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RESEARCH ARTICLE

Influence of biostimulants on growth and yield attributes of tomato (*Solanum lycopersicum* L.)

Armita Parida[1*] & Eggadi Ramesh[2]

[1]Department of Horticulture, M S Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi 761 211, Odishsa, India

[2]Department of Horticulture, Centurion School of Smart Agriculture, Centurion University of Technology and Management, Vizianagaram 535 003, Andhra Pradesh, India

*Correspondence email - armitaparida@gmail.com

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Abstract

Being a natural repository of health-promoting nutrients and economically significant crop, tomato (*Solanum lycopersicum* L.) plays a significant role in Indian agroeconomy. Though production is high, difficulties persist owing to imbalanced chemical usage and limited awareness of sustainable inputs. To address this, the research was conducted during Rabi 2023–24 and 2024–25 at Post Graduate Research Farm, Centurion University of Technology and Management, Paralakhemundi, Odisha to assess the impact of biostimulants with recommended dose of fertilizers on growth and yield. The experiment employed randomized block design (10 treatments), including panchagavya, jeevamruta, seaweed extract and fish jaggery extract, applied individually and in conjuction with 100 % recommended dose of fertilizers (RDF). Data on morphology and yield traits were recorded and statistically analyzed. Among the treatments, T_8 recorded highest fruit yield per plant (3.882 kg), yield per m^2 (4.26 kg/m^2) and yield per hectare (42.6 t ha^{-1}) surpassing the control plot. T_3 improved plant height and flower clusters. T_6 produced the thickest stems, while T_{10} showed early flowering and maximum branching. The research highlighted the synergistic effects of bioenhancers and chemical fertilizers. Panchagavya and jeevamruta contributed growth hormones, beneficial microbes and enzymes that enhanced nutrient uptake and photosynthetic activity. Fish jaggery extract and seaweed extract boosted chlorophyll and soil nutrient cycling. Thus, the finding indicates that the integrated approach, combining 3 % panchagavya and 3% jeevamruta with RDF (T_8) significantly optimized the performance of tomato. This investigation recommends such combinations for biocompatible and high-productivity cultivation, emphasizing its potential in sustainable horticulture.

Keywords: biostimulants; growth; sustainable horticulture; Tomato; yield

Introduction

The crop tomato botanically termed as *Solanum lycopersicum* L. is significantly crucial to the Indian agroeconomic sector. The plant is a dicotyledonous, herbaceous and pubescent annual species associated with the Solanaceae family. It is diploid in nature (2n = 24). It is presumed to be originated in the Andean region of South America then gradually spread worldwide (1). The worldwide tomato production reached to an impressive 192 million metric tonnes in 2023, according to FAO statistical yearbook 2023 (2). Remarkably China ranks number one yielding approximately 68.2 million metric tonnes while India occupies second place with a spectacular production of 20.7 million metric tonnes.

Tomatoes are highly nutrient dense being a repository of numerous beneficial compounds. The major bioactive compounds include carotenoids such as lycopene, which exhibit cancer-inhibiting properties; carotene, which is advantageous for eye health and lutein, which has therapeutic effect against cardiovascular diseases. The vitamin profile of tomato is noteworthy, containing vitamin C, which plays a key role in lowering cholesterol level. Additionally, folates expertly modulate homocysteine metabolism. Among phenolic compounds it possesses flavonoids which exhibits antioxidant and anti-inflammatory properties. Phenolic acids show antioxidative protection against colon cancer and Tannins being source of antibacterial, antiviral, anticarcinogenic and cardiovascular action (3).

Owing to these exceptional nutritional qualities tomatoes have earned the recognition of being a protective food on a global scale with considerable economic relevance. Plant biostimulants now a days represent an emerging class of agricultural inputs consisting of biological substances or microbial inoculants that intensify physiological processes in plants (4). They function indirectly by modulating the metabolic pathways enhancing nutrient assimilation and tolerance to abiotic stresses (4).

Among the array of biostimulants some noteworthy bioenhancers are:

Panchagavya: An indigenous traditional cow product formulation to reduce chemical dependency (5).

Jeevamruta: A nutrient rich liquid organic fertilizer derived from cow dung and urine (6).

Seaweed extract: It is produced from species of seaweeds to improve crop yields (7).

Fish jaggery extract: A fermented product from fish waste and jaggery, though not yet fully characterized nutritionally but used as a fermented biostimulant in local farms.

Preliminary studies suggest that it supplies amino acids and few micronutrients (8). The majority of cultivators face challenges in accomplishing both high yield and better fruit quality, mostly due to limited knowledge of advanced agricultural practices, particularly the adequate application of organic and inorganic nutrient sources (9). Usually, farmers tend to do imbalanced use of chemical fertilizers and indiscriminate application of pesticides in chasing of higher yields.

However, prolonged dependence on chemical fertilizers leads to the accumulation of heavy metals in the soil, deteriorating its health and fertility, thereby compromising its capacity to support sustainable plant growth over time. Overuse of synthetic fertilizers contribute to ground water pollution, air pollution by releasing volatile compounds, harm non-target organisms. They also act as potent greenhouse gas contributors, thereby influencing global climatic issues (9).

In the context of sustainable agriculture, it is unrealistic to rely entirely on pure organic farming, as it may adversely impact food security and farmer livelihoods by initially resulting in lower yields. Hence, implementing such farming practices which combine both organic and synthetic fertilizers can optimize crop yields, as well as help reduce environmental impacts. A gradual transition to organic practices combined with integrated usage of both inputs can effectively help mitigate these challenges and maintain ecological resilience in a well-balanced manner. Considering the previously mentioned insights this research was undertaken to investigate the effect of integrating biostimulants with conventional fertilizers (NPK) on the growth performance, yield attributes and post-harvest quality parameters of tomato plants.

Materials and Methods

Research location

The experiment was conducted within the Post Graduate Research Farm, Department of Horticulture, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management R. Sitapur, Paralakhemundi, Odisha during Rabi 2023–24 and 2024–25. It is located at 18.77° North latitude and 84.10° East longitude, with an altitude of 57m above sea level.

Treatment details

For the present experiment, panchagavya, jeevamruta and fish jaggery extract were prepared following standardized methods. Briefly panchagavya was prepared using cow dung (10 kg) and ghee (1 kg), which were fermented in a drum for 3 days, after which cow urine (10 L) and water (3 L) were added. The mixture was stirred twice daily for 15 days, followed by the addition of milk (2 L), curd (2 L), jaggery (100 g) and twelve ripe bananas. The mixture was stirred twice daily and was allowed to ferment for 30 days. Jeevamruta was prepared by mixing cow dung (10 kg), cow urine (10 L), jaggery (2 kg) and a small amount of farm soil. The mixture was placed in a drum and was stirred thrice daily. After 10 days of fermentation, it was ready.

In case of fish jaggery extract, equal parts of fish waste and jaggery were fermented in an airtight jar for 10 days. The resulting honey-like liquid was filtered and used. Seaweed extract was the commercial one from Biovita, used directly in the experiment.

The demonstration was structured following a randomized block design incorporating 3 replications and 10 distinct treatment combinations as follows:

T_1- control (100 % RDF),

T_2- RDF + 3 % panchagavya,

T_3- RDF + 3 % jeevamruta,

T_4- RDF + 2 mL seaweed extract,

T_5- RDF + 5 % fish jaggery extract,

T_6- RDF + 3 % panchagavya + 5 % fish jaggery extract,

T_7- RDF + 3 % jeevamruta + 2 mL seaweed extract,

T_8- RDF + 3 % panchagavya + 3 % jeevamruta,

T_9- RDF + 5 % fish jaggery extract + 2 mL seaweed extract

T_{10}- RDF + 3 % panchagavya + 3 % jeevamruta+ 5 % fish jaggery extract.

The 30-day-old seedlings were planted in the spacing of 45 cm × 60 cm.

Observations

The pre-harvest observations included plant height of five tagged plants observed at 30, 45 and 60 DAT; it was measured using scale in centimeters. The number of primary branches was counted manually at harvest and stem girth was recorded in millimeters. Days to 50 % flowering were noted when half of the plants showed flowering and flower clusters per plant were manually counted at 45 DAT. The parameters such as number of fruit clusters, fruits per cluster and fruits per plant were counted and mean values were computed. Individual fruit weight was measured using digital weighing machine in grams, equatorial and polar diameters were measured using digital caliper in mm. Fruit yield per plant, fruit yield per m^2 and fruit yield per hectare were calculated manually and noted. The economic feasibility was calculated using total cost of cultivation, gross and net returns and benefit-cost ratio.

Statistical computation

All the recorded prost-harvest and post-harvest parameters values were analyzed using standard statistical methods. Mean, standard error and critical difference were determined and obtained results were tested for significance at the 5 % level using SPSS software.

Results

The data on growth and yield parameters of tomato influenced by different biostimulant treatments are summarized in Table 1. Significant variations were observed among treatments for several traits.

Growth attributes

The study analyzed various parameters with significant results, in case of plant height T_3 (RDF + 3 % jeevamruta) excelled in height at 30, 45 and 60 DAT with values of 57.33 cm, 94.80 cm and 117.87 cm, respectively, compared to the lowest values of 47.67 cm in T_{10} (RDF + 3 % panchagavya + 3 % jeevamruta + 5 % fish

Table 1. Growth and yield attributes of Tomato under different treatments

	PH-30DAT (cm)	PH-45DAT (cm)	PH-60DAT (cm)	PB	SG	DF	FLCP	FPC	FCPP	FPP	IFW	PD	ED	Y/P	Y/m2	Y/ha
T_1	48.87^{cd}	81.00^{d}	98.73^{d}	3.20^{bd}	16.8^{bd}	25.33	14.6^{c}	3.67^{a}	8.60^{d}	28.45^{d}	78.27^{bc}	43.44^{b}	57.77^{ab}	2.28^{d}	2.56^{g}	21.79^{g}
T_2	50.93^{bd}	84.20^{cd}	104.5^{cd}	3.13^{be}	18.8^{ac}	25	17.4^{b}	5.15^{ab}	10.67^{bc}	43.07^{bc}	82.16^{ab}	47.87^{a}	60.38^{a}	3.13^{cd}	3.64^{ce}	30.95^{ce}
T_3	57.33^{a}	94.80^{a}	117.8^{a}	2.93^{e}	14.5^{cd}	25.67	21.4^{a}	4.55^{b}	13.00^{a}	50.16^{a}	76.19^{bc}	42.29^{b}	54.34^{bc}	3.55^{ab}	4.07^{ab}	34.60^{ab}
T_4	51.53^{bd}	85.67^{bd}	110.6^{ac}	3.27^{bc}	16.7^{bd}	25.33	17.13^{b}	4.75^{b}	10.47^{bc}	46.99^{ab}	83.44^{ab}	42.54^{b}	57.56^{ab}	3.22^{bd}	3.3^{ef}	28.59^{ef}
T_5	49.07^{cd}	91.53^{ab}	113.5^{ab}	3.27^{bc}	16.0^{bd}	25.67	15.33 ^{c}	4.73^{b}	10.53^{bc}	40.79^{c}	83.89^{a}	42.42^{b}	56.16^{bc}	2.99^{c}	3.98^{ac}	33.80^{ac}
T_6	52.07^{bd}	90.13^{ac}	105.2^{cd}	3.07^{ce}	21.71^{a}	25.67	20.47^{a}	4.62^{b}	12.27^{ab}	45.73^{b}	70.44^{c}	41.36^{b}	53.03^{c}	3.25^{bd}	3.80^{bd}	32.33^{bd}
T_7	53.60^{ac}	93.27^{a}	113.7^{ab}	3.33^{b}	18.9^{ac}	25.67	17.5^{b}	5.54^{a}	9.87^{cd}	44.33^{bc}	78.61^{bc}	42.77^{b}	56.07^{bc}	3.44^{bc}	3.08^{f}	26.18^{f}
T_8	50.47^{cd}	92.20^{ab}	112.7^{ab}	3.20^{bd}	14.1^{d}	25.67	17.13^{b}	4.89^{b}	10.67^{bc}	50.54^{a}	80.28^{b}	42.22^{b}	56.80^{ac}	3.82^{a}	4.26^{a}	36.24^{a}
T_9	55.33^{ab}	89.20^{ac}	108.5^{bc}	3.00^{de}	18.3^{ad}	24.67	18.47^{b}	4.67^{b}	12.27^{ab}	44.59^{bc}	76.24^{bc}	41.99^{b}	54.85^{bc}	3.52^{ab}	3.49^{de}	29.69^{de}
T_{10}	47.67^{d}	88.73^{ac}	112.8^{ab}	3.60^{a}	19.9^{ab}	24.67	17.13^{b}	4.61^{b}	10.80^{bc}	45.85^{b}	80.91^{ab}	42.02 ^{b}	55.11^{bc}	3.44^{bc}	3.48^{de}	29.60^{de}
S.Em (±)	1.43	2.09	2.32	0.07	1.37	0.91	0.54	0.19	0.58	1.35	2.56	1.17	1.25	0.11	0.11	1.08
CD(p=0.05)	4.24	6.20	6.89	0.20	4.06	NS	1.61	0.58	1.73	4.02	7.62	3.47	3.71	0.32	0.33	3.21
CV%	4.78	4.06	3.66	3.64	13.42	6.22	5.30	7.12	9.22	5.32	5.62	4.72	3.85	5.72	5.44	6.17

Note: ph- plant height, pb- number of primary branches, sg- stem girth, df- days to 50 % flowering, flcp- number of flower cluster per plant, fcpp- number of fruit cluster per plant, fpc- number of fruits per cluster, fpp- number of fruits per plant, ifw- individual fruit weight, pd- polar diameter of fruit, ed- equitorial diameter of fruit, y/p- fruit yield per plant, y/m2- fruit yield per m2, y/ha- fruit yield per hectare.

jaggery extract), 81 cm and 98.73 cm in T_1 (Control). The highest stem girth (21.71 mm) achieved in T_6 (RDF+ 3 % panchagavya + 5 % fish jaggery extract), while the lowest (14.15 mm) observed in T_8 (RDF + 3 % panchagavya + 3 % jeevamruta). The maximum primary branches (3.6) recorded in T_{10} and least (2.93) was found in T_3. It was found that minor variations were there in number of primary branches across treatments suggesting that the primary branching in tomato was less responsive to biostimulants. The earliest 50 % flowering at 24.67 days was observed in T_9 and T_{10}. This variation in flowering days was non-significant indicating that the initiation of flowers may be attributed to inherent varietal character rather than treatment effects. Highest flower clusters (21.40) were produced by T_3, while T_1 had the least number of flower clusters (4.67).

Yield parameters

The study's key results include that the maximum fruit clusters/plant produced in T_3 with 13 clusters and lowest (8.6) in T_1. The highest fruits per cluster found in T_7 with 5.54 fruits and least was 3.67 in control. The maximum fruits per plant was observed in T_8 with 50.54 fruits and fewest (28.45) in T_1. Individual fruit weight was found to be significantly more in T_5 with 83.89 g and lightest fruits (78.27 g) in T_1. The thickest pericarp observed in T_{10} with 6.63 mm diameter and thinner ones (5.03 mm) in T_1. The maximum polar diameter recorded in T_2 with 47.87 mm and lowest (41.36 mm) in T_6. The highest equatorial diameter was found in T_2 with 60.38 mm and lowest (53.03 mm) in T_6. The highest fruit yield per plant was highest in T_8 with 3.82 kg and lowest (2.28 kg) in T_1, while maximum fruit yield m^{-2} obtained in T_8 with 4.26 kg, lowest (2.56 kg) in T_1. The highest fruit yield ha^{-1} recorded in T_8 with 36.24 t ha^{-1} and lowest in T_1 (21.79 t ha^{-1}). The overall field view and fruit appearance under each treatment, are shown in Fig. 1–10 reflecting the variations in plant vigor and fruit development.

Discussion

The findings of the study suggest that various traditional biostimulants, when used in conjunction with RDF, brought about a significant improvement in morphological growth and yield attributes of tomato. The superior growth performance was attributed to the combinational impact of bioactive compounds with inorganic fertilizers (NPK) (10). Among the growth attributes, the application of panchagavya enhanced plant growth because it serves as a contributory source of natural plant growth promoters such as auxins, gibberelins and cytokinins. They collectively enhance root development, leading to better nutrient assimilation and increasing photosynthetic activity (11). Jeevamruta has proved to catalyze vegetative proliferation of plants as it's abundant in density of beneficial microbial load which helps slow mineralization of organic supplements (11). Being rich in amino acids and antioxidants, they accelerate chlorophyll synthesis, photosynthetic efficiency and gaseous exchange (12). These regulatory effects promoted plant vigor (13).

The application of seaweed extracts significantly improved chlorophyll concentrations in tomato foliage while it provided bioactive compounds that stimulate physiological

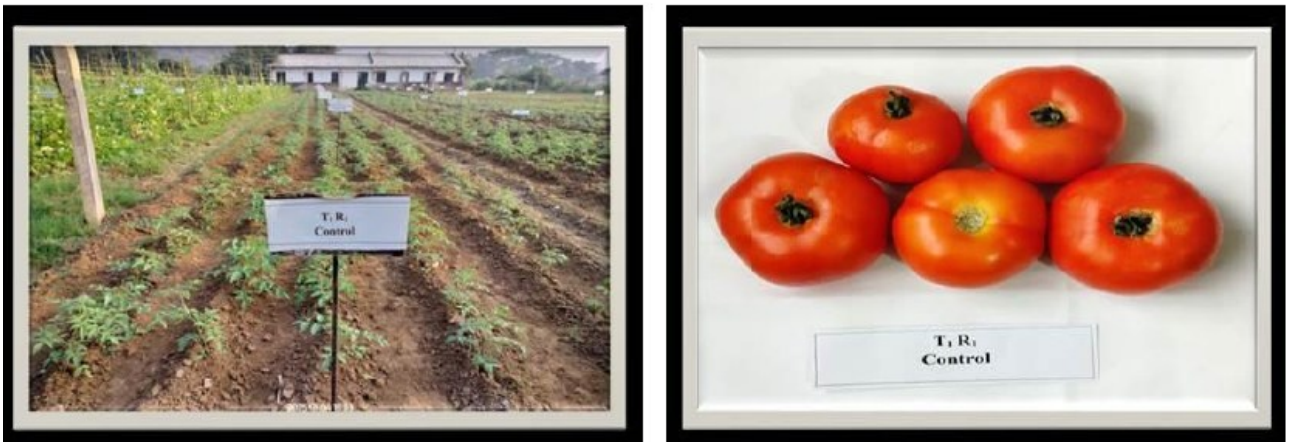

Fig. 1. T_1: Control.

Fig. 2. T_2: RDF + 3 % Panchagavya.

Fig. 3. T_3: RDF + 3 % Jeevamruta.

Fig. 4. T_4: RDF + 2 mL Seaweed extract.

Fig. 5. T_5: RDF + 5 % Fish jaggery extract.

Fig. 6. T_6: RDF + 3 % Panchagavya + 5 % Fish jaggery extract.

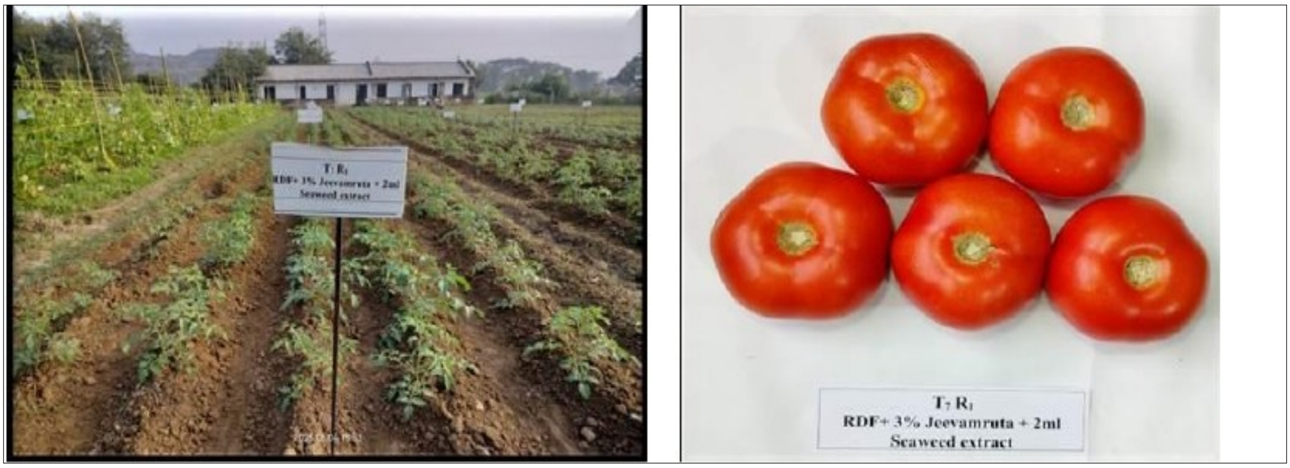

Fig. 7. T_7: RDF + 3 % Jeevamruta + 2 mL Seaweed extract.

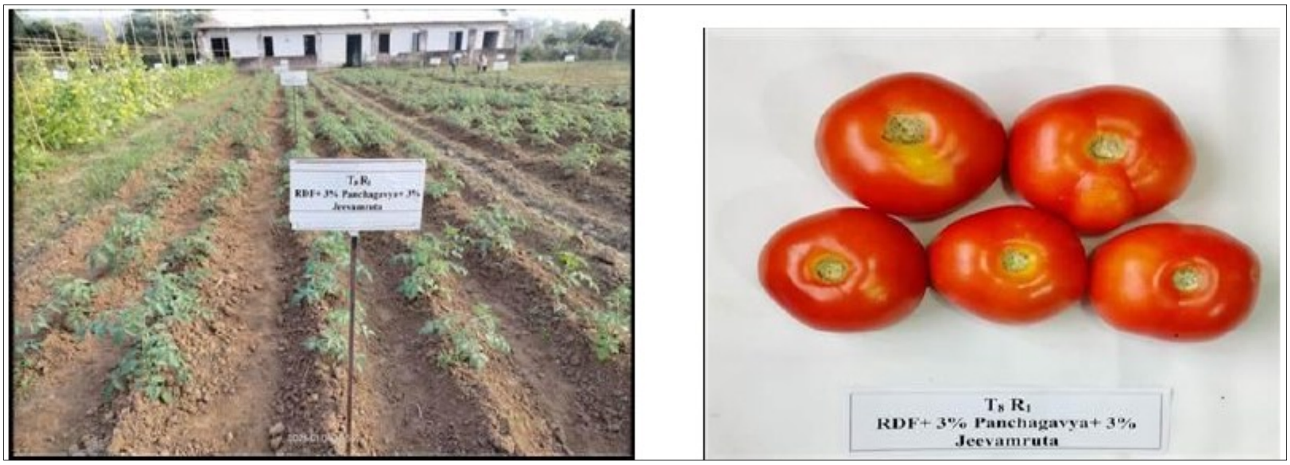

Fig. 8. T_8: RDF + 3 % Panchagavya + 3 % Jeevamruta.

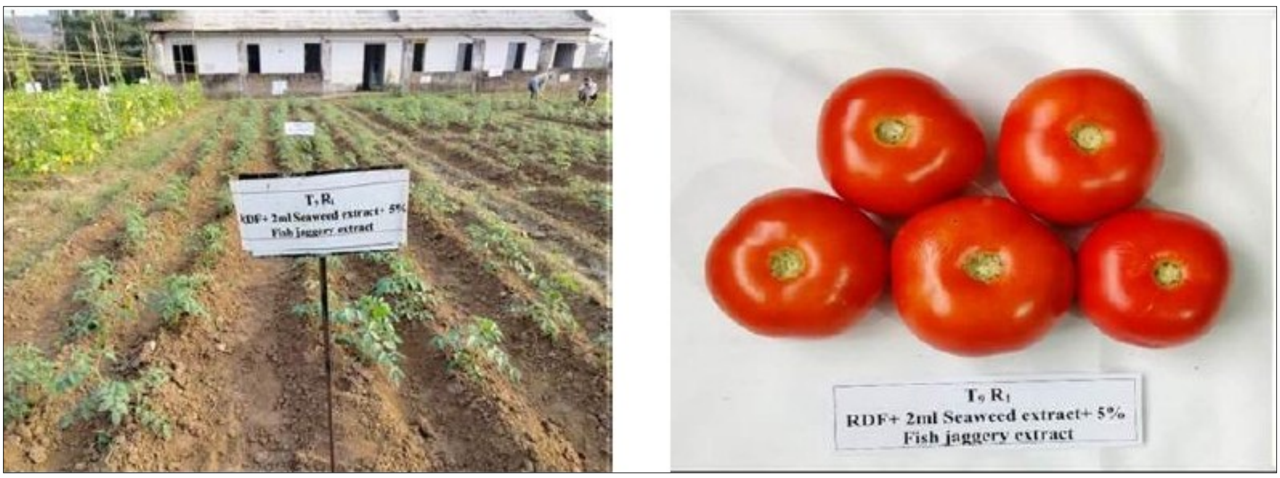

Fig. 9. T_9: RDF + 2 mL Seaweed extract + 5 % Fish jaggery extract.

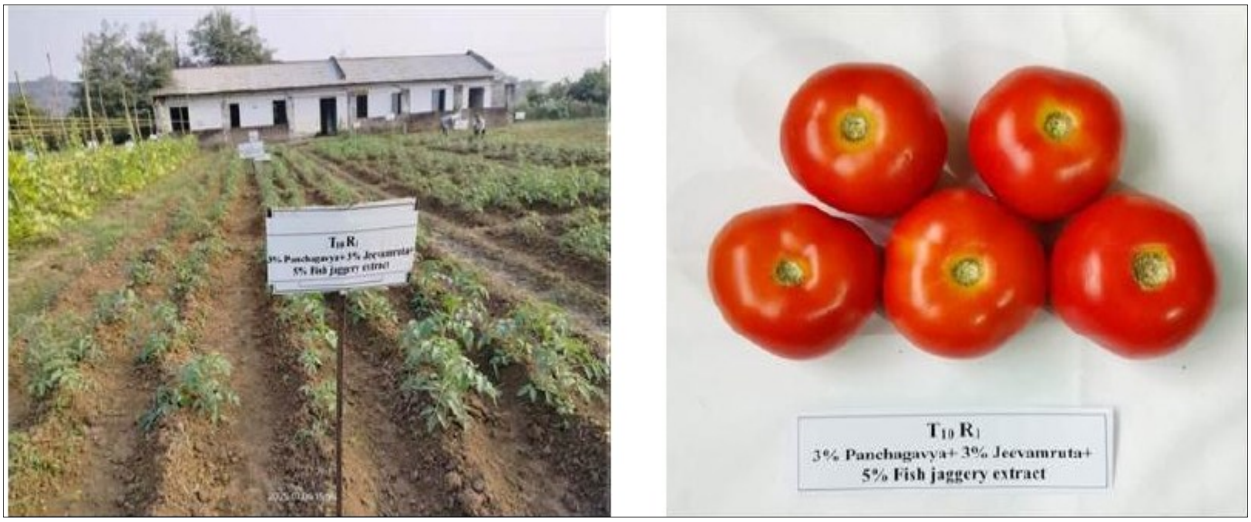

Fig. 10. T_{10}: 3 % Panchagavya + 3 % Jeevamruta + 5 % Fish jaggery extract.

processes (14). The yield parameters were significantly affected by the coordinated utilization of bioenhancers and RDF leading to superior harvest. This was mainly possible due to adequate availability of micro- and macro-nutrients from both sources. Several studies have reported that the advantageous microbes strengthen root system of plants and the extensive root system with more surface area accumulates more nutrient and also the less mobile ones. This intensifies metabolic functions, ensures effective translocation of nutrients from source organs to other branching parts.

The substantial increase in tomato production was linked to the steady nutrient supply combined with bioactive compounds present in panchagavya, including auxins and gibberellins, these growth promotors enhanced root proliferation and shoot elongation (15). Better chlorophyll content and photosynthetic efficiency contributed to more biomass accumulation and enhanced translocation of photoassimilates played a vital role in boosting overall plant productivity. According to some studies the fermented organic biostimulants, panchagavya and jeevamruta containing beneficial microbial load like actinomycetes, fungi, methylotrophs, lactic acid bacteria, *Pseudomonas, Azospirillum, Azotobacter* and phosphobacteria as they are cow derived products, but the comprehensive and consistent profiling of these species is still lacking.

Although microbial profiling was not performed in the present study, the observed improvements with organic biostimulants may partly reflect microbial-mediated nutrient mobilization reported in previous studies (6). The enzyme activity in them accelerates soil fertility. It is evident that their application has resulted in increased dehydrogenase activity and phosphatase activity, both of which contributes to enhanced microbial biomass that stores plant available nitrogen, phosphorus and sulfur, supporting continuous nutrient cycling and improving soil nutrient availability (16).

Conclusion

The investigation uncovered that the combined application of biostimulants and RDF significantly enhanced crop performance. Field evaluations indicated that the most favorable site-specific response was observed in 3 % panchagavya + 3 % jeevamruta combined with 100 % of the RDF and the treatment labeled as T_8 delivered the best results across both growth and yield parameters. It led to the highest fruit production/ plant (3.82 kg), yield per meter square (4.26 kg) and yield ha^{-1} (42.6 t ha^{-1}), which is beyond average range generally reported for Pari F1 hybrid tomato (28-36 t ha^{-1}), indicating a positive response to the treatments under the present experiment conditions, along with significant improvements in plant growth attributes. The significant efficacy of this combination justifies its consideration for adoption in future agricultural practices to optimize the overall growth and yield potential of tomato.

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Authors' contributions

AP was responsible for the conception and execution of the experiment, field operations, data collection, statistical analysis and manuscript drafting under technical guidance of ER. ER provided continuous guidance and academic supervision throughout the entire research project. Both the authors contributed to reviewing and approving the final manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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