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 transitioning 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. The organic amendments were composted farmyard manure (FYMC), vermicompost (VC) and poultry manure (PM) along with biofertilizers [*Azotobacter* + Phosphorus solubilizing Bacteria (*Pseudomonas striata*)]. The bell pepper yield under organic management was markedly lower (33-53% and 18-40% less in first and second year of conversion, respectively) compared with conventional practice (FYMC 10 Mg ha^{-1} + NPK – 100:22:41.5 kg ha^{-1}). Composted FYM 20 Mg ha^{-1} + biofertilizers (BF), and combined application of three organic amendments (FYMC 10 Mg ha^{-1} + PM and VC each 1.5 Mg ha^{-1} + BF) produced similar but significantly higher yield (27.9 and 26.1 Mg ha^{-1}, respectively) of bell pepper compared with other organic amendment treatments. Composted FYM 20 Mg ha^{-1} + BF and combined application of three organic amendments greatly lowered soil bulk density (1.15-1.17 Mg m^{-3}), and enhanced pH (7.1) and oxidizable organic carbon (1.2-1.3%) of soil compared with conventional practice and unamended control after a two-year transition period. However, the N, P and K levels were highest in the plots under conventional practice. Plots amended with FYMC 20 Mg ha^{-1} + BF had higher soil microbial activities of dehydrogenase, acid phosphatase and β-glucosidase compared with other treatments. However, the urease activity was greater in the plots under conventional practice. Among the treatments involving organic amendments alone, FYMC 20 Mg ha^{-1} + BF gave the highest gross margin (US $ 8237.5 ha^{-1}) compared to other treatments. We conclude that FYMC 20 Mg ha^{-1} + BF was found more suitable for enhancing bell pepper growth and yield, through improved soil properties, during conversion to organic production.

Keywords: Crop yield; Economics; Organic Conversion; Organic farming; Soil properties

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 initially 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 growers. Because synthetic inputs (i.e. chemical fertilizers and pesticides) are disallowed in organic crop production, there is 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 like farmyard manure (FYM) and green manure improve 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 do conventionally managed systems (Reganold, 1988; Drinkwater et al., 1995; Castillo and Joergensen, 2001; Fliesbach 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 a good potential as soil quality indicator, as they reflect better 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 better understand 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 effect of different organic amendments and biofertilizers on performance of bell pepper and on soil properties; and (ii) to evaluate the economics of organic bell pepper production in comparison with conventional production during the two-year conversion period.

2. Materials and methods

2.1 Experimental set-up and crop management

A field experiment was conducted during summer (April – July) season of 2005 and 2006 at experimental farm, Hawalbagh ($29^0$36' N, $79^0$40' E and 1250 m above mean level), Uttarakhand situated in Indian Himalayas. Before the present experiment, the land was 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%, available N 403 kg, available P 16.2 kg, available 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^{o}C during 2005, and 32.5 and 9.4^{o}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, conventional practice (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 composting cattle dung and bedding material 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 filled in a pit of size 2 m (L) X 1.5 m (W) X 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 with hands twice at an interval of 30 days. The compost was removed from the pit after 90 days and earthworms were separated using 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 moisture and nutrient composition (Table 1). The amount 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 two 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 in the plots under conventional practice at the time of transplanting through urea (46-0-0, N-P-K), single superphosphate (0-7-0, N-P-K), and muriate of potash (0-0-50, N-P-K). Remaining N was top-dressed in two equal splits, 45 and 60 days after planting. Seedlings of bell pepper (45 days old) were transplanted in the planting geometry of 50X50 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 liters water ha^{-1} and the roots of bell pepper seedlings were dipped in the solution for 30 minutes before transplanting. Crop was irrigated adequately. No chemical insecticides, fungicides or herbicides were used in keeping with organic standards. Weeds were managed by hand-weeding once followed by two hoeings with a manually operated wheel-hoe. The crop was not infested by any major insect-pests and diseases in both the years. However, azadirachtin [a neem (*Azadirachta indica*) based formulation] was sprayed two times during crop growth as a prophylactic measure against insect-pests. All plant and soil parameters were measured from the center four rows of each plot. At the vegetative growth stage (45 days after transplanting), random samples of five plants from each plot were taken 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 5-cm diameter tube auger and bulked. Soil samples were air-dried and ground to pass a 2-mm sieve. All soil samples meant for chemical analysis were stored at room temperature until analysis. Rest of the soil samples were immediately transferred to the laboratory

for analysis of microbial activities. Soil samples were stored at 4°C in plastic bags and analyzed within 2 weeks. Bulk density was determined by determining the soil dry weight (dried at 110^{0}C) and volume of the soil sample. The soil pH was determined in 1:2.5 soil/amendment: 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 1 N NH_4OAc and a flame photometer (Jackson, 1962). All chemical results are means of triplicate analyses and are expressed on an oven-dry basis. Soil moisture was determined after drying at 105°C for 24 h.

Soil dehydrogenase activity was estimated by reducing 2, 3, 5-triphenyltetrazolium chloride (Casida et al., 1964). Soil sample (5 g) was mixed with 50 mg $CaCO_3$ and 1 ml 3 % (w/v) 2, 3, 5-TTC and incubated for 24 h at 37±1 ^{0}C.

Dehydrogenase enzyme converts TTC to 2, 3, 5-triphenylformazan (TPF). The TPF formed was extracted with acetone (3 × 15 ml), the extracts were filtered through Whatman No. 5 and absorption was measured at 485 nm in a spectrophotometer (Analytik Jena, Germany). Urease activity in soil was measured following the method developed by Tabatabai and Bremner (1972). Soil sample (5 g) was incubated with 5 ml of 0.05 M THAM buffer (pH 9.0) and 1 ml (0.2%) of urea solution at 37^0C for 2 h. Excess urea was extracted with KCl-PMA solution and estimated colorimetrically at 527 nm. Acid phosphatase was assayed using 1 g soil (wet equivalent), 4 ml 0.1 M modified universal buffer (pH 6.5), and 1 ml 25 mM *p*-nitrophenyl phosphate (Tabatabai and Bremner, 1969). After incubation for 1 h at 37±1°C, the enzyme reaction was stopped by adding 4 ml 0.5 M NaOH and 1 ml 0.5 M $CaCl_2$ to prevent dispersion of humic substances. The absorbance of *p*-nitrophenol in the supernatant was measured at 400 nm. β-glucosidase activity was estimated by determination of the *p*-nitrophenol released after 1 h of incubation with *p*-nitrophenyl-*β*-D-glucopyranoside (Eivazi and Tabatabai, 1977). Two ml of 0.1 M maleate buffer and 0.5 ml of substrate were added to 0.5 g of sample and incubated at 37^o C for 60 min. The reaction was stopped by trishydroxymethyl aminomethane (THAM). The amount of *p*-NP was determined using a spectrophotometer at 400 nm (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 to 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). Conventional practice being at par with FYMC 20 Mg ha^{-1} + BF and combined application of FYMC 10 Mg ha^{-1} + PM and VC each 1.5 Mg ha^{-1} + BF recorded significantly higher plant height compared to other treatments in both the years. However, the lowest values were obtained from plants treated with VC 7.5 Mg ha^{-1} + BF. Conventional practice produced significantly higher number of fruits $plant^{-1}$

compared to other treatments in both the years. Among the organic amendments, FYMC 20 Mg ha^{-1} + BF recorded the highest number of fruits plant^{-1} in both the years. It was, however, at par with combined application of organic amendments (FYMC 10 Mg ha^{-1}, PM and VC each 1.5 Mg ha^{-1} and BF) but significantly superior to other treatments. In both the years, PM 5 Mg ha^{-1} + BF and VC 7.5 Mg ha^{-1} + BF recorded similar but significantly higher number of fruits plant^{-1} compared to unamended control.

In 2005, conventional practice being at par with FYMC 20 Mg ha^{-1} + BF recorded significantly higher fruit length compared to other treatments. Other treatments, however, had no significant effect on fruit length compared to unamended control. In 2006 also, conventional practice being at par with FYMC 20 Mg ha^{-1} + BF and combined application of organic amendments (FYMC 10 Mg ha^{-1}, PM and VC each 1.5 Mg ha^{-1} and BF) gave significantly higher fruit length compared to other treatments. PM 5 Mg ha^{-1} + BF and VC 7.5 Mg ha^{-1} + BF had similar effect on fruit length and were significantly superior to unamended control. There were significant differences among treatments with respect to bell pepper yield in both years (Table 4). In general, the crop yield under all the treatments except unamended control was higher in 2006 than in 2005. Conventional practice produced significantly higher fruit yield compared to all other treatments in both the years. The yield reduction under the best organic treatment (FYMC 20 Mg ha^{-1} + BF) compared to conventional practice was 33.1% in 2005 and 18% in 2006. These results suggest that the yield gap between the conventional practice and organic amendment treatments narrowed down in second year of conversion. Among the treatments involving organic amendments, FYMC 20 Mg ha^{-1} + BF and combined application of organic amendments (FYMC 10 Mg ha^{-1}, PM and VC each 1.5 Mg ha^{-1} and BF) being at par gave significantly higher fruit yield compared to other treatments.

3.2 Soil properties

The soil bulk density was reduced significantly in all the treatments except PM 5 Mg ha^{-1} + BF compared with unamended control (Table 5). Composted FYM 20 Mg ha^{-1} + BF registered the lowest bulk density closely followed by combined application of organic amendments (FYMC 10 Mg ha^{-1}, PM and VC each 1.5 Mg ha^{-1} and BF). The soil pH increased significantly in all the plots applied with organic amendments compared with unamended control after two years of conversion (Table 5). Composted FYM 20 Mg ha^{-1} + BF and combined application of organic amendments registered similar but significantly higher soil pH (7.1) compared with conventional practice and unamended control. Similarly to pH, soil organic carbon (SOC) was also significantly higher in manure and compost amended plots compared with unamended control. Composted FYM 20 Mg ha^{-1} + BF application resulted in the highest SOC compared with other treatments. The plots under conventional practice, however, had significantly higher levels of available N, P and K compared with other treatments.

The enzymes assayed in this study were chosen because they play central roles in C, N, and P cycling in soils. Soil enzyme activities varied considerably among the treatments studied (Fig. 1.). The enzyme involved in intracellular microbial metabolism, i.e. dehydrogenase, increased significantly in the plots amended with FYMC 20 Mg ha^{-1} + BF followed by combined application of organic amendments (Fig. 1A). The dehydrogenase activity was lower in the plots amended with VC 7.5 Mg ha^{-1} + BF. The activity of acid phosphatase, which plays an essential role in the mineralization of organic P, was greater in FYMC 20 Mg ha^{-1} + BF amended plots followed by conventional practice (Fig. 1B). The activity of β-glucosidase, which plays critical role in releasing sugars of lower molecular weight, also showed similar trend as that of acid phosphatase

(Fig. 1C). However, the urease activity was greater in the plots under conventional practice (Fig. 1D). Overall, our results have shown that the addition of organic amendments to an agricultural soil has a variety of effects on enzyme activities.

3.3 Economics of bell pepper cultivation

In general, the cost of cultivation was higher with the use of different organic amendments except PM 5 Mg ha^{-1} + BF compared to conventional practice (Table 6). It was highest (Rs 4880 ha^{-1} or US $ 116.2 ha^{-1}) with vermicompost 7.5 Mg ha^{-1} + BF due to higher input cost of amendment (Rs 2000 Mg^{-1} or US $ 47.6 Mg^{-1}). Conventional practice gave the highest gross margin and benefit:cost (B:C) ratio compared to other treatments. Among the treatments involving organic amendments alone, FYMC 20 Mg ha^{-1} + BF gave the highest gross margin compared to other treatments. Combined application of FYMC 10 Mg ha^{-1}, PM and VC each 1.5 Mg ha^{-1} and BF was the next best treatment followed by PM 5 Mg ha^{-1} + BF. The latter, however, recorded the highest B:C ratio compared to other organic amendments. This was due mainly to low input cost of poultry manure.

The gross margin with conventional practice was higher compared to other treatments involving organic amendments, even when 20% price premium (Rs 18 kg^{-1} or US $ 0.43 kg^{-1}) was assumed for organic bell pepper (Fig. 3). However, at 40% price premium for organic bell pepper, the gross margin under FYMC 20 Mg ha^{-1} + BF and combined application of organic amendments (FYMC 10 Mg ha^{-1}, PM and VC each 1.5 Mg ha^{-1} and BF) was comparable with that of conventional practice. At 60% price premium for organic bell pepper, the former two treatments recorded higher gross margin whereas, PM 5 Mg ha^{-1} + BF gave similar gross margin as that of conventional practice.

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 modules compared with conventional practice. 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). Conventional practice 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 mobile nitrogen sources. In our study, the yield reduction under the best organic treatment (FYMC 20 Mg ha^{-1} + BF) compared to conventional practice 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 Canbardella, 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). In another study, we have reported lowering of bulk density during conversion period due to application of organic amendments. (Gopinath et al., 2008). Highest bulk density was found in unamended control and lowest in FYMC 20 Mg ha^{-1} + BF.

Soil pH also increased from 6.7 in unamended control to 7.1 in FYMC 20 Mg ha^{-1} + BF. 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). Long term applications, especially N, therefore had acidifying effects resulting in lowering of pH. This confirms earlier findings that most N-containing fertilizers tend to acidify soil (Aref et al., 1998; Belay et al., 2002). This is mainly due to the fact that most fertilizers supply N as NH_4 first, which upon oxidation releases H^+ ions (Magdof et al., 1997).

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 C levels may increase linearly with the amount of organic matter input (Carter, 2002; Parton et al., 1996). 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 unamended control. Further increases in soil organic matter are 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 organic materials particularly during initial years of conversion to organic production (Brusko, 1989; Liebhardt et al., 1989; MacRae et al., 1993).

The enzymes assayed in this study were chosen because they play central roles in C, N, and P cycling in soils. Indeed, the variable effect of organic amendment application on exocellular enzyme activity was due to the interaction of several factors. Mainly, organic amendment applications increased organic matter content and microbial biomass. Therefore, the soil has the better potential for greater enzyme production. This may explain the increases in most enzymatic activities. Organic amendment can foster beneficial microorganisms, which in turn facilitates soil enzymatic activities (Doran, 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 FYMC plots. This confirms that FYMC is more efficient in enhancement of microbial activity than VC or PM. This maximum activity might be linked to more substrate availability in these soils. 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 extracellular enzymes through complexation with humic substances (Burns, 1982; Colvan et al., 2001; Nannipieri et al., 1978). In contrast, urease followed a different pattern, where organic manure had very little effect on the activity. The plots under conventional practice had highest urease activity.

In our study, β-glucosidase activity was slightly greater in plots under conventional practice than that under organic amendments. Highest activity was observed in unamended control. Our result is in contrast with Garcia-Gill et al. (2000). 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 (Turion et al., 2000). No changes in soil phosphatase activity were observed among FYMC, PM and VC treatments when applied alone but more activity was recorded in organic mixture and conventional practice. Interestingly, acid phosphatase activity was maximum in unamended control, which may be attributed to slightly lower soil pH (Eivazi and Tabatabai, 1977). Our result is consistent with Garcia-Gill et al. (2000), who reported similar phosphatase activity in mineral fertilized and control soil.

Urease activity was highest in FYMC and conventional practice and lowest in control. Composted FYM-amended plots had the greatest urease activity, followed by plots treated with VC and PM. This might be attributed to 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). Maximum urease activity was observed in conventional practice treatment along with FYMC. Garcia-Gill et al. (2000) reported higher urease activity in mineral fertilized soil.

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 conventional practice. Russo and Taylor (2006) also opined 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 conventional practice. Among the organic amendments, FYMC + BF was found 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.

Acknowledgements

We are thankful to “Technology Mission for Integrated Development of Horticulture (Mini Mission-I), Government of India” for providing the financial support during the course of the study.

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Figure captions:

Fig. 1. Effect of organic amendments on soil dehydrogenase (A), acid phosphatase (B), β-glucosidase (C) and urease (D) activities. (*FYMC* composted farmyard manure, *PM* poultry manure, *VC* vermicompost, *Organic mix* FYMC+PM+VC, *ICM* Integrated crop management). Bars with different letters within each sub-figure are significantly ($P <$ 0.05) different.

Fig. 2. Gross margin at 0, 20, 40 and 60% price premium for organic capsicum grown with different organic amendments (─●─ FYMC 20 Mg ha^{-1} + 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, ─✕─ Conventional practice).

Table captions:

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

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

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

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

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

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

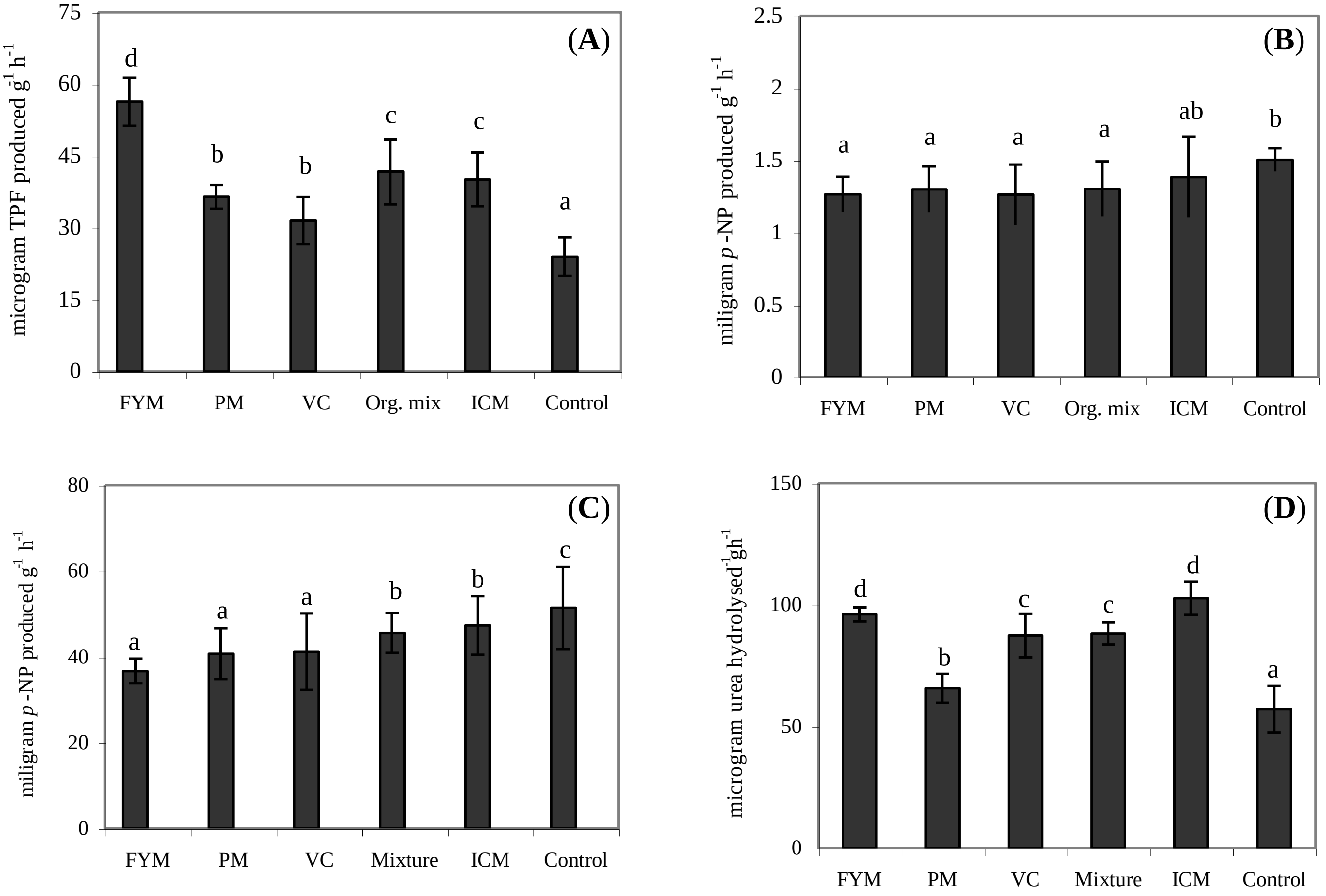
(A)
microgram TPF produced g^{-1} h^{-1}
0
15
30
45
60
75
d
b
b
c
c
a
FYM
PM
VC
Org. mix
ICM
Control
(B)
miligram p -NP produced g^{-1} h^{-1}
0
0.5
1
1.5
2
2.5
a
a
a
a
ab
b
FYM
PM
VC
Org. mix
ICM
Control
(C)
miligram p -NP produced g^{-1} h^{-1}
0
20
40
60
80
a
a
a
b
b
c
FYM
PM
VC
Mixture
ICM
Control
(D)
microgram urea hydrolysed^{-1}gh^{-1}
0
50
100
150
d
b
c
c
d
a
FYM
PM
VC
Mixture
ICM
Control

Figure 1.

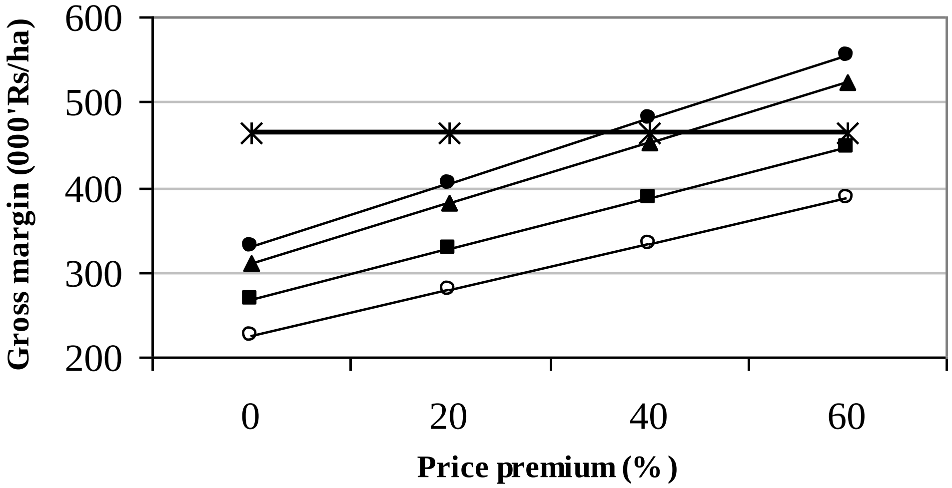
600
500
400
300
200
Gross margin (000'Rs/ha)
0
20
40
60
Price premium (%)

Figure 2.

Table 1

Organic amendment	Year	Moisture (%)	Nutrient content ($g\ kg^{-1}$)			Nutrient content ($mg\ kg^{-1}$)			
			N	P	K	Zn	Cu	Fe	Mn
FYMC	2005	52	11.2	4.30	6.60	290	59	5215	311
	2006	56	10.3	4.80	7.20	298	54	6500	374
Poultry manure	2005	43	17.2	16.1	8.20	362	77	4635	402
	2006	48	18.5	17.6	7.90	355	84	4206	407
Vermicompost	2005	58	15.5	6.30	5.30	124	34	11028	326
	2006	61	16.0	6.10	5.60	136	55	12100	315

FYMC composted farmyard manure

Table 2

Treatment	Nutrients added (kg ha^{-1})					
	N		P		K	
	2005	2006	2005	2006	2005	2006
FYMC 20 Mg ha^{-1} + BF	224	206	86	96	132	144
PM 5 Mg ha^{-1} + BF	86	93	81	88	41	40
VC 7.5 Mg ha^{-1} + BF	116	120	47	46	40	42
FYMC 10 Mg ha^{-1} + PM & VC each 1.5 Mg ha^{-1} + BF	161	155	76	84	86	92
Conventional practice	212	203	65	70	108	114
Unamended control	-	-	-	-	-	-

FYMC composted farmyard manure, *PM* poultry manure, *VC* vermicompost, *BF* biofertilizers.

Table 3

Parameter	Actual values (Rs)
Price of seed	1800 ha^{-1}
Price of NPK	2230 ha^{-1}
Price of FYMC	900 Mg^{-1} DW
Price of poultry manure	664 Mg^{-1} DW
Price of vermicompost	3067 Mg^{-1} DW
Labor cost for planting bell pepper	2000 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	15000 Mg^{-1}

FYMC composted farmyard manure, *DW* dry weight basis, One US \$ = Rs 40.

Table 4

Treatment	Plant height (cm)		Fruits plant^{-1}		Fruit length (cm)		Fruit yield (Mg ha^{-1})	
	2005	2006	2005	2006	2005	2006	2005	2006
FYMC 20 Mg ha^{-1} + BF	58.7^{a}	57.9^{ab}	18.8^{b}	20.0^{b}	6.2^{ab}	6.7^{abc}	23.6^{b}	32.3^{b}
PM 5 Mg ha^{-1} + BF	53.4^{b}	54.8^{bc}	13.2^{c}	16.5^{cd}	5.8^{bc}	6.2^{bc}	18.1^{c}	25.9^{c}
VC 7.5 Mg ha^{-1} + BF	52.7^{b}	51.2^{c}	12.5^{c}	16.2^{d}	5.6^{bc}	6.1^{c}	16.7^{c}	23.7^{c}
FYMC 10 Mg ha^{-1} + PM & VC each 1.5 Mg ha^{-1} + BF	56.3^{ab}	59.9^{ab}	18.0^{b}	19.0^{bc}	5.9^{bc}	6.8^{ab}	21.9^{b}	30.4^{b}
Conventional practice	58.9^{a}	62.5^{a}	22.5^{a}	25.0^{a}	6.8^{a}	7.1^{a}	35.3^{a}	39.4^{a}
Unamended control	41.4^{c}	43.6^{d}	9.2^{d}	9.0^{e}	5.2^{c}	5.0^{d}	8.8^{d}	6.5^{d}

FYMC composted farmyard manure, *PM* poultry manure, *VC* vermicompost, *BF* biofertilizers. Means in the same column with different letters are significantly ($P < 0.05$) different.

Table 5

Treatment	BD ($Mg\ m^{-3}$)	pH	SOC (%)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)
FYMC 20 Mg ha^{-1} + BF	1.15^{d}	7.1^{a}	1.3^{a}	452.6^{b}	21.8^{ab}	252.0^{a}
PM 5 Mg ha^{-1} + BF	1.26^{ab}	7.0^{ab}	1.2^{ab}	450.4^{b}	20.7^{ab}	231.8^{bc}
VC 7.5 Mg ha^{-1} + BF	1.22^{bc}	7.0^{ab}	1.1^{b}	440.9^{b}	19.2^{bc}	223.8^{cd}
FYMC 10 Mg ha^{-1} + PM & VC each 1.5 Mg ha^{-1} + BF	1.17^{cd}	7.1^{a}	1.2^{ab}	449.3^{b}	21.4^{ab}	247.1^{ab}
Conventional practice	1.20^{bcd}	6.9^{b}	1.1^{b}	483.5^{a}	23.4^{a}	260.9^{a}
Unamended control	1.31^{a}	6.7^{c}	0.9^{c}	408.1^{c}	16.9^{c}	210.4^{d}

FYMC composted farmyard manure, *PM* poultry manure, *VC* vermicompost, *BF* biofertilizers, *BD* bulk density, *SOC* soil organic carbon. Means in the same column with different letters are significantly ($P < 0.05$) different.

Table 6

Treatment	Cost of cultivation (000'Rs ha^{-1})	Gross margin (000'Rs ha^{-1})	Benefit: Cost ratio
FYMC 20 Mg ha^{-1} + BF	47.0	329.5	7.0
PM 5 Mg ha^{-1} + BF	29.4	267.6	9.1
VC 7.5 Mg ha^{-1} + BF	48.8	224.2	4.6
FYMC 10 Mg ha^{-1} + PM & VC each 1.5 Mg ha^{-1} + BF	41.7	310.8	7.4
Conventional practice	39.7	464.3	11.7
Unamended control	22.5	81.0	3.6

FYMC composted farmyard manure, *PM* poultry manure, *VC* vermicompost, *BF* biofertilizers. One US $ = Rs 40.