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Influence of integrated nutrient management (INM) on soil physico-chemical properties and nutrient uptake of cauliflower (*Brassica oleracea* var. *botrytis* L.)

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ABSTRACT

The present study was carried out with cauliflower cv. Pusa Snowball K-1 at the Experimental Farm of Department of Soil Science and Water Management, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, (Himachal Pradesh) during 2014-15 and 2015-16 in a randomized complete block design with the objective to develop an integrated plant nutrient supply system for higher productivity of cauliflower on sustainable basis. The experiment comprised of seven treatments *viz.,* T_1:100% NPK + FYM, T_2: 100% NPK + FYM+ PGPR, T_3: 100% NPK+ 50% FYM and 50% VC on N equivalence basis + PGPR, T_4: 75% NPK+50% FYM and 50% vermicompost (VC) on N equivalence basis, T_5: 75% NPK+50% FYM and 50% VC on N equivalence basis+ PGPR, T_6: 50% NPK+ 50% FYM and 50% VC on N equivalence basis and T_7: 50% NPK+ 50% FYM and 50% VC on N equivalence basis + PGPR. Conjoint use of fertilizers, manures and plant growth promoting rhizobacteria (PGPR) significantly influenced soil nutrient status and nutrient uptake pattern of cauliflower crop. Treatment T_3 resulted in significantly maximum soil macro and micro-nutrient contents which was found statistically at par with T_5. From present investigation, it can be concluded that above integrated combination of chemical fertilizers, organic manures (FYM, VC) and PGPR resulted in better nutrient status and uptake as evident by post fertility status of soil and plant analysis.

1. INTRODUCTION

For boosting crop production, nutrient balance in the soil is the key component. Agriculturists have been focusing their attention towards the efficient and judicious utilization of available resources to increase the total productivity and profitability per unit area to meet out the food and other demands of ever increasing population. The exploitative agriculture for centuries in our country has brought down the fertility status of the soil to a level that even the application of fertilizers at higher rates is not able to sustain the productivity of the soil. Therefore, in order to sustain the productivity and promote the health of the soil, combined use of organic and chemical fertilizers is imperative. On one hand chemical fertilizers alone do not provide all the nutrients in balanced quantities needed by the plants and on the other hand encourage depletion of soil organic matter content, adversely affect the physical and biological properties of soil, also their increasing prices, soil health deterioration, sustainability and pollution consideration in general have led to renewed interest in the use of organic manures. Use of organic manure not only helps to sustain crop yields but also play a key role by exhibiting both direct as well as indirect influence on the nutrient availability in soil by improving the physical, chemical and biological properties of soil and also improve the use efficiency of applied fertilizers (Singh and Biswas, 2000). Organic manures though have all the essential elements present, but are in small quantities. They are bulky in nature and release nutrients slowly. Since, organic manures cannot meet the total nutrient needs of the modern agriculture, Integrated use of nutrients from fertilizers and organic sources seems to be need of the hour.

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the most important winter vegetable crop belonging to the genus *Brassica* of the family *Cruciferae*. It is being grown all over India for its nutritive value and wider adaptability under different agro-ecological regions. In Himachal Pradesh, it is grown as off-season crop which brings remunerative returns to the small and marginal hill farmers. Mineral nutrition plays an important role in enhancing the yield and quality of cauliflower (Savci, 2012). Cauliflower is heavy feeder of mineral elements. In general, the cauliflower growing soils have problems of nitrogen availability, phosphorus fixation with varying deficiencies of micro-nutrient elements in the state. To achieve higher yield levels, farmers are indiscriminately using chemical fertilizers which is leading to deterioration of soil health without any appreciable increase in the yield. The INM paves the way to overcome all these problems which involves conjuctive use of chemical fertilizers, manures and bio-fertilizers to sustain crop production as well as maintenance of soil health (Nanjappa *et al*., 2001).

Microbial inoculation in vegetable crops has resulted in significant improvement in growth, yield and quality. The substitution of synthetic fertilizers through VC and bio-inoculants in cauliflower significantly increased yield and quality (Sharma *et al*. 2007). So present investigation was planned with chemical fertilizers (Urea, SSP, MOP), organic manures (FYM, VC) and PGPR as bio-fertilizer to frame an integrated module of plant nutrient supply to crop.

2. MATERIALS AND METHODS

The present investigation was carried out with late group of cultivar Pusa Snowball- K1 of cauliflower crop during 2014-2015 and 2015-2016 in the experimental farm of Department of Soil Science and Water Management, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, (Himchal Pradesh). It is located at 30º51′N latitude and 76º11′E longitude and an elevation of 1175 m above mean sea level (AMSL) having average slope of 7-8%. The study area Nauni falls in sub-temperate, sub-humid agro-climatic zone of Himachal Pradesh (Zone-2). The experiment was arranged in 'Randomised Block Design' wherein following treatments were tried in triplicate. There are seven treatment combinations consisting of inorganic fertilizers, organic manures and PGPR, the details of which are given below: T_1: 100% NPK + FYM, T_2: 100% NPK + FYM + PGPR, T_3: 100% NPK + 50% FYM and 50% VC on N equivalence basis + PGPR, T_4: 75% NPK + 50% FYM and 50% VC on N equivalence basis, T_5: 75% NPK + 50% FYM and 50% VC on N equivalence basis + PGPR, T_6: 50% NPK + 50% FYM and 50% VC on N equivalence basis and T_7: 50% NPK + 50% FYM and 50% VC on N equivalence basis + PGPR. The seeds of cultivar 'PSBK-1' were sown at the experimental farm in 3 x 1 x 0.15 m seedbeds. The seeds were sown in nursery beds on September 18, 2015 and 14 September 2016, respectively. One month old seedlings were transplanted at a spacing of 60 x 45 cm in 3 x 2 m size plots in the second fortnight of October each year. The chemical fertilizers nitrogen, phosphorous and potassium were applied as per treatment through - urea, single super phosphate and muriate of potash, respectively. Full dose of FYM (250 q ha^{-1}) and muriate of potash (120 kg ha^{-1}) was given to plots as basal dressing as per treatment. Single super phosphate (475 kg ha^{-1}) was also be applied as basal dressing as per treatment. Urea (272 kg ha^{-1}) was given in three split doses - first dose was given at the time of field preparation, second after one month of transplanting and third during curd initiation. PGPR (*Bacillus pumilus*) was inoculated through seedling dip for half an hour before transplanting**.** PGPR of 10^8 cfu ml^{-1} concentration was applied at the rate of 50 ml $plant^{-1}$.

Statistical Analysis

The data generated from present investigation were subjected to statistically analysis using the statistical package SPSS (14.0) and Microsoft Excel. Critical difference (CD) at 5% level was used for testing the significant difference among the treatment means.

Soil Analysis

Collection and preparation of soil samples: Representative soil samples from 0-15 cm depth were collected before sowing and at the time of curd harvesting during both the years of study. Collected soil samples were air dried in shade and ground with the help of pestle mortar. These ground samples were then passed through 2 mm sieve and stored in polyethylene bags for further analysis of soil as per the methods given in Table 1. The information on chemical characteristics and available nutrient status of the soil before start of experiment, is enumerated in Table 2.

The nutrient uptake by plant was calculated by using the following formula:

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

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

3. RESULTS AND DISCUSSION

Physico-chemical Properties of Soil

Conjoint application of inorganic and organic sources of nutrients had no significant effect on soil pH, electrical conductivity, bulk density, particle density and porosity (Table 3 and 4). The probable reason for non-significant changes in most of the physico-chemical properties might be shorter time period (3-4 months) between sowing and harvesting of the crop. The studies of Selvi *et al*. (2004) and Bajpai *et al*. (2006) clearly revealed**,** that only long term experimentation may brought changes in some of the physico-chemical properties of soil.

Organic Carbon

The data presented in Table 3 showed that treatment T_3 recorded significantly highest organic carbon (1.50%) among all the treatments which was found statistically at par with T_5 (1.46%). Kong *et al*. (2005) observed higher level of organic carbon content and attributed due to increased microbial activities in the root zone which decomposed organic manures and also fixed unavailable form of mineral nutrients into available forms in soil, thereby substantiated crop requirements and improved organic carbon level and stabilized soil pH. Similar results were also observed by Merentola *et al*. (2012) in cabbage.

Macro-nutrients

There were significant variations in the available N, P and K status of soil after crop harvest among different treatments cited in Table 5. Maximum available N, P and K content in soil was recorded under the treatment T_3 (100% NPK + 50% FYM + 50% VC on N equivalence basis + PGPR) which indicated that available N, P and K increased by 33.99, 42.88 and 30.54% over the values recorded before execution of experiment, respectively. Swain *et al*. (2013) who also noted maximum available nitrogen in the plots supplied with 100% chemical fertilizers, explained that in chemical fertilizers, mineralization process was faster and thereby has shown immediate release of N and its availability in the soil. A majority of other nutrient modules,

Table: 1
Methods followed for the analysis of soil

S.No.	Parameter	Reference (Method)
1	pH	1:2 Soil : water suspension, measured with digital pH meter (Jackson, 2005)
2	EC	1:2 Soil : water suspension, measured with digital EC meter (Jackson, 2005)
3	Organic carbon	Walkley and Black wet digestion method (Walkley and Black, 1934)
4	Available N	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
5	Available P	Olsen's method (Olsen *et al.,* 1954)
6	Available K	Ammonium acetate method (Merwin and Peech, 1951)
7	Exchangeable Ca	Ammonium acetate method (Merwin and Peech, 1951)
8	Exchangeable Mg	Ammonium acetate method (Merwin and Peech, 1951)
9	$SO4^{2-}$ - S	0.15% $CaCl_2$ extractant and turbidi-metric determination (Chesnin and Yien, 1950)
10	Cu	DTPA extractant (Lindsay and Norvell, 1978)
11	Fe	DTPA extractant (Lindsay and Norvell, 1978)
12	Mn	DTPA extractant (Lindsay and Norvell, 1978)
13	Zn	DTPA extractant (Lindsay and Norvell, 1978)

Table: 2
Physico-chemical properties of experimental soil before the start of experiment

Properties	Value
Bulk density (g cm^{-3})	1.34
Particle density (g cm^{-3})	2.35
Porosity (%)	42.97
pH (1:2)	6.89
EC (dS m^{-1})	0.25
Organic carbon (%)	1
Available N (kg ha^{-1})	295.63
Available P (kg ha^{-1})	48.17
Available K (kg ha^{-1})	193.58
Exchangeable Ca (mg kg^{-1})	670.58
Exchangeable Mg (mg kg^{-1})	412.68
Sulphate Sulphur (kg ha^{-1})	20.6
Available Zn (mg kg^{-1})	2.7
Available Cu (mg kg^{-1})	3.58
Available Fe (mg kg^{-1})	13.38
Available Mn (mg kg^{-1})	6.83

Table: 3
Effect of INM on pH, EC and OC of soil

Treatments	pH (1:2)			EC (dS m^{-1})			OC (%)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	6.81	6.83	6.82	0.35	0.36	0.35	1.27	1.35	1.31
T_2	6.82	6.87	6.85	0.33	0.33	0.33	1.37	1.42	1.39
T_3	6.89	6.90	6.90	0.33	0.34	0.34	1.46	1.53	1.50
T_4	6.81	6.83	6.82	0.29	0.30	0.30	1.24	1.32	1.28
T_5	6.86	6.87	6.87	0.33	0.34	0.34	1.41	1.50	1.46
T_6	6.80	6.80	6.80	0.30	0.31	0.30	1.05	1.14	1.10
T_7	6.81	6.82	6.81	0.27	0.28	0.28	1.15	1.28	1.21
Mean	6.83	6.84		0.35	0.36	0.35	1.28	1.36	
CD (0.05)	NS	NS		NS	NS		0.06	0.05	
T		NS			NS		0.06		
Y		NS			NS		0.03		
T× Y		NS			NS		NS		

Table: 4
Effect of INM on bulk density, particle density and porosity of soil

Treatments	Bulk Density (g cm^{-3})			Particle Density (g cm^{-3})			Porosity (%)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	1.29	1.29	1.29	2.34	2.34	2.34	45.01	44.87	44.94
T_2	1.28	1.29	1.29	2.34	2.33	2.34	44.67	45.33	45.00
T_3	1.28	1.28	1.28	2.33	2.32	2.32	44.96	45.48	45.22
T_4	1.30	1.29	1.29	2.35	2.35	2.35	44.97	45.05	45.01
T_5	1.29	1.29	1.29	2.35	2.35	2.35	45.11	45.01	45.06
T_6	1.30	1.30	1.30	2.36	2.36	2.36	45.37	44.68	45.02
T_7	1.29	1.29	1.29	2.37	2.36	2.37	45.54	44.86	45.20
Mean	1.29	1.29		2.35	2.34		45.09	45.04	
CD (0.05)	NS	NS		NS	NS		NS	NS	
T	NS			NS			NS		
Y	NS			NS			NS		
T× Y	NS			NS			NS		

Table: 5
Effect of INM on soil N, P and K status

Treatments	N (kg ha^{-1})			P (kg ha^{-1})			K (kg ha^{-1})		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	380.48	383.68	382.08	65.63	66.48	66.06	246.63	248.67	247.65
T_2	388.81	391.46	390.14	65.97	67.48	66.72	248.51	249.48	248.99
T_3	394.09	398.18	396.13	68.28	69.38	68.83	251.63	253.77	252.70
T_4	353.32	356.29	354.80	63.55	63.93	63.74	245.41	246.40	245.90
T_5	392.19	395.18	393.69	67.18	68.51	67.84	250.63	252.00	251.32
T_6	317.78	320.08	318.93	57.41	58.86	58.14	236.09	238.97	237.53
T_7	333.46	336.17	334.82	61.49	62.38	61.94	238.85	240.24	239.55
Mean	365.73	368.72		64.22	65.29		245.39	247.07	
CD (0.05)	2.91	2.03		1.65	2.36		2.68	2.20	
T		2.51			2.03			245	
Y		1.34			1.09			1.31	
T× Y		NS			NS			NS	

comprising reduced inorganic (NP) @ 75 or 50% RDF along with organics (VC and FYM) with or without bio-inoculation of plants also recorded available nitrogen at par with RPF (T_1). Increase in available N through integration of VC and FYM with reduced inorganic composition with or without bio-inoculation of plants could be attributed to the direct addition of nitrogen through these manures and multiplication of soil microbes, which could convert organically bound N to inorganic form to the available pool of the soil. Besides its better nutrient contents, the organic manures could have increased the efficiency of added chemical fertilizer by its temporary immobilization, which reduces leaching of plant nutrients (Das *et al*., 2006).

The favorable effect of combined application of inorganic and organic source of nutrients in enhancing the P availability may be defined as the reduction in fixation of water soluble P and increase in mineralization that enhanced the availability of P. The organic acids and hydroxyl acids liberated during the decomposition of organic matter may form complex or chelate Fe, Al, Mg and Ca and prevented them from reacting with phosphate (Sharma *et al*. 2001). The increase in available P might have resulted by the solubilization of insoluble P due to application of PGPR isolates having very high P solubilization efficiency. The release of various organic acids might have solubilized insoluble P fractions and thus resulting into a significant increased content of available P in the soil (Kaushal *et al*., 2013 and Antibus *et al*. (1991). The beneficial effect of VC and FYM 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 organic manures + bio-inoculants + chemical fertilizers in promoting inherent fertility status of soil was earlier reported by Parmar *et al*. (2006) in cauliflower. Choudhury *et al*. (2004) reported significantly higher amount of available potassium through application of PSB + *Azotobacter* + FYM in conjunction with inorganic fertilizers in cauliflower.

Effect of different organic and inorganic nutrients with bacterial inoculation on exchangeable Ca, Mg and SO_4^{2-} -S were noted to be significant (Table 6) and highest exchangeable Ca, Mg and SO_4^{2-}- S content was recorded under T_3 which was found statistically at par with treatment T_5.

Exchangeable Ca and Mg were significantly influenced by organic sources of nutrients with or without inoculation. Since Phosphorus is synergistic to calcium and this might be the reason for more uptake of calcium with increasing phosphorus concentrations. But when P was given with PGPR, Mg uptake increased which might be due to the effect of phosphorus solubilizing bacteria on the improvement of general soil conditions as well as mineralization of salts present in the soil thus making them readily available to the plant. Significantly higher amount of exchangeable Ca and Mg might be due to the production of nutrient solubilising enzymes by microorganisms (Kholer *et al*., 2007).

The application of FYM or in combination with VC generally resulted in buildup of available S status of the soil. Singh and Singh (1977) in an incubation study observed an increase in the soil micro-organism population. These soil micro-organisms apparently utilize organically bound S and convert it into cystine and methionine, which are further converted in to inorganic sulphate by micro-organisms. The buildup of available S of the soil with the addition of FYM after the harvest of crop has also been reported by Nambiar and Ghosh (1984).

Micro-nutrients

Different combinations of inorganic fertilizers and organic manures increased the available Zn, Cu, Fe and Mn content by 35.55, 33.24, 54.93 and 49.92%, respectively over initial status of experimental soil.

A scrutiny of data presented in Table 7 showed higher concentration of Zn, Cu, Fe and Mn were recorded in treatment T_3 which was found statistically at par with T_5. Increase in DTPA-extractable ions (Zn, Cu, Fe and Mn) can be ascribed to the addition of these micro-nutrients by organics and their release from native sources on account of solubilising action of organic acids produced during decomposition process (Singh *et al*., 2010). Marathe *et al*. (2009) reported that significant increase in available Zn, Cu, Fe and Mn were observed with organic manure especially VC, either alone or in combination with inorganic or bio-fertilizers. Such an increase in these micro-nutrients appeared to be due to mineralization of organically bound forms and formation of stable water complexes or organic chelates of higher stability, which decrease their susceptibility to absorption, fixation and/or precipitation.

NPK Uptake

Different treatments had variable impact on uptake of NPK content of cauliflower (Fig. 1). Maximum NPK uptake was recorded under treatment T_3 which was found statistically at par with treatment T_5.

The combined application of 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. This increase may be attributed to more availability of N and P in soil as a result of inoculation with efficient isolate(s) of PGPR and increased in root length, root hair development and volume of soil forage by them. 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 by improved physical and biochemical condition of soil (Sarangthem *et al*., 2011) Direct enhancement of mineral uptake due to increase in specific ion fluxes at root surface in the presence of PGPR

Table: 6
Effect of INM on exchangeable Ca and Mg and SO_4^{2-} S status

Treatments	Exchangeable Ca (mg kg^{-1})			Exchangeable Mg (mg kg^{-1})			SO_4^{2-} S (kg ha^{-1})		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	694.64	696.22	695.43	429.61	433.19	431.40	35.78	38.23	37.01
T_2	697.35	699.12	698.23	433.96	436.88	435.42	38.37	40.82	39.59
T_3	703.05	704.75	703.90	437.60	439.41	438.51	42.17	44.33	43.25
T_4	688.50	689.54	689.02	428.20	431.59	429.90	28.30	29.97	29.14
T_5	699.85	703.59	701.72	435.27	437.63	436.60	40.80	43.80	42.30
T_6	676.44	678.13	677.28	420.60	424.07	422.34	22.02	23.43	22.73
T_7	681.61	683.24	682.43	425.68	427.66	426.67	25.87	28.03	26.95
Mean	691.63	693.51		430.13	432.92		33.33	35.52	
CD (0.05)	2.45	1.89		1.94	1.87		1.06	1.59	
T	2.19			1.91			1.35		
Y	1.17			1.02			0.72		
T× Y	NS			NS			NS		

Table: 7
Effect of INM on soil Zn, Cu, Fe and Mn status of soil

Treatments	Zn (mg kg^{-1})			Cu (mg kg^{-1})			Fe (mg kg^{-1})			Mn (mg kg^{-1})		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T1	3.57	3.58	3.58	4.10	4.04	4.07	18.14	18.41	18.28	9.56	9.68	9.62
T2	3.59	3.61	3.60	4.20	4.23	4.22	19.12	19.62	19.37	9.65	9.77	9.71
T3	3.65	3.67	3.66	4.73	4.80	4.77	20.52	20.94	20.73	10.23	10.25	10.24
T4	3.32	3.34	3.33	3.76	3.80	3.78	16.02	16.21	16.12	7.43	7.55	7.49
T5	3.62	3.64	3.63	4.71	4.74	4.73	20.33	20.52	20.42	10.17	10.20	10.19
T6	2.62	2.65	2.63	2.96	3.03	3.00	12.92	13.10	13.01	5.08	5.77	5.42
T7	2.84	2.87	2.85	3.22	3.26	3.24	14.86	14.95	14.90	6.43	6.96	6.70
Mean	3.31	3.34		3.96	3.99		17.41	17.68		8.36	8.60	
CD	0.08	0.04		0.04	0.03		0.51	0.46		0.06	0.03	
T		0.07			0.03			0.49			0.04	
Y		NS			0.02			0.26			0.02	
T × Y		NS			0.05			NS			0.06	

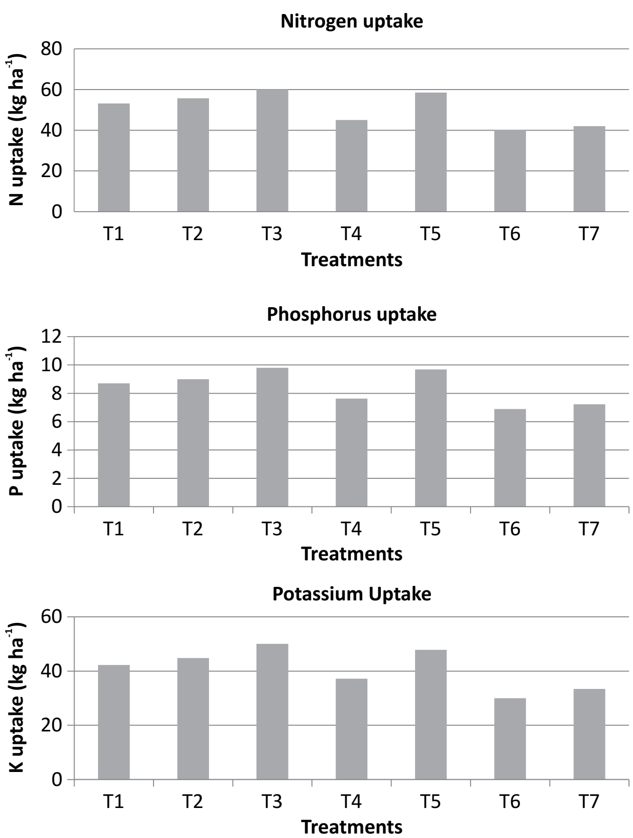

Fig. 1. Effect of different treatments on plant N, P and K uptake of cauliflower

has also been reported by Bertrand *et al*. (2000) and Bais *et al*. (2004). Tilak *et al*. (2005) also reported that PGPR isolates helps in uptake of minerals such as nitrate, phosphate and potassium Sharma *et al*. (2009) also reported increased uptake of nutrients due to added supply of these through organic and inorganic sources which might have resulted in improved physical environment; favoured proliferous root system for better absorption of water and nutrients.

4. CONCLUSIONS

On the basis of two years study, it may be concluded that the treatment T_3 registered significantly maximum values of organic carbon, macro (N, P, K, Exchangeable Ca and Mg, SO_4^{2-}-S) and micro-nutrients (Zn, Cu, Fe, Mn) of the soil after crop harvest which was statistically at par with the treatment T_5. The results on plant uptake followed the same trend. Treatment T_5 was found to be equally promising as the T_3 with net saving of 25% of fertilizers.

It is therefore, concluded that T_5 (75% NPK + 50% FYM and 50% VC on N equivalence basis + PGPR) is the most suitable nutrient module for cauliflower under INM on sustainable basis.

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