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Influence of INM on productivity and soil fertility in bell pepper under sub temperate zone of western Himalayas

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Abstract
A field experiment was carried out at the Experimental farm of the Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni Solan, HP (India) to evolve integrated plant nutrient supply system for higher productivity of sweet pepper on sustainable basis. The experiment was laid out in RBD with 03 replicates comprising 15 integrated combinations of inorganic and organics including Bio-fertilizers/PGPR. Integrated use of fertilizers, organic manures and PGPR significantly influenced yield and plant growth attributes of sweet pepper. The conjoint use of 75 % recommended dose of NP + Vermicompost and Enriched compost @ 2.5 t/ha + PGPR (T_{14}) resulted in significantly maximum fruit weight (50.37 g), fruit yield/plot (23.57 kg/ha) and fruit yield/ha (371.01 q/ha). This treatment recorded 60.89 per cent increase in yield over recommended practice (T_1). From present investigation, it can be concluded that above integrated combination of chemical fertilizers, organic manures (VC and EC) and PGPR resulted in saving of 25 % chemical fertilizers (NP), higher yield, and enhanced soil health.

Keywords: Bio-fertilizer; organic manures; soil health; yield

Introduction
In the last few decades, India has made a quantum jump in vegetable production, securing the second position after China in the world with an area of 9.542 million hectares and production of 168.3 million tonnes (Anonymous, 2015). Our demand of vegetables will be 225 million tonnes by 2020 and 350 million tonnes by 2030, to meet out the requirement of 300 g per capita per day for balanced diet (Anonymous, 2011).

Population growth and urbanisation are creating increased demand of food and there is growing concern of malnutrition. To meet the full dietary needs of common man, to eliminate malnutrition, deficiency diseases and to relieve overstress on cereals, there is greater need of enhanced vegetable production. Among the various factors of production of vegetables, nutrient management is more important with regard to sustain the production and productivity.

Bell pepper (*Capsicum annuum* L.) is a high value solanaceous vegetable crop originated in New World Tropics and subtropics and was introduced to India by the British in the in the 19th century in Shimla hills of Himachal Pradesh (Greenleaf, 1986).

Bell pepper, considered as a prosperous vegetable, is a rich source of vitamin A and C, used as salad, cooked, pickled and processed and admired globally for its flavour, aroma and colour (Pierce, 1987). In India, bell pepper is cultivated over an area of 30 thousand hectares with its annual production of 172 thousand metric tonnes. While in Himachal Pradesh, the area under bell pepper cultivation is 2.07 thousand hectares with annual production of 34.13 metric tonnes (Anonymous, 2016).

According to Larson and Pierce (1994), apart from nourishing plants, 'mother earth' creates a congenial atmosphere for the survival of the soil organisms. Therefore, better soil health is inevitable for better growth and development of crop leading to higher production .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*. 2003).

Therefore, the present investigation was undertaken to determine the influence of INM on productivity, profitability and soil fertility in bell pepper under sub temperate zone of western Himalayas.

Materials and methods
Experiment was carried out at Dr YSP University of Horticulture and Forestry, Nauni Solan, (HP) during the year 2015 to evolve *INMS* for higher productivity along with quality and soil

Health. The experiment was laid out in RBD with 03 replicates comprising 15 combinations of inorganic and organics including PGPR viz. T_1**:** RPF = (RDF (100 N: 75 P: 55 K kg/ha) + FYM 20 t/ha)), T_2**:** 75 % NP + VC@ 2.5 t/ha, T_3**:** 50 % NP + VC@ 2.5 t/ha, T_4**:** 75 % NP + EC@ 2.5 t/ha, T_5**:** 50 % NP + EC@ 2.5 t/ha, T_6**:** 75 % NP + PGPR, T_7**:** 50 % NP + PGPR, T_8**:** 75 % NP + VC@ 2.5 t/ha + PGPR, T_9**:** 50 % NP + VC@ 2.5 t/ha + PGPR, T_{10}**:** 75 % NP + EC@ 2.5 t/ha + PGPR, T_{11}**:** 50 % NP + EC@ 2.5 t/ha + PGPR, T_{12}**:** 75 % NP + VC and EC@ 2.5 t/ha, T_{13}**:** 50 % NP + VC and EC@ 2.5 t/ha, T_{14}**:** 75 % NP + VC and EC@ 2.5 t/ha + PGPR and T_{15}**:** 50 % NP + VC and EC@ 2.5 t/ha + PGPR.

The seeds/seedlings of sweet pepper cv. 'Solan Bharpur' were soaked in culture broth of bacterium (*Bacillus subtilis*)/sterilized water in sterilized petri-plates for 3-4 hours before sowing/transplanting in different growing media as per treatment. Seeds were sown in the nursery on 10th March, and subsequently; seedlings transplanted on April 21, 2015 in the treatment plots each measuring 3.0 m x 1.8 m, following a spacing of 60 cm x 45 cm. The NPK fertilizers were applied through – Urea, SSP and MOP, respectively. N & P as per treatments and full K were given to all the plots as basal dressing. N was given in three spilt doses, 1/3rd as basal dressing and rest further at one month interval. Recommended dose of FYM to all the plots and the other manures (vermicompost (VC) and enriched compost (EC)) as per treatments were incorporated at the time of preparation of individual plot manually. The data were recorded on fruit weight and yield along with post-harvest soil fertility status of the soil.

Results and Discussion

Fruit weight (g) and Yield per plot (kg) and / hectare (q)

The treatment module T_{14} observed maximum fruit weight (50.37 g) as presented through Table 1. The fruits harvested from plots planted with PGPR inoculated seed & seedling and fertilized with 75 % of recommended NP and full K (T_6) and in 50 % of recommended NP and full K (T_7) also observed statistically similar weight potential per fruit (48.98 g and 47.68 g, respectively) as above with T_{14}.

On account of higher fruit weight (50.37 g), T_{14} also exhibited highest yield (23.57 kg) from a plot area of 5.4 m^2 vis-à-vis RPF which recorded 14.65 kg fruits per plot. Transforming per plot yield potential to hectare basis, integrated module T_{14} with an yield outlay of 371.01 q/ha statistically excelled the recommended practice (230.60 q/ha) as well as all the other integrated modules. The treatment combination T_6 (75 % NP + PGPR) even without any compensation by way of any organics (VC and EC) for reduced synthetic content (NP) seems to have worked well as evident through its 2nd highest record of yield (329.30 q/ha) after $T_{14.}$ The higher yielding attributes and yield of capsicum through treatments supplemented with vermicompost alone or along with enriched compost in the present study could also be the result of regulated liberalization and balanced supply of nutrients, tilting microbial dynamics in favour of growth and creation of salutary soil environmental conditions for crop growth. In addition, besides its better nutrient contents, it could have increased the efficiency of added chemical fertilizers by its temporary immobilization, which reduces leaching of plant nutrients (Das *et al.*, 2006). Further, the PGPR can provide biologically fixed nitrogen to plants by meeting requirement up to 15-20 kg N/ha and secretes beneficial growth promoting substances like IAA, GA, kinetin, riboflavin, and thiamine, which can result in better plant growth (Malik *et al.*, 2005). Rani *et al.*, (2015) also recorded higher green chilli yield on account of higher fruit number and weight when 150 % of recommended dose of nitrogenous fertilizer was sourced half through inorganic and another half from organic sources *viz.* FYM (25 %) and Neem Cake (25 %) as basal and vermicompost as top dressing (50 %). The reasons for increased fruit yield in chilli were attributed to the increased solubilization effect and availability of nutrient by the addition of organics and increased physiological activity leading to the build-up of sufficient food reserves for the developing sinks and better portioning towards the developing fruits.

Table1. Effect of integrated nutrient management on fruit weight and yield of capsicum

Treatments	Fruit weight (g)	Yield per plot (kg)	Yield per hectare (q)
RPF = (RDF (100 N: 75 P: 55 K kg/ha)+ FYM 20 t/ha	43.53	14.65	230.60
75 % NP + VC@ 2.5 t/ha	48.27	18.47	290.68
50 % NP + VC@ 2.5 t/ha	45.47	14.53	228.71
75 % NP + EC@ 2.5 t/ha	44.10	14.77	232.44
50 % NP + EC@ 2.5 t/ha	43.06	14.05	221.21
75 % NP + PGPR	48.98	20.92	329.30
50 % NP + PGPR	47.68	17.86	281.13
75 % NP + VC@ 2.5 t/ha + PGPR	47.33	19.42	305.69
50 % NP + VC@ 2.5 t/ha + PGPR	46.14	15.77	248.28
75 % NP + EC@ 2.5 t/ha + PGPR	46.98	14.95	235.38
50 % NP + EC@ 2.5 t/ha + PGPR	43.70	12.93	203.58
75 % NP + VC and EC@ 2.5 t/ha	47.67	17.02	267.86
50 % NP + VC and EC@ 2.5 t/ha	44.69	14.59	229.61
75 % NP + VC and EC@ 2.5 t/ha + PGPR	50.37	23.57	371.01
50 % NP + VC and EC@ 2.5 t/ha +PGPR	48.54	19.81	311.88
Mean	46.43	16.89	265.82
$CD_{(0.05)}$	1.70	1.68	26.47

Available N, P and K content in soil (kg/ha)

Significantly maximum available N, P and K was through the integrated modules comprising 75 % NP + VC and EC@ 2.5t/ha + PGPR (T_{14}) and gain was to the tune of 32.91, 51.36 and 16.23 per cent, respectively over the recommended package of fertilization i.e. T_1 (Table 2). The conjoint use of organic manures particularly vermicompost, PGPR and chemical fertilizers could result in saving of at least 25 % of synthetic fertilizers (N, P and K) are in conformity with conclusion drawn by many researchers as enumerated below.

Sharma *et al.*, (2014) evaluated the integrated plant nutrient system in cauliflower-french bean-okra cropping sequence and found treatments comprising 20 t/ha VC +75 % NPK + PGPR and 20 t/ha FYM + 100 % NPK (recommended practice) remained at par with each other and maintained the highest available N, P and K content in the soil over sole recommended NPK application. Increase in available N might be attributed to the direct addition of nitrogen through vermicompost and farmyard manure and multiplication of soil microbes, which could convert organically bound N to inorganic form to the available pool of the soil. Similarly, the increase in available P content might be due to the incorporation of organic manures, which attributed to the direct addition of P as well as release of various organic acids on their decomposition chelating with Fe and Al and helps in solubilization of native P. The organic materials form a cover on sesquioxides and thus reduce the phosphate fixing capacity of the soil. The beneficial effect of vermicompost and farm yard manure on available K may be ascribed to the direct potassium addition to the potassium pool of the soil besides the reduction in potassium fixation and its release due to interaction of organic matter with clay particles.

At the end of capsicum crop, the soil analysis exhibited 339.08, 37.95 and 415.20 kg/ha of mean availability of N, P and K, respectively. The content of nitrogen and phosphorus increased by 6.19 and 8.77 per cent, respectively over the initial nutrient status of the soil, however, the availability of potash decreased by 10.23 % at the end of capsicum harvest. The decrease in potash availability may be due to either high removal of K by capsicum in a cropping sequence or high initial accumulation of exchangeable K.

Table 2. Effect of integrated nutrient management on the nutrient status of the soil after harvest

Treatments	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)
RPF = (RDF (100 N: 75 P: 55 K kg/ha) + FYM 20 t/ha	314.59	34.27	399.54
75 % NP + VC@ 2.5 t/ha	333.46	39.75	412.10
50 % NP + VC@ 2.5 t/ha	298.97	36.63	409.45
75 % NP + EC@ 2.5 t/ha	296.16	29.24	400.57
50 % NP + EC@ 2.5 t/ha	297.92	21.36	384.77
75 % NP + PGPR	390.82	43.94	447.47
50 % NP + PGPR	380.44	40.80	431.06
75 % NP + VC@ 2.5 t/ha + PGPR	375.89	44.10	417.40
50 % NP + VC@ 2.5 t/ha + PGPR	311.49	39.09	401.49
75 % N P + EC@ 2.5 t/ha + PGPR	313.59	40.14	402.84
50 % NP + EC@ 2.5 t/ha + PGPR	286.60	23.84	383.65
75 % NP + VC and EC@ 2.5 t/ha	379.45	42.73	421.88
50 % NP + VC and EC@ 2.5 t/ha	310.47	37.68	407.76
75 % NP + VC and EC@ 2.5 t/ha + PGPR	418.13	51.87	464.37
50 % NP + VC and EC@ 2.5 t/ha + PGPR	378.17	43.88	443.68
Mean	339.08	37.95	415.20
$C.D_{(0.05)}$	23.58	5.45	13.53

*****Initial soil fertility status- 319.32 N: 34.89 P: 457.70 K

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