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Influence of integrated nutrient management and biofertilizer on growth, yield and quality of cauliflower (*Brassica oleracea* var. *Botrytis* L.)

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Abstract

Cauliflower (*Brassica oleracea* var. *Botrytis* L.) is a significant horticultural crop within India, particularly in the agro-climatic context of Uttar Pradesh. The crop's growth, yield and quality are notably impacted by nutrient management strategies, where unregulated chemical fertilization often leads to soil degradation and decreased productivity. Therefore, an experiment was conducted using field trials in the Rabi season of 2025-2026 at the Horticulture Research Farm, Department of Horticulture, Faculty of Agricultural Sciences & Allied Industries, Rama University, Kanpur (U.P.). The experiment was done using the design of Randomized Block Design (RBD), which involved 10 treatments, along with three replications. These treatments included various ratios of NPK, organic manures (vermicompost, FYM, poultry manure), and bio-fertilizers (azotobacter and PSB). The major goals were to assess the influence of integrated nutrient management (INM) and bio-fertilizers on the growth, yield and quality attributes of cauliflower cv. Snowball-16.

According to the results of the current study, Treatment T₃ (75% NPK + 25% Vermicompost) recorded the best effects on growth attributes, including the highest plant height of [31.01 cm (30 DAT), 41.01 cm (60 DAT) and 47.02 cm (90 DAT)], the maximum number of leaves per plant (24.01) and the longest leaf length (48.02 cm). It also significantly accelerated maturity, recording the least days to 50% curd formation (54.01 days) and the shortest duration from curd initiation to harvest (40.01 days). Regarding yield and quality parameters, T₃ achieved the maximum curd equatorial diameter (15.01 cm) and the highest yield per hectare (313.12 q), while the significantly minimum yield was observed in the control (192.43 q). In terms of quality, T₃ produced the highest Total Soluble Solids (6.80 °Brix), maximum Ascorbic Acid content (77.83 mg/100g) and the highest Total Sugars (4.90%). Notably, treatment T₆ (50% NPK + 50% Vermicompost + PSB (2.5 kg/ha)) was found statistically at par with T₃ across most parameters, suggesting it as a viable sustainable alternative for high-quality cauliflower production with reduced chemical inputs.

Keywords: Azotobacter, bio-fertilizers, cauliflower, FYM, integrated nutrient management (INM), poultry manure, quality, vermicompost and yield

Introduction

With the global population projected to reach 9 billion by 2050, mitigating widespread micronutrient malnutrition requires a dramatic upgrade in vegetable production systems (Darnton-Hill, 2019) ^[4]. India is the world's second-largest vegetable producer, yet meeting its projected domestic demand of 350 million tonnes by 2030 requires a 200-300% boost in current productivity levels (Anonymous, 2024) ^[2]. Within the *Brassicaceae* family, cauliflower (*Brassica oleracea* L. var. *Botrytis*) stands out as a primary cruciferous crop cultivated in India (Singh *et al.*, 2021) ^[13]. Beyond its high commercial value, it features a rich nutritional profile notably rich in protein, dietary fiber, vitamin C (48.2 mg/100g), and diverse anticancer and antimicrobial bioactive compounds like glucosinolates and flavonoids (Agagunduzet *et al.*, 2022) ^[1].

Despite its widespread cultivation across major Indian states, including Uttar Pradesh, standard production protocols face steep ecological and physiological challenges. Cauliflower demands high levels of primary nutrients, leading growers to apply chemical fertilizers in an unregulated, non-selective manner. This over-fertilization results in developmental disorders like premature buttoning or blind buds, degrades core curd quality, and diminishes antioxidant accumulation

(Ojetayo *et al.*, 2011; Kaur & Mal, 2018) [8, 5]. Furthermore, up to 50% of applied chemical nitrogen is lost via leaching and gaseous emission, while nearly 70% of soluble chemical phosphorus becomes locked into insoluble complexes with soil cations, triggering heavy environmental degradation and groundwater contamination (Singh *et al.*, 2014) [11].

To reverse these unsustainable trends, Integrated Nutrient Management (INM) offers a balanced paradigm by blending optimized chemical inputs with organic manures and microbial bio-fertilizers. Traditional amendments like farmyard manure (FYM), poultry manure, and nutrient-dense vermicompost safely improve soil aggregation, moisture retention, and microbial active pools while providing a steady, slow-release matrix of macro- and micronutrients (Khan *et al.*, 2010; Rehman *et al.*, 2023) [6, 10]. This biological framework is further accelerated by the inclusion of bio-fertilizers: free-living diazotrophs like *Azotobacter* fix atmospheric nitrogen and secrete vital phytohormones (auxins and gibberellins) that cut chemical nitrogen requirements by 10-20% (Mohandas, 1999) [7], while phosphorus-solubilizing bacteria (PSB) release organic acids to liberate bound phosphorus into plant-available forms (Wang *et al.*, 2014) [19]. In the agro-climatic context of Uttar Pradesh, formulating an optimal INM matrix is highly necessary to secure long-term soil health and scale up crop performance.

Keeping these facts in view, the present study entitled “Influence of Integrated Nutrient Management and biofertilizer on Growth, Yield and Quality of Cauliflower (*Brassica oleracea* var. *Botrytis* L.)” was undertaken.

Materials and Methods

The experimental trial on the rabi fields was performed in the 2025-26 season at the Primary Experimental Station of Rama University, located in Kanpur (U.P.). It is represented by typical physiography of the central Gangetic alluvium plains and semi-arid/sub-tropical climate in the Central Plain zone of Uttar Pradesh. The experimental area was delimited by geographical coordinates ranging from 25°34' N to 26°11' N latitude and 81°19' E to 82°27' E longitude, with an average altitude of 137 m above mean sea level. Physicochemical analysis of the soil profile in its upper layers (from 0 to 15 cm) showed its sandy loam composition, the pH value of 7.2, thus demonstrating slightly alkaline properties of the soil, and electrical conductivity amounting to 0.27 dS/m. The soil medium contained a lack of organic carbon, whose deficiency was equal to 0.51%. Nutrient composition of the soil was defined as containing 171.48 kg N/ha of available nitrogen and 17.60 kg P/ha of available phosphorus, while the amount of available potassium reached 216.40 kg K/ha. Meteorological parameters recorded for the entire period of cultivation (October 2025-March 2026) indicated high humidity stability and temperature variability; the total sum of rainfall measured was 7.54 mm. The experiment consisted ten treatments viz. T₁: Control (No fertilizer), T₂: 75% NPK + 25% FYM, T₃: 75% NPK + 25% Vermicompost, T₄: 75% NPK + 25% Poultry manure, T₅: 50% NPK + 50% FYM + *Azotobacter* (2.5 kg/ha), T₆: 50% NPK + 50% Vermicompost + PSB (2.5 kg/ha), T₇: 50% NPK + 50% Poultry manure + *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha), T₈: 25% NPK + 75% FYM + *Azotobacter* (2.5 kg/ha), T₉: 25% NPK + 75% Vermicompost + PSB (2.5 kg/ha) and T₁₀: 25% NPK + 75% Poultry manure +

Azotobacter (2.5 kg/ha) + PSB (2.5 kg/ha) which was analyzed in randomized block design with three replications. The experimental field was subjected to deep ploughing followed by harrowing to achieve a well-pulverized, fine tilth. Prior to transplanting, raised nursery beds measuring 3 m × 1 m at an elevation of 20 cm were meticulously prepared, cleared of weeds and crop remnants, and sown with seeds of cauliflower variety 'Snowball-16' that were pre-treated with the systemic fungicide Carbendazim (Bavistin) to mitigate soil-borne pathogens. For specified biological treatments, bio-fertilizers including *Azotobacter* and Phosphorus-Solubilizing Bacteria (PSB) were soil-applied by pre-mixing the inoculants with the organic manure. Uniform, healthy seedlings were carefully transplanted during the evening hours of October 25, 2025, at a standardized spacing of 60 cm between rows and 45 cm between plants, immediately followed by irrigation for proper crop establishment. A consistent plant population was maintained through gap-filling operations executed one-week post-transplanting. A systematic irrigation schedule was maintained at 15-day intervals and a total of five manual weeding operations were rigorously executed using weeding hooks at 15-day intervals up to 80 days post-transplanting. The crop was supplied with a standardized recommended inorganic nutrient dose of 120 kg of nitrogen (N), 80 kg of phosphorus (P₂O₅) and 40 kg of potassium (K₂O) per hectare utilizing Urea, Single Super Phosphate and Muriate of Potash. The fertilization strategy involved the basal application of the entire quantum of phosphorus and potassium alongside fifty percent of the total nitrogen at transplanting, while the remaining half of the nitrogen was top-dressed 30 days post-transplanting. Organic amendments consisting of farmyard manure (FYM), vermicompost or poultry manure were incorporated basally in accordance with specific treatment requirements, while foliar sprays of Acephate (15 g L⁻¹) and Dichlorvos (20 ml L⁻¹) were applied to manage aphid vectors causing yellow vein mosaic disease. Crucial observations concerning vegetative growth (at 30, 60 and 90 DAT), curd yield traits and physical and biochemical quality parameters were documented from five tagged, representative plants chosen at random within each treatment replicate. Statistical analysis of the experimental data was conducted using the Analysis of Variance (ANOVA) technique as defined by Panse and Sukhatme (1985) [9] and the significance of the treatment differences was evaluated using the "F" test at a 5% probability level.

Result and Discussion

Effect of integrated nutrient management and bio-fertilizer on growth attributes of cauliflower.

The data on growth traits of cauliflower presented in the table 1 indicates the significant effects of integrated nutrient management and bio-fertilizer. Plant vegetative parameters, including plant height and the number of leaves, varied significantly across different treatments. The highest plant height was consistently recorded in treatment 75% NPK + 25% Vermicompost (T₃), observing a maximum height of 47.02 cm, which significantly surpassed all other treatments except 50% NPK + 50% Vermicompost + PSB (2.5 kg/ha) (T₆), which was found to be statistically at par with a height of 46.26 cm. Conversely, the minimum plant height was recorded under the Control (No fertilizer) (T₁) at 32.60 cm.

Regarding the leaf characteristics, the number of leaves per plant followed a corresponding trend, showing highly significant variations among the nutrient regimes. The maximum number of leaves (24.01) was achieved under 75% NPK + 25% Vermicompost (T_3), showing a significant increase over the Control (No fertilizer) (T_1), which recorded the lowest number of leaves per plant (17.01 leaves). Similarly, the maximum leaf length and leaf width were also recorded under 75% NPK + 25% Vermicompost (T_3), observing 48.02 cm leaf length and 23.01 cm leaf width, respectively. The lowest leaf length (34.02 cm) and leaf width (16.04 cm) were consistently observed in the Control (No fertilizer) (T_1).

The physiological transition period, measured by the days to curd initiation and days from curd initiation to harvest, also showed significant variations among the treatment combinations and was found to be statistically significant at the 5% level of significance. The minimum number of days to curd initiation and days from curd initiation to harvest was successfully achieved under 75% NPK + 25% Vermicompost (T_3), requiring only 54.01 and 40.01 days respectively, while the maximum duration to curd initiation and days from curd initiation to harvest was documented under the Control (No fertilizer) (T_1), observing 64.81 and 48.46 days respectively, demonstrating that a lack of balanced integrated nutrition noticeably delays the phenological development of the crop.

The significant acceleration and enhancement of vegetative growth attributes and phenological transitions in cauliflower under 75% NPK + 25% Vermicompost (T_3) is a direct result of the favorable nutritional and physiological environment established by combining structured organic substrates with inorganic fertilizers, which consistently maximized plant height, leaf number, leaf length and leaf width while accelerating crop maturity by minimizing days to curd initiation and the duration from initiation to harvest. This superior development stems from the synergistic interplay where chemical fertilizers provide an immediate nutrient surge with nitrogen and potassium catalyzing early cell division, chlorophyll synthesis, and turgor pressure regulation while the nutrient-rich humus in vermicompost ensures a sustained release of macro- and micronutrients, improves soil aeration and water-holding capacity, and introduces natural bioactive growth regulators like humic acid, auxins, and cytokinins to stimulate lateral laminar expansion. Similar results were also documented by Thapa *et al.* (2023), Wu *et al.* (2023) and Sharma *et al.* (2022) [13, 15, 11].

Effect of integrated nutrient management and bio-fertilizer on yield attributes and yield of cauliflower

The data on the yield attributes and yield of cauliflower presented in the table 2 reveals a highly significant impact from the integrated nutrient management and bio-fertilizers. The physical dimensions of the cauliflower curd, measured via curd polar length and curd equatorial diameter, exhibited notable variations across the different nutrient treatments. The maximum curd polar and equatorial diameter was recorded under 75% NPK + 25% Vermicompost (T_3) at 12.00 cm and 15.01 cm, respectively. On the other hand, the least curd polar and equatorial diameter was observed in the Control (No fertilizer) (T_1), recording 8.06 cm polar length and 9.62 cm equatorial length, respectively.

The curd compactness followed a corresponding trend, showing a highly significant response to the synchronized nutrient treatments. The least curd compactness value which represented optimal volumetric head expansion was successfully achieved under 75% NPK + 25% Vermicompost (T_3) observing 40.33% compactness index, while the Control (No fertilizer) (T_1) recorded the highest compactness value at 88.36%.

Total yield was strongly influenced by the various nutrient management matrices. Reflecting the patterns observed in curd dimensions, treatment 75% NPK + 25% Vermicompost (T_3) produced the maximum yield at 313.12 q/ha. The lowest total yield was documented under the Control (No fertilizer) (T_1) at 192.43 q/ha yield, showing that a complete lack of integrated nutrient management and balanced fertilization severely restricts overall crop productivity.

The significant acceleration and enhancement of yield attributes and total yield in cauliflower under 75% NPK + 25% Vermicompost (T_3) is a direct result of the favorable nutritional and physiological environment established by combining structured organic substrates with chemical fertilizers, which achieved a maximum curd polar length, curd equatorial diameter and a maximum total yield of 313.12 q/ha. This superior production highlights the importance of a balanced nutrient supply in driving the vertical and radial expansion of the inflorescence, which can be attributed to the efficient translocation and partitioning of photo-assimilates from the vegetative leaves to the reproductive curd sink. The combination of chemical NPK and vermicompost ensures that the plant has access to an immediate and steady flux of macronutrients particularly Nitrogen for vegetative vigor and Potassium for maintaining cell turgidity and osmotic balance crucial for lateral tissue expansion alongside vital micronutrients like Boron and Molybdenum provided by the organic fraction, which prevent physiological disorders like hollow stems and ensure solid curd development. Consequently, the lower curd compactness value observed in treatment 75% NPK + 25% Vermicompost (T_3) is a direct consequence of this massive volumetric head expansion, where rapid biomass accumulation and the elongation of floral branches distributed weight over a much larger surface area, creating a desirable, tender curd structure. Bopcheet *et al.* (2024), Thapa *et al.* (2023) and Sharma *et al.* (2022a) found similar results [3, 13, 11].

Effect of integrated nutrient management and bio-fertilizer on quality attributes of cauliflower

The data on the quality parameters of cauliflower presented in the table reveals that integrated nutrient management regimes and bio-fertilizer application exert a distinct influence on the physical structure and biochemical composition of the crop. The biochemical sweetness and consumer preference index, evaluated through Total Soluble Solids (TSS), showed highly significant variations across the treatment combinations. The highest TSS concentration was successfully achieved under 75% NPK + 25% Vermicompost (T_3), reaching a peak value of 6.80°Brix, while the lowest accumulation of soluble solids was documented under the Control (No fertilizer) (T_1), observing 4.80 °Brix TSS.

The antioxidant and nutritional profile of the cauliflower curds, quantified by the ascorbic acid (Vitamin C) content, was strongly enhanced by the integrated bio-organic

frameworks. Consistent with the other quality metrics, 75% NPK + 25% Vermicompost (T₃) produced the maximum ascorbic acid content at 77.83 mg/100g. Conversely, the Control (No fertilizer) (T₁) resulted in a significant reduction in nutritional quality, recording the minimum ascorbic acid concentration of 54.92 mg/100g.

Similarly, the total sugar content was significantly maximized with the application of 75% NPK + 25% Vermicompost (T₃), yielding a value of 4.90%, while the lowest total sugar concentration was recorded under the Control (No fertilizer) (T₁) at 2.60%. This demonstrates that unbalanced or deficient fertilization strategies lacking integrated macro- and micronutrient mobilization constraints can negatively impact the plant's overall biochemical biosynthesis and nutritional value.

The significant enhancement of quality parameters and biochemical profiles in cauliflower under 75% NPK + 25% Vermicompost (T₃) is a direct result of the favorable nutritional and physiological environment established by combining structured organic substrates with chemical fertilizers, which achieved a peak Total Soluble Solids (TSS) concentration, a maximum ascorbic acid content and a maximized total sugar percentage. This superior physiological state heavily accelerated carbohydrate metabolism and enzyme activation due to an elevated rate of carbon fixation and efficient source-to-sink translocation of photo-assimilates from the wider foliar canopy to the economic curd. The steady supply of nitrogen from inorganic sources, coupled with humic substances and

micronutrients like Boron and Iron in vermicompost, directly optimizes chlorophyll activity and the enzymatic pathways necessary for the synthesis of hexose sugars, which serve as the primary precursors for L-ascorbic acid biosynthesis. Patel *et al.* (2023), Zargaret *et al.* (2022) and Tiwari *et al.* (2021) found similar results ^[10, 16, 14].

Conclusion

From the above results of the current experiment, 75% NPK + 25% Vermicompost (T₃) had the best effect in terms of growth attributes, yield parameters, and quality traits of cauliflower. In terms of integrated nutrient management practices, 75% NPK + 25% Vermicompost (T₃) was found to be significantly effective over all other treatments on growth and yield attributes like plant height, number of leaves per plant, leaf length, leaf width, curd dimensions (polar length and equatorial diameter) and total yield (313.12 q/ha), while successfully managing structural configurations like curd compactness and optimizing biochemical quality indices including TSS, total sugars, and ascorbic acid content.

Given that this is based on a single season trial, additional evaluation trials are required to validate the findings.

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Table 1: Effect of integrated nutrient management and bio-fertilizer on growth attributes of cauliflower

S. No.	Treatment	Treatment combination	Plant height (cm)	Day to 50% curd formation	Number of leaves per plant	Leaf length (cm)	Leaf width (cm)	Days from curd initiation to harvest
1	T ₁	Control (No fertilizer)	32.60	64.81	17.01	34.02	16.04	48.46
2	T ₂	75% NPK + 25% FYM	44.24	56.01	22.63	45.26	21.61	41.58
3	T ₃	75% NPK + 25% Vermicompost	47.02	54.01	24.01	48.02	23.01	40.01
4	T ₄	75% NPK + 25% Poultry manure	40.96	58.81	21.01	42.02	19.95	43.79
5	T ₅	50% NPK + 50% FYM + Azotobacter (2.5 kg/ha)	42.43	56.71	21.66	44.02	20.91	42.14
6	T ₆	50% NPK + 50% Vermicompost + PSB (2.5 kg/ha)	46.26	54.61	23.64	47.28	22.61	40.49
7	T ₇	50% NPK + 50% Poultry manure + Azotobacter (2.5 kg/ha) + PSB (2.5 kg/ha)	41.61	58.21	21.32	42.64	20.29	43.30
8	T ₈	25% NPK + 75% FYM + Azotobacter (2.5 kg/ha)	38.41	61.01	19.73	39.46	18.67	45.52
9	T ₉	25% NPK + 75% Vermicompost + PSB (2.5 kg/ha)	39.19	60.41	20.12	40.23	19.07	45.03
10	T ₁₀	25% NPK + 75% Poultry manure + Azotobacter (2.5 kg/ha) + PSB (2.5 kg/ha)	36.10	62.51	19.36	38.12	18.23	46.69
S.E. (m) (±)			1.42	1.70	0.73	1.33	0.66	1.70
C.D. @ 5%			4.23	5.06	2.17	3.96	1.95	5.06

Table 2: Effect of integrated nutrient management and bio-fertilizer on yield attributes and yield of cauliflower

S. No.	Treatment	Treatment combination	Curd polar diameter (cm)	Curd equatorial diameter (cm)	Curd compactness (g/cm ³)	Yield per hectare (q)
1	T ₁	Control (No fertilizer)	8.06	9.62	88.36	192.43
2	T ₂	75% NPK + 25% FYM	11.18	13.85	46.85	289.45
3	T ₃	75% NPK + 25% Vermicompost	12.00	15.01	40.33	313.12
4	T ₄	75% NPK + 25% Poultry manure	10.20	12.44	55.54	253.81
5	T ₅	50% NPK + 50% FYM + Azotobacter (2.5 kg/ha)	10.98	13.53	47.99	278.77
6	T ₆	50% NPK + 50% Vermicompost + PSB (2.5 kg/ha)	11.75	14.62	42.04	303.78
7	T ₇	50% NPK + 50% Poultry manure + Azotobacter (2.5 kg/ha) + PSB (2.5 kg/ha)	10.41	12.76	53.35	261.70

8	T ₈	25% NPK + 75% FYM + Azotobacter (2.5 kg/ha)	9.46	11.42	64.30	230.81
9	T ₉	25% NPK + 75% Vermicompost + PSB (2.5 kg/ha)	9.70	11.78	61.22	239.15
10	T ₁₀	25% NPK + 75% Poultry manure + Azotobacter (2.5 kg/ha)+ PSB (2.5 kg/ha)	9.14	11.14	68.51	225.53
S.E. (m) (±)			0.34	0.43	3.75	8.94
C.D. @ 5%			1.00	1.28	11.14	26.58

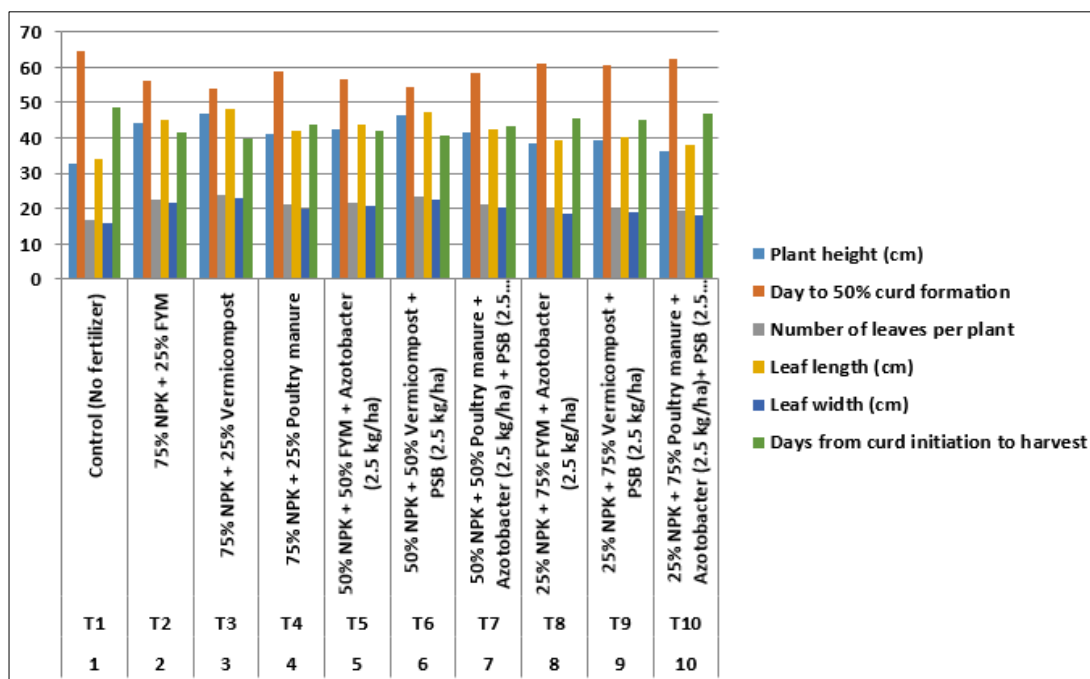


Fig 1: Effect of integrated nutrient management and bio-fertilizer on growth attributes of cauliflower

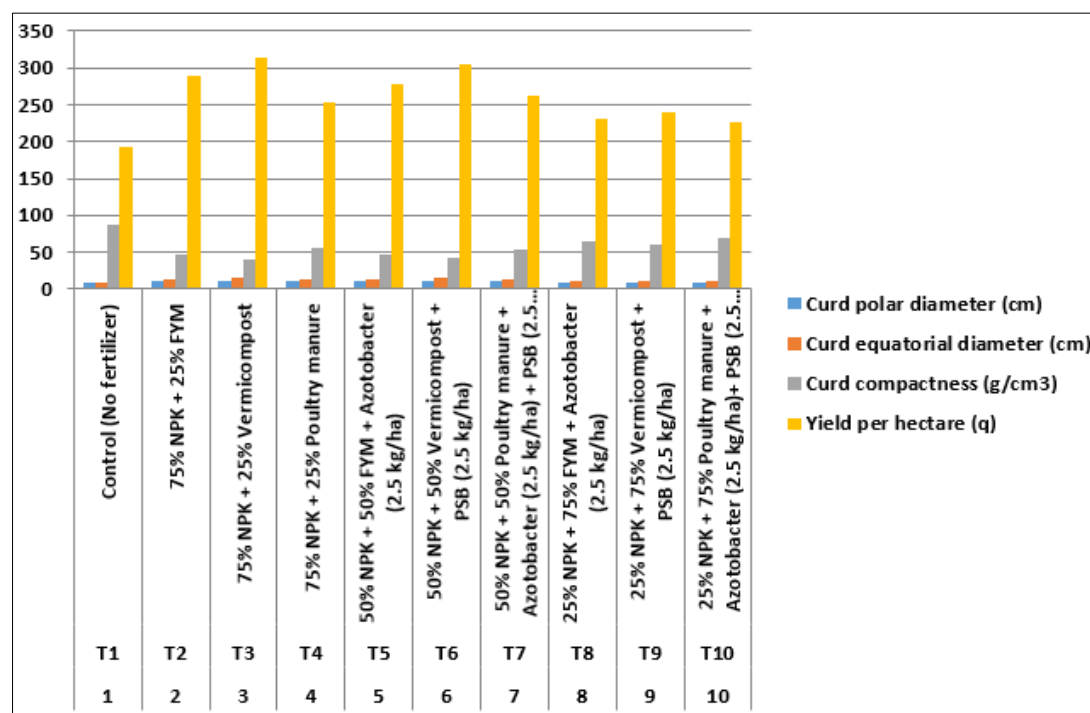


Fig 2: Effect of integrated nutrient management and bio-fertilizer on yield attributes and yield of cauliflower

Table 3: Effect of integrated nutrient management and bio-fertilizer on quality attributes of cauliflower

S. No.	Treatment	Treatment combination	TSS (°Brix)	Ascorbic acid (mg/100g)	Total sugars (%)
1	T ₁	Control (No fertilizer)	4.80	54.92	2.60
2	T ₂	75% NPK + 25% FYM	6.40	73.29	4.36
3	T ₃	75% NPK + 25% Vermicompost	6.80	77.83	4.90

4	T ₄	75% NPK + 25% Poultry manure	5.94	67.94	3.69
5	T ₅	50% NPK + 50% FYM + Azotobacter (2.5 kg/ha)	6.23	72.39	4.18
6	T ₆	50% NPK + 50% Vermicompost + PSB (2.5 kg/ha)	6.69	76.60	4.69
7	T ₇	50% NPK + 50% Poultry manure + Azotobacter (2.5 kg/ha) + PSB (2.5 kg/ha)	6.03	68.99	3.86
8	T ₈	25% NPK + 75% FYM + Azotobacter (2.5 kg/ha)	5.58	63.76	3.24
9	T ₉	25% NPK + 75% Vermicompost + PSB (2.5 kg/ha)	5.69	65.02	3.42
10	T ₁₀	25% NPK + 75% Poultry manure + Azotobacter (2.5 kg/ha) + PSB (2.5 kg/ha)	5.41	59.95	2.94
S.E. (m) (±)			0.16	1.57	0.08
C.D. @ 5%			0.46	4.67	0.23

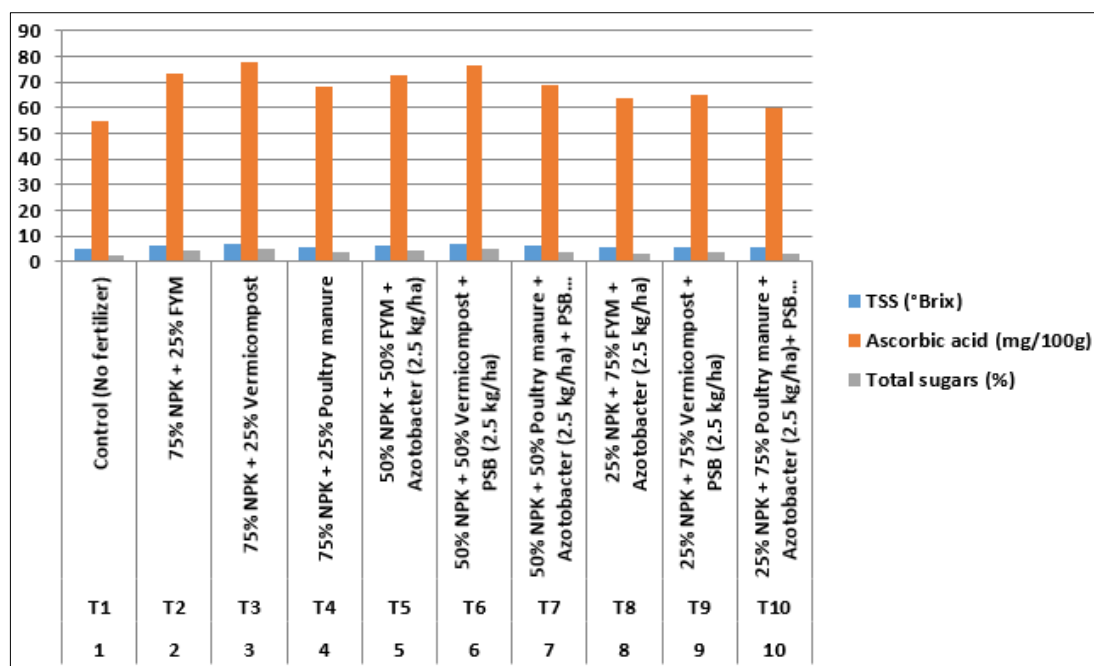


Fig 3: Effect of integrated nutrient management and bio-fertilizer on quality attributes of cauliflower

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