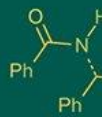


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(4): 1213-1218
www.biochemjournal.com
Received: 05-01-2026
Accepted: 09-02-2026

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Evaluation of various bio-inoculants on quality attributes of cauliflower (*Brassica oleracea* var. *botrytis* L.) cv. white crystal under Chhattisgarh plain conditions

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i4So.8290>

Abstract

The present investigation was carried out during the rabi seasons of 2023-24 and 2024-25 at the Centre of Excellence on Protected Cultivation and Precision Farming (COEPCPE), Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), to evaluate the effect of different bio-inoculants on quality parameters of cauliflower (*Brassica oleracea* var. *botrytis* L.) under Chhattisgarh plain conditions. The experiment was laid out in a randomized block design with fifteen treatments and three replications. The results revealed that bio-inoculants application significantly improved chlorophyll content, total soluble solids (TSS), protein content and nutrient composition (N, P, and K) in the curd. In pooled analysis, treatment T₈ (T₁ + 3 foliar sprays of *Trichoderma atroviride* @ 10 g/l of water) recorded the highest chlorophyll content (44.53 SPAD value) at 40 DAT. The same treatment also resulted in maximum TSS (7.85 °Brix), ascorbic content (61.75 mg/100 g), protein content (15.41%), nitrogen (2.47%), phosphorus (0.27%) and potassium (3.37%) content in curd, while the lowest values for these parameters were observed under the control treatment T₁₅. The enhancement in quality attributes may be attributed to improved nutrient availability, increased microbial activity, and better root development, which facilitated efficient nutrient uptake, assimilation, and translocation within the plant system. These processes ultimately led to improved photosynthetic efficiency and accumulation of soluble sugars, proteins, and mineral nutrients. Thus, the study demonstrates that the application of bio-inoculants, particularly *Trichoderma atroviride*, is an effective and sustainable approach for improving the quality and nutritional status of cauliflower under Chhattisgarh plain agro-climatic conditions.

Keywords: Cauliflower (*Brassica oleracea* var. *botrytis* L.), bio-inoculants, *Trichoderma* spp, *Bacillus*, *Pseudomonas*, quality, seedling root dip and foliar application

Introduction

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is an important cruciferous vegetable cultivated world wide and is one of the most popular crops among the cole group. This group is believed to have originated from wild cabbage, commonly known as “cole warts,” and belongs to the family Brassicaceae (2n = 18) in 1822 (Swarup and Chatterjee, 1972) [14]. Cauliflower was introduced into India during the early nineteenth century and has since emerged as one of the most significant cool-season vegetable crops grown across diverse agro-climatic regions of the country. The crop is well adapted to a wide range of environmental conditions and performs optimally in fertile soils with good nutrient availability. The edible portion of cauliflower, referred to as the “curd,” consists of a compact mass of thickened, immature floral buds formed from a suppressed apical meristem. The term cauliflower is derived from the Latin words *caulis* (cabbage) and *floris* (flower), reflecting its botanical nature. Due to its high nutritional value and versatility, cauliflower is widely used in various culinary preparations, including soups, pickles, and vegetable-based dishes.

In India, cauliflower is grown over an area of approximately 473,000 hectares, producing about 9.28 million tonnes with an average productivity of 19.62 t/ha (Anonymous, 2022-23) [1]. In Chhattisgarh, the crop occupies nearly 24,260 hectares, yielding around 484,250 tonnes with a slightly higher productivity of 19.96 t/ha (Anonymous, 2022-23) [1].

Bio-inoculants, commonly referred to as microbial inoculants, consist of beneficial microorganisms that promote plant growth through a range of direct and indirect processes. In horticultural systems, species belonging to *Trichoderma*, *Bacillus*, and *Pseudomonas* are considered highly effective due to their diverse plant growth-promoting attributes. These microorganisms contribute to enhanced nutrient availability through mechanisms such as phosphate solubilization and biological nitrogen fixation, along with the production of phytohormones and suppression of plant pathogens. Their multifaceted role in improving plant health and productivity has been well documented (Vessey, 2003) [9].

They are eco-friendly and cheapest source of nutrients. Bio-inoculants are increasingly being adopted as eco-friendly alternatives to chemical fertilizers and pesticides due to their role as plant bio-stimulants. Among these, *Pseudomonas fluorescens*, *Bacillus* spp., and *Trichoderma* spp. are widely recognized for their multifaceted plant growth-promoting activities. *Pseudomonas fluorescens* enhances plant growth through the production of siderophores, antibiotics, lytic enzymes, and phytohormones, along with inducing systemic resistance and improving nutrient availability (Gravel *et al.*, 2007; Weller, 2007) [3, 10]. Similarly, non-symbiotic rhizobacteria such as *Pseudomonas* and *Bacillus* positively influence plant development, and their combined use in microbial consortia has been shown to reduce chemical fertilizer requirements by 25-30% while improving yield (Kloepper, 1980; Nalini *et al.*, 2017) [11, 5].

The use of bio-inoculants has been reported to improve soil structure, enhance nutrient uptake efficiency, and ultimately increase crop yield. The increasing adoption of organic farming systems highlights the importance of microbial bio-inoculants in reducing reliance on synthetic fertilizers. This integrated approach not only sustains soil fertility but also improves crop quality and ensures long-term agricultural sustainability (Narayanamma *et al.*, 2005) [6]. Although chemical fertilizers have played a crucial role in boosting vegetable production, their excessive and unregulated use has negatively impacted soil health, natural resources, and ecological stability, posing potential risks to both environmental and human well-being (Sable and Bhamare, 2007) [7].

Methods and Materials

The experiment was conducted at the Centre of Excellence on Protected Cultivation and Precision Farming (COEPCPE), Department of Vegetable Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during year 2023-24 and 2024-25 *rabi* season. The soil of the experimental site was comes under sub-tropical conditions and located at 21°16' N latitude and 81°31' E longitude with an altitude of 298.56 meters above the mean sea level an annual rainfall range from 1200-1400 mm and deep, loose, sandy loam, having good drainage capacity and locally known as "Kanhra".

The field was prepared by ploughing with a mouldboard plough, followed by two cross harrowings, and finally brought to a fine tilth using a rotavator. Well-decomposed farmyard manure (FYM) @ 20 t ha⁻¹ was applied before layout. The plots were labelled uniformly and were laid down as per the design of the experiment. The trial was laid down in a randomized block design (RBD) corresponding to 15 treatments and three replications. The experimental area was divided into 45 plots, each measuring 3m² and spacing of 45 cm (Row to Row) x 45 cm (Plant to Plant). Recommended dose fertilizer nitrogen, phosphorus, and potassium were applied in the form of urea, diammonium phosphate (DAP), and muriate of potash (MOP), respectively. Bio-inoculants were applied through root dip and foliar spray methods. For the root dip, seedling roots were treated with a bio-inoculants solution 10-15 g/l of water for one hour before transplanting. Foliar sprays of the same concentration were applied at 15, 30, and 45 days after transplanting (DAT) to promote plant growth and improve nutrient uptake. Seedlings were irrigated twice weekly until establishment, followed by light irrigation after transplanting and subsequent irrigation at 10-15 day intervals depending on soil conditions. The experimental plots were kept weed-free throughout the crop period by timely manual weeding based on weed incidence and crop growth. Harvesting was performed at the stage of physiological maturity when the curds attained compactness and an off-white color. The curds were cut using a sharp sickle, and observations were taken from tagged plants.

Table 1: Treatments details

	Treatments First foliar spray-15 DAT Second foliar spray-30 DAT Third foliar spray-45 DAT
T ₁	<i>Trichoderma atroviride</i> @ 10 g/l of water in root dip treatment
T ₂	<i>Trichoderma harzianum</i> isolate 1 @ 10 g/l of water in root dip treatment
T ₃	<i>Trichoderma harzianum</i> isolate 2 @ 10 g/l of water in root dip treatment
T ₄	<i>Trichoderma harzianum</i> isolate 3 @ 10 g/l of water in root dip treatment
T ₅	<i>Trichoderma harzianum</i> isolate 4 @ 10 g/l of water in root dip treatment
T ₆	<i>Pseudomonas</i> @ 10 g/l of water in root dip treatment
T ₇	<i>Bacillus</i> @ 10 g/l of water in root dip treatment
T ₈	T ₁ + 3 Foliar Spray of <i>Trichoderma atroviride</i> @ 10 g/l of water
T ₉	T ₂ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 1 @ 10 g/l of water
T ₁₀	T ₃ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 2 @ 10 g/l of water
T ₁₁	T ₄ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 3 @ 10 g/l of water
T ₁₂	T ₅ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 4 @ 10 g/l of water
T ₁₃	T ₆ + 3 Foliar Spray of <i>Pseudomonas</i> @ 10 g/l of water
T ₁₄	T ₇ + 3 Foliar Spray of <i>Bacillus</i> @ 10 g/l of water
T ₁₅	Control

Results and Discussion

Quality attributes

Effect of different bio-inoculants application on quality attributes were presented in Table 1 (a, b, c)

Chlorophyll content in leaves (SPAD Value)

The statistical data revealed that the application of different bio-inoculants was significantly increased the chlorophyll content in leaves. In the case of pooled mean, the maximum chlorophyll content was observed under treatment T₈ (T₁ + 3 foliar sprays of *Trichoderma atroviride* @ 10 g/l of water) with a value of 44.53, which was significantly superior over all other treatments at 40 days. However, it remained statistically at par with T₉ (44.30), T₁₀ (43.50), T₁₁ (43.26), T₁₂ (42.69), T₁₃ (42.11) and T₁₄ (41.45). The minimum chlorophyll content was recorded under the control treatment T₁₅ (36.59). The enhanced chlorophyll levels observed with bio-inoculants application may be attributed to improved uptake of essential nutrients, particularly nitrogen and magnesium, along with increased root development and microbial activity in the rhizosphere. These factors likely contributed to better nutrient assimilation, expanded leaf area, and enhanced chlorophyll synthesis, ultimately leading to improved plant growth and productivity. Similar findings have also been reported by Chandra *et al.* (2022)^[2] in broccoli, Kaur *et al.* (2020)^[4] in cauliflower, and Chaudhary *et al.* (2017)^[12] in knolkhol.

Total soluble solid (%)

In the pooled analysis, treatment T₈ recorded the highest TSS content of curd (7.85 °Brix), it remained statistically at par with T₉ (7.80), T₁₀ (7.75) and T₁₁ (7.71). Conversely, the lowest TSS value was observed under the control treatment T₁₅ (7.24 °Brix). The increase in TSS content under bio-inoculants treatments may be attributed to enhanced nutrient availability and their efficient translocation within the plant system. This likely promoted the enzymatic conversion of complex carbohydrates into simple sugars, resulting in greater accumulation of soluble solids in the curd. The present findings are supported by earlier studies, which also reported increased TSS content due to improved nutrient availability and uptake under bio-inoculants application. Similar results were observed by Zargar *et al.* (2021)^[17] in cabbage, Kaur *et al.* (2020)^[4] in cauliflower and Shivran *et al.* (2017)^[8] in broccoli.

Ascorbic acid content in curd (mg/100 g)

In the pooled analysis, treatment T₈ recorded the highest ascorbic acid content in curd (61.75 mg/100 g), which was statistically at par T₉ (61.02), T₁₀ (60.27) and T₁₁ (59.97). The lowest value was observed under the control treatment T₁₅ (55.60 mg/100 g). The increase in ascorbic acid content may be attributed to improved nutrient availability and enhanced metabolic activity due to bio-inoculants application, which promoted its synthesis and accumulation. These findings are in agreement with earlier reports by Zargar *et al.* (2021)^[17] in cabbage, Singh *et al.* (2020b)^[13] in broccoli and Shree *et al.* (2014)^[15] in cauliflower.

Protein content (%)

Significant differences were observed among the treatments with respect to protein content in the curd. In the pooled analysis, the highest protein content was recorded under treatment T₈ (15.41%), which was statistically at par with T₉ (15.31%), T₁₀ (15.16%) and T₁₁ (15.06%). The lowest protein content was noted under the control treatment T₁₅ (13.69%). The increase in protein content may be attributed to the improved nutritional environment in the phyllosphere and more efficient utilization of nutrients by the plants. Enhanced nutrient availability likely promoted greater protein synthesis and accumulation in the curd. Similar findings were reported by Sable and Bhamare (2007)^[7] in cauliflower, who observed that improved nutrient status significantly enhances protein content. Additionally, Zahraa *et al.* (2020)^[16] also reported increased protein content with the application of bio-inoculants, which may be due to enhanced soil enzymatic activity, improved nutrient uptake, and stimulation of protein biosynthesis in plants.

N content (%) in curd

In the pooled analysis, the highest nitrogen content in curd (%) was recorded under treatment T₈ (2.47), which was statistically at par with T₉ (2.45), T₁₀ (2.43) and T₁₁ (2.41). The lowest nitrogen content was observed under the control treatment T₁₅ (2.19%). The increased nitrogen content observed in the present study may be attributed to the enhanced availability of nitrogen through biological nitrogen fixation mediated by bio-inoculants. This improved nitrogen supply likely facilitated better nutrient uptake and accumulation in plant tissues. Similar findings have been reported by Chaudhary *et al.* (2017)^[12] in knolkhol and Zahraa *et al.* (2020)^[16] in cauliflower.

P content (%) in curd

In the pooled analysis, the highest phosphorus content in curd (%) was recorded under treatment T₈ (0.27), which was statistically at par with T₉ (0.26), T₁₃ (0.25) and T₁₄ (0.24). The lowest phosphorus content was observed under the control treatment T₁₅ (0.22%). The increased phosphorus content observed in the present study may be attributed to the enhanced root growth and microbial activity in the rhizosphere might have further facilitated phosphorus absorption and accumulation in the curd.

K content (%) in curd

In the pooled analysis, the highest potassium content in curd (%) was recorded under treatment T₈ (3.37), which was statistically at par with T₉ (3.34), T₁₀ (3.31) and T₁₁ (3.29). The lowest potassium content was observed under the control treatment T₁₅ (3.00%). The increased potassium content recorded in the present study may be attributed to enhanced solubilization and availability of potassium in the soil mediated by bio-inoculants. These microorganisms improve nutrient dynamics by releasing organic acids and activating soil enzymes, thereby converting unavailable forms of potassium into forms accessible to plants.

Table 1(a): Effect of different bio-inoculants on Chlorophyll content in leaf of cauliflower

Treatments	Chlorophyll content in leaf		
	2023-24	2024-25	Pooled Mean
T ₁ : <i>Trichoderma atroviride</i> @ 10 g/l of water in root dip treatment	41.24	41.53	41.38
T ₂ : <i>Trichoderma harzianum</i> isolate 1 @ 10 g/l of water in root dip treatment	41.19	40.90	41.04
T ₃ : <i>Trichoderma harzianum</i> isolate 2 @ 10 g/l of water in root dip treatment	40.83	40.30	40.57
T ₄ : <i>Trichoderma harzianum</i> isolate 3 @ 10 g/l of water in root dip treatment	38.98	40.07	39.52
T ₅ : <i>Trichoderma harzianum</i> isolate 4 @ 10 g/l of water in root dip treatment	38.80	39.89	39.35
T ₆ : <i>Pseudomonas</i> @ 10 g/l of water in root dip treatment	40.69	38.84	39.77
T ₇ : <i>Bacillus</i> @ 10 g/l of water in root dip treatment	40.27	38.72	39.49
T ₈ : T ₁ + 3 Foliar Spray of <i>Trichoderma atroviride</i> @ 10 g/l of water	45.15	43.90	44.53
T ₉ : T ₂ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 1 @ 10 g/l of water	44.79	43.81	44.30
T ₁₀ : T ₃ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 2 @ 10 g/l of water	44.20	42.79	43.50
T ₁₁ : T ₄ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 3 @ 10 g/l of water	43.73	42.78	43.26
T ₁₂ : T ₅ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 4 @ 10 g/l of water	43.00	42.38	42.69
T ₁₃ : T ₆ + 3 Foliar Spray of <i>Pseudomonas</i> @ 10 g/l of water	42.27	41.94	42.11
T ₁₄ : T ₇ + 3 Foliar Spray of <i>Bacillus</i> @ 10 g/l of water	42.16	40.74	41.45
T ₁₅ : Control	35.27	37.74	36.51
SEm (±)	1.64	1.27	0.96
CD (p = 0.05)	4.76	3.69	2.72
CV (%)	6.86	5.37	6.16

Table 1(b): Effect of different bio-inoculants on TSS (^oBrix) and ascorbic acid content in curd (mg/100 g) of cauliflower

Treatments	TSS (^o Brix),			Ascorbic acid content in curd (mg/100 g)		
	2023-24	2024-25	Pooled Mean	2023-24	2024-25	Pooled Mean
T ₁ : <i>Trichoderma atroviride</i> @ 10 g/l of water in root dip treatment	7.67	7.44	7.56	58.88	58.56	58.72
T ₂ : <i>Trichoderma harzianum</i> isolate 1 @ 10 g/l of water in root dip treatment	7.62	7.40	7.51	58.37	58.22	58.30
T ₃ : <i>Trichoderma harzianum</i> isolate 2 @ 10 g/l of water in root dip treatment	7.59	7.38	7.49	58.10	58.16	58.13
T ₄ : <i>Trichoderma harzianum</i> isolate 3 @ 10 g/l of water in root dip treatment	7.57	7.36	7.46	57.92	57.92	57.92
T ₅ : <i>Trichoderma harzianum</i> isolate 4 @ 10 g/l of water in root dip treatment	7.48	7.32	7.40	57.76	57.65	57.70
T ₆ : <i>Pseudomonas</i> @ 10 g/l of water in root dip treatment	7.42	7.27	7.35	57.22	57.08	57.15
T ₇ : <i>Bacillus</i> @ 10 g/l of water in root dip treatment	7.37	7.24	7.31	56.66	56.36	56.51
T ₈ : T ₁ + 3 Foliar Spray of <i>Trichoderma atroviride</i> @ 10 g/l of water	7.91	7.78	7.85	61.55	61.94	61.75
T ₉ : T ₂ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 1 @ 10 g/l of water	7.89	7.71	7.80	60.41	61.62	61.02
T ₁₀ : T ₃ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 2 @ 10 g/l of water	7.85	7.65	7.75	60.19	60.35	60.27
T ₁₁ : T ₄ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 3 @ 10 g/l of water	7.81	7.61	7.71	59.88	60.06	59.97
T ₁₂ : T ₅ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 4 @ 10 g/l of water	7.76	7.58	7.67	59.53	59.60	59.56
T ₁₃ : T ₆ + 3 Foliar Spray of <i>Pseudomonas</i> @ 10 g/l of water	7.72	7.53	7.63	59.22	59.44	59.33
T ₁₄ : T ₇ + 3 Foliar Spray of <i>Bacillus</i> @ 10 g/l of water	7.70	7.49	7.60	59.03	59.00	59.01
T ₁₅ : Control	7.29	7.18	7.24	55.47	55.74	55.60
SEm (±)	0.27	0.26	0.27	2.24	2.00	2.12
CD (p = 0.05)	NS	NS	NS	NS	NS	NS
CV (%)	6.13	6.09	6.11	6.62	5.89	6.26

Table 1(c): Effect of different bio-inoculants on protein content in curd (%) and N, P & K content (%) in curd of cauliflower

Treatments	Protein content (%)			Nitrogen content (%)			Phosphorus content (%)			Potassium content (%)		
	2023-24	2024-25	Pooled Mean	2023-24	2024-25	Pooled Mean	2023-24	2024-25	Pooled Mean	2023-24	2024-25	Pooled Mean
T ₁ : <i>Trichoderma atroviride</i> @ 10 g/l of water in root dip treatment	14.56	14.63	14.59	2.33	2.34	2.34	0.23	0.24	0.24	3.18	3.17	3.18
T ₂ : <i>Trichoderma harzianum</i> isolate 1 @ 10 g/l of water in root dip treatment	14.44	14.57	14.50	2.31	2.33	2.32	0.23	0.24	0.23	3.15	3.14	3.14
T ₃ : <i>Trichoderma harzianum</i> isolate 2 @ 10 g/l of water in root dip treatment	14.30	14.35	14.34	2.29	2.30	2.30	0.23	0.23	0.23	3.11	3.12	3.12
T ₄ : <i>Trichoderma harzianum</i> isolate 3 @ 10 g/l of water in root dip treatment	14.20	14.25	14.22	2.27	2.28	2.28	0.23	0.23	0.23	3.09	3.10	3.10
T ₅ : <i>Trichoderma harzianum</i> isolate 4 @ 10 g/l of water in root dip treatment	14.13	14.06	14.09	2.26	2.25	2.26	0.22	0.23	0.22	3.08	3.07	3.08
T ₆ : <i>Pseudomonas</i> @ 10 g/l of water in root dip treatment	14.00	13.87	13.94	2.24	2.22	2.23	0.22	0.22	0.22	3.06	3.05	3.06
T ₇ : <i>Bacillus</i> @ 10 g/l of water in root dip treatment	13.94	13.81	13.88	2.23	2.21	2.22	0.22	0.22	0.22	3.05	3.04	3.05
T ₈ : T ₁ + 3 Foliar Spray of <i>Trichoderma atroviride</i> @ 10 g/l of water	15.50	15.31	15.41	2.48	2.45	2.47	0.26	0.27	0.27	3.38	3.35	3.37
T ₉ : T ₂ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 1 @ 10 g/l of water	15.38	15.25	15.31	2.46	2.44	2.45	0.26	0.26	0.26	3.35	3.32	3.34
T ₁₀ : T ₃ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 2 @ 10 g/l of water	15.18	15.12	15.16	2.43	2.42	2.43	0.26	0.26	0.26	3.33	3.29	3.31
T ₁₁ : T ₄ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 3 @ 10 g/l of water	15.06	15.06	15.06	2.41	2.41	2.41	0.25	0.26	0.25	3.31	3.27	3.29
T ₁₂ : T ₅ + 3 Foliar Spray of <i>Trichoderma harzianum</i> isolate 4 @ 10 g/l of water	14.94	15.00	14.97	2.39	2.40	2.40	0.25	0.25	0.25	3.28	3.25	3.26
T ₁₃ : T ₆ + 3 Foliar Spray of <i>Pseudomonas</i> @ 10 g/l of water	14.81	14.87	14.84	2.37	2.38	2.38	0.24	0.25	0.25	3.24	3.21	3.23
T ₁₄ : T ₇ + 3 Foliar Spray of <i>Bacillus</i> @ 10 g/l of water	14.75	14.69	14.72	2.36	2.35	2.36	0.24	0.24	0.24	3.21	3.19	3.20
T ₁₅ : Control	13.77	13.62	13.69	2.20	2.18	2.19	0.21	0.22	0.22	3.02	2.98	3.00
SEm (±)	0.5	0.5	0.5	0.1	0.1	0.1	0.01	0.01	0.01	0.09	0.10	0.10
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	5.53	6.32	5.94	5.54	6.32	5.93	8.10	8.25	8.17	5.25	5.67	5.46

Conclusion

On the basis of the present investigation, it can be concluded that the application of bio-inoculants had a significant and positive influence on the quality parameters of cauliflower. Among the different treatments, T₈ (T₁ + three foliar sprays of *Trichoderma atroviride* @ 10 g l⁻¹ of water) consistently recorded superior performance in terms of chlorophyll content, total soluble solids (TSS), ascorbic acid content in curd (mg/100 g) protein content, and nutrient composition (N, P, and K) in the curd under pooled analysis. The improvement in quality attributes may be attributed to enhanced nutrient availability, better root development, and increased microbial activity in the rhizosphere, which collectively facilitated efficient nutrient uptake, assimilation, and translocation within the plant system. This, in turn, promoted higher chlorophyll synthesis, accumulation of soluble sugars, and improved protein and mineral content in the curd. Thus, the integration of bio-inoculants, particularly *Trichoderma atroviride*, can be considered an effective and sustainable approach for improving the quality and nutritional status of cauliflower under Chhattisgarh plain conditions.

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