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Growth and yield of capsicum (*Capsicum annum*) and garden pea (*Pisum sativum*) as influenced by organic manures and biofertilizers

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ABSTRACT

Field experiments were conducted during 2006–08 to study the effect of different organic manures in comparison to inorganic inputs on growth, yield, and quality attributes of capsicum (*Capsicum annum* L.) and garden pea *(Pisum sativum* L.). Application of poultry manure (5 tonnes/ha) + biofertilizer produced capsicum plant biomass and yield at par with integrated nutrient management (recommended NPK + farmyard manure@10 tonnes/ha + biofertilizer). Highest ascorbic acid content (25.23 mg/100 g) was recorded with integrated nutrient management, followed by poultry manure+ biofertilizer (19.26 mg/100 g) and combined use of farmyard manure + poultry manure + vermicompost + biofertilizer (18.83 mg/100 g). Minimum incidence of cercospora leaf spot (11.18%) was recorded in poultry manure + biofertilizer treatment, integrated nutrient management and vermicompost+ biofertilizer treatments. Significantly higher incidence of leaf blight of capsicum was observed in organic treatments in comparison to integrated nutrient management. Poultry manure + biofertilizer resulted in plant height, number of pods/plant, pod length, number of seeds/pod and yield of garden pea at par with integrated nutrient management. Significant change in physico-chemical properties of soil like bulk density, *p*H, organic carbon, available nitrogen and available phosphorus was observed in different treatments. Incidence of Fusarium root rot was lower in poultry manure + biofertilizer (11.42%) and FYM treatments (12.06%) compared to integrated nutrient management (46.75%). Highest B:C ratio was recorded with poultry manure+ biofertilizer for capsicum (35.4) and garden pea (14.3).

Key words: Ascorbic acid, Biofertilizers, Capsicum, *Capsicum annuum*, Cercospora leaf spot, Garden pea, Organic manures, *Pisum sativum*, Root rot

The increased use of chemicals under intensive cultivation has not only contaminated the ground and surface water but has also disturbed the harmony existing among the soil, plant and microbial population (Bahadur *et al*. 2006). There has been a growing public concern about adverse impacts of pesticides and chemical fertilizers on the environment and on the safety and quality of food. Organic manures can be used to promote the healthy population of beneficial organisms in the soil. Biofertilizers, on the other hand are cost-effective and renewable source of plant nutrients to supplement the parts of chemical fertilizers. A judicious use of organic manures and biofertilizers may be effective not only in sustaining crop productivity and in soil health, but also in supplementing chemical fertilizers of the crops. There are several reports, which show that the combined and/or sole application of organic manures and biofertilizers increased yield and influence quality attributes in vegetables (Worthington 2001, Bahadur *et al*. 2003, 2006). Off season vegetables are best suited for production on small farms and play a major role in the economic upliftment of small and marginal farmers, who constitute the major (~80%) farming community in Uttarakhand hills. Capsicum and garden pea are considered as money-spinner to the hill farmers as they fetch high remuneration due to off-season cultivation (Sharma *et al*. 2010, Negi *et al*. 2008). With organic farming being pursued as the state policy our long-term objective remains to evaluate different organic manures alone, and in combination with plant growth-promoting micro-organisms to be used as a viable, economic and environment-friendly alternative to the use of synthetic chemicals.

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MATERIALS AND METHODS

Studies were conducted during 2006–08 at Organic Block of VCSG College of Horticulture, GB Pant University of Agriculture and Technology, Bharsar, Pauri Garhwal located at latitude of 30°35//N, longitude of 78°42// E and at an altitude of 2 200 m above mean sea level. The climate of the area is wet temperate (maximum temperature 26°C, minimum temperature –2°C and annual rainfall 1 360 mm). Initial soil samples (0–15 cm depth) were collected to analyze the properties of soil. At the time of termination of experiment soil status was again determined. Soil samples were analyzed for *p*H, EC, organic carbon, available nitrogen, phosphorus and potassium as per the standard procedures (Jackson 1973). A total of five treatments including INM were replicated four times in a randomized block design. The treatments were; T_1, farmyard manure @ 20 tonnes/ha + biofertilizers *(Azotobacter/ Rhizobium* + phosphate-solubilizing bacteria) ; T_2, poultry manure @ 5 tonnes/ha + biofertilizers; T_3, vermicompost @ 7.5 tonnes/ ha + biofertilizers; T_4, farmyard manure @ 10 tonnes/ha + poultry manure + vermicompost each @ 1.5 tonnes/ha + biofertilizers; T_5, recommended doses of nutrients (capsicum: 100 kg N+75 kg P_2O_5+50 kg K_2O+ farmyard manure @ 10 tonnes /ha; pea: 25 kg N+75 kg P_2O_5+50 kg K_2O+ farmyard manure @ 5 tonnes /ha), i e control. The nitrogen content in the manures samples was analyzed by Kjeldahl method (A O A C 1970). Phosphorus and potassium were estimated by tri-acid mixture (9:4:1 HNO_3: $HClO_4$: H_2SO_4) as given by Jackson (1973). The calculated equivalent amount of N, P_2O_5 and K_2O in different organic manures is presented in Table 1.

Capsicum (‘California Wonder’) was grown during rainy *(kharif)* season (April–August) and garden pea (‘Arkel’) was grown in winter *(rabi)* season (September–March). Capsicum was planted at a distance of 60 cm × 45 cm, while garden pea was sown at a distance of 30 cm × 10 cm in a plot size of 3 × 2 m^2. Manures were incorporated as basal dose at the time of field preparation. In INM plots, half dose of N and full amount of P and K were applied as basal during planting, and rest of N was top-dressed in two splits at 30 and 60 days after planting. Biofertilizers (*Rhizobium/ Azotobacter* + phosphorus-solubilizing bacteria) were applied as seed and root dip treatments before sowing of garden pea and transplanting of capsicum, respectively. No application of any pesticide was done to control insects or diseases.

Capsicum fruit samples of 10 g in each replicate were taken for the estimation of ascorbic acid. The ascorbic acid content was estimated titrametrically, using 2,6 dichlorophenol indophenol dye, as per the method of Rangana (1976).

To work out the economics of capsicum and garden pea crops, the seed and manure/fertilizer cost were included in input cost as these two parameters were variable and others were constant. Since the presentation of the data for individual crop in each season from an experiment would be very voluminous, hence average of three season for each crop are given in this paper.

RESULTS AND DISCUSSION

Crop yield and yield attributes

Use of organic manures and biofertilizers showed significant impact on yield and other attributes of capsicum (Table 2). The plant height varied significantly among the treatments and maximum plant height (90.3 cm) was recorded in recommended NPK + farmyard manure + biofertilizers treatment. However, among different organic amendments, higher plant height was recorded in farmyard manure + biofertilizers treatment (82.3 cm).The lowest value was observed in poultry manure + biofertilizers treatment (65.3 cm). Similar trend was observed for root length but the values did not differ significantly. Highest dry biomass of the plant (3.58 tonnes/ha) was recorded in integrated nutrient management treatment, followed by poultry manure + biofertilizers.

Highest fruit yield (9.27 tonnes/ha) was recorded in plots receiving recommended NPK + farmyard manure + biofertilizers, followed by poultry manure + biofertilizers (8.58 tonnes/ha) and combined use of organic manures

Table 1 Supply of nutrients through incorporation of organic manures

Treatment	Quantity of manure added (tonnes/ha)	Nutrient concentration (%)			Quantity of nutrients supplied*		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
T_1, farmyard manure + biofertilizers	20.0	0.60	0.25	0.30	120.0	50.0	60.0
T_2, poultry manure + biofertilizers	5.0	2.50	1.20	1.20	125.0	60.0	60.0
T_3, vermicompost + biofertilizers	7.5	1.60	0.80	0.73	120.0	60.0	55.0
T_4, farmyard manure + poultry manure + vermicompost + biofertilizers	10+1.5+1.5				121.5	55.0	54.0
T_5, INM (recommended NPK+ farmyard manure + biofertilizers)							
Pea	5.0				30.0	12.5	15.0
Capsicum	10.0				60.0	25.0	30.0

*Quantities worked out on fresh weight basis (farmyard manure + poultry manure + vermicompost + biofertilizers) treatment (8.45 tonnes/ha), while lowest fruit yield (7.13 tonnes/ha) was recorded in farmyard manure + biofertilizers treatment. The better growth in terms of plant height, biomass production and yield in recommended NPK+ farmyard manure + biofertilizers treatment could be ascribed to better availability of nutrients. Amendment of poultry manure + biofertilizers registered highest yield among the treatments containing organic nutrient sources indicating that poultry manure mineralized rapidly and provided optimum nutrients to the crop. Poultry manure contains significant amount of nitrogen in both inorganic and organic forms and inorganic forms are readily available for plant uptake (Kara *et al.* 2006). Significantly higher number of fruits/ plant and fruit yield was observed under INM compared with organic nutrient supply (Gopinath *et al.* 2008).

Similarly, significantly higher ascorbic acid content (25.23 mg/100 g) in capsicum was recorded in integrated nutrient management treatment in comparison to organic treatments. Among organic manures, poultry manure + biofertilizers resulted in higher amount (19.8 mg/100 g) of vitamin C while least amount (11.86 mg/100 g) was produced in farmyard manure + biofertilizers treatment. The differences in the management of soil fertility under organic practices affect soil dynamics and plant metabolism, which result in differences in plant composition and nutritional quality (Worthington 2001). Improvement in ascorbic acid content in capsicum fruits with poultry manure may be because of slow but continuous supply of all major and micro-nutrients, which might have helped in the assimilation of carbohydrates and in turn synthesis of ascorbic acid. Bahadur *et al.* (2009) also noticed significantly higher vitamin C content in lettuce where

Table 2 Effect of organic manures on yield and quality attributes of 'California Wonder' capsicum during 2006–08

Treatment	Shoot length (cm)	Root length (cm)	Plant biomass (tonnes/ha)	Yield (tonnes/ha)	Ascorbic acid (mg/100 g)	Disease incidence (%)	
						Cercospora leaf spot	Leaf blight
T_1, farmyard manure @ 20 tonnes/ha + biofertilizers	82.3	23.0	2.31	7.13	11.86	34.00 (35.61) *	39.77 (39.06)
T_2, poultry manure @ 5 tonnes/ha + biofertilizers	65.3	20.0	3.41	8.59	19.26	11.18 (19.05)	45.79 (42.58)
T_3, vermicompost @ 7.5 tonnes/ha + biofertilizers	73.6	20.0	2.86	7.91	14.50	13.50 (21.21)	30.12 (33.25)
T_4, farmyard manure + poultry manure + vermicompost (@ 10+1.5+1.5 tonnes/ha)+ biofertilizers	77.3	23.0	1.98	8.45	18.83	31.15 (33.89)	30.21 (33.28)
T_5, INM (recommended $N_{100}P_{75}K_{50}$ + farmyard manure @ 10 tonnes/ ha + biofertilizers)	90.3	26.0	3.58	9.27	25.23	13.15 (21.01)	9.21 (17.38)
CD (*P*=0.05)	3.24	NS	0.59	1.16	4.02	9.95 (6.25)	8.43 (6.49)

*Values in parentheses are angular transformed values

Table 3 Effect of organic manures on yield and other parameters of garden pea during 2006–08

Treatment	Plant height (cm)	Number of pods/ plant	Pod length (cm)	No. of seeds/ pod	No. of nodules/ plant	Pod yield (tonnes/ha)	Incidence of root rot (%)
T_1, farmyard manure @ 20 tonnes/ha + biofertilizers	85.6	37.2	7.3	6.4	12.5	3.71	12.06 (20.23)
T_2, poultry manure @ 5 tonnes/ha + biofertilizers	93.6	58.4	9.8	8.8	18.4	6.56	11.42 (19.71)
T_3, vermicompost @ 7.5 tonnes/ha + biofertilizers	76.0	46.2	8.4	7.2	25.8	6.06	35.37 (36.47)
T_4, farmyard manure + poultry manure + vermicompost (@ 10 +1.5 +1.5 tonnes/ha) + biofertilizers	72.0	48.5	9.2	8.4	28.3	6.12	41.41 (40.03)
T_5, INM (recommended $N_{25}P_{75}K_{50}$ + farmyard manure @ 5 tonnes /ha + biofertilizers)	90.3	60.2	10.1	9.1	26.8	6.61	46.75 (43.13)
CD (*P*=0.05)	11.6	13.1	1.7	0.9	8.3	0.77	6.48 (4.81)

*Values in parentheses are angular transformed values organic manures were combined with *Azotobacter* or VAM. Organically grown pumpkins accumulated greater amounts of dry matter (1.5%), beta-carotene (0.4 mg/100 g) and vitamin E (0.5 mg/100 g), while in commercially grown pumpkins greater amounts of dietary fibre (2.1%) and ascorbic acid (5.2 mg/100 g) accumulated (Danilcenko *et al*. 2003).

Similarly, the growth and yield of garden pea was also significantly influenced by the use of organic manures and biofertilizers (Table 3). Poultry manure + biofertilizers resulted in highest plant height (93.6 cm), followed by recommended doses of NPK + farmyard manure + biofertilizers. The next best treatment was farmyard manure + biofertilizers treatment, while minimum plant height was recorded in the treatment where combined organic manures (farmyard manure + poultry manure + vermicompost + biofertilizers) were used. The number of pods/plant was highest (60.2) in recommended NPK + farmyard manure + biofertilizers, followed by poultry manure + biofertilizers and these two treatments were statistically at par. Similar trend was observed for pod length and number of seeds/pod. The better nodulation (28.3 nodules/plant) was recorded in consortia of organic manures (farmyard + poultry manure + vermicompost + biofertilizers treatment), followed by integrated nutrient management and vermicompost + biofertilizers, whereas, least nodulation (12.5 nodules/plant) was recorded in farmyard manure + biofertilizers treatment. The integrated nutrient management treatment was found to be significantly superior than the others and recorded 6.61 tonnes/ha green pod yield and amongst organics, poultry manure + biofertilizers was found to be better compared to others. Enhancement in yield and other attributes with poultry manure may be due to availability of more nutrients to the plants.

Disease incidence

Poultry manure + biofertilizers treatment registered minimum incidence (11.18%) of cercospora leaf spot *(Cercospora capsici* Heald & Wolf), followed by integrated nutrient management and vermicompost + biofertilizers treatments and these two were at par with each other. The highest incidence of cercospora leaf spot was recorded in farmyard manure + biofertilizers and combined use of farmyard manure + poultry manure + vermicompost + biofertilizers treatments in descending order. On the other hand, highest incidence of leaf blight *(Phytophthora nicotianae* var. *nicotianae* Waterhouse) was recorded in organic manure treatments, while least incidence was recorded in integrated nutrient management (recommended NPK + farmyard manure + biofertilizers). Amongst organic manures, highest incidence (45.79%) was recorded in poultry manure + biofertilizers, followed by farmyard manure + biofertilizers while least (30.12%) was recorded in vermicompost + biofertilizers treatment which was at par with farmyard manure + poultry manure + vermicompost + biofertilizers treatment. Samayoa-Juarez and Sanchez-Garita (2001) found higher incidence of *Cercospora coffeicola* in conventional coffee production system than in the organic system. Incidence of leaf blight of capsicum in the present study was found higher under organic treatments. However, care should be taken in choosing amendments and cropping systems in organic disease management programmes as some have potential to aggravate rather than suppress soil-borne pathogens (Davis *et al*. 2002).

Poultry manure + biofertilizers treatment resulted in minimum incidence of Fusarium root rot caused by *Fusarium solani* (Mart.) Sacc. f.sp. *pisi* (Jones) Synder and Hansen (11.42%), while the highest incidence was recorded in integrated nutrient management (recommended NPK+ farmyard manure + biofertilizers) which indicated that plants supplied with chemical fertilizers were more susceptible than those supplied with only organic manures. Alternative fertility amendments enhanced beneficial soil micro-organisms and reduced pathogen population (Bulluck *et al*. 2002). Seed treatment with *Rhizobium* strains and biofertilizers resulted in maximum reduction of seed rot and foot/root rot *(Fusarium oxysporum*) of bushbean (Khalequzaman and Hossain 2008).

Soil properties

Application of organic manures and biofertilizers influenced the soil properties over a period of three years (Table 4). The addition of organic manures had a positive

Table 4 Change in physico- chemical properties of soil during 2006–08

Treatment	Bulk density (Mg/m^3)	*p*H	EC (dS/m)	Organic carbon (g/kg)	Available nutrient (kg/ha)		
					N	P_2O_5	K_2O
T_1, farmyard manure @ 20 tonnes/ha + biofertilizers	1.13	6.10	0.22	12.90	255.00	12.30	438.0
T_2, poultry manure @ 5 tonnes/ha + biofertilizers	1.29	6.00	0.23	8.80	280.00	21.70	448.0
T_3, vermicompost @ 7.5 tonnes/ha + biofertilizers	1.23	5.36	0.23	9.20	265.70	18.00	445.0
T_4, farmyard manure + poultry manure + vermicompost (@10 +1.5 + 1.5 tonnes/ha) + biofertilizers	1.19	5.78	0.22	12.08	262.00	14.70	443.0
T_5, INM (recommended NPK + farmyard manure @ 5/10 tonnes /ha + biofertilizers)	1.24	5.40	0.24	10.10	290.00	23.33	450.0
CD (*P*=0.05)	0.025	0.20	NS	1.71	14.30	4.20	NS
Initial value	1.32	5.40	0.21	7.70	226.00	11.60	434.0

effect on bulk density of soil in all the treatments. The value of bulk density was found to be lowest (1.13 Mg/m^3) in farmyard manure-treated plots and highest (1.29 Mg/m^3) under poultry manure + biofertilizers treatment. This might be due to the variation in amount of organics added to the soil. These findings are in line with Gedam *et al*. (2008) who reported lower bulk density, increased organic carbon content and altered soil reaction towards neutral over control with the addition of organic manures. The change was more pronounced in phosphocompost, vermicompost and FYM.

The initial soil of the experimental plots was acidic in *p*H (5.40) and it increased significantly in treatments involving farmyard manure + biofertilizers (6.10), poultry manure + biofertilizers (6.00) and combined use of farmyard manure + poultry manure + vermicompost + biofertilizers (5.78) treatments. Significant increase in organic carbon was found in the plots under farmyard manure + biofertilizers, farmyard manure + poultry manure + vermicompost + biofertilizers and in integrated nutrient management. These findings are in accordance with Bulluck *et al*. (2002) who reported that alternative fertility amendments increased soil organic matter, total carbon, and cation exchange capacity, and lowered bulk density thus improving soil quality. The plant available soil nitrogen in different treatments ranged from 255 to 290 kg/ha, which falls between low to medium categories from the availability point of view. This low status was due to low prevailing temperature (between 26°C and –2°C), which might have retarded the mineralization process (JaiPaul and Sandal 2008). However, the available nitrogen increased significantly in all treatments over the initial value. The maximum increase was observed in integrated nutrient management, followed by poultry manure + biofertilizers treatments. Similar trend was observed for available phosphorus content in soil. The highest available phosphorus (23.33 kg/ha) was recorded in integrated nutrient management and was significantly superior to poultry manure + biofertilizer treatment. Although the soil was acidic in reaction even then it showed an increase in available phosphorus over the initial value, indicating that addition of organic manures and biofertilizers, specially phosphate-solubilizing bacteria, increased the solubility of phosphorus by producing certain organic acids and thereby increased the soil available phosphorus (Jeon *et al*. 2003). The observation reveals that the soil of the region was rich in mica type mineral, which might have contributed potassium to available pool through various processes and because of that non-significant change has been observed in available-K content (Raina and Gupta 2009). Similarly, higher soil *p*H and organic carbon were reported in organically-amended plots compared to INM (Gopinath *et al.* 2008). The latter, however, recorded higher N, P, and K contents in organically-amended soils.

Economics

The total cost of production ranged between ₹ 3880 and ₹ 23 880/ha for capsicum and ₹ 7 330 and ₹ 27 330/ha for garden pea (Table 5). The total production cost was the lowest (₹ 3 880/ha and ₹ 7 330/ha) for the poultry manure + biofertilizers and the highest (₹ 23 880 and ₹ 27 330/ha) for vermicompost + biofertilizers-treated plots. The output cost for different treatments ranged between ₹ 114000 and ₹ 148800/ha for capsicum and ₹ 59360 and ₹ 105808/ha for garden pea. The highest net returns (₹ 141300) were obtained from integrated nutrient management, followed by poultry manure + biofertilizers (₹ 133480) in capsicum. Similar trend was observed for garden pea. The benefit:cost:ratio was found to be the highest (35.40 and 14.30) in poultry manure + biofertilizers treatment, followed by integrated nutrient management, while the lowest (5.20 and 3.54) benefit:cost ratio was recorded from the vermicompost + biofertilizers treatment. From the economic point of view, the above result indicated that poultry manure + biofertilizers treatment was more profitable than other treatments for both the crops. The lowest B:C ratio in case of vermicompost + biofertilizers is due to high price of the input, i e vermicompost. Gopinath *et al*. (2008) reported that in bell pepper the highest gross margin and B:C ratio were recorded under integrated nutrient management treatment in comparison to treatments containing only organic sources of nutrients.

Table 5 Economics of capsicum and garden pea grown under different organic modules

Treatment	Capsicum				Garden pea			
	Input* cost (₹)	Output cost (₹)	Returns (₹)	B:C ratio	Input* cost (₹)	Output cost (₹)	Returns (₹)	B:C ratio
T_1, farmyard manure @ 20 tonnes/ha + biofertilizers	7 380	114 000	106 620	15.4	10 830	59 360	48 530	5.48
T_2, poultry manure @ 5 tonnes/ha + biofertilizers	3 880	137 360	133 480	35.4	7 330	104 880	97 550	14.30
T_3, vermicompost @ 7.5 tonnes/ha + biofertilizers	23 880	126 416	102 536	5.2	27 330	96 992	69 662	3.54
T_4, farmyard manure + poultry manure + vermicompost (@ 10+1.5+1.5 tonnes/ha) + biofertilizers	9 630	135 120	125 490	14.0	13 080	97 952	84 872	7.48
T_5, INM (recommended NPK + farmyard manure (@ 5 /10 tonnes/ha) + biofertilizers	7 500	148 800	141 300	19.84	8622	105 808	97 186	12.27

*To work out the economics of capsicum and garden pea, seed and manure/fertilizer cost were included in input cost as these two parameters were variable and others were fixed

The quantity of manure significantly changed the bulk density, *p*H and organic carbon in the soil, whereas concentration of nutrients in the manures significantly changed their status in the soil. The significant changes in these properties certainly reflected through growth and yield of crops. The integrated nutrient management treatment recorded highest yield and net returns, proved superior over the others as it provided balance and optimum supply of nutrients during different stages of crop growth. Nevertheless, among the organics, poultry manure along with biofertilizers was proved better in terms of yield and net returns. Finally, it is concluded that not only chemical fertilizers can produce a good yield and fetch a good remuneration but the application of organic manures like poultry manure along with biofertilizers can also achieve the yield target and good returns under better management practices. Simultaneously, the organic manures are locally available, eco-friendly and helpful in sustaining the soil health.

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