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Effect of different combinations of organic materials and biofertilizers on productivity, grain quality and economics in organic farming of basmati rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted at Indian Agricultural Research Institute, New Delhi during crop year of 2006 and 2007 to find out a suitable combination of organic materials and biofertilizers for organic farming of basmati rice. The experiment was laid out in a randomized block design with six replications. Treatments consisted of seven combinations of different organic materials and biofertilizers [control, farmyard manure (FYM), vermicompost (VC), FYM + wheat residue (WR), VC + WR, FYM + WR + biofertilizers (B) and VC + WR + B. FYM and VC were applied on nitrogen basis @ 60 kg/ha, whereas WR was applied at 6 t/ha. For biofertilizers, blue green algae, cellulolytic culture and phosphorus solubilising bacteria were used. Application of FYM or VC significantly increased growth parameters and yield attributes of rice over control which led to 23-34% increase in grain yield and 14-18 % increase in net profit but had no significant effect on grain quality of basmati rice. Combination of FYM + WR or VC + WR resulted in higher increase in growth and yield attributing characters of rice than FYM or VC alone and increased grain yield over control by 38-49% and net profit by 25-31%. The combinations of FYM + WR + B and VC + WR + B resulted in highest increase growth and yield attributing characters of rice and increased grain yield of basmati rice over control by 51-58%, and net return by 37-47%. These combinations were significantly superior to all other combinations in all the growth and yield parameters, yield, net profit and grain quality of basmati rice and thus hold a great promise in organic farming of basmati rice.

Key words: Basmati rice, Economics, Grain quality, Organic farming, Productivity

Rice (*Oryza sativa* L.) crop cultivated on 43.7 million ha area in India contributes about 41.7% of the total food grain production (Kumar *et al*., 1998). Organic farming often has to deal with a scarcity of readily available nutrients in contrast to inorganic farming which rely on soluble fertilizers. The aim of nutrient management in organic systems is to optimize the use of on–farm resources and minimize losses (Kopke, 1995). Incorporation of straw, results in recycling of a sizable amount of plant nutrients. For example wheat straw accounts for about 35-40% N, 10-15% of P and 80-90% of K removal by wheat crop (Sharma and Sharma, 2002). However, there is a great difficulty in using the crop residue of cereals due to higher C: N ratio. Hence there is an urgent need to develop a suitable technology to use crop residue in organic farming of rice. We have to mix the crop residues of cereals with well decomposed farmyard manures/compost/vermicompost or crop residue of legumes for narrowing down C:N ratio so as to overcome the adverse effect of immobilization of native soil N. Hence, the present study was conducted to study the effect of different combinations of organic manures, wheat residues and biofertilizers in organic farming of rice.

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MATERIALS AND METHODS

A field experiment was conducted at research farm of the Indian Agricultural Research Institute, New Delhi for two years (2006 and 2007). The soil was medium in organic C (0.51%), low in available nitrogen (73.1 kg/ha) and medium in available phosphorus (8.42 kg/ha) and available potassium (108.9 kg/ha) and had a pH 8.16. The experiment was laid out in a randomised block design with six replications. Treatments consisted of seven combinations of different organic materials and biofertilizers [control, farmyard manure (FYM), vermicompost (VC), FYM + wheat residue (WR), VC + WR, FYM + WR+ biofertilizers (B) and VC + WR+ B]. FYM and VC were applied on nitrogen basis @ 60 kg/ha, whereas wheat residue was applied @ 6 t/ha. For biofertilizers, blue green algae (BGA), cellulolytic culture and phosphorus solubilising bacteria (PSB) were used. Farmyard manure used in the experiment was well decomposed. It contained 6,100-6,200 mg N/kg FYM, 2,500-2,700 mg P/kg FYM, 3,000-3,100 mg K/kg FYM, 39-40 mg Zn /kg FYM, 21-22 mg Fe/kg FYM, 11-12 mg Mn/kg FYM and 2.6-2.7 mg Cu/kg FYM and had a C:N ratio of 23-24. Similarly VC contained 11,900-12,000 mg N/ kg VC, 6,265-6,300 mg P/kg VC, 6,900-7,000 mg K/kg VC, 86-88 mg Zn/kg VC, 57-58 mg Fe/kg VC , 37-38 mg Mn/kg VC, and 8-9 mg Cu/kg VC and had a C:N ratio of 17-18. Wheat residue (WR) contained 3,900-4,100 mg N/kg WR , 490-500 mg P/kg WR, 15,600-15,700 mg K/kg WR, 2,989-3,467 mg Zn/kg WR, 350-373 mg Fe/kg WR, 74-78 mg Mn/kg WR and 16-17 mg Cu/kg WR and had a C:N ratio of 71-72. The nutrients added through various organic materials are given in Table 1. Wheat residue was incorporated during the puddling, whereas FYM and VC were applied after the puddling. Cellulolytic culture containing four fungi, *Aspergillus awamori, Trichome virile, Phanerochete chrysosporium* and *Aspergillus wolulens* was inoculated at the time of residue incorporation, whereas Multani mitti based BGA containing four micro-organisms *Aulosira fertilissima, Nostoc muscorum, Tolyparthrix tenuis* and *Anabaena variabilies* was inoculated 20 days after rice transplantig. The inoculation of PSB was done by dipping the roots of rice seedling in PSB slurry before transplanting. Rice 'Pusa Basmati 1' was transplanted in mid-July with 2 to 3 seedlings/hill of 21-25 days of age at a spacing of 20 cm x 10 cm. Rice was irrigated frequently to maintain 2-3 cm standing water in all the plots. The irrigation was stopped 10 days before harvesting. Rice was harvested in the first week of November.

RESULTS AND DISCUSSION

Growth, yield attributes and yields

Application of FYM or VC significantly increased plant height, number of panicles/m^2 in both years and number of filled grains/panicle in second year over control (Table 2), which led to 23-34% increase in grain yield over control (Table 3). Awan *et al*. (2000), Shanmugam and Veeraputhran (2001) and Bhattacharya *et al*. (2003) also reported beneficial effects of FYM and VC application on growth, yield parameters and yield of rice. Combination of FYM + WR and VC + WR resulted in higher increase in growth and yield attributing characters of rice which led to 38-49% increase in grain yield over control and 12-17% over FYM and VC alone. However, FYM + WR and VC + WR were not significantly superior to FYM and VC alone. Sharma and Prasad, (2001) also reported that rice did not respond to incorporation of residues. Mishra *et al.* (2006) on the other hand, reported that incorporation of vermicompost in combination with rice residue significantly increased the grain yield of rice. The combinations of FYM + WR + B and VC + WR + B resulted in highest increase in grain yield (51-58%) over control, 18-22% over FYM and VC alone and 6-10% over FYM + WR and VC + WR FYM and VC. The increase in grain yield was according to the quantity of nutrients added through various organic materials and biofertilers under different treatments (Table 1).

Grain quality

Since the N, P, K, Zn, Fe, Mn and Cu concentration in rice grain did not differ significantly in two years the mean data over the two years are presented in Table 4. Application of FYM or VC significantly increased N, K, Mn and Cu concentration in rice grain over control but did not affect the P, Zn and Fe concentration of rice grain significantly. The effect of FYM +WR and VC + WR were similar and significantly increased N, P, K, Fe Mn and Cu concentration over control. The combinations of FYM + WR + B and VC + WR + B were at par and significantly increased N, P, K, Zn, Fe, Mn and Cu concentration in rice grain over control. The increase in the nutrient concentration with FYM+WR+B or VC+WR+B was higher as compared to those obtained with other nutrient combination. The concentration of a particular nutrient in rice grain was, thus, linked with the supply of that particular nutrient through organic materials applied in different treatments (Table 1).

The milling, physical and cooking quality of rice was also affected by different nutrient combinations. The mean data over the two years indicated that hulling and milling per cent, kernel length and breadth before and after cooking were significantly more with FYM and VC as compared to control (Table 5). Zhang and Shao (1999) and Prakash *et al*. (2002) also reported a significant increase in hulling per cent of rice with FYM application. Head rice recovery and the length elongation ratio and breadth expansion ratio after cooking remained unaffected by FYM and VC application. The effects of FYM + WR and VC + WR were similar to those of FYM and VC but significantly increased head rice recovery, kernel length elongation ratio and breadth expansion ratio after cooking over control. The combinations of FYM + WR+ B and VC + WR+ B were more effective and significantly increased hulling per cent, milling per cent and kernel breadth expansion ratio over FYM and VC alone. Chinnusamy *et al*. (2006) also reported that the combination BGA + PSB + VAM + *Azospirillum* was best for improvement in growth and yield traits and nutritional status of rice.

Nutrient uptake

Application of FYM significantly increased quantity of N, P, K, Zn, Fe, Mn and Cu removed by rice grain over control (Table 6). Vermicompost proved its superiority over FYM in respect of P, Zn, Fe, Mn and Cu removal by rice grain. Application of wheat residue with FYM or VC

Table 1. Quantity (kg/ha/year) of N, P, K, Fe, Zn, Mn and Cu added through organic materials and biofertilizers under various treatments

Treatment	N	P	K	Fe	Zn	Mn	Cu
Farmyard manure (FYM)	60	25-27	30-31	0.21-0.22	0.40	0.12	0.03
Vermicompost (VC)	60	31-32	35	0.29	0.43-0.44	0.19	0.04
FYM + Wheat residue (WR)	83	28-29	124-125	2.31-2.32	0.58-0.61	0.56-0.59	0.13
VC + WR	83	35	128-129	2.39-2.52	0.61-0.65	0.46-0.63	0.14
FYM + WR + Biofertilizer (B)	108	40-41	124-125	2.31-2.32	0.58-0.61	0.56-0.59	0.13
VC + WR + B	108	47	128-129	2,39-2.52	0.61-0.65	0.46-0.63	0.14

Table 2. Effect of organic materials and biofertilizers on growth and yield parameters of rice

Treatment	Plant height (cm)		Panicles (No/m^2)		Filled grains/ panicle		Test weight (g)	
	2006	2007	2006	2007	2006	2007	2006	2007
Control	94.3	95.4	219	215	81.7	82.2	19.9	20.1
FYM	104.3	105.1	272	287	84.7	113.2	21.1	21.5
VC	106.2	107.7	285	294	85.7	123.3	21.5	21.7
FYM + WR	105.7	107.0	290	297	87.2	124.1	21.7	22.2
VC + WR	108.4	109.7	310	327	89.3	133.6	22.0	22.6
FYM + WR + Biofertilizer (B)	109.7	107.9	307	321	88.1	133.5	22.0	22.7
VC + WR + B	107.0	110.9	351	371	90.7	141.5	22.3	22.8
SEm ±	3.7	3.4	12.9	12.8	2.7	4.1	0.8	0.8
CD (P=0.05)	11.4	10.5	39.8	39.3	8.2	12.5	2.4	2.6

Table 3. Effect of organic materials and biofertilizers on grain and straw yields and harvest index of rice

Treatment	Grain yield (t/ha)		Biological yield (t/ha)		Harvest index (%)	
	2006	2007	2006	2007	2006	2007
Control	3.26	3.45	8.80	9.53	37.0	36.2
FYM	4.02	4.28	10.60	11.26	37.9	38.0
VC	4.27	4.61	11.30	12.08	38.0	38.2
FYM + WR	4.57	4.77	11.97	12.47	38.1	38.2
VC + WR	4.77	5.15	12.48	12.97	38.2	39.6
FYM + WR + Biofertilizer (B)	4.92	5.23	12.78	13.21	38.5	39.6
VC + WR + B	5.04	5.47	12.93	13.53	39.0	40.5
SEm ±	0.18	0.20	0.45	0.48	0.4	0.6
CD (P=0.05)	0.57	0.60	1.39	1.45	1.1	1.9

Table 4. Effect of organic materials and biofertilizers on nutrient concentration of rice grain

Treatment	N(%)	P(%)	K(%)	Zn (ppm)	Fe (ppm)	Mn(ppm)	Cu (ppm)
Control	1.19	0.210	0.221	30.9	34.5	32.8	11.4
Farmyard manure (FYM)	1.27	0.216	0.239	32.7	35.7	34.6	12.5
Vermicompost (VC)	1.33	0.224	0.245	33.0	36.0	35.8	13.6
FYM + Wheat residue (WR)	1.33	0.238	0.248	33.5	36.5	35.6	13.1
VC + WR	1.38	0.244	0.255	34.0	37.0	36.8	14.2
FYM + WR + Biofertilizer (B)	1.39	0.251	0.257	34.2	37.3	36.4	13.9
VC + WR + B	1.44	0.256	0.263	34.6	37.8	37.6	15.0
SEm ±	0.03	0.007	0.005	1.1	0.7	0.6	0.4
CD (P=0.05)	0.10	0.021	0.016	3.3	2.1	1.7	1.3

also resulted in a significant increase in nutrient removal by rice grain. Kachroo *et al.* (2006) also reported that incorporation of wheat residue in rice significantly increased the nutrient uptake of rice as compared to without residue incorporation. Similarly inoculation of biofertilizers along with FYM+WR or VC+WR significantly increased the quantity of nutrient removal by rice grain.

Economics

The cost of cultivation of rice varied from Rs. 20,610/ha for control plot to Rs. 37,770/ha for VC+WR+B in first year and from Rs. 20,990/ha for control plot to Rs. 40,650/ha for VC+WR+B in second year of study. Application of FYM increased cost of cultivation by 34-38%, VC by 61-71%, FYM+WR by 56-60%, VC+WR by 82-93%, FYM+CR+B by 57-61% and VC+WR+B by 83-94%. Application of FYM significantly increased net income of rice over control by Rs 6,060-9,050/ha (Table 7). Hargilas (2006) also reported an increase in net income of rice with FYM application. FYM and VC did not differ significantly in term of net income of rice. Application of FYM + WR gave significantly higher net profit of rice than

Table 5. Effect of organic materials and biofertilizers on milling, physical and cooking quality parameters of rice (Mean over two years)

Treatmet	Milling quality			Physical quality				Cooking quality	
	Hulling per cent	Milling per cent	Head rice recovery (%)	Kernel length (mm)		Kernel breadth (mm)		Length elongation ratio after cooking	Breadth expansion ratio after cooking
				Before cooking	After cooking	Before cooking	After cooking		
Control	65.9	57.9	48.8	5.95	9.32	1.32	1.67	1.56	1.25
Farmyard manure (FYM)	71.3	62.5	51.4	6.69	11.25	1.48	1.86	1.67	1.26
Vermicompost (VC)	71.8	64.0	52.3	6.88	11.66	1.49	1.97	1.68	1.31
FYM + Wheat residue (WR)	73.5	65.2	52.7	6.98	12.11	1.50	2.06	1.73	1.36
VC + WR	74.3	66.3	53.7	7.08	12.35	1.55	2.21	1.74	1.42
FYM + WR + Biofertilizers (B)	76.9	67.1	54.0	7.21	12.78	1.57	2.25	1.77	1.44
VC + WR + B	77.7	68.7	54.9	7.33	13.12	1.58	2.42	1.78	1.52
SEm ±	1.4	1.5	1.2	0.21	0.60	0.05	0.08	0.05	0.05
CD (P=0.05)	4.4	4.6	3.6	0.64	1.87	0.16	0.23	0.16	0.16

Table 6. Effect of organic materials and biofertilizers on nutrient uptake by rice grain

Treatment	N	P	K	Zn	Fe	Mn	Cu
Control	40.0	7.0	7.4	103.7	115.7	110.0	38.2
Farmyard manure (FYM)	52.6	8.9	9.9	135.7	148.1	143.6	51.9
Vermicompost (VC)	59.2	9.9	10.9	146.5	159.8	158.9	60.4
FYM + Wheat residue (WR)	62.0	11.1	11.6	165.8	170.4	166.2	61.2
VC + WR	68.4	12.1	12.6	168.6	183.5	182.5	70.4
FYM + WR + Biofertilizer (B)	70.2	12.7	13.0	173.6	189.3	184.7	70.5
VC + WR + B	75.7	13.5	13.8	181.8	198.6	197.6	78.8
SEm ±	2.2	0.3	0.7	0.2	0.1	0.1	0.1
CD (P=0.05)	6.8	0.8	2.1	0.6	0.4	0.3	0.3

* : Uptake in g/ha

Table 7. Effect of organic materials and biofertilizers on economics of cultivation of rice

Treatment	Cost of cultivation ($10^3 \times$ Rs/ha)		Net return ($10^3 \times$ Rs/ha)		B : C ratio	
	2006	2007	2006	2007	2006	2007
Control	20.6	21.0	35.9	51.0	1.74	2.43
Farmyard manure (FYM)	27.6	29.0	42.0	60.1	1.52	2.07
Vermicompost (VC)	33.1	36.0	40.9	60.0	1.23	1.66
FYM + Wheat residue (WR)	32.1	33.5	47.0	65.8	1.46	1.96
VC + WR	37.6	40.5	45.0	66.4	1.19	1.64
FYM + WR + Biofertilizer (B)	32.3	33.7	52.4	74.9	1.64	2.23
VC + WR + B	37.8	40.7	49.3	72.8	1.31	1.79
SEm ±			0.8	0.9	0.16	0.19
CD (P=0.05)			2.4	2.6	0.47	0.56

FYM alone in both the years of study. Similarly VC + WR was significantly superior to VC alone. Inoculation of biofertilizers with FYM + WR and VC+WR also significantly increased net profit of rice over FYM + WR and VC+WR, respectively.

The present study, thus indicates that a combination of FYM + WR + biofertilizers or VC + WR + biofertilizers holds a promise for organic farming of basmati rice.

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