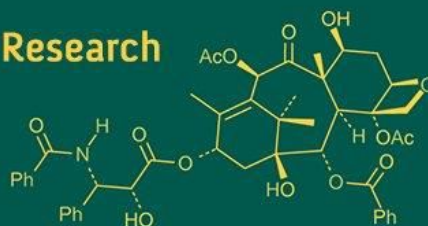
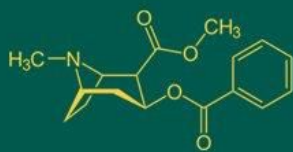


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(10): 1422-1428
www.biochemjournal.com
Received: 07-07-2025
Accepted: 10-08-2025

Jagrati Shrivastav
Research Scholar at
Department of Horticulture
(Vegetable Science) CoA,
Indore, Madhya Pradesh,
India

Swati Barche
Professor at Department of
Horticulture CoA, Indore,
Madhya Pradesh, India

Anvita Sharma
Faculty at Department of
Horticulture CoA, Indore,
Madhya Pradesh, India

Dr. Rajesh Jatav
Faculty at Department of
Horticulture CoA, Indore,
Madhya Pradesh, India

Sumit Khede
Research Scholar at
Department of Horticulture
(Vegetable Science) CoA,
Indore, Madhya Pradesh,
India

Corresponding Author:
Anvita Sharma
Faculty at Department of
Horticulture CoA, Indore,
Madhya Pradesh, India

Response of bio stimulants and bio pesticides on growth, yield and quality of tomato (*Solanum lycopersicum* L.)

Jagrati Shrivastav, Swati Barche, Anvita Sharma, Rajesh Jatav and Sumit Khede

DOI: <https://www.doi.org/10.33545/26174693.2025.v9.i10Sr.6029>

Abstract

An experiment was carried out on “Response of Biostimulants and Biopesticides on Growth, Yield and Quality of Tomato (*Solanum lycopersicum* L.) under Malwa Conditions of Madhya Pradesh” at the Experimental field, Department of Horticulture, College of Agriculture, Indore, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) during the Rabi season 2024-25. The experiment was laid out in randomized block design with nine treatments and three replications. Treatments included bio-stimulants (Amino Acids @ 2 ml/L, Seaweed Extracts @ 2 ml/L), biopesticides (*Bacillus thuringiensis* @ 5 ml/L, *Trichoderma* sp. @ 5 g/L), and their combinations. Results revealed significant differences among treatments for growth, yield, and quality parameters. The combination of Seaweed Extracts + *Trichoderma* sp. (T₈) recorded the highest plant height, number of branches and leaves per plant, internode length, leaf area, and leaf area index at 15, 30, and 45 days after transplanting. T₈ also performed best in terms of early flowering and fruiting, number of flowers per cluster, and flower clusters per plant. Maximum yield per plant (1.91 kg), per plot (30.61 kg), and per hectare (637.84 q) were obtained in T₈, along with highest TSS (5.21 °Brix), titratable acidity (5.57 g/L), ascorbic acid (20.76 mg/g), and lower physiological loss in weight (11.26%). T₈ also showed the lowest disease intensity and pest incidence, and the highest benefit-cost ratio (1:4.8), making it the most effective treatment for enhancing tomato growth, productivity, and quality.

Keywords: Tomato, biostimulants, biopesticides, seaweed extract, *Trichoderma*, *Bacillus thuringiensis*, amino acids

Introduction

Tomato (*Solanum lycopersicum* L.), a member of the Solanaceae family with a chromosome number of 2n = 24, is the second most important vegetable crop globally, valued for its nutritional and economic significance. Native to the Andean region of South America, tomato is widely cultivated for its edible fruit, rich in vitamins A, B, and C, lycopene, flavonoids, and other phytochemicals known for antioxidant, anticancer, and cardiovascular benefits. Despite comprising about 94% water, tomatoes are highly nutritious and commonly referred to as the “poor man’s apple.” In India, tomato is cultivated over 8.41 million hectares, yielding 20.3 million metric tonnes (NHB, 2023). Madhya Pradesh is one of the leading producers, contributing around 3.5 million tonnes across 1.5 million hectares (Anonymous, 2023) [3]. However, tomato cultivation is often challenged by biotic and abiotic stresses, including pests, diseases, drought, and soil degradation, which adversely affect yield and quality. To address these challenges, biostimulants and biopesticides have emerged as sustainable alternatives to chemical inputs. Biostimulants such as amino acids, seaweed extracts, and *Trichoderma* spp. improve plant metabolism, nutrient uptake, stress tolerance, and overall productivity. They enhance root growth, flowering, fruit set, and nutritional quality, including lycopene and vitamin C content (Yildiz Dasgan *et al.*, 2024; Sharma *et al.*, 2014) [27, 20].

Amino acids support photosynthesis, flowering, and disease resistance, while seaweed extracts supply essential nutrients and natural hormones (auxins, cytokinins, gibberellins), boosting yield and resilience (Colla *et al.*, 2017) [7]. Biopesticides such as *Bacillus thuringiensis* and *Trichoderma* offer effective pest and disease control with minimal

environmental impact. *B. thuringiensis* targets lepidopteran pests like fruit borers, and *Trichoderma* suppresses soil-borne pathogens, promotes root health, and enhances plant defense (Sridhar *et al.*, 2019; Muhorakeye *et al.*, 2024) ^[21, 16]. These eco-friendly inputs represent vital components of sustainable tomato production, enhancing growth, yield, and quality while reducing dependency on synthetic chemicals.

Materials and Methods

A field experiment on Tomato was conducted at Experimental field, Department of Horticulture, College of Agriculture, Indore, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) during the Rabi season 2024-25. The spacing between row to row 0.6 m and plant to plant 0.5 m were maintained. The experiment was laid out in randomized block design with nine treatments and three replications. The treatments consist of two Bio stimulants viz., (Amino Acids @ 2 ml/L, Seaweed Extracts @ 2 ml/L), and two Bio pesticides viz., (*Bacillus thuringiensis* @ 5 ml/L, *Trichoderma* sp. @ 5 g/L) sprayed at 15, 30 and 45 DAT. The treatments consists of T₀ (Control), T₁ (Amino Acids @ 2 ml/L), T₂ (Seaweed Extracts @ 2 ml/L), T₃ (*Bacillus thuringiensis* @ 5 ml/L), T₄ (*Trichoderma* sp. @ 5 g/L), T₅ (Amino Acid @ 2 ml/L+ *Bacillus thuringiensis* @ 5 ml/L), T₆ (Amino Acid @ 2 ml/L+ *Trichoderma* sp. @ 5 g/L), T₇ (Seaweed Extracts @ 2 ml/L+ *Bacillus thuringiensis* @ 5 ml/L), and T₈ (Seaweed Extracts @ 2 ml/L+ *Trichoderma* sp. @ 5 g/L). The required amounts of treatments were applied to the corresponding plots, following the specified treatment schedules and at the correct growth stages. Five plants were randomly chosen and tagged in each treatment to record the observations of growth and flowering characteristics.

Results and Discussion

Growth parameters

Data presented in Table 1(a) give idea about the growth parameters such as plant height (cm), number of branches per plant, number of leaves per plant, while Table 1(b) presents the data of internode length (cm), leaf area (cm²), and leaf area index (LAI). It reveals that all are significantly influenced by the topical application of biostimulants and biopesticides. The significantly maximum values for growth parameters such as plant height in cm (35.24, 71.20, 102.02 at 15, 30 and 45 DAT respectively), number of branches per plant (6.00, 13.20, 20.05 at 15, 30 and 45 DAT respectively) number of leaves per plant (27.90, 56.73, 80.20 at 15, 30 and 45 DAT respectively) were recorded in treatment T₈ (Seaweed extract @ 2 ml/L + *Trichoderma* sp. @ 5 g/L), while the minimum values were observed in treatment T₀ (Control). This enhanced vegetative growth in T₈ may be attributed to the presence of macro- and micronutrients, amino acids, vitamins, and other growth-promoting compounds in seaweed extracts that stimulate cellular metabolism, improve photosynthetic efficiency, and facilitate the translocation of assimilates. Seaweed extracts act synergistically as bio-stimulants, improving physiological and biochemical activities in plants, thereby enhancing vegetative growth. These results are in accordance with the findings of Silva *et al.*, (2019) ^[22], Soares *et al.*, (2020) ^[23], and Pohl *et al.*, (2019) ^[17], who reported improved plant performance through seaweed extract application. Additionally, *Trichoderma* sp. played a crucial role in enhancing nutrient uptake, root development,

and phytohormone production, which collectively improved shoot elongation, leaf proliferation, and biomass accumulation. These findings are in line with Li *et al.* (2015) ^[15], who reported that inoculation with *Trichoderma harzianum* significantly increased plant height and leaf area in tomato.

The significantly maximum internode length in cm (5.03, 6.50, 7.05 at 15, 30 and 45 DAT respectively), leaf area in cm² (477.26, 781.34, 1026.31 at 15, 30 and 45 DAT respectively), and leaf area index (LAI) (0.177, 0.289, 0.379 at 15, 30 and 45 DAT respectively) were recorded in T₈ (Seaweed extract @ 2 ml/L + *Trichoderma* sp. @ 5 g/L), while the minimum values were observed in treatment T₀ (Control). This is due to the combined application of seaweed extract and *Trichoderma* sp. exhibited a synergistic effect in promoting vegetative growth there by increasing internode length and leaf area, as also observed by Ashmawi (2021) ^[4] found that foliar spraying of seaweed extract improved plant height and leaf area, while *Trichoderma* spp. promoted root development and phytohormone activity. Fatimah *et al.* (2018) ^[9], also reported enhanced hypocotyl and root development with foliar application of *Sargassum* sp. extract.

Phenological Parameters

Data presented in Tables 2 revealed that phenological parameters such as days to first flower initiation, days to first fruit set, days to first picking, number of flowers per clusters and number of flower cluster per plant were significantly influenced by the external application of biostimulants and biopesticides. The significantly earliest flower initiation (22.05 days), fruit set (75.24 days), and days to first picking (36.85 days) were recorded in treatment T₈ (Seaweed Extract @ 2 ml/L + *Trichoderma* sp. @ 5 g/L), whereas the minimum values were observed in treatment T₀ (Control). This may be due to the presence of bioactive compounds in seaweed extract that stimulate hormonal activity, particularly auxins, cytokinins, and gibberellins, which play crucial roles in promoting early flowering and fruit development. Seaweed extracts are also known to enhance enzyme activity, protein synthesis, and nutrient availability, which together accelerate floral initiation and support reproductive growth. These results are supported by Subramaniyan *et al.* (2023) ^[24], who reported that foliar application of *Ascophyllum nodosum* extract significantly improved flowering traits and fruit yield in tomato.

The significantly maximum number of flowers per clusters (7.00) and number of flower clusters per plant (10.51) were recorded in treatment T₈ (Seaweed Extract @ 2 ml/L + *Trichoderma* sp. @ 5 g/L), whereas the minimum values were observed in treatment T₀ (Control). The enhancement of phenological traits under T₈ may be due to the fact as seaweed-based biostimulants enhanced plant growth, number of flowers per clusters and clusters per plant, chlorophyll content, flowers and fruit production as observed by Ali *et al.* (2019) ^[2]. The synergistic effect of seaweed extract and *Trichoderma* spp. in treatment T₈ likely created favorable physiological and hormonal conditions for early flowering and fruit setting. *Trichoderma* spp. are known to enhance root development, nutrient uptake, and phytohormone production, which positively influence plant vigor and reproductive traits. This is in line with the findings of Harman *et al.* (2004) ^[10] and Contreras-Cornejo

et al. (2009) [8], who demonstrated that *Trichoderma* species improve plant architecture and stimulate auxin and gibberellin production, leading to earlier floral development and better fruit set. While previous studies focused primarily on individual treatments, the superior performance observed under the combined application in this study highlights its potential as a promising strategy for enhancing reproductive efficiency and yield under open-field conditions.

Yield Parameters

Data presented in Tables 3 showed that yield parameters such as number of fruits per plant, average fruit weight (g), number of fruits per cluster, fruit diameter (cm), yield per plant (kg), yield per plot (kg), and yield per hectare (q) were significantly influenced by the external application of biostimulants and biopesticides. The highest values of number of fruits per plant (34.78), average fruit weight (55.01 g), number of fruits per cluster (3.50), fruit diameter (5.51 cm) were recorded in treatment T₈ (Seaweed Extract @ 2 mL/L + *Trichoderma* spp. @ 5 g/L), while the lowest were observed in treatment T₀ (Control), indicating the superior efficacy of the combined treatment in enhancing fruit yield and related attributes. The improvement in yield parameters under T₈ may be attributed to the presence of essential macro-and micronutrients, amino acids, and plant growth-promoting substances in seaweed extracts, which collectively stimulate vegetative and reproductive development. Seaweed-based biostimulants enhance photosynthetic efficiency, chlorophyll content, and assimilate translocation, resulting in an increased number of fruits, greater fruit size, and overall yield. Foliar application of seaweed extracts such as *Sargassum horneri* and *Ascophyllum nodosum* has been reported to improve photosynthetic activity and significantly enhance fruit number, clusters, and yield in tomato (Hussain *et al.*, 2021) [11].

The significantly highest values of number of yield per plot (30.61 kg), and yield per hectare (637.84 q) across all yield-related traits were recorded in treatment T₈ (Seaweed Extract @ 2 mL/L + *Trichoderma* spp. @ 5 g/L), while the lowest were observed in treatment T₀ (Control). Colla *et al.* (2014) [7] reported a similar promoting effect of plant-derived protein hydrolysate on tomato, demonstrating that the application of this biostimulant stimulated flowering, fruit setting and final yield through an elicited endogenous phytohormonal biosynthesis. In terms of microbial inoculants, Uddin *et al.* (2016) [25] demonstrated that *Trichoderma* spp. increased tomato yield from 1.4 kg to 3.0 kg per plant by improving nutrient solubilization and plant vigor. Lanzuise *et al.* (2022) [14] similarly demonstrated that co-application of *Trichoderma* strains with medium-long chain fatty acid mixtures resulted in yield increases of up to 90% in tomato, lettuce, and kohlrabi, reinforcing the synergistic effect of microbial consortia and organic biostimulants in enhancing crop productivity and quality.

Quality Parameters

Data presented in Tables 4 revealed that quality parameters such as total soluble solids (TSS °Brix), titratable acidity (g/L), physiological loss in weight (%), and ascorbic acid content (mg/g) were significantly influenced by the external application of biostimulants and biopesticides. The significantly highest values of total soluble solids (TSS 5.21°Brix), titratable acidity (5.57 g/L), physiological loss in

weight (11.26 %), and ascorbic acid content (20.76 mg/g) were recorded in treatment T₈ (Seaweed Extract @ 2 mL/L + *Trichoderma* spp. @ 5 g/L), while the lowest were observed in treatment T₀ (Control). The significant improvement of quality parameters under T₈ may be attributed to the presence of essential nutrients and bioactive compounds in seaweed extracts that promote carbohydrate accumulation, enhance metabolic activity, and stimulate the biosynthesis of sugars. *Ascophyllum nodosum* seaweed extract application enhances tomato fruit quality by increasing TSS, vitamin C, and flavor index. Soil drenching with the extract is especially effective under water-deficit conditions, improving ascorbic acid content and reducing physiological weight loss. (Jalali *et al.*, (2022) [12] and Ahmed *et al.*, (2022) [1]. The inclusion of *Trichoderma* sp. in the treatment further contributed to improved fruit quality by enhancing nutrient uptake, promoting root health, and increasing the plant's physiological activity as observed by Khan *et al.* (2017) [13] that increased antioxidant compounds such as ascorbic acid, lycopene and β-carotene in ripe tomato fruits due to the application of 100% *Trichoderma* bio-compost in field conditions. The combined effects of seaweed extract and *Trichoderma* sp. thus resulted in improved ascorbic acid content and reduced physiological loss in weight, as reflected in the present study.

Disease and Pest Incidence Parameters

Data presented in Tables 5 revealed that disease and pest incidence parameters, including Percent Disease Intensity (PDI %) and Percent Pest Incidence (PPI %), were significantly influenced by the external application of biostimulants and biopesticides. Among all treatments, the lowest values of Percent Disease Intensity (18.86 %) and Percent Pest Incidence (15.11 %), were recorded by T₈ (Seaweed Extract @ 2 mL/L + *Trichoderma* sp. @ 5 g/L) indicating its strong suppressive effect on both disease and pest pressure in tomato plants. In contrast, the maximum incidence of disease and pest attack was observed in the untreated control (T₀) due to Seaweed-based formulations are rich in polysaccharides, phytohormones, and other bioactive compounds that activate plant immune responses. Ramesh *et al.* (2022) [18] reported that foliar spraying of seaweed extracts in tomato effectively reduced early blight severity and fruit borer infestation due to stimulated plant defense responses. The addition of *Trichoderma* sp. further enhanced disease and pest suppression through biological control mechanisms such as competition, mycoparasitism, and the secretion of hydrolytic enzymes. *Trichoderma* spp. are well-documented antagonists of soil-borne pathogens like *Fusarium oxysporum*, *Pythium*, and *Rhizoctonia*. Muhorakeye *et al.* (2024) [16] reported that *T. asperellum* significantly reduced *fusarium wilt* severity and nematode infestation in tomato by degrading pathogen cell walls and promoting rhizosphere colonization. Likewise, Brotman *et al.* (2022) [5] found that *T. atroviride* enhanced resistance to insect pests in tomato by inducing systemic defense responses and modifying volatile emissions that deter pest activity. The synergistic effect of seaweed extract and *Trichoderma* sp. contributed not only to disease and pest resistance but also to improved nutrient uptake and root development, creating an environment less favorable for pathogen and pest establishment. These findings are supported by Du Jardin (2015), who highlighted that seaweed-based formulations improve stress tolerance and

nutrient assimilation through their rich composition of polysaccharides, amino acids, and phytohormones.

Economic Parameters

Data presented in Table 6 indicated that economic parameters, specifically the Benefit:Cost (B:C) ratio, were significantly influenced by the application of biostimulants and biopesticides. Among all treatments, T₈ (Seaweed Extract @ 2 mL/L + *Trichoderma* sp. @ 5 g/L) recorded the highest B:C ratio (1:4.8), reflecting its superior economic viability and profitability under treated conditions. In contrast, the control treatment (T₀) exhibited the lowest B:C ratio. The higher profitability observed in T₈ may be attributed to the combined effects of increased yield, improved quality parameters, and reduced incidence of pests and diseases, which together contribute to greater marketable produce and reduced input losses. Foliar application of *A. nodosum* extract significantly reduced bacterial spot and early blight incidence in tomato by up to

50% compared to untreated controls. Similarly, Sanap *et al.* (2019)^[19] reported that the use of *Opteine* (a seaweed-based extract) effectively reduced pest populations and disease progression, thereby improving overall plant vigor and final yield. In terms of economic returns, the application of seaweed extracts has also demonstrated positive impacts. Yao *et al.* (2023)^[26] observed that seaweed extract derived from *Sargassum horneri* improved tomato yield by 4.6% to 6.9%, largely due to enhanced photosynthetic efficiency. The highest yield was achieved at an application rate of 60 kg·hm². Additionally, the treatment shortened the ripening period, enabling harvest during more favorable market windows, thereby increasing net economic returns by up to 13.6% compared to untreated plots. Building upon these findings, the present study confirms that the combined use of seaweed extract and *Trichoderma* sp. further improves economic outcomes by enhancing productivity, reducing crop cycle duration, and boosting resilience under field conditions.

Table 1(a): Response of biostimulants and biopesticides on growth parameters in tomato

Treatments		Plant height (cm)			Number of leaves/plant			Number of branches/plant		
		15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT
T ₀	Control	30.36	64.45	95.1	5.11	11.31	18.26	23.10	50.20	75.58
T ₁	Amino Acids @ 2 ml/L	32.43	67.32	97.90	5.41	12.19	19.26	25.37	54.07	77.31
T ₂	Seaweed Extracts @ 2 ml/L	33.08	69.38	98.79	5.57	12.37	19.50	25.93	54.70	77.82
T ₃	<i>Bacillus thuringiensis</i> @ 5 ml/L	31.14	65.60	95.43	5.22	11.54	18.69	23.73	52.62	76.10
T ₄	<i>Trichoderma</i> sp. @ 5 g/L	31.97	66.55	96.53	5.35	12.04	19.09	24.53	53.22	76.52
T ₅	Amino Acid @ 2 ml/L+ <i>Bacillus thuringiensis</i> @ 5 ml/L	33.20	69.87	99.8	5.65	12.60	19.63	26.30	55.18	78.31
T ₆	Amino Acid @ 2 ml/L+ <i>Trichoderma</i> sp. @ 5 g/L	33.87	70.12	100.72	5.76	12.78	19.70	26.77	55.40	78.88
T ₇	Seaweed Extracts @ 2 ml/L+ <i>Bacillus thuringiensis</i> @ 5 ml/L	34.66	70.74	101.25	5.85	12.97	19.93	27.00	56.20	79.48
T ₈	Seaweed Extracts @ 2 ml/L+ <i>Trichoderma</i> sp. @ 5 g/L	35.34	71.20	102.02	6.00	13.20	20.05	27.90	56.73	80.20
SEm ±		2.84	0.32	0.14	0.19	0.17	0.21	0.19	0.27	0.26
C.D. (at 5%)		8.28	0.93	0.40	0.54	0.50	0.62	0.54	0.78	0.76

Table 1(b): Response of biostimulants and biopesticides on growth parameters in tomato

Treatments		Internode length (cm)			Leaf Area (cm ²)			Leaf Area Index (LAI)		
		15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT
T ₀	Control	4.07	5.06	6.07	320.23	623.10	821.20	0.119	0.232	0.304
T ₁	Amino Acids @ 2 ml/L	4.48	5.73	6.55	383.88	680.42	910.49	0.129	0.249	0.336
T ₂	Seaweed Extracts @ 2 ml/L	4.53	5.90	6.64	397.29	694.74	930.64	0.131	0.253	0.344
T ₃	<i>Bacillus thuringiensis</i> @ 5 ml/L	4.13	5.10	6.29	340.53	630.66	841.84	0.123	0.238	0.319
T ₄	<i>Trichoderma</i> sp. @ 5 g/L	4.28	5.48	6.32	364.12	652.22	870.63	0.127	0.245	0.325
T ₅	Amino Acid @ 2 ml/L+ <i>Bacillus thuringiensis</i> @ 5 ml/L	4.69	6.04	6.72	400.56	718.06	957.16	0.138	0.259	0.350
T ₆	Amino Acid @ 2 ml/L+ <i>Trichoderma</i> sp. @ 5 g/L	4.73	6.10	6.80	429.00	748.70	980.30	0.153	0.265	0.367
T ₇	Seaweed Extracts @ 2 ml/L+ <i>Bacillus thuringiensis</i> @ 5 ml/L	4.94	6.37	6.90	452.77	761.20	1006.22	0.162	0.274	0.370
T ₈	Seaweed Extracts @ 2 ml/L+ <i>Trichoderma</i> sp. @ 5 g/L	5.03	6.50	7.05	477.26	781.34	1026.31	0.177	0.289	0.379
SEm ±		2.84	0.12	0.24	0.20	10.84	8.54	6.05	0.01	0.01
C.D. (at 5%)		8.28	0.34	0.71	0.57	31.52	24.81	17.58	0.02	0.03

Table 2: Response of biostimulants and biopesticides on phenological parameters in tomato

Treatments		Days to first flower initiation	Days to first picking	Days to first fruit set	Number of flowers/clusters	Number of flowers clusters/plant
T ₀	Control	25.12	81.55	39.21	6.07	9.08
T ₁	Amino Acids @ 2 ml/L	24.11	79.70	38.26	6.43	9.50
T ₂	Seaweed Extracts @ 2 ml/L	23.79	78.49	38.03	6.67	9.71
T ₃	<i>Bacillus thuringiensis</i> @ 5 ml/L	24.78	80.98	38.94	6.18	9.18
T ₄	<i>Trichoderma</i> sp. @ 5 g/L	24.59	80.11	38.53	6.26	9.36
T ₅	Amino Acid @ 2 ml/L+ <i>Bacillus thuringiensis</i> @ 5 ml/L	23.37	77.94	37.80	6.72	9.89
T ₆	Amino Acid @ 2 ml/L+ <i>Trichoderma</i> sp. @ 5 g/L	23.13	77.52	37.43	6.85	10.05
T ₇	Seaweed Extracts @ 2 ml/L+ <i>Bacillus thuringiensis</i> @ 5 ml/L	22.87	76.46	37.13	6.90	10.37
T ₈	Seaweed Extracts @ 2 ml/L+ <i>Trichoderma</i> sp. @ 5 g/L	22.05	75.24	36.85	7.00	10.51
SEm ±		0.36	0.31	0.20	0.08	0.21
C.D. (at 5%)		1.05	0.91	0.58	0.22	0.62

Table 3: Response of biostimulants and biopesticides on yield parameters in tomato.

Treatments		Number of fruits/plant	Average fruit weight/fruit (g)	Number of fruits/cluster	Fruit diameter (cm)	Yield/plant (kg)	Yield/plot (kg)	Yield/hectare (q)
T ₀	Control	25.34	50.11	3.03	4.50	1.27	20.27	422.42
T ₁	Amino Acids @ 2 ml/L	29.12	52.98	3.23	4.70	1.44	24.64	507.41
T ₂	Seaweed Extracts @ 2 ml/L	31.88	53.27	3.30	4.85	1.56	25.32	551.11
T ₃	<i>Bacillus thuringiensis</i> @ 5 ml/L	27.80	51.82	3.13	4.58	1.33	22.26	461.09
T ₄	<i>Trichoderma</i> sp. @ 5 g/L	28.35	52.37	3.20	4.66	1.37	23.52	479.92
T ₅	Amino Acid @ 2 ml/L+ <i>Bacillus thuringiensis</i> @ 5 ml/L	32.41	53.80	3.37	5.08	1.63	26.57	556.99
T ₆	Amino Acid @ 2 ml/L+ <i>Trichoderma</i> sp. @ 5 g/L	35.35	54.40	3.41	5.16	1.67	27.49	600.00
T ₇	Seaweed Extracts @ 2 ml/L+ <i>Bacillus thuringiensis</i> @ 5 ml/L	33.90	54.92	3.45	5.31	1.72	29.47	620.00
T ₈	Seaweed Extracts @ 2 ml/L+ <i>Trichoderma</i> sp. @ 5 g/L	34.78	55.01	3.50	5.51	1.91	30.61	637.84
SEm ±		0.29	0.29	0.08	0.21	0.21	0.12	0.30
C.D. (at 5%)		0.85	0.85	0.24	0.61	0.61	0.35	0.87

Table 4: Response of biostimulants and biopesticides on quality parameters in tomato

Treatments		TSS (°Brix)	Titration acidity (g/l)	Physiological loss in weight (%)	Ascorbic acid (mg/g)
T ₀	Control	3.37	4.08	18.16	18.03
T ₁	Amino Acids @ 2 ml/L	4.37	4.52	14.65	19.00
T ₂	Seaweed Extracts @ 2 ml/L	4.59	4.78	14.00	19.55
T ₃	<i>Bacillus thuringiensis</i> @ 5 ml/L	3.68	4.22	16.92	18.53
T ₄	<i>Trichoderma</i> sp. @ 5 g/L	4.11	4.43	15.54	18.86
T ₅	Amino Acid @ 2 ml/L+ <i>Bacillus thuringiensis</i> @ 5 ml/L	4.68	4.99	13.59	19.89
T ₆	Amino Acid @ 2 ml/L+ <i>Trichoderma</i> sp. @ 5 g/L	4.89	5.26	12.70	20.02
T ₇	Seaweed Extracts @ 2 ml/L+ <i>Bacillus thuringiensis</i> @ 5 ml/L	5.14	5.38	12.30	20.32
T ₈	Seaweed Extracts @ 2 ml/L+ <i>Trichoderma</i> sp. @ 5 g/L	5.21	5.57	11.26	20.76
SEm ±		0.35	0.27	0.69	0.49
C.D. (at 5%)		1.03	0.79	2.01	1.42

Table 5: Response of biostimulants and biopesticides on Disease intensity PDI (%) and pest incidence PPI (%) in tomato

Treatments		Disease intensity PDI (%)	Pest incidence PPI (%)
T ₀	Control	25.43	20.76
T ₁	Amino Acids @ 2 ml/L	23.11	17.21
T ₂	Seaweed Extracts @ 2 ml/L	22.14	16.88
T ₃	<i>Bacillus thuringiensis</i> @ 5 ml/L	24.70	19.55
T ₄	<i>Trichoderma</i> sp. @ 5 g/L	24.19	18.53
T ₅	Amino Acid @ 2 ml/L+ <i>Bacillus thuringiensis</i> @ 5 ml/L	21.26	16.30
T ₆	Amino Acid @ 2 ml/L+ <i>Trichoderma</i> sp. @ 5 g/L	20.32	15.72
T ₇	Seaweed Extracts @ 2 ml/L+ <i>Bacillus thuringiensis</i> @ 5 ml/L	19.89	15.39
T ₈	Seaweed Extracts @ 2 ml/L+ <i>Trichoderma</i> sp. @ 5 g/L	18.86	15.11
SEm ±		1.19	1.00
C.D. (at 5%)		3.47	2.90

Table 6: Response of biostimulants and biopesticides on economic parameters in tomato

S. No.	Cost of cultivation (Rs.)			Yield/hectare (q)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C
	Common cost	Extra cost	Total cost				
T ₀	1,03,000	0	1,03,000	422.42	4,22,240	3,19,240	1:3.1
T ₁	1,03,000	2480	1,05,480	507.41	5,07,410	4,01,930	1:3.8
T ₂	1,03,000	2530	1,05,530	551.11	5,51,110	4,55,580	1:4.2
T ₃	1,03,000	3970	1,06,970	461.09	4,61,090	3,54,120	1:3.3
T ₄	1,03,000	4020	1,07,020	479.92	4,97,920	3,90,900	1:3.6
T ₅	1,03,000	6450	1,09,450	556.99	5,66,990	4,75,540	1:4.1
T ₆	1,03,000	6500	1,09,500	600.00	6,00,000	4,90,500	1:4.4
T ₇	1,03,000	6800	1,09,800	620.00	6,20,000	5,10,200	1:4.6
T ₈	1,03,000	6500	1,09,500	637.84	6,37,840	5,28,340	1:4.8

Conclusion

The present investigation demonstrated that the combined application of Seaweed Extract @ 2 mL/L and *Trichoderma* sp. @ 5 g/L had a significant and positive influence on the growth, phenological, yield, quality, disease and pest resistance, and economic performance of tomato (*Solanum lycopersicum*). Among all treatments, T₈ consistently recorded the best results across all observed parameters, including plant height, leaf area, flowering, fruit setting, fruit yield, total soluble solids (TSS), ascorbic acid content, and reduced Percent Disease Intensity (PDI%) and Percent Pest Incidence (PPI%). The synergistic action of bioactive compounds present in seaweed extract and the beneficial effects of *Trichoderma* sp. contributed to enhanced nutrient uptake, improved plant physiology, stimulated defense mechanisms, and increased crop productivity. These outcomes not only enhanced tomato growth and yield but also improved fruit quality and minimized losses caused by biotic stress. Economically, the highest Benefit:Cost (B:C) ratio was recorded, indicating its superior profitability compared to other treatments. This suggests that the integration of seaweed extract and *Trichoderma* sp. can serve as a sustainable and eco-friendly alternative to conventional chemical inputs in tomato cultivation. Based on these findings, it can be concluded that the combined use of seaweed extract and *Trichoderma* sp. offers a promising strategy for improving the productivity, quality, and profitability of tomato under open-field conditions.

References

- Ahmed M, Ullah H, Piromsri K, Tisarum R, Cha-um S, Datta A. Effects of an *Ascophyllum nodosum* seaweed extract application dose and method on growth, fruit yield, quality, and water productivity of tomato under water-deficit stress. *S Afr J Bot.* 2022;151:95-107.
- Ali O, Ramsubhag A, Jayaraman J. Biostimulatory activities of *Ascophyllum nodosum* extract in tomato and sweet pepper crops in a tropical environment. *PLOS ONE.* 2019;14(5).
- Anonymous. Statista Research Department. 2023.
- Ashmawi EA, Abd Elwahed AHM, Awaad AHH. Evaluation of seaweed extract impact on growth and yield of tomato plants under salinity stress conditions. *Ann Agric Sci Moshtohor.* 2021;59(2):515-526.
- Brotman Y, Hernandez-Raquet G, Meir S, Viterbo A. *Trichoderma atroviride* P1 colonization of tomato plants enhances both direct and indirect defense barriers against insects. *Front Physiol.* 2022;10:813.
- Colla G, Roupheal Y, Canaguier R, Svecova E, Cardarelli M. Biostimulant action of a plant-derived protein hydrolysate produced through enzymatic hydrolysis. *Front Plant Sci.* 2014;5:448.
- Colla G, Cardarelli M, Bonini P, Roupheal Y. Foliar applications of protein hydrolysate, plant and seaweed extracts increase yield but differentially modulate fruit quality of greenhouse tomato. *HortScience.* 2017;52(9):1214-1220.
- Contreras-Cornejo HA, Macías-Rodríguez L, Cortés-Penagos C, López-Bucio J. *Trichoderma virens*, a plant beneficial fungus, enhances biomass production and promotes lateral root growth through an auxin-dependent mechanism in Arabidopsis. *Plant Physiol.* 2009;149(3):1579-1592.
- Fatimah S, Alimon H, Daud N. The effect of seaweed extract (*Sargassum* sp) used as fertilizer on plant growth of *Capsicum annuum* (chilli) and *Lycopersicon esculentum* (tomato). *Indones J Sci Technol.* 2018;3(2):115-123.
- Harman GE, Howell CR, Viterbo A, Chet I, Lorito M. *Trichoderma* species — opportunistic, avirulent plant symbionts. *Nat Rev Microbiol.* 2004;2(1):43-56.
- Hussain IH, Kasinadhuni N, Arioli T. The effect of seaweed extract on tomato plant growth, productivity and soil. *J Plant Nutr.* 2021;33:1305-1314.
- Jalali P, Roosta HR, Khodadadi M, Torkashvand AM, Ghanbari Jahromi M. Effects of brown seaweed extract, silicon, and selenium on fruit quality and yield of tomato under different substrates. *PLOS ONE.* 2022;17(12).
- Khan MY, Haque MM, Molla AH, Rahman MM, Alam MZ. Antioxidant compounds and minerals in tomatoes by *Trichoderma*-enriched biofertilizer and their relationship with the soil environments. *J Integr Agric.* 2017;16(3):691-700.
- Lanzuise S, Manganiello G, Guastaferrero VM, Vincenzo C, Vitaglione P, Ferracane R, et al. Combined biostimulant applications of *Trichoderma* spp. with fatty acid mixtures improve biocontrol activity, horticultural crop yield, and nutritional quality. *Agronomy.* 2022;12(2):275.
- Li RX, Cai F, Pang G, Shen QR, Li R, Chen W. Solubilization of phosphate and micronutrients by *Trichoderma harzianum* and its relationship with tomato plant growth. *Acta Agric Scand B Soil Plant Sci.* 2015;65(1):27-36.
- Muhorakeye MC, Namikoye ES, Khamis FM, Akutse KS. Biostimulant and antagonistic potential of endophytic fungi against Fusarium wilt pathogen of tomato (*Fusarium oxysporum* f. sp. *lycopersici*). *Sci Rep.* 2024;14:66101.

17. Pohl A, Kalisz A, Sekara A. Seaweed extracts' multifactorial action: Influence on physiological and biochemical status of Solanaceae plants. *Acta Agrobot.* 2019;72:1999.
18. Ramesh S, Kumar P, Singh A. Effect of seaweed extract and *Trichoderma* spp. on growth and yield of tomato (*Solanum lycopersicum* L.). *J Plant Protect Environ.* 2022;19(3):145-153.
19. Sanap PB, Nigade PM, Thaware BG. Bio-efficacy of Opteine-seaweed Extract in Promoting Growth and Yield of Chilli and Tomato. *J Indian Soc Coast Agric Res.* 2019;37(1):92-95.
20. Sharma HSS, Fleming C, Selby C, Rao JR, Martin T. Plant biostimulants: A review on the processing of macroalgae and use of extracts for crop management to reduce abiotic and biotic stresses. *J Appl Phycol.* 2014;26(1):465-490.
21. Sridhar V, Naik SO, Nitin KS, Asokan R, Swathi P, Gadad H. Efficacy of integrated pest management tools evaluated against *Tuta absoluta* (Meyrick) on tomato in India. *J Biol Control.* 2019;33(3):264-270.
22. Silva LD, Bahcevandziev K, Pereira L. Production of bio-fertilizer from *Ascophyllum nodosum* and *Sargassum muticum* (Phaeophyceae). *J Oceanol Limnol.* 2019;37:918-927.
23. Soares C, Švarc-Gajić J, Oliva-Teles MT, Pinto E, Nastić N, Savić S, *et al.* Mineral composition of subcritical water extracts of *Saccorhiza polyschides*, a brown seaweed used as fertilizer in the north of Portugal. *J Mar Sci Eng.* 2020;8:244.
24. Subramaniyan L, Veerasamy R, Prabhakaran J, Selvaraj A, Alagarwamy S, Karuppasami KM, *et al.* Biostimulation effects of seaweed extract (*Ascophyllum nodosum*) on phytomorpho-physiological, yield, and quality traits of tomato (*Solanum lycopersicum* L.). *Horticulturae.* 2023;9(3):348.
25. Uddin AFMJ, Hussain MS, Rahman SS, Ahmad H, Roni MZK. Effect of *Trichoderma* concentrations on growth and yield of tomato. *Bangladesh Res Publ J.* 2015;11(3):228-232.
26. Yao Y, Wang X, Chen B, Zhang M, Ma J. Seaweed extract improved yields, leaf photosynthesis, ripening time, and net returns of tomato (*Solanum lycopersicum* Mill.). *ACS Omega.* 2020;5(8):4242-4249.
27. Yildiz Dasgan H, Aksu KS, Zikaria K, Gruda NS. Biostimulants enhance the nutritional quality of soilless greenhouse tomatoes. *Plants.* 2024;13(18):2587.