	Land use efficiency (%)	Economic efficiency (₹/ha/day)	Net returns ($\times 10^3$ ₹/ha)	Energy input ($\times 10^3$ MJ/ha)	Energy output ($\times 10^3$ MJ/ha)	Net energy returns ($\times 10^3$ MJ/ha)	Energy use efficiency
<i>Cropping sequence</i>								
Rice–potato–onion	97.5	91.4	738	268.7	61.1	187.1	126.0	3.06
Rice–green pea–onion	67.5	85.8	502	182.2	45.6	123.8	78.2	2.66
Rice–potato–cowpea	88.1	90.7	691	251.9	54.8	177.8	123.0	3.17
Rice–green pea–cowpea	53.1	83.3	387	141.3	39.4	110.4	71.0	2.77
Rice–rajma–onion	81.7	90.7	579	211.2	50.4	136.8	86.4	2.69
Rice–rajma–cowpea	68.5	89.5	507	185.2	44.2	124.4	80.2	2.80
Rice–maize–cowpea	66.09	85.4	487	177.9	47.9	165.0	117.12	3.46
SEm±	1.32	2.59	4	1.52	N A	7.20	7.02	0.15
CD (P=0.05)	4.09	7.98	13	4.69	N A	22.19	21.63	0.46
<i>Organic treatment</i>								
Control	38.7	86.4	154	55.9	35.0	92.2	57.2	2.64
100% RDN through OM	88.5	88.2	711	259.5	55.3	167.0	111.8	3.01
100% RDN through OM + BF	96.7	89.8	803	292.4	56.9	180.2	123.3	3.15
SEm±	0.77	0.40	2	1.04	N A	2.73	2.72	0.05
CD (P=0.05)	2.23	1.15	7	3.02	N A	7.91	7.89	0.15

Table 3. Effect of cropping system and organic treatment on fertility balance of soil

Treatment	Soil organic carbon (%)			Soil available nitrogen (kg/ha)			Soil available phosphorus (kg/ha)			Soil available potassium (kg/ha)		
	A	B	C	A	B	C	A	B	C	A	B	C
<i>Cropping sequence</i>												
Rice–potato–onion	0.50	0.51	0.01	185.5	185.8	0.3	20.4	19.9	-0.4	210.3	205.1	-5.2
Rice–green pea–onion	0.50	0.52	0.02	185.5	193.3	7.8	20.4	21.7	1.4	210.3	218.4	8.1
Rice–potato–cowpea	0.50	0.52	0.02	185.5	190.3	4.8	20.4	21.1	0.8	210.3	212.8	2.5
Rice–green pea–cowpea	0.50	0.53	0.03	185.5	192.6	7.1	20.4	21.6	1.2	210.3	216.6	6.3
Rice–rajma–onion	0.50	0.52	0.02	185.5	191.1	5.6	20.4	21.0	0.6	210.3	212.8	2.5
Rice–rajma–cowpea	0.50	0.53	0.03	185.5	192.8	7.3	20.4	22.0	1.7	210.3	220.5	10.2
Rice–maize–cowpea	0.50	0.51	0.01	185.5	189.1	3.6	20.4	21.8	1.5	210.3	210.9	0.6
<i>Organic treatment</i>												
Control	0.50	0.48	-0.02	185.5	177.2	-8.3	20.4	19.7	-0.7	210.3	201.4	-9.0
100% RDN through OM	0.50	0.54	0.04	185.5	197.0	11.5	20.4	22.1	1.7	210.3	219.5	9.1
100% RDN through OM + Biofertilizer	0.50	0.54	0.04	185.5	197.9	12.4	20.4	22.2	1.8	210.3	220.8	10.5

A, Initial available nutrient; B, Final value of available nutrient after harvest of crop; C, Actual gain/loss (B-A)

return ($123.3 \times 10^3 \text{ MJ/ha}$) followed by equal dose of nitrogen through organic manure ($167.0 \times 10^3 \text{ MJ/ha}$ and $111.8 \times 10^3 \text{ MJ/ha}$) alone. Both the manurial treatments were found significantly superior to the control.

In general, higher energy input resulted in lower energy-use efficiency while higher energy output is directly proportional to energy-use efficiency (ratio of energy output of total biomass and energy input). This result corroborates the findings of Billore *et al.* (1994). Analysis (Table 2) of the data revealed that among the various cropping systems, rice–maize–cowpea systems recorded significantly highest energy-use efficiency than the other systems during both the years except rice–potato–cowpea systems, which was statistically at par with each other. This was owing to higher stover yield of maize than that of other crops responsible for highest energy-use efficiency. However, among organic manure treatments, application of 100% recommended dose of nitrogen through organic manures along with biofertilizers recorded higher energy use efficiency about 4.65% and 19.32% over organic manure alone and control treatment, respectively, which was significantly superior to the control but at par with organic manure alone.

Soil fertility balance

Data pertaining to balance sheet of organic carbon and available NPK 2 years after experiment showed that all the cropping systems recorded marginal but positive increase in soil organic carbon, available N, P and K over the initial values except for a little negative balance for P and K under rice–potato–onion cropping system (Table 3). This was might be owing to nutrient mining from the same depth of soil because of shallow root system of potato and onion, as well as their high requirement of phosphorus and

potassium. Similar results were reported by Yadav *et al.* (2013a).

Application of either organic manure alone or with biofertilizers improved the soil status with respect to soil organic carbon and available NPK. This increase may be attributed to higher microbial activity in the manurial treatments which favoured the conversion of the organically bound nitrogen to inorganic form Yadav *et al.* (2013b) also reported similar increase in available nutrients in soil owing to addition of organic manure and biofertilizers.

It was concluded that rice–potato–onion cropping system was found more productive, profitable and energy efficient than the other cropping system with application of 100% recommended dose of nitrogen through organic sources along with biofertilizers.

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