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Effect of bio-stimulants and bio-pesticides on growth, yield and quality of radish (*Raphanus sativus* L.)

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Abstract

A field experiment was conducted to study the effect of bio-stimulants and bio-pesticides on the growth, yield, and quality of radish (*Raphanus sativus* L.) under Malwa conditions. Various treatments comprising different combinations of bio-stimulants and bio-pesticides were applied. Parameters such as plant height, number of leaves, root length, root diameter, and yield were recorded. The treatment T₆ (Humic acid@1.5ml/L + Azotobacter@3g/L) showed the most significant improvement in growth and yield parameters. However, the T₀ (Control) observed minimum as compare to other treatments. The study confirms the potential of integrated use of bio-stimulants and bio-pesticides to enhance radish production sustainably.

Keywords: Radish, bio-stimulants, bio-pesticides, humic acid, amino acid, trichoderma, azotobacter

Introduction

Radish (*Raphanus sativus* L.) is locally known as 'Mooli'. It belongs to the family Brassicaceae having chromosome number 2n=2x=18. Radish is originated in Europe and Asia. Radish is good source of Vitamin B₆, Calcium, Copper, Magnesium, Riboflavin. Radish is also a good source of Vitamin C contains 15-40mg per 100g of edible portion. Ideal temperature for growth and development of quality roots in radish is 10-15.5 °C. West Bengal, Bihar, Uttar Pradesh, Karnataka, Punjab, Assam are major radish growing states. In India, area of radish is 209 million hectares and production is 3347 MT according to National Horticulture Board (2021-22). Madhya Pradesh accounts for 5.84% of India's production according to National Horticulture Board data of 2021-22. Although the radish are the most quickest and easiest crop grown in India but still it faces many growth problem. Radish are mainly known for its zesty roots but sometimes the roots fail to form, or are weak and spindly. Sometimes premature flowering (Bolting) can also occur due to high temperature. Many physiological problems like forked or misshapen roots and pithiness can also be seen. Radish also suffers from diseases and pests which can affect the growth and quality production.

Hence, this proposed research work will help to overcome the above constraints by using the Bio-stimulants like Humic Acid and Amino Acid as well as Bio-pesticides like *Trichoderma* and *Azotobacter* have been found effective to overcome these constraints by manipulating plant physiological processes and the growth habitat of the plants. Humic acid can increase the firmness of radish roots and increase macronutrients. Amino acid increases nutrient uptake and improve plant growth, yield and morphology. Amino acid can also promote the biosynthesis of plant hormones, which regulate plant processes. Different isolates of *Trichoderma* spp. can help control soil-borne diseases such as bacterial leaf spot and damping-off, that affect radishes. *Trichoderma* can help radishes grow, and can increase shoot dry weight by upto 26%. *Azotobacter* can help produce hormones that promote plant growth as well as produce antifungal chemicals that help inhibit the growth of harmful fungi. *Trichoderma* along with *Azotobacter* when applied to radish helps in increase root fresh weight, root dry weight, root length, root diameter and leaf fresh and dry weight.

Materials and Methods

The present investigation was conducted during the Rabi season of 2024-25 at the Research Farm, Department of Horticulture, College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Indore (M.P.). The experiment was laid out in a Randomized Block Design (RBD) with three replications and comprised nine treatment combinations: T₁ (Control), T₂ (Humic acid @ 2 ml/L), T₃ (Amino acid @ 2 ml/L), T₄ (Azotobacter @ 3 g/L), T₅ (Trichoderma @ 5 g/L), T₆ (Humic acid @ 1.5 ml/L + Azotobacter @ 3 g/L), T₇ (Humic acid @ 1.5 ml/L + Trichoderma @ 5 g/L), T₈ (Amino acid @ 3 ml/L + Azotobacter @ 3 g/L), and T₉ (Amino acid @ 3 ml/L + Trichoderma @ 5 g/L). Treatments involved foliar applications of bio-stimulants and bio-pesticides, with vermicompost incorporated into the soil. The crop variety used was ‘Musashi’ radish. Observations on growth parameters were recorded at 15-day intervals up to harvest. For data collection, five plants were randomly selected from each plot within every replication. The collected data were subjected to statistical analysis using the method suggested by Fisher (1938). Economic analysis was also performed, wherein net returns per hectare were calculated by deducting the cost of cultivation from the gross returns for each

treatment.

Results and Discussion

1. Morphological Parameters

The application of various combinations of bio-stimulants and bio-pesticides significantly influenced the morphological traits (Plants height, Number of leaves, Leaf area) of radish plants. Treatment T₆ (Humic acid @1.5 ml/L + Azotobacter @3 g/L) consistently recorded the highest values for plant height (16.47 cm at 15 DAS and 24.21 cm at harvest), number of leaves (4.00 at 15 DAS and 10.22 at harvest), and leaf area (119.97 cm² at 15 DAS and 243.22 cm² at harvest). This was closely followed by Treatment T₈ (Amino acid @3 ml/L + Azotobacter @3 g/L) and T₇ (Humic acid @1.5 ml/L + Trichoderma @5 g/L). The minimum values were consistently observed in the control treatment (T₁), indicating the clear beneficial effect of bio-input combinations on vegetative growth. These results highlight the synergistic role of humic acid and Azotobacter in promoting radish plant development through enhanced nutrient uptake and growth hormone stimulation. The present findings were in agreement with those of Meena *et al.* (2017), (Wani *et al.*, 2010), (Kumar *et al.*, 2014)^[10] in radish.

Table 1: Response of bio-stimulants and bio-pesticides on morphological parameters in radish

Treatment	Plant Height (cm)	Plant Height (cm)	Number of Leaves	Number of Leaves	Leaf Area (cm ²)	Leaf Area (cm ²)
	15 DAS	Harvesting	15DAS	Harvesting	15 DAS	Harvesting
T ₁	9.33	22.43	2.22	7.36	104.57	124.69
T ₂	14	23.42	3.47	9.71	112.63	205.59
T ₃	13.44	23.72	3.44	9.63	111.13	189.64
T ₄	12.44	22.97	3.42	9.61	109.7	168.75
T ₅	11.44	22.54	3.33	9.53	107.83	154.52
T ₆	16.47	24.21	4	10.22	119.97	243.22
T ₇	15.37	23.97	3.58	9.81	117.65	212.95
T ₈	16	24.14	3.71	10.1	119.03	225.34
T ₉	15	23.82	3.56	9.74	115.23	210.71
S.Em (±)	0.58	0.21	0.19	0.11	0.56	0.25
C.D. @ 5%	1.68	0.62	0.55	0.33	1.64	0.74

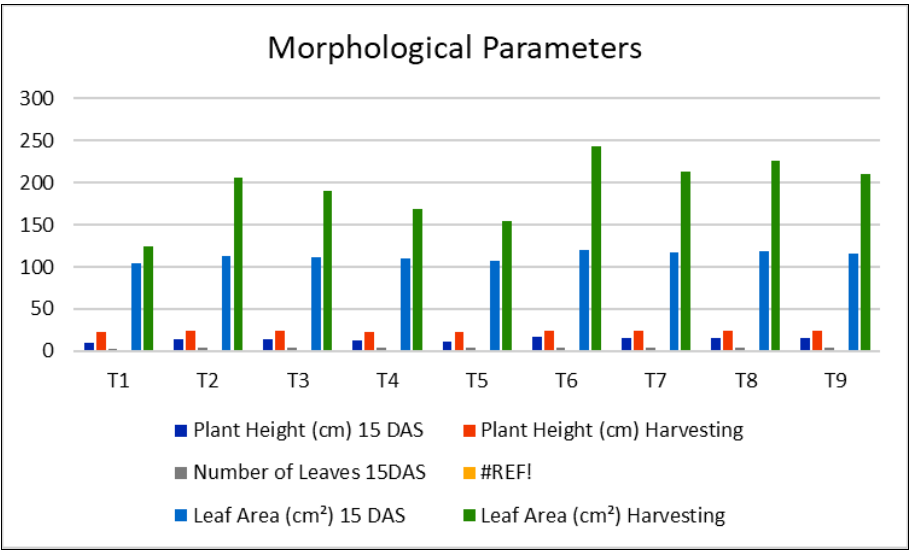


Fig 1: Response of bio-stimulants and bio-pesticides on morphological parameters in radish

2. Phenological Parameters

The data pertaining to number of days to first picking in radish as influenced by different treatments of bio-stimulants and bio-pesticides. The results indicated a significant difference among treatments. The earliest first picking was recorded in treatment T₆ (Humic acid @ 1.5 ml/L + Azotobacter @ 3 g/L) with 42.81

days, followed by T₈ (Amino acid @ 3 ml/L + Azotobacter @ 3 g/L) and T₇ (Humic acid @ 1.5 ml/L + Trichoderma @ 5 g/L) with 43.20 and 43.73 days, respectively. On the other hand, the maximum number of days to first picking was observed in the control (T₁) with 45.24 days. The earlier maturity in combined treatments, especially T₆, can be attributed to the enhanced

physiological efficiency, nutrient uptake, and metabolic activities induced by humic acid and *Azotobacter*. These results confirm that integrated use of bio-stimulants and bio-pesticides significantly accelerates early development and maturity in radish. These findings are in agreement with earlier research by Meena *et al.*, who reported that radish plants treated with biofertilizers like *Azotobacter* matured earlier than untreated plants. Likewise, Singh *et al.* also.

3. Yield Parameters

The findings of the study demonstrated that the application of various bio-stimulants and bio-pesticides, whether used individually or in combination, had a significant impact on the yield characteristics of radish (*Raphanus sativus* L.). Among the treatments, T₆ (Humic acid @ 1.5 ml/L + *Azotobacter* @ 3 g/L) consistently outperformed others across all yield-related parameters. This treatment recorded the highest values for fresh root weight (120.64 g), root length (25.18 cm), root diameter (5.20 cm), dry root weight (16.69 g), vegetative yield per plot (9.66 kg), vegetative yield per hectare (193.27 q/ha), root yield per plot (6.61 kg), root yield per hectare (132.33 q/ha), and

harvest index (7.53%). These results suggest a strong synergistic interaction between humic acid and *Azotobacter*, which significantly enhanced root development and overall yield. T₈ (Amino acid @ 3 ml/L + *Azotobacter* @ 3 g/L) was the second most effective treatment, also showing high performance in most yield parameters, followed closely by T₇ (Humic acid @ 1.5 ml/L + *Trichoderma* @ 5 g/L). These findings indicate that combining bio-stimulants with beneficial microbes can effectively boost radish growth and productivity. On the other hand, the control treatment (T₁) consistently recorded the lowest values across all parameters, clearly highlighting the importance of bio-inputs in improving crop performance. Additionally, the standalone application of humic acid (T₂) also produced significantly better results than the control and some combination treatments, indicating that even alone, humic acid contributes positively to radish growth and yield. Similar findings were reported by (Canellas *et al.*, 2002) where he summarized that use of bio-stimulants derived from natural substance can result in enhanced vegetative biomass Wani *et al.*, (2010); Kumar *et al.*, (2014)^[10] also agreed on these findings.

Table 2: Response of bio-stimulants and bio-pesticides on yield parameters in radish

Treatment	Fresh Root Weight (g)	Root Length (cm)	Root Diameter (cm)	Dry Root Weight (g)	Vegetative Yield per Plot (kg)	Vegetative Yield per Hectare (q)	Root Yield per Plot (kg)	Root Yield per Hectare (q)	Harvest Index (%)
T ₁	60.74	15.41	2.92	10.49	7.68	153.6	4.15	82.93	4.55
T ₂	120.64	22.94	3.99	14.1	8.49	174.07	5.62	112.33	6.83
T ₃	75.52	22.43	3.9	13.07	8.45	169.07	5.47	109.33	6.7
T ₄	88.17	21.01	3.79	12.5	8.11	162.13	5.39	107.87	6.57
T ₅	97.79	20.82	3.62	11.86	7.99	159.8	5.04	100.87	6.2
T ₆	109.5	25.18	5.2	16.69	9.66	193.27	6.61	132.33	7.53
T ₇	111.39	23.42	4.58	15.81	8.77	179.53	5.93	118.53	7.22
T ₈	112.19	24.5	4.81	16.17	9.21	184.27	6.29	125.87	7.47
T ₉	115.16	22.5	4.07	15.21	8.7	175.47	5.74	114.73	7.07
S.Em (±)	0.95	0.27	0.39	0.38	0.36	6.21	0.22	4.37	0.21
C.D. at 5	2.75	0.77	1.13	0.81	1.04	18.05	0.63	12.70	0.60

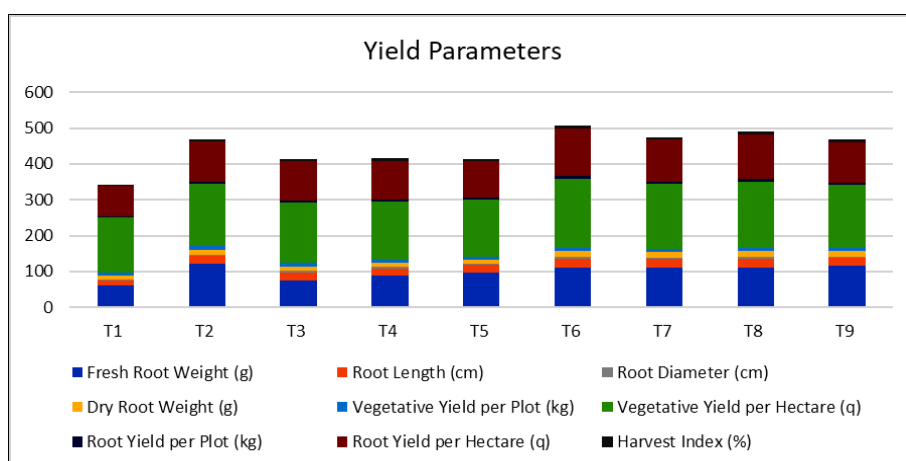


Fig 2: Response of bio-stimulants and bio-pesticides on yield parameters in radish

4. Physiological Parameters

The physiological attributes of radish, specifically Leaf Area Index (LAI) and chlorophyll content, were significantly influenced by the application of various bio-stimulants and bio-pesticides. The highest LAI (0.144) was recorded in treatment T₆ (Humic acid @ 1.5 ml/L + *Azotobacter* @ 3 g/L), indicating enhanced canopy development and photosynthetic area. This was closely followed by T₈ (Amino acid @ 3 ml/L + *Azotobacter* @ 3 g/L) with an LAI of 0.142 and T₇ (Humic acid

@ 1.5 ml/L + *Trichoderma* @ 5 g/L) with 0.141. These results suggest that the synergistic effect of humic acid or amino acid combined with beneficial microbes like *Azotobacter* and *Trichoderma* leads to better vegetative growth. Similarly, chlorophyll content, a direct indicator of photosynthetic efficiency, was also found to be highest in T₆ (40.70 mg/100g), followed by T₈ (38.37 mg/100g) and T₇ (37.97 mg/100g). The increased chlorophyll levels in these treatments highlight their role in enhancing metabolic activity, which ultimately

contributes to better growth and yield. The control treatment (T₁) consistently recorded the lowest LAI (0.127) and chlorophyll content (34.32 mg/100g), reaffirming the importance of bio-inputs in improving the physiological performance of radish. This finding is consistent with studies by El-Nemr *et al.* (2012), who reported improved LAI in crops treated with humic acid, and Bharucha *et al.* (2013), who highlighted the role of Azotobacter in enhancing vegetative parameters through nitrogen enrichment.

Table 3: Response of bio-stimulants and bio-pesticides on physiological parameters in radish

Treatment	Leaf Area Index (LAI)	Chlorophyll Content (mg/100g)
T ₁	0.127	34.32
T ₂	0.14	37.38
T ₃	0.139	37.25
T ₄	0.138	36.96
T ₅	0.137	36.76
T ₆	0.144	40.7
T ₇	0.141	37.97
T ₈	0.142	38.37
T ₉	0.14	37.46
S.Em (±)	0.01	0.16
C.D. at 5%	0.01	0.47

5. Quality Parameters

The application of bio-stimulants and bio-pesticides had a significant influence on the quality parameters of radish, including total soluble solids (TSS), ascorbic acid content, and physiological loss in weight (PLW) during storage. The best performance across all quality traits was consistently observed in Treatment T₆ (Humic acid @ 1.5 ml/L + Azotobacter @ 3 g/L). This treatment recorded the highest TSS (4.03 °Brix), indicating enhanced sugar accumulation; the highest ascorbic acid content (14.70 mg/100g), reflecting improved nutritional value; and the lowest physiological loss in weight (7.86%), suggesting better post-harvest shelf life. Following T₆, treatments T₈ (Amino acid @ 3 ml/L + Azotobacter @ 3 g/L) and T₇ (Humic acid @ 1.5 ml/L + Trichoderma @ 5 g/L) also performed well across all three parameters. T₈ recorded 3.70 °Brix, 14.33 mg/100g ascorbic acid, and 8.87% PLW, while T₇ achieved 3.60 °Brix, 13.80 mg/100g ascorbic acid, and 9.09% PLW. These results suggest that the integration of bio-stimulants with beneficial microorganisms improves not only yield but also the quality and storability of radish. On the other hand, the control treatment (T₁) consistently recorded the lowest quality, with 2.60 °Brix, 11.23 mg/100g ascorbic acid, and the highest PLW (12.67%), underscoring the importance of bio-inputs for enhancing quality parameters. This is in line with findings by Ali *et al.* (2020) ^[1], who reported that humic acid application reduced water loss and delayed senescence in root crops.

Table 4: Response of bio-stimulants and bio-pesticides on quality parameters in radish

Number of treatments	TSS (°Brix)	Ascorbic acid (mg/100 g)	Physiological loss in weight (%)
T ₁	2.6	11.23	12.67
T ₂	3.15	13.3	10.29
T ₃	3.1	12.9	10.93
T ₄	2.9	12.5	11.47
T ₅	2.7	11.9	11.97
T ₆	4.03	14.7	7.86
T ₇	3.6	13.8	9.09
T ₈	3.7	14.33	8.87
T ₉	3.3	13.47	9.6
S.Em (±)	0.25	0.66	0.53
C.D. at 5%	0.74	1.91	1.22

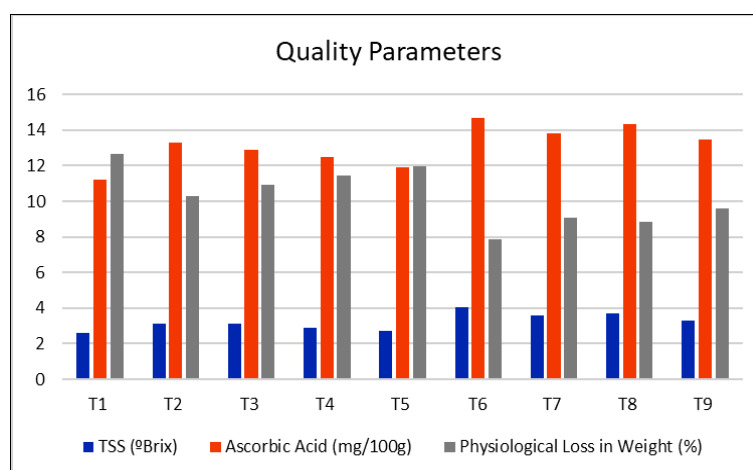


Fig 3: Response of bio-stimulants and bio-pesticides on quality parameters in radish

6. Disease and Pest incidence Parameters

The present study demonstrated that the application of bio-stimulants and bio-pesticides, particularly in combination, significantly reduced both disease intensity (PDI) and pest incidence (PPI) in radish. These inputs appear to enhance the plant's resistance to biotic stress, possibly by improving overall

plant vigor, root development, and microbial activity in the rhizosphere. The lowest disease intensity (2.00%) and lowest pest incidence (2.13%) were both observed in Treatment T₆ (Humic acid @ 1.5 ml/L + Azotobacter @ 3 g/L). This clearly indicates the superior efficacy of this combination in managing both white rust infection and pest pressure under field

conditions. Following T₆, treatments T₈ (Amino acid @ 3 ml/L + Azotobacter @ 3 g/L) and T₇ (Humic acid @ 1.5 ml/L + Trichoderma @ 5 g/L) also showed commendable results with PDI values of 2.20% and 4.50%, and PPI values of 2.3% and 5.53%, respectively. These combinations suggest a synergistic effect in enhancing plant defenses when bio-stimulants are combined with beneficial microbes. In contrast, the control treatment (T₁) had the highest levels of disease intensity (9.30%) and pest incidence (9.23%), highlighting the vulnerability of untreated plants and reinforcing the importance of integrated bio-inputs for disease and pest management in radish cultivation. The findings align with those of Yadav *et al.* (2019), who observed that bio-pesticides, especially Azotobacter, when used in combination with organic amendments like humic acid, significantly reduced the population of insect pests in root crops.

Table 5: Response of bio-stimulants and bio-pesticides on disease and pest incidence parameters in radish

Treatment No.	Disease Intensity (PDI%)	Pest Incidence (PPI%)
T ₁	9.3	9.23
T ₂	7	6.67
T ₃	6.59	7.4
T ₄	5.7	6
T ₅	4.9	4.9
T ₆	2	2.13
T ₇	4.5	5.53
T ₈	2.2	2.3
T ₉	5.9	6.2
S.Em (±)	0.049	0.085
C.D. at 5%	0.148	0.254

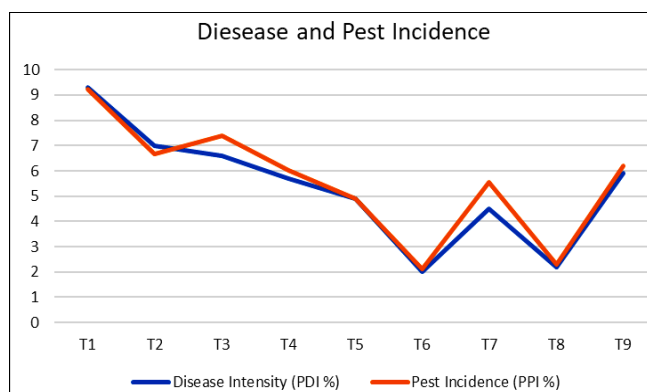


Fig 4: Response of bio-stimulants and bio-pesticides on disease and pest incidence parameters in radish

7. Economic Parameter

The economic evaluation of different treatments revealed significant variation in gross return, net return, and benefit-cost (B:C) ratio among the applied combinations of bio-stimulants and bio-pesticides in radish cultivation. The treatment T₆, which involved the application of Humic acid (1.5 ml/L) as a bio-stimulant and Azotobacter (3 g/L) as a biopesticide, recorded the highest economic returns among all treatments. This treatment (T₆) significantly outperformed the others with the maximum gross return, attributed to the increased root yield per hectare due to enhanced vegetative and reproductive growth. The net return was also highest in T₆, indicating that the cost of input application was efficiently compensated by the improved yield. The B:C ratio, a critical measure of profitability, was most favorable under T₆, suggesting excellent economic viability of integrating humic acid and Azotobacter for radish cultivation. In contrast, T₁ (control or no bio-stimulants/bio-pesticides

application) consistently showed the lowest gross and net returns and an unfavorable B:C ratio, signifying poor cost efficiency and lower yield performance. The reduced marketable yield and suboptimal crop quality under T₁ directly impacted the economic returns, reinforcing the importance of bio-stimulants and bio-pesticides inputs. Ramesh *et al.* (2020) ^[15], who demonstrated that the combined use of humic acid and Azotobacter significantly enhanced the economic returns in root vegetables due to better root development and nutrient uptake. Kumar and Sharma (2018) ^[10] reported an improved B:C ratio in radish with the application of Azotobacter, highlighting its role in sustainable and cost-effective production systems.

Table 6: Economics

S. No.	Cost of cultivation (Rs.)			Root yield per hectare(q)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C
	Common cost	Extra cost	Total cost				
T ₁	45000	-	45000	82.93	165860	120860	1:3.69
T ₂	45000	7110	52110	112.33	224660	172550	1:4.31
T ₃	45000	7205	52205	109.33	218660	166455	1:4.19
T ₄	45000	6590	51590	107.87	215740	164150	1:4.18
T ₅	45000	7019	52019	100.87	201740	149721	1:3.88
T ₆	45000	7315	52315	132.33	264660	212345	1:5.06
T ₇	45000	7620	52620	118.53	237060	184440	1:4.51
T ₈	45000	7418	52418	125.87	251740	199322	1:4.80
T ₉	45000	7580	52580	114.73	229460	176880	1:4.37

Conclusion

The integrated application of bio-stimulants (Humic acid, Amino acid) and bio-pesticides (Azotobacter, Trichoderma) significantly improved growth, yield, quality, and reduced disease and pest incidence in radish. Treatment T₆ (Humic acid @1.5 ml/L + Azotobacter @3 g/L) consistently outperformed others, making it the most effective combination for sustainable radish cultivation.

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