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Influence of biostimulants on growth and yield of green chilli (*Capsicum annuum* L.) under Southern Transitional Zone of Karnataka

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ABSTRACT

A field experiment was conducted during kharif 2025 at the College of Agriculture, Navile, Shivamogga, Karnataka, in the Southern Transitional Zone, to evaluate the influence of biostimulants on growth and yield of green chilli. The experiment was laid out in a randomized complete block design with nine treatments replicated thrice, comprising the recommended package of practices (100:50:50 kg N:P₂O₅:K₂O ha⁻¹ + farmyard manure @ 25 t ha⁻¹) alone and in combination with 0.2 per cent foliar sprays of humic acid, amino acid and seaweed extract, applied before flowering and at fruit development. Combined application of humic acid and seaweed extract along with the recommended package of practices (T₇) recorded superior growth and yield performance. At harvest, T₇ recorded the highest plant height (47.3 cm), primary branches (7.2 plant⁻¹), secondary branches (14.3 plant⁻¹), number of leaves (172.6 plant⁻¹), leaf area (556.77 cm² plant⁻¹) and stem girth (9.05 mm). Among the yield attributes, T₇ recorded the highest number of fruits (36.6 plant⁻¹), fruit length (13.43 cm), fruit weight (5.65 g) and fruit girth (10.60 mm), resulted in the highest green chilli yield (4304 kg ha⁻¹), while the absolute control recorded the lowest yield (1339 kg ha⁻¹). The results indicate that foliar application of humic acid and seaweed extract at 0.2 per cent each along with the recommended package of practices can effectively enhance vegetative growth and improve green chilli productivity under the Southern Transitional Zone of Karnataka.

Keywords: Green chilli, Biostimulants, Humic acid, Seaweed extract, Yield

Introduction

Green chilli (*Capsicum annuum* L.), belonging to the family Solanaceae, is an important vegetable-cum-spice crop widely cultivated in tropical and subtropical regions for its economic, nutritional and culinary value. The crop is valued for its characteristic pungency and diverse uses as a fresh vegetable, spice, condiment and processed product, making it an important component of food and horticultural production systems (Bosland *et al.*, 2012; Tripodi *et al.*, 2019) [1, 2]. Improving productivity is therefore an important objective, particularly under intensive cultivation where efficient nutrient management is essential. Growth, flowering, fruit development and yield of chilli are strongly influenced by nutrient availability throughout the crop growth period.

Continuous and imbalanced use of chemical fertilizers may contribute to nutrient imbalance, declining resource-use efficiency and environmental concerns associated with intensive agricultural production (Pretty, 2007) [3]. Hence, sustainable nutrient-management approaches that improve crop performance and nutrient-use efficiency have gained importance. Plant biostimulants have emerged as promising inputs for enhancing plant performance by stimulating physiological and biochemical processes beyond their direct nutritional effects (Calvo *et al.*, 2014; Yakhin *et al.*, 2017; Rouphael *et al.*, 2020) [4, 5, 6]. Biostimulants encompass diverse materials, including humic substances, protein hydrolysates and amino acids, and seaweed extracts, which can influence plant growth, nutrient acquisition, stress tolerance and crop productivity (Calvo *et al.*, 2014; Yakhin *et al.*, 2017) [4].

Among the important biostimulants, humic substances can promote root development, nutrient acquisition and plant metabolic processes, thereby supporting plant growth and nutrient-use efficiency (Canellas *et al.*, 2015) [7]. The reported effects of humic substances include changes in root and shoot development associated with nutrient uptake, assimilation and distribution. Amino acid- and protein hydrolysate-based biostimulants provide organic compounds involved in plant metabolic processes and are recognized as an important category of plant biostimulants (Calvo *et al.*, 2014) [4]. Seaweed extracts contain biologically active constituents and have been reported to influence plant growth and development through effects beyond their simple nutrient contribution. The development of soluble seaweed extracts has also enabled direct application to plant organs such as leaves and roots (Craigie, 2011) [8]. Foliar application therefore provides a direct means of delivering these bioactive substances to plant tissues, particularly during critical stages of crop growth.

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The response of chilli to biostimulants can vary with the type of biostimulant, method and timing of application, crop genotype and prevailing environmental conditions. Biostimulant efficacy is also influenced by the nature and composition of the applied material and the physiological status of the crop (Calvo *et al.*, 2014; Yakhin *et al.*, 2017) [4, 5]. Therefore, systematic evaluation of foliar-applied biostimulants under region-specific production conditions is important for identifying suitable practices for improving crop growth and productivity. The present investigation was undertaken to evaluate the influence of foliar-applied biostimulants on growth, yield attributes and yield of green chilli under the Southern Transitional Zone of Karnataka.

Materials and Methods

The field experiment was conducted during *kharif* 2025 at the College of Agriculture, Navile, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India, located in the Southern Transitional Zone at 13°58'–14°01' N latitude and 75°34'–75°42' E longitude, with an elevation of 615 m above mean sea level. The soil was sandy loam in texture, comprising 74.86 per cent sand, 17.43 per cent silt and 7.71 per cent clay, and was classified as *Typic Haplustalf*. The soil was near-neutral in reaction (pH 6.65), with low organic carbon (0.48%) and available nitrogen (296.47 kg ha⁻¹), high available phosphorus (48.20 kg ha⁻¹) and medium available potassium (246.5 kg ha⁻¹). During the crop period from July to December 2025, the experiment received 504.6 mm rainfall against the long-term normal of 763.3 mm, with mean maximum and minimum temperatures of 28.7 and 18.5 °C, respectively, mean relative humidity of 76.1 per cent and mean bright sunshine duration of 4.8 h day⁻¹. Meteorological data were obtained from the Agro-Meteorological Observatory of Gramin Krishi Mausam Seva, Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga. The experiment was laid out in a randomized complete block design with nine treatments and three replications. The gross and net plot sizes were 6.00 m × 4.05 m and 4.50 m × 3.15 m, respectively. *Thirty-day-old seedlings* of green chilli hybrid Esha-4431 were transplanted at 75 cm × 45 cm spacing. The recommended package of practices (POP), comprising 100:50:50 kg N:P₂O₅:K₂O ha⁻¹ along with farmyard manure @ 25 t ha⁻¹, was applied to all treatments except the absolute control. Half of the recommended fertilizer dose was applied basally and the remaining half at 60 days after transplanting. The biostimulants used were humic acid (98%; Humic Power), amino acid formulation (Samras, 20%) and seaweed extract (Kelpak; liquid extract derived from *Ecklonia maxima*). The treatment details are given below;

Time of spraying: 1st before flowering and 2nd @ fruit development stage

For preparation of the spray solutions, 2 g of humic acid, 2 ml of amino acid formulation and 2 ml of seaweed extract were separately diluted with water and the volume was made up to 1 L. The biostimulants were applied as 0.2 per cent foliar sprays twice, before flowering and at the fruit development stage, using a knapsack sprayer during morning or evening hours under relatively low-wind conditions. The experimental field was brought to fine tilth through ploughing, harrowing, clod crushing and levelling. Gap filling was carried out wherever necessary using healthy seedlings of the same age. Weeds were controlled by hand weeding at approximately 30-day intervals, while intercultivation, earthing up and soil loosening were performed as required. Irrigation was provided depending on soil moisture and prevailing weather conditions, and necessary plant protection measures were adopted throughout the crop period to maintain a healthy crop.

Growth parameters

Plant height (cm)

Plant height was measured from ground level to the growing point using a measuring scale and expressed in centimetres.

Number of primary branches per plant

Primary branches arising directly from the main stem were counted on the five tagged plants and expressed as number plant⁻¹.

Number of secondary branches per plant

Secondary branches borne on the primary branches were counted on the five tagged plants and expressed as number plant⁻¹.

Number of leaves per plant

Number of fully grown leaves produced in five randomly chosen, tagged plants were counted. The average number of leaves per plant was calculated and reported.

Leaf area per plant (cm² plant⁻¹)

Leaf area was determined by the disc method. Fifty leaf discs of known area were obtained using a cork borer from randomly selected leaves. The leaf discs and remaining leaf blades were oven dried at 65 °C, and leaf area was calculated from the ratio of the oven-dry weight of the total leaf sample to that of the known-area leaf discs, following the method described by Vivekanandan *et al.* (1972) [9]. The leaf area was expressed as cm² plant⁻¹.

Stem girth (mm)

stem girth was measured using a digital vernier from five randomly tagged plants and average stem girth was worked out and expressed in millimeters

Yield attributes and yield

Number of fruits per plant

The number of fruits per plant was determined by counting the fruits harvested from the five tagged plants at each picking and calculating the average number of fruits per plant.

Fruit length (cm)

The length of five fruits was measured using scale from each pickings and average length was expressed in centimeter (cm)

Fruit weight (g)

Average fruit weight was calculated from the harvested fruits of the tagged plants and expressed in grams.

Fruit girth (mm)

Fruit girth was measured on five randomly selected fruits using vernier callipers and expressed in millimetres.

Green chilli yield per plant (g plant⁻¹)

The weight of fruits from all the pickings was recorded from five tagged plants and the total weight of green fruits per plant was calculated and expressed in grams.

Green chilli yield per plot (kg plot⁻¹)

The weight of fruits from all the pickings was recorded from each plot and the total weight of green fruits per plot was calculated and expressed in kg plot⁻¹.

Green chilli yield per hectare (kg ha⁻¹)

Fresh green chilli yield per hectare was calculated from plot yield and expressed as kg ha⁻¹

Statistical analysis

The data recorded for the growth and yield parameters were subjected to analysis of variance appropriate for a randomized complete block design following the procedure described by Gomez *et al.* (1984) [10]. The significance of treatment effects was tested at the 5 per cent prob

ability level ($P = 0.05$), and critical difference values were calculated wherever the F -test was significant.

T ₁	Absolute control
T ₂	POP
T ₃	POP + 0.2% Humic acid (foliar spray, 2 times)
T ₄	POP + 0.2% Amino acid (foliar spray, 2 times)
T ₅	POP + 0.2% Seaweed extract (foliar spray, 2 times)
T ₆	POP + 0.2% Humic acid + 0.2% Amino acid (foliar spray, 2 times)
T ₇	POP + 0.2% Humic acid + 0.2% Seaweed extract (foliar spray, 2 times)
T ₈	POP + 0.2% Amino acid + 0.2% Seaweed extract (foliar spray, 2 times)
T ₉	POP + 0.2% Humic acid + 0.2% Amino acid + 0.2% Seaweed extract (foliar spray, 2 times)

Note: POP (RDF = 100:50:50 kg N:P₂O₅:K₂O ha⁻¹ + FYM = 25 t ha⁻¹)

Results and Discussion

Plant height

Plant height was significantly influenced by foliar application of biostimulants, particularly during fruit development and at harvest (Table 1). At the fruit development stage, T₇ (POP + humic acid @ 0.2% + seaweed extract @ 0.2%) recorded the highest plant height (38.0 cm), which was significantly on par with T₈ (36.3 cm), whereas the absolute control (T₁) recorded the lowest plant height (24.3 cm). At harvest, T₇ maintained the highest plant height (47.3 cm), which was significantly on par with T₈ (47.1 cm), while T₁ recorded the lowest value (41.4 cm). The superior plant height under T₇ may be attributed to improved nutrient acquisition and the growth-promoting effects of humic substances and seaweed-derived bioactive compounds, which

may have favoured cell division, cell elongation and overall vegetative development. Similar improvement in plant height following the application of humic acid with micronutrients was reported by Manas *et al.* (2014) [11] in chilli. The increases in plant height with seaweed extract and humic acid application were in line with Singh *et al.* (2025) [12] in capsicum and Wani *et al.* (2025) [13] in chilli, respectively.

Number of primary and secondary branches

The number of primary and secondary branches per plant differed significantly among treatments (Table 1). T₇ (POP + humic acid @ 0.2% + seaweed extract @ 0.2%) recorded the highest primary branches at fruit development (5.9) and harvest (7.2), while T₁ recorded the lowest (3.2 and 4.0, respectively). Similarly, T₇ recorded the highest secondary branches (10.1 and 14.3), followed by T₈ (10.0 and 12.4), whereas T₁ recorded the lowest (5.2 and 6.6). The increased branching in T₇ may be attributed to improved nutrient uptake together with the hormone like activity of seaweed extract and the growth promoting effect of humic acid, which stimulated axillary bud development and branch proliferation. Similar responses were reported by Fathima *et al.* (2013) [14], Sridhar *et al.* (2012) [15], Chaitra *et al.* (2024) [16], Wani *et al.* (2025) [13] and Chakravarthy *et al.* (2023) [17].

Stem girth

Stem girth also showed significant variation among treatments (Table 2). At fruit development, T₇ recorded the highest stem girth (8.23 mm), followed by T₈ (7.41 mm), while T₁ recorded the lowest value (4.12 mm). At harvest, T₇ again recorded the maximum stem girth (9.05 mm), significantly on par with T₈ (8.27 mm), while the minimum was recorded in T₁ (5.48 mm). The increased stem girth in T₇ may be attributed to improved nutrient uptake and greater accumulation of structural carbohydrates, resulted in better vascular development and overall plant vigour. Jan *et al.* (2020) [18] and Zohaib *et al.* (2024) [19] also reported the increased stem girth in chilli following foliar application of humic acid.

Table 1. Plant height, primary and secondary branches of green chilli as influenced by biostimulants

Treatment	Plant height (cm)		Number of primary branches per plant		Number of secondary branches per plant	
	At fruit development	At harvest	At fruit development	At harvest	At fruit development	At harvest
T ₁	24.3	41.4	3.2	4.0	5.2	6.6
T ₂	28.5	42.7	4.2	4.5	7.1	8.3
T ₃	35.3	43.5	4.7	5.3	8.0	10.3
T ₄	31.7	42.8	4.3	4.7	7.2	8.5
T ₅	35.2	44.4	4.7	5.5	8.1	10.7
T ₆	35.3	44.8	4.9	5.7	8.5	11.0
T ₇	38.0	47.3	5.9	7.2	10.1	14.3
T ₈	36.3	47.1	5.8	6.5	10.0	12.4
T ₉	35.9	45.7	5.7	5.8	9.7	11.1
S.Em. ±	1.08	1.42	0.15	0.18	0.29	0.33
CD at 5%	3.14	4.12	0.4	0.5	0.8	0.9

Number of leaves

Number of leaves per plant was also significantly influenced by the treatments (Table 2). At fruit development, T₇ recorded the highest number of leaves (74.0 plant⁻¹), which was significantly on par with T₈ (73.3 plant⁻¹), whereas T₁ recorded the lowest value (37.8 plant⁻¹). At harvest, T₇ recorded the maximum number of leaves (172.6 plant⁻¹), followed by T₈ (154.9 plant⁻¹), while T₁ recorded the minimum (82.8 plant⁻¹). The greater leaf production in T₇ may be attributed to improved nutrient assimilation and enhanced vegetative growth, which favoured continuous leaf initiation and maintenance of a larger photosynthetic canopy. The stimulatory effect of humic substances and seaweed-derived biostimulants on vegetative growth, including leaf production, has been documented in horticultural crops,

including chilli and *Capsicum*, by Canellas *et al.* (2015) [7], Sridhar *et al.* (2012) [15] and Chaitra *et al.* (2024) [16].

Leaf area

Leaf area showed a similar treatment response (Table 2). At fruit development, T₇ recorded the highest leaf area (633.5 cm² plant⁻¹), which was significantly on par with T₈ (622.8 cm² plant⁻¹), whereas T₁ recorded the lowest value (369.7 cm² plant⁻¹). At harvest, T₇ maintained the highest leaf area (556.8 cm² plant⁻¹), followed by T₈ (523.4 cm² plant⁻¹), while T₁ recorded the minimum value (303.4 cm² plant⁻¹). The greater leaf area in T₇ may be attributed to enhanced cell expansion, improved nutrient uptake and greater canopy development, resulting in improved light interception and photosynthetic efficiency. Comparable increases in leaf area and veg

etative growth in response to biostimulant application have been reported in chilli and *Capsicum* by Manas *et al.* (2014) [11], Wani *et al.* (2025) [13] and Singh *et al.* (2025) [12].

Yield attributes and green chilli yield

Number of fruits per plant

The number of fruits per plant was significantly influenced by biostimulant application (Table 3). T₇ recorded the highest number of fruits (36.6 plant⁻¹), followed by T₈ (34.2 plant⁻¹), whereas T₁

recorded the lowest value (12.5 plant⁻¹). The higher fruit number in T₇ may be attributed to enhanced vegetative growth, greater leaf area and increased branching, which improved assimilate production and availability for reproductive development, thereby favouring fruit set and retention. These observations are supported by the findings of Parihar *et al.* (2025) [20], Suhaini *et al.* (2023) [21] and Kasar *et al.* (2010) [22] in chilli.

Table 2. Leaf production, leaf area and stem girth of green chilli as influenced by biostimulants

Treatment	Number of leaves per plant		Leaf area (cm ² plant ⁻¹)		Stem girth (mm)	
	At fruit development	At harvest	At fruit development	At harvest	At fruit development	At harvest
T ₁	37.8	82.8	369.7	303.4	4.12	5.48
T ₂	47.0	116.9	426.6	353.3	5.05	6.06
T ₃	60.7	135.9	457.8	415.6	6.57	7.88
T ₄	60.1	124.5	442.1	391.2	6.03	6.35
T ₅	64.5	142.0	538.2	420.0	6.62	7.90
T ₆	69.3	147.6	547.7	421.6	7.39	7.98
T ₇	74.0	172.6	633.5	556.8	8.23	9.05
T ₈	73.3	154.9	622.8	523.4	7.41	8.27
T ₉	69.3	151.4	574.5	431.2	7.38	8.10
S.Em. ±	2.07	5.12	19.2	16.8	0.22	0.28
CD at 5%	6.02	14.90	55.9	48.9	0.63	0.80

Fruit length, fruit weight and fruit girth

Fruit length, fruit weight and fruit girth were significantly influenced by the treatments (Table 3). T₇ recorded the highest fruit length (13.43 cm), fruit weight (5.65 g) and fruit girth (10.60 mm), followed by T₈ with 12.17 cm, 5.14 g and 9.58 mm, respectively. The absolute control recorded the lowest values for these attributes. The improvement in fruit size may be attributed to enhanced nutrient uptake,

greater photosynthetic efficiency and improved translocation of assimilates to developing fruits, together with the hormone-like activity of seaweed extract, which promotes cell division, cell elongation and fruit development. The present findings are in agreement with those of Deori *et al.* (2023) [23], Nimmala *et al.* (2021) [24], Manas *et al.* (2014) [11], Jan *et al.* (2020) [18] and Suhaini *et al.* (2023) [21], who also reported improvements in fruit size following biostimulant application in chilli.

Table 3. Yield attributes and green chilli yield as influenced by biostimulants

Treatment	Number of fruits plant ⁻¹	Fruit length (cm)	Fruit weight (g)	Fruit girth (mm)	Green chilli yield (g plant ⁻¹)	Green chilli yield (kg plot ⁻¹)	Green chilli yield (kg ha ⁻¹)
T ₁	12.5	10.23	4.48	8.14	53.2	1.90	1339
T ₂	25.0	10.83	4.53	8.75	120.8	4.97	3506
T ₃	27.6	11.47	4.84	9.23	132.4	5.27	3717
T ₄	26.1	11.17	4.74	9.22	124.8	5.13	3614
T ₅	28.3	11.71	4.95	9.27	143.7	5.41	3816
T ₆	29.6	11.84	5.01	9.32	148.0	5.63	3969
T ₇	36.6	13.43	5.65	10.60	180.6	6.10	4304
T ₈	34.2	12.17	5.14	9.58	176.1	5.93	4184
T ₉	31.5	11.86	5.08	9.48	163.8	5.85	4124
S.Em. ±	0.81	0.37	0.15	0.29	4.30	0.15	112
CD at 5%	2.3	1.07	0.44	0.85	12.52	0.45	326

Green chilli yield per plant, green chilli yield per plot and green chilli yield per hectare

Green chilli yield followed the overall trend observed for the yield attributes (Table 3). T₇ recorded the highest green chilli yield per hectare (4304 kg ha⁻¹), followed by T₈ (4184 kg ha⁻¹) and T₉ (4124 kg ha⁻¹), whereas T₁ recorded the lowest yield (1339 kg ha⁻¹). T₇ was significantly on par with T₈ and T₉ for green chilli yield, as the difference between their yields was smaller than the reported critical difference. Yield per plant and yield per plot also followed a simi-

lar trend, with T₇ recorded the highest values of 180.6 g plant⁻¹ and 6.10 kg plot⁻¹, respectively, followed by T₈ with 176.1 g plant⁻¹ and 5.93 kg plot⁻¹. The superior yield under T₇ may be attributed to the combined improvement in vegetative growth, canopy development and yield attributes, particularly the greater number of fruits and improved fruit size. The combined application of humic acid and seaweed extract may have improved nutrient acquisition and plant growth, thereby favoured fruit development and final productivity. Similar positive responses of chilli yield to humic acid and seaweed-

based biostimulants have been reported by Soliman *et al.* (2025) [25], Wani *et al.* (2025) [13] and Sridhar *et al.* (2012) [15].

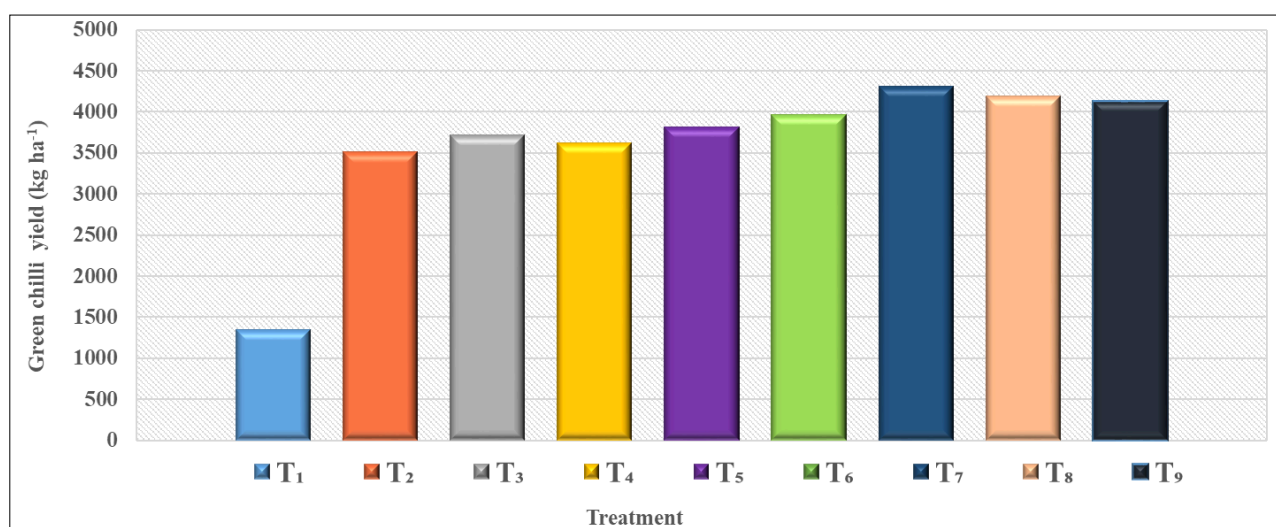


Figure 1. Green chilli yield as influenced by different biostimulant application

Conclusion

The present investigation revealed that foliar application of biostimulants significantly influenced the growth and yield of green chilli hybrid Esha-4431 over the recommended package of practices alone. Among the treatments, combined foliar application of humic acid (0.2%) and seaweed extract (0.2%) along with the recommended package of practices, applied before flowering and at fruit development (T₇), recorded the highest plant height, primary and secondary branches, number of leaves, leaf area and stem girth. T₇ also recorded superior yield attributes, particularly number of fruits per plant, fruit length, fruit weight and fruit girth, resulted in the highest green chilli yield of 4304 kg ha⁻¹. The superior performance of T₇ may be attributed to the complementary effects of humic acid and seaweed extract in promoting vegetative growth, nutrient acquisition and reproductive development. The findings suggest that combined foliar application of humic acid and seaweed extract along with the recommended package of practices is a promising strategy for enhancing the growth and productivity of green chilli under the Southern Transitional Zone of Karnataka.

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