Indian Journal of Agronomy **63** (2): 137—144 (June 2018)

Research Paper

Evaluation of nutrient sources for organic production of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system in north-west India

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Received : February 2017; Revised accepted : February 2018

ABSTRACT

A field experiment was conducted during the rainy (*kharif*) season 2009 to winter (*rabi*) season 2011-12 at Ludhiana to evaluate different sources of nutrition for organic production of rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.). The experiment was laid out in a split-plot design with main plots consisting of recommended chemical fertilizers (RDF), farmyard manure (FYM_{200}) to supply 200 kg N/ha, FYM_{100} to supply 100 kg N/ha and unfertilized control. The subplots included *jeevamrit* as soil application, *jeevamrit* as soil and foliar application and control plot without *jeevamrit*. Rice grain yields with FYM_{200} and FYM_{100} were lower by 13.3 and 17.7%, respectively, than RDF during the Ist year and were statistically at par during subsequent years. The reduction in wheat grain yield during 1st year was 34.6 and 40.5% with FYM_{200} and FYM_{100}, respectively, as compared to RDF. The corresponding reductions during 2nd and 3rd year were 18.6, 36.2 and 11.7, 29.5% respectively. The FYM_{200} proved significantly better than FYM_{100} in wheat. Soil organic carbon improved with FYM at both the rates as compared to RDF. The soil microbial population increased with application of *jeevamrit*, but it did not influence the productivity of the crops. Thus, rice yields at par with RDF could be obtained with both the FYM levels of FYM_{100} and FYM_{200} from 2nd year onwards; however, wheat yields even with FYM_{200} remained lower than RDF in 3rd year also. *Jeevamrit* was not effective in influencing the grain yield of rice and wheat, indicating its inability to contribute to the nutrition of these crops.

Key words **:** Farmyard manure, India, Jeevamrit, Organic, Rice, Wheat

Organic food market is the fastest growing sector of agriculture in the world, with a world organic food market of 80 billion US $ in 2014. In response to this growing sector of agriculture, organic farming has spread to 43.7 million ha area in 172 countries of the world which constitutes about 0.99% of the world's agricultural land (Willer and Julia, 2016). The certified area under organic cultivation in India increased from 42,000 ha during 2003-04 to 1.49 million ha during 2015 (APEDA, 2016). The organic farming in Northwest India is at nascent stage. Though organic cultivation of crops has been recommended by substituting chemical fertilizers and pesticides with organic manures and biopesticides respectively (PAU, 2017) but there is little response for this due to very high input-intensive conventional agriculture in this part of the country. The commonly used organic manures like farmyard manure (FYM), composts, vermicompost and non-edible cakes are required in large quantities to meet the nutritional requirement of crops. Moreover, limited availability of these bulky organic manures demands their integration with other available nutrient-management options. The combined use of organic manures and specially prepared organics (*jeevamrit, panchgavya*) helps in sustaining soybean and wheat yields in organic nutrient-management system (Shwetha *et al.,* 2009). Combined application of green manures, crop residues and composts along with liquid manures like *beejamrit*, *jeevamrit*, *panchgavya*, *sasyamruit,* vermiwash can release the nutrients in a more synchronized manner as per need of crop (Kanwar *et al.,* 2006). *Jeevamrit* enhances microbial activity in soil and helps in improvement of soil fertility (Joshi, 2012). *Jeevamrit* is claimed to be a panacea for organic farming to fulfil the nutritional requirement of crops and pest management as well. The *jeevamrit* must be prepared from dung and urine of Indian cow only and dung and urine of 1 cow is sufficient for organic cultivation of 12 ha (Palekar, 2009). Organic growers primarily depend on *jeevamrit* for organic farming (Joshi, 2008; Singh, 2009).

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Rice–wheat is the predominant cropping system in Punjab, with rice and wheat occupying an area of 2.89 and 3.51 m ha, respectively, during 2014–15 (PAU, Ludhiana 2017). Hence a field experiment was conducted to evaluate the potential of organic farming in these crops and also the potential of *jeevamrit* as liquid manure to supply nutrition to these crops.

MATERIALS AND METHODS

The field experiment was conducted on rice–wheat cropping system from rainy (*kharif*) season 2009 to winter (*rabi)* season of 2011–12 at the Punjab Agricultural University, Ludhiana (30°–54' N, 75°–48' E, 247 m above mean sea-level). The experiment was laid out in a split-plot design with 3 replications. The main plots consisted of recommended chemical fertilizers (RDF), farmyard manure (FYM) to supply 100 kg N/ha (FYM_{100}), FYM to supply 200 kg N/ha (FYM_{200}) and unfertilized control. The subplots included *jeevamrit* as soil application (S), *jeevamrit* as soil and foliar application (S+F) and a control plot without *jeevamrit*.

The experimental site has sub-tropical and semi-arid type of climate. The average annual rainfall at Ludhiana is 489.1 mm and about 80% of it is received from June to September. The experiment site soil was loamy sand, with *p*H 7.08 and medium (0.44%) organic carbon (wet digestion method) and 194.4, 90.1 and 188.0 kg/ha available nitrogen (alkaline permanganate oxidisable), phosphorus (0.5 M $NaHCO_3$ extractable) and potassium (1 M ammonium acetate exchangeable) respectively.

The rice nursery of variety 'PAU 201' ('PR 120' in 2011) was sown on 29 May during 2009 and on 21 May during 2010 and 2011 and the crop was transplanted on 3 July during 2009 and 2010 and on 25 June during 2011. The transplanting was done at a row- to- row and plant- to-plant distance of 20 cm and 15 cm respectively (33 hills/m^2). The water was ponded in the field continuously for first 15 days after transplanting the crop and subsequent irrigations were given 2 days after the ponded water had infiltered into the soil. Farmyard manure (FYM), based on the per cent nitrogen on dry-weight basis, was used to supply nutrients as per the treatments. The entire quantity of FYM was applied before transplanting the crop. The chemical fertilizers (urea, diammonium phosphate and muriate of potash) were applied to supply 120 kg N, 30 kg P_2O_5 and 30 kg K_2O/ha. One-third of N and whole amount of P and K were applied at the time of puddling. The remaining N was applied in 2 equal splits at 3 and 6 weeks after transplanting the crop. The pest management in organic nutrition treatments and unfertilized control was done by using Tricho-cards and neem-based biopesticide (Econeem). The Tricho-cards were used 5 times @ 100 cards/ha, starting from 30 days after transplanting at weekly intervals. One spray of Econeem @ 500 ml/ha was done. The pest management in RDF treatment was done by using 2 sprays of Monocil 36 SL (monocrotophos) @ 1,400 ml/ha and one of Dursban 20 EC (chlorpyriphos) @ 2.5 litres/ha. Two sprays of Tilt @ 500 ml/ha were also done in RDF treatment. The crop was harvested on 3 November, 20 October and 7 October during 2009, 2010 and 2011 respectively.

Wheat variety 'PBW 550' was sown on 19 November, 12 November and 5 November during 2009, 2010 and 2011 respectively. The crop was sown at a row spacing of 20 cm by using 112.5 kg seed/ha. The entire quantity of FYM, as per the treatments, was applied at field capacity moisture of the field and mixed well at the time of seed bed preparation. The FYM contained 1% N, 0.2% P and 0.5% K. The chemical fertilizers (urea, diammonium phosphate and muriate of potash) were applied to supply 120 kg N, 60 kg P_2O_5 and 30 K_2O/ha. One-half of the N and whole amount of P and K were applied at the time of sowing and remaining N was applied at 1st irrigation. The aphid management in organic nutrition treatments and unfertilized control was done by using neem-based biopesticide (Econeem) @ 500 ml/ha. In RDF treatment, 1 spray of Rogor 30 EC (dimethoate) @ 375 ml/ha was used. The crop was harvested on 9, 12 and 20 April during 2009, 2010 and 2011 respectively.

Jeevamrit was prepared by using 10 kg dung and 10 litre urine of Indian cow, 2 kg jaggery, 2 kg chickpea flour, half kg virgin soil and the final volume was made 200 litres with water. It was fermented under shade for 5 days and applied 4 times to each crop as soil application @ 500 litres/ha and foliar application @ 300 litres/ha as per the treatments. It was applied to rice at monthly intervals starting from the time of transplanting and to wheat at the time of each irrigation. The *jeevamrit* was prepared afresh every time before its application. On an average, *jeevamrit* had 7.19 g carbon, 0.04 g nitrogen, 0.04 g phosphorus, 0.28 g potassium and 0.43 g sulphur/litre. Joshi (2012) reported 0.1–0.5% N, 0.02–0.04% P and 0.2–0.4% K in *jeevamrit*. Reddy (2009) also reported low concentrations of nitrogen, phosphorus and potassium in the *jeevamrit* solutions. The microbial population was studied in the soil taken from 0–15 cm depth of the plots receiving *jeevamrit* as soil + foliar application and control after the 4th application of *jeevamrit* to each crop. The economic analysis was done by taking mean yield of the crops. The organic treatments were compared both at normal produce price and at 30% price premium as price premium varies from 30% in rice to about 100% in wheat.

Data on crop yields and soil microbial population were statistically analyzed by using statistical methods as per by

Gomez and Gomez (1984) and the software used was CPCS1 developed by the Department of Statistics, Punjab Agricultural University, Ludhiana.

RESULTS AND DISCUSSION

Effect of nutrient sources

Rice: The plant height under RDF was significantly more than that under all the other treatments except FYM_{200} which was statistically at par during 2009. The plant height did not vary significantly with different treatments during 2010. The plant height in the 3rd year of study was significantly more under RDF than all the other treatments (Table 1). The FYM_{100} and FYM_{200} treatments were statistically at par with each other and showed significantly more plant height than the unfertilized control. Effective tillers/m^2 were significantly higher with RDF than all the other treatments during 1st year, but during the 2nd and 3rd year these were statistically at par with that of FYM_{100} and FYM_{200}. And FYM_{100} and FYM_{200} were also statistically at par with each other. Dry-matter accumulation was statistically at par among RDF, FYM_{100} and FYM_{200} during 1st and 3rd year, but during the 2nd year it was significantly more with RDF than both the FYM treatments. Panicle length was significantly longer with RDF than all the other treatments during the first year, but it did not vary significantly with nutrition treatments during the 2nd and 3rd year. Number of grains/panicle was significantly higher with RDF than all other treatments in the 1st year of the study and it did not vary significantly in the 2nd and 3rd year (Table 2). Thousand grain weight did not vary significantly with nutrition treatments during all the years of experimentation. The mean 1,000-grain weight was 25.3, 24.9 and 24.7 g with RDF, FYM_{200} and FYM_{100} respectively.

The mean grain yield was significantly higher with RDF (7.51 t/ha) than both the levels of FYM, i.e. FYM_{100} (6.95 t/ha) and FYM_{200} (7.09 t/ha), the latter two being statistically at par with each other but significantly better than unfertilized control (Table 2). The mean grain yield with RDF was 5.9% higher than that of FYM_{200}. The grain yield was significantly higher with RDF (8.69 t/ha) than FYM_{200} (7.53 t/ha) and FYM_{100} (7.15 t/ha) during 2009 but during 2010 and 2011, it did not vary significantly with different nutrition treatments. The FYM_{100} was able to give statistically similar grain yield to that with FYM_{200} and it was significantly higher than unfertilized control during all the 3 years. Recommended dose of fertilizer resulted in 21.5 and 15.4% higher grain yield than lower (FYM_{100}) and higher (FYM_{200}) levels of FYM, respectively, in the 1st year, but in the 2nd and 3rd year there were non-significant differences in the grain yield under these treatments. The straw yield was significantly higher with RDF than FYM_{200} and FYM_{100} during the 1st year and in the 2nd year RDF and FYM_{200} were statistically at par but FYM_{100} was significantly poor than the RDF. In the 3rd year, RDF, FYM_{200} and FYM_{100} were statistically at par in respect of straw yield.

The results indicated that continuous supply of FYM to both rice and wheat associated with high temperature and moisture conditions during rice-growing period was able to supply the required nutrition to rice at both the levels of FYM during 2nd and 3rd year of experimentation and resulted in at par growth, yield attributes and grain yield of rice to that with recommended fertilizers. Kharub and

Table 1. Growth and yield-attributing characters of rice as affected by different nutrient sources

Treatment	Plant height at maturity (cm)			Dry-matter accumulation at maturity (g/hill)			Effective tillers/m^2			Panicle length (cm)		
	2009	2010	2011	2009	2010	2011	2009	2010	2011	2009	2010	2011
Nutrient source												
RDF	73.4	72.1	91.6	62.2	58.0	52.7	293	341	286	25.5	26.6	22.9
FYM_{100}	68.2	68.8	87.5	50.3	47.5	52.6	243	317	281	23.6	25.3	23.6
FYM_{200}	69.4	69.2	86.5	54.1	50.1	53.1	249	340	280	23.9	25.4	23.9
Unfertilized control	65.7	65.9	78.5	41.4	37.6	45.7	241	269	246	23.3	25.2	23.3
SEm±	1.5	1.4	0.4	4.3	2.1	1.2	4.6	8.3	7.4	0.3	0.4	0.3
CD (P=0.05)	4.2	NS	1.5	12.1	7.3	4.3	13	29	26	0.8	NS	NS
Jeevamrit application												
Jeevamrit (S)	68.8	69.7	86.1	51.0	47.6	50.5	255	316	266	24.0	25.4	23.7
Jeevamrit (S+F)	69.9	68.2	85.8	54.1	50.2	51.6	262	321	281	24.4	26.0	23.4
Control	68.7	69.1	86.2	50.8	47.2	51.0	253	313	272	23.9	25.5	23.1
SEm±	0.6	0.9	0.9	1.1	2.4	1.2	2.6	15.4	6.4	0.2	0.3	0.4
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

RDF, Recommended dose of fertilizers; FYM, farmyard manure; FYM_{100}, farmyard manure to supply 100 kg N/ha; FYM_{200}, farmyard manure to supply 200 kg N/ha; *Jeevamrit* (S), *jeevamrit* as soil application; *Jeevamrit* (S+F), *jeevamrit* as soil and foliar application (S+F) and control, plot without *jeevamrit*.

Chander (2008) and Pilbeam *et al*. (1999) reported similar rice productivity under organic and chemical systems.

Wheat

The plant height of wheat was significantly higher with RDF than FYM_{200} and FYM_{100} during 2009–10 and 2010–11 but it was statistically at par with FYM_{200} but significantly higher than FYM_{100} during 2011–12 (Table 3). Application of FYM_{200} resulted in significantly higher plant height than FYM_{100} during 1st year, but both were statistically at par during the 2nd and 3rd year. The effective tillers/m^2 were significantly higher with RDF than both the FYM levels during all the 3 years of experimentation. Treatments FYM_{200} and FYM_{100} were statistically at par with each other during 2009–10 and 2010–11; however, FYM_{200} showed significantly higher number of effective tillers than FYM_{100} during 2011–12. The dry-matter accumulation was significantly higher with RDF than both the levels of FYM during all the years. Application of FYM_{200} was significantly better than FYM_{100} in dry-matter accumulation except during 2009–10. The unfertilized control had significantly lower dry-matter accumulation than all the other treatments except in the 1st year when it was statistically at par with FYM_{100}. The ear length was significantly higher with RDF than FYM_{200} and FYM_{100} during 2009–10, but it was statistically at par among the nutrition treatments during 2010–11 and 2011–12. FYM_{200} and FYM_{100} treatments had non-significant differences with each other during all the 3 years. The number of grains/ear with RDF was significantly higher than FYM_{200} and FYM_{100}, the latter two being statistically at par during 2009–10. The number of grains/ear did not differ significantly with different nutrition treatments during 2010–11 and 2011–12 (Table 4). Thousand grains weight was significantly higher with FYM_{200} than RDF and it was statistically at par with FYM_{100} during 2009–10. Treatment FYM_{100} was also statistically at par with RDF. Thousand grains weight did not vary significantly during 2010–11 and 2011–12.

The mean and year-wise grain yields were significantly higher with RDF than both the levels of FYM, and FYM_{200} gave significantly higher grain yield than that with FYM_{100} (Table 4). The lowest level of FYM (FYM_{100}) resulted in significantly higher grain yield than the unfertilized control. The reduction in wheat grain yield even during the 3rd year of study was 11.7 and 29.7% with FYM_{200} and $FYM_{100,}$ respectively, as compared to RDF indicating that FYM even at highest dose for 3 years was not capable of supplying nutrition to the crop equivalent to the chemical fertilizers. This might be due to colder climate during wheat-growth period that might be responsible for slow release of nutrients from the FYM. The decrease in mean grain yield with FYM_{200} and FYM_{100} as compared to RDF was 21.3 and 35.3% respectively (Table 4). The higher level of FYM (FYM_{200}) resulted in 21.6% more yield than lower level of FYM (FYM_{100}). The straw yield with RDF was significantly higher than FYM_{200} and FYM_{100} during all the 3 years. The straw yield with FYM_{200} was statistically at par with FYM_{100} except during 2010–11 when it was significantly higher than $FYM_{100.}$ Pilbeam *et al*. (1999) and Kharub and Chander (2008) also reported lower wheat productivity under organic than under chemical system.

Table 2. Yield-attributing characters, grain and straw yields of rice as affected by different nutrient sources

Treatment	Filled grains/panicle			1,000-grain weight (g)			Grain yield (t/ha)				Straw yield (t/ha)		
	2009	2010	2011	2009	2010	2011	2009	2010	2011	Pooled	2009	2010	2011
Nutrient source													
RDF	193	155	100	25.7	26.4	23.9	8.69	7.20	6.64	7.51	17.7	16.7	11.4
FYM_{100}	175	155	106	23.9	26.0	24.2	7.15	7.14	6.58	6.95	13.8	13.4	11.3
FYM_{200}	178	165	112	24.3	26.2	24.2	7.53	7.15	6.60	7.09	14.5	15.1	12.3
Unfertilized control	158	150	106	23.7	25.9	23.9	6.54	6.16	5.34	6.01	11.2	9.8	9.3
SEm±	7.5	6.7	8.5	1.2	0.3	1.2	0.17	0.13	0.15	0.09	1.02	0.87	0.52
CD (P=0.05)	21	NS	NS	NS	NS	NS	0.60	0.44	0.51	0.26	2.8	3.0	1.8
Jeevamrit application													
Jeevamrit (S)	178	154	104	23.6	26.1	25.2	7.43	6.94	6.23	6.87	14.3	13.4	10.7
Jeevamrit (S+F)	179	158	110	25.4	26.3	23.2	7.62	7.03	6.30	6.99	14.6	14.1	11.2
Control	170	156	105	24.2	25.9	23.7	7.38	6.76	6.33	6.82	14.0	13.8	11.4
SEm±	3.9	6.6	5.7	0.8	0.2	1.0	0.15	0.13	0.15	0.08	0.49	0.49	0.42
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

RDF, Recommended dose of fertilizers; FYM, farmyard manure; FYM_{100}, farmyard manure to supply 100 kg N/ha; FYM_{200}, farmyard manure to supply 200 kg N/ha; *Jeevamrit* (S), *jeevamrit* as soil application; *Jeevamrit* (S+F), *jeevamrit* as soil and foliar application (S+F) and control, plot without *jeevamrit*.

Table 3. Growth and yield-attributing characters of wheat as affected by different nutrient sources

Treatment	Plant height at maturity (cm)			Dry-matter accumulation at maturity (g/m^2)			Effective tillers/m^2			Spike/ear length(cm)		
	2009–10	2010–11	2011–12	2009–10	2010–11	2011–12	2009–10	2010–11	2011–12	2009–10	2010–11	2011–12
Nutrient source												
RDF	80.1	83.4	74.1	1,064	1,207	1,334	451	452	453	10.9	10.6	10.3
FYM_{100}	70.3	76.0	69.1	766	777	1,062	264	313	326	10.2	10.8	10.3
FYM_{200}	74.0	77.6	70.9	893	856	1,202	266	356	386	10.1	10.6	10.5
Unfertilized control	65.3	72.8	66.5	623	591	808	255	261	283	9.6	10.5	9.4
SEm±	0.6	1.2	1.0	46.3	19.4	36.5	11.6	18.5	13.2	0.1	0.1	0.2
CD (P=0.05)	2.2	4.1	3.6	160	67	126	40	64	46	0.4	NS	0.7
Jeevamrit application												
Jeevamrit (S)	72.8	76.5	69.1	839	901	1,126	306	344	364	10.2	10.7	10.1
Jeevamrit (S+F)	71.3	77.7	71.3	844	814	1,097	310	353	364	10.1	10.5	10.2
Control	73.1	78.2	70.1	826	858	1,082	311	339	357	10.3	10.7	10.0
SEm±	0.7	0.8	1.0	40.3	50.8	30.2	7.0	14.3	11.4	0.1	0.1	0.2
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

RDF, Recommended dose of fertilizers; FYM, farmyard manure; FYM_{100}, farmyard manure to supply 100 kg N/ha; FYM_{200}, farmyard manure to supply 200 kg N/ha; *Jeevamrit* (S), *jeevamrit* as soil application; *Jeevamrit* (S+F), *jeevamrit* as soil and foliar application (S+F) and control, plot without *jeevamrit.*

System productivity

The system productivity was evaluated in terms of system rice-equivalent yield (SREY). The year-wise and mean SREY was the highest with RDF which was significantly higher than both the levels of FYM (Table 5). Treatment FYM_{200} was significantly better than FYM_{100} which was further significantly better than the unfertilized control. The lower system productivity with the highest level of FYM even after 3 crop cycles was due to reduced wheat grain yields under organic nutrition.

Effect of jeevamrit on rice, wheat and system productivity

Different *jeevamrit* treatments, viz. soil application, soil + foliar application and control (no application) did not differ significantly among themselves in respect of growth and yield-attributing characters, grain yields of rice and wheat (Tables 1, 2, 3 and 4) and system productivity (Table 5) indicating that *jeevamrit* was not able to influence growth and yield-attributing characters either alone or in combination with recommended chemical fertilizer or FYM. The mean data revealed that soil + foliar application of *jeevamrit* resulted in 17.8 and 48.1% reduction in grain yields of rice and wheat, respectively, as compared to recommended fertilizers. However, *jeevamrit* had been reported to enhance the productivity of crops by Shwetha *et al.* (2009) and Palekar (2009).

Effect of nutrition sources and jeevamrit on soil properties

The effect of different nutrient sources on soil *p*H and electrical conductivity (EC) was non-significant. The soil organic carbon improved significantly with FYM application at both the levels as compared to RDF and unfertilized control (Table 6). The increase in soil organic carbon with FYM_{200} and FYM_{100} was 28.3 and 41.3%, respectively, over the recommended fertilizers. This might be owing to continuous application of FYM for 3 years to these treatments. The FYM_{200} and FYM_{100} did not differ significantly among each other. The soil-available N status was significantly higher with all nutrition treatments than unfertilized control. The FYM_{200} had significantly higher available N than the RDF but was statistically at par with FYM_{100}. The RDF and FYM_{100} were also statistically at par with each other. The available soil P was significantly higher with FYM_{200} than all the other treatments. Treatments of RDF and FYM_{100} were statistically at par with each other but were significantly better than unfertilized control. The available soil K was significantly higher with all the nutrition treatments than the unfertilized control. Both the FYM levels were statistically at par with each other but were significantly better than the RDF.

Table 4. Yield-attributing characters and grain yield of wheat as affected by different nutrient sources

Treatment	Grains/ear			1,000-grain weight(g)			Grain yield (t/ha)				Straw yield (t/ha)		
	2009–10	2010–11	2011–12	2009–10	2010–11	2011–12	2009–10	2010–11	2011–12	Pooled	2009–10	2010–11	2011–12
Nutrient source													
RDF	53.5	54.0	56.0	38.2	38.9	42.5	5.63	5.80	6.17	5.87	7.96	8.33	7.30
FYM_{100}	50.1	54.1	56.2	41.1	40.5	41.0	3.35	3.70	4.35	3.80	4.58	5.09	5.24
FYM_{200}	51.5	54.9	57.1	43.1	40.3	41.5	3.68	4.72	5.45	4.62	4.83	5.81	6.83
Unfertilized control	48.9	53.3	50.6	41.0	39.3	38.8	2.73	2.90	3.22	2.95	3.75	3.24	4.10
SEm±	0.6	1.7	1.8	0.9	0.9	0.8	0.07	0.21	0.14	0.10	0.25	0.23	0.23
CD (P=0.05)	2.0	NS	NS	3.1	NS	NS	0.24	0.74	0.48	0.26	0.85	0.78	0.78
Jeevamrit application													
Jeevamrit (S)	52.8	53.7	54.6	40.4	39.6	40.8	3.92	4.26	4.83	4.34	5.29	5.67	5.92
Jeevamrit (S+F)	49.8	54.2	55.1	40.5	39.7	40.9	3.80	4.35	4.82	4.32	5.18	5.49	5.74
Control	50.4	54.3	55.2	41.5	39.9	41.1	3.82	4.24	4.73	4.26	5.37	5.70	5.95
SEm±	1.4	1.7	1.6	1.0	0.8	0.6	0.09	0.06	0.12	0.09	0.09	0.16	0.16
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

RDF, Recommended dose of fertilizers; FYM, farmyard manure; FYM_{100}, farmyard manure to supply 100 kg N/ha; FYM_{200}, farmyard manure to supply 200 kg N/ha; *Jeevamrit* (S), *jeevamrit* as soil application; *Jeevamrit* (S+F), *jeevamrit* as soil and foliar application (S+F) and control, plot without *jeevamrit*.

Yadav *et al.* (2009) also reported improved soil health with all the organic manures.

The *jeevamrit* was not able to influence soil properties significantly. The population of bacteria, actinomycetes and fungi was higher with application of *jeevamrit* in all the nutrition sources in both rice and wheat (Table 6), but the data on grain yield of crops revealed that this higher microbial population could not affect the grain yield of crops. The per cent increase in bacterial population in rice with application of *jeevamrit* was the highest under unfertilized condition followed by FYM application and RDF. The per cent increase in bacterial population in wheat was higher with FYM application than that under RDF and unfertilized control. The quantum of increase in microbial population was higher in the *rabi* season than *kharif*.

Table 5. Effect of different nutrient sources on system rice-equivalent yield

Treatment	System rice equivalent yield (t/ha)			
	2009	2010	2011	Pooled
Nutrient source				
RDF	14.3	13.0	12.8	13.7
FYM_{100}	10.4	10.8	10.9	10.7
FYM_{200}	11.2	11.9	12.1	11.5
Unfertilized control	9.3	9.1	8.6	9.2
SEm±	0.22	0.14	0.17	0.19
CD (P=0.05)	0.7	0.9	0.5	0.5
Jeevamrit application				
Jeevamrit (S)	11.4	11.2	11.0	11.3
Jeevamrit (S+F)	11.4	11.4	11.1	11.4
Control (C)	11.2	11.0	11.1	11.1
SEm±	0.93	0.12	0.15	0.16
CD (P=0.05)	NS	NS	NS	NS

RDF, Recommended dose of fertilizers; FYM, farmyard manure; FYM_{100}, farmyard supply 100 kg N/ha; FYM_{200}, manure to supply 200 kg N/ha; Jeemomrit (S), *jeevamrit* as soil application; Jeevamrit (StF). *jeevamrit* as soil and foliar application (S+F) and control, plot without *jeevamrit*.

Effect of nutrition sources and jeevamrit on economics

The cost of rice production under FYM_{100} was almost at par with RDF, but FYM_{200} had 11% higher and unfertilized control had 10.5% lower cost of production than RDF (Table 7). This was due to higher input and application costs of FYM under $FYM_{200.}$ The gross returns under FYM_{100} and FYM_{200} were 7.8 and 5.8% less than the RDF respectively. The net returns were 11.2 and 12.7% lower under FYM_{100} and FYM_{200} than RDF, respectively. However, net returns under FYM_{100} and FYM_{200} were 27.9 and 27.3% higher than that under RDF, respectively, if 30% organic price premium is given to these treatments. Benefit: cost ratio was the highest (2.41) under RDF at normal price but at 30% price premium to organic produce, it was the highest (3.08) under FYM_{100}. Urkurkar *et al.* (2010) also reported higher net returns with recommended fertilizers than organic treatments.

The cost of wheat production under FYM_{100} was almost at par with RFD, but under FYM_{200} it was 9.3% higher than RDF. The unfertilized control had 16.1% lower cost of production than RDF. This was due to higher input and application costs of FYM under $FYM_{200.}$ The gross returns under FYM_{100} and FYM_{200} were 35.5 and 22.2% lower than the RDF respectively. The net returns were 47.0 and 33.4% lower under FYM_{100} and FYM_{200} than RDF respec-

Table 6. Effect of different nutrient sources on soil properties after 3 cycles of rice-wheat cropping system

Treatment	*p*H (1:2)	Electrical conductivity (dS/m)	Available nutrients (kg/ha)			Organic carbon (%)	Microbial population (cfu*/g soil)			
							Rice		Wheat	
			N	P	K		Bacteria (× 10^6)	Fungi (× 10^3)	Bacteria (× 10^6)	Fungi (× 10^3)
Nutrient source										
RDF	6.98	0.201	255.3	103.3	126.1	0.453	22.3	23.5	18.4	29.0
FYM_{100}	6.94	0.204	257.9	110.5	148.7	0.581	22.1	25.7	18.3	31.6
FYM_{200}	6.93	0.206	269.3	121.9	154.4	0.640	21.6	24.2	18.4	28.8
Unfertilized control	7.01	0.199	198.8	77.1	93.0	0.433	21.3	25.6	17.0	29.9
SEm±	0.13	0.006	3.31	2.11	3.06	0.025	0.52	0.85	0.48	1.1
CD (P=0.05)	NS	NS	11.5	7.3	10.6	0.070	NS	NS	NS	NS
Jeevamrit application										
Jeevamrit (S)	6.97	0.206	242.2	100.5	129.4	0.527	-	-	-	-
Jeevamrit (S+F)	6.96	0.198	247.0	103.7	133.7	0.527	23.2	27.6	20.5	33.7
Control (C)	6.96	0.203	246.8	105.4	128.6	0.528	20.4	21.9	15.6	25.9
SEm±	0.051	0.004	2.12	2.67	2.5	0.015	1.0	1.9	1.2	1.8
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	5.0	3.2	4.8

Cfu, colony-forming units; RDF, Recommended dose of fertilizers; FYM, farmyard manure; FYM_{100}, farmyard manure to supply 100 kg N/ha; FYM_{200}, farmyard manure to supply 200 kg N/ha; *Jeevamrit* (S), *jeevamrit* as soil application; *Jeevamrit* (S+F), *jeevamrit* as soil and foliar application (S+F) and control, plot without *jeevamrit*.

Table 7. Effect of different nutrient sources on economics of rice and wheat production

Treatment	Cost of production (×10^3 ₹/ha)		Gross returns (×10^3 ₹/ha)		Net returns (× 10^3 ₹/ha)		Benefit: cost ratio	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Nutrient source								
RDF	32.61	27.57	111.3	104.8	78.65	77.2	2.41	2.80
FYM_{100}	32.70	26.62	102.6 (133.3)	67.53 (87.78)	69.86 (100.6)	40.91 (61.16)	2.14 (3.08)	1.54 (2.30)
FYM_{200}	36.20	30.12	104.9 (136.3)	81.54 (106.0)	68.66 (100.1)	51.42 (75.88)	1.90 (2,77)	1.71 (2.52)
Unfertilized control	29.20	23.12	88.18	52.03	58.98	28.91	2.02	1.25
Jeevamrit application								
Jeevamrit (S)	33.72	27.9	101.3	77.01	67.58	49.11	2.00	1.76
Jeevamrit (S+F)	34.31	28.49	103.0	76.32	68.73	47.83	2.00	1.68
Control (C)	32.67	26.85	100.7	75.95	68.05	49.10	2.08	1.83

Figures in parentheses are with 30% organic price premium. RDF, Recommended dose of fertilizers; FYM, farmyard manure; FYM_{100}, farmyard manure to supply 100 kg N/ha; FYM_{200}, farmyard manure to supply 200 kg N/ha; *Jeevamrit* (S), *jeevamrit* as soil application; Jeevamrit (S+F), *jeevamrit* as soil and foliar application (S+F) and control, plot without *jeevamrit*.

tively. However, net returns under FYM_{100} and FYM_{200} were 20.8 and 1.7% lower than that under RDF, respectively, even after adding 30% organic price premium to these treatments. Benefit: cost ratio was the highest under RDF even at 30% price premium to the organic wheat indicating that organic wheat is not economical even at 30% price premium vis-à-vis the conventionally grown wheat.

The economics of rice and wheat did not vary much with *jeevamrit* treatments due to its very low cost and negligible effect on crop yields.

It was concluded that in rice–wheat cropping system, rice grain yields at par with RDF can be obtained with FYM supplying 100 kg N/ha from 2nd year onwards but wheat grain yields even at FYM supplying 200 kg N/ha remained lower than RDF even in 3rd year. *Jeevamrit* both as soil and foliar application was unable to contribute towards yield improvement of both the crops. The net returns of rice were higher than RDF under organic management at 30% price premium but in wheat these were lower than RDF even at 30% price premium.

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