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Response of integrated nutrient management on soil chemical properties and yield of cauliflower (*Brassica oleracea* L.)

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Abstract
The world is confronted with unprecedented challenges as it endeavors to supply food and fibre for an extra 2 billion people by 2050. This task is already difficult, but several additional constraints make it even more daunting. Finally, the area of land used to grow our crops and raise our animals cannot be increased any further. All remaining natural forests and ecosystems must be conserved to maintain habitat, protect biodiversity and sustain planetary cycles. Therefore, a sustainable intensification of current production systems is the only alternative. 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. In keeping the above fact in view, a field trail was carried out at CRF, SHUATS, NAI Prayagraj during *Rabi* season 2021 on Response of Integrated Nutrient Management on soil Physico-chemical properties of soil and yield of Cauliflower with nine different treatments which were replicated thrice. The results revealed the best treatment was T_9 which improved Soil chemical properties *i.e.* pH 7.547 0-15cm and 7.582 15-30cm, EC (dSm^{-1}) 0.209 0-15 cm and 0.198 15-30cm, OC (%) 0.271 0-15cm and 0.351 15-30cm, Available Nitrogen (kg ha^{-1}) 248.85 kg ha^{-1} 0-15 cm and 257.32 kg ha^{-1} 15-30cm, Available Phosphorus (kg ha^{-1}) 18.54 kg ha^{-1} 0-15 cm and 21.74 kg ha^{-1} 15-30cm, Available Potassium (kg ha^{-1}) 175.35 kg ha^{-1} 0-15cm and 178.34 kg ha^{-1} 15-30cm, was recorded maximum.

Keywords: Nutrient, management, chemical, cauliflower, *Brassica oleracea* L.

Introduction
Cauliflower (*Brassica oleracea* L. Var. *botrytis*), a temperate vegetable crop from the crucifer family, is endemic to the Mediterranean region. The state of West Bengal is currently India's largest producer of cauliflower (22%). (NHB, 2014). Cauliflower is grown over 454 thousand hectares in India, with an annual production of 8,557 metric tonnes. Cauliflower (*Brassica oleracea* L. Var. *botrytis*), is a popular salad ingredient, as well as a boiled vegetable, a curry ingredient, a pickling ingredient, and a dehydrated vegetable. It is best known for its white soft curd and is widely grown around the world. Vitamin A (51 IU), vitamin C (56 mg), riboflavin (0.10 mg), thiamin (0.04 mg), nicotinic acid (1.0 mg), calcium (33 mg), phosphorus (57 mg), potassium (138 mg), moisture (90.8 g), carbohydrates (4.0 g), protein (2.6 g), fat (0.4 g), fibre (1.2 g), and iron (1.5 mg) per 100 g edible portion of cauliflower are considered essential nutrients (Fageria *et al.*, 2012) [6]. It also has medical potential, since it contains a high concentration of glucothiocyanate and indol-3-Carbinol, both of which have anti-inflammatory qualities, and has been found to be beneficial in inhibiting carcinogenesis (Basnet & Shakya, 2016) [1].

Cauliflower requires considerable amount of nutrients for growth and development (Chatterjee, 1993; Thakur *et al.*,1991) [5, 27]. Constant supply of manures and fertilizer in higher doses is required to obtain good yield (Subedi *et al.*, 2019) [26]. Mineral nutrition does play an important role in influencing the quality of crops and it is fact that the soil health deteriorates due to continuous use of chemical fertilizers (Savci, 2012) [22]. Biofertilizers are the inoculation of microorganisms, which are capable of mobilizing nutritive elements from non-usable form to usable form through biological process. They are a cost-effective and low-cost source of plant nutrients, do not require nonrenewable energy during production, boost crop growth and quality by releasing plant hormones, and aid in long-term crop production by maintaining soil productivity. (Gautam, 2012) [8].

Nitrogen is a vital nutrient for plants, as it plays a role in physiological processes and enzyme activity. In order to improve curd initiation and curd size in cauliflower, farmers use a lot of urea as a nitrogen fertilizer. Nitrogen may boost cauliflower production, however it lowers the quality of the curd. Cauliflower's storage life may be shortened because to high nitrogen levels combined with nutritional deficiencies. (Kirthisinghe, 2006) [9]. P buildup in many soils has occurred from indiscriminate use of P fertilizers and P-rich manures, lowering P fertilizer efficiency and causing P losses through runoff and eutrophication of surface rivers (Zhang *et al.*, 2014) [30]. As a result, improving P-use efficiency in crop production necessitates maximising the utilisation of residual P and other P pools in soils, as well as optimising P fertilizer supply. In this regard, root–microbe–soil interactions may play a critical role in Phosphorus use efficiency (Shen *et al.*, 2014) [23]. Despite the fact that potassium (K) is an important macronutrient for agricultural output, its economic significance is frequently overlooked. Potassium boosts crop yields while improving crop quality. K is a nutrient that is found in plants and is linked to crop quality. Zinc (Zn) is a micronutrient that both food crops and humans require (FAO, 2002) [7]. As a result, the likelihood of wilting is reduced, and available water is better utilised, resulting in the creation of protein and chlorophyll, as well as improved quality (Rutkauskiene and Poderys, 1999) [21]. Despite recent advances in global food and energy supplies, zinc deficiency still affects the majority of developing countries (Cakmak, 2017) [3]. Zinc (Zn) is an important plant micronutrient that is on par with major nutrients in terms of agricultural production (Padbhushan and Kumar, 2014: Rattan *et al.*, 2009) [17, 19]. Plant micronutrients such as zinc (Zn) are crucial for crop productivity, and their importance is comparable to that of main nutrients. (Rattan *et al*. 2009; Padbhushan and Kumar 2014) [19, 18].

Excessive or inefficient use of chemical fertilizers (CFs) is a major cause of nutrient imbalance in soil, resulting in high losses, particularly of nitrogen from the fertilizer, low nitrogen recovery (30%) (Krupnik *et al.*, 2004) [10], and low nitrogen use efficiency (about 35%) (Cao *et al.*, 2013) [4] in rice. Excessive use of organic manures, on the other hand, may result in harmful effects due to diminished metabolite intermediates. (Liang *et al.*, 2003) [11]. Because organic sources alone cannot provide a crop's nutritional needs due to the gradual release of their constituent nutrients (Miah, 1994) [13], judicious use of both organic and inorganic sources of nutrients is usually recommended to get the best yield and soil sustainability. Because of their mixed and synergistic effect in enhancing soil physical, chemical, and biological properties, the INM concept encourages integrated applications with judicious combination of mineral fertilizer with consisting of organic sources of nutrients, which results in higher crop productivity (KC & Bhattarai, 2012) [2].

Materials and Methods

Experimental site: The experiment was conducted at SHUATS' Soil Science Research Farm in Prayagraj; Prayagraj climate is subtropical, having summer and winter extremes. Summer temperatures (May-June) can reach 45-48 degrees Celsius, while winter temperatures (particularly in December and January) can drop to as low as 3-5 degrees Celsius. Summers are notorious for their sweltering winds, yet frost can happen at any time. The annual rainfall is between 850 and 1100 mm, with the majority of rain falling during the monsoon season (July to September) and a few showers scattered throughout the year the winter months.

Soil Collection and Analysis

After the crop harvest, soil samples were obtained from the experimental plot at depths of 0-15 cm and 15-30 cm using a soil auger and khurpi. These dirt samples were crushed and blended with a wooden mallet. Conning and quartering were employed to minimize the size of the soil sample, which was then filtered through a 2 mm screen before being analyzed mechanically, physically, and chemically.

Experimental Design and Treatments

With varying doses of Phosphorus and Zinc, the experiment was conducted out using a randomized block design (RBD). The treatments have been performed in triplicate by splitting the experimental area into twenty-seven plots and dividing the experimental area into three times. The treatments were applied to a plot that was 2m × 2m in size. T_1 Control (Absolute control), T_2 (50% Zn+0%Fe), T_3 (0%Zn+50%Fe), T_4 (100% Zn+0% Fe), T_5 (0% Zn+100% Fe), T_6 (50% Zn+100% Fe), T_7 (100% Zn+50% Fe), T_8 (50%Zn+50%Fe) T_9 (100%Fe+100%Zn). Sources of NPK were urea, SSP, MOP and Zn, Fe were Zinc sulphate, Iron chelates.

Soil physical properties *i.e.* Graduated Measuring Cylinder was used to determine BD, PD, percent Pore space, and Water Retaining Capacity, while a hydrometer was used to determine soil texture (Muthuval *et al.*, 1992) [14]. In terms of chemical characteristics, pH was assessed using a potentiometric approach using soil water suspensions, while EC was evaluated using a digital EC metre. Organic Carbon was measured using the wet-oxidation method (Walkley and Black, 1947) [29]. In an 800 mL kjeldahl flask, the alkaline permanganate method was employed to determine the amount of nitrogen available (Subbaih and Asija, 1956) [25]. Using a colorimetric approach and a spectrophotometer, the amount of accessible Phosphorus was estimated (Olsen *et al.*, 1954) [16]. The amount of potassium and neutral ammonium acetate solutions that are available (Toth and Prince 1949) [28]. DTPA extraction was used to quantify available Zinc using an Atomic Absorption Spectrophotometer (Lindsay and Norwell, 1978) [12].

Results and Discussion

Table 1: Response of yield parameters for Integrated Nutrient Management on Cauliflower

Treatment	Diameter of curd (cm)	weight of curd (kg)	yield (q ha^{-1})
T_1	13.5	0.564	96.32
T_2	14	0.586	120.23
T_3	14.23	0.612	126.78
T_4	16.15	0.632	105.87
T_5	16.7	0.643	123.78
T_6	17.15	0.682	137.98
T_7	17.52	0.712	113.65
T_8	17.85	0.745	145.65
T_9	18.1	0.776	158.45
F-test	S	S	S
S.Em+	0.09	0.005	0.07
C.D. at 5%	0.27	0.01	0.23

The largest curd diameter (cm) was reported at treatment T_9

(18.1), which used 100 percent NPK, Zn+100 percent FYM+100 percent Rhizobium. Treatment T_1 (13.5) with 0 percent NPK, Zn+0 percent FYM+0 percent Rhizobium resulted in the smallest curd diameter. Curd diameter has a high economic value in terms of marketable yield. The increased diameter of curd could be attributed to the use of Zinc in combination with NPK, FYM, and Rhizobium, which boosted nutrient availability and improved soil nutritional status. This could be attributed to the plant's photosynthetic activity increasing in tandem with its general growth, as well as a rise in chlorophyll content. The higher chlorophyll content resulted in more photosynthesis being diverted to curd growth, resulting in improved curd feeding. With the application of 100 percent NPK, Zn+100 percent FYM+100 percent Rhizobium, treatment T_9 (0.776) produced the most curd weight. Treatment T_1 (0.564) with 0 percent NPK, Zn+0 percent FYM+0 percent Rhizobium resulted in the lowest curd weight. The administration of increased levels of Nitrogen and Phosphorus, as well as Rhizobium, increased the curd weight of cauliflower. The use of Rhizobium in combination with NPK increased cauliflower's vegetative and reproductive growth. Increased amounts of nutrients were used, which resulted in a significant rise in curd weight. The increased curd size in the integrated treatment with rhizobium and FYM could be owing to the increased availability of nutrients and the proliferous root system, which allows for improved water and nutrient absorption as well as the physical environment. By enhancing the cation exchange capacity of roots, zinc aids in the absorption of vital elements. Treatment T_9 (158.45) had the best yield when 100 percent NPK, Zn+100 percent FYM+100 percent Rhizobium were applied. Treatment T_1 (96.32) had the lowest yield, with 0 percent NPK, Zn+0 percent FYM+0 percent Rhizobium applied. According to Singh *et al.*, 2015, the treatment of Rhizobium combined with NPK and Zn significantly altered yield metrics such as curd diameter, weight, and yield q ha^{-1}. Zinc application resulted in a considerable boost in yield. Zinc also plays a key role in plants, promoting appropriate growth and development by controlling auxin concentration. It is well recognized that adding organic matter to soil improves its physical, chemical, and biological qualities, resulting in greater nutrient absorption by plants and higher yields.

Table 2: Response of Integrated Nutrient Management on chemical properties of soil after crop harvest of Cauliflower

Treatment/depth	pH		EC (dS m^{-1})		OC (%)	
	0-15 cm	15-30cm	0-15 cm	15-30cm	0-15 cm	15-30cm
T_1	7.625	7.789	0.191	0.185	0.210	0.264
T_2	7.615	7.745	0.193	0.186	0.219	0.272
T_3	7.603	7.713	0.197	0.189	0.235	0.289
T_4	7.589	7.642	0.195	0.187	0.226	0.284
T_5	7.571	7.632	0.198	0.188	0.237	0.294
T_6	7.563	7.621	0.201	0.193	0.248	0.315
T_7	7.558	7.612	0.203	0.191	0.253	0.321
T_8	7.551	7.596	0.205	0.195	0.259	0.337
T_9	7.547	7.582	0.209	0.198	0.271	0.351
F-test	NS	NS	S	S	S	S
S.E+M	-	-	0.12	0.15	0.003	0.003
C.D.@5%	-	-	1.975	2.943	1.015	1.160

With the administration of 0 percent NPK, Zn+0 percent FYM+0 percent Rhizobium, the maximum pH was found at treatment T1 (7.625) at 0-15 cm deep and (7.789) at 15-30 cm depth. With the administration of 100 percent NPK, Zn+100 percent FYM+100 percent Rhizobium, the minimum pH was found at treatment T9 (7.547) at 0-15 cm deep and (7.582) at 15-30 cm depth. With increased treatment of Rhizobium+FYM+NPK+Zn, there is a steady reduction that is shown to be non-significant. This could be because higher Rhizobium, FYM, and Nitrogen rates boosted microbial activity, which in turn increased soil Organic Carbon, lowering soil pH. With the administration of 100 percent NPK, Zn+100 percent FYM+100 percent Rhizobium, the greatest EC was found at treatment T_9 (0.209) at 0-15 cm deep and (0.198) at 15-30 cm depth. With the administration of 0 percent NPK, Zn+0 percent FYM+0 percent Rhizobium, the minimum EC was found at treatment T_1 (0.191) at 0-15 cm deep and (0.185) at 15-30 cm depth. With increased treatment of Rhizobium+FYM+NPK+Zn, there was a gradual increase in EC, which was shown to be significant. This could be because the Rhizobium, in combination with FYM and nitrogen, boosted soil microbial activity, releasing Organic Carbon and increasing soluble salts in the soil at the same time. the highest possible OC with the application of 100 percent NPK, Zn+100 percent FYM+100 percent Rhizobium, was discovered at treatment T_9 (0.271) at 0-15 cm depth and (0.351) at 15-30 cm depth. With the application of 0 percent NPK, Zn+0 percent FYM+0 percent Rhizobium, the minimum OC was found at treatment T1 (0.210) at 0-15 cm deep and (0.264) at 15-30 cm depth. With increased treatment of Rhizobium+FYM+NPK+Zn, there was a gradual increase in OC, which was shown to be significant. This could be because Rhizobium, in combination with FYM, boosted soil microbial activity, resulting in the release of Organic Carbon.

Table 3: Response of Integrated Nutrient Management on Macro and micro of soil after crop harvest of Cauliflower

Treatment /depth	Available Nitrogen (kg ha^{-1})		Available Phosphorus (kg ha^{-1})		Available Potassium (kg ha^{-1})		Available Zinc (mg kg^{-1})	
	0-15 cm	15-30cm	0-15 cm	0-15 cm	0-15 cm	15-30cm	0-15 cm	15-30cm
T_1	231.10	240.30	16.12	17.21	160.64	164.33	0.381	0.354
T_2	233.32	243.54	16.77	17.84	162.34	166.66	0.386	0.357
T_3	237.33	245.26	17.59	18.67	165.36	169.69	0.398	0.364
T_4	235.42	248.32	17.46	19.65	164.18	167.65	0.395	0.360
T_5	239.34	250.58	18.18	19.78	167.60	170.34	0.401	0.361
T_6	241.34	253.43	18.25	20.35	171.65	173.36	0.411	0.365
T_7	238.40	251.57	18.38	20.68	168.57	171.38	0.404	0.367
T_8	243.80	254.34	18.42	21.49	173.68	175.85	0.408	0.369
T_9	248.85	257.32	18.54	21.74	175.35	178.34	0.416	0.371
F-test	S	S	S	S	S	S	S	S
S.E+M	0.004	0.003	0.120	0.080	0.242	0.786	0.004	0.003
C.D.@5%	0.627	0.540	0.913	0.633	0.206	0.891	1.871	2.031

With the application of 100 percent NPK, Zn+100 percent FYM+100 percent Rhizobium, the highest Available Nitrogen (kg ha^{-1}) was found at treatment T9 (248.85) at 0-15 cm deep and (257.32) at 15-30 cm depth. With the application of 0% NPK, Zn+0 percent FYM+0 percent Rhizobium, the minimum available nitrogen (kg ha^{-1}) was found at treatment T_1 (231.10) at 0-15 cm depth and (240.30) at 15-30 cm deep. With increased application of Rhizobium+FYM+NPK+Zn, there was a gradual increase in Available Nitrogen, which was shown to be substantial. This could be because Rhizobium aids in nitrogen fixation, increasing the amount of nitrogen available. With the application of 100 percent NPK, Zn+100 percent FYM+100 percent Rhizobium, the highest Available Phosphorus (kg ha^{-1}) was found at treatment T_9 (18.54) at 0-15 cm depth and (21.74) at 15-30 cm depth. With the application of 0% NPK, Zn+0 percent FYM+0 percent Rhizobium, the Minimum Available Phosphorus (kg ha^{-1}) was determined at treatment T_1 (16.12) at 0-15 cm depth and (17.21) at 15-30 cm depth. With increased application of Rhizobium+FYM+NPK+Zn, there was a gradual increase in Available Phosphorus, which was shown to be substantial. This could be because Rhizobium, in combination with Nitrogen, boosted microbial activity, which in turn solubilized Phosphorus, hence increasing Phosphorus availability.With the application of 100 percent NPK, Zn+100 percent FYM+100 percent Rhizobium, the highest Available Potassium (kg ha^{-1}) was found at treatment T_9 (175.35) at 0-15 cm depth and (178.34) at 15-30 cm deep. With the application of 0% NPK, Zn+0 percent FYM+0 percent Rhizobium, the minimum available potassium (kg ha^{-1}) was found at treatment T_1 (160.64) at 0-15 cm deep and (164.33) at 15-30 cm depth. With increased application of Rhizobium+FYM+NPK+Zn, there was a gradual increase in Available Potassium, which was shown to be substantial. With the application of 100 percent NPK, Zn+100 percent FYM+100 percent Rhizobium, the highest Available Zinc (mg kg^{-1}) was found at treatment T_9 (0.416) at 0-15 cm deep and (0.371) at 15-30 cm depth. With the application of 0% NPK, Zn+0 percent FYM+0 percent Rhizobium, the Minimum Available Zinc (mg kg-^{1}) was discovered at treatment T_1 (0.381) at 0-15 cm deep and (0.354) at 15-30 cm depth. With increased application of Rhizobium+FYM+NPK+Zn, there was a gradual increase in Available Zinc, which was shown to be substantial. Kumar *et al.*, 2020 and Goswami and Singh, 2016 both reported similar findings.

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