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Integrated nutrient supply system for cauliflower-French bean-okra cropping sequence in humid temperate zone of north-western Himalayas

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ABSTRACT

A field experiment was conducted for three consecutive years at Vegetable Farm, Himachal Pradesh Agricultural University, Palampur to investigate the response of integrated nutrient management on cauliflower-French bean-okra cropping sequence. A total of 10 treatment combinations comprising of manures alone, their integration with plant growth promoting *Rhizobacteria* (PGPR) and different levels of NPK fertilizers were laid out in RBD, replicated thrice in vegetable based sequence of cauliflower, French bean and okra. Integrated use of manures, fertilizers and PGPR significantly influenced yield and plant growth attributes in all three crops. The highest yield was recorded in treatment comprising of vermicompost @ 20 t ha^{-1} + 75% of recommended dose of NPK + PGPR (T_8) with average increase of 9.46, 2.36 and 1.14% over the recommended practice (T_2) in cauliflower, French bean and okra, respectively alongwith highest annual net returns. The uptake of N, P and K was similar in T_8 and T_2 in the respective crops and these treatments also maintained the highest available NPK contents in the soil over T_1. This can be concluded that conjoint use of vermicompost, PGPR and chemical fertilizers resulted in saving of 25% fertilizers (NPK), better performance of growth attributes, higher yield and net returns besides enhanced soil health.

Key words: Vegetable based sequence, yield, nutrient uptake, soil health.

INTRODUCTION

In the era of crop diversification, vegetable cultivation in Himachal Pradesh in general and in mid-hills in particular is gaining significant importance on account of favourable agro-climatic conditions for growing quality off-season vegetables, *e.g.* pea, tomato, cauliflower, cabbage, French bean, okra etc. The use of chemical fertilizers to enhance soil fertility and crop productivity has often negatively affected the complex system of biogeochemical cycles (Roberts, 15). 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, 5). 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 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, 3). Hence, the present study was, therefore, aimed at to evolve integrated plant nutrient supply system for vegetable-based cropping systems.

MATERIALS AND METHODS

The field study was conducted for three years at Vegetable Research Farm, Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Agro-climatically, the location represents the mid-hill zone of Himachal Pradesh (Zone-II) and is characterized by humid sub-temperate climate with high rainfall (2,500 mm). The soil is clay loam with pH 5.6 and is classified as Typic Hapludalf. Ten treatments, *viz.*, T_1 = 100% of the recommended NPK dose, T_2 = 20 t farmyard manure/ha + 100% NPK (recommended practice), T_3 = 30 t farmyard manure/ha, T_4 = T_3 + PGPR, T_5 = 30 t vermicompost/ ha, T_6 = T_5 + PGPR, T_7 = 20 t farmyard manure/ha + 75% of the recommended NPK + PGPR,

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T_8 = 20 t vermicompost/ ha + 75% of the recommended NPK + PGPR, T_9 = 20 t farmyard manure/ ha + 50% of the recommended NPK + PGPR, and T_{10} = 20 t vermicompost/ ha + 50% of the recommended NPK + PGPR, were laid out in randomized complete block design with three replications. These treatments were applied in vegetable based sequence of three crops, *viz.*, cauliflower cv. Pusa Snowball K1, French bean cv. 'Contender' and okra cv. P-8 under irrigated conditions. The plots assigned to a particular treatment were used over three years of the experiment for each crop.

Annually, cauliflower was transplanted in mid October at a spacing of 45 cm × 45 cm, while French bean and okra were sown in last week of March and first fortnight of June, respectively at a spacing of 45 cm × 15 cm. To produce transplants of cauliflower, seeds were sown in a raised nursery bed of size 3 m × 1 m × 15 cm in the second week of September in each year. Organic manures (farmyard manure and vermicompost) were incorporated manually into the soil one week before transplanting/ sowing as per treatments to all the three crops. The vermicompost was prepared using cowdung, *Lantana* and different crop biomass with the use of *Eudrilus euginiae* earthworm species which contained 1.92% N, 0.96% P and 0.58% K. On the other hand, farmyard manure contained 0.6% N, 0.28% P and 0.45% K. The recommended rate (100%) of N, P and K for cauliflower, French bean and okra is 125:33:50, 50:40:50 and 75:26:50 kg/ha, respectively and were applied as per treatment at different stages of crop growth. Full dose of P and K were given at the time of transplanting/ sowing of the crops as single super phosphate, and muriate of potash, respectively. N was applied in full at sowing in French bean whereas in case of cauliflower and okra, half of the N was applied at transplanting/ sowing and remaining N in two splits at one-month intervals through calcium ammonium nitrate. Seedlings of cauliflower were inoculated by dipping the roots for 15 min. in slurry containing *Azotobacter chroococcum* prior to transplanting, while seeds of French bean and okra were inoculated with slurry of *Rhizobium leguminosarum* and *Azotobacter chroococcum*, respectively followed by drying of seeds in the shade before sowing.

Five plants were randomly tagged in each treatment and replication for recording data on different growth and yield related attributes namely, plant spread (cm^2), curd depth (cm), curd diameter (cm), gross curd weight (g), marketable curd weight (g) and net curd weight (g) in cauliflower; pod length (cm) and plant height (cm) in French bean; and fruit length (cm), fruits/ plant and plant height (cm) in okra. Marketable yield (kg) was recorded on plot basis in each crop and converted to tonnes/ ha. Uptake of N, P, and K was calculated as:

Nutrient uptake (kg ha^{-1}) = Concentration (%) of nutrient × yield on dry weight basis (kg ha^{-1})

Soil samples were collected at completion of the experiment and analyzed for change in available N, P and K status using standard methods (Jackson, 7). Mean values were statistically analyzed using the F-test (Gomez and Gomez, 6). The data of the three years on each character under study were pooled using standard statistical procedures. Economic comparisons were analyzed on the basis of prevailing market prices of inputs and outputs.

RESULTS AND DISCUSSION

Application of integrated use of organic manures, chemical fertilizers and PGPR significantly influenced the plant growth and yield related attributes in cauliflower, French bean and okra (Table 1). Treatment T_8 (vermicompost @ 20 t ha^{-1} + 75% NPK + PGPR) resulted in significantly more plant spread alongwith significant increase in marketable curd weight over recommended practice of application of farmyard manure @ 20 t ha^{-1} + 100% NPK (T_2) and sole application of 100% synthetic fertilizers (T_1) in cauliflower. In French bean, the performance of yield attributing traits like pod length and plant height was maximum in T_8, which was at par with recommended practice but significantly higher than the sole application of fertilizers (T_1) in pooled over years. Similarly, in okra, fruits/ plant and plant height were significantly higher in T_8 over both T_2 and T_1 with no significant differences for pod length over the years. This increase could be ascribed to increased activities of beneficial micro organisms due to increased organic pool in soil, which resulted in production of growth-promoting substances and improved nutrient availability for longer period throughout the crop growth and resulted in better photosynthetic activities and ultimately high biomass production (Kumar and Dhar, 9). The beneficial effects of integration of organics, PGPR and fertilizers on various growth attributes were also observed by Sharma *et al.* (16), Rajput *et al.* (14) and Bairwa *et al.* (2) in cauliflower, French bean and okra, respectively.

The performance of these attributes further reflected on the marketable yield of cauliflower, French bean and okra (Table 2) where treatments comprising of conjoint use of organic manure and chemical fertilizers in the presence/ absence of PGPR resulted in significantly higher yield over the sole use of chemical fertilizers (T_1). This could be attributed to efficient utilization of nutrients from integrated sources compared to a single source. On

Table 1. Effect of integrated use of organic manures, bio-inoculants and fertilizers on plant growth and curd attributes in cauliflower-French bean-okra cropping sequence.

Treatment	Cauliflower				French bean		Okra		
	Plant spread (cm^2)	Curd depth (cm)	Curd dia. (cm)	Marketable curd wt. (g)	Pod length (cm)	Plant height (cm)	Fruit length (cm)	Fruits/ plant	Plant height (cm)
T_1	1785.28	6.64	9.20	320.64	14.85	34.66	15.40	6.60	75.12
T_2	2600.11	7.95	12.44	494.44	16.44	40.51	15.78	8.59	90.64
T_3	1618.08	6.25	9.57	209.00	14.63	33.79	13.49	6.12	66.88
T_4	1641.08	6.76	9.87	230.44	15.20	35.03	14.42	6.22	69.51
T_5	1626.92	6.73	9.90	226.78	15.04	34.83	13.76	6.30	65.34
T_6	1667.50	6.92	10.14	269.66	15.51	36.78	14.37	6.94	75.91
T_7	2561.70	7.86	12.19	455.67	16.33	39.97	14.89	8.35	91.84
T_8	2654.12	8.17	13.01	521.67	16.78	41.51	15.30	9.56	97.24
T_9	2060.58	7.37	10.88	388.33	15.00	37.67	14.81	7.79	81.54
T_{10}	2147.05	7.60	11.59	404.44	15.57	39.30	14.55	7.91	83.52
CD ($P \leq 0.05$)	31.81	0.38	0.62	25.95	0.51	2.38	0.85	0.44	4.32

the other hand, the organic treatment combinations (T_3 to T_6) significantly resulted in overall poor plant growth which led to the poor performance of different yield attributes in all these crops (Table 1), which ultimately led to low marketable yield (Table 2) in comparison to those treatments integrated with chemical fertilizers. This showed that sink capacity of a plant depend mainly on vegetative growth which is affected positively by application of nutrients and supply of photosynthates for the formation of yield components (Kumar *et al.*, 10).

The increase in yield was much higher when equal amounts of vermicompost was applied in place of farmyard manure under both conditions of pure organic treatments and those of organic manures integrated with PGPR and chemical fertilizers during three years of experimentation (Table 2). For example, sole application of 30 t ha^{-1} vermicompost (T_5) recorded 21.75, 13.69 and 2.49% increase in yield over sole application of 30 t farmyard manure ha^{-1} (T_3) in cauliflower, French bean and okra, respectively. Similar trends were also observed in the treatments comprising of vermicompost integrated with inorganic fertilizers plus bio-inoculants. The highest yield was recorded in treatment T_8 (vermicompost @ 20 t ha^{-1} + 75% NPK + PGPR) over the years which resulted in net saving of 25% NPK fertilizers along with average increase of 9.46, 2.36 and 1.14% in yield over the recommended practice of farmyard manure @ 20 t ha^{-1} + 100% NPK (T_2) in cauliflower, French bean and okra, respectively. The increase in yield was much higher to the tune of 72.93, 28.48 and 30.06% in the respective crops of the sequence in comparison to sole fertilizer application (T_1). This indicates that integrated use of organic materials, synthetic fertilizers, and bio-inoculants can likely be used to produce sustainable yields.

The higher yields in treatments supplemented with vermicompost could 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 fertilizer by its temporary immobilization, which reduces leaching of plant nutrients (Das *et al.*, 4). Further, the PGPR can provide biologically fixed nitrogen to plants by meeting requirement up to 15-20 kg N ha^{-1} and secret beneficial growth promoting substances like IAA, GA, kinetin, riboflavin, and thiamine, which can result in better plant growth (Malik *et al.*, 11). The PGPR have the capacity to promote the plant growth by increase in the root surface area or the general root architecture. This in turn releases higher amounts of C in root exudates and promote increase in microbial activity which might have made more nutrients available from the soil pool, influencing nutrients flux into plant roots, and the plant is able to take up more available nutrients (Adesemoye *et al.*, 1). The advantage on yields by following different combinations of treatments by the integrated use of organic manures, bio-fertilizers and chemical fertilizers were also reported in cauliflower (Sharma *et al.*, 16), French bean (Rajput *et al.,* 14) and okra (Sharma *et al.*, 18).

Table 2. Effect of integrated use of organic manures, bio-inoculants and fertilizers on marketable yield and monetary returns in cauliflower- French bean-okra cropping sequence.

Treatment	Cauliflower			French bean			Okra			Annual benefit	
	Marketable curd yield (t/ ha)	Net returns (Rs. in million)	Benefit: cost ratio	Pod yield (t/ ha)	Net returns (Rs. in million)	Benefit: cost ratio	Fruit yield (t/ ha)	Net returns (Rs. in million)	Benefit: cost ratio	Net returns (Rs. in million)	Benefit: cost ratio
T_1	11.40	0.05	2.46	7.82	0.09	3.79	5.85	0.039	2.26	0.18	2.81
T_2	18.03	0.10	3.20	10.65	0.12	4.10	7.52	0.040	2.04	0.26	3.12
T_3	6.96	0.03	1.68	6.36	0.09	3.14	5.26	0.038	1.94	0.16	2.22
T_4	7.82	0.04	1.387	6.86	0.10	3.35	5.04	0.50	2.21	0.19	2.44
T_5	8.47	0.04	1.65	7.23	0.09	2.76	5.39	0.047	1.92	0.18	2.09
T_6	9.49	0.05	1.83	7.55	0.10	2.50	5.77	0.052	2.02	0.20	2.21
T_7	16.98	0.09	3.05	9.93	0.11	3.87	7.00	0.045	2.18	0.25	3.03
T_8	19.71	0.11	3.00	10.90	0.12	3.52	7.61	0.045	1.96	0.27	2.83
T_9	14.91	0.08	2.74	9.26	0.10	3.71	6.56	0.041	2.10	0.22	2.84
T_{10}	15.39	0.07	2.39	9.69	0.10	3.20	6.41	0.031	1.69	0.20	2.42
CD ($P \leq 0.05$)	0.99	0.01	0.18	0.77	0.01	0.18	0.55	0.009	0.22	0.01	0.21

The performance of these treatments reflected in monetary gains by following cauliflower-French bean-okra cropping sequence (Table 2). The highest net return of Rs 2.67 lakhs ha^{-1} was obtained from treatment T_8 which was at par with those of T_2 over pool years. However, on account of higher cost of vermicompost, the benefit: cost ratio was more in the latter treatment. Though, it is pertinent to mention that the vermicompost also resulted in good build up of nutrient status in soil over the years (Table 4), besides it also helps in reducing air pollution. The organic treatments significantly resulted in low net returns comparing to those supplemented with synthetic fertilizers.

Total uptake of nutrients by plants increased with combined application of organic manures, biological inoculants and synthetic fertilizers in all three crops grown in the sequence (Table 3). The uptake of these nutrients was higher in treatments comprising of vermicompost over those having farmyard manure, which shows the better nutrient status of the former treatment. The highest amount of N, P and K uptake of 129.42, 44.80 and 66.26 kg ha^{-1} was registered in treatment T_8, respectively with respective significant increase of 112.02, 122.33 and 128.96% over sole application of 100% NPK (T_1) in cauliflower. Similar trends were also observed in French bean and okra where T_8 registered an increase of 71.90, 79.78 and 61.28% in N, P and K uptake in French bean, respectively over the sole application of fertilizers (T_1) while in okra, the respective increase of these nutrients was in the range of 39.77, 140.76 and 158.58%. This indicates that integrated nutrient supply system resulted in enhanced uptake of nutrients, which may be attributed to stimulated microbial growth and root growth owing to the improvement in the soil physical conditions with the addition of organic material (Kachot *et al.*, 8) and this might have resulted in better absorption of water and nutrients. Application of organic amendments may increase supply of macro- and micro-nutrients to plants and could mobilize unavailable nutrients to available forms, and as a cumulative effect, nutrient uptake is higher than synthetic fertilizers (Sharma *et al.*, 17). Many workers while working on single crop have also reported the increased nutrient use efficiency by the conjoint use of organic manures and inorganic fertilizers with or without PGPR, which reflected in yield and nutrient uptake in cauliflower (Narayanamma *et al.*, 12) and French bean (Rajput *et al.*, 14).

The integrated use of organic manures, chemical fertilizers and bio-inoculants significantly increased available N, P and K contents of the soil over the three years of experimentation (Table 4). Treatments comprising of 20 t vermicompost ha^{-1} + 75% NPK + PGPR (T_8) and 20 t farmyard manure ha^{-1} + 100% NPK (T_2) remained at par with each other and maintained the highest available N, P and K contents in the soil over sole NPK application (T_1). The former treatment (T_8) increased the available N, P and K level in the soil by 24.27, 28.87 and 46.09%, respectively, while the

Table 3. Effect of integrated use of organic manures, bio-inoculants and fertilizers on nutrient uptake in cauliflower-French bean and okra.

Treatment	Cauliflower			French bean			Okra		
	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
T_1	61.04	20.15	28.94	39.48	18.00	28.85	38.30	8.12	9.03
T_2	115.74	39.33	59.16	65.66	31.14	44.77	53.97	17.55	22.35
T_3	35.29	11.17	16.41	30.62	12.15	21.86	32.80	4.93	7.037
T_4	40.91	12.99	19.79	34.33	13.57	24.23	32.25	5.44	7.16
T_5	43.26	14.62	21.57	36.34	14.89	25.83	34.06	5.51	7.73
T_6	51.36	17.02	25.13	39.20	16.57	27.69	38.11	6.98	9.44
T_7	106.22	33.78	53.26	57.70	27.65	40.67	48.55	15.15	19.74
T_8	129.42	44.80	66.26	67.87	32.36	46.53	53.53	19.55	23.35
T_9	84.80	29.21	42.30	50.99	22.50	34.45	42.11	9.75	15.04
T_{10}	89.39	31.66	44.88	54.42	24.38	37.83	41.51	9.74	15.50
CD ($P \leq 0.05$)	5.66	2.11	3.02	2.99	1.29	2.03	3.83	1.36	1.60

Table 4. Effect of integrated use of organic manures, bio-inoculants and fertilizers on available nutrient status in cauliflower-French bean-okra cropping sequence.

Treatment	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	252.80	22.93	229.38
T_2	307.12	28.45	335.10
T_3	219.28	18.67	154.65
T_4	224.24	19.27	172.94
T_5	220.45	18.89	161.05
T_6	228.11	20.95	177.12
T_7	294.16	26.67	329.59
T_8	314.17	29.55	343.96
T_9	251.44	23.93	306.66
T_{10}	256.61	24.52	313.69
CD ($P \leq 0.05$)	12.12	2.60	16.68

Initial status of soil at the start of experiment N = 212 kg ha^{-1}, P = 15 kg ha^{-1} and K = 152 kg ha^{-1}

increase in T_2 was recorded to the tune of 21.49% N, 24.07% P and 49.95% K at the completion of the experiment over sole application of 100% NPK (T_1). 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 farmyard 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. The beneficial effects of integration of manures + bio-inoculants + chemical fertilizers in promoting inherent fertility status of soil was earlier reported by Parmar *et al.* (13) in cauliflower.

The gain in soil fertility in terms of available N, P and K was comparatively higher in treatments augmented with vermi-compost in comparison to farmyard manure. On the other hand, available N, P and K contents in the soil with organic treatments were significantly very low over all treatments supplemented with inorganic fertilizers. This suggests that the integrated use of organic sources, biofertilizers and chemical fertilizers may be helpful in nutrient management.

It can be concluded that conjoint use of vermicompost, PGPR and chemical fertilizers resulted in saving of 25% N, P and K synthetic fertilizers, better plant growth, higher yield and net returns gave in cauliflower-French bean-okra sequence besides enhancing soil health as evident by nutrient uptake and post-harvest soil fertility status.

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