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Effect of integrated nutrient management for sustainable production of cauliflower and capsicum

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Abstract
To get more yield farmers tend to use excessive chemical fertilizers, while current energy crisis prevailing higher prices and lack of proper supply system of fertilizers and deterioration of soil health calls for more efficient nutrient management using conjunctive use of organic manure, inorganic fertilizers and biofertilizer to sustain yield levels. Therefore, two year field trial was conducted during 2015 and 2016 by using Randomized block design. The results revealed that combination of 80% NPKM + 20% N through FYM and VC (50:50) + PGPR recoded higher yield (329.30 and 344.80 q ha^{-1}), total nitrogen uptake (64.57 and 66.01 kg ha^{-1}), phosphorus uptake (9.89 and 10.62 kg ha^{-1}), potassium uptake (51.43 and 55.45 kg ha^{-1}), nitrogen use efficiency (17.04 and 29.34 kg kg^{-1}), phosphorus use efficiency (25.50 and 37.83 kg kg^{-1}) and potassium use efficiency (38.0 and 29.36 kg kg^{-1}) with higher B:C ratio (3.42 and 3.61) under cauliflower and capsicum crops, respectively Thus, study suggests that cauliflower and capsicum can be successfully grown under mid hill zone on 80% NPKM + 20% N through FYM and VC (50:50) + PGPR and harvest maximum productivity and profitability besides, improving used efficiency of nutrients.

Keywords: INM, nutrient use efficiency, nutrient uptake and sustainability

Introduction

Utilization of indigenous sources of organics act as alternatives and supplements to chemical fertilizers and even help in increasing the productivity. Among different vegetable crops, cauliflower (*Brassica oleracea* var. botrytis L.) is one of the most important winter vegetable crops belonging to the genus Brassica of the family Cruciferae. Area under cauliflower production in India is 4, 14,000 hectare with a production of 78,97,000 metric tons (Department of Agriculture, GOI, 2016). In Himachal Pradesh, it is grown as a cash crop which brings remunerative returns to the small and marginal hill farmers. In general, the cauliflower growing soils of hilly areas having problems of nitrogen availability, phosphorus fixation with varying deficiencies of micronutrient elements. To achieve higher yield levels, farmers are indiscriminately using chemical fertilizers, which are leading to deterioration of soil health without any appreciable increase in the yield levels. Moreover, in the wake of high input cost of chemical fertilizers, there is need to substitute a part of the nutrient requirement through organic sources of nutrients to make crop cultivation an economically viable proposition. *Capsicum annuum* L. commonly known as bell pepper or sweet pepper or Shimla mirch belongs to nightshade family i.e. Solanaceae. This crop is native to Mexico with secondary centre of origin at Gautemela. Bell pepper is the second-most consumed vegetable worldwide. In India, it is raised over an area of 32,000 hectares with annual production of 1, 83,000 metric tons. In Himachal Pradesh, capsicum is being cultivated as an important summer season vegetable crop, providing rich dividends to the farmer with an annual production of 34,130 metric tons grown in an area of about 2,070 hectares (NHB, 2015). Bell pepper is an important agricultural crop, not only because of its economic importance, but also for the nutritional value of fruits, as is characterized by its high levels of vitamin C, carotene and calcium (Pariari and Khan, 2013) [2]. Capsicum is consumed as salad, cooked, mixed, stuffed vegetable and is appreciated worldwide for its flavour, aroma and colour. It is also recommended for the treatment of dropsy, toothache and cholera (Chopra *et al.,* 2005) [3].

Himachal Pradesh is the leading supplier of high quality fresh fruits and vegetables, to the plains during summer and rainy seasons which bring lucrative returns to the small and marginal hill farmers. But, the productivity of cauliflower and bell pepper is still low as compared to China, Japan and some European countries. The balanced supply of nutrients and scientific management practices has a potential to increase the productivity of these vegetable

Crops. The crop yield and quality can be improved considerably by the balanced supply of nutrients through different inorganic and organic nutrient sources. Microbial inoculation in vegetable crops has resulted in significant improvement in growth, yield and quality. The substitution of synthetic fertilizers through vermicompost and bio-inoculants significantly increased yield and quality of cauliflower (Sharma *et al*., 2007) [5]. To get more yield farmers tend to use excessive chemical fertilizers, but decision on fertilizer use requires knowledge of the expected crop yield response to nutrient application, which is a function of crop nutrients need, supply of nutrients from soil as an indigenous source its inherent capacity to supply nutrients and the short and long term fate of fertilizer applied. The current energy crisis prevailing lack of proper supply system and higher prices of fertilizers, distortion of soil fertility and deterioration of soil health calls for more efficient nutrient management by using conjunctive use of organic manure and inorganic fertilizers to sustain yield levels. An effective nutrient management is the one which involves site specific nutrient recommendations to crops. This includes timely application of fertilizers using appropriate methods and developing and practicing integrated plant nutrient supply system. Using chemical fertilizers, organic manures, crop residues and biofertilizers and balanced fertilizer nutrient application (Satish *et al.,* 2011) [6].

Material and Methods

Studies were conducted in two consecutive years (2015 and 2016) in the Department of Soil Science and Water Management, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh located at 30º 51′ N latitude and 76º 11′ E longitude and an elevation of 1175 m above mean sea level having average slope of 7-8 percent. A total of nine treatments; T_1 -Absolute control, T_2 -70% NPKM + 30% N through FYM and VC (50:50), T_3 -80% NPKM + 20% N through FYM and VC (50:50), T_4 -90% NPKM + 10% N through FYM and VC (50:50), T_5 -100% NPK + FYM, T_6 -100% NPK + VC, T_7 -110% NPKM (50:50 of FYM and VC as per N content), T_8 -120% NPKM (50:50 of FYM and VC as per N content), T_9 -130% NPKM (50:50 of FYM and VC as per N content) were evaluated in Randomized Block Design with the three replications. Manures were incorporated as basal dose at the time of field preparation. In INM plots, half dose of N and full amount of P and K were applied as basal during planting, and rest of N was top dressed in two splits at 30 and 60 days after planting. The source of nitrogen, phosphorus and potash were urea, single super phosphate and muriate of potash, respectively. PGPR was applied as root dip treatment for 30 minutes before transplanting of cauliflower and capsicum. The nutrient uptake by plant was calculated by using the following formula:

$$\text{Nutrient uptake (kgha}^{1}\text{)} = \frac{\text{Nutrient content (\%) x dry matter yield (kg ha}^{-1}\text{)}}{100}$$

The nutrient uptake in foliage, curd and root was added to calculate total uptake by whole plant.

The NUE was calculated by using the following formula

$$\text{NUE (kg kg}^{-1}\text{)} = \frac{\text{Yield in treated plot – yield in control plot}}{\text{Amount of nutrient applied}}$$

Economic study Benefit: cost ratio in terms of net return per rupee investment was calculated by using the following formula: B : C = Net return (Rs/ha) / Cost of cultivation (Rs/ha).

Statistical analysis: The data obtained were subjected to analyze statistically as outlined by Gomez and Gomez (1984) [7].

Results and Discussion

Effect of integrated nutrient management on nutrient uptake of cauliflower and capsicum

Application of 80% NPKM + 20% N through FYM and VC (50:50) + PGPR recoded higher nitrogen uptake under treatment T_3 (64.57 and 66.01 kg ha^{-1}) which was found statistically at par with T_9 (63.47 and 65.67 kg ha^{-1}), T_8 (63.62 and 65.53 kg ha^{-1}) and lowest with T_1 (42.01 and 40.73 kg ha^{-1}) in both cauliflower and capsicum cropping sequence, respectively (Table 1). Pooled analysis of data in table 2 showed that effect of integrated nutrient management was significant and the pattern was similar to both the years of study. Significantly higher P uptake (9.91 and 10.84 kg ha^{-1}) was recorded under T_3 which was statistically at par with T_9 (9.89 and 10.62 kg ha^{-1}), T_8 (9.88 and 10.79 kg ha^{-1}) and lower under T_1 (6.89 and 7.39 kg ha^{-1}) in both the crops, respectively. Significantly highest K uptake (51.43 and 55.54 kg ha^{-1}) was recorded under T_3 which was statistically at par with T_9 (50.77 and 54.65 kg ha^{-1}), T_8 (50.42 and 54.67 kg ha^{-1}) and lowest with T_1 (31.92 and 28.48 kg ha^{-1}) under both cauliflower and capsicum crop, respectively (Table 3). The combined application of organic and chemical fertilizers with bacterial isolates also increased the uptake of N, P and K significantly over uninoculated control. The different treatments showed significant effect on total N uptake for both years and also in pooled analysis. The similar trend was obtained in case of P and K uptake for both the years of experimentation. By addition of FYM and VC there is enhancement of nutrient availability (NPK) which ultimately enhanced microbial activity and conversion of unavailable to available form of nutrients and improved physical and biochemical condition of soil (Sarangthem *et al*., 2011) [8]. Direct enhancement of mineral uptake due to increase in specific ion fluxes at root surface in the presence of plant growth promoting rhizobacteria has also been reported by Bais *et al.*(2004) [9]. Tilak *et al.* (2005) [10] also reported that PGPR isolates helps in uptake of minerals such as nitrate, phosphate and potassium. Milosevic *et al*. (1995) [11] also reported that increase in nitrogen uptake is due to increase in bacterial count in cabbage growing soil. Sharma *et al*. (2009) [12] also reported increased uptake of nutrients due to organic and inorganic sources which might have resulted in improved physical environment proliferous root system for better absorption of water and nutrients.

Table 1: Effect of integrated nutrient management on nitrogen uptake in cauliflower and capsicum

Treatments	Cauliflower			Capsicum		
	N uptake (kg ha^{-1})					
	2014-15	2015-16	Pooled	2015	2016	Pooled
T_1	43.77	40.25	42.01	41.74	39.73	40.73
T_2	54.46	55.98	55.22	52.14	52.55	52.34
T_3	63.77	65.36	64.57	65.88	66.14	66.01
T_4	57.51	58.66	58.09	53.47	53.66	53.56
T_5	50.96	52.73	51.84	48.76	49.06	48.91
T_6	51.40	54.99	53.19	50.81	51.18	51.00
T_7	59.97	59.02	59.50	56.00	56.36	56.18
T_8	62.96	64.27	63.62	65.40	65.66	65.53
T_9	62.43	64.51	63.47	65.54	65.80	65.67
Mean	56.36	57.31		55.53	55.57	
CD (0.05)	2.47	3.03		1.12	1.91	
t	1.87			1.09		
Y	0.88			NS		
T×Y	NS			NS		

Table 2: Effect of integrated nutrient management on phosphorus uptake in cauliflower and capsicum

Treatments	Cauliflower			Capsicum		
	P uptake (kg ha^{-1})					
	2014-15	2015-16	Pooled	2015	2016	Pooled
T_1	6.89	6.89	6.89	7.62	7.15	7.39
T_2	9.25	9.37	9.31	9.39	9.56	9.47
T_3	9.85	9.94	9.89	10.22	11.02	10.62
T_4	9.36	9.41	9.39	9.50	9.67	9.59
T_5	9.10	9.17	9.14	9.21	9.36	9.29
T_6	9.18	9.24	9.21	9.29	9.51	9.40
T_7	9.41	9.47	9.44	9.60	9.73	9.67
T_8	9.84	9.93	9.88	10.54	11.03	10.79
T_9	9.88	9.93	9.91	10.61	11.07	10.84
Mean	9.20	9.26		9.55	9.79	
CD (0.05)	0.57	0.61		0.69	0.83	
t	0.40			0.52		
Y	NS			NS		
T×Y	NS			NS		

Table 3. Effect of integrated nutrient management on potassium uptake in cauliflower and capsicum

Treatments	Cauliflower			Capsicum		
	K uptake (kg ha^{-1})					
	2014-15	2015-16	Pooled	2015	2016	Pooled
T_1	32.51	31.33	31.92	30.99	25.96	28.48
T_2	42.74	42.96	42.85	50.62	50.87	50.74
T_3	51.06	51.80	51.43	55.17	55.73	55.45
T_4	45.85	46.95	46.40	50.85	51.48	51.17
T_5	38.65	40.32	39.49	47.14	47.22	47.18
T_6	39.69	40.37	40.03	49.10	49.21	49.16
T_7	48.17	48.95	48.56	51.91	52.46	52.19
T_8	50.06	50.77	50.42	54.58	54.76	54.67
T_9	50.52	51.01	50.77	54.43	54.88	54.65
Mean	44.36	44.94		49.42	49.17	
CD (0.05)	1.49	1.45		1.50	1.47	
t	1.00			1.01		
Y	NS			NS		
T×Y	NS			NS		

Effect of integrated nutrient management on nutrient use efficiency

Table 4 embodying the data revealed that N use efficiency was significantly influenced by different treatments during both the years of study. Pooled analysis of data showed that effect of different treatment combinations was also significant and the pattern was similar to both the years of study. Significantly higher N use efficiency was recorded under T_3 (17.04 And 29.34 kg kg^{-1}) when compared with RPF (T_5) followed by treatment T_7 (15.65 and 26.61 kg kg^{-1}) and T_8 (12.99 and 25.17 kg kg^{-1}) in both cauliflower and capsicum crop, respectively. Table 5 indicated significantly higher P use efficiency (25.50 and 27.83 kg kg^{-1}) was recorded under T_3 and lower under T_6 (6.80 and 5.94 kg kg^{-1}) in both the crops, respectively. The data on interaction effect between treatment and year (T×Y), year (Y) recorded non-significant effect. Significantly highest K use efficiency (29.36 and 38.00 kg kg^{-1}) was recorded under T_3 and lowest with T_6 (4.26 and 10.42

kg kg^{-1}) under both cauliflower and capsicum crop, respectively (Table 6). The data on interaction effect between treatment and year (T×Y), year(Y) recorded non-significant effect. The results revealed that balanced use of organic, inorganic fertilizers with PGPR obtained higher productivity as well as nutrient use efficiency. Laximinarayana and Patiram (2006) [13] also recorded similar results. They found that integrated use inorganic and organic manures not only enhance the productivity of rice but also increases nutrient use efficiency. These results are in line with the findings of Mahapatra *et al.* (1997) [14].

Table 4. Effect of integrated nutrient management on nitrogen use efficiency in cauliflower and capsicum

Treatments	Cauliflower			Capsicum		
	Nitrogen Use Efficiency (kg kg^{-1})					
	2014-15	2015-16	Pooled	2015	2016	Pooled
T_1	-	-	-	-	-	-
T_2	5.96	6.04	6.00	13.32	13.34	13.33
T_3	17.03	17.05	17.04	29.22	29.47	29.34
T_4	13.73	13.78	13.75	23.43	23.58	23.51
T_5	0.00	0.00	0.00	0.00	0.00	0.00
T_6	3.89	3.91	3.90	8.37	8.61	8.49
T_7	15.64	15.66	15.65	26.54	26.69	26.61
T_8	12.95	13.03	12.99	25.03	25.31	25.17
T_9	11.75	11.86	11.81	23.50	23.63	23.56
Mean	9.00	9.04		16.60	16.74	
CD $_{(0.05)}$	1.34	1.95		3.84	2.29	
t	1.14			2.14		
Y	NS			NS		
T×Y	NS			NS		

Table 5: Effect of integrated nutrient management on phosphorus use efficiency in cauliflower and capsicum

Treatments	Cauliflower			Capsicum		
	Phosphorus Use Efficiency (kg kg^{-1})					
	2014-15	2015-16	Pooled	2015	2016	Pooled
T_1	-	-	-	-	-	-
T_2	11.00	11.02	11.01	17.23	17.34	17.29
T_3	25.38	25.62	25.50	37.79	37.86	37.83
T_4	21.36	21.29	21.33	30.31	30.53	30.42
T_5	-	-	-	-	-	-
T_6	6.75	6.85	6.80	5.92	5.95	5.94
T_7	18.75	18.76	18.75	32.56	32.70	32.63
T_8	16.02	16.12	16.07	31.60	31.85	31.72
T_9	14.98	15.29	15.14	30.04	30.37	30.20
Mean	12.70	12.77		20.60	20.73	
CD $_{(0.05)}$	2.94	2.13		3.87	4.10	
t	1.74			2.70		
Y	NS			NS		
T×Y	NS			NS		

Table 6: Effect of integrated nutrient management on potassium use efficiency in cauliflower and capsicum

Treatments	Cauliflower			Capsicum		
	Potassium Use Efficiency (kg kg^{-1})					
	2014-15	2015-16	Pooled	2015	2016	Pooled
T_1	-	-	-	-	-	-
T_2	10.25	10.32	10.28	23.09	23.39	23.24
T_3	29.23	29.49	29.36	37.98	38.02	38.00
T_4	27.10	27.40	27.25	30.46	30.64	30.55
T_5	-	-	-	-	-	-
T_6	4.26	4.26	4.26	10.30	10.53	10.42
T_7	26.85	26.96	26.91	36.62	36.75	36.69
T_8	22.19	22.46	22.33	35.48	35.66	35.57
T_9	20.51	20.55	20.53	33.67	33.73	33.70
Mean	15.60	15.72		23.07	23.19	
CD $_{(0.05)}$	2.50	4.56		2.38	4.97	
t	2.50			2.64		
Y	NS			NS		
T×Y	NS			NS		

Effect of integrated nutrient management on yield of cauliflower and capsicum

Table 7 showed that treatment received 80% NPKM +20% N through FYM and VC (50:50) recorded better curd and fruit yield irrespective of integration with organics (FYM and VC) or bacterium inoculation during both the years of study. During first year, significantly highest curd and fruit yield (325.6, 343.3 q ha^{-1}) was recorded in treatment T_3. Similar trend was also recorded during second year, treatment T_3 recorded significantly highest curd and fruit yield (332.9, 346.5 q ha^{-1}) under cauliflower and capsicum crops, respectively. However, lowest yield was recorded under T_1 (216.5, 213.3 q ha^{-1} and 203.7, 204.3) in both cauliflower and capsicum crops, respectively. Pooled data revealed that significantly highest curd yield was recorded under T_3 (329.3 q ha^{-1}) which was statistically at par with treatment T_9 (319.4 q ha^{-1}) and T_8 (315.2 q ha^{-1}), whereas, lowest curd yield was recorded under T_1 (210.1 q ha^{-1}) in cauliflower. Under capsicum significantly higher fruit yield recorded under treatment T_3 (344.8 q ha^{-1}) which was statistically at par with treatment T_9 (342.1 q ha^{-1}), T_8 (341.9 q ha^{-1}) and T_7 (341.2 q ha^{-1}) while, lowest fruit yield was recorded under T_1 (208.8 q ha^{-1}). The findings suggested that reduction of 20 % in recommended inorganic fertilizers is possible if we add FYM and vermicompost with PGPR inoculation of plants. Kanwar and Paliyal (2006) [15] were able to execute a net saving of 50% of synthetic fertilizers by substituting vermicompost for FYM along with 100% NPK. Chatterjee (2010) [16] revealed that higher amount of organic manures (8 and 16 t/ha FYM and 2.5 and 5 t/ha VC) and reduced levels of inorganic fertilizers (75 % RDF) significantly influenced yield attributes and head yield of cabbage as compared to sole application of recommended inorganic fertilizers (150:80:75 kg NPK/ha) and vermicompost emerged as better organic nutrient source over farm yard manure. Inoculation with biofertilizers exerted more positive effect over un-inoculated treatments and benefits of biofertilizers application were more in the presence of vermicompost and farm yard manure.

Table 7: Effect of integrated nutrient management on yield (q ha^{-1}) in cauliflower and capsicum

Treatments	Cauliflower			Capsicum		
	Yield (q ha^{-1})					
	2014-15	2015-16	Pooled	2015	2016	Pooled
T_1	216.4	203.7	210.1	213.3	204.3	208.8
T_2	283.3	285.3	284.3	303.3	303.7	303.5
T_3	325.6	332.9	329.3	343.3	346.3	344.8
T_4	306.0	314.9	310.5	329.5	330.0	329.8
T_5	266.1	269.7	267.9	266.3	271.4	268.8
T_6	271.2	278.2	274.7	281.1	283.3	282.2
T_7	305.4	314.2	309.8	340.5	341.9	341.2
T_8	312.0	318.3	315.1	341.2	342.6	341.9
T_9	311.4	327.4	319.4	341.3	342.9	342.1
Mean	288.6	293.8		307.0	307.0	
CD (0.05)	19.27	22.84		7.56	9.35	
t	14.31			5.76		
Y	NS			NS		
T×Y	NS			NS		

Effect of integrated nutrient management on B: C ratio in cauliflower

Table 8 and 9 indicated showed that the highest net return of Rs 3,46,931 and 3,68,617 ha^{-1} was obtained from treatment T_3 (80% NPKM + 20% FYM and VC on N equivalence basis + PGPR) which also recorded highest benefit cost ratio of 3.42 and 3.61 during both the years of study, respectively. The high profitability in T_3 was on account of the highest yield (325.59 and 332.91 q ha^{-1}) recorded by this treatment after incurring Rs. 1,20093 ha^{-1} towards cost of cultivation during both the years, respectively. Sharma *et al*. (2014) [17] observed highest annual net returns in cauliflower, French bean and okra cropping sequence through treatment comprising of vermicompost @ 20 t ha^{-1}+ 75% of recommended dose of NPK + PGPR over the recommended practice (100% NPK + 20 t FYM ha^{-1}).

Table 8: Effect of integrated nutrient management on B:C ratio in cauliflower

Treatments	2015				2016		
	Cost (Rs ha$_{-1}$)	Gross returns (Rs ha$_{-1}$)	Net returns (Rs ha$_{-1}$)	B:C ratio	Gross returns (Rs ha$_{-1}$)	Net returns (Rs ha$_{-1}$)	B:C ratio
T_1	48000	108185	60185	2.25	101870	53870	2.12
T_2	136232	424875	288642	2.12	427920	291687	2.14
T_3	120093	467025	346931	3.42	491040	368617	3.61
T_4	114762	459060	344297	3.00	472380	357618	3.09
T_5	87801	399135	311334	3.40	404475	316674	3.55
T_6	201008	406755	205747	1.02	417315	216307	1.08
T_7	174785	458145	283359	1.62	471330	296544	1.69
T_8	186766	467970	281204	1.51	477420	290654	1.55
T_9	198746	488385	289639	1.46	499365	300619	1.51

Table 9: Effect of integrated nutrient management on B:C ratio in capsicum

Treatments	2015				2016		
	Cost (Rs ha-1)	Gross returns (Rs ha-1)	Net returns (Rs ha-1)	B:C ratio	Gross returns (Rs ha-1)	Net returns (Rs ha-1)	B:C ratio
T_1	48000	106665	58665	2.22	102165	54165	2.13
T_2	94328	454890	360561	3.82	455490	361161	3.83
T_3	84518	511935	427416	5.62	514290	429771	5.63
T_4	74707	494310	419602	5.06	494940	420232	5.09
T_5	64897	399450	334552	5.16	407040	342142	5.27
T_6	124897	421665	296767	2.38	424995	300097	2.40
T_7	100086	510810	410723	4.10	512820	412733	4.12
T_8	105277	511830	406552	3.86	513945	408667	3.88
T_9	107217	514995	407778	3.80	519390	412173	3.84

Conclusion

Based on two year field experimentation and with support of the previous works, it could be inferred that performance, productivity, nutrient uptake and nutrient use efficiency used efficiency in cauliflower and capsicum was improved by combination of organic, inorganic and bioferilizer. Application of 80% NPKM + 20% N through FYM and VC (50:50) + PGPR was found to be more effective for improving performance, productivity, profitability and nutrient use efficiency in cauliflower and capsicum than all over rest of the treatments. Thus, study suggests that cauliflower and capsicum can be successfully grown under mid hill zone of HP on 80% NPKM + 20% N through FYM and VC (50:50) + PGPR and harvest maximum productivity and profitability besides, improving nutrient use efficiency

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