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Effect of organic and inorganic nutrient sources on growth, yield and quality of bell pepper (*Capsicum annuum* L.) grown under polyhouse condition

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Abstract
The present investigation entitled “Effect of organic and inorganic nutrient sources on growth, yield and quality of bell pepper (*Capsicum annuum* L.) Grown under polyhouse condition” was conducted during 2015 at the polyhouse of Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab, India. The experiment was laid out in a randomized block design with three replications. The treatments consisted of T_1: RDF (100% NPK @125:75:30 kg ha^{-1}), T_2: 50% RDF + *Azotobacter*, T_3: 75% RDF + *Azotobacter*, T_4: 50% RDF + Vermicompost, T_5: 75% RDF + Vermicompost, T_6: 50% RDF + *Azotobacter* + Vermicompost, T_7: 75% RDF + *Azotobacter* + Vermicompost. Application of different levels of fertilizers in combination with organic manures and biofertilizers significantly increased the growth, yield and quality of capsicum. The maximum plant height, plant spread, days to 50 % flowering, days to first picking, harvest duration, average fruit weight, fruit length, fruit diameter, number of fruits per plant, fruit yield per plant, fruit yield and fruit firmness were recorded with the combined application of 75 % NPK + *Azotobacter* + vermicompost whereas, shelf life, ascorbic acid, TSS were recorded maximum with the conjoint application of 50 % NPK + *Azotobacter* + vermicompost. The treatment T_7 (75% RDF + *Azotobacter* + Vermicompost) also produced the highest net returns along with maximum benefit: cost ratio.

Keywords: Capsicum, polyhouse, organic, inorganic, *Azotobacter*, vermicompost, yield and B: C ratio

Introduction
Bell pepper (*Capsicum annuum* L.) is an annual and day neutral plant belongs to Solanaceae family. It is a one of the most important vegetable crop grown in India as well as in the world, because of its nutritive value, flavor, colour and is considered as one of the major commercial crops of the world (Tiwari *et al*. 2013) [36]. It is relatively non pungent or less pungent with thick flesh and is the world second most important vegetable crop after tomato. Sweet pepper has little energy value but the nutritive value of sweet pepper is high especially for vitamin A and vitamin C (Roy *et al*. 2011) [27]. In India, capsicum is grown for its mature fruits and widely used in stuffing, baking and consumed as salad, noodles and soup preparations (Kumari and Kaushal, 2014) [17].

Production of any crop can be increased by supplying quality inputs. Nutrition play an important role in the growth and development of any crop including capsicum, because it is known to exhibit positive response to the application of nitrogenous, phosphoric and potassium fertilizers. Fertilizer is one of the major factors of crop production (Satyanarayana *et al*., 2002) [29]. Combined application of organic and inorganic fertilizers attained a great significance in vegetable production as large amount of nutrients required for continuous production, hectare^{-1} yield of vegetables and fertilizer alone cannot sustain the productivity of soils under highly intensive cropping systems. Further, use of organic manures in integrated nutrient management help in mitigating multiple nutrient deficiencies. Soil health is one of the key factors which decide the yield (Singh and Jain, 2004). [32] Organic manures are basic source of essential plant nutrients and applied in large quantities. Application of organic manures to soil not only improves the physical properties but also increases the availability of nutrients. It supplies the plant nutrients including micronutrients to increases the yield of crop (Saravaiya, 2010) [28].

Biofertilizers have also emerged promising components of nutrient supply system. Application of biofertilizers which is environment friendly and low cost input, with organic and inorganic fertilizers as a part of an integrated nutrient management strategy and play significant role in plant nutrition (Lal and Kanaujia, 2013) [6]. Crops grown with organic fertilizers are nutritionally and environmentally superior to those fertilized with inorganic forms of nutrients. Addition of biofertilizers like *Azotobacter*, *Azospirillium*, Phosphate Solubilizing Bacteria (PSB) to the crop will not only improve quality and yield but also improve soil health. Capsicum was found to respond positively to inoculation with VAM fungus *Glomus itraradices*. Alarmed with the decline in the soil health and chemicalization of modern day farming, greater emphasis on integrated nutrient management system is being given in the recent years. Moreover, this approach is economically cheap, technically sound and practically feasible, and is capable of maintaining the sustainability in the production (Kumar and Shrivastava, 2006) [15].

Material and Methods

The present experiment was carried out at polyhouse of Department of Agriculture, Mata Gujri College, Fatehgarh Sahib in the year 2015. The experiment was laid down in randomized block design with three replications. The treatment consisted of T_1: RDF (100% NPK @125:75:30 kg ha^{-1}), T_2: 50% RDF + *Azotobacter*, T_3: 75% RDF + *Azotobacter*, T_4: 50% RDF + Vermicompost, T_5: 75% RDF + Vermicompost, T_6: 50% RDF + *Azotobacter* + Vermicompost, T_7: 75% RDF + *Azotobacter* + Vermicompost. N, P and K were given through Urea, SSP and MOP, respectively. Half of the recommended dose of nitrogen and whole phosphorous and potassium were applied as basal dose. Rest half of the nitrogen was applied at the time of flowering as top dressing. Vermicompost were incorporated as per treatment in respective plot 20 days before transplanting. *Azotobacter* was inoculated to seedlings prior to transplanting as seedling dip method @ 2.5 kg ha^{-1}. Ascorbic acid (mg $100g^{-1}$) was determined by 2, 6-dichlorophenol indophenols visual titration method. Total soluble solid was determined using hand refractrometer and results expressed in °brix. Fruit Firmness (kg cm^{-2}) was determined by using 'Agrosta 14'. The collected soil samples were mixed and reduced into 500 g and then dried under shade and sieved through 2 mm sieve. Soil samples were analyzed for electrical conductivity, pH with the help of digital pH meter (Jackson, 1973) [12], available nitrogen content was analyzed with alkaline potassium permagnate method (Subbiah and Asija, 1956) [33], available phosphorus content was analyzed with Olsen method (Olsen *et al*., 1954) [25], and available potassium content was estimated with Ammonium acetate method of Merwin and Peech (1951) [20]. Organic carbon was analyzed with Walkey and Black (1934) [39] method. The statistical analysis was carried out as per procedure given by Panse and Sukhatme (1987) [26]. Economical analysis was carried out by calculating the amount of material needed for one hectare, calculating annual cost of production by considering present market rate, depreciation, life of material and annual interest. Benefit-cost ratio was worked out by dividing net returns from total cost of cultivation.

Result and discussion

Growth attributes

Improvement in growth characters is considered to be pre-requisite to increased yield (Table1). Early flowering leads to early fruit formation, first picking and consequently helps in timing of the crop. Minimum number of days to 50 % flowering and first picking was recorded in T_7 (75% RDF + *Azotobacter* + Vermicompost). It may be due to the earliness in flowering might be due to accelerated photosynthesis and rapid translocation of photosynthesis towards initiating flower buds in early flowering (Ademola and Agele, 2015) [1]. Another possible reason for early flowering may be the organic manures which accelerated the blooming date, which may be due to continuous decomposition of organic manures after application, resulting in increased temperature in the rhizosphere. This increase in temperature and the higher amounts of potassium may be responsible for acceleration of the onset of flowering (Zahra, 2014) [40].

Plant height is an important parameter as more the plant height, more will be the number of laterals, fruits and ultimately yield. Application of 75 % RDF + *Azotobacter* + Vermicompost (T_7) recorded maximum plant height, plant spread and prolonged harvest duration. The increase in plant height may be attained due to the release of the fixed nitrogen, hence increasing the concentration and availability of nitrogen in the root zone. Nitrogen enhances protein synthesis, plant growth and its development was obtained (Fawzy *et al.*, 2012). [7] Manures and *Azotobacter* applied with inorganic fertilizers improved the effectiveness of chemical fertilizers and improves growth of bell pepper plants (Bhattarai *et al.*, 2011) [3]. The results of present investigation are in concordance with the findings reported earlier by Kumar *et al.* (2014) [16] and Chumei *et al.* (2013) [6]. The increase in plant spread was attributed due to increase in fertilizer and organic manure application may be ascertained to increase amount of nutrients such as nitrogen, phosphorus and potassium in plants, leading to increase in the formation of plant metabolites that helped to build the plant tissues (Malik *et al.*, 2011) [19]. According to Hadwani *et al.* (2013) []10 increase in plant spread might be due to better nutrient uptake, photosynthesis, besides excellent physiological and biochemical activities due to presence of *Azotobacter* and PSB. These results are in conformity with the findings of Kumar *et al.* (2013) [], Tekasangla *et al.* (2015) and Islam *et al.* (2013). The increase [14] in duration duration may be due to the capability of vermicompost in producing growth hormones and enzymes, which in turn enhanced growth and extended the duration of harvesting (Singh *et al*., 2015). Tripathi *et al.* (2015) also reported that the duration of harvest increased with the application of *Azotobacter* and vermicompost alone and in combination. The above findings are in accordance with Mishra and Tripathi (2011).

Yield and Yield Contributing Characters

Integrated application of chemical fertilizers, organic manures and biofertilizers increased yield and yield attributing characters of capsicum (Table-1). Application of 75 % RDF + *Azotobacter* + Vermicompost (T_7) recorded maximum values of all yield attributing characters like average fruit weight, fruit length, fruit diameter and number of fruits $plant^{-1}$. This might be due to favourable effect of organic manures in integrated nutrient management by supplying essential nutrient in balanced ratio and improving physical, chemical and biological properties of soil which helps in better nutrient absorption and utilization by plant resulting higher value of yield attributing characters (Lal and Kanaujia, 2013) [6]. Similar findings were also reported by Ghimire *et al.* (2013) in sweet pepper. Fruit size is directly correlated with yield and this is a character which appeals to the consumers. Large sized fruits yield more and consumer also prefers large size fruits with prominent lobes. Higher vegetative growth might have helped in the synthesis of greater amount of fruit material which was later translocated into developing fruits resulting in increased fruit length and diameter (Lal and

Kanaujia, 2013) [6]. Another possible reason behind maximum fruit size may be due to the role of biofertilizers on increasing the availability of nitrogen for plant absorption which in turn increases the plant growth and fruit size (Fawzy *et al.*, 2012) [7]. Bhattarai *et al*. (2011) [3] also reported that the effect of *Azotobacter* and manures registered noticeable increase in fruit size. Kumar *et al*. (2014) [16], Islam *et al.* (2013) and Moraditochaee *et al.* (2011) confirmed the above findings. Increased number of fruits per plant may be obtained due to the plants receiving the integrated nutrient input could be attributed to synergistic effect of organic and inorganic resources (Sileshi *et al.*, 2011). Another possible reason might be due to favourable effect of organic manures in integrated nutrient management in supplying essential nutrient in balanced ratio (Lal and Kanaujia, 2013) [6].

The maximum fruit yield plant^{-1} and fruit yield hectare^{-1} was recorded in treatment (T_7) receiving 75 % RDF + *Azotobacter* + Vermicompost. This might be due to continuous availability of more nutrients in higher amount and better utilization by plants (Chetri *et al.*, 2012) [5]. The combination of mineral N fertilizer and organic manure had an interactive effect on flowering and fruit production. This may be due to the increased N availability to the plants from the organic and inorganic fertilizer combinations (Olaniyi and Ajibola, 2008) [24]. Similar findings are also reported by Lal and Kanaujia (2013) [6] and Fawzy *et al*. (2012) [7] in capsicum.

Quality Characters

Quality of capsicum was evaluated by fruit firmness, TSS, shelf life and ascorbic acid. It is evident from table1 that maximum value of fruit firmness was recorded with 50 % RDF + *Azotobacter* + Vermicompost (T_7). The possible reason for firm fruits, on account of proper and adequate availability of all macro and micro nutrients (Gosavi *et al.*, 2010) [9]. Chatterjee *et al*. (2013) [4] observed that increased levels of organic manure yielded firmer fruit with vermicompost giving better results and addition of biofertilizer further increased the firmness. The maximum values of TSS, shelf life and ascorbic acid were recorded with 75 % RDF + *Azotobacter* + Vermicompost (T_6). The possible cause depicted in the increase in TSS may be due to difference in mineralization, continuous availability of more nutrients in higher amount and better utilization by plants (Chetri *et al.*, 2012) [5]. Another possible reason for TSS may be the release of fixed nitrogen, hence increasing the concentration and availability of nutrients in root zone (Fawzy *et al.*, 2012) [7]. The reason for better shelf life may be due to low respiration and transpiration rates, resulting in a reduced level of shrinkage and reduced ethylene metabolism (Chatterjee *et al.*, 2013) [4]. The findings of Hadwani *et al.* (2013) [10] are in line with the present results. The increase in ascorbic acid may be due to the 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 (Jaipaul *et al.*, 2011) [13]. The increased activity of ascorbic acid oxidase enzyme in the presence of micronutrients may be concerned to another reason for increase in ascorbic acid content (Malik *et al.*, 2011) [19].

Table 1: Effect of organic and inorganic nutrient sources on growth, yield and quality attributes of capsicum cv. California Wonder

Observation/Treatments	Days to 50% flowering	Days to First picking	Plant Height (cm)	Plant Spread (cm)	Harvest Duration (Days)	Average Fruit weight (g)	Fruit Length (cm)	Fruit Diameter (cm)	Number of fruits plant^{-1}	Fruit Yield plant^{-1} (g)	Fruit Yield (q ha^{-1})	Fruit Firmness (kg cm^{-2})	TSS (°Brix)
T_1: 100 % RDF	49.93	81.13	51.93	36.2	59.8	84.33	8.49	5.78	9.07	764.64	283.2	3.7	6.56
T_2: 50 % RDF + *Azotobacter*	54.93	87.73	45.18	30.99	56.67	74.32	7.42	4.44	7.93	604.53	223.9	2.77	5.68
T_3: 75 % RDF + *Azotobacter*	53.87	87.27	46.02	31.02	57.53	75.72	7.61	4.93	8.2	620.85	229.95	3.06	6.14
T_4: 50 % RDF + Vermicompost	52.73	86.2	46.15	31.31	58.33	77.91	8.1	5.19	8.4	654.52	242.41	2.95	5.76
T_5: 75 % RDF + Vermicompost	51.07	82.33	51.54	35.56	59.27	80.66	8.22	5.32	8.6	698.87	258.84	3.Q27	6.34
T_6: 50 % RDF + *Azotobacter* + Vermicompost	51.73	83.93	47.42	33.01	60.73	86.28	8.58	5.66	9.2	793.72	293.97	4.36	6.76
T_7: 75 % RDF + *Azotobacter* + Vermicompost	49.6	80.87	52.49	36.74	61.53	86.52	9.28	6.27	9.8	819.13	303.38	4.52	6.72
SE(m)	0.27	0.3	0.44	0.39	0.25	0.32	0.15	0.1	0.13	13.48	4.99	0.05	0.02
$CD_{(0.05)}$	0.84	0.93	1.35	1.2	0.74	0.99	0.45	0.31	0.4	41.55	15.39	0.17	0.05

Soil Chemical Properties

Sustainability of a cropping system is being evaluated on the basis of crop yield as well as nutrient status of the soil after harvest of the crop. Available NPK, electrical conductivity, organic carbon and pH were influenced by application of NPK, organic manures and biofertilizers alone or in combination (Table-2). Maximum available nitrogen was recorded in treatment T_7 (75 % RDF + *Azotobacter* + Vermicompost) which might be due to the synergistic effect of nitrogen fixing bacteria was result in higher accumulation of N in the soil, the mineralization of native organic matter increased the N. Moreover, the presence of vermicompost might have resulted in release of more nitrogenous substances in the soil and might have increased the efficiency of soil to hold the nutrients (Vijaya and Seethalakshmi, 2011) [38]. The significant effect due to organomineral application could be attributed to easy dissolution effect of released plant nutrient leading to improved nutrient status of the soil (Ademola and Agele, 2015) [1]. Chetri *et al.* (2012) [5], Jaipaul *et al.* (2011) [13] and Zahra *et al*. (2013) [41] expressed the similar views.

The data pertaining to available phosphorous content was maximum in 75 % NPK, *Azotobacter* and vermicompost. The increase P content may be due to the chelating effect of organic materials resulted in reduced phosphorus fixation, enhanced solubilization of insoluble P fractions and released available phosphorus (Chetri *et al.*, 2012) [5]. The application of organic and inorganic fertilizers marginally increased the available P (Ademola and Agele, 2015) [1]. The above findings are in accordance with Vijaya and Seethalakshmi (2011) [38].

The study revealed that potassium content in the soil was more in 75 % NPK, *Azotobacter* and vermicompost. This might be due to the fact that application of organic manures in bulk quantity and subsequently their slow mineralization resulted in gradual build up of available K (Chetri *et al.*, 2012) [5]. Another possible reason might be due to reduced solubility of Al and Fe and improved the CEC of the soil and thus increased the retention of K in exchangeable form by a mass action effect (Lal and Kanaujia, 2013) [6]. Thingujam *et al.* (2016) [35] and Prativa and Bhattarai (2011) [3] expressed the same views.

Conjoint application of inorganic and organic nutrient sources did not influence the pH, EC and OC of soil significantly. The increase in soil EC might be due to the application of organic and inorganic fertilizers together (Zahra *et al.*, 2013) [41]. The pH increased slightly in the plots receiving only chemical fertilizers and slightly moved towards the neutrality in the plots treated with combination of organic and inorganic nutrients which indicated that use of organic amendments have positive influence on soil health (Nandi *et al.*, 2002). The net increase in organic carbon might be due to the combined application of organic manures, inorganic fertilizers and biofertilizers (Lal and Kanaujia, 2013) [6]. The present findings are in accordance with those of Jaipaul *et al.* (2011) [13], Vijaya and Seethalakshmi, (2011) [38] and Thingujam *et al.* (2016) [35]. Organic carbon of soil acts as a sink and source of nutrients for microbial population, which regulates the availability of different nutrients through microbial transformation. The net increase in organic carbon may be due to increased microbial activities in the root zone which decomposed organic manures and also fixed unavailable form of mineral nutrients into available forms in soil thereby substantiated crop requirements and improved organic carbon level and stabilized soil pH (Chumei *et al.*, 2013) [6].

Table 2: Effect of organic and inorganic nutrient sources on economics capsicum cv. California Wonder and nutrient status of soil

Observation Treatments	Gross Income (□/ha)	Net return (□/ha)	B: C ratio	Electrical Conductivity (dSm^{-1})	Organic Carbon (%)	Soil pH	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})
T_1: 100 % RDF	2,68,200	1,98,791.55	2.86	0.64	0.97	7.89	218.90	28.10	133.52
T_2: 50 % RDF + *Azotobacter*	2,23,900.30	1,65,809.45	2.85	0.60	0.82	7.69	228.35	31.20	145.09
T_3: 75 % RDF + *Azotobacter*	2,29,945.20	1,70,070.55	2.84	0.63	0.85	7.63	232.51	32.28	150.77
T_4: 50 % RDF + Vermicompost	2,42,413.60	1,75,572.75	2.63	0.62	0.87	7.52	222.59	29.82	138.40
T_5: 75 % RDF + Vermicompost	2,58,839.20	1,90.214.56	2.77	0.63	0.89	7.60	224.64	30.27	140.89
T_6: 50 % RDF + *Azotobacter* + Vermicompost	2,93,970.60	2,25,879.75	3.31	0.63	0.98	7.40	235.71	34.84	152.08
T_7: 75 % RDF + *Azotobacter* + Vermicompost	3,03,380.70	2,33,506.05	3.34	0.68	0.97	7.20	239.72	35.20	155.54
SE(m)				0.02	0.07	0.37	1.05	0.53	1.01
$CD_{(0.05)}$				NS	NS	NS	3.23	1.62	3.12

Economics of Treatments

The economics of the bell pepper production as affected by various treatments (Table-3) revealed that maximum net returns and benefit: cost ratio was computed by the application of 75 % NPK in combination with *Azotobacter* and vermicompost. The reason for increased profit and benefit: cost ratio is due to maximum marketable yield due to healthy and better fruit size and higher net returns as compared to other treatments. Hence, the application of 75 % NPK with *Azotobacter* and vermicompost is rated as the most economical treatment for quality production of capsicum. Economics was also calculated by Jaipaul *et al*. (2011) [13] and Lal and Kanaujia (2013) [6].

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