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Residual influence of organic materials, crop residues, and biofertilizers on performance of succeeding mung bean in an organic rice-based cropping system

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Abstract

Background

The present investigation was undertaken to assess the residual influence of organic materials and biofertilizers applied to rice and wheat on yield, nutrient status, and economics of succeeding mung bean in an organic cropping system. The field experiments were carried out on the research farm of IARI, New Delhi during crop cycles of 2006 to 2007 and 2007 to 2008 to study the effects of residual organic manures, crop residues, and biofertilizers applied to rice and wheat on the performance of succeeding mung bean. The experiment was laid out in a randomized block design with three replications. Treatments consisted of six combinations of different residual organic materials, and biofertilizers included residual farmyard manure (FYM) and vermicompost (VC) applied on nitrogen basis at 60 kg ha^{-1} to each rice and wheat crops, FYM + wheat and rice residues at 6 t ha^{-1} and mung bean residue at 3 t ha^{-1} in succeeding crops (CR), VC + CR, FYM + CR + biofertilizers (B), VC + CR + B, and control (no fertilizer applied). For biofertilizers, cellulolytic culture, phosphate-solubilizing bacteria and *Rhizobium* applied in mung bean.

Results

Incorporation of crop residue significantly increased the grain yield of mung bean over residual of FYM and VC by 25.5% and 26.5%, respectively. The combinations of FYM + CR + B and VC + RR + B resulted in the highest increase growth and yield attributing characters of mung bean and increased grain yield of mung bean over the control by 47% and net return by 27%.

Conclusions

The present study thus indicate that a combination of FYM + CR + B and VC + CR + B were economical for the nutrient need of mung bean in organic farming of rice-based cropping system.

Keywords

Crop residues, Economics, FYM, Green gram, Nutrient concentration, Vermicompost

Introduction

The rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system (RWCS) occupies about 28.8 million hectares (m ha) in five Asian countries, namely, India, Pakistan, Nepal, Bangladesh, and China (Prasad 2005). These five countries represent 43% of the world population on 20% of the world's arable land (Singh and Paroda 1994). In India, RWCS occupy 12 m ha and contributes about 31% of the total food grain production (Kumar and Yadav 2006). Similarly in China, RWCS occupies about 13 m ha (Jasdan and Hutchaon 1996) and contributes about 25% of the total cereal production in the country (Lianzheng and Yixian 1994). Thus, RWCS are of considerable significance in meeting Asia's food requirements. However, practice of following a cereal-cereal cropping system on the same piece of land over years has led to soil fertility deterioration, and questions are being raised on its sustainability (Duxbury and Gupta 2000; Ladha et al. 2000; Prasad 2005). Efforts were, therefore, made to find out alternate cropping systems. Sharma and Prasad (1999) recommended that growing a short-duration mung bean after wheat and incorporating of its residue in succeeding rice made rice-wheat cropping system more productive, remunerative, and soil recuperative than traditional rice-wheat cropping system.

Organic farming of Basmati rice-based cropping system is another alternative system for sustainability of crop production and natural resources. Moreover, there is a great demand of organically grown food in European and Middle East countries and offer two to two and a half times higher prices for organic produce (Partap 2006). Organic farming often has to deal with a scarcity of readily available nutrients in contrast to inorganic farming which relies 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). Maximum use of crop residues has been suggested towards building soil fertility (Jasdan and Hutchaon 1996). Rice and wheat straw have large potential for plant nutrients in organic farming of rice-wheat system. The straw in the system accounts about 35% to 40% N, 10% to 15% of P, and 80% to 90% of K removal by these crops (Sharma and Sharma 2004). Incorporation of straw, thus, results in recycling of a sizable amount of plant nutrients. However, there is a great difficulty in using the plant 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. We have to mix the plant residues of cereals with well-decomposed farmyard manures or plant residue of legumes for narrowing down of C/N ratio so as to overcome the adverse effect of immobilization of native plant nutrients. Sharma and Prasad (1999) reported that incorporation of mung bean residue was found to be at par with Sesbania green manure in rice-wheat system.

The responses of the succeeding crops in a cropping system are influenced greatly by the preceding crops and the inputs applied therein. Therefore, recently greater emphasis is being laid on the cropping system as a whole rather than on the individual crops. In addition, organic manures and biofertilizers have carry-over effect on the succeeding crops. Jamaval (2006) reported that around 30% of the applied nitrogen as manure may become available to the immediate crop and rest to the subsequent crops. Maintenance of soil fertility is important for obtaining higher and sustainable yield due to large turnover of nutrient in the soil-plant system. Mung bean (*Vigna radiate* L.), commonly known as green gram, is an important conventional pulse crop in India. It has an edge over other pulses because of its high nutritive value, digestibility, and non-flatulent behavior. It is grown principally for its protein-rich edible seeds (Haq 1989). An important feature of the mung bean crop is its ability to establish a symbiotic partnership with specific bacteria, setting up the biological N_2 fixation in root nodules that supplies required nitrogen to the plant (Mandal et al. 2009). The present investigation was therefore undertaken to assess the residual influence of organic materials and biofertilizers applied to rice and wheat on yield, nutrient status, and economics of succeeding mung bean in an organic cropping system.

Methods

Experimental design

The field experiment was conducted during spring 2007 and 2008 at the research farm of the Indian Agricultural Research Institute, New Delhi, India to study the residual effects of organic materials, crop residues, and biofertilizers applied to the cropping system on performance of succeeding mung bean crop (Figure 1). It is situated at 28.4°N latitude and 77.1°E longitude at an elevation of 228.6 m above the mean sea level (Arabian Sea) for two years (2006 to 2007 and 2007 to 2008). The soil was medium in organic C (5.1-mg kg^{-1} soil), low in available nitrogen (73.1-mg kg^{-1} soil), medium in available phosphorus (8.42-mg kg^{-1} soil), available potassium (108.87-mg kg^{-1} soil), and had a pH 8.16. The experiment was laid out in a randomized block design with three replications.

Figure 1 Timetable of the cropping system

Treatment regimen

Treatments consisted of six combinations of different residual organic materials and biofertilizers and control as follows:

1. Farmyard manure (FYM) applied on nitrogen basis at 60 kg ha^{-1} to each rice and wheat crops
2. Vermicompost (VC) applied on nitrogen basis at 60 kg ha^{-1} to each rice and wheat crops. FYM and VC were applied to both rice and wheat, whereas mung bean was grown on residual fertility
3. FYM + crop residue (CR) whereas rice and wheat residues were applied at 6 t ha^{-1} to wheat and mung bean, respectively, and mung bean residue applied at 3 t ha^{-1} to rice
4. VC + CR
5. FYM + CR + biofertilizers (B) including cellulolytic culture (CC) and phosphate-solubilizing bacteria (PSB) were used in all the crops, whereas BGA, *Azotobacter*, and

Rhizobium applied in rice, wheat, and mung bean, respectively

6. VC + CR + B
7. Control (no fertilizer applied)

As biofertilizers, CC and PSB were used in all the crops, whereas BGA, *Azotobacter*, and *Rhizobium* applied in rice, wheat, and mung bean, respectively. Cellulolytic culture containing four fungi (*Aspergillus awamori*, *Trichoderme viride*, *Phanerochaete chrysosporium*, and *Aspergillus wolulens*) was inoculated at the time of residue incorporation, whereas *Azotobacter*, *Rhizobium*, and PSB (*Pseudomonas striata*) were used to inoculate the seeds as per the treatments. Farmyard manure used in the previous crops was well decomposed. It contained N (6,150 mg kg^{-1}), P (2,600 mg kg^{-1}), K (3,150 mg kg^{-1}), Mn (11.5 mg kg^{-1}), Zn (39.5 mg kg^{-1}), Cu (2.65 mg kg^{-1}), and Fe (21.5 mg kg^{-1}) and had a C/N ratio of 23.5. Similarly VC contained N (1,1950 mg kg^{-1}), P (6,283mg kg^{-1}), K (6,950 mg kg^{-1}), Mn (37.5 mg kg^{-1}), Zn (87 mg kg^{-1}), Cu (8.5 mg kg^{-1}), and Fe (57.5 mg kg^{-1}) and had a C/N ratio of 17.5. The chemical compositions of crop residues are given in Table 1.

Table 1 Chemical composition of crop residues applied in rice-wheat-mung bean cropping system

Composition (mg kg^{-1})	2006 to 2007			2007 to 2008		
	Rice	Wheat	Mung bean	Rice	Wheat	Mung bean
Total N	4,700	3,900	15,000	5,000	4,100	15,200
Total P	680	490	1,100	700	500	1,200
Total K	14,600	15,600	4,400	14,650	15,700	4,500
Organic C	408,000	400,000	401,000	410,000	403,000	403,000
Fe	434.23	349.80	849.56	437.41	372.97	876.21
Zn	100.52	29.89	69.13	105.09	34.67	72.04
Mn	58.23	73.69	79.65	60.69	78.52	88.62
Cu	40.02	16.85	22.23	40.67	17.43	23.04

Analytical technique

Grain and stover samples of mung bean were dried in hot air oven at 60°C for 6 h and ground in a Macro-Wiley Mill (Paul N. Gardner Company, Inc., FL, USA) to pass through a 40-mesh sieve. A representative sample of 0.5-g grain and straw was taken for the determination of nitrogen, phosphorus, and potassium. The nitrogen concentration in grain and straw samples was determined by modified Kjeldahl method (Jackson 1973); total phosphorus, by Vanadomolybdo phosphoric acid yellow color method and flame photometry method, as described by Prasad et al. (2006). The NPK concentration in grain and straw was expressed in percentage. Iron, zinc, manganese, and copper were determined in diacid digest of plant tissues using AAS as in the case of soil analysis. The N, P, and K uptake in grain or straw was worked out by multiplying their percent concentrations with the corresponding yield. The total uptake of N, P, and K was obtained by adding up their respective uptake in grain and straw. This was expressed in kilogram per hectare. Protein content in mung bean grains was obtained by multiplying the N concentration of grain with a factor 6.25 (Juliano 1985). The protein yield of mung bean was calculated by multiplying its protein concentration with grain yield.

The cost of mung bean cultivation was calculated on the basis of prevailing rates of inputs, and gross income was calculated on the basis of procurement price of mung bean grain and prevailing market price of mung bean stover. The income was obtained by subtracting the cost of cultivation from the gross income, i.e.,

$$\mathrm{Netincome} = \mathrm{grossincome} - \mathrm{costofcultivation}.$$

The net profit of the rotation was calculated by adding the net profits of the rice and wheat together.

Statistical analysis

The data relating to each character were analyzed by applying the technique of ‘analysis of variance’ for randomized block design as described by Cochran and Cox (1957). Critical difference at 5% level of significance was calculated for comparing the mean of difference presented in the summary table.

Results and discussion

Yield attributes

During both years of study, application of FYM had no significant effect on the number of pods of mung bean, whereas all other combinations of organic manures and biofertilizers significantly (p = 0.05) increased the number of pods per plant over the control (Table 2). During the second year of experiment, the combination of VC + CR + B was significantly superior to FYM and VC alone. The increased pod formation in treatments, where organic manures and crop residues were applied, may be attributed due to better plant development through efficient utilization of soil resources by the plant, where primary growth elements were available in sufficient amount. During the first year, FYM, VC, FYM + CR, VC + CR, and FYM + CR + B had no significant effect on the number of grains per pod, whereas VC + CR + B significantly increased the number of grains per pod. During the second year, the results were similar to those observed in the first year except that VC + CR, FYM + CR + B also significantly increased the number of grains per pod over the control. Similar results were reported by Srinivas and Shaik (2002). During both years, FYM and VC applied to rice and wheat did not affect the test weight of mung bean, whereas all other combinations of organic manures and biofertilizers significantly increased the test weight of mung bean over the control. Effects of different combinations of organic manures and biofertilizers applied to rice, wheat, and mung bean on the grain yield of mung bean were greater in the second year as compared to the first year. Residual effect of organics was also noticed by Reddy and Reddy (2005) wherein the plant height, number of leaves, leaf area, yield attributes, and root yield in radish were significantly affected due to the residual effect of vermicompost in onion-radish cropping system.

Table 2 Effect of treatments on the yield attributes of mung bean

	Number of pods per plant		Number of grains per pod		Test weight (g)	
	2007	**2008**	**2007**	**2008**	**2007**	**2008**
Organic materials and biofertilizers						
Control	10.3	10.8	6.8	6.9	39.5	39.8
FYM	11.6	12.3	7.3	7.5	42.5	42.7
VC	12.9	13.7	7.4	7.7	43.1	43.3
FYM + CR	12.8	14.8	7.7	7.8	44.6	45.0
VC + CR	14.3	15.7	7.8	7.9	44.9	45.4
FYM + CR + B	13.6	16.0	7.8	7.9	45.3	45.4
VC + CR + B	15.1	16.8	8.0	8.1	45.6	46.1
SEM±	0.76	0.93	0.33	0.31	1.53	1.68
LSD (p = 0.05)	2.34	2.82	1.02	0.96	4.71	5.18

SEM±, standard error of the mean; LSD, least significant difference.

Grain and stover yields

In terms of statistical significance (p = 0.05), FYM had no significant effect on the grain yield of mung bean, whereas FYM + CR, VC + CR, FYM + CR + B, and VC + CR + B, being at par, significantly increased the grain yield of mung bean over the control, FYM, and VC alone in the first year and over the control and FYM alone in the second year (Table 3). Weather conditions during the second year of study were more favorable than those of the first year. Mean monthly maximum and minimum temperatures were relatively low during the second year as compared to the first year. Total rainfall during the crop growth period of mung bean was about five times more in the second year than in the first year. All these favorable weather conditions resulted in higher yield during the second year as compared to the first year. On the other hand, the superiority of vermicompost was attributed to its slow and steady decomposition, which probably released the nutrients slowly and in higher quantity compared to other organic materials. Poonam et al. (2007) reported that seed inoculation with *Rhizobium* recorded an increase in yield by 12% to 16%. Conjunctive use of *Rhizobium* with PSB and plant growth-promoting rhizobacteria revealed synergistic effect on the symbiotic parameters and grain yield of mung bean. In both years, stover yield of mung bean was not significantly affected by FYM and VC and FYM + CR, whereas other combinations of organic manures and biofertilizers significantly increased the stover yield of mung bean over the control. There was no significant difference between different combinations of organic manures and biofertilizers in both years of study. The findings are in corroboration with those reported by John De Britto and Sorna Girija (2006).

Table 3 Effect of treatments on the seed and stover of mung bean

	Grain yield (t ha^{-1})		Stover yield (t ha^{-1})	
	2007	**2008**	**2007**	**2008**
Organic materials and biofertilizers				
Control	0.68	0.69	2.69	2.70
FYM	0.74	0.76	2.93	3.02
VC	0.76	0.79	3.09	3.20
FYM + CR	0.92	0.96	3.30	3.44
VC + CR	0.95	1.00	3.47	3.63
FYM + CR + B	0.97	1.02	3.55	3.64

VC + CR + B	1.00	1.04	3.70	3.84
SEM±	0.050	0.051	0.20	0.28
LSD (*p* = 0.05)	0.154	0.157	0.62	0.86

SEM±, standard error of the mean; LSD, least significant difference.

NPK concentration

In 2007 as well as in 2008, all combinations of organic manures and biofertilizers significantly increased nitrogen concentration in mung bean grain over the control (Table 4). All the combinations of organic manures and biofertilizers were at par in respect of N concentration in mung bean grain in both years of study. In both years, FYM had no significant effect on N concentration in mung bean stover, whereas all other combinations of organic manures and biofertilizers significantly increased nitrogen concentration in mung bean stover over the control. There was no significant difference between the different combinations of organic manures and biofertilizers, and all the combinations, except FYM, significantly increased phosphorus concentration in mung bean grain over the control in both years. In both years, phosphorus concentration of mung bean was not significantly affected by FYM, VC, and FYM + CR, whereas other combinations of organic manures and biofertilizers significantly increased P concentration of stover over the control. There was no significant difference between different combinations of organic manures and biofertilizers in both years of study. In both years, the combinations of FYM, VC, FYM + CR, and VC + CR were at par and significantly increased K concentration in mung bean over the control. Similarly, FYM + CR + B and VC + CR + B, being at par, significantly increased K concentration in mung bean grain over FYM. In 2007 as well as in 2008, FYM had no significant effect on potassium concentration in mung bean stover, whereas VC, FYM + CR, VC + CR, and FYM + CR + B, being at par, significantly increased P concentration over the control. The combination of VC + CR + B was at par with VC + CR and FYM + CR + B but significantly superior to VC and FYM + CR combinations. This is in conformity with the result obtained by applying seaweed extract as a biostimulant in organic farming of green gram (Zodape et al. 2010).

Table 4 Effect of treatments on nitrogen, phosphorus, and potassium concentrations (%) in mung bean

	Nitrogen				Phosphorus				Potassium			
	Grain		Stover		Grain		Stover		Grain		Stover	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Organic materials and biofertilizers												
Control	2.91	2.92	1.29	1.28	0.316	0.316	0.08	0.08	0.77	0.76	0.38	0.37
FYM	3.31	3.24	1.50	1.52	0.342	0.351	0.10	0.10	0.83	0.84	0.42	0.43
VC	3.26	3.29	1.55	1.57	0.350	0.357	0.11	0.12	0.84	0.85	0.44	0.46
FYM + CR	3.27	3.29	1.54	1.57	0.348	0.356	0.11	0.12	0.85	0.87	0.44	0.46
VC + CR	3.32	3.38	1.59	1.62	0.356	0.363	0.12	0.13	0.87	0.89	0.47	0.50
FYM + CR + B	3.36	3.41	1.62	1.65	0.358	0.363	0.12	0.14	0.89	0.91	0.47	0.51
VC + CR + B	3.43	3.50	1.65	1.68	0.369	0.378	0.13	0.16	0.91	0.94	0.50	0.53
SEM±	0.10	0.10	0.08	0.09	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
LSD (*p* = 0.05)	0.31	0.32	0.25	0.27	0.03	0.04	0.03	0.06	0.06	0.06	0.05	0.07

SEM±, standard error of the mean; LSD, least significant difference.

NPK uptake by grain and stover

In both years, FYM and VC had no significant effect on nitrogen uptake over the control, whereas other combinations of organic manures and biofertilizers resulted in significantly (p = 0.05) higher nitrogen uptake by mung bean grain than the control (Table 5). In 2007 and 2008, FYM had no significant effect on nitrogen uptake by mung bean stover over the control, whereas VC, FYM + CR, VC + CR, and FYM + CR + B, being at par, significantly increased nitrogen uptake by mung bean stover over the control. The combination of VC + CR + B was at par with FYM + CR, VC + CR, and FYM + CR + B but significantly superior to VC and FYM alone. In 2007 and 2008, FYM had no significant effect on nitrogen uptake by mung bean, whereas VC, FYM + CR, and VC + CR, being at par, significantly increased nitrogen uptake by mung bean over the control. Similarly, FYM + CR + B and VC + CR + B were at par and significantly increased N uptake by mung bean over FYM and VC alone.

Table 5 Effect of treatments on nitrogen uptake (kg ha^{-1}) by mung bean

	2006			2007		
	Grain	**Straw**	**Total**	**Grain**	**Straw**	**Total**
Organic materials and biofertilizers						
Control	19.8	34.7	54.5	20.1	34.6	54.7
FYM	23.8	44.0	67.8	24.6	45.9	70.5
VC	24.8	47.9	72.7	26.0	50.2	76.2
FYM + CR	30.1	50.8	80.9	31.6	54.0	85.6
VC + CR	31.5	55.2	86.7	33.8	58.8	92.6
FYM + CR + B	32.6	57.5	90.1	34.8	60.1	94.9
VC + CR + B	34.3	61.1	95.4	36.4	64.5	100.9
SEM±	2.13	3.70	5.62	2.72	4.42	5.88
LSD (p = 0.05)	6.56	11.40	17.32	8.38	13.62	18.13

SEM±, standard error of the mean; LSD, least significant difference.

In both years, FYM and VC did not affect P uptake by mung bean grain significantly, whereas FYM + CR, VC + CR, FYM + CR + B, and VC + CR + B, being at par, significantly increased phosphorus uptake by mung bean grain over the control (Table 6). Also, FYM + CR + B and VC + CR + B were also significantly superior to FYM and VC alone. The combinations of FYM, VC, and FYM + CR in both years and VC + CR in only the first year had no significant effect on P uptake by mung bean stover, whereas FYM + CR + B and VC + CR + B in both years and VC + CR in the second year significantly increased phosphorus uptake by mung bean stover over the control. In both years, FYM and VC had no significant effect on P uptake by mung bean, whereas all other combinations of organic manures and biofertilizers significantly increased phosphorus uptake by mung bean over the control, the difference between different combinations being not significant.

Table 6 Effect of treatments on phosphorus uptake (kg ha^{-1}) by mung bean

	2006			2007		
	Grain	**Straw**	**Total**	**Grain**	**Straw**	**Total**
Organic materials and biofertilizers						
Control	2.2	2.2	4.4	2.2	2.2	4.4
FYM	2.5	2.9	5.6	2.7	3.0	5.7
VC	2.7	3.4	6.1	2.8	3.4	6.6

FYM + CR	3.2	3.6	6.8	3.4	4.1	7.5
VC + CR	3.4	4.2	7.6	3.6	4.7	8.3
FYM + CR + B	3.5	4.3	7.8	3.7	5.1	8.8
VC + CR + B	3.7	4.8	8.5	3.9	6.1	10.0
SEM±	0.21	0.65	0.71	0.25	0.79	0.87
LSD (p = 0.05)	0.65	2.01	2.19	0.78	2.43	2.68

SEM±, standard error of the mean; LSD, least significant difference.

In 2007 as well as in 2008, FYM and VC had no significant effect on K uptake by mung bean, whereas FYM + CR, VC + CR, FYM + CR + B, and VC + CR + B significantly increased potassium uptake by mung bean over the control (Table 7). There was no significant difference between different combinations of organic manures and biofertilizers in the second year, whereas in the first year, FYM + CR, VC + CR, FYM + CR + B, and VC + CR + B were at par but significantly superior to FYM alone. In both years, there was no significant effect of FYM, VC, and FYM + CR on potassium uptake by mung bean stover, whereas other combinations of organic manures and biofertilizers resulted in significantly higher potassium uptake than the control. The differences between different combinations of organic manures and biofertilizers were not significant in both years of study. In 2007, FYM and VC had no significant effect on K uptake by mung bean, whereas FYM + CR, VC + CR, and FYM + CR + B, being at par, significantly increased potassium uptake by mung bean over the control. The combination of VC + CR + B was at par with VC + CR and FYM + CR + B but significantly superior to FYM, VC, and FYM + CR. In 2008, FYM and VC also had no significant effect on K uptake by mung bean, whereas other combinations of organic manures and biofertilizers resulted significantly higher K uptake than the control. There was no significant difference between different combinations of organic manures and biofertilizers during this year.

Table 7 Effect of treatments on potassium uptake (kg ha^{-1}) by mung bean

	2006			2007		
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
Organic materials and biofertilizers						
Control	5.2	10.2	15.4	5.2	10.0	15.2
FYM	6.1	12.3	18.4	6.4	13.0	19.4
VC	6.4	13.6	20.0	6.7	14.7	21.4
FYM + CR	7.8	14.5	22.3	8.4	15.8	24.2
VC + CR	8.3	16.3	24.6	8.9	18.2	27.1
FYM + CR + B	8.6	16.7	25.3	9.3	18.6	27.9
VC + CR + B	9.1	18.5	27.6	9.8	20.4	30.2
SEM±	0.54	1.89	1.70	0.69	2.23	2.15
LSD (p = 0.05)	1.66	5.82	5.24	2.12	6.87	6.61

SEM±, standard error of the mean; LSD, least significant difference.

Micronutrient concentration in grain

In 2007, FYM, VC, and FYM + CR, being at par, significantly (p = 0.05) increased Zn concentration of mung bean over the control (Table 8). Similarly, VC + CR, FYM, CR + B, and VC + CR + B were at par and significantly increased zinc concentration of mung bean grain over FYM. In 2008, FYM, VC, and FYM + CR, being at par, significantly increased Zn concentration of mung bean grain. Similarly, VC + CR was at par with FYM + CR + B but significantly superior to FYM and VC. Similarly, VC + CR + B was at par with FYM + CR + B but significantly superior to FYM, VC, FYM + CR, and VC + CR.

Table 8 Effect of treatments on micronutrient concentration (ppm) by mung bean grain

	Zinc		**Copper**		**Iron**		**Manganese**	
	2007	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
Organic materials and biofertilizers								
Control	15.4	15.2	15.8	15.7	58.1	58.1	55.3	55.1
FYM	16.2	16.4	17.0	17.3	59.4	59.8	57.1	57.3
VC	16.4	16.7	17.4	17.6	60.2	60.8	57.5	57.7
FYM + CR	16.5	16.6	17.5	17.7	60.2	60.7	57.5	57.7
VC + CR	16.8	17.1	18.0	18.5	61.4	62.3	57.8	58.2
FYM + CR + B	16.9	17.5	18.3	18.7	61.4	62.2	58.0	58.7
VC + CR + B	17.1	17.8	19.1	19.7	62.8	63.7	58.5	59.0
SEM±	0.14	0.15	0.13	0.14	0.35	0.33	0.30	0.37
LSD (p = 0.05)	0.43	0.46	0.41	0.43	1.08	1.02	0.92	1.11

SEM±, standard error of the mean; LSD, least significant difference.

The copper concentration in mung bean grain with different combinations of organic manures and biofertilizers were found in the following increasing order: control < FYM < VC = FYM + CR < VC + CR = FYM + CR + B < VC + CR + B. In 2008, FYM, VC, and FYM + CR were at par and significantly increased Cu concentration by mung bean grain over the control. Similarly, VC + CR and FYM + CR + B were at par and resulted in significantly higher Cu concentration in mung bean grain than FYM, VC, and FYM + CR. The combination of VC + CR + B was significantly superior to other combinations of organic manures and biofertilizers.

In both years, FYM, VC, and FYM + CR, being at par, significantly increased iron concentration by mung bean over the control. Similarly, VC + CR and FYM + CR + B were at par and significantly increased Fe concentration of mung bean over FYM, VC, and FYM + CR. The combination of VC + CR + B was significantly superior to other combinations of organic manures and biofertilizers.

In the first year, FYM + VC, FYM + CR, VC + CR, and FYM + CR + B, being at par, significantly increased manganese concentration of mung bean grain over the control, whereas the combination of VC + CR + B was at par with VC + CR and FYM + CR + B but significantly superior to FYM, VC, and FYM + CR in respect to Mn concentration in mung bean grain. In the second year, FYM, VC, FYM + CR, and VC + CR were at par and significantly increased iron concentration in mung bean grain over the control. The combination of VC + CR + B was at par with VC, FYM + CR, VC + CR, and FYM + CR + B but significantly superior to FYM.

Protein

In both years, all the combinations of organic manures and biofertilizers were at par and significantly (p = 0.05) increased protein concentration in mung bean grain over the control (Table 9). In 2007, FYM, VC, and FYM + CR had no significant effect on the protein yield of mung bean, whereas VC + CR, FYM + CR + B, and VC + CR + B were at par with FYM, VC, and FYM + CR and increased the protein yield of mung bean over the control significantly. In 2008, FYM and VC had no significant effect on protein yield of mung bean, whereas FYM + CR, VC + CR, FYM + CR + B, and VC + CR + B being at par and significantly increased the protein yield of mung bean over the control. Dhaliwal et al. (2007) reported that the N and protein contents of seed in mung bean were significantly higher with both RFD (recommended fertilizer dose + residue incorporation over the chemical fertilizer treatments, being statistically on par with each other).

Table 9 Effect of treatments on protein content (%) and protein yield (kg ha^{-1}) of mung bean

	Protein content (%)		Protein yield (kg ha^{-1})	
	2007	**2008**	**2007**	**2008**
Organic materials and biofertilizers				
Control	18.2	18.3	124	126
FYM	20.1	20.3	149	154
VC	20.4	20.6	155	163
FYM + CR	20.4	20.6	188	198
VC + CR	20.8	21.1	198	211
FYM + CR + B	21.0	21.3	204	217
VC + CR + B	21.4	21.9	214	228
SEM±	0.51	0.56	21.2	23.10
LSD (p = 0.05)	1.56	1.74	65.47	71.05

SEM±, standard error of the mean; LSD, least significant difference.

Economics

In both years, FYM and VC were at par and significantly (p = 0.05) increased the gross income from mung bean over the control. Similarly, FYM + CR and VC + CR being at par and significantly increased the gross income of mung bean over FYM and VC alone (Table 10). The combinations of FYM + CR + B and VC + CR + B were at par with VC + CR but significantly superior to FYM, VC, and FYM + CR in respect of the gross income from mung bean.

Table 10 Effect of treatments on economics (×10^3 Rs ha^{-1}) of cultivation of mung bean

	Gross return		Cost of cultivation		Net return	
	2007	**2008**	**2007**	**2008**	**2007**	**2008**
Organic materials and biofertilizers						
Control	23.4	26.2	5.16	5.27	18.2	20.9
FYM	25.4	28.9	5.16	5.27	20.3	23.6
VC	26.2	30.1	5.16	5.27	21.0	24.8
FYM + CR	31.3	36.1	11.16	11.27	20.1	24.8
VC + CR	32.4	37.6	11.16	11.27	21.2	26.4
FYM + CR + B	33.0	38.3	11.34	11.45	21.7	26.9
VC + CR + B	34.1	39.2	11.34	11.45	22.8	27.8
SEM±	0.50	0.53	-	-	0.39	0.44
LSD (p = 0.05)	1.55	1.63	-	-	1.17	1.32

SEM±, standard error of the mean; LSD, least significant difference; Rs, Indian Rupees (Rs 1 = $0.0224)

The costs of cultivation of 2 years are given in Table 10. The cost of cultivation of a particular treatment did not vary in three replications; hence, data on cost of cultivation were not analyzed statistically. The cost of cultivation varied from Rs 5,160 to 5,270 to Rs 1,1340 to 1,1450. The incorporation of CR increased the cost of cultivation by 116% in the first year and 114% in the second year, whereas inoculation of biofertilizers increased the cost of cultivation by 1.6% in both years.

In the first year, FYM, VC, FYM + CR, and VC + CR were at par and significantly increased the net income of mung bean over the control. The combination of FYM + CR + B was at par with VC + CR and VC but significantly superior to FYM and FYM + CR. Similarly, VC + CR + B was at par with FYM + CR + B but significantly superior to FYM, VC, FYM + CR, and VC + CR. In the second year, FYM, VC, and FYM + CR were at par and significantly increased the net return of mung bean over the control. The combination of FYM + CR + B was at par with VC + CR and FYM + CR but significantly increased the net return of mung bean over FYM, VC, and FYM + CR. Similarly, VC + CR + B was at par with FYM + CR + B and significantly increased the net return of mung bean over FYM, VC, FYM + CR, and VC + CR. Naeem et al. (2006) reported the maximum net benefit of mung bean obtained from the treatment, where poultry manure was applied.

Conclusions

Organic farming may not lead to higher production and income in the short run as its returns are of long term nature. It is initially a soil-building process. Organic farming systems ensure built-in capacity to maintain and increase soil health and fertility leading to sustained increase in yield and production and low variability of crops which result to the stabilization and high jump in income and sustainability in agriculture. Findings of this study provided a sound base to believe that FYM + CR, VC + CR, FYM + CR + B, and VC + CR + B, being at par, significantly increased the grain yield of mung bean over the control, but incorporation crop residue plus inoculation of seeds with biofertilizers (CC + PSB + *Rhizobium*) resulted the most economical treatment with respect to increasing net profit. This was because of the low price of biofertilizers compared with crop residue. Both of FYM + CR + B and VC + CR + B combinations resulted in improved grain quality and nutrient uptake by grain. The present study thus indicates that a combination of FYM + CR + biofertilizers or VC + RR + biofertilizers holds a promise for organic farming of mung bean.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

This work is part of the Ph.D. thesis of MD where SNS supervised the thesis and MM participated in the statistical analysis and correction of the manuscript. All authors read and approved the final manuscript.

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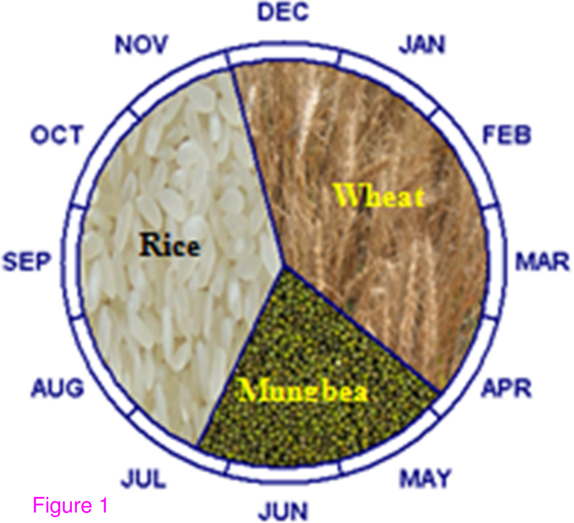
DEC
JAN
FEB
MAR
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Wheat
Rice
Mungbea

Figure 1