

Effect of organic farming on yield, quality and soil-fertility status under basmati rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment to explore the possibility of improving the productivity and sustainability of basmati rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L. emend. Fiori & Paol.) through organic source was conducted at Karnal during 2004-05 to 2006-07. Rice productivity was at par under inorganic and organic fertilization where farmyard manure (FYM) application was 22.5 t/ha in rice and 20 t/ha or more in wheat. Rice grain-protein content (8.13-8.52%) was at par under all the treatments but the protein yield was significantly higher under inorganic compared to under organic source except under the highest dose (30 t/ha in rice and 40 t/ha in wheat) of FYM. Wheat productivity was lower (30.5% on pooled basis) under organic than under inorganic fertilization even under the highest FYM dose. Protein content in wheat increased with increase in the dose of FYM; but the highest protein content (11.24%) was recorded under inorganic fertilizer. FYM application for three years significantly improved the initial values of soil organic carbon (14.3%), available N (10.7%), P (5.4%) and K (2.6%). System's productivity in terms of rice-equivalent yield was 9.99 t/ha with inorganic fertiliser and 8.88 t/ha with FYM application (30 t/ha in rice and 40 t/ha in wheat). Net returns (Rs 74,170) and benefit : cost ratio (2.1) were significantly higher under inorganic fertilization.

Key words: Basmati rice, Economics, Grain protein, Organic farming, Soil fertility, System's productivity, Wheat

Organic farming is a production system that avoids the use of synthetic chemical fertilisers, pesticides and growth-regulating hormones, and raises the crops with the use of organic manures, crop rotation, legumes, green-manure and biological pest control. India is the third largest consumer of fertilisers in the world, having currently fertilizer consumption 20.3 million t (Anonymous, 2007). This has resulted in not only self-sufficiency in foodgrains production but also made the country food surplus. Use of these high-analysis chemical fertilizers in imbalanced and indiscriminate manner has developed many problems like decline of soil-organic matter, increase in salinity and sodicity, deterioration in the quality of crop produce, increase in hazardous pests and diseases, and increase in soil pollutants (Chakarborti and Singh, 2004). Continuous use of inorganic fertilizers has not only brought about loss of vital soil fauna and flora but also resulted in loss of secondary and micro-nutrients. In view of these facts, supply of all the plant nutrients has been advocated through organic sources only, but organic farming may not be feasible in modern commercial agriculture because it is unable to sustain high level of production to meet the

foodgrain supply for the ever-increasing population (Tarafdar *et al.*, 2008). There is very little research work on total use of organic sources and that too is limited to horticultural and vegetable crops. Till now the research was oriented to increase the yield through integrated use of organic and inorganic sources. Experiences in the past have shown that it is impossible to attain sustainable agricultural production through the use of inorganic fertilizers. Hence, the present study was conducted to explore the possibility of improving the productivity and sustainability of rice-wheat system by supply of nutrients through organic source.

MATERIALS AND METHODS

A field experiment was conducted at research farm of Directorate of Wheat Research, Karnal for three years (2004-05 to 2006-07). The soil was sandy clay-loam (22% clay), low in organic C (0.36%) and available N (139 kg/ha), and medium in available P (16.5 kg/ha) and K (154 kg/ha) content. Electrical conductivity and pH were 0.27 dS/m and 7.95 respectively. A total of 17 nutrient combinations (different doses of FYM in wheat and rice) were tried including an inorganic control (recommended chemi-

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cal fertiliser) in randomised block design. The treatments were T₁, zero fertiliser or farmyard manure (FYM) in rice and wheat; T₂, zero fertiliser or FYM in rice and 20 t FYM/ha in wheat; T₃, zero fertiliser or FYM in rice and 30 t FYM/ha in wheat; T₄, zero fertiliser or FYM in rice and 40 t FYM/ha in wheat; T₅, 15 t FYM/ha in rice and zero fertiliser or FYM in wheat; T₆, 15 t FYM/ha in rice and 20 t FYM/ha in wheat; T₇, 15 t FYM/ha in rice and 30 t FYM/ha in wheat; T₈, 15 t FYM/ha in rice and 40 t FYM/ha in wheat; T₉, 22.5 t FYM/ha in rice and zero fertiliser or FYM in wheat; T₁₀, 22.5 t FYM/ha in rice and 20 t FYM/ha in wheat; T₁₁, 22.5 t FYM/ha in rice and 30 t FYM/ha in wheat; T₁₂, 22.5 t FYM/ha in rice and 40 t FYM/ha in wheat; T₁₃, 30 t FYM/ha in rice and zero fertiliser or FYM in wheat; T₁₄, 30 t FYM/ha in rice and 20 t FYM/ha in wheat; T₁₅, 30 t FYM/ha in rice and 30 t FYM/ha in wheat; T₁₆, 30 t FYM/ha in rice and 40 t FYM/ha in wheat; and T₁₇, N, P and K @ 150, 60, 60 kg/ha respectively in rice and wheat through inorganic fertilisers. Farmyard manure used in the experiment contains 0.52% N, 0.21% P and 0.48% K; and the doses of 0, 15, 22.5 and 30 t FYM/ha in rice and 0, 20, 30 and 40 t FYM/ha in wheat supply nitrogen 0, 67, 100 and 125% of the recommended dose. Phosphorus and potassium were automatically supplied through FYM and no additional chemical fertiliser was added. No chemical fertiliser herbicide or pesticide was applied to rice and wheat. Biofertilisers, viz. (*Azobacter* and Phosphate solubilizing bacteria (PSB) were applied as seed treatment in all organic treatments in wheat, and *Azolla* was used in rice to solubilise the nutrients already available in the soil. For pests and diseases, neem-based bio-pesticide was used both in rice and wheat. Irrigation was applied on the basis of critical physiological stages of different crops. The wheat variety 'PBW 343' and rice variety 'Pusa Basmati 1' were grown in all the years of experimentation. Protein content in wheat and rice grain was estimated through NIR by taking whole grain under near-infra red waves (AOAC, Washington 1995). Organic carbon and available nutrients were estimated by standardised methodology. System's productivity was calculated on the basis of prevailing prices of wheat and rice during the years of experimentation. Net returns were calculated by subtracting the input cost from gross returns. Input cost includes the cost of all the inputs required for crop production and cost of FYM was taken as per the market rate (Rs 200/t). Benefit : cost ratio was also calculated by dividing net returns by input cost.

RESULTS AND DISCUSSION

Growth and yield attributes

In rice tillers/m² were 235–320 in all treatments and there was no significant difference in organic and inor-

ganic fertilization (Table 1). The 1,000-grains weight 21–28 g, the lowest under zero fertilizer application and the highest under 30 and 40 t FYM/ha application in rice and wheat respectively. However, inorganic fertilizer application recorded higher 1,000-grain weight, which was significantly superior to organic fertilization. Panicle length was on a par with under organic and inorganic fertilizer application but grains/panicle were higher in inorganic (140) than under organic (115–123) fertilizer application. The plant height of wheat increased significantly with the application of successive doses of FYM and the highest was (85.9 cm) under organic treatments where maximum FYM was applied (30 t/ha in rice and 40 t/ha) in wheat; however, it was significantly inferior to that under inorganic fertilizer application (89.6 cm). Ears/ m² were 148 under zero fertilizer application, which increased to 268 at the highest FYM (30 and 40 t/ha in rice and wheat respectively) level and further to 388 with inorganic fertilizer application (Table 2). The 1,000-grain weight (43.8–45.9 g) of wheat remained unaffected by organic or inorganic fertilizer application. Similarly, the highest grains/ear (45) were recorded with inorganic fertilizer application, it was 40 under the highest dose of FYM application (30 and 40 t/ha in rice and wheat respectively).

Grain and straw yields

Rice yield increased during the successive years under FYM application but the margin was less compared with that of wheat. It increased under graded doses of FYM application (4.67–5.35 t/ha), the highest under 30 and 40 t FYM/ha in rice and wheat respectively (Table 1). The rice yield under inorganic fertilizer application was 5.47 t/ha, which was on a par with that under 22.5 and 20 t FYM/ha in rice and wheat and also at its higher doses. Similar trend was observed in the yield of rice straw, which was 7.6–10.8 t/ha under inorganic fertilizer and 7.9 to 9.9 t/ha under FYM. Kumar *et al.* (1995) reported reduction in rice yield with organic sources. In the initial years 25–50% substitution of fertilizers through organic sources (farmyard manure, green-manure and wheat straw) reduced the rice yield by 6–23% compared with 100% NPK fertilizers (120 kg N + 26.2 kg P + 33.2 kg K/ha) alone. In a study at New Delhi, Singh *et al.* (2007) reported that rice-grain yield increased by 114 to 116.8% compared with that under on application of all the four organic amendments (blue-green algae) 15 kg/ha, *Azolla* 1.0 t/ha, vermicompost and farmyard manure 5.0 t/ha).

The grain and straw yields of wheat increased with successive doses of FYM application, but their highest yields were obtained under inorganic fertilizer in all the three years (Table 2). The mean wheat yield ranged from 1.49 t/ha under zero fertilizer application to 3.14 t/ha under the

Table 1. Effect of organic fertilization on growth, yield attributes, productivity and quality of rice

FYM (t/ha) Rice-wheat	Tillers/ m ² (Mean data of three years)	Panicle length (cm)	Grains/ panicle	1000- grain weight (g)	Grain yield (t/ha)				Straw yield (t/ha)				Protein content (%)				Protein yield (kg/ha) (Pooled)
					2004- 05	2005- 06	2006- 07	Pooled	2004- 05	2005- 06	2006- 07	Pooled	2004- 05	2005- 06	2006- 07	Pooled	
0-0	260	31.5	115	21	3.22	4.0	5.56	4.26	7.2	7.6	8.1	7.6	8.31	8.53	8.72	8.52	363
0-20	275	31.7	117	21	3.44	4.92	5.65	4.67	7.5	7.8	8.4	7.9	8.33	8.61	8.56	8.50	397
0-30	235	33.0	124	21	3.48	5.38	5.66	4.84	7.6	8.1	8.5	8.1	8.35	8.67	8.48	8.50	411
0-40	280	32.7	114	21	3.61	5.43	5.72	4.92	7.9	8.2	8.7	8.3	8.36	8.71	8.25	8.44	415
15-0	240	32.0	116	23	3.74	4.67	5.92	4.78	7.6	8.1	8.5	8.1	8.15	8.05	8.19	8.13	389
15-20	255	32.3	116	23	3.78	5.0	5.98	4.92	7.9	8.4	8.6	8.3	8.12	8.21	8.42	8.25	406
15-30	250	32.3	122	24	3.74	5.39	5.99	5.04	8.1	8.6	8.9	8.5	8.31	8.46	8.55	8.44	425
15-40	300	31.3	113	23	3.89	5.47	6.02	5.13	8.4	8.9	9.2	8.8	8.33	8.56	8.22	8.37	429
22.5-0	320	32.0	123	25	3.81	4.63	6.43	4.96	8.1	8.5	8.7	8.4	8.08	8.21	8.28	8.19	406
22.5-20	290	32.0	125	26	3.96	5.0	6.50	5.15	8.4	9.1	9.1	8.9	8.09	7.95	7.96	8.00	412
22.5-30	320	32.0	114	26	3.85	5.32	6.51	5.23	8.6	9.3	9.3	9.1	8.17	8.32	8.44	8.31	434
22.5-40	290	32.7	135	25	3.89	5.46	6.58	5.31	8.9	9.5	9.5	9.3	8.07	8.36	8.32	8.25	438
30-0	290	32.3	112	28	3.85	4.66	6.61	5.04	8.6	9.2	9.3	9.0	8.19	8.28	8.46	8.31	419
30-20	255	33.0	127	29	4.01	4.94	6.63	5.19	9.0	9.5	9.6	9.4	8.21	8.15	8.21	8.19	425
30-30	300	32.7	123	28	4.19	5.24	6.67	5.37	9.1	9.7	10.0	9.6	8.13	8.32	8.30	8.25	443
30-40	270	31.3	123	28	3.89	5.47	6.69	5.35	9.3	10.1	10.4	9.9	8.27	8.58	8.71	8.52	456
Chem. fertilizer	320	32.0	140	32	4.22	5.64	6.55	5.47	10.3	11.0	11.2	10.8	8.32	8.56	8.62	8.50	464
SEm+	10	1.9	9	1	0.14	0.18	0.16	0.17	0.26	0.27	0.29	0.34	0.76	1.11	1.18	1.33	15
CD (P=0.05)	28	NS	NS	3	0.39	0.51	0.44	0.46	0.72	0.75	0.81	0.94	NS	NS	NS	NS	41

Table 2. Effect of organic fertilization on growth, yield attributes, productivity and quality of wheat

FYM (t/ha) Rice-wheat	Plant height (cm)	Tillers/m ²	Grains/ear	1000-grain weight (g)	Grain yield (t/ha)				Straw yield (t/ha)				Protein content (%)				Protein yield (kg/ha) (Pooled)				
					2004-05		2005-06		2006-07		Pooled		2004-05		2005-06			2006-07		Pooled	
					05	06	05	06	05	06	05	06	05	06	05	06		05	06	05	06
0-0	66.4	148	23	43.9	1.32	1.52	1.62	1.49	1.75	2.15	2.09	2.00	8.99	9.01	9.42	9.14	136.2				
0-20	73.4	174	25	44.8	1.60	1.59	2.29	1.83	1.90	2.23	3.48	2.54	9.05	9.13	9.87	9.35	171.1				
0-30	73.9	187	26	45.0	1.73	1.6	2.50	1.95	2.16	2.36	3.73	2.75	9.17	9.3	10.03	9.5	185.3				
0-40	77.2	201	28	45.7	1.89	2.58	3.01	2.49	2.31	3.11	4.95	3.46	9.23	9.51	9.49	9.41	234.3				
15-0	69.1	170	25	44.1	1.51	1.71	1.75	1.66	1.85	2.40	2.48	2.24	8.95	9.21	9.35	9.17	152.2				
15-20	74.8	187	27	45.2	1.65	1.92	2.59	2.05	2.00	2.61	3.77	2.79	9	9.31	9.35	9.22	189.0				
15-30	80.0	200	30	45.6	1.87	2.2	3.20	2.42	2.30	2.84	5.17	3.44	9.03	9.43	9.92	9.46	228.9				
15-40	83.2	233	31	45.8	2.12	2.92	3.28	2.77	2.66	3.42	5.79	3.96	9.11	9.55	9.96	9.54	264.3				
22.5-0	74.3	190	27	43.8	1.55	1.87	1.83	1.75	1.92	2.50	2.99	2.47	9.01	9.33	9.77	9.37	164.0				
22.5-20	79.0	212	29	45.2	1.82	2.09	2.78	2.24	2.28	2.61	4.47	3.12	9.16	9.37	9.73	9.42	211.0				
22.5-30	79.4	229	32	45.2	2.06	2.4	2.99	2.48	2.42	2.92	4.87	3.40	9.21	9.5	10.03	9.58	237.6				
22.5-40	83.0	258	33	45.7	2.18	3.09	3.91	3.06	2.58	3.60	6.46	4.20	9.25	9.45	10.49	9.73	297.7				
30-0	76.1	201	28	44.4	1.65	2.00	2.17	1.94	2.02	2.56	3.38	2.65	9.12	9.37	10.91	9.8	190.1				
30-20	81.3	211	32	45.1	1.81	2.38	2.81	2.34	2.33	2.91	4.41	3.22	9.21	9.67	10.70	9.86	230.7				
30-30	83.8	237	34	45.7	2.02	2.6	3.33	2.65	2.50	3.25	5.62	3.79	9.29	9.81	10.84	9.98	264.5				
30-40	85.9	268	37	45.9	2.39	3.56	3.45	3.14	2.79	4.22	6.19	4.40	9.81	10.29	10.98	10.36	325.3				
Chemical fert.	89.6	388	45	44.3	4.22	4.70	4.64	4.52	5.74	5.89	6.90	6.18	11.03	11.16	11.53	11.24	508.0				
SE _{ms} ±	1	13	1	2.4	0.15	0.14	0.14	0.16	0.26	0.25	0.28	0.34	0.31	0.38	0.33	0.46	60.1				
CD (P=0.05)	3	35	3	NS	0.42	0.40	0.39	0.44	0.71	0.69	0.78	0.91	0.86	1.06	0.92	1.28	166				

highest FYM application (30 and 40 t/ha in rice and wheat respectively), whereas it was 4.52 t/ha inorganic fertilizer which was significantly superior to all the treatments. Even the highest dose of FYM application produced 30.5% less yield on pooled basis compared with that of inorganic fertilizer application. During the first year the reduction was more (43.4%) which decreased in successive years mainly because of residual effect of organic fertilizer applied in the previous years. The straw yield ranged from 2.0 t/ha under zero fertilizer or FYM to 6.18 t/ha under inorganic fertilizer. It recorded up to 4.40 t/ha under the highest dose of organic fertilization which was 28.8% less than that under inorganic fertilizer application. Dumaresq (1997) from Australia reported that the majority of studies done on organic farming around the world reported yields lower or similar to that of conventional farming. Our study further confirmed his findings that wheat yields under organic fertilizers were only 65% of those of conventional farms. Hegde (1998) evaluated the effects of different combinations of organic and inorganic fertilizers on rice-wheat crop rotation and found that wheat-equivalent yield could be maintained while substituting 50% of the N requirement of rice by farmyard manure (FYM) rather than mineral N. Sherchan *et al.* (1999) reported that yield of rice was greater when manure rather than fertilizer was applied, but that of wheat was less.

Grain quality

In rice the grain-protein content was statistically similar under all the treatments, but the protein yield was significantly higher under treatments where the highest dose of FYM was applied compared with that of 0 fertiliser application (Table 1) i.e. 8.13-8.52%. The highest total protein yield (464 kg/ha) was recorded under inorganic fertilizer application but the difference between organic (443 kg/ha) and inorganic fertilization was non-significant. Singh *et al.* (2007) from rice-grain analysis for micronutrients reported a significant increase in the Fe and Mn content on the use of organic amendments compared with the control. The protein content in wheat increased with increase in the dose of FYM, and highest (11.24%) under inorganic fertilizer application (Table 2). On pooled basis, the protein content on inorganic fertilizer application was 18.7% more than with no fertiliser and 7.8% more than with

organic fertilization. Therefore, wheat under FYM alone showed less protein content than under chemical fertilizer. This may be ascribed to short supply of nutrients, especially nitrogen, at low soil temperature in winter season, which reduce the microbial activity and thus decreased the mineralization of nutrients from FYM. The total protein yield was 136.2-508.0 kg/ha, (325.3 kg/ha) with FYM, which was significantly lower than with inorganic fertilization.

Soil fertility status

The continuous application of FYM for three years significantly improved the soil-organic carbon (C) compared with that of inorganic fertilizer and no fertilizer application (Table 3). The soil-organic C increased from 0.32% on no fertilizer application to 0.42% under the highest FYM application. The increase was 14.3% compared with the initial value, however at the end of experiment it was 0.36% with inorganic fertilizer, being equivalent to initial value. Similarly, the availability of major nutrients also improved significantly in the FYM-treated plots in those receiving inorganic fertilizer and zero fertilizer. The available N increased from 139 (initial value) to 154 kg/ha, available P from 16.5 (initial value) to 17.4 kg/ha and available K from 154 (initial value) to 158 kg/ha under the highest dose of FYM, showing 10.7, 5.4 and 2.6% increase respectively. However, the available N, P and K values were 141, 17.2 and 148 kg/ha respectively at the end of the experiment. The available K content decreased with the in-

organic fertilization because of its lesser application and greater removal from the soil through rice and wheat crops. The soil pH (7.79 to 7.94) and electrical conductivity (0.26-0.27) remained statistically similar under all the treatments. Singh *et al.* (2007) reported that soil-organic C and available P contents increased significantly due to organic farming practice compared with the control as well as chemical fertilizer application. Hegde (1998) reported that continuous rice-wheat cropping had variable effects on soil fertility, depending on the soil type, nutrient application and productivity levels.

System's productivity and economics

The productivity of the system in terms of rice-equivalent yield was calculated on the basis of prevailing market price of wheat and rice. It was 9.99 t/ha with inorganic fertilizer application and 5.94 t/ha with zero fertilizer or FYM, which increased with graded doses of FYM application being the highest (8.88 t/ha) with the highest level FYM application. The system's productivity was more than 8.35 t/ha under 22.5-40, 30-30 and 30-40 t/ha FYM application in rice and wheat respectively, which were on a par among themselves but significantly inferior to that with inorganic fertilizer application (Table 4). The input cost varied from Rs 31,500 to 41,500 under treatments having different doses of FYM application. Input costs of some of the FYM doses were more than of the inorganic fertilizer application (Rs 34,500) due to bulkiness of FYM and greater quantity required. The net returns (Rs 42,463

Table 3. Effect of continuous organic fertilization in rice and wheat on soil fertility status after three years of experimentation

FYM (t/ha) Rice-wheat	Organic C (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	pH (1 : 2)	Electrical conductivity (dS/m)
0-0	0.32	129	14.7	143	7.94	0.27
0-20	0.35	144	14.9	145	7.92	0.27
0-30	0.36	145	15.3	146	7.90	0.27
0-40	0.38	147	15.6	148	7.90	0.27
15-0	0.33	143	15.1	144	7.90	0.27
15-20	0.36	145	15.6	147	7.86	0.27
15-30	0.38	147	15.7	149	7.85	0.26
15-40	0.39	148	15.9	152	7.85	0.26
22.5-0	0.35	145	15.6	146	7.86	0.27
22.5-20	0.37	149	16.1	148	7.82	0.27
22.5-30	0.39	148	16.4	151	7.84	0.27
22.5-40	0.40	151	16.8	154	7.82	0.27
30-0	0.36	148	15.7	147	7.83	0.27
30-20	0.39	150	16.5	154	7.80	0.27
30-30	0.40	153	16.9	157	7.78	0.27
30-40	0.42	154	17.4	158	7.78	0.27
Chemical fertilizer	0.36	141	17.2	148	7.79	0.27
SEm±	0.01	2	0.7	2	0.84	0.11
CD (P=0.05)	0.04	6	1.9	5	NS	NS
Initial	0.36	139	16.5	154	7.95	0.27

Table 4. System's productivity and economics of basmati rice-wheat cropping system under organic farming

FYM (t/ha) Rice-wheat	System's productivity (t/ha)	Total cost of cultivation (x10 ³ Rs/ha)	Net returns (x10 ³ Rs/ha)	Benefit : cost ratio
0-0	5.94	27.5	42.5	1.54
0-20	6.73	31.5	47.5	1.51
0-30	7.03	33.5	49.1	1.46
0-40	7.72	35.5	55.2	1.56
15-0	6.65	30.5	47.4	1.56
15-20	7.23	34.5	50.3	1.46
15-30	7.76	36.5	54.8	1.50
15-40	8.25	38.5	58.7	1.52
22.5-0	6.93	32.0	49.4	1.54
22.5-20	7.67	36.0	54.3	1.51
22.5-30	8.02	38.0	56.4	1.48
22.5-40	8.75	40.0	63.1	1.58
30-0	7.22	33.5	51.7	1.54
30-20	7.82	37.5	54.9	1.47
30-30	8.35	39.5	59.3	1.50
30-40	8.88	41.5	63.8	1.54
Chemical fertilizer	9.99	34.5	74.2	2.15
SEm±	0.34	0.8	0.9	0.07
CD (P=0.05)	0.93	2.2	2.7	0.19

to 74,170) were significantly higher under inorganic fertilization compared with all other treatments. Similarly, the highest benefit : cost ratio was obtained under inorganic (2.15) which was significantly higher compared with that under organic (1.46-1.54 under different doses) fertilisation.

It was concluded that wheat yield was significantly lower under organic fertilization than under inorganic fertilization, but basmati rice yield was at par under both the types of nutrient supply. The system's productivity and benefit : cost ratio were also less under organic fertilization than under inorganic fertilization, but soil fertility

improved significantly under organic fertilization. Thus economically it is not beneficial to produce organic wheat. Therefore it is necessary to give premium price support for the wheat produced under organic sources to make the organic farming remunerative under basmati rice-wheat cropping system.

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