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

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Abstract

In two consecutive years (2023 and 2024), a field experiment was set up at the Faculty of Agriculture Science's experimental farm at United University to assess the impact of integrated nutrient management (INM) on soil fertility and cauliflower (Brassica oleracea var. botrytis L.) productivity. PGPR strains (Bacillus spp.) were used in studies that combined the usage of organic and inorganic fertilizers. The nine therapies, Absolute control (T1), 70% NPKM + 30% N through FYM and VC (50:50), 80% NPKM + 20% N through FYM and VC (50:50), 90% NPKM + 10% N through FYM and VC (50:50), 100% NPK + FYM (T5), 100% NPK + Vermicompost (T6), The NPKM values for T7, T8, and T9 are 50:50 of FYM and VC according to N content, 50:50 of FYM and VC according to N content, and 120% and 130%, respectively. With the exception of T1, T5, and T6, all treatments were subject to PGPR. Three replicates of the experimental setup were established using a randomized block design (RBD). In contrast to treatment T5 -100% NPK + FYM (RDF), the results showed that treatment T3 -80% NPKM + 30% N through FYM and VC (50:50) with PGPR greatly boosted the cauliflower yield by 22.91%. Following harvest, the soil's condition was evaluated, and the usage of fertilizers and PGPR together raised the soil's nutrient concentration.

Keywords: Cauliflower; FYM; Vermicompost; Integrated Nutrient Management; Sustainable

1. Introduction

Among winter vegetables, cauliflower (Brassica oleracea var. botrytis L.) is the most often consumed. For improved growth and increased yield, it needs a sufficient and well-balanced supply of nutrients. The idea of integrated nutrient management has become a key instrument for preserving crop productivity and soil fertility. Utilizing organic, inorganic, and bio-sources of plant nutrients to their fullest potential is essential to the integrated nutrition management concept. according to the ecological, social, and economic potential of every farming scenario and cropping type. Crop development and soil fertility are enhanced by the combined use of fertilizer, manure, and biofertilizers. By generating growth regulators and antibacterial and antifungal chemicals, they are also said to play a significant part in enhancing disease resistance in the crop (Singh, 2000). INM is the integration of biological, inorganic, and organic elements to maintain soil fertility for future use and boost crop productivity. All of this is accomplished without having any long-term negative effects on the soil's physico-chemical and biological characteristics (Gruhn et al. 2000). [10]. When organic and chemical fertilizers were applied in tandem with PGPR, cauliflower yield and weight rose significantly compared to the control group (Kaushal et al. 2013) [1]. Because organic inputs have positive effects, integrated applications that carefully combine mineral fertilizer with organic and biological sources of nutrients are not only complementary but also synergistic (Roy et al. 2006). [12]. Therefore, INM was used to increase soil fertility and productivity as well as to make cauliflower farming sustainable. The growth, yield, nutrient concentration, and quality of cauliflower were all examined in relation to the combined effects of organic and inorganic fertilizer and plant growth

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promoting rhizobacteria (PGPR) at different dosages. Thus, research was conducted to use INM to improve cauliflower growth and productivity.

2. Material and Methods

Two years in a row (2023 and 2024) saw research carried out at United University Rawatpur Jhalwa Prayagraj's Faculty of Agriculture and Allied Sciences. Initial soil samples (0-15 cm depth) were obtained to examine the parameters of soil before the experiment started (Table 2). The soil status was once more assessed at the end of the experiment. In accordance with conventional protocols, soil samples were examined for organic carbon, available nitrogen, available phosphorus, available potassium, and sulphate sulphur (Table 1). Nine treatments in all—T1 being the absolute control, T2 being 70% NPKM + 30% N through FYM and VC (50:50), T3 being 80% NPKM + 20% N through FYM and VC (50:50), T4 being 90% NPKM + 10% N through FYM and VC (50:50), T5 being 100% NPK + FYM, T6 being 100% NPK + Vermicompost, T7 being 110% NPKM (50:50 of FYM and VC as per N content), T8 being 120% NPKM (50:50 of FYM and VC as per N content), and T9 being 130% NPKM (50:50 of FYM and VC as per N content) were all assessed using a Randomized Block Design with three replications. During field preparation, manures were added as a basal dose. Half of the N and all of the P and K were administered as a basal treatment at planting in INM plots, and the remaining N was top-dressed in two splits 30 and 60 days later. Urea, single superphosphate, and muriate of potash were the sources of nitrogen, phosphorus, and potash, respectively. Before the cauliflower was transplanted, PGPR was used as a root dip therapy for half an hour. Several quantitative characteristics of cauliflower, including leaf number, leaf area, curd diameter, curd weight, and curd yield, were observed. To ascertain the contents of N, P, and K during harvest using conventional methods, five plant samples were also randomly selected from each plot and mixed individually (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	$SO4^{2-}$ - S	0.15% $CaCl_2$ extractant and turbidimetric determination (Chesnin and Yien, 1950)
	Leaf Analysis	
1	N	Micro kjeldhal method (Jackson, 1973)
2	p	Vando-molybdate phosphoric yellow colour method (Jackson, 1973)
3	k	Flame photometer method (Jackson, 1973)

Table 2 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

3. Results and Discussion

Cauliflower yield and other characteristics were significantly impacted by the use of organic manures, inorganic fertilizers, and PGPR (Table 3). There were substantial differences in the number of leaves between the treatments; T9 (20) had the most leaves, followed by T3 (19), T, (19), and T8 (19). In T1, the number of leaves had the lowest value (15). For leaf area, a similar pattern was noted. T9 has the highest leaf area index (0.71), followed by T8 (0.70), T7 (0.65), and T3 (0.65). In fact, the meristematic region of the plant saw rapid cell division, multiplication, and elongation as a result of integrated nutrient utilization, which aided in the plant's vegetative growth (Yadav et al. 2007). The polar diameter was significantly lower in T1 (9.50 cm) and significantly higher under T9 (15.30 cm), which was statistically comparable to T8 (15.00 cm). Regarding the equatorial diameter, the treatment (T9) that recorded the largest equatorial diameter also measured the equatorially maximum by a substantial amount (19.30 cm), which was determined to be statistically comparable to T8 (19.30 cm) and T7 (19.20). Treatment T3 (80% NPKM + 30% N through FYM and VC 50:50) produced higher curd weight (977.40g) and yield (329.30 q/ha) regardless of whether it was integrated with organics (FYM and VC) or inoculated with bacteria. The enhanced growth and production of cauliflower resulting from the combined application of chemical fertilizers and organic manure with PGPR may be the consequence of enhanced photosynthetic and metabolic activity, which raised the levels of several plant compounds that cause cell elongation (Hatwar et al. 2003) [11]. []. The results indicated that if plants are inoculated with FYM and Vermicompost with PGPR, a 20% reduction in the recommended inorganic can be achieved. By using Vermicompost in place of FYM and 100% NPK, Kanwar and Paliyal (2006) [2] were able to achieve a net savings of 50% of synthetic fertilizer. When compared to the sole application of recommended inorganic fertilizers (150:80:75 kg NPK/ha), Chatterjee (2010) [13] found that higher amounts of organic manures (8 and 16 t/ha FYM and 2.5 and 5 t/ha VC) and lower levels of inorganic fertilizers (75% RDF) significantly influenced cabbage yield attributes and head yield. Vermicompost was found to be a superior organic nutrient source over farm yard manure.

A leaf is an essential plant organ that performs critical metabolic tasks linked to growth and reproduction maintenance. Therefore, a plant's growth and fruitfulness can be regarded as an indicator of the leaf's nutritional status. Therefore, adding the right measures to ensure optimal nutrient status will help keep cauliflower and capsicum in a vigorous state, which will guarantee optimal productivity levels. According to pooled analysis results, T3 had significantly greater leaf nitrogen (5.29%), which was statistically comparable to T9 (5.20%), T8 (5.25%), T7 (5.11%), and T6 (4.91%). T1 had the lowest leaf nitrogen (4.03%).

Additionally, T3 had the highest leaf P (0.84%), which was statistically comparable to T9 (0.78%) and T8 (0.81%), while treatment T1 had the lowest (0.36%). K also followed the similar pattern, with T3 having the highest leaf K (3.53%), which was statistically comparable to T9, T8, T7, and T4, while T1 had the lowest (2.07%). The addition of FYM, Vermicompost, and PGPR to cauliflower leaves may have increased the availability of macronutrients (N, P, and K) because it has accelerated microbial nitrogen fixation, improved the physical condition of the soil, allowed mycorrhizal fungi's mycelia network to develop roots, increased moisture retention, and consequently increased water and nutrient absorption. The rise in leaf nutrient content in several treatments that received microbial fertilizers and organic manures further implies that these fertilizers enhance the uptake of macronutrients and solubilize the soil's accessible nutrient pool. These outcomes are consistent with those of Patel et al. (2009) [14], who found that applying 75% RDF + Azotobacter +AMF and micronutrients improved the crop's uptake of N, P, K, Fe, Mn, Cu, and Zn nutrients. This may be explained by Azotobacter's capacity to fix nitrogen, improved phosphorus mobilization, and increased micronutrient uptake brought on by the use of AM fungi. Vermicompost applied in conjunction with chemical fertilizers has been linked by several researchers to an increase in nutrient concentration in index leaves (Ziauddin, 2009, Bhattarai and Tomar, 2009, Naik and Babu 2007). Major leaf nutrients, such as N, P, and K, were found to be significantly higher in plants treated with 75% RDF + 10 kg Vermicompost, according to Athani et al. (2009) [15, 16, 17, 20].

Table 3 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})
T1	15	0.51	9.5	11.2	754.3	208.8	4.03	0.36	2.07
T2	16	0.60	11.7	14.9	886.3	303.5	5.06	0.71	3.17
T3	19	0.65	13.6	17.4	977.4	344.8	5.29	0.84	3.53
T4	18	0.63	12.8	16.6	959.1	329.8	5.13	0.73	3.51

T5	16	0.54	10.1	13.7	875.4	268.8	4.48	0.60	3.05
T6	16	0.57	11.0	14.4	884.7	282.2	4.91	0.66	3.12
T7	19	0.65	14.8	19.2	965.2	341.2	5.11	0.72	3.45
T8	19	0.70	15.0	19.3	963.4	341.9	5.25	0.81	3.43
T9	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

3.1. Soil Properties

Over a two-year period, integrated nutrient management had an impact on the soil's characteristics. Organic carbon, accessible nitrogen, phosphorus, potassium, and sulfur sulfate were all positively impacted by the addition of organic, inorganic, chemical, and biofertilizers (PGPR) in various combinations (Table 2). Treatment T9 had the greatest organic carbon value (12.63 g kg-1) while treatment T1 had the lowest (10.38 g kg-1). As the number of fertilizers, FYM, and vermicompost grew, the amount of organic carbon in the soil also increased dramatically. According to Choudhary et al. (2005) [18], the organic carbon content of the soil in cauliflower was considerably increased by combining biofertilizers and FYM with inorganic fertilizers. From the perspective of availability, the available N in the various treatments ranged between 318.01 kg ha-1 and 406.55 kg ha-1, which is in the middle range. The improved mineralization is ascribed to the greater amount of accessible nitrogen brought about by the addition of organic material. Swain et al. (2013) [7] also observed that the plots that received only chemical fertilizers had the highest amount of nitrogen accessible. They explained that this was because the mineralization process in chemical fertilizers was accelerated, resulting in an instantaneous release of nitrogen and its availability in the soil. The amount of accessible phosphorus in the soil showed a similar pattern. The amount of accessible phosphorus in the soil showed a similar pattern. Treatment T9 had the highest available P (69.20 kg ha-1) and treatment T1 had the lowest (46.79 kg ha-1). According to Upadhyay et al. (2012), adding organic manure such as FYM and crop residue in addition to inorganic fertilizer has a positive impact on raising the phosphate availability. [19] The administration of PGPR isolates with extremely high P solubilization efficiency may have caused the insoluble P to become soluble, increasing the amount of accessible P. A pooled analysis of the data showed that the effects of the various treatments were significant, with T9 recording the greatest potassium level (309.35 kg ha-1) and T1 recording the lowest (227.35 kg ha-1). In addition to the decrease in potassium fixation and its release as a result of organic matter's interaction with clay particles, the direct potassium addition to the soil's potassium pool may be the cause of Vermicompost and FYM's positive impact on available K. In cauliflower, Parmar et al. (2006) [6] previously described the positive impacts of combining organic manures, bio-inoculants, and chemical fertilizers to promote the soil's natural fertility condition. Choudhury and associates. (2004) [5] found that using PSB + Azotobacter + FYM in combination with inorganic fertilizers to cauliflower resulted in a noticeably larger amount of accessible potassium. The trend for sulphur was nearly same. Sulphur content in cauliflower was much lower with T1 (35.44 kg ha-1) and significantly higher with T9 (60.71 kg ha-1). Applying FYM or Vermicompost together typically led to an increase in the soil's available S status. In an incubation research, Singh and Singh (1977) [4] found that the population of soil microorganisms increased. They appeared to use organically bound S and transform it into cystine and methionine, which the bacteria then transformed into inorganic sulphate. Nambiar and Ghosh (1984) have also documented the accumulation of accessible S in soil following crop harvest when FYM is added.

Table 4 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})
T1	10.38	318.01	46.79	227.35	37.70
T2	12.31	386.28	63.70	293.06	50.15
T3	12.37	393.85	66.99	283.10	53.28
T4	12.21	389.32	65.87	279.24	50.87
T5	11.22	366.71	60.18	270.93	45.87
T6	11.94	373.27	61.61	274.22	47.91
T7	12.42	396.59	67.31	285.83	57.01

T8	12.58	404.25	67.38	295.79	57.35
T9	12.63	406.55	69.20	309.35	59.20
CD 0.05	0.35	17.23	1.94	5.19	1.78

4. Conclusion

According to the aforementioned study, treatment T3, which consisted of 80% NPKM + 20% N through FYM and vermicompost on nitrogen equivalent ratio, resulted in a 22.91% increase in cauliflower yield as compared to RDF. The two-year trial suggests that the T9 treatment (130% NPKM + 50% FYM + 50% VC on N equivalency basis + PGPR) is effective. PGPR with 80% of the recommended dose of N, P, and K fertilizers along with FYM and VC, or T3, can be recommended as an effective nutrient module for achieving higher yield and quality with 20% net fertilizer savings in cauliflower cultivation on a sustainable basis. This is because the macronutrients (N, P, K, and SO42-S) and organic carbon values were significantly higher than average.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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