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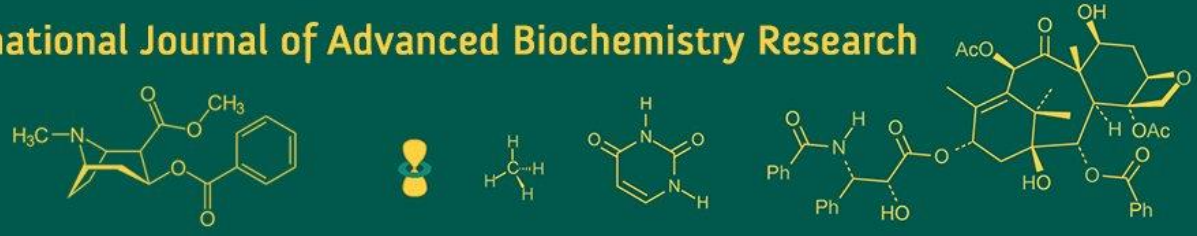

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Assessment of bio-efficacy and safety of SV FULORA biostimulant on growth, yield and quality of tomato (*Solanum lycopersicum* L.)

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Abstract
The field experiment was conducted at Zonal Agricultural and Horticultural Research Station (ZAHRS), Navile, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India, from December 2023 to May 2024 in a randomized complete block design with seven treatments replicated thrice to evaluate the bio-efficacy and safety of SV FULORA biostimulant on tomato (*var*. Arka Rakshak). SV FULORA was applied as foliar spray (1.25, 2.50 and 5.00 ml/L) or soil drenching (0.5, 1.0 and 1.5 L/acre) at 40 and 70 days after transplanting; morphological and physiological parameters, flowering, yield attributes, phytotoxicity and pre-and post-harvest soil nutrient status were recorded and data analysed by ANOVA at P = 0.05. SV FULORA significantly improved plant height (up to 92.0 cm), number of branches (26.3/plant), leaf area (8065 cm^2/plant), total chlorophyll content (2.501 mg/g fresh weight), number of flowers (99.5/plant) and fruits (45.0/plant) and fruit yield (58.89 t/ha) compared to the untreated control (82.0 cm, 21.3 branches, 6550 cm^2 leaf area, 2.017 mg/g chlorophyll, 85.4 flowers, 38.0 fruits and 50.70 t/ha). No phytotoxic symptoms were observed in any treatment and post-harvest soil analysis revealed only slight nutrient decline, indicating enhanced nutrient uptake efficiency. SV FULORA proved effective and safe, increasing tomato yield by up to 16.2% and is recommended for integration with standard fertilizer practices.

Keywords: Tomato, biostimulant, SV FULORA, bio-efficacy, phytotoxicity, yield, chlorophyll

Introduction
Tomato (*Solanum lycopersicum* L.) is one of the most important solanaceous vegetable crops grown worldwide due to its wide adaptability and suitability for fresh consumption and processed food industries. It serves as a vital income source for small and marginal farmers while contributing significantly to consumer nutrition through minerals, antioxidants, vitamin C and carotenoids [1].

However, tomato production faces numerous constraints, including high costs of chemical fertilizers, improper application leading to nutrient deficiencies such as blossom end rot, intensive cultivation depleting secondary nutrients and exclusion of organic manures resulting in reduced productivity and soil health [2]. Blossom end rot, a physiological disorder linked to calcium deficiency and moisture stress, severely impacts fruit quality and yield [3].

To address these, integrated approaches enhancing tolerance to abiotic and biotic stresses, nutrient availability and immune responses are essential for sustainable yields [4]. Biostimulants, substances that stimulate plant growth, nutrient efficiency and stress tolerance without nutrient content, have gained prominence [5]. Derived from humic acids, phytohormones, seaweed extracts, algae and plant growth-promoting bacteria, biostimulants improve yield and quality in crops like tomato [6]. Studies show they enhance nutrient uptake, reduce fertilizer needs and boost resistance to stresses [7].

This study evaluates the novel biostimulant SV FULORA for its bio-efficacy on tomato growth, phytotoxicity, yield and quality.

Materials and Methods

The field experiment was conducted at C-6 block, Zonal Agricultural and Horticultural Research Station (ZAHRS), Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences (KSNUAHS), Shivamogga (13°58' N, 75°34' E, 650 m amsl), under Southern Transitional Zone (Agro-climatic Region-4, Zone-VII) of Karnataka, India, from December 2023 to May 2024. A randomized complete block design with seven treatments replicated thrice was used. Plot size: 3.0 m × 3.0 m; spacing: 90 cm × 60 cm.

Table 1: Treatment Details

Tr. No.	Treatment & Dosage	No. of applications	Method of application	Stage of application (DAT)
T_1	SV FULORA @ 1.25 ml L^{-1}	2	Foliar Spray	40-45, 65-70
T_2	SV FULORA @ 2.50 ml L^{-1}	2	Foliar Spray	40-45, 65-70
T_3	SV FULORA @ 5.00 ml L^{-1}	2	Foliar Spray	40-45, 65-70
T_4	SV FULORA @ 0.5 L $acre^{-1}$	2	Soil Drenching	40-45, 65-70
T_5	SV FULORA @ 1.0 L $acre^{-1}$	2	Soil Drenching	40-45, 65-70
T_6	SV FULORA @ 1.5 L $acre^{-1}$	2	Soil Drenching	40-45, 65-70
T_7	Untreated control	-	-	-

DAT = Days after transplanting

Composite soil (0-30 cm) was red sandy loam, slightly acidic (pH 6.25). Initial soil characteristics are presented in Table 2.

Table 2: Initial Soil Characteristics

Sl. No.	Particulars	Values
1	Sand (%)	82.8
2	Silt (%)	8.3
3	Clay (%)	8.9
4	Soil texture	Red sandy loam
5	Soil pH	6.25
6	EC (dS m^{-1})	0.17
7	Organic Carbon (g kg^{-1})	3.62
8	Available Nitrogen (kg ha^{-1})	219.52
9	Available Phosphorus (kg ha^{-1})	80.54
10	Available Potassium (kg ha^{-1})	225.79
11	Exchangeable Calcium [cmol(p^+) kg^{-1}].	1.80
12	Exchangeable Magnesium [cmol(p^+) kg^{-1}].	0.92
13	Available Sulphur (ppm)	17.1
14	Zinc (ppm)	1.44
15	Iron (ppm)	14.48
16	Copper (ppm)	0.84
17	Manganese (ppm)	8.27

Climatic conditions during the crop period are summarised in Tables 3a and 3b (meteorological data). Variety: Arka Rakshak (F1 hybrid). Crop management included FYM at 25 t ha^{-1} and RDF 250:250:250 kg NPK ha^{-1}. Data on morphological parameters (plant height, branches, leaf area, LAI), physiological parameters (chlorophyll content), yield

Table 3a: Meteorological data from December 2023 to May 2024 (crop growth period) comprising monthly normal (30 years average), actual and deviation from the normal at ZAHRS, Shivamogga

Month	Total rainfall (mm)			Number of rainy days (days)			Maximum temperature (°C)			Minimum temperature (°C)		
	N	A	D	N	A	D	N	A	D	N	A	D
December-23	10.5	0.0	-10.5	1	0	-1.0	30.0	30.8	0.8	17.7	17.6	-0.1
January-24	1.9	10.0	8.1	0	2	2.0	31.2	31.4	0.2	16.8	15.1	-1.7
February-24	1.6	0.0	-1.6	0	0	0.0	33.4	34.6	1.2	17.5	16.4	-1.1
March-24	11.2	0.0	-11.2	0	0	0.0	35.7	36.1	0.4	20.7	18.1	-2.6
April-24	55.8	51.8	-4.0	3	2	-1.0	36.3	37.3	1.0	22.1	20.7	-1.4
May-24	82.9	227.0	144.1	4	9	5.0	34.6	34.2	-0.4	22.6	22.4	-0.2
Total	163.9	288.8	124.9	8	13	5.0	----	-----	----	----	----	----

N-Normal meteorological data (1993-2023) A-Actual meteorological data (Cropping Period) D-Deviation from the Normal (A-N)

Table 3b: Meteorological data from December 2023 to May 2024 (crop growth period) comprising monthly normal (30 years average), actual and deviation from the normal at ZAHRS, Shivamogga

Month	Relative humidity (%)			Wind speed (km hr^{-1})			Sunshine hours (hr day^{-1})			Evaporation (mm/day)		
	N	A	D	N	A	D	N	A	D	N	A	D
December-23	64	74	10.0	4.3	4.0	-0.3	8.2	7.4	-0.8	5.0	4.5	-0.5
January-24	60	67	7.0	3.9	4.5	0.6	8.9	9.6	0.7	5.1	5.3	0.2
February-24	57	54	-3.0	4.7	3.8	-0.9	9.0	9.8	0.8	5.7	6.1	0.4
March-24	54	52	-2.0	4.8	4.2	-0.6	6.8	8.6	1.8	6.4	6.9	0.5
April-24	60	51	-9.0	5.7	4.9	-0.8	8.1	8.9	0.8	6.4	7.6	1.2
May-24	66	65	-1.0	6.4	5.8	-0.6	7.3	6.9	-0.4	5.7	4.8	-0.9
Total	----	----	----	----	----	----	----	-----	----	----	----	----

N-Normal meteorological data (1993-2023) A-Actual meteorological data (Cropping Period) D-Deviation from the Normal (A-N)

Components, phytotoxicity (0-10 scale) and post-harvest soil nutrients were recorded. Statistical analysis: ANOVA at P = 0.05.

Results and Discussion

Morphological Parameters: SV FULORA significantly influenced morphological growth at later stages. Maximum plant height (92.0 cm), number of branches (26.3 plant^{-1}) and leaf area (8065 cm^2 plant^{-1}) were recorded in T_3 (foliar 5.00 ml L^{-1}) and T_6 (soil drench 1.5 L acre^{-1}) compared to control.

Table 4: Morphological parameters influenced by SV FULORA

Treatment	Plant height (cm)	Branches (no.)	Leaf area (cm^2)	LAI
	30 DAT	50 DAT	80 DAT	30
T_1	36.9	66.5	85.0	6.3
T_2	35.8	67.5	89.0	6.7
T_3	39.4	70.0	92.0	7.0
T_4	37.3	65.5	82.0	6.7
T_5	40.1	66.5	85.5	6.7
T_6	38.5	68.0	87.0	6.3
T_7 (Control)	38.0	65.0	82.0	6.7
S.Em. ±	2.13	2.08	2.30	0.35
CD (5%)	NS	NS	6.5	NS

These improvements are attributed to hormone stimulation and enhanced nutrient uptake by biostimulants [8].

Physiological Parameters

Total chlorophyll content was significantly higher at 80 DAT in treated plants (maximum 2.501 mg g^{-1} in T_6).

Table 5: Physiological parameters (chlorophyll content, mg g^{-1} leaf fresh wt.)

Treatment	Chl a	Chl b	Total Chl (30 DAT)	Chl a	Chl b	Total Chl (50 DAT)	Chl a	Chl b	Total Chl (80 DAT)
T_1	1.104	0.410	1.514	1.389	0.517	1.913	1.646	0.634	2.283
T_2	1.202	0.447	1.650	1.452	0.538	1.998	1.695	0.621	2.328
T_3	1.124	0.418	1.542	1.485	0.552	2.042	1.720	0.630	2.362
T_4	1.103	0.413	1.516	1.326	0.478	1.809	1.642	0.601	2.260
T_5	1.164	0.434	1.598	1.415	0.505	1.935	1.783	0.648	2.424
T_6	1.178	0.438	1.616	1.438	0.526	1.987	1.814	0.666	2.501
T_7	1.167	0.432	1.599	1.280	0.451	1.742	1.461	0.554	2.017
S.Em. ±	0.094	0.021	0.079	0.085	0.044	0.085	0.092	0.026	0.117
CD (5%)	NS	NS	NS	NS	NS	0.252	0.250	0.071	0.323

Yield and Yield Components

Higher doses significantly increased flowers per cluster, cumulative flowers, fruits per plant and yield (maximum 58.89 t ha^{-1} in T_3).

Table 6: Flowering pattern

Treatment	Days to 50% flowering	Flowers/cluster	Flowers/plant (60 DAT)	(70 DAT)	(80 DAT)
T_1	39.0	3.3	42.5	70.8	89.7
T_2	40.7	4.0	44.2	74.0	97.8
T_3	39.7	4.0	45.9	75.3	99.5
T_4	39.3	3.3	39.4	67.4	87.6
T_5	39.7	3.7	41.6	69.3	92.0
T_6	40.3	3.7	43.8	72.7	96.2
T_7	40.7	3.0	38.7	65.1	85.4
S.Em. ±	1.32	0.22	1.40	1.89	2.18
CD (5%)	NS	0.64	4.31	5.82	6.71

Table 7: Yield and yield components

Treatment	Fruit length (mm)	Fruit diameter (mm)	Fruit weight (g)	Fruits/plant (no.)	Yield/plant (kg)	Plot yield (kg)	Yield (t ha^{-1})
T_1	46.3	34.4	92.4	43.0	3.97	47.57	55.06
T_2	45.5	33.2	93.1	42.5	3.91	48.63	56.29
T_3	47.2	32.5	91.5	45.0	4.12	50.88	58.89
T_4	46.4	33.5	93.8	40.5	3.75	45.03	52.12
T_5	48.0	35.0	97.3	39.0	3.79	47.72	55.23
T_6	47.8	36.0	100.5	40.0	4.02	50.32	58.24
T_7	44.6	32.0	88.5	38.0	3.36	43.81	50.70
S.Em. ±	1.53	1.45	1.71	1.50	0.15	1.05	1.14
CD (5%)	NS	NS	4.80	4.23	0.46	3.23	3.26

Phytotoxicity

No phytotoxic symptoms (wilting, chlorosis, necrosis, epinasty/hyponasty) were observed across all treatments and observation periods (Tables 8 and 9; all scores = 0).

Post-harvest Soil Properties

Mild nutrient depletion was observed, indicating efficient uptake without adverse effects on soil health.

Table 10: Post-harvest soil properties

Particulars	Initial	Foliar spray	Soil drenching
pH	6.25	6.28	6.34
EC (dS m^{-1})	0.17	0.16	0.14
Organic Carbon (g kg^{-1})	3.62	3.58	3.65
Available N (kg ha^{-1})	219.52	207.60	202.59
Available P (kg ha^{-1})	80.54	79.23	75.77
Available K (kg ha^{-1})	225.79	205.24	209.36
Exch. Ca [cmol(p$^+$) kg^{-1}].	1.80	1.50	1.62
Exch. Mg [cmol(p$^+$) kg^{-1}].	0.92	0.83	0.79
Available S (ppm)	17.1	15.2	15.7
Zn (ppm)	1.44	1.06	1.12

Conclusion

SV FULORA applied as foliar spray (optimal 2.50-5.00 ml L^{-1}) or soil drench (optimal 1.0-1.5 L acre^{-1}) at 40 and 70 days after transplanting significantly enhanced tomato growth, physiological parameters, flowering, fruiting and yield (up to 16.2% increase) with complete phytotoxic safety and improved nutrient use efficiency. It can be recommended as a safe adjunct to standard fertilization practices.

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Competing Interests

Authors have declared that no competing interests exist.

Authors' Contributions

RNS and GM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. KSM and SJK managed the analyses of the study. JKA and NBK managed the literature searches. All authors read and approved the final manuscript.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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