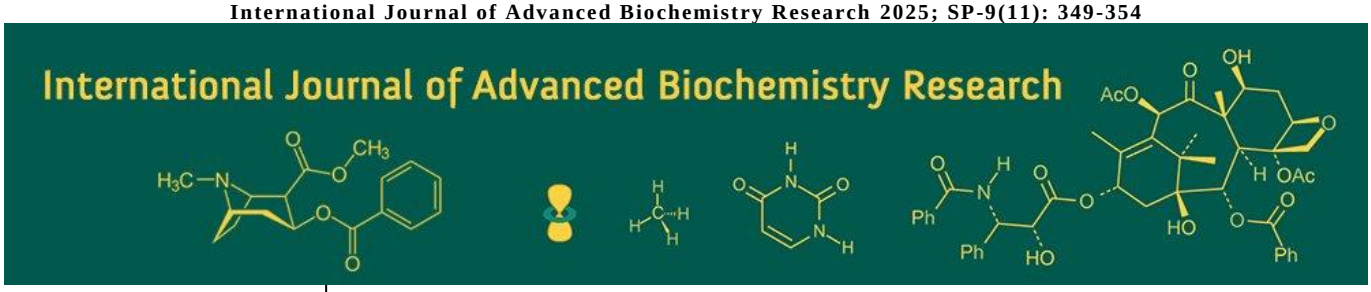

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Comparative assessment on effect of seaweed extracts and levels of RDF on growth, yield and economics of tomato (*Solanum lycopersicum* L.) var. Saaho

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Abstract
The study was conducted during the Rabi seasons of 2023-24 and 2024-25 at the Horticultural Research Farm, SHUATS, Prayagraj, to evaluate the effect of foliar-applied seaweed extracts with Recommended Dose of Fertilizer (RDF) on tomato growth and yield. The experiment, arranged in a Randomized Block Design with 15 treatments and three replications, included 50% and 100% RDF combined with K-SAP and S-SAP at 2%, 4%, and 6%, along with controls. Results showed that T_{14} (100% RDF + 6% S-SAP) recorded maximum plant height (129.90 cm), branches (14.43), early flowering (57.11 days), and highest fruit yield (5.95 kg/plant) and maximum economic returns (₹5,02,918 ha^{-1}) with a benefit-cost ratio of 7.03, followed by T_{11} (100% RDF + 6% K-SAP). The superior performance of T_{14} was attributed to growth-promoting compounds and micronutrients in S-SAP, which enhanced nutrient uptake and efficiency. Minimal seasonal variation confirmed result stability. The findings suggest that integrating seaweed extracts with RDF can sustainably improve tomato growth, yield, and quality.

Keywords: Tomatoes, K SAP, S SAP, seaweed extract

Introduction
Tomato (*Solanum lycopersicum* L.) is one of the most significant horticultural crops bearing chromosome number of 2n=2X=24 (Fedorov, 1969) [5], with a global production exceeding 138 million metric tonnes. Taxonomically, it belongs to the Solanaceae family, with *Solanum pimpinellifolium* recognized as its closest wild relative (Preedy and Watson, 2008) [12]. Tomato is a globally significant vegetable, ranking second in both production and consumption. In the United States, it is the second most consumed fresh vegetable, with an annual per capita intake of 6-7 kg (FAOSTAT, 2020) [4]. Tomatoes are renowned for their rich nutritional profile, offering an abundant source of essential vitamins, minerals, and bioactive compounds. They provide significant amounts of vitamin C, pro-vitamin A, β-carotene, and folate, along with vital minerals such as potassium. Additionally, they are rich in secondary metabolites, including lycopene, flavonoids, phytosterols, and polyphenols, which contribute to their health-promoting properties (Luthria *et al.* 2006) [11]. Excessive fertilizer use contributes to water pollution through surface runoff, as rainfall erodes chemically treated soils, carrying nitrogen and phosphorus into water bodies. This non-point source pollution leads to eutrophication and the formation of "dead zones" in rivers, lakes, and oceans, depleting oxygen levels and threatening aquatic ecosystems (Singh *et al.* 2017) [15]. Furthermore, chemical pesticides not only target harmful pests but also pose risks to non-target plant and animal species, including humans. Concerns over pesticide residues in food, groundwater contamination, and biodiversity loss have amplified the need for safer agricultural practices. To mitigate these detrimental effects, recent agricultural practices are increasingly incorporating natural plant-based fertilizers. Among these, seaweed-based bio-fertilizers have gained significant attention for their eco-friendly properties. Seaweed extracts, rich in essential nutrients, bioactive compounds, and growth-promoting hormones, offer a sustainable alternative to synthetic fertilizers (Hong *et al.* 2007) [8]. Unlike chemical inputs, seaweed fertilizers are biodegradable, non-toxic, and environmentally benign, posing no threat to humans, animals, or birds (Begum *et al.* 2018) [1]. Thus, the adoption of natural bio-fertilizers is a promising step towards sustainable agriculture, promoting soil health and

reducing chemical dependency. Therefore, evaluating growth and yield of tomatoes using seaweed extracts becomes crucial, as it offers a potential solution to overcome nutrient deficiencies, reduce chemical dependency, and promote sustainable agricultural practices, ultimately ensuring food security and environmental sustainability.

Materials and Methods

The present investigation was meticulously carried out at the Horticultural Research Farm of the Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, Uttar Pradesh, during the Rabi seasons of 2023-24 and 2024-25. The distinguished university is strategically situated approximately 5 kilometres from Prayagraj City, along the Prayagraj-Rewa National Highway, offering convenient accessibility. In the present investigation the design used for analysis of variables was Randomized Block Design (RBD) comprising 3 replications comprising of foliar application of micronutrients total treatment combinations being fifteen. The treatments comprised T_0 (Control); T_1 (50% RDF + Water Spray); T_2 (100% RDF + Water Spray); T_3 (50% RDF + 2% K SAP); T_4 (50% RDF + 4% K SAP); T_5 (50% RDF + 6% K SAP); T_6 (50% RDF + 2% S SAP); T_7 (50% RDF + 4% S SAP); T_8 (50% RDF + 6% S SAP); T_9 (100% RDF + 2% K SAP); T_{10} (100% RDF + 4% K SAP); T_{11} (100% RDF + 6% K SAP); T_{12} (100% RDF + 2% S SAP); T_{13} (100% RDF + 4% S SAP) and T_{14} (100% RDF + 6% S SAP). Characters like Plant height (cm) [90 and 120 DAT]; number of branches per plant [90 and 120 DAT], days to 50% flowering, number of fruits per plant, days to first harvest and average fruit weight (gm), fruit diameter (cm), number of fruit per plant and Yield per plant (kg/plant) were observed. Analysis of Variance was worked out using Fisher and Yates (1967) [6].

Results and Discussion

Plant height and Number of branches per plant

Among the different treatments applied, T_{14} (100% RDF + 6% S SAP) showed maximum height of plant [Table 1] at 90 DAT (105.95, 106.92 and 106.43 cm) followed by T_{11} (100% RDF + 6% K SAP) having 99.54, 99.37 and 99.46 cm for both year 2023-24, 2024-25 and pooled mean respectively. However, minimum height of plant (64.88, 68.06 and 66.47 cm) at 90 DAT was observed in T_0 (Control). Among the different treatments applied, T_{14} (100% RDF + 6% S SAP) showed maximum number of branches per plant [Table 1] at 90 DAT (11.90, 10.35 and 11.13 branches) followed by T_{11} (100% RDF + 6% K SAP) having 11.00, 10.08 and 10.54 branches for both year 2023-24, 2024-25 and pooled mean respectively. However, minimum number of branches per plant (5.65, 4.48 and 5.06 branches) at 90 DAT was observed in T_0 (Control).

Evaluation of the interaction effect over the two years revealed that its magnitude was relatively low, indicating minimal variation in treatment performance between the years. This small interaction effect also suggests that the treatment rankings remained largely consistent across both years. Consequently, the interaction can be regarded as non-significant and negligible, implying that the treatment effects derived from the pooled analysis are generally stable and dependable. The findings for plant height and number of branches per plant in tomato demonstrated superior performance under treatment T_{14} (100% RDF + 6% S SAP), followed by T_{11} (100% RDF + 6% K SAP), indicating the positive influence of liquid seaweed extract. The enhanced growth in T_{14} may be attributed to the presence of essential micronutrients, plant growth hormones, and bioactive compounds in S SAP, which likely promoted cell elongation and division. Similarly, K SAP also contributed to improved vegetative growth in T_{11}. Both treatments provided a synergistic effect with RDF, enhancing nutrient uptake and physiological processes, thereby outperforming all other treatments in terms of plant height. Hernandez-Herrera *et al*. (2013) [7] working with seaweed extracts application on tomatoes revealed SLF to be effective biostimulants to improve tomato growth, highlighting the potential of Mexican seaweed resources for sustainable agricultural practices. Similarly, Selvakumari *et al*. (2013) [13] reported improved tomatoes growth through the combined RDF with seaweed extracts, highlighting the significant role of secondary and micronutrients in optimizing crop productivity across different cropping systems.

Days to 50% flowering and days to first harvest

Among the various treatments applied, T_{14} (100% RDF + 6% S SAP) exhibited the earliest flowering [Table 2], recording 58.95, 55.27, and 57.11 days to 50% flowering during the years 2023-24, 2024-25, and in the pooled mean, respectively. This was closely followed by T_{11} (100% RDF + 6% K SAP), which took 59.74, 55.75, and 57.75 days across the same periods. Among all treatments, T_{14} (100% RDF + 6% S SAP) resulted in the earliest harvest [Table 2], recording 98.57 days in 2023-24, 94.80 days in 2024-25, and a pooled mean of 96.69 days. This was followed closely by T_{11} (100% RDF + 6% K SAP), which achieved harvest at 99.36, 95.59, and 97.48 days, respectively. The observed earliness in these treatments is likely due to the presence of bioactive constituents such as auxins, cytokinins, and micronutrients in the seaweed extracts, which stimulate growth, accelerate flowering, and enhance overall physiological development. The combined application with RDF likely ensured optimal nutrient availability and uptake, further promoting earlier maturity. In contrast, the control treatment T_0 showed the latest harvest (113.42, 111.10, and 112.26 days), reflecting delayed growth due to the absence of nutritional supplementation. These results clearly highlight the positive impact of seaweed liquid SAP—especially when integrated with recommended fertilizer doses—on reducing the time to marketable harvest, thereby improving the productivity and profitability of tomato cultivation. Hussain *et al*. (2021) [9] investigated the effects of seaweed extract (SWE) derived from brown algae *Durvillaeapotatorum* and *Ascophyllum nodosum* on tomato plants and reported earliness in maturity in fruits.

Number of fruits per plant

Among the treatments assessed, T_{14} (100% RDF + 6% S SAP) emerged as the most effective, recording the highest number of fruits per plant—67.29 in 2023-24, 86.10 in 2024-25, and a pooled average of 76.70 fruits [Table 2]. This remarkable enhancement in fruit set is largely attributed to the presence of bioactive compounds in the S SAP-based liquid seaweed extract, such as auxins, cytokinins, gibberellins, amino acids, and essential

micronutrients. These constituents are known to stimulate reproductive development by promoting floral differentiation, enhancing flower viability, improving pollen germination, and facilitating successful fertilization. The synergistic interaction between the seaweed extract and the recommended dose of fertilizers (RDF) likely enhanced nutrient assimilation and hormonal equilibrium, thereby boosting fruit-setting potential. T_{11} (100% RDF + 6% K SAP) also demonstrated commendable results, yielding 56.80, 79.15, and 67.97 fruits per plant during the respective years. The potassium-enriched SAP was instrumental in supporting flower retention, optimizing energy transfer, and enhancing carbohydrate metabolism—all critical processes for robust fruit development. Conversely, the control treatment (T_0) registered the lowest fruit count—19.14, 18.98, and 19.06 fruits—highlighting the pivotal role of integrated nutrient management, particularly the application of liquid seaweed extracts, in significantly improving the reproductive efficiency and productivity of tomato plants. Youssif and Tawfeeq (2021) [9] in cauliflower and Vijayanand *et al*. (2023) [18] in cluster bean put forward the effectiveness of Seaweed extract application for enhancement of fruiting in crops.

Fruit diameter, fruit weight and fruit yield per plant and per hectare

Among the various treatments administered, T_{14} (100% RDF + 6% S SAP) recorded the largest fruit diameter, with values of 7.30 cm in 2023-24, 7.91 cm in 2024-25, and a pooled mean of 7.60 cm. This was closely followed by T_{11} (100% RDF + 6% K SAP), which achieved fruit diameters of 6.82, 7.45, and 7.13 cm, respectively [Table 3], over the same periods. In contrast, the smallest fruit diameter was observed in the control treatment (T_0), which registered 4.91 cm, 5.20 cm, and a pooled average of 5.06 cm. Among the various treatments administered, T_{14} (100% RDF + 6% S SAP) recorded the largest fruit weight, with values of 79.65 grams in 2023-24, 76.16 grams in 2024-25, and a pooled mean of 77.91 grams [Table 3]. This was closely followed by T_{11} (100% RDF + 6% K SAP), which achieved fruit weights of 74.90, 70.79 and 72.84 grams, respectively, over the same periods. In contrast, the smallest fruit weight was observed in the control treatment (T_0), which registered 45.73 grams, 43.10 grams, and a pooled average of 44.41 grams. Among the treatments evaluated, T_{14} (100% RDF + 6% S SAP) demonstrated the highest fruit yield per plant [Table 3], recording 5.35 kg/plant in 2023-24, 6.55 kg/plant in 2024-25, and an average of 5.95 kg/plant. T_{11} (100% RDF + 6% K SAP) followed closely, yielding 4.26, 5.60, and 4.93 kg/plant during the same periods. Conversely, the control treatment (T_0) exhibited the lowest yields, with figures of 0.89 kg/plant, 0.82 kg/plant, and an average of 0.85 kg/plant. Among the treatments evaluated, T_{14} (100% RDF + 6% S SAP) demonstrated the highest fruit yield per hectare [Table 3], recording 1154.88 q/ha in 2023-24, 1190.14 q/ha in 2024-25, and an average of 1172.51 q/ha. T_{11} (100% RDF + 6% K SAP) followed closely, yielding 986.78, 1154.01 and 1070.39 q/ha during the same periods. Conversely, the control treatment (T_0) exhibited the lowest yields, with figures of 141.93 q/ha, 164.04 q/ha, and an average of 152.98 q/ha. An analysis of the interaction effect over the two years revealed a relatively low magnitude, indicating minimal variation in treatment responses from year to year. This limited interaction effect suggests that the performance rankings of the treatments were largely consistent across both seasons, leading to the conclusion that the interaction effect is statistically non-significant and practically negligible, thereby reinforcing the reliability and stability of the pooled analysis results. The exceptional fruit yield observed in T_{14} (100% RDF + 6% S SAP) can be credited to the collaborative effects of vital nutrients and bioactive substances found in S SAP, including auxins, cytokinins, and amino acids. These components significantly improve flowering, fruit set, and nutrient absorption. When paired with RDF, they enhance plant growth and reproductive success, resulting in higher yields. Similarly, T_{11} (100% RDF + 6% K SAP) exhibited remarkable results, largely due to potassium's contribution to carbohydrate metabolism, water management, and flower retention. Both treatments surpassed all others by promoting superior physiological functions and nutrient uptake, highlighting the advantages of combining seaweed extracts with RDF to optimize tomato yield. Kharbyngar and Singh (2019) [10] in cauliflower demonstrated the cost-effective enhancement of fruit yields using a mixture seaweed extracts along with recommended fertilizer dose applied as foliar spray.

Economics Parameter

Maximum gross returns were recorded in treatment T_{14} (100% RDF + 6% S SAP) with (Rs 5,77,438; Rs 5,95,072 and Rs 5,86,255 ha^{-1}) for year 2024, 2025 and mean respectively [table 4] followed by T_{11} (100% RDF + 6% K SAP) with (Rs 4,93,390; Rs 5,77,003 and Rs 5,35,196 ha^{-1}) for year 2024, 2025 and mean respectively and the minimum (Rs70, 966; Rs 82,018 and Rs 76,492 ha^{-1}) was recorded in treatment T_0 (Control) for year 2024, 2025 and mean respectively. Maximum net returns were recorded in treatment T_{14} (100% RDF + 6% S SAP) with (Rs 4,94,101; Rs 5,11,735 and Rs 5,02,918 ha^{-1}) for year 2024, 2025 and mean respectively followed by T_{11} (100% RDF + 6% K SAP) with (Rs 4,10,101; Rs 4,93,714 and Rs 4,51,907 ha^{-1}) for year 2024, 2025 and mean respectively and the minimum (loss of Rs9,107 in year 2024; Rs 1,945 in year 2025 and overall loss of Rs 3,581 ha^{-1}) was recorded in treatment T_0 (Control). Maximum benefit cost ratio was recorded in treatment T_{14} (100% RDF + 6% S SAP) with (6.93, 7.14 and 7.03ha^{-1}) for year 2024, 2025 and mean respectively followed by T_{11} (100% RDF + 6% KSAP) with (5.92, 6.93 and 6.43ha^{-1}) for year 2024, 2025 and mean respectively and the minimum (0.89, 1.02 and 0.96ha^{-1}) was recorded in treatment T_0 (Control) for year 2024, 2025 and pooled mean respectively.

Table 1: Comparative Assessment on effect of Seaweed Extracts and levels of RDF for plant height and number of branches per plant of tomato at 90 DAT.

Treatment Details		Plant height (cm) [90 DAT]			Number of branches per plant [90 DAT]		
		2023-24	2024-25	Pooled Mean	2023-24	2024-25	Pooled Mean
T_0	Control	64.88	68.06	66.47	5.65	4.48	5.06
T_1	50% RDF + Water Spray	81.93	83.70	82.82	6.23	5.51	5.87
T_2	100% RDF + Water Spray	87.93	89.70	88.82	6.85	6.30	6.57
T_3	50% RDF + 2% K SAP	91.91	93.68	92.80	8.47	8.30	8.39
T_4	50% RDF + 4% K SAP	93.94	95.71	94.83	9.56	7.28	8.42
T_5	50% RDF + 6% K SAP	95.68	97.45	96.57	9.62	6.97	8.29
T_6	50% RDF + 2% S SAP	91.46	93.23	92.35	9.67	7.04	8.36
T_7	50% RDF + 4% S SAP	92.02	93.79	92.91	8.97	6.77	7.87
T_8	50% RDF + 6% S SAP	93.24	95.01	94.13	9.17	6.97	8.07
T_9	100% RDF + 2% K SAP	91.04	92.81	91.93	7.43	5.49	6.46
T_{10}	100% RDF + 4% K SAP	91.83	93.60	92.72	8.30	6.10	7.20
T_{11}	100% RDF + 6% K SAP	99.54	99.37	99.46	11.00	10.08	10.54
T_{12}	100% RDF + 2% S SAP	91.35	93.12	92.24	9.25	7.05	8.15
T_{13}	100% RDF + 4% S SAP	93.91	95.68	94.80	10.25	9.93	10.09
T_{14}	100% RDF + 6% S SAP	105.95	106.92	106.43	11.90	10.35	11.13
SE. m (±)		1.98	1.89	1.72	0.30	0.44	0.26
$CD_{0.05}$		5.73	5.48	5.00	0.87	1.26	0.75
CV. (%)		4.84	4.57	4.19	5.89	10.41	5.61

Table 2: Comparative Assessment on effect of Seaweed Extracts and levels of RDF for Days to 50% flowering, Number of fruits per plant and Days to first marketable harvest of Tomato

Treatment Details		Days to 50% flowering			Number of fruits per plant			Days to first marketable harvest		
		2023-24	2024-25	Pooled Mean	2023-24	2024-25	Pooled Mean	2023-24	2024-25	Pooled Mean
T_0	Control	71.30	68.24	69.77	19.14	18.98	19.06	113.42	111.10	112.26
T_1	50% RDF + Water Spray	69.29	66.71	68.00	21.34	25.03	23.18	110.92	107.15	109.04
T_2	100% RDF + Water Spray	66.40	66.29	66.35	24.66	36.88	30.77	106.02	102.25	104.14
T_3	50% RDF + 2% K SAP	60.34	57.05	58.69	41.35	65.46	53.41	102.04	97.98	100.01
T_4	50% RDF + 4% K SAP	65.95	56.05	61.00	42.20	60.08	51.14	105.57	101.80	103.69
T_5	50% RDF + 6% K SAP	67.06	62.27	64.67	42.22	64.04	53.13	106.68	102.91	104.80
T_6	50% RDF + 2% S SAP	66.95	63.38	65.17	32.92	62.43	47.68	106.57	102.80	104.69
T_7	50% RDF + 4% S SAP	67.73	63.27	65.50	38.22	52.80	45.51	107.35	103.58	105.47
T_8	50% RDF + 6% S SAP	69.40	64.05	66.73	40.78	59.43	50.10	109.02	105.25	107.14
T_9	100% RDF + 2% K SAP	65.32	62.72	64.02	26.92	39.31	33.11	104.94	101.17	103.06
T_{10}	100% RDF + 4% K SAP	62.20	61.64	61.92	34.30	41.51	37.90	101.82	98.05	99.94
T_{11}	100% RDF + 6% K SAP	59.74	55.75	57.75	56.80	79.15	67.97	99.36	95.59	97.48
T_{12}	100% RDF + 2% S SAP	60.82	56.06	58.44	39.13	67.36	53.24	100.44	96.67	98.56
T_{13}	100% RDF + 4% S SAP	60.84	57.14	58.99	51.87	58.53	55.20	100.46	96.69	98.58
T_{14}	100% RDF + 6% S SAP	58.95	55.27	57.11	67.29	86.10	76.70	98.57	94.80	96.69
SE. m (±)		0.87	0.59	0.48	1.54	1.72	1.25	1.44	1.22	0.89
$CD_{0.05}$		2.52	1.72	1.39	4.46	4.97	3.62	4.18	3.53	2.58
CV.%		2.33	1.68	1.32	6.90	5.46	4.65	2.38	2.09	1.49

Table 3: Comparative Assessment on effect of Seaweed Extracts and levels of RDF of tomato for various yield parameters

Treatment Details		Fruit diameter (cm)			Fruit weight (grams)			Fruit yield per plant (kg/plant)			Fruit yield per hectare (q/ha)		
		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_0	Control	4.91	5.20	5.06	45.73	43.10	44.41	0.89	0.82	0.85	141.93	164.04	152.98
T_1	50% RDF + Water Spray	5.72	6.63	6.17	53.93	50.90	52.41	1.15	1.27	1.21	425.50	476.75	451.12
T_2	100% RDF + Water Spray	5.82	6.95	6.38	62.89	56.30	59.60	1.55	2.08	1.81	574.46	663.52	618.99
T_3	50% RDF + 2% K SAP	5.95	7.37	6.66	59.00	56.11	57.56	2.44	3.70	3.07	903.87	598.76	751.32
T_4	50% RDF + 4% K SAP	6.05	7.17	6.61	55.83	57.88	56.85	2.36	3.47	2.92	872.72	633.13	752.92
T_5	50% RDF + 6% K SAP	6.25	7.32	6.78	56.47	58.26	57.37	2.39	3.73	3.06	883.36	688.86	786.11
T_6	50% RDF + 2% S SAP	6.05	7.14	6.59	53.90	56.15	55.02	1.77	3.50	2.64	656.65	571.76	614.20
T_7	50% RDF + 4% S SAP	6.23	7.56	6.89	53.90	56.78	55.34	2.06	2.99	2.53	763.47	637.40	700.43
T_8	50% RDF + 6% S SAP	6.40	7.96	7.18	57.19	58.37	57.78	2.33	3.47	2.90	861.89	718.31	790.10
T_9	100% RDF + 2% K SAP	6.27	7.22	6.74	65.45	64.15	64.80	1.76	2.52	2.14	652.49	727.47	689.98
T_{10}	100% RDF + 4% K SAP	5.82	7.31	6.56	68.78	66.23	67.51	2.36	2.75	2.56	874.99	932.91	903.95
T_{11}	100% RDF + 6% K SAP	6.82	7.45	7.13	74.90	70.79	72.84	4.26	5.60	4.93	986.78	1,154.01	1,070.39
T_{12}	100% RDF + 2% S SAP	6.47	7.22	6.84	68.20	63.16	65.68	2.67	4.25	3.46	457.77	674.17	565.97
T_{13}	100% RDF + 4% S SAP	5.58	7.69	6.63	70.90	64.61	67.76	3.67	3.79	3.73	658.59	796.81	727.70
T_{14}	100% RDF + 6% S SAP	7.30	7.91	7.60	79.65	76.16	77.91	5.35	6.55	5.95	1,154.88	1,190.14	1,172.51
SE. m (±)		0.15	0.28	0.16	1.58	1.89	1.33	0.11	0.16	0.10	27.23	41.49	26.06
$CD_{0.05}$		0.44	0.81	0.47	4.59	5.49	3.85	0.31	0.47	0.30	78.89	120.18	75.49
CV.%		4.27	6.74	4.20	4.44	5.47	3.79	7.61	8.34	6.21	6.51	10.14	6.30

Table 4: Comparative Assessment on effect of Seaweed Extracts and levels of RDF for economic parameters of Tomato

Treatment symbol	Description	Total cost of cultivation (INR)	Gross Return (INR)			Net Return (INR)			BC ratio		
			2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
T_0	Control	80,073	70,966	82,018	76,492	-9,107	1,945	-3,581	0.89	1.02	0.96
T_1	100% RDF + Water Spray	82,809	2,12,751	2,38,373	2,25,562	1,29,942	1,55,564	1,42,753	2.57	2.88	2.72
T_2	50% RDF + Water Spray	81,441	2,87,231	3,31,761	3,09,496	2,05,790	2,50,320	2,28,055	3.53	4.07	3.80
T_3	100% RDF + 2% K SAP	81,601	4,51,937	2,99,380	3,75,658	3,70,336	2,17,779	2,94,057	5.54	3.67	4.60
T_4	100% RDF + 4% K SAP	81,761	4,36,358	3,16,565	3,76,462	3,54,597	2,34,804	2,94,701	5.34	3.87	4.60
T_5	100% RDF + 6% K SAP	81,921	4,41,682	3,44,430	3,93,056	3,59,761	2,62,509	3,11,135	5.39	4.20	4.80
T_6	100% RDF + 2% S SAP	81,617	3,28,324	2,85,878	3,07,101	2,46,707	2,04,261	2,25,484	4.02	3.50	3.76
T_7	100% RDF + 4% S SAP	81,793	3,81,733	3,18,700	3,50,216	2,99,940	2,36,907	2,68,423	4.67	3.90	4.28
T_8	100% RDF + 6% S SAP	81,969	4,30,945	3,59,157	3,95,051	3,48,976	2,77,188	3,13,082	5.26	4.38	4.82
T_9	50% RDF + 2% K SAP	82,969	3,26,247	3,63,737	3,44,992	2,43,278	2,80,768	2,62,023	3.93	4.38	4.16
T_{10}	50% RDF + 4% K SAP	83,129	4,37,497	4,66,455	4,51,976	3,54,368	3,83,326	3,68,847	5.26	5.61	5.44
T_{11}	50% RDF + 6% K SAP	83,289	4,93,390	5,77,003	5,35,196	4,10,101	4,93,714	4,51,907	5.92	6.93	6.43
T_{12}	50% RDF + 2% S SAP	82,985	2,28,887	3,37,083	2,82,985	1,45,902	2,54,098	2,00,000	2.76	4.06	3.41
T_{13}	50% RDF + 4% S SAP	83,161	3,29,297	3,98,406	3,63,852	2,46,136	3,15,245	2,80,691	3.96	4.79	4.38
T_{14}	50% RDF + 6% S SAP	83,337	5,77,438	5,95,072	5,86,255	4,94,101	5,11,735	5,02,918	6.93	7.14	7.03
Selling price of Tomatoes Rs 5.50/kg											

Conclusions

The study clearly demonstrated that the combined application of 100% Recommended Dose of Fertilizers (RDF) with seaweed-based biostimulants, particularly 6% S SAP (T_{14}), significantly enhanced the vegetative and reproductive growth parameters of tomato plants across two consecutive years. T_{14} consistently outperformed all other treatments in plant height, number of branches per plant, earliness to flowering and harvesting, number of fruits per plant, fruit size, weight, and ultimately fruit yield per plant. The superiority of T_{14} is attributed to the presence of growth-promoting compounds such as auxins, cytokinins, gibberellins, amino acids, and essential micronutrients in the S SAP, which synergistically improved nutrient uptake, physiological processes, and hormonal balance when applied alongside RDF. T_{11} (100% RDF + 6% K SAP) also demonstrated considerable improvement in growth and yield attributes, largely due to potassium's role in enhancing energy transfer and metabolic activities. Economically, T_{14} proved the most profitable, with the highest net returns (₹ 5,02,918 ha^{-1}) and benefit-cost ratio (7.03), reinforcing its viability for commercial adoption. The findings strongly support integrating seaweed extracts, particularly S SAP, with RDF as a sustainable, cost-effective approach to improving tomato productivity and profitability.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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