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Influence of INM on productivity and soil fertility under pea-capsicum-radish cropping system

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Abstract
A field experiment was carried out for two consecutive years (2014-16) at Dr YS Parmar University of Horticulture and Forestry, Nauni Solan, Himachal Pradesh to evolve *INPS* system for higher productivity and profitability from pea-capsicum-radish cropping system. Results indicated that module T_6 resulted in highest yields 152.93, 351.55 and 341.68 q/ha in pea, capsicum and radish respectively. T_6 also enhanced soil health as envisaged through the increased post-harvest availability of N, P and K by 13.95, 26.80 and 22.22 per cent, over the initial content. Therefore, it can be concluded that integrated module T_6 resulted in saving of 10 % of fertilizers (NPK), better growth, improving yield, and also enhanced soil health thus, can be a cost effective combination for getting higher yield with grater quality on sustainable basis.

Keywords: Influence, INM, productivity, soil fertility under pea-capsicum

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.

For enhancing high yield of vegetable crops, soil health is crucial factor. Unfortunately, deteriorating soil fertility is principally responsible for low yield of vegetables across the country. Enhancing soil fertility and crop productivity through use of chemical fertilizers has often negatively affected the complex system of biogeochemical cycles Roberts (2008). For example, fertilizer use has caused leaching and run-off of nutrients, especially nitrogen (N) and phosphorus (P), leading to environmental degradation. Therefore, there must be a balance between optimal nutrient use efficiency and optimal crop productivity. Amongst the several indicators of soil degradation, over mining of nutrients is considered to be the major concern particularly under vegetable based cropping systems, which have high irrigation requirement. This is happening so because nutrient removal by crops from soil has far exceeded their replenishment through fertilizers and manures causing negative balance of nutrients in soil Gangawar and Prasad (2005). Therefore, interest has grown in environmentally sustainable agricultural practices.

The potential way to decrease negative environmental impacts resulting from inefficient use of chemical fertilizers is to follow integrated use of organic manures, mineral fertilizers and inoculation with bio-fertilisers / plant growth promoting rhizobacteria (PGPR). This will in turn help to meet out the nutrient requirement of the crops as well as maintaining sustainability in terms of productivity and soil fertility

Integrated approach has helped in increasing the fertilizer use efficiency under intensive cropping systems Chettri and Bandhopadhaya (2005). Therefore the present was to study the effect of integrated use of organic manures, inorganic fertilizers and plant growth promoting rhizobacteria/bio-fertilizers on physico-chemical properties of the soil as well as economics under pea-capsicum and radish cropping sequence.

Materials and Methods

Experiment was carried out for two years (2014-2016) at Dr YS Parmar University of Horticulture and Forestry, Nauni Solan, (HP) to evolve *INPS* system for higher productivity and soil health. Agro-climatically, the location falls in the mid hill zone of HP and is characterized by sub-temperate to sub-tropical climate with moderate rainfall (1000-1300 mm). The experiment was laid out in RBD with 03 replicates comprising 13 integrated combinations of inorganic and organics including Bio-fertilizers/PGPR viz. T_1: RPF= (RDF (NPK) + FYM), T_2: 90 % RDF + 10 % EC + FYM + Bio-fertilizer/PGPR T_3: 80 % RDF + 10 % EC + FYM + Bio-fertilizer/PGPR, T_4: 70 % RDF + 10 % EC + FYM + Bio-fertilizer/PGPR, T_5: 60 % RDF + 10 % EC + FYM + Bio-fertilizer/PGPR, T_6: 90 % RDF + 10 % SMC + FYM + Bio-fertilizer/PGPR, T_7: 80 % RDF + 10 % SMC + FYM + Bio-fertilizer/PGPR, T_8: 70 % RDF + 10 % SMC + FYM + Bio-fertilizer/PGPR, T_9: 60 % RDF + 10 % SMC + FYM + Bio-fertilizer/PGPR, T_{10}: 90 % RDF + FYM + Bio-fertilizer/PGPR, T_{11}: 80 % RDF + FYM + Bio-fertilizer/PGPR, T_{12}: 70 % RDF + FYM + Bio-fertilizer/PGPR and T_{13}: 60 % RDF + FYM + Bio-fertilizer/PGPR. The reduced RDF was supplemented through organic manures (EC, SMC) on Nitrogen eqivalent basis. Seeds of pea cultivar Punjab- 89 were sown at spacing of 60 x 7.5cm, while capsicum cv. Solan Bharpur was spaced at 60 x 45 cm. Similarly, radish cv. Japanese White was sown 30 x 7.5 cm apart. The inoculated/un-inoculated seeds of capsicum were sown at Experimental Farm during both the years under special care in 1 x 1 x 0.15 m seed beds. Available N, available P, available K was determined by the methods adopted by Subbiah and Asija (1956), Olsen *et al.* (1954) and Merwin and Peech (1951) respectively. Statistical analysis was performed as per the design suggested by Gomez and Gomez (1983).

Results and Discussion

Yield

In pea, T_6 (90 % RDF + 10 % SMC + FYM + Bio-fertilizer/PGPR) harvested the highest pods (179.35 q/ha), closely followed by T_2 and T_7 with an on par yield potentials of 176.18 and 171.32 q/ha, respectively. All the three modules (T_6, T_2 and T_7) statistically excelled the RPF which yielded @ 157.17q/ha, respectively similarly, in capsicum, T_6 again emerged the top yielder (351.55 q/ha) followed by T_2 (335.89 q/ha) and both were statistically superior to the RPF (T_1) by 24.53 and 18.98 %, respectively. In radish too, maximum roots were harvested in T_6 (341.68 q/ha) followed by T_7 (329.24 q/ha) and T_2 (327.12 q/ha) Overall, the findings based on the productivity reveals that in pea and radish, 20 % and by capsicum, 10 % saving of inorganic is possible through their substitution with organic manures (EC, SMC) and bio-inoculation of planting material with relevant bio-fertilizers/PGPR (*Bacillus subtilis*). The reasons for increased yield 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. Similar observations were recorded by Sharma *et al.* (2014) in cauliflower, French bean and okra, respectively, Reddy *et al*. (2014) in cluster bean, Sahay *et al.* (2016) in pigeon pea, Rani *et al*. (2015) and Kapse *et al*. (2017) *in* green chilli and Patil *et al.* (2016) in carrot.

Available N, P and K

The significant variations amongst different integrated modules were observed for macronutrient (NPK) availability in the soil after studying annual sequence's (pea-capsicum-radish) growth and yield performance in filed for two years. The significantly maximum available N (471.89 Kg/ha) was through the integrated module comprising of 90 % RDF + 10 % SMC + FYM + Bio-fertilizer/PGPR (T_6) which was statistically at par to T_2 (90 % RDF + 10 % EC + FYM + Bio-fertilizer/PGPR), T_7 (80 % RDF + 10 % SMC + FYM + Bio-fertilizer/PGPR), T_{10} (90 % RDF + FYM + Bio-fertilizer/PGPR) and T_3 (80 % RDF + 10 % EC + FYM + Bio-fertilizer/PGPR,) recording 469.23, 465.94, 462.76 and 461.83 kg N/ha, respectively, The gain in nitrogen availability in soil through above five treatment modules was to the tune of 15.17, 14.51 13.71, 12.94 and and 12.71 per cent, respectively over the recommended package of fertilization i.e. T_1 (409.74 kg/ha). As far Phosphorus, T_6 and T_2 again registered significantly maximum mean P i.e. 59.78 and 57.73 kg/ha, respectively, among all modules including RPF (50.38 kg P/ha). The difference between T_6 and T_2 was not significant. The mean content of K was also maximum (214.70 kg/ha) with T_6 (90 % RDF + 10 % SMC + FYM + Bio-fertilizer/PGPR) followed at par by T_2 (90 % RDF + 10 % EC + FYM + Bio-fertilizer/PGPR) and T_7 (80 % RDF + 10 % SMC + FYM + Bio-fertilizer/PGPR) which recorded 212.30 and 209.55 kg K/ha, respectively The finding suggests that reduction up to 20 % of inorganics (NPK) is possible through their substitution with organic manures (EC, SMC) and bio-inoculation of planting material with PGPR (*Bacillus subtilis*). The increase in available N 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. These findings are in conformity with the findings of Sharma *et al.* (2014) in cauliflower-French bean-okra cropping sequence, Chaintanya *et al.* (2013), Choudhary *et al*. (2005), Prativa and Bhattarai (2011).

Table 1: Effect of different INM treatments on productivity profitability and fertility under cropping sequence pea - capsicum - radish cropping sequence over two years of experimentation

	Pea	Capsicum	Radish	Soil Properties		
TC	Pod yield (t/ha)	Fruit yield (t/ha)	Root yield (t/ha)	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)
1	157.17	282.31	296.31	409.74	50.38	189.99
2	176.18	335.89	327.12	469.23	57.73	212.30
3	167.71	286.70	303.74	461.83	54.34	205.73
4	163.89	264.14	270.98	447.96	49.23	198.51
5	152.93	255.95	252.57	440.89	47.10	196.68
6	179.35	351.55	341.68	471.89	59.78	214.70
7	171.32	309.95	329.24	465.94	56.35	209.55
8	164.91	285.92	289.09	453.1	50.56	200.72
9	156.67	271.75	274.05	445.29	48.63	199.01
10	170.45	305.49	307.16	462.76	55.88	209.07
11	160.07	281.93	274.34	457.11	52.22	201.61
12	147.44	249.66	245.67	440.28	46.72	197.09
13	137.46	242.81	227.05	432.74	45.41	193.91
CD (0.005)	10.37	14.28	45.34	11.42	2.51	5.33

Initial Soil Fertility Status: 414.13N: 43.76P: 175.67K (kg/ha)

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