International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(2): 2988-2991

Received: 15-01-2018
Accepted: 16-02-2018

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Influence of integrated nutrient management on growth and yield of cauliflower (*Brassica oleraceae)* var. *botrytis*) and soil nutrient status

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Abstract
Field experiment was laid out at the experimental farm of Department of Soil Science and Water Management, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) in two consecutive years (2015 and 2016) to evaluate effect of integrated nutrient management (INM) on yield of cauliflower (*Brassica oleracea* var *botrytis* L.) and soil fertility. Studies employed integrated use of organic and inorganic fertilizers with PGPR strains (*Bacillus* spp.*)*. The 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 + Vermicompost, 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). PGPR applied to all treatments except T_1, T_5 and T_6. Experimental set up was laid down in a randomized block design (RBD) with three replicates. Results revealed that treatment T_3 -80% NPKM + 30% N through FYM and VC (50:50) with PGPR, significantly increased the cauliflower yield by 22.91% as compared to treatment T_5 -100% NPK + FYM (RDF). Soil status was assessed after harvest and concentration of nutrients increased in soil with the combined use of fertilizers and PGPR.

Keywords: Cauliflower, fym, vermicompost, integrated nutrient management, sustainable

Introduction
Cauliflower (*Brassica oleracea* var. *botrytis* L.) is the most popular in winter vegetables. It requires balanced and sufficient supply of nutrients for better growth and higher yield. The concept of integrated nutrient management has emerged as important tool for maintaining soil fertility and crop productivity. The concept of integrated nutrient management requires optimum use of organic, inorganic and bio-sources of plant nutrients. In an integrated manner to each cropping system and farming situation in it's ecological, social and economic possibility. Integrated use of fertilizer, manure and biofertilizers improve soil fertility and crop growth. They are also reported to have an effective role in improving disease resistance in the crop by producing antibacterial and and anti-fungal compounds and also produce growth regulators (Singh, 2000). INM refers to integration of organic, inorganic and biological components to increase crop productivity and maintenance of soil fertility for future use. This is all done without any deleterious effect on the physico-chemical and biological properties of the soil on a long term basis (Gruhn *et al.* 2000) [10]. The conjoint application of organic, chemical fertilizers with PGPR significantly increased yield and weight in cauliflower over control (Kaushal *et al.* 2013) [1]. Integrated applications having judicious combination of mineral fertilizer with organic and biological sources of nutrients are not only complimentary but also synergistic as organic inputs have beneficial effects (Roy *et al.* 2006) [12]. So, INM was applied to make cauliflower cultivation sustainable and to improve soil productivity and fertility. The combined effect of organic, inorganic fertilizer with plant growth promoting rhizobacteria (PGPR) at varying doses was observed on growth, yield, concentration of nutrients and quality of cauliflower. Therefore studies were done to enhance growth and yield of cauliflower by employing INM.

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. Initial soil samples (0-15 cm depth) were collected to analyze the properties of soil before the experiment started (Table 4). At the time of termination of experiment soil status was again determined. Soil samples were analyzed for organic carbon, available nitrogen, available phosphorus, available potassium and sulphate sulphur as per standard procedures (Table 1). 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 + Vermicompost, 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. The observations were recorded on different quantitative characters of cauliflower, viz. (number of leaves, leaf area, curd diameter, curd weight and curd yield). Five plant samples at the time of harvest were also randomly collected from each plot and mixed separately to determine concentrations of N, P and K at harvest using standard procedures (Table 1).

Table 1: Methods followed for the analysis of soil, plant and microbial parameters

Sr. No.	Parameter	Reference (Method)
1.	Organic carbon	Walkley and Black wet digestion method (Walkley and Black, 1934)
2.	Available N	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
3.	Available P	Olsen's method (Olsen *et al*., 1954)
4.	Available K	Ammonium acetate method (Merwin and Peech, 1951)
5.	SO_4^{2-} - S	0.15% $CaCl_2$ extractant and turbidimetric determination (Chesnin and Yien, 1950)
	Leaf Analysis	
1.	N	Microkjeldhal method (Jackson, 1973)
2.	P	Vando-molybdate phosphoric yellow color method (Jackson, 1973)
3.	K	Flame photometer method (Jackson, 1973)

Table 4: Physico-chemical properties of experimental soil before the start of experiment

Properties	Value
Bulk density (g cm^{-3})	1.33
Particle density (g cm^{-3})	2.35
Porosity (%)	43.40
pH (1:2)	6.76
EC (dS m^{-1})	0.38
Organic carbon (g kg^{-1})	10.98
Available N (kg ha^{-1})	351.78
Available P (kg ha^{-1})	56.89
Available K (kg ha^{-1})	257.69
Sulphate Sulphur (kg ha^{-1})	43.87

Results and Discussion

Use of organic manures, inorganic fertilizers and PGPR showed significant impact on yield and other attributes of cauliflower (Table 2). The number of leaves varied significantly among the treatments and maximum number of leaves was recorded under T_9 (20) followed by T_3 (19), T, (19) and T_8 (19). A lowest value for number of leaves was recorded in T_1 (15). Similar trend was observed for leaf area. Maximum leaf area index was recorded under T_9 (0.71) followed by T_8 (0.70) T_7 (0.65) and T_3 (0.65). Integrated use of nutrients actually resulted in rapid cell division, multiplication and cell elongation in meristematic region of plant which promoted vegetative growth of the plant (Yadav *et.al.* 2007) Significantly higher polar diameter was recorded under T_9 (15.30cm) which was found statistically at par with T_8 (15.00 cm) and lower was in T_1 (9.50 cm). As far the equatorial diameter was concerned, the same treatment (T_9) which registered the highest equatorial diameter also measured significantly maximum (19.30 cm) equatorially which was found statistically at par with T_8 (19.30 cm) and T_7 (19.20). Treatment T_3 80% NPKM +30% N through FYM and VC (50:50) observed higher curd weight (977.40g) and yield (329.30 q/ha) irrespective of integration with organics (FYM and VC) or bacterium inoculation. The improved growth and yield of cauliflower as a result of integrated use of organic manure, chemical fertilizers with PGPR might be due to improved photosynthetic and metabolic activity, which led to increase in various plant metabolites responsible for cell elongation (Hatwar *et al.*2003) [11]. The findings suggested that, reduction of 20% recommended inorganic is possible if FYM and Vermicompost with PGPR inoculation of plants. Kanwar and Paliyal (2006) [2] were able to execute a net saving of 50% of synthetic fertilizer by substituting Vermicompost for FYM along with 100% NPK. Chatterjee (2010) [13] 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.

Leaf constitutes a vital organ in plant and accomplishes important metabolic function relating to maintenance of growth and reproductive processes. The growth and fruitfulness of a plant can therefore, be considered as an index of nutrient status of the leaf so addition of appropriate measures to ensure optimum nutrient status will go a long way in maintaining cauliflower and capsicum in vigorous state which will ensure optimum levels of productivity. Pooled analysis data revealed that significantly higher leaf nitrogen was recorded under T_3 (5.29%) which was found statistically at par with T_9 (5.20%), T_8 (5.25%), T_7 (5.11%) and T_6 (4.91%), however lowest under T_1 (4.03%). Further, higher leaf P was recorded under T_3 (0.84%) which was statistically at par with T_9 (0.78%) and T_8 (0.81%) whereas, lowest in treatment T_1 (0.36%). Similarly K followed the same trend with higher leaf K under T_3 (3.53%) which was found statistically at par with T_9, T_8, T_7 and T_4, however lowest in T_1 (2.07%). The increased availability of macro nutrients (N,P and K) in cauliflower leaves with the addition of FYM, Vermicompost and PGPR might be due to acceleration of microbial nitrogen fixation, improved physical condition of soil, root development by mycelia network of mycorrhizal fungi, more moisture retention and thus increased absorption of water and nutrient. The increase in leaf nutrient content in different treatments receiving organic manures and microbial fertilizers also suggest that these microbial fertilizers solubilize the available nutrient pool in the soil and improves the uptake of macro nutrients. These results are in line with the findings of Patel *et al.* (2009) [14] reported that nutrient uptake of N, P, K, Fe, Mn, Cu and Zn in crop was enhanced with the application of 75% RDF + *Azotobactor* +AMF and micronutrients. This could be attributed to the nitrogen fixation ability of *Azotobacto*r, better phosphorus mobilization and enhanced uptake of micronutrients due to AM fungi application. Several workers have reported an increase in nutrient concentration in index leaf due to application of Vermicompost along with chemical fertilizers (Ziauddin, 2009, Bhattarai and Tomar, 2009, Naik and Babu 2007). Athani *et al.* (2009) [15, 16, 17, 20] reported that major leaf nutrients i.e. N, P and K were recorded significantly more when plants were treated with 75% RDF + 10 kg Vermicompost.

Table 2: Effect of integrated nutrient management on growth and yield parameters of cauliflower

Treatment	Number of leaves	Leaf area Index	Polar diameter (cm)	Equatorial diameter (cm)	Curd weight (g)	Curd yield (q ha^{-1})	Leaf N (kg ha^{-1})	Leaf P (kg ha^{-1})	Leaf K (kg ha^{-1})
T_1	15	0.51	9.5	11.2	754.3	208.8	4.03	0.36	2.07
T_2	16	0.60	11.7	14.9	886.3	303.5	5.06	0.71	3.17
T_3	19	0.65	13.6	17.4	977.4	344.8	5.29	0.84	3.53
T_4	18	0.63	12.8	16.6	959.1	329.8	5.13	0.73	3.51
T_5	16	0.54	10.1	13.7	875.4	268.8	4.48	0.60	3.05
T_6	16	0.57	11.0	14.4	884.7	282.2	4.91	0.66	3.12
T_7	19	0.65	14.8	19.2	965.2	341.2	5.11	0.72	3.45
T_8	19	0.70	15.0	19.3	963.4	341.9	5.25	0.81	3.43
T_9	20	0.71	15.3	19.3	963.8	342.1	5.20	0.78	3.38
$CD_{0.05}$	0.50	0.03	0.44	0.59	28.51	5.76	0.42	0.06	0.23

Soil Properties

Integrated nutrient management influenced the soil properties over a period of two years. Addition of organic, inorganic, chemical and biofertilizers (PGPR) in different combinations had a positive effect on organic carbon, available nitrogen, phosphorus, and potassium and sulphate sulphur (Table 3). The value of organic carbon (12.63 g kg^{-1}) was highest under treatment T_9 and lowest (10.38 g kg^{-1}) under T_1. Organic carbon in soil increased significantly with the increase level of fertilizers along with FYM and Vermicompost. Choudhary *et al.* (2005) [18] reported that the incorporation of biofertilizers and FYM with inorganic fertilizers significantly improved the organic carbon content of the soil in tomato. The available N in different treatments ranged from 318.01 kg ha^{-1} to 406.55 kg ha^{-1} which falls in medium range from the availability point of view. The increased available N due to incorporation of organic material is attributed to the enhanced mineralization. Swain *et al.* (2013) [7] also noted maximum available nitrogen in the plots supplied with 100% chemical fertilizers and explained that in chemical fertilizers, mineralization process was faster and thereby has shown immediate release of N and its availability in the soil. Similar trend was observed for available phosphorous content in soil. The highest available P (69.20 kg ha^{-1}) was recorded under treatment T_9 and lowest (46.79 kg ha^{-1}) under T_1. Addition of organic manure like FYM, crop residue along with inorganic fertilizer had a beneficial effect in increasing the phosphate availability, which was also observed by Upadhyay *et al.* 2012. [19] 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. Pooled analysis of data revealed that the effect of different treatments was significant and highest potassium 309.35 kg ha^{-1} was recorded under T_9 and lowest 227.35 kg ha^{-1} in T_1. The beneficial effect of Vermicompost 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) [6] in cauliflower. Choudhury *et al.* (2004) [5] reported significantly higher amount of available potassium through application of PSB + *Azotobacter* + FYM in conjunction with inorganic fertilizers in cauliflower. Almost similar trend was recorded for sulphur. Significantly higher sulphate sulphur was recorded for T_9 (60.71 kg ha^{-1}) and lower with T_1 (35.44 kg ha^{-1}) in cauliflower. The application of FYM or in combination with Vermicompost generally resulted in buildup of available S status of the soil. Singh and Singh (1977) [4] in an incubation study observed an increase in the soil microorganism population apparently utilize organically bound S and convert it into cystine and methionine, which are further converted in to inorganic sulphate by microorganisms. The buildup of available S in soil with the addition of FYM after the harvest of crop has also been reported by Nambiar and Ghosh (1984) [3].

Table 3: Effect of integrated nutrient management on chemical properties of soil.

Treatment	Organic carbon	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	SO_4^{2-} S (kg ha^{1})
T_1	10.38	318.01	46.79	227.35	37.70
T_2	12.31	386.28	63.70	293.06	50.15
T_3	12.37	393.85	66.99	283.10	53.28
T_4	12.21	389.32	65.87	279.24	50.87
T_5	11.22	366.71	60.18	270.93	45.87
T_6	11.94	373.27	61.61	274.22	47.91
T_7	12.42	396.59	67.31	285.83	57.01
T_8	12.58	404.25	67.38	295.79	57.35
T_9	12.63	406.55	69.20	309.35	59.20
$CD_{0.05}$	0.35	17.23	1.94	5.19	1.78

Conclusion

From the above study it can be concluded that the yield of cauliflower was increased 22.91% in treatment T_3 comprising of 80% NPKM + 20% N through FYM and vermicompost on nitrogen equivalent ratio as compared with that of RDF. On the basis of two years study, it may be concluded that the treatment T_9 (130% NPKM + 50% FYM+ 50% VC on N equivalence basis + PGPR) registered significantly maximum values of organic carbon, macro (N, P, K, SO_4^{2-}S) Hence, PGPR with 80 per cent of recommended dose of N, P and K fertilizers along with FYM and VC i.e. T_3 can be suggested as a effective nutrient module for getting higher yield and quality with 20% net saving of fertilizers in cauliflower cultivation on sustainable basis

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