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Studies on bio-stimulants and bio-pesticides efficacy on cultivation of cauliflower (*Brassica oleracea var*. RZ-Tirsuli)

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Abstract
The present investigation entitled "Studies on Bio-stimulants and Bio-pesticides Efficacy on Cultivation of Cauliflower (*Brassica oleracea* var. RZ-Tirsuli) Under malwa condition of Madhya Pradesh" The present experiment was laid out at Horticulture Research Farm, Department of Horticulture, College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Indore, (M.P.) during the Rabi season 2023-24. During the investigation, the 09 treatments *viz*., T_1 (Control), T_2 (Humic acid @ 2 ml/L), T_3 (Amino acid @ 2 ml/L), T_4 (Neem oil @ 5 ml/L), T_5 (*Bacillus thuringiensis* @ 5 ml/L), T_6 (Humic acid @ 2 ml/L+ Neem oil @ 5 ml/L), T_7 (Humic acid @ 2 m/L+ *Bacillus thuringiensis* @ 5 ml/L), T_8 (Amino acid @ 2 ml/L+ Neem oil @ 5 ml/L) and T_9 (Amino acid @ 2 ml/L+ *Bacillus thuringiensis* @ 5 ml/L) replicated three times with RBD experimental design. The study investigated the Studies on Bio-stimulants and Bio-pesticides Efficacy on Cultivation of Cauliflower (*Brassica oleracea* Var. Botrytis). Several treatments were evaluated, with the combination of Humic acid and *Bacillus thuringiensis* (T_7) showing the most significant improvements across various growth parameters. At 15, 30, and 45 days after transplanting (DAT), T_7 demonstrated the highest plant height, number of leaves, stem diameter, outpacing other treatments and the control. In terms of reproductive growth, T_7 also accelerated days to curd initiation, and days to curd maturity. Moreover, T_7 resulted in the highest curd compactness (23.23 g), per plot (10.65 kg), and per hectare (117.75 q). It also significantly improved fruit quality, with the highest curd dry matter (%) at 11.36% and ascorbic acid (mg) (54.94 mg). Disease intensity (PDI %) and pest incidence (PPI%) were lowest in T_8, indicating better pest and disease management. Despite higher T_8 exhibited a favourable benefit-cost ratio of 1.68, indicating its potential as an effective treatment for improving cauliflower productivity and quality.

Keywords: Humic acid, amino acid, *Bacillus thuringiensis*, neem oil, cauliflower

Introduction
Cauliflower (*Brassica oleracea* var. Botrytis) is an important winter season vegetable crop that belongs to the family Cruciferae and has a chromosome number of 2n = 2x = 18. It is grown for its highly suppressed prefloral fleshy apical meristem branches, called "curd." It has high nutritional value due to its high levels of antioxidant compounds, such as glucosinolates, vitamins, phenolic compounds, and carotenoids, which have beneficial effects on our health. It is a versatile vegetable used in various culinary forms, including raw in salads, steamed, boiled, roasted, or sautéed, and as an ingredient in soups, curries, and stir-fries. It is also a low-carb substitute for grains, such as riced or mashed it. Rich in vitamins C and K, folate, and fiber, it supports digestive health, immunity, and bone health. Additionally, it is used in processed forms like pickles, frozen products, and in gluten-free and vegan recipes. In India, it is cultivated extensively in states of West Bengal while several other states, including Madhya Pradesh, Bihar, Gujarat, and Haryana also cultivated cauliflower. The total occupied an area of 0.48 million hectares with the production of 9.53 million tonnes. (National horticulture board, 2021-2022). According to the National Horticulture Board's 2020, Madhya Pradesh cultivated it over an area of approximately 385, 690 hectares, yielding a production of about 791, 639 metric tons.

As demand for higher-quality food grows, there is an increasing need for agricultural practices that improve crop yield and quality while promoting sustainability. Bio-stimulants like humic acid and amino acids, along with bio-pesticides like neem oil and *Bacillus thuringiensis*, have emerged as effective, eco-friendly alternatives to synthetic fertilizers and chemical pesticides. These are essential in farming as they promote sustainable agricultural practices by reducing the reliance on synthetic chemicals. Bio-stimulants enhance plant growth, improve nutrient uptake, and increase stress resistance, while biopesticides effectively control pests and diseases without harming beneficial organisms.

Cauliflower faces various challenges, including pest attacks from aphids, caterpillars, and flea beetles, as well as diseases such as downy mildew, root rot, and cauliflower mosaic virus. Additionally, environmental stresses like temperature fluctuations and water scarcity can negatively affect growth and curd development. To combat these problems, bio-stimulants and bio-pesticides are widely employed. Bio-stimulants such as seaweed extracts, amino acids, and humic substances promote plant growth by enhancing stress tolerance, stimulating root growth, and improving nutrient absorption, leading to healthier plants and better curd formation. Meanwhile, biopesticides like *Bacillus thuringiensis* effectively control pests and manage diseases without harming beneficial organisms, providing an eco-friendly alternative to chemical pesticides. Together, these approaches contribute to sustainable agriculture by increasing cauliflower resilience, minimizing environmental impact, and producing higher-quality yields.

Bio-stimulants and bio-pesticides play a crucial role in sustainable agriculture by enhancing plant growth and protecting crops without the harmful effects of synthetic chemicals. Bio-stimulants, such as amino acids, seaweed extracts, and humic acids, improve nutrient uptake, stress tolerance, and overall plant health, leading to higher yields and better crop quality. Bio-pesticides, derived from natural organisms, offer eco-friendly pest and disease control, targeting specific pests while preserving beneficial insects and the environment. Together, they support integrated pest management (IPM) and promote environmentally sustainable farming practices, reducing reliance on chemical inputs.

Materials and Methods

A field experiment on cauliflower was conducted at Research Farm of Rajmata Vijayraje Scindia Krishi Vishwa Vidvalaya, Department of Horticulture, College of Agriculture Indore, during Rabi Season 2023-2024.The spacing between row to row 0.6m and plant to plant 0.5 m were maintained. The treatment was laid out in randomized block design with twenty seven treatment and three replications. The treatment consist of two Bio-stimulants viz., humic acid and amino acid (@ 2 ml and @ 2 ml respectively), and two Bio-pesticides viz., *Bacillus thuringiensis* and Neem oil (@ 5 ml and @ 5 ml respectively) sprayed at three different growth stages viz., 15, 30, and 45 days after transplanting. The treatment consist of T_0 (control), T_1 (Humic acid @ 2 ml), T_2 (Amino acid @ 2 ml), T_3 (Neem oil @ 5 ml), T_4 (*Bacillus thuringiensis* @ 5 ml), T_5 (Humic acid @ 2 ml + Neem oil @ 5 ml), T_6 (Humic acid @ 2 ml + *Bacillus thuringiensis* @ 5 ml), T_7 (Amino acid @ 2 ml + Neem oil @ 5 ml) and T_8 (Amino acid @ 2 ml +*Bacillus thuringiensis* @ 5 ml). The required amounts of Bio-stimulants and Bio-pesticides were applied to corresponding plots, following the specified treatments schedules and at the correct growth stages. plants were randomly chosen and tagged in each treatment to record the observations of growth and flowering characteristics.

Results and Discussion

1. Growth parameters

Data presented in Table 1 indicate that growth parameters such as plant height, number of leaves, stem diameter, days to curd initiation, and days to curd maturity were significantly influenced by the application of bio-stimulants and bio-pesticides. The highest values for these traits such as plant height in cm (15.30, 25.71, 37.08 at 15, 30 and 45 DAT respectively), number of leaves (5.07, 7.16, 10.22 at 15, 30 and 45 DAT respectively), stem diameter in cm (1.09, 3.16, 4.51 at corresponding growth stages), days to curd initiation (55.03) and days to curd maturity (64.69) were recorded under treatment T_7 (Humic acid @ 2 mL/L + *Bacillus thuringiensis* @ 5 mL/L), while the lowest values were observed in the control treatment (T_1). The enhanced vegetative growth in T_7 may be attributed to the synergistic effects of humic acid and *B. thuringiensis*. Humic acid is rich in organic compounds that improve soil fertility and facilitate nutrient uptake, leading to enhanced plant growth. It promotes root development and microbial activity in the rhizosphere, which supports the better absorption of essential nutrients. Ali *et al.* (2022) [17] reported that humic acid significantly improves vegetative growth by stimulating physiological processes such as photosynthesis, respiration, and enzyme activity. Additionally, humic substances exhibit auxin-like activity, contributing to increased stem thickness and leaf expansion (Yadav & Kumar, 2019) [21]. These effects also help in early curd initiation and shortening the curd maturity period. Furthermore, humic acid increases cell membrane permeability, improves nitrogen metabolism, and delays senescence, thereby promoting sustained growth and productivity (Canellas *et al.*, 2015) [5]. *Bacillus thuringiensis*, primarily known for its bio-pesticidal activity against lepidopteran pests, indirectly supports plant growth by reducing pest-related foliage damage, thus maintaining photosynthetic efficiency (Kumar *et al.*, 2014) [11].

2. Yield parameters

Data showed in Table 2 revealed that yield parameters such as curd weight, curd depth, curd diameter, curd compactness, and overall curd yield were significantly influenced by the external application of bio-stimulants and bio-pesticides. Among all treatments, T_7 (Humic acid @ 2 mL/L + *Bacillus thuringiensis* @ 5 mL/L) recorded the highest values for these yield attributes such as curd weight (521.11 g), curd depth (7.79 cm), curd diameter (12.33 cm), curd yield per plot (10.65 kg), yield per hectare (117.75q) indicating a superior effect on cauliflower performance. In contrast, the lowest values were observed in T_1 (Control), highlighting the effectiveness of T_7 over untreated plants. The enhanced curd weight in T_7 can be attributed to effects of humic acid. Humic acid promotes cell expansion, improves soil structure, enhances water and nutrient retention, and stimulates root growth, all of which contribute to improved nutrient uptake and translocation to the developing curd. These effects result in deeper, denser, and more uniform curds with larger diameters and higher marketable yield. These findings align with previous studies by Dizayee (2019) [6], Meena *et al.* (2018) [14], and De Moura *et al.* (2023) [7]. *Bacillus thuringiensis* contributes to yield enhancement by acting as a biopesticide and plant growth-promoting rhizobacterium (PGPR). Its insecticidal properties reduce damage from lepidopteran pests such as *Plutella xylostella* (diamondback moth), which are common in cauliflower fields. This pest control preserves leaf area, maintains photosynthetic efficiency, and reduces stress on the plant, indirectly boosting curd development and size (Kumar *et al.*, 2014) [11]. Moreover, Bt strains have been shown to produce phytohormones such as indole-3-acetic acid (IAA), and other bioactive compounds that stimulate root development and nutrient absorption (Raddadi *et al.*, 2008; El-Komy *et al.*, 2021) [18, 8]. These PGPR traits contribute to better plant vigour and higher yields.

3. Quality parameters

Data presented in Table 1 revealed that quality parameters such as curd dry matter (%) and ascorbic acid content (mg/100 g) were significantly influenced by the external application of bio-stimulants and bio-pesticides. The highest values Among all treatments, T_7 (Humic acid @ 2 mL/L + *Bacillus thuringiensis* @ 5 mL/L) recorded the highest values for quality parameter such as curd dry matter (11.36%) and ascorbic acid content (54.94 mg) indicating a notable improvement in the quality of cauliflower. In contrast, the lowest values were observed under T_1 (Control), clearly demonstrating the superior effectiveness of T_7 over untreated plants. The enhancement in curd quality under T_7 may be attributed primarily to the beneficial effects of humic acid, which facilitates greater nutrient uptake, enhances carbon assimilation, and promotes the accumulation of essential biochemical compounds. These findings are consistent with reports by Bhat *et al.* (2010) [4] and Al-Bayati (2019) [1], who observed significant improvements in dry matter and ascorbic acid content with humic acid application. According to Kumar *et al.* (2019), humic acid enhances physiological functions such as photosynthesis and protein synthesis, leading to denser and more nutrient-rich curds. Similarly, Singh and Rani (2021) [20] reported that humic acid improves ascorbic acid synthesis by stimulating enzyme activity and enhancing metabolic function.In addition to humic acid, *Bacillus thuringiensis* also plays a significant role in improving cauliflower quality, albeit indirectly. Primarily known for its bio-pesticidal action, Bt reduces pest damage—especially from lepidopteran larvae like *Plutella xylostella*—which helps preserve foliage and ensures optimal photosynthesis and nutrient flow throughout the crop (Kumar *et al.*, 2014) [11]. This reduction in biotic stress contributes to better translocation of nutrients and metabolites to the curd, enhancing its composition and nutritional quality. According to Shishir *et al.* (2022) [19], Bt-based formulations have also been linked to improved nutritional quality in treated vegetables by maintaining physiological homeostasis and enhancing resistance to environmental stresses. Thus, the combined use of humic acid and *Bacillus thuringiensis* not only contributes to higher yields but also significantly enhances quality traits such as dry matter and ascorbic acid content, ultimately improving the nutritional value and market appeal of cauliflower.

4. Economic parameters

Data presented in table 3 indicated that economics parameters such as cost-benefit ratio, gross return and net return were significantly influenced by the external application of bio-stimulants and bio-pesticide. The Significantly maximum cost-benefit ratio (1:68), gross return (176625 Rs/ha.)) and net return (110755 Rs/ha), was found to be highest in treatment T_7 (Humic acid @ 2 mL/L + *Bacillus thuringiensis* @ 5 mL/L), indicating its superior economic viability compared to other treatments. The lowest cost-benefit ratio, gross return and net return was recorded in the control treatment (T_1), highlighting the enhanced profitability and cost-effectiveness of T_7 over untreated conditions. The application of humic acid has also shown promising results in terms of economic returns in vegetable cultivation. Improved plant growth, yield, and reduced pest and disease incidence contribute to higher marketable produce, thereby enhancing profitability. Several studies have indicated that the combined use of humic acid with fertilizers not only boosts yield but also improves the Benefit: Cost (B:C) ratio, making it a cost-effective approach for farmers. According to Reddy *et al.* (2020) [22], the integration of humic acid in nutrient management practices led to better input-use efficiency and higher net returns, underlining its potential as a sustainable and economically viable option in vegetable production systems.

Table 1: Response of bio-stimulants and bio-pesticide on growth and quality attributes in cauliflower

Number of treatments	Treatment	Stem diameter (cm)			Plant height (cm)			No. of leaves			Days to curd initiation	Days to curd maturity	Ascorbic acid (%)	Curd dry matter (%)
		15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT				
T_1	Control	0.47	2.09	3.54	8.64	13.04	19.82	2.57	3.88	5.69	60.41	82.37	42.51	7.58
T_2	Humic acid @ 2 ml/L	0.62	2.60	4.21	14.00	24.50	35.56	4.62	6.70	9.71	57.35	78.74	46.65	10.41
T_3	Amino acid @ 2 ml/L	0.54	2.39	4.03	13.34	23.89	34.98	4.59	6.59	9.61	58.34	80.71	46.13	10.09
T_4	Neem oil @ 5 ml/L	0.71	2.29	3.67	13.O8	23.30	34.45	4.56	6.54	9.63	59.43	80.66	45.55	9.88
T_5	*Bacillus thuringiensis* @ 5 ml/L	0.77	2.11	3.62	12.82	22.77	33.75	4.14	6.51	9.53	59.71	81.67	44.28	9.28
T_6	Humic acid @ 2 ml/L+ Neem oil @ 5 ml/L	0.91	2.82	4.37	14.39	25.38	36.22	4.71	6.80	9.81	56.27	74.67	49.58	11.04
T_7	Humic acid @ 2 m/L+ *Bacillus thuringiensis* @ 5 ml/L	1.09	3.16	4.51	15.30	25.71	37.08	5.07	7.16	10.22	55.03	64.69	54.94	11.36
T_8	Amino acid @ 2 ml/L+ Neem oil @ 5 ml/L	0.83	2.78	4.32	14.21	24.72	35.90	4.70	6.76	9.74	57.00	75.01	47.83	10.74
T_9	Amino acid @ 2 ml/L+ *Bacillus thuringiensis* @ 5 ml/L	0.99	3.07	4.49	14.60	25.64	36.82	4.74	6.92	10.10	55.47	65.49	50.21	11.23
SE(m)		0.07	0.24	0.13	0.48	0.55	0.34	0.17	0.13	0.14	0.16	0.12	1.95	0.12
C.D. @ 5%		0.21	0.70	0.37	1.39	1.60	0.99	0.48	0.39	0.42	0.47	0.34	5.66	0.35

Table 2: Response of bio-stimulants and bio-pesticide on yield attributes of cauliflower

Number of treatments	Treatment	Curd weight (g)	Curd depth (cm)	Curd diameter (cm)	Curd compactness (g/cm)	Curd yield per plot (kg)	Yield per ha (q)
T_1	Control	220.36	3.50	6.37	15.38	4.86	84.19
T_2	Humic acid @ 2 ml/L	443.59	7.20	11.67	20.47	8.80	95.78
T_3	Amino acid @ 2 ml/L	430.04	7.03	11.40	20.10	8.59	94.19
T_4	Neem oil @ 5 ml/L	418.62	6.86	11.17	19.60	8.32	93.38
T_5	*Bacillus thuringiensis* @ 5 ml/L	407.35	6.62	10.83	19.20	8.21	92.77
T_6	Humic acid @ 2 ml/L+ Neem oil @ 5 ml/L	460.11	7.39	12.00	22.40	9.21	111.33
T_7	Humic acid @ 2 m/L+ *Bacillus thuringiensis* @ 5 ml/L	521.11	7.79	12.33	23.23	10.65	117.75
T_8	Amino acid @ 2 ml/L+ Neem oil @ 5 ml/L	447.41	7.25	11.83	21.54	8.88	99.70
T_9	Amino acid @ 2 ml/L+ *Bacillus thuringiensis* @ 5 ml/L	491.26	7.66	12.12	22.67	9.58	112.21
SE(m)		20.26	0.33	0.27	0.14	0.35	1.41
C.D. @ 5%		58.89	0.96	0.79	0.41	1.02	4.10

Table 3: Response of bio-stimulants and bio-pesticides on Economics of cauliflower

S. No.	Cost of cultivation (Rs.)			Yield per hectare (q)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C
	Common cost	Extra cost	Total cost				
T_1	60, 000	-	60, 000	84.19	126285	66285	1.10
T_2	60, 000	5450	65, 450	95.78	143670	78220	1.19
T_3	60, 000	5210	65, 210	94.19	141285	76075	1.16
T_4	60, 000	5430	65, 430	93.38	140070	74640	1.15
T_5	60, 000	4890	64, 890	92.77	139155	74265	1.14
T_6	60, 000	4995	64, 995	111.33	166995	102000	1.56
T_7	60, 000	5870	65, 870	117.75	176625	110755	1.68
T_8	60, 000	5340	65, 340	99.70	149550	84210	1.28
T_9	60, 000	5289	65, 289	112.21	168315	103026	1.57

Conclusion

The study demonstrated that the external application of bio-stimulants and bio-pesticides significantly enhanced growth yield, quality and economic parameters in cauliflower. Treatment with humic acid @ 2 ml + *Bacillus thuringiensis* @ 5 ml at 15, 30 and 45 days after transplanting (T_7) resulted in the highest number of leaves, plant height, days to curd initiation, days to curd maturity, curd weight, curd diameter, curd compactness, curd yield per plot and hectare as well as quality parameter and economic return. These finding suggest that using bio-stimulants and bio-pesticide, particularly humic acid and *Bacillus thuringiensis* can optimize curd yield, quality and profitability in cauliflower cultivation.

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