E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(12): 1210-1216
Received: 05-09-2025
Accepted: 07-10-2025

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Impact of SV SUGARBAN on growth, yield and crop safety of tomato (*Solanum lycopersicum* L.)

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DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i12q.4564

Abstract
Tomato (*Solanum lycopersicum* L.) is a vital vegetable crop facing production challenges such as nutrient deficiencies, biotic stresses and reduced soil fertility, leading to lower yields and quality, with biostimulants like SV SUGARBAN-containing humic acids, phytohormones and seaweed extracts-explored to enhance nutrient efficiency, stress tolerance and productivity. A field experiment was conducted from December 2023 to May 2024 at ZAHRS, Navile, KSNUAHS, Shivamogga, India, using a randomized block design with three replications and seven treatments involving soil drenching of SV SUGARBAN at 0, 2.5, 5.0, 7.5 and 10.0 L acre^{-1} at 40 days after transplanting (DAT) on Arka Rakshak hybrid tomato, assessing morphological (plant height, branches, leaf area, LAI), physiological (chlorophyll content), yield components (flowering, fruit traits, yield) and phytotoxicity parameters at specified intervals, alongside pre- and post-harvest soil analyses, with data analysed using ANOVA at P=0.05. At 80 DAT, SV SUGARBAN at 10.0 L acre^{-1} significantly increased leaf area (7104 cm^2), LAI (1.316), chlorophyll a (1.864 mg g^{-1}), b (0.702 mg g^{-1}) and total (2.566 mg g^{-1}) compared to control (6234 cm^2, 1.154, 1.500, 0.573, 2.073 mg g^{-1}, respectively), with flowers per cluster higher (3.7) at 10.0 and 7.5 L acre^{-1} vs. control (3.0), fruit yield reaching 59.49 t ha^{-1} at 10.0 L acre^{-1} vs. 52.29 t ha^{-1} in control, no phytotoxicity observed across doses and post-harvest soil nutrients showing slight declines indicative of efficient uptake. SV SUGARBAN application via soil drenching safely enhances tomato growth, physiological efficiency and yield by 13.77% at optimal doses, promoting sustainable nutrient use without soil residue buildup.

Keywords: Biostimulant, chlorophyll content, phytotoxicity, *Solanum lycopersicum*, SV SUGARBAN and yield

Introduction
Tomato (*Solanum lycopersicum* L.) is one of the most important solanaceous vegetable crops grown throughout the world because of its wider adaptability and suitability for a variety of uses in fresh as well as processed food industries. It is also a very good source of income for small and marginal farmers and contributes to the nutrition of the consumer. In terms of human diet, it is a major component of daily meals in many countries and constitutes an excellent source of health-providing compounds due to a balanced mixture of minerals and antioxidants including vitamin C and carotenoids.

There are many constraints in tomato crop production *viz.*, high cost of chemical fertilizers and lack of knowledge about proper application methods of fertilizers lead to nutrient deficiency disorders (blossom end rot) of the crop (Valenzuela *et al*., 2025). Intensive cultivation as well as lack of returning crop residue to soil has led to reduction in secondary nutrient status of most soils. Further, exclusion of manures and unscientific method of fertilizer application caused decreased crop productivity and poor soil health. Though there are various complex fertilizers available in the market, adoptability by the farming community is very less. However, external application of major nutrients *viz.*, nitrogen, potassium, phosphorus, as straight fertilizer is necessary to maintain crop productivity at current levels and will be even more crucial if yields are to be increased. In addition to that, susceptibility of the crop to pests and diseases drastically reduces the yield and quality of crop (Kumar *et al*., 2022) [5]. To manage these biotic stresses, it requires intensive and costly plant protection practices. These constraints and their management

result in increased cost of cultivation. Additionally, combined abiotic and biotic stresses can exacerbate yield losses up to 70% (Rivero *et al*., 2018) [6]. All the above factors result in reduced yield, quality, shortened shelf life, keeping quality and nutrient profile in the tomato crop. Considering the importance of the tomato crop across the globe, approaches that integrate practices to boost crop's tolerance to both biotic and abiotic stresses, improve nutrient availability and increase its immune response towards pests, diseases, etc., are widely addressed to obtain a viable yield, quality and ensure high productivity. In this regard, application of biomolecules shows some anticipation to deal with these constraints. Wherein, biostimulants are gaining interest as a way to ensure nutrient efficiency, stimulate plant growth and, thereby, improving yield, quality and productivity. Many research studies have established the potential of biostimulants in improving crop yield and quality.

Biostimulants are products that reduce the need for fertilizers and increase plant growth, resistance to biotic and abiotic stresses. In small concentrations, these substances are efficient, favouring the good performance of the plant's vital processes and allowing high yields and good quality products. In addition, biostimulants enhance nutrition efficiency, abiotic stress tolerance and/or plant quality traits, regardless of its nutrient contents. Furthermore, various raw materials have been used in biostimulants composition, such as humic acids, phytohormones, seaweed extracts, algae extracts and plant growth-promoting bacteria etc. Using these components, many novel biostimulants with new formulations are developed. Several researches have been conducted in order to evaluate the biostimulants in improving plant growth, development, yield, quality and productivity. In this regard, the present study was conducted to evaluate a new biostimulant for growth, bio-efficacy, phytotoxicity and also the yield and quality on tomato.

Materials and Methods

Field experiment was conducted to evaluate the bio-efficacy and phytotoxicity responses of SV SUGARBAN and also its impact on yield and quality of tomato, at ZAHRS Navile, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga for a duration of five months from December 2023 to May 2024.

Location of the Experimental Site

Field trial was conducted at C-6 block of Zonal Agricultural and Horticultural Research Station, KSNUAHS, Shivamogga, which is situated at 13° 58' North latitude and 75° 34' East longitude with an altitude of 650 meters above mean sea level. It comes under Agro-climatic Region-4 and Zone-VII (Southern Transitional Zone) of Karnataka.

Soil and Its Characteristics

A composite soil sample was collected from 0-30 cm depth at the time of tomato seedlings transplanting and the data on physical and chemical properties of experimental site soil is presented in Table 1. According to USDA classification, the soils are Typic haplustalf. Further, the soil analysis data indicated that the soil of the experimental site was sandy loam in texture. The soil was found to be slightly acidic in reaction with normal electrical conductivity and medium in organic carbon. The soil was low in available nitrogen and phosphorus, medium in available potassium status. Also, soil was found to be sufficient in exchangeable calcium and magnesium and medium in available Sulphur. Among the analysed micronutrients status, available iron, copper and manganese content was high while, available zinc in the soil was low.

Table 1: Soil characteristics of the experimental site

Sl. No.	Particulars	Values	
I. Physical properties: Mechanical analysis			
Soil separates in per cent			
1.	Sand	82.8%	
2.	Silt	8.3%	
3.	Clay	8.9%	
4.	Soil texture	Red Sandy loam	
II. Chemical properties:			
1.	Soil pH	6.25	Slightly Acidic
2.	EC (dSm^{-1}at 25°C)	0.17	Normal
3.	Organic Carbon (g kg^{-1})	3.62	Medium
4.	Available Nitrogen (kg ha^{-1})	219.52	Low
5.	Available Phosphorus (kg ha^{-1})	80.54	Low
6.	Available Potassium (kg ha^{-1})	225.79	Medium
7	Exchangeable Calcium[cmol(p^{+}) kg^{-1}]	1.80	Sufficient
8	Exchangeable Magnesium [cmol(p^{+}) kg^{-1}]	0.92	Sufficient
9	Available Sulphur (ppm)	17.1	Medium
10	Zinc (ppm)	1.44	Low
11	Iron (ppm)	14.48	High
12	Copper (ppm)	0.84	High
13	Manganese (ppm)	8.27	High

Climatic Conditions

The normal climatic data (30 years average) and the actual weather conditions that prevailed during crop growth period and the deviations from the normal with respect to rainfall, maximum and minimum temperature, mean relative humidity and wind speed for a period of December 2023 to May 2024 are presented in Table 2a & 2b.

Normal Climatic Conditions

Normal total rainfall (30 years average) during the cropping period (December 2023 to May 2024) of ZAHRS, UAHS, Shivamogga was 163.9 mm received from 8 rainy days and the major portion was received in April & May. The highest normal rainfall was received in the month of May (82.9 mm) with 4 rainy days. The mean maximum temperature ranged from 30.0

ºC (December-23) to 36.3 ºC (April-24) and the mean minimum temperature from 16.8 ºC (January-24) to 22.6 ºC (May-24). The maximum relative humidity (66%) was observed in the month of May and minimum (54%) during March. The wind speed ranged from 6.4 km hr^{-1} (May-24) to 3.9 km hr^{-1} (January-24). The maximum sunshine hours of 9.0 hr day^{-1} was observed during February while, minimum was observed in May (7.3 hr day^{-1}). The highest evaporation was observed in March-24 and April-24 (6.4 mm/day) and lowest in December-23 (5.0 mm/day)

Table 2a: 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 (ºC)			Minimum temperature (ºC)		
	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 2b: 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)

Actual Climatic Conditions

During crop growth period (December 2023 to May 2024), actual total rainfall of 288.8 mm was received from 13 rainy days which was 124.9 mm higher than the normal. Actual rainfall received was higher than the normal in the month of May-24 (227.0 mm from 9 rainy days) and January-24 (10.0 mm from 2 rainy days). While, it was lower in the month of April-24 (51.8 mm from 2 rainy days) and there was no rainfall (0.0 mm) in the month of December-23, February-24 and March-24. The mean maximum temperature was slightly higher and the mean minimum temperature was slightly lower during crop growth period compared to normal. Monthly mean maximum temperature ranged between 30.8 ºC and 37.3 ºC in the month of December-23 and April-24, respectively. A positive deviation of 1.2 ºC followed by 1.0 ºC for mean maximum temperature compared to normal were noticed during February-24 and April-24 respectively which were coinciding with flowering and fruit development stages. Further the deviation for mean maximum temperature was positive in all the months except in May-24 compared to normal indicating a warmer day during the cropping period. Lowest monthly mean minimum temperature was observed during January-24 (15.1 ºC) and was highest during May-24 (22.4 ºC). During the cropping period the deviations for mean minimum temperature was negative in all the months indicating cold nights. The mean monthly relative humidity ranged from 51 (April-24) to 74 per cent (December-23). During the cropping period the deviation for relative humidity was negative in all the months except in the initial cropping period (December-23 & January-24) indicating the crop may experience the humidity stress. The maximum wind speed was recorded in the month of May-24 (5.8 km hr^{-1}) and minimum during February-24 (3.8 km hr^{-1}). The maximum sunshine hours of 9.8 hr day^{-1} was observed during February-24 followed by 9.6 hr day^{-1} (January-24) while, minimum was observed in May-24 and December-23 (6.7 & 7.4 hr day^{-1}, respectively). The maximum evaporation was recorded in the month of April-24 (7.6 mm/day) and minimum during December-23 (4.5 mm/day).

Treatment Details

Influence of SV SUGARBAN on bio-efficacy and phytotoxicity of tomato was evaluated with seven treatments and the details of treatments are as follows:

Table 3: Treatment details

Treatment	Details
T_1	Control (Water drench)
T_2	SV SUGARBAN @ 2.5 L acre^{-1}
T_3	SV SUGARBAN @ 5.0 L acre^{-1}
T_4	SV SUGARBAN @ 7.5 L acre^{-1}
T_5	SV SUGARBAN @ 10.0 L acre^{-1}
T_6	Standard check (if any)
T_7	Untreated

Soil drenching at 40 DAT.

Parameters Assessment Details

DAT - Days after transplanting. Observations on morphological, physiological, yield and phytotoxicity parameters were recorded as detailed below.

Layout Plan

Randomized Block Design with 7 treatments, 3 replications, plot size 3.6 m × 3.0 m, with border rows.

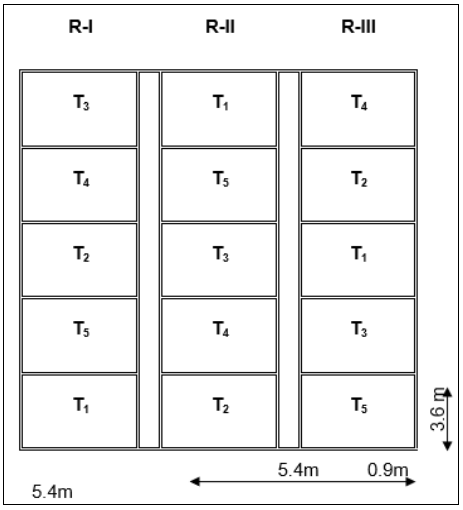

Fig 1: Plan of layout of experiment.

Cultural Operations

Field Preparation

Main field was prepared 3 weeks prior to transplanting by deep ploughing followed by passing disc harrow and cultivator to enable good land preparation. Farm yard manure @ 25.0 t ha^{-1} was spread uniformly along with last cultivation. Ridges at 90 cm distance to a height of 15-20 cm were prepared. On each ridge planting spot was marked at a spacing of 60 cm. Seedlings of pencil thickness with 4-5 leaf (25-30 days old seedlings) were transplanted on the ridges.

Varietal Description

Arka Rakshak was developed by crossing IIHR-2834 and IIHR-2833. It is the first F1 hybrid tomato in India to be resistant to three diseases: Tomato Leaf Curl Virus, Bacterial Wilt and Early Blight. The fruit is large, firm and deep red in color, with a square-round shape. It weighs around 90-100 grams. It is a high-yielding hybrid, producing 75-80 tonnes per hectare in 140 days. It is suitable for both fresh market and processing.

Intercultural Operations

Intercultivation was carried out for 5 times at an interval of 8-10 days. Earthing up was taken up 3 times to get better root growth and establishment. As the crops were widely spaced intercultural operations-cum-manual weeding was carried out from time to time to keep the plots weed free. When the plants were well established, staking was given to each plant with bamboo pole to keep them erect and firm. Irrigation was given twice in a week as per the crop requirement.

Fertilizer Application

Recommended farm yard manure @ 25.0 t ha^{-1} was spread uniformly along with last cultivation before transplanting. The recommended dose of fertilizers (250:250:250 kg ha^{-1} N: P_2O_5: K_2O) were applied commonly to all plots. Basal dose was applied 7 days after transplanting. The subsequent 1st and 2nd top dressings were made at 35 and 55 DAT, respectively. The sources of nutrients applied were in the form of Urea (46% N), Di Ammonium Phosphate (18% N, 46% P_2O_5) and Muriate of Potash (60% K_2O).

Plant Protection

The required plant protection measures were taken commonly against Serpentine leaf miner, White flies, Powdery mildew and Blossom end rot as per the recommendation of package of practice for tomato crop.

Harvesting

Light yellowish red stage fruits were harvested 60 days after transplanting. Fruits were harvested at 5 to 7 days interval depending on the weather conditions. A total of 14 pickings were done.

Collection of Experimental Data

Three plants of uniform size were selected randomly and tagged from each treatment plot for recording various biometric observations on different morphological, physiological, yield and phytotoxicity parameters.

Morphological Parameters

Plant Height

Height of the randomly selected three labelled plants from the ground level to the tip of the main stem was measured in centimetres. The average of three plants was taken as plant height (cm).

Number of Branches

Average number of branches from randomly selected three labelled plant was taken as the number of branches per plant.

Leaf Area

Leaf area was calculated by gravimetric method. Fully opened fresh green leaves of a plant were cleaned and 30 discs were taken this is kept on the conveyer to record the leaf area of plant. Similarly, three plants leaf area was recorded and average was taken as leaf area per plant in cm^2 $plant^{-1}$.

Leaf Area Index

The leaf area index (LAI) is the ratio of leaf area per plant to the land area occupied by the plant and was calculated by using the formula given by Watson (1952) [9]. LAI = Leaf area (cm^2) / Land area (cm^2)

Physiological Parameters

Chlorophyll Content

Chlorophyll-a, chlorophyll-b and total chlorophyll content in leaves were measured at 30, 60 and 90 days after transplanting by using dimethyl sulfoxide (DMSO) method given by Shoaf and Lium (1976) [7]. Fresh and fully matured leaves from randomly selected three labelled plants were brought to laboratory in ice box from the field. Leaf sample were cut into small pieces from that 100 mg weighed and taken to incubate in 7.0 ml of DMSO in dark for 12 hours. After the incubation period, the supernatant was collected by decanting and leaf tissue was discarded, then the volume of the supernatant was made up to 10 ml using DMSO. The absorbance of the extract was measured at 645 nm and 663 nm using DMSO as blank in the spectrophotometer model VISISCAN - 167. By using the formula given below the chlorophyll-a, chlorophyll-b and total chlorophyll content was calculated and expressed as mg g^{-1} leaf fresh weight. Chl a = [12.7(A663) − 2.69(A645) × V] / [100 × W × a] mg g^{-1} leaf fresh weight Chl b = [22.9(A645) - 4.68(A663) × V] / [100 × W × a] mg g^{-1} leaf fresh weight Total Chl = [20.2(A645) + 8.02(A663) × V] / [100 × W × a] mg g^{-1} leaf fresh weight Where, A = Absorbance at wavelength (645 and 663 nm); V = Final volume of the chlorophyll extract (10 ml); W = Fresh weight of the sample (100 mg); a = Path length of light in the cuvette (1 cm).

Yield and Yield Components

Days to Fifty Per Cent Flowering

Number of days from transplanting to first flower appearance in 50 per cent of the plants in each treatment plot was recorded and the average was computed.

Average Flowers Per Cluster

Total number of fully opened flowers in a cluster per plant was recorded in three tagged plant in all treatment plots at 50 days after transplanting (10 days after first application) and at 80 days after transplanting (10 days after second application) and the average was computed.

Cumulative Number of Flowers Per Plant

The total number of fully opened flowers in a cluster per plant was recorded in three tagged plant in all treatment plots at 60, 70 & 80 DAT and the number of flowers in clusters was added successively to compute cumulative number of flowers per plant.

Average Fruit Weight

Ten fruits randomly selected at third and fourth picking were considered and average individual fruit weight was calculated by using the formula given below. Average fruit weight (g) = Cumulative weight of ten fruits drawn at 3rd and 4th pickings / Total number of fruits

Fruit Length

Fruit length (mm) was measured from stalk end to blossom end of ten randomly selected fruits at third harvest by using digital Vernier calipers and average of ten fruits was computed.

Fruit Diameter

Fruit diameter (mm) at the highest bulged portion was measured in same ten randomly selected fruits at third harvest by using digital Vernier calipers and average of ten fruits was worked out.

Number of Fruits Per Plant

Total number of fruits in three selected plants was counted at each picking the cumulative of all picking were averaged and considered as number of fruits per plant.

Fruit Yield Per Plant

Total weight of fruits of the three plants was recorded and the average yield of fruits per plant was worked out in kg by sum up of all the pickings.

Net Plot Yield

Fruit yield of plants from each plot excluding 2 border rows in all the four sides of the plot was harvested separately to work out net plot yield in kg.

Yield Per Hectare

Fruit yield per hectare (t ha^{-1}) was calculated for each treatment using the net plot yield.

Phytotoxicity Observations

The phytotoxicity rating was done based on the visual toxic symptoms on crop *viz.*, chlorosis, necrosis, wilting, yellowing, scorching, hyponasty and epinasty using 0-100 scale (1-10 score), [i.e., 0 = No adverse effect of herbicides on crop and 100 = severe adverse effect of herbicide on crop] was recorded on 1, 3, 5, 7 and 10 days after the crop emergence. Phytotoxicity rating Scale (0-100): 0=0%, 1=1-10%, 2=11-20%, 3=21-30%, 4=31-40%, 5=41-50%, 6=51-60%, 7=61-70%, 8=71-80%, 9=81-90%, 10=91-100%.

Statistical Analysis of Data

The experimental data collected at different growth stages was subjected to statistical analysis as described by Gomez and Gomez (1984) [4]. The level of significance used in 'F' and 't' test was P = 0.05. Critical difference values were calculated for P = 0.05 wherever 'F' test was found significant.

Results

Field experiment on evaluation of bio-efficacy and phytotoxicity of SV SUGARBAN and its impact on yield of tomato was conducted at ZAHRS, Navile, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga for a duration of five months. The application of SV SUGARBAN via soil drenching at 40 DAT influenced various growth, physiological and yield parameters.

Morphological Parameters

The data on morphological parameters *viz.*, plant height, number of branches, leaf area and leaf area index (LAI) as influenced by different application rates of test product (SV SUGARBAN) is presented in Table 4. Plant height was found non-significant at all the recorded crop growth stages at 30, 50 & 80 DAT (days after transplanting) among the treatments (P = 0.05). Number of branches per plant was also found non-significant in all the plots at 30, 50 & 80 DAT (P = 0.05). Leaf area and leaf area index (LAI) were found non-significant at 30 DAT (before treatment imposition) and also at 50 DAT (10 days after treatment imposition) while, they were significant at 80 DAT (40 days after treatment imposition) (P = 0.05). At 80 DAT, higher leaf area (7104 cm^2) & LAI (1.316) was recorded with application of test product SV SUGARBAN @ 10.0 L acre^{-1} (T_5) followed by T_3 with SV SUGARBAN @ 5.0 L acre^{-1} (6724 cm^2 leaf area & 1.245 LAI) compared to control (6234 cm^2 leaf area & 1.154 LAI).

Physiological Parameters

Physiological parameters *viz.*, chlorophyll 'a', chlorophyll 'b' and total chlorophyll contents at 30 DAT (before treatment imposition), 50 DAT (10 days after treatment imposition) and 80 DAT (40 days after treatment imposition) are presented in the Table 5. All the chlorophyll contents (Chl 'a', Chl 'b' & total Chl) were found non-significant among the treatments in tomato leaves at 30 & 50 DAT (P = 0.05). Whereas, at 80 DAT (40 days after treatment imposition) higher Chl 'a', Chl 'b' & total Chl content of 1.864, 0.702 & 2.566 mg g^{-1} leaf fr. wt., respectively was recorded in T_5 with SV SUGARBAN @ 10.0 L acre^{-1} followed by T_4 with SV SUGARBAN @ 7.5 L acre^{-1} (1.823, 0.697 & 2.520 mg g^{-1} leaf fr. wt.) and T_3 with SV SUGARBAN @ 5.0 L acre^{-1} (1.786, 0.642 & 2.296 mg g^{-1} leaf fr. wt.) compared to control (1.500, 0.573 & 2.073 mg g^{-1} leaf fr. wt.) (P = 0.05).

Yield and Yield Components

The data on the time taken for 50% flowering, average number of flowers per cluster at 50 DAT (10 days after treatment imposition), data pertaining to yield and yield components *viz.*, fruit length, fruit diameter, fruit weight, number of fruits per plant and fruit yield (per plant, net plot & per hectare) as influenced by different doses of test product (SV SUGARBAN) are presented in Table 6. Days taken for fifty per cent flowering were observed between 39 to 40 days after transplanting in all

the plots and the time duration among the treatment plots was non-significant (P = 0.05). Average number of flowers per cluster was significantly higher (3.7) with the application of the test product SV SUGARBAN @ 10.0 & 7.5 L acre^{-1} compared to control plot (3.0) (P = 0.05).

Table 4: Morphological parameters as influenced by application of SV SUGARBAN (soil drenching) at 40 DAT^{+} on tomato

Treatment & Dosage	Plant height (cm)			Number of Branches (no.)			Leaf area (cm^2)			LAI		
	30*	50**	80**	30	50	80	30	50	80	30	50	80
	Days after transplanting											
T_1: SV SUGARBAN @ 2.5 L acre^{-1}	37.3	67.1	95.0	6.7	18.0	21.0	650	3850	6455	0.120	0.713	1.195
T_2: SV SUGARBAN @ 5.0 L acre^{-1}	39.6	70.5	98.7	7.0	19.3	22.3	608	3784	6724	0.113	0.701	1.245
T_3: SV SUGARBAN @ 7.5 L acre^{-1}	38.3	69.4	99.3	6.7	18.7	22.0	570	3681	6506	0.106	0.682	1.205
T_4: SV SUGARBAN @ 10.0 L acre^{-1}	35.9	67.9	96.2	6.3	19.0	22.3	645	3947	7104	0.119	0.731	1.316
T_5: Untreated control	36.2	65.3	89.7	6.7	17.3	19.7	597	3653	6234	0.111	0.676	1.154
S. Em. ±	1.41	1.89	3.26	0.15	0.73	0.90	27.4	108.9	162.2	0.005	0.021	0.029
C.D. (5%)	NS	NS	NS	NS	NS	NS	NS	NS	468.5	NS	NS	0.084

DAT^{+} - Days after transplanting 30* - before treatment imposition
50** - 10 days after application 80*** - 40 days after application

Table 5: Physiological parameters as influenced by application of SV SUGARBAN (soil drenching) at 40 DAT^{+} on tomato

Treatment & Dosage	30 DAT*			50 DAT**			80 DAT**		
	Chl 'a'	Chl 'b'	Total Chl	Chl 'a'	Chl 'b'	Total Chl	Chl 'a'	Chl 'b'	Total Chl
	(mg^{-1}g leaf fr.wt.)								
T_1: SV SUGARBAN @ 2.5 L acre^{-1}	1.059	0.376	1.435	1.294	0.480	1.774	1.592	0.609	2.201
T_2: SV SUGARBAN @ 5.0 L acre^{-1}	1.030	0.383	1.413	1.298	0.475	1.773	1.654	0.642	2.296
T_3: SV SUGARBAN @ 7.5 L acre^{-1}	1.068	0.408	1.476	1.363	0.498	1.861	1.823	0.697	2.520
T_4: SV SUGARBAN @ 10.0 L acre^{-1}	1.081	0.400	1.481	1.320	0.479	1.799	1.864	0.702	2.566
T_5: Untreated control	1.072	0.395	1.467	1.273	0.462	1.735	1.500	0.573	2.073
S. Em. ±	0.018	0.011	0.025	0.032	0.013	0.053	0.057	0.021	0.075
C.D. (5%)	NS	NS	NS	NS	NS	NS	0.165	0.061	0.217

DAT^{+} - Days after transplanting 30* - before treatment imposition
50** - 10 days after application 80*** - 40 days after application

Table 6: Days to 50 per cent flowering, flowers per cluster, yield and yield components as influenced by application of SV SUGARBAN (soil drenching) at 40 DAT^{+} on tomato

Treatment & Dosage	Days to 50 per cent flowering	Flowers per cluster	Fruit length	Fruit diameter	Fruit weight	Fruits per plant	Fruit yield per plant	Net plot yield	Fruit yield
	(days)	(number)	(mm)	(mm)	(gm)	(number)	(kg)	(kg)	(t ha^{-1})
T_1: SV SUGARBAN @ 2.5 L acre^{-1}	40.0	3.3	42.9	35.5	85.1	43.5	3.53	48.8	56.48
T_2: SV SUGARBAN @ 5.0 L acre^{-1}	39.0	3.3	43.5	35.7	84.7	45.3	3.71	50.5	58.45
T_3: SV SUGARBAN @ 7.5 L acre^{-1}	39.7	3.7	45.5	38.0	87.3	44.2	3.62	49.9	57.75
T_4: SV SUGARBAN @ 10.0 L acre^{-1}	40.0	3.7	47.1	38.5	88.5	43.8	3.85	51.4	59.49
T_5: Untreated control	39.3	3.0	41.6	35.2	84.2	40.7	3.32	45.2	52.29
S. Em. ±	0.45	0.13	1.85	1.15	1.48	0.94	0.09	1.62	1.82
C.D. (5%)	NS	0.38	5.35	NS	NS	2.72	0.26	4.68	5.26

DAT^{+} - Days after transplanting

The data pertaining to yield and yield components showed that application of test product (SV SUGARBAN) influenced yield and yield components of tomato crop. Fruit length was significantly higher (47.1 mm) with SV SUGARBAN @ 10.0 L acre^{-1} compared to control (41.6 mm) however, the application of remaining doses of test product SV SUGARBAN was non-significant for the fruit length (P = 0.05). The variation for fruit diameter among the treatments was non-significant. Fruit weight was also non-significant. Application of different doses of test product SV SUGARBAN recorded significant influence in number of fruits per plant and fruit yield per plant (P = 0.05). Among the different treatments, T_3, T_4 and T_5 recorded higher fruits per plant (45.3, 44.2 and 43.8, respectively) compared to control (40.7). Fruit yield per plant was higher (3.85, 3.71 and 3.62 kg) in T_5, T_3 and T_4 compared to control (3.32 kg). Higher net plot yield and fruit yield per hectare was recorded in all the treatments except SV SUGARBAN @ 2.5 L acre^{-1} (P = 0.05). Among the varied doses of SV SUGARBAN, higher fruit yield (59.49 t ha^{-1}) was recorded in T_5 followed by T_4 (57.75 t ha^{-1}) and T_3 (58.45 t ha^{-1}) compared to control (52.29 t ha^{-1}).

Phytotoxicity

No symptoms of wilting, chlorosis/yellowing, necrosis and epinasty/hyponasty due to application of the test product (SV SUGARBAN) at any of the applied doses after 1, 3, 5 & 10 days of application (score = 0).

Soil Properties After Crop Harvest

Soil analysis data (Table 4.4) has not revealed any noticeable impact on soil chemical properties (P = 0.05). After crop harvest in the SV SUGARBAN applied plots, there was a slight decline in all the estimated nutrients compared to the soil analysed before the conduct of the experiment (initial soil analysis).

Table 7: Effect of application of SV SUGARBAN (soil drenching) at 40 DAT^+ on soil chemical properties and nutrient status after tomato crop harvest

Sl. No.	Particulars	Initial	Final
1.	Soil pH	6.25	6.30
2.	EC (dSm^{-1}at 25ºC)	0.17	0.15
3.	Organic Carbon (g kg^{-1})	3.62	3.65
4.	Available Nitrogen (kg ha^{-1})	219.52	198.85
5.	Available Phosphorus (kg ha^{-1})	80.54	75.39
6.	Available Potassium (kg ha^{-1})	225.79	205.13
7	Exchangeable Calcium [cmol(p^+) kg^{-1}]	1.80	1.61
8	Exchangeable Magnesium [cmol(p^+) kg^{-1}]	0.92	0.82
9	Available Sulphur (ppm)	17.1	15.7
10	Zinc (ppm)	1.44	1.18
11	Iron (ppm)	14.48	13.73
12	Copper (ppm)	0.84	0.70
13	Manganese (ppm)	8.27	8.03

DAT^+ - Days after transplanting

Discussion

The application of SV SUGARBAN via soil drenching at 40 DAT positively influenced various growth, physiological and yield parameters, aligning with literature on biostimulants enhancing nutrient uptake and stress tolerance (du Jardin, 2015) [3]. Plant height showed improvement in all treated plots compared to control, possibly due to enhanced root development and hormone-like effects of biostimulants. Number of branches per plant escalated compared to control, indicating improved axillary bud growth. The enhancement in leaf area and LAI at 80 DAT can be attributed to increased cell division and expansion stimulated by biostimulant components like humic acids and phytohormones.

The increase in chlorophyll content at 80 DAT suggests improved photosynthetic efficiency, likely due to better nitrogen assimilation facilitated by the biostimulant, consistent with studies on seaweed extracts (Shukla *et al*., 2019) [8]. Average number of flowers per cluster reflected stimulated reproductive growth. Yield attributing parameters like fruit length showed significant increases at higher doses. The improvements in number of fruits per plant and fruit yield are linked to better photosynthate translocation and sink strength, as reported in biostimulant trials (Bulgari *et al*., 2019) [1]. All applied doses were safe, confirming non-toxic nature as per regulatory standards. Post-harvest soil analysis indicated efficient nutrient uptake by the crop rather than residue accumulation, supporting the role of biostimulants in promoting nutrient use efficiency without altering soil fertility adversely (Calvo *et al*., 2014) [2].

Conclusion

Application of test product SV SUGARBAN showed confirmatory influence by improving plant height, stem branches, leaf area (morphological parameters) and also physiological parameter i.e., chlorophyll content of photosynthesizing tissue. Application of SV SUGARBAN is effective in increasing number of flowers per cluster and showed significant enhancement in fruits per plant, escalating fruit weight that in turn ensuing elevated fruit yield. All the applied doses of the SV SUGARBAN from 2.5 L $acre^{-1}$ to 10.0 L $acre^{-1}$ were found to be biologically safe without any symptoms of phytotoxicity to tomato crop. Comparison of initial (before transplanting) and final (after harvest) soil analysis indicated that the applied test product SV SUGARBAN helps in efficient usage of applied nutrients (manures and fertilizers) and uptake of available native nutrients of soil. Overall, biostimulant SV SUGARBAN (soil drenching) in tomato in the present study may help increasing the uptake of plant nutrients which plausibly boost growth promoting hormones and its linked physiological effects. Further, application of bio-stimulants may stimulate absorption of macro and micronutrients of the soil and facilitates effective synthesis of plant-biomolecules that promote cell metabolic functions. Further, the applied biostimulant enables improved vegetative growth and enhances higher supply of photosynthates from source to sink, thereby increasing yield attributes and yield. Thus, from the results cited in detail and the facts discussed analytically it can be concluded that the bio-stimulant SV SUGARBAN was found highly effective in improving the plant growth, flowering, yield attributes and yield of tomato crop. Its application helps in balanced assimilation, better translocation of photosynthates to sink further, its hormonal effect improved all the recorded growth and yield parameters linearly from 8.01 to 13.77 percent over control with an increased dose from 2.5 to 10.0 L $acre^{-1}$ soil drenching and are biologically safe for the crop. So, farmers can use this bio-stimulant along with recommended dose fertilizer profitably in tomato crop. The novelty lies in demonstrating dose-dependent efficacy of this novel biostimulant formulation under field conditions, contributing to sustainable tomato production by enhancing yield while ensuring crop safety and nutrient efficiency.

Acknowledgement

The authors acknowledge the facilities provided by KSNUAHS, Shivamogga and funding/support from relevant sources.

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