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Bell pepper yield and soil properties during conversion from conventional to organic production in Indian Himalayas

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ABSTRACT

A conversion period of at least two years is required for annual crops before produce may be certified as organically grown. There is a need for better understanding of the various management options for implementing from conventional to organic production. The purpose of this study was to evaluate the effects of three organic amendments on growth and yield of bell pepper (*Capsicum annuum* L.), the benefit:cost ratio, soil fertility and enzymatic activities during conversion to organic production. For that purpose six treatments were established: composted farmyard manure (FYMC, T_1); vermicompost (VC, T_2); poultry manure (PM, T_3) along with biofertilizers (BF) [*Azotobacter* + phosphorus solubilizing bacteria (*Pseudomonas striata*)] and mix of three amendments (FYMC + PM + VC + BF, T_4); integrated crop management (FYMC + NPK, T_5) and unamended control (T_6). The bell pepper yield under organic management was markedly lower (33–53% and 18–40% less in first and second year of conversion, respectively) than with the integrated crop management (FYMC 10 Mg ha^{-1} + NPK – 100:22:41.5 kg ha^{-1}) treatment (T_5). Combined application of three organic amendments (FYMC 10 Mg ha^{-1} + PM and VC each 1.5 Mg ha^{-1} + BF, T_4) and T_1 produced similar but significantly higher bell pepper yield (27.9 and 26.1 Mg ha^{-1}, respectively) compared with other organic amendment treatments. Both T_4 and T_1 greatly lowered soil bulk density (1.15–1.17 Mg m^{-3}), and enhanced soil pH (7.1) and oxidizable organic carbon (1.2–1.3%) compared with T_5 and unamended control (T_6) after a two-year transition period. However, the N, P and K levels were highest in the plots under integrated management. T_1 plots showed higher dehydrogenase activity values. However, acid phosphatase and β-glucosidase activities were higher in T_6 plots whereas urease activity was greater in T_5 plots compared with other treatments. Among the treatments involving organic amendments alone, T_1 gave a higher gross margin (US $ 8237.5 ha^{-1}) than other treatments. We conclude that T_1 was found more suitable for enhancing bell pepper growth and yield, through improved soil properties, during conversion to organic production.

1. Introduction

In the past five decades, the traditional knowledge and practices of organic farming have almost eroded from many parts of India due to influx of modern "green revolution" technologies. However, many communities particularly in the hill and mountain regions have sustained this knowledge. Hence, most of the cultivated area in north-western Himalayas of India has largely remained organic by default. In view of the renewed interest in organic farming and demand for organic products worldwide including India, these areas have vast potential to emerge as major suppliers of organic products. The world organic market is estimated at more than 30 billion Euros in 2006 (Willer and Yussefi, 2007). This organic market expansion makes it possible for farmers to sell their products at high price premiums. India's National Program for Organic Production (NPOP) requires at least a two-year conversion period for annual crops before produce may be certified as organically grown. These two years pose many challenges, because the changes in the chemical, physical, and biological properties of the soil take time to reach an ecological balance. Several experimental transitional studies have reported initial lower yields, followed by yields similar to those of conventional production (Liebhardt et al., 1989; MacRae et al., 1993; Astier et al., 1994). Lower yields in the transition from conventional to organic production are expected, due to lower nutrient concentration and slower release rates of organic materials (Liebhardt et al., 1989; MacRae et al., 1993). Nutrient management is, therefore, one of the most critical management areas for organic

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growers. Because synthetic inputs (i.e. chemical fertilizers and pesticides) are disallowed in organic crop production, there is a need for research on organically approved soil amendments and methods for improving soil fertility in organic farming systems, particularly during initial years. Organic fertility inputs such as farmyard manure (FYM) and green manure improve the soil physical properties by lowering bulk density, increasing water-holding capacity, and improving infiltration rates (Tester, 1990; Werner, 1997; Petersen et al., 1999; Bulluck et al., 2002; Gopinath et al., 2008). Several studies have shown that organic farming improves soil fertility over time (Drinkwater et al., 1995; Clark et al., 1998; Petersen et al., 1999; Van Diepeningen et al., 2006; Fliessbach et al., 2007; Saha et al., 2008). These organic systems also lead to higher soil quality and more biological activity in soil than conventionally managed systems (Reganold, 1988; Drinkwater et al., 1995; Castillo and Joergensen, 2001; Fliessbach et al., 2007; Garcia-Ruiz et al., 2008). Soil biological and biochemical properties are highly sensitive to environmental stress and changes in management practices (Dick, 1994). Therefore, measurement of selected soil enzymes has good potential as a soil quality indicator, as they better reflect the complex properties affecting soil quality (Trasar-Cepeda et al., 1998).

Vegetable farmers in Indian Himalayas routinely apply composted farmyard manure (FYMC), vermicompost and poultry manure to their soil either alone or in combination with mineral fertilizers. However, there is limited research on the effects of these organic amendments on yield of crops and on soil properties, particularly during the period of transition to organic production. We chose to evaluate the impact of different organically approved soil amendments on bell pepper (*Capsicum annuum* L.), an important off-season vegetable cultivated during summer and rainy seasons in north-western Himalayas of India. To understand better the efficacy of likely alternatives to conventional practices, we used on-farm inputs or locally produced manures such as FYMC, vermicompost, poultry manure and biofertilizers in this study. The objectives of the study were (i) to assess the short-term effect of different organic amendments and biofertilizers on soil chemical and biological properties and bell pepper yield in transition period to organic farming; and (ii) to evaluate the economics of organic bell pepper production in comparison with integrated crop management during the two-year conversion period. We hypothesized that different organic amendments will have variable effects on soil properties and crop yield during transition to organic production.

2. Materials and methods

2.1. Experimental set-up and crop management

A field experiment was conducted during the summer (April–July) season of 2005 and 2006 at an experimental farm, Hawalbagh (29°36′N, 79°40′E and 1250 m above mean level), Uttarakhand situated in Indian Himalayas. Before the present experiment, the land had been farmed almost exclusively in a maize–wheat rotation, which included the application of commercial fertilizer and pesticides. Soil samples taken from the surface 15 cm before treatment applications had organic C content of 1.13%, Kjeldahl-N 403 kg, Olsen-P 16.2 kg, ammonium acetate extractable-K 210 kg ha^{-1}, and a pH of 6.7. The experimental site received 211 mm and 354.5 mm rainfall during summer of 2005 and 2006, respectively. The mean weekly maximum and minimum temperatures ranged between 35.8 and 10.1 °C during 2005, and 32.5 and 9.4 °C during 2006.

This experiment included six treatments which were as follows: T_1, composted farmyard manure (FYMC) 20 Mg ha^{-1} + biofertilizers [*Azotobacter* + phosphorus solubilizing bacteria (*Pseudomonas striata*)]; T_2, poultry manure (PM) 5 Mg ha^{-1} + biofertilizers (BF); T_3, vermicompost (VC) 7.5 Mg ha^{-1} + BF; T_4, FYMC 10 Mg ha^{-1} + PM and VC each 1.5 Mg ha^{-1} + BF; T_5, integrated crop management (ICM) (FYMC 10 Mg ha^{-1} + recommended NPK – 100:22:41.5 kg ha^{-1}); and T_6, unamended control. The experiment was laid out in a randomized complete block design with four replications.

Composted FYM and vermicompost were produced on the Research Farm of Vivekananda Institute of Hill Agriculture, India. The FYMC was prepared after cattle dung and bedding material had been composted for 30 days. Residues of soybean (sourced from organic farming block of the institute) and partially decomposed cattle dung were used in 2:1 ratio (w/w) for vermicomposting. These materials were thoroughly mixed and put into a pit of size 2 m (L) × 1.5 m (W) × 0.5 m (D). Water was sprinkled to make the material sufficiently wet, and 4000 earthworms (*Eisenia foetida*) were introduced into the pit and was covered with a jute bag to prevent direct exposure to sunlight. The material in the pit was thoroughly mixed by hand twice, at an interval of 30 days. The compost was removed from the pit after 90 days, and the earthworms were separated with a sieve. Poultry manure was collected from the poultry farm located 2 km away from the research farm. The manure was stored for about 30 days before its application in the field. Composite samples of each amendment were collected 1 week before application to plots and were analyzed for different properties (Table 1). The amounts of nutrients (N–P–K) added in each treatment and year are given in Table 2.

All the experimental plots were manually tilled to a depth of 15 cm using a spade in both years. The organic amendments were treated with *Trichoderma viridae* at 2.5 kg ha^{-1}, as a prophylactic measure against soil-borne diseases, then incubated for about 20 days and were thoroughly incorporated into 15 cm surface soil 2 weeks before transplanting of bell pepper. All the organic amendments were applied on dry weight basis. Half the N and full P and K were applied at the time of transplanting in the plots under ICM through urea 109 kg ha^{-1}, single superphosphate 313 kg ha^{-1}, and muriate of potash 83 kg ha^{-1}. Remaining N was top-dressed in two equal splits, 45 and 60 days after planting.

Table 1
Moisture and nutrient contents of organic amendments used in the experiment.

Organic amendment	Year	Moisture (%)	Total nutrient content						
			N (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})	Fe (g kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})
FYMC	2005	52	11.2	4.30	6.60	5.22	290	59	311
	2006	56	10.3	4.80	7.20	6.50	298	54	374
Poultry manure	2005	43	17.2	16.1	8.20	4.64	362	77	402
	2006	48	18.5	17.6	7.90	4.21	355	84	407
Vermicompost	2005	58	15.5	6.30	5.30	11.03	124	34	326
	2006	61	16.0	6.10	5.60	12.10	136	55	315

FYMC: composted farmyard manure.

Table 2
Amount of nutrients added to bell pepper in each year.

Treatment	Nutrients added (kg ha^{-1})					
	N		P		K	
	2005	2006	2005	2006	2005	2006
T_1	224	206	86	96	132	144
T_2	86	93	81	88	41	40
T_3	116	120	47	46	40	42
T_4	161	155	76	84	86	92
T_5	212	203	65	70	108	114
T_6	–	–	–	–	–	–

T_1: composted farmyard manure (FYMC) 20 Mg ha^{-1} + biofertilizers (BF); T_2: poultry manure (PM) 5 Mg ha^{-1} + BF; T_3: vermicompost (VC) 7.5 Mg ha^{-1} + BF; T_4: FYMC 10 Mg ha^{-1} + PM & VC each 1.5 Mg ha^{-1} + BF; T_5: integrated crop management; T_6: unamended control.

Table 3
Parameters used to calculate economics of bell pepper cultivation.

Parameter	Actual values (Rs.)
Price of seed	1,800 ha^{-1}
Price of NPK	2,230 ha^{-1}
Price of FYMC	900 Mg^{-1} DW
Price of poultry manure	664 Mg^{-1} DW
Price of vermicompost	3,067 Mg^{-1} DW
Labor cost for planting bell pepper	2,000 ha^{-1}
Labor cost for fertilizer application	400 ha^{-1}
Labor cost for manure spreading and incorporation	200 Mg^{-1} DW
Price of bell pepper	15,000 Mg^{-1}

FYMC: composted farmyard manure; DW: dry weight basis; one US $ = Rs. 40.

Seedlings of bell pepper (45 days old) were transplanted in the planting geometry of 50 cm × 50 cm on 26 April 2005, and 20 April 2006 in the experimental plots. The seedlings were treated with biofertilizers before transplanting in the plots under different organic amendments. *Azotobacter* and PSB each at 2 kg ha^{-1} were mixed in 50 l water ha^{-1}, and the roots of bell pepper seedlings were dipped in the solution for 30 min before transplanting. Crop was irrigated adequately. No chemical insecticides, fungicides or herbicides were used in all the plots. Although chemicals can be used for pest management in ICM plots, their need was not felt, as any major insect-pests, weeds and diseases did not infest the crop in both the years. Weeds were managed by hand-weeding once, followed by two hoeings with a manually operated wheel-hoe. Azadirachtin [a neem (*Azadirachta indica*) based formulation] was sprayed twice during crop growth as a prophylactic measure against insect-pests. All the plant and soil parameters were measured from the center four rows of each plot. Random samples of five plants were taken from each plot at the vegetative growth stage (45 days after transplanting) for determination of plant height (cm). At harvesting time (60 days after transplanting), pepper fruits were picked weekly through the harvesting period for estimation of yield parameters such as fruits per plant, fruit length, and yield (Mg ha^{-1}).

2.2. Sampling and analysis of soil

Soil samples were collected from the surface layer (0–15 cm) of all the plots before treatment applications and immediately after bell pepper harvest in July 2006. Five random cores were taken from each plot with a 5-cm diameter tube auger and bulked. Soil samples were air-dried and ground to pass through a 2-mm sieve. All soil samples meant for chemical analysis were stored at room temperature until required for analysis. The rest of the soil samples were immediately transferred to the laboratory for analysis of enzyme activities. Soil samples were kept at 4 °C in plastic bags and analyzed within 2 weeks. Bulk density was determined by calculating the soil's dry weight (dried at 110 °C) and volume of the soil sample. The soil pH was determined in 1:2.5 soil:water suspension (Jackson, 1962). Oxidizable soil organic C was determined by the method of Walkley and Black (1934), Kjeldahl-N with a FOSS Tecator analyzer (Model 2200), and available P by the method of Olsen et al. (1954). Available K was determined with 1N NH_4OAc and flame photometer (Jackson, 1962). All chemical results are given as means of triplicate analyses and are expressed on an oven-dry basis. Soil moisture was determined after being dried at 105 °C for 24 h.

Soil dehydrogenase activity was estimated according to Casida et al. (1964). Soil was incubated with triphenyltetrazolium chloride and the triphenylformazan absorbance was measured at 485 nm. Urease activity in soil was measured by following the method of Tabatabai and Bremner (1972). Soil sample was incubated with THAM buffer (pH 9.0) and urea solution, excess urea was estimated colorimetrically at 527 nm. Acid phosphatase was determined according to Tabatabai and Bremner (1969) after soil incubation with *p*-nitrophenyl phosphate disodium and measuring the *p*-nitrophenol absorbance at 400 nm. β-Glucosidase activity was estimated by determination of the *p*-nitrophenol released after 1 h of soil incubation with *p*-nitrophenyl-β-D-glucopyranoside (Eivazi and Tabatabai, 1977). The amount of *p*-nitrophenol was determined at 400 nm using a spectrophotometer (Tabatabai and Bremner, 1969).

2.3. Economic analysis of bell pepper cultivation

Economic analysis was based on the prevailing cost of input/operations and price of produce (Table 3). The cost of bell pepper cultivation involved the expenditure towards land preparation, seed and sowing, manures/mineral fertilizers and their application, pest control, irrigation, harvesting, and rental value of land. The farm gate prices of various inputs were taken for economic analysis. The seed and mineral fertilizer costs were from agro-input retailers. Manure can represent a substantial cost to organic producers and can vary widely depending on transport distances and the costs of obtaining the manure (Archer et al., 2007). However, all the organic amendments did not have market price in the study area and hence they were costed in terms of the labor involved in different activities of composting, loading and transportation within 2 km of the field. A wage rate of Rs. 10 (US $ 0.25) h^{-1} was used in calculating labor costs. A price premium ranging from 10 to 100% higher than that for conventional produce is already being realized in many organically produced crops including bell pepper in India (Chadha and Choudhary, 2007). Therefore, economic evaluation of organic bell pepper cultivation was also done by assuming different price premiums (0–60%) for the produce to assess whether bell pepper can be profitably grown under organic farming conditions in comparison with conventional practice.

2.4. Statistical analysis

All of the soil and plant data were analyzed by using Duncan's multiple range tests (Duncan, 1955) at the $P < 0.05$ level. Differences between mean values were evaluated by a one-way analysis of variance (ANOVA) (SPSS version 10.0).

3. Results

3.1. Crop performance

In both the years, plant height was significantly greater for all the treatments than those for the unamended control (Table 4). T_5 and T_1

Table 4
Effect of different organic amendments on growth and yield of bell pepper.

Treatment	Plant height (cm)		Fruits plant^{-1}		Fruit length (cm)		Fruit yield (Mg ha^{-1})	
	2005	2006	2005	2006	2005	2006	2005	2006
T_1	58.7^a	57.9^{ab}	18.8^b	20.0^b	6.2^{ab}	6.7^{abc}	23.6^b	32.3^b
T_2	53.4^b	54.8^{bc}	13.2^c	16.5^{cd}	5.8^{bc}	6.2^{bc}	18.1^c	25.9^c
T_3	52.7^b	51.2^c	12.5^c	16.2^d	5.6^{bc}	6.1^c	16.7^c	23.7^c
T_4	56.3^{ab}	59.9^{ab}	18.0^b	19.0^{bc}	5.9^{bc}	6.8^{ab}	21.9^b	30.4^b
T_5	58.9^a	62.5^a	22.5^a	25.0^a	6.8^a	7.1^a	35.3^a	39.4^a
T_6	41.4^c	43.6^d	9.2^d	9.0^e	5.2^c	5.0^d	8.8^d	6.5^d

T_1: composted farmyard manure (FYMC) 20 Mg ha^{-1} + biofertilizers (BF); T_2: poultry manure (PM) 5 Mg ha^{-1} + BF; T_3: vermicompost (VC) 7.5 Mg ha^{-1} + BF; T_4: FYMC 10 Mg ha^{-1} + PM & VC each 1.5 Mg ha^{-1} + BF; T_5: integrated crop management; T_6: unamended control. Means in the same column with different superscript letters are significantly ($P < 0.05$) different.

Table 5
Effect of organic amendments on different soil properties after two years.

Treatment	BD (Mg m^{-3})	pH	SOC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	1.15^d	7.1^a	1.3^a	452.6^b	21.8^{ab}	252.0^a
T_2	1.26^{ab}	7.0^{ab}	1.2^{ab}	450.4^b	20.7^{ab}	231.8^{bc}
T_3	1.22^{bc}	7.0^{ab}	1.1^b	440.9^b	19.2^{bc}	223.8^{cd}
T_4	1.17^{cd}	7.1^a	1.2^{ab}	449.3^b	21.4^{ab}	247.1^{ab}
T_5	1.20^{bcd}	6.9^b	1.1^b	483.5^a	23.4^a	260.9^a
T_6	1.31^a	6.7^c	0.9^c	408.1^c	16.9^c	210.4^d

T_1: composted farmyard manure (FYMC) 20 Mg ha^{-1} + biofertilizers (BF); T_2: poultry manure (PM) 5 Mg ha^{-1} + BF; T_3: vermicompost (VC) 7.5 Mg ha^{-1} + BF; T_4: FYMC 10 Mg ha^{-1} + PM & VC each 1.5 Mg ha^{-1} + BF; T_5: integrated crop management; T_6: unamended control. BD: bulk density; SOC: soil organic carbon. Means in the same column with different superscript letters are significantly ($P < 0.05$) different.

had significantly higher plant height compared to T_2, T_3 and T_4 treatments in both years. However, the lowest values were obtained from plants treated with VC. T_5 produced significantly higher number of fruits per plant than other treatments in both years. Among the organic amendments, T_1 and T_4 presented the highest number of fruits per plant than other treatments in both years.

T_5 showed highest fruit length compared to other treatments in both years. However, it was not showed statistical differences in fruit length among soil unamended control and T_1, T_2, T_3 and T_4 treatments. In both years, T_5 treatment had the highest fruit yield, showing statistical differences with respect to other treatments, whereas T_6 showed the lowest fruit yield. Crop yield in T_1 treatment was a 33.1% in 2005 and 18% in 2006 lower than crop yield in T_5.

3.2. Soil properties

The soil bulk density was reduced significantly in all the treatments except T_2 compared to T_6 (Table 5). Application of FYMC (T_1) resulted in the lowest bulk density closely followed by T_4. The soil pH increased significantly in all the plots applied with organic amendments compared with T_6 after two years of conversion (Table 5). Similarly to pH, soil organic carbon (SOC) was also significantly higher in manure and compost amended plots compared with T_6. Plots under T_1 treatment had the highest SOC compared with other treatments. The plots under T_5, however, had significantly higher levels of available N, P and K compared with other treatments.

Soil enzyme activities varied considerably among the treatments (Fig. 1.). The dehydrogenase activity increased significantly in T_1 plots followed by T_4 and T_5 treatments (Fig. 1A). The dehydrogenase activity was lowest in T_3 and T_6 plots. The activity of acid phosphatase was greater in T_6 plots followed by T_5 (Fig. 1B). Different organic amendments (T_1–T_4) had similar effect on the activity of acid phosphatase. The activity of β-glucosidase also showed similar trend as that of acid phosphatase (Fig. 1C). However, the urease activity was greater in the plots under T_5 treatment and lowest in T_6 plots (Fig. 1D). Among the organic treatments, T_1 plots had higher urease activity.

3.3. Economics of bell pepper cultivation

In general, the cost of bell pepper cultivation was higher with the use of different organic amendments except T_2 compared to T_5 (Table 6). It was highest (Rs. 4880 ha^{-1} or US $ 116.2 ha^{-1}) with T_3 due to higher input cost of amendment (Rs. 2000 Mg^{-1} or US $ 47.6 Mg^{-1}). T_5 gave the highest gross margin and benefit:cost (B:C) ratio compared to other treatments. Among the organic treatments, T_1 gave the highest gross margin compared to other treatments. However, T_2 gave the highest B:C ratio compared to other organic treatments. This was due mainly due to the low input cost of poultry manure.

The gross margin from T_5 was higher compared to other treatments even when 20% price premium (Rs. 18 kg^{-1} or US $ 0.43 kg^{-1}) was assumed for organic bell pepper (Fig. 2). However, at 40% price premium for organic bell pepper, the gross margin from T_1 and T_4 was comparable with that of T_5. At 60% price premium for organic bell pepper, the former two treatments gave higher gross margin whereas, T_2 gave similar gross margin as that of T_5.

4. Discussion

A better understanding of the efficacy of various management options is necessary for a smooth transitioning from conventional to organic crop production. Our results show that the bell pepper growth and yield attributes were poor in the plots under organic management compared with T_5. Amor (2006) also reported that all plant growth parameters of sweet pepper were reduced in the organic treatment compared with the conventional counterpart. There were significant differences among treatments with respect to bell pepper yield in both years (Table 4). ICM produced significantly higher fruit yield compared to all other treatments in both the years. Russo and Taylor (2006) reported that in the first year, bell pepper yields for the plants in the transition plots were lower than for the plants in the conventional production. In contrast, Chellemi and Rosskopf (2004) reported that organic pepper yields from soil-solarized plots were similar to yields obtained by conventional farmers using high inputs of rapidly

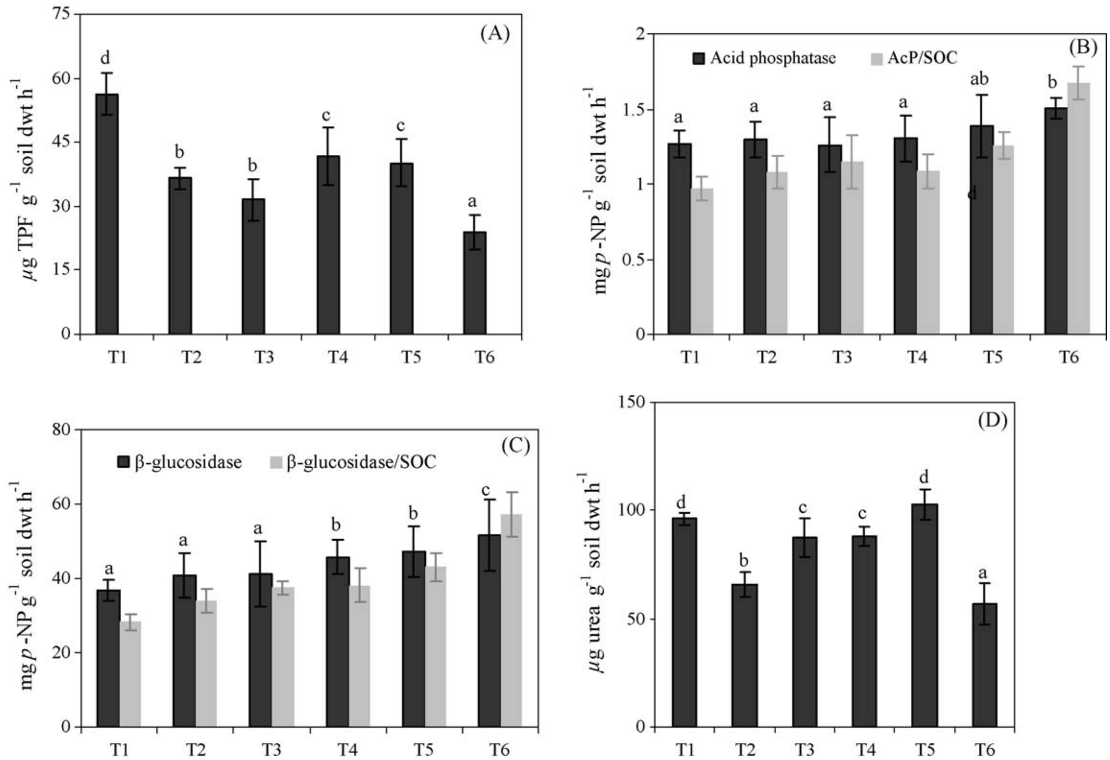

Fig. 1. Effect of organic amendments on soil dehydrogenase (A), acid phosphatase (B), β-glucosidase (C) and urease (D) activities. T_1: composted farmyard manure (FYMC) 20 Mg ha^{-1} + biofertilizers (BF); T_2: poultry manure (PM) 5 Mg ha^{-1} + BF; T_3: vermicompost (VC) 7.5 Mg ha^{-1} + BF; T_4: FYMC 10 Mg ha^{-1} + PM & VC each 1.5 Mg ha^{-1} + BF; T_5: integrated crop management; T_6: unamended control. Bars with different letters within each sub-figure are significantly ($P < 0.05$) different.

mobile nitrogen sources. In our study, the yield reduction under the best organic treatment (T_1) compared to T_5 was 33.1% in 2005 and 18% in 2006. Lower crop growth and yields in the plots amended with organic manures and composts may have been associated with the less readily available nutrients in the initial years of conversion (Table 5), as nutrient cycling processes in first-year organic systems change from inorganic N fertilization to organic amendments (Harris et al., 1994; Reider et al., 2000) and slower release rates of organic materials (Liebhardt et al., 1989; MacRae et al., 1993). Soil fertility in organic production systems is controlled by organic amendments, such as FYMC, vermicompost and poultry manure used in this study. Nitrogen availability in particular is maintained through the synchronization across space and time of net N mineralization from soil organic N pools and plant uptake of inorganic N. This process depends on the constant renewal of biologically available N to soil organic N pools (Delate and Cambardella, 2004).

The use of organic amendments has been associated with many desirable soil properties including lowering of bulk density (Tester, 1990; Werner, 1997; Petersen et al., 1999; Bulluck et al., 2002; Gopinath et al., 2008). Highest bulk density was found in T_6 and lowest in T_1. Soil pH also increased from 6.7 in T_6 to 7.1 in T_1. Soil pH tended to increase in the organic systems, whereas the integrated systems had the lower pH values (Fliessbach et al., 2007). Our results are consistent with earlier reports (Reganold et al., 1993; Drinkwater et al., 1995; Werner, 1997; Clark et al., 1998) where organic systems had higher pH levels in mildly acidic soils than their conventional counterparts. This illustrates the important role organic amendments and other organic matter inputs can have in buffering the soil (Stroo and Alexander, 1986; Arden-Clarke and Hodges, 1988).

An important feature of environmental benefit due to a change in agricultural practice is the soil carbon content (Carter et al., 1997). Depending on soil type, climate, management, and the capacity of a soil to store organic matter, SOC levels may increase linearly with the amount of organic matter input (Carter, 2002).

Table 6
Effect of different organic amendments on cost of cultivation and economic returns.

Treatment	Cost of cultivation (000'Rs. ha^{-1})	Gross margin (000'Rs. ha^{-1})	Benefit:cost ratio
T_1	47.0	329.5	7.0
T_2	29.4	267.6	9.1
T_3	48.8	224.2	4.6
T_4	41.7	310.8	7.4
T_5	39.7	464.3	11.7
T_6	22.5	81.0	3.6

T_1: composted farmyard manure (FYMC) 20 Mg ha^{-1} + biofertilizers (BF); T_2: poultry manure (PM) 5 Mg ha^{-1} + BF; T_3: vermicompost (VC) 7.5 Mg ha^{-1} + BF; T_4: FYMC 10 Mg ha^{-1} + PM & VC each 1.5 Mg ha^{-1} + BF; T_5: integrated crop management; T_6: unamended control. One US $ = Rs. 40.

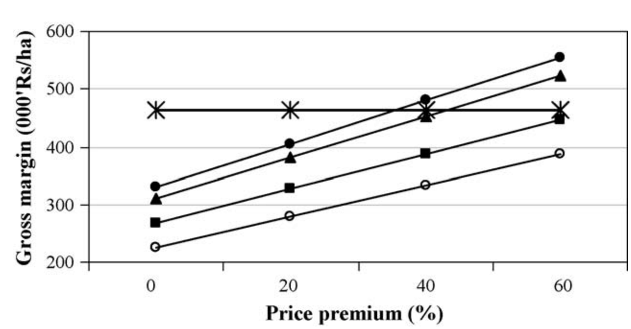

Fig. 2. Gross margin at 0, 20, 40 and 60% price premium for organic capsicum grown with different organic amendments —●— Composted farmyard manure (FYMC) 20 Mg ha^{-1} + biofertilizers (BF), —■— Poultry manure (PM) 5 Mg ha^{-1} + BF, —○— Vermicompost (VC) 7.5 Mg ha^{-1} + BF, —▲— FYMC 10 Mg ha^{-1} + PM & VC each 1.5 Mg ha^{-1} + BF, —✳— Integrated crop management.

This part of soil organic matter is usually bound to clay and silt particles and aggregates. SOC was increased by 44 per cent due to application of composted farmyard manure compared with T_6. Further increase in soil organic matter is likely to be found in particulate organic matter, which is merely part of the sand fraction. During the conversion years from conventional to organic farming systems, soils show a very slow but important increase in soil organic matter (Kuo et al., 1997; Clark et al., 1998). Furthermore, lower availability of plant nutrients in plots applied with organic amendments is expected due to slower release rates of nutrients from organic materials particularly during initial years of conversion to organic production (Brusko, 1989; Liebhardt et al., 1989; MacRae et al., 1993).

Organic amendments can foster beneficial microorganisms, which in turn facilitates soil enzymatic activities (Doran et al., 1996; Drinkwater et al., 1995). Dehydrogenase activity basically depends on the metabolic state of the soil biota. A significant increase in dehydrogenase activity occurred in the T_1 plots, indicating that there is more microbial activity in FYMC treatment than in other treatments (Gopinath et al., 2008). This maximum activity might be linked to more substrate availability in FYMC amended plots. Being the substrate for microbial activity, soil organic matter plays an important role in protecting soil enzymes, which become immobilized in a three-dimensional network of clay and humus complexes (Tabatabai, 1994). This reflects the greater biological activity in these plots and the stabilization of extra-cellular enzymes through complexation with humic substances (Burns, 1982; Colvan et al., 2001; Nannipieri et al., 1978).

In our study, β-glucosidase activity was slightly higher in T_5 plots than those under organic amendments. Highest activity was observed in T_6. Our result is in contrast with Garcia-Gill et al. (2000). Higher activity of β-glucosidase in T_6 might be attributed to higher utilization of comparatively less complex molecules like cellobiose in this soil by microorganisms for their carbon source. Whilst, in other treatments, more readily available carbon source might have been utilized by microbes, supplied in the form of composted FYM, vermicompost or poultry manure. The result is further supported by higher ratio of β-glucosidase activity to soil organic carbon in T_6 (Fig. 1C), indicating greater extra-cellular enzymatic activity in T_6 treatment.

Phosphatases play an important role in P cycling, where organic P is more due to limited biological mineralization of organic matter as a result of formation of complexes of organic P with active Al and Fe and the amount of available P is low (Turrion et al., 2000). No changes in soil phosphatase activity were observed among T_1, T_2 and T_3 treatments, but more activity was recorded in T_4 and T_5. Interestingly, acid phosphatase activity was higher in T_6, which may be attributed to slightly lower soil pH (Eivazi and Tabatabai, 1977). Furthermore, the ratio of acid phosphatase to soil organic carbon was highest in T_6 treatment (Fig. 1B) that could be due to greater extra-cellular enzymatic activity. Our result is consistent with Garcia-Gill et al. (2000), who reported similar phosphatase activity in mineral fertilized and control soil.

Urease activity was higher in T_1 and T_5 and the lowest in T_6. Among organic treatments, FYMC amended plots had the greatest urease activity, followed by plots treated with VC and PM. This might be attributed to the presence of more simplified organic compounds in FYMC, which leads to faster mineralization. Similar results were observed in our earlier study (Saha et al., 2008). It was also reported that urease activity was positively correlated with N content of soil (Frankerberger and Dick, 1983). The higher urease activity in T_1 and T_5 plots and lesser activity in other treatments might be attributed to more available N content in T_5 and T_1 plots (Table 5) compared with other treatments.

Manure can represent a substantial cost to organic producers and can vary widely depending on transport distances and the costs of obtaining the manure (Archer et al., 2007). We also observed significant reduction in bell pepper yield and higher production costs for treatments involving organic amendments. As a result, organic bell pepper cultivation may not be as profitable as that grown with integrated crop management practices during conversion period, when no price premium is available for organic bell pepper. Furthermore, at least 40% price premium for organic bell pepper may be required to offset the higher cost of cultivation and low yields under organic production system compared with integrated crop management. Russo and Taylor (2006) also reported that if a price premium is assigned to the value of organically grown bell pepper then the costs of production could be mitigated.

5. Conclusion

The comparison of different organic amendments such as FYMC, PM, VC and combined application of organic amendments, along with biofertilizers revealed that there was 25.1–45.9% reduction in bell pepper yield compared with T_5. Among the organic amendments, T_1 was found to be better in improving soil properties and crop growth and yield during conversion to organic production. At least 40% price premium for organic bell pepper may be required to offset the higher cost of cultivation and low yields under organic production system. We conclude that composted farmyard manure along with biofertilizers can be used for quick stabilization of soil fertility as well as biological activity, which in turn help in nutrient availability during transition period and minimum loss in yield.

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