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Evaluation of Organic Manures, Fermented Organics and PGPR on Plant Growth and Soil Properties under Capsicum (*Capsicum annuum* L.)

Perminder Singh Brar*, Rajesh Kaushal, Gitika Bhardwaj

Department of Soil Science and Water Management, Dr Y S Parmar University of Horticulture and Forestry Nauni, Solan, Himachal Pradesh 173230, India

**Corresponding author*

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A B S T R A C T

The present investigation was carried out to find out combined effect of bulky manures, liquid organic inputs and bio fertilizers on plant growth, plant nutrient content and soil properties under capsicum (*Capsicum annuum* L.). The experiment was laid out in Randomized Block Design with 7 different treatments. The maximum plant height (58.5 cm), plant biomass (66.40 g plant^{-1}), number of fruits (15.24 plant^{-1}) were recorded significantly in treatment T_2 comprising 90% RDN along with PGPR and fermented organics. The maximum fruit yield (31.15 t ha^{-1} and 1.051 kg plant^{-1}), NPK content in shoot (5.29, 0.64 and 6.27%), root (4.23, 0.66 and 3.54%), fruit (4.63, 0.61 and 4.23%) and the highest uptake of NPK (14.25, 1.87 and 13.81 kg ha^{-1}) and among soil properties, significant higher value of available macronutrient (445.33, 77.80, and 296.69 kg ha^{-1}), available micronutrient Zn, Cu, Fe, and Mn (2.37, 2.33, 6.73 and 2.62ppm respectively) and organic carbon (1.33%) were observed in treatment T_2. Similarly, among various microbial properties viz, microbial count, microbial biomass and soil enzymes such as Dehydrogenase, Phosphatase and Urease activities were also recorded significantly maximum in treatment T_2 as compared to T_1. This investigation concluded that the application of treatment T_2 (90 % RDN by Vermicompost and Poultry Manure along with fermented organics i.e. Panchagavya, Jeevamrut, Amritpani and liquid bio-fertilizer) significantly enhanced plant growth parameters, soil parameters and microbiological properties of soil.

Introduction

Bell peppers are enriched with vitamin A and C. *Capsicum annuum* and *C. frutescens* are 3rd among the cultivated vegetables which are also used as spice (Nwachukwu *et al.*, 2007). The fruits are ascorbic acid rich and recognized by capsaicin and capsanthin content. Capsicum is cultivated in an area of about 32,150 ha and annual production of 1.82 lakh MT in India whereas in Himachal Pradesh, the capsicum is cultivated over an area about 2070 ha, annual production is 34.13 thousand MT (Anonymous, 2016). The states which are leading in production of capsicum in India are Himachal Pradesh, Karnataka, Tamil Nadu, Maharashtra, Andhra Pradesh, Uttaranchal, Madhya Pradesh, West Bengal, Rajasthan, Punjab, and Orissa.

Organic farming is promoted due to its efficient approach which bind crop yield to ecology and associate with common objective of healthy environment for all the living beings. Organic manure increases the yield and long-term usage will give maximum output (Brar *et al.*, 2019). The ill effects of chemical inputs both on yield, soil and human health has generated, interest among the scientific community for the use of non-polluting, environment friendly organic amendments and it became imperative to use cheaper source of nutrients like organic manures to improve crop productivity and soil health (Follett *et al.*, 1981).

A significant higher plant height, canopy and yield of bell pepper recorded by the application of organic fertilizers compared to the use of synthetic fertilizers (Legaspi *et al.*, 2007). To achieve sustainable crop productivity without degrading soil health significant role is played by bulky manures (like Farm Yard Manure, Vermicompost and Poultry Manure), concentrated manures (edible and non-edible cakes) and liquid organic formulations (Panchagavya, Jeevamrut and Amritpani). These sources of nutrients along with bio-fertilizers/PGPR are becoming popular among farmers who are converting themselves from chemical farming to Organic Farming (OF).

Materials and Methods

The experimental field is situated at the research farm of the Department of Soil Science and Water Management, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) and field experiments were conducted during 2017. The climate of experimental area falls in sub-temperate, sub-humid agro-climatic zone-II of Himachal Pradesh. In this area, the hottest months are May and June whereas coldest months are December-January. The maximum rainfall received during monsoon period (mid-June to mid-September) and the average annual rainfall is about 1115 mm. The experimental area is having soil fall in order Inceptisol, sub group Eutrochrept according to Soil Taxonomy of USDA. The experiment was laid out in Randomized Block Design with seven treatments and three replications during 2017. The seven treatment combinations viz.

T_1:100% Recommended Doses of Nutrients only through Poultry manure and Vermicompost. T_2: 90% RDN through Poultry manure and Vermicompost with application of PGPR and fermented organic formulation (Panchagavya, Jeevamrut and Amritpani).

T_3: 80% RDN through Poultry manure and Vermicompost with application of PGPR and fermented organic formulation (Panchagavya, Jeevamrut and Amritpani).

T_4: 70% RDN through Poultry manure and Vermicompost with application of PGPR and fermented organic formulation (Panchagavya, Jeevamrut and Amritpani).

T_5: 60% RDN through Poultry manure and Vermicompost with application of PGPR and fermented organic formulation (Panchagavya, Jeevamrut and Amritpani).

T_6: 50% RDN through Poultry manure and Vermicompost with application of PGPR and fermented organic formulation (Panchagavya, Jeevamrut and Amritpani).

T_7: 40% RDN through Poultry manure and Vermicompost with application of PGPR and fermented organic formulation (Panchagavya, Jeevamrut and Amritpani).

Vermicompost, poultry manure (both are applied in 50:50 of Nitrogen equivalence), PGPR is applied as seedling dip for 2 hours at the time of transplanting and organic liquid manures like Panchagavya, Jeevamrut and Amritpani were applied @5% and 50 ml per plant at 15 days interval repeatedly, acts as source of nutrients and applied in according to treatments.

Plant analysis

The plant height, root length plant biomass and was measured at the end of crop season. Plant samples (fruit, shoot, and root) collected were washed, air dried in shade, subsequently in an oven at 65±5ºC till constant weight, grounded in an electric grinder and stored in paper bags for chemical analysis. Total nitrogen was determined by micro-kjeldahl method. Phosphorous in the extract was determined by vanado-molybdo yellow colour method (Jackson, 1973). Potassium was determined by flame photometric method. The Cu, Fe, Mn, Zn were determined in the extract using Atomic Absorption Spectrophotometer.

Soil analysis

Composite soil samples from 0-15 cm soil depth were collected before start of experiment. After crop harvesting soil samples from each plot were collected to ascertain the effect of different organic inputs on pH and EC, which were determined in soil: water suspension (1:2) according to Jackson (1973). Organic carbon was determined by Rapid titration method (Walkley and Black, 1934). Available N in soil was determined by Alkaline potassium permanganate method (Subbiah and Asija, 1956), available P by stannous chloride reduced ammonium molybdate method using Olsen's extractant (Olsen *et al.*, 1954) and available potassium was extracted by Ammonium acetate method (Merwin and Peech, 1951) and estimated on flame photometer and DTPA extractable Zn, Fe, Mn, Cu were estimated on Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). Among microbiological properties, total microbial count which was determined by standard spread plate technique (Subbarao, 1999). The estimation of Microbial biomass-C was carried out by soil fumigation extraction method (Vance *et al.*, 1987). Soil enzymes i.e. Dehydrogenase was estimated by method given by Casida *et al.*, (1964), Phosphatase enzyme estimation by method given by Tabatabai and Bremmer (1969) and Urease enzyme was determined by method given by Hoffman (1965).

Results and Discussion

Plant growth parameters

Plant growth parameters like plant height, root length, plant biomass, number of fruits per plant, fruit yield (per hectare and per plant) were significantly affected by different organic amendments like Poultry manure, Vermicompost and FYM, Panchagavya, Jeevamrut, Amritpani (given in Table 1). Plant with 90 % Recommended dose of nutrients (RDN) + PGPR inoculation + fermented organics i.e. T_2 treatment exhibited maximum increase in plant height (58.5 cm) of capsicum, higher plant biomass (66.40 g plant^{-1}), highest (15.24) number of fruits per plant were significantly recorded. Also, maximum fruit yield (31.15 t ha^{-1} and 1.051 kg fruit yield per plant) was recorded with treatment T_2. Also, studies conducted by Brar *et al.,* (2020) concluded that the bulky manures (vermicompost and poultry manure) in combination with PGPR and folk liquid manures have significant impact to increase the plant height and biomass in capsicum crop. Increase in rice yield with integrated use of different combinations of FYM, *Sesbania* and chemical fertilizers was also reported by Mehdi *et al.,* (2011). Significantly higher number of fruits by the application of farm yard manure and vermicompost in Watermelon was recorded by Aniekwe and Nwoku (2013). However maximum (15.6 cm) root length was recorded in T_3 with 80%

RDN + PGPR + fermented organics and the minimum (10.4 cm) root length was revealed in T_7 i.e. 40 % RDN + PGPR + fermented organics. However, T_1 (100 % RDN) and T_4 (70 % RDN + PGPR + fermented organics) was statistically at par with root length of 12.8 cm and 13.1 cm, respectively. Similar results were observed by Brar *et al.,* (2020) who found that with increasing application of bulky manures + folk liquid manures and PGPR, root length in capsicum crop increases.

Plant nutrient content

Total NPK content in shoot

Total NPK content in shoot was significantly influenced by different treatments as shown in Table 2. The effect of different treatments was significant and highest (5.29 %) total nitrogen, (0.64 %) total phosphorous content, total potassium (6.27 %) were recorded for treatment T_2 (90 % RDN along with PGPR and fermented organics). Similar results were also found by Ravimycin (2016), who reported that by application of vermicompost and farm yard manure there is increase in nutrient content of coriander plants.

Total NPK content in root

An examination of the data presented in Table 2 reveals that the highest total nitrogen content (4.23 %), (0.66 %) total phosphorous content and (3.54 %) total potassium content in root, observed under treatment T_2 (90 % RDN + PGPR + fermented organics). Similar results were also reported by Mia *et al.,* (2010) who observed that PGPR inoculation enhanced NPK content in roots.

Total NPK content in fruit

The data presented in Table 2 indicated that highest total NPK content in fruit i.e. 4.62 %, 0.61 % and 4.23 % respectively was observed under treatment T_2 (90 % RDN + PGPR + fermented organics). These results are in line with the studies carried out by Weber *et al.,* (2007) who found that application of compost significantly increased NPK content in plant and along with this soil properties are also affected.

Total uptake

The total uptake by plant is influenced significantly by different treatments. The highest value of total nitrogen (14.25 kg ha^{-1}), phosphorous (1.87 kg ha^{-1}) and potassium (13.81 kg ha^{-1}) uptake was recorded in treatment T_2 (90 % RDN + fermented organics + PGPR) as given in Table 2. The lowest value of total uptake of nitrogen (6.54 kg ha^{-1}), phosphorous (0.62 kg ha^{-1}) and potassium (7.16 kg ha^{-1}) was recorded in treatment T_7 (40 % RDN + PGPR + fermented organics). Similar findings were reported by Turan *et al.,* (2010), they found that by the application of PGPR, there is significant increase in macro and micro-nutrient nutrient uptake.

Soil properties

Among soil properties, soil pH and EC were non-significantly affected by different treatment combinations however the value of pH and EC ranged from 6.63 to 7.53 and 0.57 to 78 dS m^{-1} respectively. These results are in accordance with the results of Brar *et al.,* (2020) who found that application of manures, Soil recipes and PGPR have no significant effect on soil pH and EC in bell pepper. The organic carbon, available Nitrogen, available Phosphorus and available Potassium and DTPA extractable micronutrient cations were significantly affected by different treatment combinations. The highest (1.33 %) organic carbon was recorded in T_2 and lowest (1.03 %) was recorded in T_7 (40 % RDN through vermicompost and poultry manure + PGPR + fermented organics). These results are in accordance with the results of Das and Singh (2014) who reported that application of farm yard manure (FYM), legume compost, cereal compost and PGPR had significantly increase organic carbon of soil.

Also significant higher (445.33 kg ha^{-1}) value of available nitrogen, higher (77.80 kg ha^{-1}) content of available phosphorous and higher (296.69 kg ha^{-1}) value of available potassium was recorded under treatment T_2 having 90 % RDN with PGPR and also fermented organics (panchagavya, jeevamrut and amritpani). Studies carried out by Boateng *et al.*, (2006) also demonstrated that in maize there was 53 % increase in available N by the application of poultry manure. Also results are in accordance with the findings of Singh and Subba Rao (1979) who found that bio-fertilizers (*Azospirillum brasilense* with *Rhizobium japonicum*) increased the available phosphorus content in soil. Further Aziz *et al.*, (2010) observed that application of farm yard manure significantly enhance the available potassium content in soil.

The maximum Zn, Cu, Fe, Mn *viz.* 2.37 ppm, 2.33 ppm, 6.73 ppm, 2.62 ppm available micronutrients cations were also recorded in T_2 with 90 % RDN + PGPR + fermented organics and minimum (Zn, Cu, Fe, Mn *viz.* 1.19 ppm, 1.24 ppm, 4.76 ppm, 1.08 ppm) available micronutrient cations were obtained in T_7 i.e. 40 % RDN + PGPR + fermented organics. The present results are similar with the results of Jain *et al.*, (2014) who reported that Panchagavya application had significant effect on available micronutrient in different plant seedlings.

Table.1 Evaluation of organic manures, fermented organics and PGPR on plant growth parameters under Capsicum (*Capsicum annuum* L.)

Treatments	Plant Height (cm)	Root Length (cm)	Plant Biomass (g $plant^{-1}$)	No. of fruits per plant	Fruit yield per plant (kg)	Fruit yield (t ha^{-1})
T1	45.7	13.0	57.95	13.17	0.737	21.85
T2	58.5	14.7	66.40	15.24	1.051	31.15
T3	49.7	15.6	63.73	13.03	0.847	25.09
T4	47.0	13.4	58.20	12.91	0.749	22.18
T5	43.9	12.2	54.77	10.78	0.571	16.93
T6	38.4	11.5	53.47	9.40	0.479	14.20
T7	36.9	10.4	44.67	10.03	0.391	11.59
Mean	45.7	13.0	57.03	12.08	0.689	20.43
CD $_{(0.05)}$	3.21	1.42	3.31	1.77	0.12	3.44

Table.2 Evaluation of organic manures, fermented organics and PGPR on plant nutrient content under Capsicum (*Capsicum annuum* L.)

Treatments	Shoot (%)			Root (%)			Fruit (%)			Uptake (kg ha^{-1})		
	N	P	K	N	P	K	N	P	K	N	P	K
T1	4.46	0.58	5.96	3.92	0.57	3.40	4.31	0.53	3.92	10.89	1.45	11.40
T2	5.29	0.64	6.27	4.23	0.66	3.54	4.63	0.61	4.23	14.25	1.87	13.81
T3	4.51	0.59	6.16	3.95	0.63	3.49	4.54	0.57	3.95	12.27	1.70	12.84
T4	4.46	0.58	5.96	3.92	0.60	3.40	4.31	0.53	3.93	10.94	1.47	11.45
T5	3.68	0.58	5.75	3.84	0.51	3.28	4.09	0.44	3.84	9.08	1.25	10.45
T6	3.55	0.51	5.64	3.39	0.47	3.13	3.94	0.34	3.39	7.95	1.06	8.96
T7	3.32	0.31	5.25	3.23	0.39	2.88	3.84	0.24	3.23	6.54	0.62	7.16
Mean	4.18	0.54	5.86	3.78	0.55	3.30	4.24	0.47	3.78	10.28	1.35	10.87
CD (0.05)	0.25	0.15	0.20	0.22	0.16	0.39	0.20	0.16	0.22	1.21	0.24	0.86

Table.3 Evaluation of organic manures, fermented organics and PGPR on available macro and micronutrient content in soil under Capsicum (*Capsicum annuum* L.)

Treatments	pH	EC	Organic Carbon (%)	Macronutrient (kg ha^{-1})			Micronutrient (ppm)			
				N	P	K	Zn	Cu	Fe	Mn
T1	6.63	0.70	1.23	428.03	71.70	279.30	1.37	1.82	5.66	1.76
T2	6.96	0.70	1.33	445.33	77.80	296.69	2.37	2.33	6.73	2.62
T3	7.53	0.64	1.30	440.43	74.16	284.42	1.72	1.98	5.88	2.05
T4	7.00	0.57	1.24	428.27	71.17	278.25	1.37	1.82	5.66	1.75
T5	7.10	0.73	1.19	403.61	67.56	273.52	1.28	1.31	5.16	1.61
T6	7.13	0.59	1.14	388.12	57.44	271.58	1.25	1.29	4.83	1.18
T7	6.96	0.78	1.03	374.77	67.29	264.70	1.19	1.24	4.76	1.08
Mean	7.05	0.67	1.21	415.51	69.59	278.35	1.51	1.68	5.53	1.72
CD (0.05)	NS	NS	0.04	5.49	3.48	7.94	0.70	0.73	1.09	0.54

Table.4 Evaluation of organic manures, fermented organics and PGPR on various soil microbial properties in soil under Capsicum (*Capsicum annuum* L.)

Treatment	Microbial Count ($\times10^5$ cfu g^{-1} soil)	Microbial Biomass (µg g^{-1} soil)	Dehydrogenase (mg TPF h^{-1} g^{-1} soil)	Urease (mg NH^{4+} g^{-1} soil)	Phosphatase (µmole PNP h^{-1} g^{-1} soil)
T1	129.33	48.63	4.31	0.23	25.63
T2	147.33	60.33	4.96	0.28	30.41
T3	137.00	55.50	4.65	0.26	28.24
T4	130.00	49.53	4.30	0.23	25.60
T5	120.33	39.90	3.97	0.20	23.86
T6	109.00	25.73	3.40	0.16	22.94
T7	116.33	31.70	2.89	0.19	19.21
Mean	127.05	44.48	4.07	0.22	25.13
CD $_{(0.05)}$	6.98	10.58	1.02	0.05	1.35

Soil microbiological properties

Microbial count

The viable microbial count differed significantly with application of Bulky and concentrated organic manures, liquid organic inputs and bio-fertilizers. The treatment T_2 recorded maximum microbial count (147.33×10^5 cfu g^{-1} soil) whereas the lowest microbial count (109×10^5 cfu g^{-1} soil) was recorded in treatment T_6. These findings are similar with results obtained by Jain *et al.*, (2014), they reported that the application of Panchagavya, vermicompost and FYM increase microbial counts as compared to control.

Along with this maximum value of microbial biomass-C (60.33 µg g^{-1} soil) was recorded in T_2. These results are in line with findings presented by Beckman, (1973); Udoh *et al.*, (2005). The activity of various soil enzymes (Dehydrogenase, Phosphatase and Urease) also influence significantly by the application of different treatments. The maximum (4.96 mg TPF h^{-1} g^{-1} soil) value of dehydrogenase, was observed in treatment T_2 followed by Treatment T_3 (4.65 mg TPF h^{-1} g^{-1} soil), the treatment T_1 (4.31 mg TPF h^{-1} g^{-1} soil) was statistically at par with treatment T_4 (4.30 mg TPF h^{-1} g^{-1} soil) as given in Table 4.

These findings are similar with those of Kohler *et al.*, (2007) who also reported that by application of PGPR, alone or in consortium, there is increase in dehydrogenase in rhizospheric soil in lettuce. The application of organic amendments also influences phosphatase activity. Significantly higher (30.41 µmole PNP h^{-1} g^{-1} soil) value of phosphatase was observed in treatment T_2. Treatment T_1 (25.63 µmole PNP h^{-1} g^{-1} soil) was statistically at par with treatment T_4 (25.60 µmole PNP h^{-1} g^{-1} soil) and lowest (19.21 µmole PNP h^{-1} g^{-1} soil) value of phosphatase enzyme was noted in treatment T_7.

These results are in line with findings of Kohler *et al.,* (2007) which stated that due to the application of PGPR, there is increase in phosphatase activity near the rhizospheric soil. The urease enzyme activity also influenced by different treatments enumerated in Table 4. It was found that significant higher (0.28 mg NH^{4+} g^{-1} soil) value of urease enzyme activity was recorded in treatment T_2.

However lowest (0.16 mg NH^{4+} g^{-1} soil) value of urease enzyme activity was reported in treatment T_6. These results are similar with findings of Albiach *et al.*, (2000) and Nayak *et al.*, (2007), they stated that soil enzymes activities are influenced by the application of organic inputs and compost in the soil.

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