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Study on the effect of biofertilizers in combination with inorganic nutrients on yield and economics of purple cauliflower (*Brassica oleracea* var. *botrytis*) grown in polyhouse under the Gwalior region

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Abstract
A field experiment was conducted during *Rabi* season 2023-2024 to study on the effect of biofertilizers in combination with inorganic nutrients on yield and economics of purple cauliflower (*Brassica oleracea* var. *botrytis*) at the Vegetable Research Farm (CRC-3), Under the poly house, School of Agriculture, Department of Horticulture, ITM University, Gwalior, (MP) with three replications and eleven treatments. The treatments included the application of the recommended dose of fertilizers (RDF) along with various organic manures such as farmyard manure (FYM), vermicompost (VM) and azotobacter. Throughout the experiment, growth and yield attributes were measured, with the highest values for plant height recorded in treatment T_{11} (75% RDF + 20% Vermicompost + Azotobacter), diameter of curd was recorded in treatment T_{11} (75% RDF + 20% Vermicompost + Azotobacter) and yield recorded in treatment T_6 (75% RDF + 10% FYM +15% Vermicompost) and T_8 (75% RDF + 25% Vermicompost + Azotobacter). The results indicate that the integrated application of organic inputs and a 50% reduction in chemical fertilizers are the most effective strategies for maintaining crop productivity and improving soil health. Economic studies on treatment applications are crucial for farmers, as they prioritize monetary returns and profitability when choosing crop recommendations and adopting specific agricultural practices. Therefore, assessing the economic viability of various treatments is essential to determine the best approach. Desired traits include higher gross returns, lower cultivation costs, and favourable benefit-cost ratios (B). In this study, the economics of different treatments for cauliflower cultivation were evaluated based on the cost of cultivation (₹ per hectare), gross returns (₹ per hectare), net returns (₹ per hectare), and benefit-cost ratio.

Keywords: RDF, vermicompost, azotobacter, gross return, cost of cultivation, benefit-cost ratio

Introduction

Cauliflower (*Brassica oleracea* var. *botrytis*) is one of an important cool season vegetable of Brassicaceae family. Purple cauliflower stands out as a distinctive and nutritious variety of cauliflower, notable for its vibrant 'purple' color attributed to anthocyanins. This type has several health advantages in addition to its attractive appearance, such as antioxidant qualities, vitamin richness, high fibre content, low calorie content, and phytonutrient content.

After the Green Revolution, Indian agriculture encountered numerous challenges. These included stagnant or declining production and productivity of key crops, soil fertility deterioration, reduced factor productivity, limited diversity in production systems, and rising production costs. These issues arose partly due to prolonged crop cycles without adequate nutrient management and the indiscriminate application of agrochemicals on both soil and crops (Sharma and Subehia, 2014) [29]. The Green Revolution in India marked a significant shift with the introduction of high-yielding crop varieties and intensive farming practices involving inorganic fertilizers, pesticides, and other inputs. India ranks first globally in fruit production (71 million tonnes) and second in vegetable production (71 million tonnes) (Gaur, 2006) [9].

India is the leading producer of cauliflower globally, with China, France, Italy, Spain, and Poland also being significant producers. Because, cauliflower and broccoli are important vegetable crops which are being grown worldwide on 1395152 ha with a production of 25984758 tons annually (FAOSTAT, 2017) [8].

It is 5th important vegetable crop in India (which stand 2nd after China) cultivated on 454,000 ha area with 8,557,000 tons production (NHB Database, 2017) [20]. It has large consumer base across the geographic regions and economic strata of Indian population and biofortifying this crop with health-beneficial compounds like anthocyanins can benefit public sustainably. The production of vegetables is estimated to be 212.91 million tonnes in the year 2022-23 compared to 209.14 million tonnes in the year 2021-22 (Ministry of Agriculture & Farmers Welfare).

Despite challenges in producing purple cauliflower in polyhouses, sustainable agricultural methods offer solutions for improving productivity and economy. Polyhouse farming involves growing crops in a controlled environment, protecting them from external factors like extreme weather and insects. This method allows for year-round planting, higher yields, and top-quality produce. Purple cauliflower, which thrives in regulated low and dry temperatures, benefits particularly from polyhouse conditions. Automated systems manage watering, fertilization, and temperature, creating an optimal growth environment. However, polyhouse cultivation faces high input costs for seeds, fertilizers, and pesticides. Additionally, temperature and humidity fluctuations can impact crop quality and yield, and the use of inorganic fertilizers can degrade soil, threatening long-term sustainability.

Growing consumer demand for colourful, nutrient-dense veggies means that growers must find ways to increase purple cauliflower's output and financial sustainability. However, because of its sensitivity to soil conditions and particular nutritional requirements, cultivation presents special obstacles. Cauliflower, like many other crops, has historically been cultivated primarily with the use of artificial fertilisers to satisfy its nutritional requirements.

Inorganic fertilizers, composed of synthetic chemicals, deliver essential nutrients in forms that plants can readily absorb, resulting in rapid and substantial increases in crop yields. Although inorganic fertilisers are good at increasing yields, overuse of them has degraded soil, polluted the environment, and raised production costs. However, overuse of inorganic fertilizers can cause soil degradation, environmental pollution, and a decline in soil fertility over time. Using integrated nutrient management strategies that don't lower output levels might be one way to help these producers. For agricultural production, using biofertilizers presents a sustainable option. The fertility and productivity of agricultural soils depend on the regular and suitable addition of microbial inoculants and organic farm waste (Kannaiyan 2002) [13].

However, there is a need for integrated nutrient management to sustain optimal crop productivity. Combining organic and inorganic fertilizers has garnered significant attention in recent years, aiming to fulfill farmers' economic needs while maintaining favorable ecological conditions in the long term (Kumar *et al*., 2007). Organic manures serve as a reservoir of plant nutrients and prevent nutrient leaching by maintaining high cation exchange capacity, thereby buffering plants against sudden changes in their chemical environment (Elnasikh and Satti, 2017) [7]. Biofertilizers, in a broader sense, provide an economically attractive and ecologically sustainable method to reduce external inputs and enhance the quantity and quality of vegetable production (Ekta *et al*., 2017) [6]. This can be achieved by gradually decreasing fertilizer doses while increasing the use of organic manures and biofertilizers. Microbial inoculation in vegetable crops has shown significant improvements in growth, yield, and quality (Singh and Singh 2007) [33].

The usage of biofertilizers is becoming more popular as the need for sustainable farming methods grows. Biofertilizers, as opposed to chemical fertilisers, provide a sustainable agricultural solution by lowering reliance on artificial inputs. Biofertilizers, containing beneficial microorganisms like nitrogen-fixing bacteria (e.g., *Rhizobium*, *Azotobacter*), phosphate-solubilizing bacteria (e.g., *Pseudomonas*, *Bacillus*), and mycorrhizal fungi, enhance soil health and plant growth by making primary nutrients more available. Inorganic nutrients and biofertilizers together present a viable approach to sustainable agriculture. This combined strategy increases crop yields, maximises economic returns, and optimises nutrient usage efficiency. This combination's synergistic actions minimise environmental impact, encourage sustainable agricultural methods, and improve soil health.

This study looks at how various mixes of inorganic nutrients and biofertilizers affect the production and financial results of growing purple cauliflower. The research attempts to determine the best fertilisation procedures that maximise yield and guarantee economic sustainability by investigating different treatment combinations. This study had been carried out in Gwalior's polyhouse that was situated in Madhya Pradesh, the state of India. The area can be divided into the subtropical climatic conditions, where there is a dry and short cold season, so the purple cauliflower can be grown throughout the whole year.

Materials and Methods

The field experiment was carried out at the Vegetable Research Farm (CRC-3), Under the poly house, School of Agriculture, Department of Horticulture, ITM University, Gwalior, (MP), during rabi season (2023-2024) from the last week of September to mid of April. Summer season is considered very hot, where the months of May and June are found to be the hottest months here with a maximum average temperature of 35 °C to 45 °C (95°F to 113°F). The place of investigation is situated in the ITM University, Gwalior district of Madhya Pradesh. It is geographically located in the Gird region of India 26˚21, N latitude and 78˚ 20’ E longitudes and an altitude of 211.5 m above sea level. It is present in the southwest of the main city centre of Gwalior. These treatments are evaluated in Randomized block design (RBD) at spacing of 90 cm x 60 cm with three replications. The experiment was consisting of eleven treatments Table 1.

The soil of the polyhouse as tested as sandy loam in texture (pH 7.2) and was well-levelled, well-drained, low in organic carbon (0.40%), medium available in N, P and K. The treatments included the application of the recommended dose of fertilizers (RDF) along with various organic manures such as farmyard manure (FYM), vermicompost (VM) and Azotobacter. Nursery of the seedlings were grown in plug trays to raise seedlings. Four plug trays with dimensions of 350 mm x 545 mm were collected for sowing the purple cauliflower seeds. In these plug trays, seeds were sown on October 25, 2023. 60 seeds were sown in one plug tray. Seeds were sown in four plug trays. After being sown, the seeds were buried at a depth of 1.5 to 2.0 cm. On

November 25th in 2023, these seedlings were moved from plug tray into beds.
To determine the cost of cultivation for each treatment, all inputs used in the study were priced at the current market rates. To calculate gross income, the cauliflower yields were evaluated in accordance with the going market rates. Net income and the benefit-to-cost ratio were then computed to evaluate the profitability of various therapies. Benefit: Cost ratio was calculated by dividing net returns with the cost of cultivation for each treatment.

$$\text{Benefit: Cost ratio} = \frac{\text{Net returns (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

The analysis of variance for the design of experiment (RBD) was carried out according to the procedure outlined by Panse and Sukhatme (1967) [39]. The significance of differences among treatment means was tested by 'F' test. To test the hypothesis $H0{:}T_1{=}T_2\ldots\ldots tn$, the fixed effect model for analysis of variance for Randomized Block Design is given bellow:

$$Y_{ij} = \mu + t_i + b_i + e_{ij}$$

Where,
Y_{ij} = Yield of i^{th} entry in the j^{th} replication
μ= General mean
t_i = Effect of the i^{th} entry (i = 1,2….)
b_i = Effect of the j^{th} replication (j = 1,2…...)
e_{ij} = Environmental effect

Results and Discussion
Different parameters related to growth and productivity of purple cauliflower (*Brassica oleracea* var. *botrytis*) reflected a significant variation under different growing media (Table 2).
Plant height ranged from 24.05 cm to 28.96 cm. The overall mean was 26.51 cm. The highest plant height was found in 75% RDF + 20% Vermicompost + Azotobacter (28.96 cm) followed by 75% RDF +10% FYM + 15% Vermicompost + Azotobacter (27.77 cm), 60% RDF + 10% Vermicompost + Azotobacter (27.16 cm). The lowest Plant height was observed in 100% RDF (24.05 cm). Days to 50 percent curd initiation ranged from 64.40 days to 71.72 days. The overall mean was 67.54 days. The earliest days to 50 percent curd initiation was found in 75% RDF + 25% Vermicompost + Azotobacter (64.40 days) followed by 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (65.56 days), 75% RDF + 25% FYM + Azotobacter (65.61 days). The maximum days to 50 percent curd initiation was observed in 100% RDF (71.72 days). Number of leaves/plants ranged from 19.00 to 27.67. The overall mean was 24.21. The maximum number of leaves/plants found in the treatment 75% RDF + 25% FYM + Azotobacter (27.67) followed by 75% RDF + 20% Vermicompost + Azotobacter (27.33) and 50% RDF + 25% FYM + 25% Vermicompost (25.33). While minimum number of leaves/plants found in 75% RDF + 25% FYM (19.00) followed by 75% RDF +10% FYM + 15% Vermicompost + Azotobacter (21.00) and 60% RDF + 10% Vermicompost + Azotobacter (22.49). The plant spread shall be noted in ascending order from 43.78 cm to 50.44 cm. The overall mean was 48.15 cm. The minimum plant spread was found in 60% RDF + 10% Vermicompost + Azotobacter (43.78 cm) followed by 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (44.22 cm) and 75% RDF + 25% FYM + Azotobacter (47.63 cm). While, the maximum plant spread was found in 75% RDF +10% FYM + 15% Vermicompost + Azotobacter (50.44 cm). The length of longest leaf ranged from 26.86 cm to 52.08 cm. The overall mean was 41.05 cm. The maximum length of longest leaf was found in 75% RDF +10% FYM + 15% Vermicompost (52.08 cm) followed by 75% RDF + 25% Vermicompost + Azotobacter (51.04 cm) and 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (47.49 cm)). The minimum length of longest leaf was found in 75% RDF +10% FYM + 15% Vermicompost + Azotobacter (26.86 cm). The width of the longest leaf ranged from 14.10 cm to 19.30 cm highest. The overall mean was 16.33 cm. The highest width of the longest leaf was found in 100% RDF (19.30 cm) followed by 75% RDF + 20% Vermicompost + Azotobacter (18.22 cm) and 75% RDF + 25% FYM (17.69 cm). The lowest width of the longest leaf was found in 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (14.10 cm). The fresh weight of the whole plant ranged from 3.32 kg to 4.80 kg highest. The overall mean was 3.95 kg. The maximum fresh weight of whole plant was found in 75% RDF + 25% Vermicompost + Azotobacter (4.80 kg) followed by 75% RDF + 10% FYM + 15% Vermicompost + Azotobacter (4.40 kg) and 50% RDF + 25% FYM + 25% Vermicompost (4.32 kg). The minimum fresh weight of whole plant was found in 100% RDF (3.32 kg). Fresh weight of trimmed curd ranged from 538.32 g to 858.87 g. The overall mean was 727.38 g. The maximum Fresh weight of trimmed curd found in 75% RDF + 25% Vermicompost + Azotobacter (858.87 g) followed by 50% RDF + 25% FYM + 25% Vermicompost (816.47 g) and 75% RDF + 10% FYM +15% Vermicompost (796.12 g). The minimum Fresh weight of trimmed curd found in 75% RDF +10% FYM + 15% Vermicompost (538.32 g). Fresh weight of untrimmed curd ranged from 1.51 kg to 2.82 kg. The overall mean was 2.18 kg. The maximum Fresh weight of untrimmed curd found in 75% RDF + 25% Vermicompost + Azotobacter (2.82 kg) followed by 60% RDF + 10% Vermicompost + Azotobacter (2.61 kg) and 75% RDF +10% FYM + 15% Vermicompost + Azotobacter (2.55 kg). The minimum Fresh weight of untrimmed curd found in 75% RDF + 10% FYM +15% Vermicompost (1.51 kg). Curd yield/plot ranged from 46.05 kg to 82.65 kg highest. Over all mean was 62.57 kg. The highest curd yield/plot was found in 75% RDF + 10% FYM +15% Vermicompost (82.65kg) followed by 75% RDF + 25% Vermicompost + Azotobacter (75.36 kg), 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (74.56 kg)). The lowest value of curd yield/plot was observed in 100% RDF (46.05 kg). Curd yield/ha ranged from 252.67 q/ha to 479.00 q/ha highest. The overall mean was 359.94 q/ha. The highest curd yield/ha was found in 75% RDF + 10% FYM +15% Vermicompost (479.00 q/ha) followed by 75% RDF + 25% Vermicompost + Azotobacter (431.00 q/ha), 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (424.33 q/ha). The lowest value of curd yield/ha was observed in 100% RDF (252.67 q/ha). Diameter of curd ranged from 15.74 cm to 20.34 cm highest. The overall mean was 17.96 cm. The highest diameter of curd was found in 75% RDF + 20% Vermicompost + Azotobacter (20.34 cm) followed by 75% RDF + 25% Vermicompost + Azotobacter (19.77 cm), 75% RDF + 25% FYM + Azotobacter (18.80 cm). The

lowest diameter of curd was observed in 60% RDF + 10% Vermicompost + Azotobacter (15.74 cm). (Table 2).

Economic studies on treatment applications are crucial for farmers, as they prioritize monetary returns and profitability when choosing crop recommendations and adopting specific agricultural practices. Therefore, assessing the economic viability of various treatments is essential to determine the best approach. Desired traits include higher gross returns, lower cultivation costs, and favorable benefit-cost ratios (B). In this study, the economics of different treatments for cauliflower cultivation were evaluated based on the cost of cultivation (₹ per hectare), gross returns (₹ per hectare), net returns (₹ per hectare), and benefit-cost ratio (B). The relative economic performance of each treatment is summarized in Table 4. Cost of cultivation ranged from 57969.5 Rs/ha 84364.5 Rs/ha. The overall mean was 71279.26545 Rs/ha. The highest Cost of cultivation was recorded in 75% RDF + 10% FYM +15% Vermicompost (814300 Rs/ha) followed by 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (81112.43 Rs/ha), 60% RDF + 10% Vermicompost + Azotobacter (77825.43 Rs/ha). However, the lowest Cost of cultivation was observed in 100% RDF (57969.50 Rs/ha). Gross income (Rs/ha) ranged from 429533.33 Rs/ha to 814300 Rs/ha highest. The overall mean was 611896.9691 Rs/ha. The highest Gross income (Rs/ha) was recorded in 75% RDF + 10% FYM +15% Vermicompost (814300 Rs/ha) followed by 75% RDF + 25% Vermicompost + Azotobacter (732700 Rs/ha) and 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (721366.67 Rs/ha). The lowest Gross income (Rs/h) observed in 100% RDF (429533.33 Rs/ha). Net income (Rs/ha) ranged from 371563.8 Rs/ha 750188.6 Rs/ha. The overall mean was 540617.7027 Rs/ha. The highest Net income (Rs/ha) was recorded in 75% RDF + 10% FYM +15% Vermicompost (750188.57 Rs/ha) followed by 75% RDF + 25% Vermicompost + Azotobacter (648335.50 Rs/ha) and 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (640254.23 Rs/ha). The lowest Net income (Rs/ha) observed in 100% RDF (371563.83 Rs/ha). Benefit cost-ratio ranged from 6.08 to 11.71 highest. The overall mean was 7.59. The highest benefit cost-ratio was found in 75% RDF + 10% FYM +15% Vermicompost (11.71) followed by 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (7.90) and 75% RDF + 25% Vermicompost + Azotobacter (7.69). The lowest benefit cost-ratio observed in 75% RDF +10% FYM + 15% Vermicompost + Azotobacter (6.08).

Inorganic fertilizer in conjunction with bio-fertilizer i.e., 75% RDF + 25% Vermicompost + Azotobacter (2.82 kg) was rated as the best treatment in terms of growth, yield, and also in quality attributes. Besides these, T_6; 75% RDF +10% FYM + 15% Vermicompost + Azotobacter treatment also had a significant influence on N, P and K uptake by recording the highest uptake by leaves and curd which resulted in the highest production of marketable curd (479.00 q/ha). It also maintained the soil fertility status as evident through post-harvest availability of N, P and K, and hence, it can be suggested for improving the growth and yield status of the cauliflower.

Discussion

The observed increase in the height of cauliflower plants under treatments with elevated levels of inorganic fertilizers can be attributed to the direct influence of higher inorganic nitrogen on plant growth. This is consistent with the findings of Kumar *et al*. (2013) [16] and Singh *et al*. (2010). The height of the plants revealed an amazing reaction to the combination of inorganic and biofertilizers. According to Rabindra *et al*. (2021) [23], plants treated with half of the NPK/ha half-dose + 2.5 tonnes/ha of vermicompost + 5 kg/ha of Azospirillum showed the highest height performance (60.50 cm) in cauliflower across all treatments. Similar to this, Anushruti *et al.* (2022) [1] found that treating cabbage with 75% of the required quantity of nutrition + Azotobacter resulted in the maximum plant height (26.34 cm). The similar pattern of findings was noted by Yadav *et al*. (2021) [40] in turnip, Atal *et al*. (2019) [41] in broccoli, and Subedi *et al*. (2019) [38] in cauliflower. According to Singh *et al*. (2015) [32], the number of leaves per broccoli plant increased significantly when a combination of nitrogen (N), phosphorus (P), potassium (K), and boron (B) was applied. This improvement can be attributed to the enhanced protein synthesis facilitated by nitrogen, which boosts carbohydrate formation, thereby supporting more leaf production and greater plant height. Phosphorus and potassium, administered at optimal levels, also play pivotal roles in this process. Phosphorus is essential for energy production and plant development, while potassium is crucial for carbohydrate metabolism and efficient water utilization. Similar observations were made by Moniruzzaman *et al.* (2007) [18], who reported comparable results in their studies. Kachari and Korla (2009) [11] found that using the recommended dose of nutrients, or a combination of reduced levels of the recommended dose of fertilizers (RDF) along with organic and bio-fertilizers, resulted in larger leaf sizes compared to the exclusive use of organic or bio-fertilizers. This outcome was similarly observed by Peerzada *et al*. (2009) [22] in their study on cabbage and by Kachari and Korla (2012) [11] in their research on cauliflower. The increase in carbohydrate accumulation, driven by enhanced photosynthesis resulting from vegetative growth, likely contributed to the greater weight of the cauliflower curd. The combined use of inorganic fertilizers and natural farming formulations promoted plant growth, which in turn facilitated the efficient transfer of photosynthates from the leaves (source) to the curd (sink), thereby boosting its weight. These findings are consistent with the studies conducted by Shree *et al*. (2014) [30], Mohanta *et al*. (2018) [17], and Singh *et al*. (2018) [31]. The increase in the weight of the cauliflower curd can be attributed to the overall growth in plant height, the number of leaves, leaf size, and plant spread, along with the enlargement of the curd itself. These observations are in line with the findings of Sharma and Singh (2003) [28], Singh *et al*. (2005) [35], Pandey *et al.* (2008), and Kumar *et al.* (2013) [16]. Research conducted by Kumar *et al.* (2013) [16], Kashyap *et al.* (2017) [14], Singh *et al.* (2018b) [34], Kaur *et al.* (2020) [15], and Neupane *et al.* (2020) [21] has demonstrated similar outcomes in cauliflower. Their studies indicated that the combined application of nutrients from both organic and inorganic sources significantly enhanced yield. This increase is attributed to improvements in the soil's physical and biological properties.

Additionally, it may be assumed that the combined application of nitrogen, organic manures, and inorganic fertilisers. The application of fixing bacteria has been observed to influence yield. It is possible that this is due to improved root zone environment and increased uptake of nutrients increased marketable yield (Sharma *et al*. (2018).

The results of Singh *et al*. (2018) [31] and Moyjul *et al.* (2019) [19] corroborate this association. Furthermore, the use of Azotobacter may have a major impact since it improves photosynthetic efficiency by improving nutrient availability through microbial activity. The studies conducted by Chand *et al*. (2017), Subedi *et al*. (2019) [38] and Selvakumar *et al.* (2009) [3]. Singh *et al*. (2018) [31] observed that the diameter of cauliflower curds increased when integrated nutrient management techniques were employed. This enhancement can be attributed to the stimulated plant growth facilitated by the enzymatic activity from the combined application of inorganic and organic nutrients. This synergistic approach boosts photosynthetic activity and leads to greater carbohydrate accumulation. These findings align with earlier research by Haque *et al*. (2006) [10], Sable and Bhamare (2007) [25], and Kanaujia *et al*. (2010) [12].

The cost of cultivation is function of all input cost used during production of purple cauliflower. It is sum of fixed and variable cost. The greater cost of cultivation in T_8, T_9 and T_{10} might be associated with higher cost of biofertilizers in combination with inorganic nutrients (Table 4.14). The highest Gross income (Rs/ha) was recorded in 75% RDF + 10% FYM +15% Vermicompost (814300 Rs/ha). The highest Net income (Rs/ha) was recorded in 75% RDF + 10% FYM +15% Vermicompost (750188.57 Rs/ha). The highest benefit cost-ratio was found in 75% RDF + 10% FYM +15% Vermicompost (11.71) followed by 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (7.90) and 75% RDF + 25% Vermicompost + Azotobacter (7.69). The lowest benefit cost-ratio observed in 75% RDF +10% FYM + 15% Vermicompost + Azotobacter (6.08). Therefore, three treatments, T_6; 75% RDF + 10% FYM +15% Vermicompost (11.71), T_9; 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (7.90), T_8; 75% RDF + 25% Vermicompost + Azotobacter (7.69) can be recommended for commercial cultivation of purple cauliflower. Azotobacter as a supplementary dose with RDF is highly remunerative for purple cauliflower cultivation. The present finding conforms with the findings of Ray *et al*. (2018) [24], Srichandan *et al*. (2015) [37], Sharma and Sharma (2010) [27].

Table 1: List of treatments used in the experiment.

S. No.	Treatment notation	Treatments detail
1	T_1	100% RDF
2	T_2	75% RDF + 25% FYM
3	T_3	75% RDF +10% FYM + 15% Vermicompost
4	T_4	50% RDF + 25% FYM + 25% Vermicompost
5	T_5	75% RDF +10% FYM + 15% Vermicompost + Azotobacter
6	T_6	80% RDF + 10% FYM +15% Vermicompost
7	T_7	75% RDF + 25% FYM + Azotobacter
8	T_8	75% RDF + 25% Vermicompost + Azotobacter
9	T_9	50% RDF + 20% FYM + 30% Vermicompost + Azotobacter
10	T_{10}	60% RDF + 10% Vermicompost + Azotobacter
11	T_{11}	75% RDF + 20% Vermicompost + Azotobacter

Table 2: Analysis of variance of purple cauliflower (*Brassica oleracea* var. *botrytis*).

Analysis of variance		
Characters	**Treatments**	**Error**
d.f.	10	20
Plant height (cm)	61.242**	51.6265
Days to 50 percent curd initiation	170.018**	80.6897
Number of leaves/plants	226.460**	47.1954
Plant spread (cm)	149.515**	58.1531
Length of longest leaf (cm)	1868.606**	105.2447
Width of the longest leaf (cm)	84.392	54.5662
Fresh weight of whole plant (kg)	6.431**	4.5799
Fresh weight of trimmed curd (g)	241196.044**	32915.8494
Fresh weight of untrimmed curd (kg)	4.485*	3.5137
Curd yield/plot (kg)	3736.808**	190.0076
Curd yield (q/ha)	139953.879**	6255.5757
Diameter of Curd (cm)	60.292**	16.2146
Cost of cultivation (Rs/ha)	2139024729.1134**	4222227.75
Gross income (Rs/ha)	404466709696.968**	18078613939.39
Net income (Rs/ha)	372415013126.084**	18400592439.87
Benefit-cost ratio	64.6241**	4.5321

Table 3: Effect of biofertilizers in combination with inorganic nutrients on plant growth and yield traits of purple cauliflower (*Brassica oleracea* var. *botrytis*).

S. No.	Treatments notation	Plant height (cm)	Days to 50 percent curd initiation	Number of leaves/plants	Plant spread (cm)	Length of longest leaf (cm)	Width of the longest leaf (cm)	Fresh weight of whole plant (kg)	Fresh weight of trimmed curd (g)	Fresh weight of untrimmed curd (kg)	Curd yield/plot (kg)	Curd yield/ha (q/ha)	Diameter of curd (cm)
1	T_1	24.05	71.72	25.00	49.45	38.96	19.30	3.32	641.12	2.03	46.05	252.67	15.93
2	T_2	24.43	70.86	19.00	49.60	43.60	17.69	3.50	683.21	2.25	54.46	308.00	17.76
3	T_3	25.33	69.71	27.33	47.76	52.08	16.63	3.51	538.32	1.92	56.76	321.33	17.16
4	T_4	26.89	67.50	25.33	48.22	39.72	16.54	4.32	816.47	2.10	60.87	347.00	17.73
5	T_5	27.77	68.32	21.00	50.44	26.86	15.43	4.40	718.49	2.55	50.97	280.67	17.51
6	T_6	27.00	66.05	23.33	49.40	32.17	14.22	3.50	796.12	1.51	82.65	479.00	18.30
7	T_7	26.27	65.61	27.67	47.63	36.12	16.10	3.82	757.56	1.82	60.45	350.67	18.80
8	T_8	26.87	64.40	27.33	49.91	51.04	14.56	4.80	858.87	2.82	75.36	431.00	19.77
9	T_9	26.83	65.56	23.29	44.22	47.49	14.10	4.16	770.96	1.96	74.56	424.33	18.56
10	T_{10}	27.16	65.78	22.49	43.78	46.34	16.89	4.03	679.89	2.61	66.25	387.00	15.74
11	T_{11}	28.96	67.44	24.56	49.22	37.22	18.22	4.09	740.19	2.37	59.89	377.67	20.34
	Mean	26.51	67.54	24.21	48.15	41.05	16.33	3.95	727.38	2.18	62.57	359.94	17.96
	SEm	0.92	1.15	0.88	0.98	1.32	0.95	0.27	23.42	0.24	1.77	10.21	0.51
	SEd	1.31	1.64	1.25	1.39	1.87	1.34	0.39	33.12	0.34	2.51	14.44	0.73
	CD at 5%	2.73	3.42	2.61	2.90	3.90	2.81	0.81	69.09	0.71	5.24	30.12	1.53
	C.V.	6.06	2.97	6.34	3.54	5.58	10.11	12.10	5.58	19.25	4.92	4.91	5.01

Table 4: Effect of biofertilizers in combination with inorganic nutrients on economic analysis of purple cauliflower (*Brassica oleracea* var. *botrytis*).

Sl. No.	Treatment notation	Curd yield q/ha	Selling Rate Rs/q	Gross return Rs/ha	Cost of cultivation Rs/ha	Net return Rs/ha	Benefit cost of ratio
1	T_1	252.67	1700.00	429533.33	57969.50	371563.83	6.41
2	T_2	308.00	1700.00	523600.00	61219.00	462381.00	7.55
3	T_3	321.33	1700.00	546266.67	66487.87	479778.80	7.22
4	T_4	347.00	1700.00	589900.00	74186.43	515713.57	6.95
5	T_5	280.67	1700.00	477133.33	67384.40	409748.93	6.08
6	T_6	479.00	1700.00	814300.00	64111.43	750188.57	11.71
7	T_7	350.67	1700.00	596133.33	73599.13	522534.20	7.10
8	T_8	431.00	1700.00	732700.00	84364.50	648335.50	7.69
9	T_9	424.33	1700.00	721366.67	81112.43	640254.23	7.90
10	T_{10}	387.00	1700.00	657900.00	77825.43	580074.57	7.45
11	T_{11}	377.67	1700.00	642033.33	75811.80	566221.53	7.47

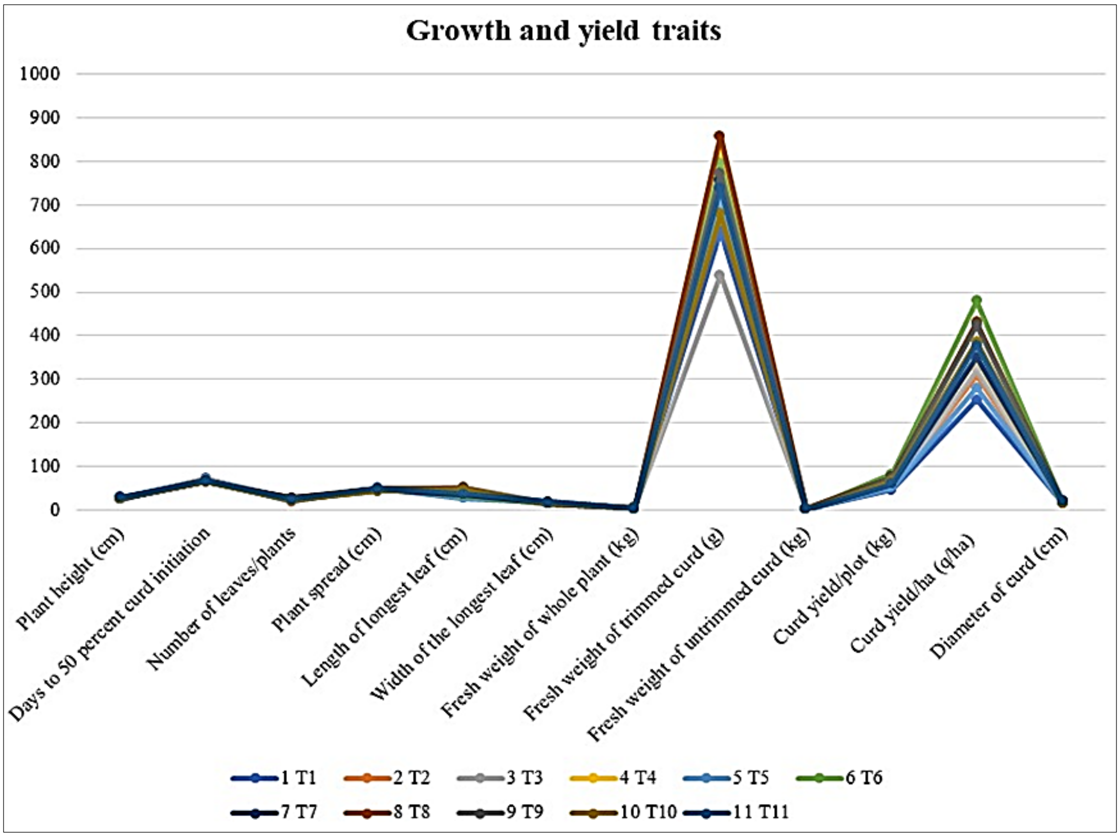

Fig 1: Graphical representation of Growth and yield traits of purple cauliflower.

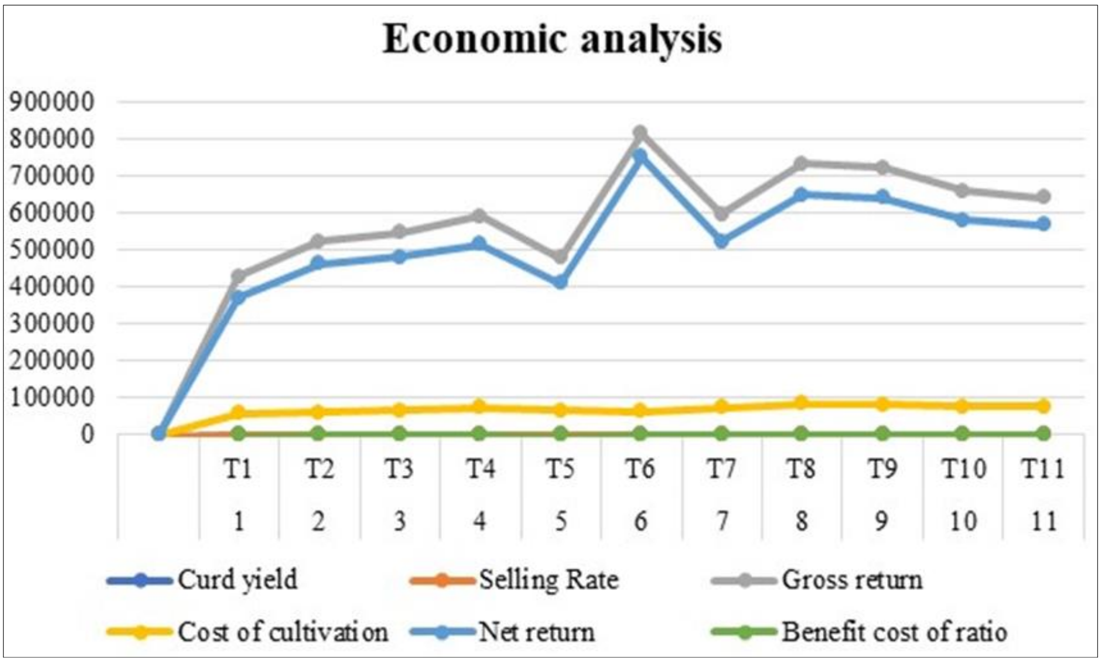

Fig 2: Graphical representation of economic analysis of purple cauliflower.

Conclusion

Inorganic fertilizer in conjunction with bio-fertilizer i.e., 75% RDF + 25% Vermicompost + Azotobacter (2.82 kg) was rated as the best treatment in terms of growth, yield, and also in quality attributes. Besides these, T_6; 75% RDF +10% FYM + 15% Vermicompost + Azotobacter treatment also had a significant influence on N, P and K uptake by recording the highest uptake by leaves and curd which resulted in the highest production of marketable curd (479.00 q/ha). It also maintained the soil fertility status as evident through post-harvest availability of N, P and K, and hence, it can be suggested for improving the growth and yield status of the cauliflower.

The greater cost of cultivation in T_8, T_9 and T_{10} might be associated with higher cost of biofertilizers in combination with inorganic nutrients (Table 4.14). Azotobacter as a supplementary dose with RDF is highly remunerative for purple cauliflower cultivation. The highest Cost of cultivation was recorded in 75% RDF + 10% FYM +15% Vermicompost (814300 Rs/ha). The highest Gross income (Rs) was recorded in 75% RDF + 10% FYM +15% Vermicompost (814300 Rs/ha). The highest Net income (Rs/ha) was recorded in 75% RDF + 10% FYM +15% Vermicompost (750188.57 Rs/ha). The highest benefit cost-ratio was found in 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (2.86) followed by 60% RDF + 10% Vermicompost + Azotobacter (2.84) and 75% RDF + 25% Vermicompost + Azotobacter (2.81). Therefore, three treatments, T_6; 75% RDF + 10% FYM +15% Vermicompost (11.71), T_9; 50% RDF + 20% FYM + 30% Vermicompost + Azotobacter (7.90),T_8; 75% RDF + 25% Vermicompost + Azotobacter (7.69) can be recommended for commercial cultivation of purple cauliflower in Madhya Pradesh. This treatment is recommended for farmers in the long run as it reduces the need for inorganic fertilizers by 55% while achieving higher net returns.

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