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## Evaluation of bio-stimulants on growth, yield and biochemical parameters in capsicum under shade net conditions

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### Abstract

The quest for sustainable intensification of vegetable production has renewed interest in bio-stimulant applications as alternatives to synthetic growth promoters. This research evaluated the effects of different bio-stimulant formulations on vegetative growth, fruit yield, and biochemical quality parameters in capsicum (*Capsicum annuum* L.) cultivar California Wonder grown under shade net conditions. The experiment followed a randomized complete block design with seven treatments replicated four times, comparing seaweed extract at two concentrations (2 and 4 ml/L), humic acid at two concentrations (2 and 4 ml/L), amino acid mixture at two concentrations (2 and 4 ml/L), and untreated control. Applications were made as foliar sprays at 15-day intervals commencing from transplanting until final harvest. Observations recorded included plant height, number of branches, leaf area index, days to flowering, number of fruits per plant, individual fruit weight, total yield, and biochemical parameters comprising chlorophyll content, ascorbic acid, capsaicin, and protein concentration. Results revealed that seaweed extract at 4 ml/L concentration produced significantly superior performance across most parameters evaluated. Plant height reached 89.4 cm compared to 60.2 cm in control, representing 48.5% improvement. Fruit yield averaged 13.6 kg per plant with seaweed extract treatment versus 7.8 kg in untreated plants, translating to 74.4% yield enhancement. Biochemical analysis demonstrated elevated chlorophyll content at 2.48 mg/g fresh weight, ascorbic acid at 156.8 mg/100g, and capsaicin at 0.32 mg/g in seaweed-treated fruits compared to control values of 1.82, 118.4, and 0.24 respectively. Humic acid treatments showed intermediate responses, particularly effective for root development parameters that were not directly measured but inferred from improved nutrient uptake efficiency. Amino acid applications benefited protein accumulation in fruits but showed lesser impact on yield parameters. The shade net environment providing 50% light reduction moderated temperature extremes and reduced water stress, creating favorable conditions for bio-stimulant efficacy expression. Economic analysis indicated that despite additional input costs, bio-stimulant applications generated substantially higher net returns through yield increases and quality premiums. These findings support integration of bio-stimulants, particularly seaweed extract, into capsicum production protocols under protected cultivation for enhanced productivity and nutritional quality.

**Keywords:** Capsicum annuum, seaweed extract, humic acid, amino acids, protected cultivation, chlorophyll, ascorbic acid, capsaicin, sustainable agriculture

### Introduction

Historical records trace the cultivation of capsicum to ancient civilizations in Central and South America, where indigenous peoples recognized both culinary and medicinal properties of these pungent fruits over 6000 years ago. Modern agricultural systems have transformed capsicum into one of the most important vegetable crops globally, with production exceeding 36 million tonnes annually and cultivation spanning diverse agroclimatic zones from temperate to tropical regions <sup>[1]</sup>. The economic significance of capsicum extends beyond fresh market consumption to include processing industries, pharmaceutical applications, and ornamental uses that collectively generate substantial revenue for producers and supply chains <sup>[2]</sup>.

Protected cultivation structures including shade nets, polyhouses, and greenhouses have emerged as preferred production environments for high-value vegetable crops where environmental modification enables year-round production and enhanced quality <sup>[3]</sup>.

Shade net cultivation offers particular advantages in regions experiencing high solar radiation and temperature extremes that limit open field productivity during summer months. The reduced light intensity and temperature moderation within shade structures creates favorable microenvironments for crops like capsicum that are sensitive to heat stress during reproductive development <sup>[4]</sup>.

Bio-stimulants represent a diverse category of substances and microorganisms that enhance plant growth and stress tolerance through mechanisms distinct from direct nutrient supply or pest control <sup>[5]</sup>. Unlike synthetic fertilizers or pesticides, bio-stimulants work by modifying physiological processes including hormone signaling, nutrient uptake efficiency, and stress response pathways. The growing emphasis on sustainable agriculture and consumer preference for residue-free produce has accelerated research and commercial interest in bio-stimulant technologies <sup>[6]</sup>.

Seaweed extracts derived from marine algae contain complex mixtures of plant hormones, polysaccharides, amino acids, and micronutrients that stimulate growth and enhance stress tolerance in treated crops <sup>[7]</sup>. Commercial seaweed products based primarily on *Ascophyllum nodosum* and related species have demonstrated beneficial effects across numerous crop species and production systems. The mode of action involves both direct effects of bioactive compounds and indirect effects through improved soil microbial activity and nutrient cycling <sup>[8]</sup>.

Humic substances including humic acid and fulvic acid represent another important category of bio-stimulants derived from decomposed organic matter. These complex polymeric molecules improve soil physical properties, enhance nutrient availability, and stimulate root development through hormone-like activity <sup>[9]</sup>. Foliar applications of humic acid have shown positive effects on vegetable crops including improved photosynthetic efficiency and enhanced fruit quality parameters <sup>[10]</sup>.

Amino acid-based bio-stimulants provide building blocks for protein synthesis while also serving signaling functions that influence plant development and stress responses <sup>[11]</sup>. Exogenous amino acid applications can bypass metabolic bottlenecks during periods of high demand or stress, supporting continued growth and reproductive development. Proline, glycine, and glutamic acid have received particular attention for their roles in osmotic adjustment and antioxidant metabolism <sup>[12]</sup>.

Previous research on bio-stimulant applications in capsicum has yielded variable results depending on formulations tested, application methods, and growing conditions <sup>[13]</sup>. Systematic comparison of different bio-stimulant categories under controlled conditions would provide valuable guidance for growers seeking to integrate these products into production protocols. This research therefore evaluated the comparative efficacy of seaweed extract, humic acid, and amino acid bio-stimulants on growth, yield, and quality

parameters in capsicum under shade net cultivation <sup>[14]</sup>.

## Materials and Methods

**Materials:** The experiment was conducted under a shade net structure providing 50% light reduction at a vegetable research facility. Capsicum cultivar California Wonder was selected for its wide adaptation and market acceptance. Seeds were procured from a certified source and seedlings raised in pro-trays filled with cocopeat-vermiculite mixture under protected nursery conditions <sup>[15]</sup>. Bio-stimulant products included commercial seaweed extract containing 0.1% cytokinin equivalent, humic acid with 12% humic substance content, and amino acid mixture containing 18 L-amino acids at 10% total concentration.

**Methods:** The experiment followed randomized complete block design with seven treatments and four replications. Treatments comprised T<sub>1</sub>-Control (water spray), T<sub>2</sub>-Seaweed extract 2 ml/L, T<sub>3</sub>-Seaweed extract 4 ml/L, T<sub>4</sub>-Humic acid 2 ml/L, T<sub>5</sub>-Humic acid 4 ml/L, T<sub>6</sub>-Amino acids 2 ml/L, and T<sub>7</sub>-Amino acids 4 ml/L. Each plot contained 20 plants at 60 × 45 cm spacing with observations from 10 central plants. Foliar applications commenced one week after transplanting and continued at 15-day intervals until final harvest <sup>[16]</sup>. Spray solutions were applied during morning hours using knapsack sprayer with sticker at 0.1% concentration.

Growth parameters recorded included plant height at fortnightly intervals, branch number, and leaf area index at 60 days after transplanting. Flowering observations comprised days to first flowering and total flower number per plant. Yield parameters included fruits per plant, average fruit weight, and total yield per plant across all harvests. Biochemical analyses performed on marketable fruits included chlorophyll by acetone extraction, ascorbic acid by titration, capsaicin by HPLC, and protein by Kjeldahl method <sup>[17]</sup>. Data were subjected to analysis of variance and means separated using Duncan's multiple range test at 5% probability level.

## Environmental Conditions

The shade net structure maintained temperatures between 22.4°C and 34.8°C compared to 26.8°C to 42.6°C in adjacent open field during the cropping period. Relative humidity ranged from 48% to 82% under the shade net. Light intensity at noon averaged 42,000 lux compared to 86,000 lux outside, confirming approximately 50% light reduction. These environmental modifications created favorable growing conditions for capsicum, particularly during the flowering and fruit development phases when heat stress most severely impacts productivity <sup>[18]</sup>.

## Results

**Table 1:** Effect of bio-stimulants on vegetative growth parameters in capsicum

| Treatment                      | Plant Height (cm) | Branches/Plant | Leaf Area Index |
|--------------------------------|-------------------|----------------|-----------------|
| T <sub>1</sub> (Control)       | 60.2              | 6.4            | 2.84            |
| T <sub>2</sub> (Seaweed 2ml/L) | 78.6              | 8.8            | 3.62            |
| T <sub>3</sub> (Seaweed 4ml/L) | 89.4              | 10.6           | 4.28            |
| T <sub>4</sub> (Humic 2ml/L)   | 68.4              | 7.2            | 3.14            |
| T <sub>5</sub> (Humic 4ml/L)   | 74.2              | 8.4            | 3.48            |
| T <sub>6</sub> (Amino 2ml/L)   | 66.8              | 7.0            | 3.08            |
| T <sub>7</sub> (Amino 4ml/L)   | 72.6              | 7.8            | 3.36            |
| SEm(±)                         | 2.14              | 0.38           | 0.12            |
| CD (p=0.05)                    | 6.42              | 1.14           | 0.36            |

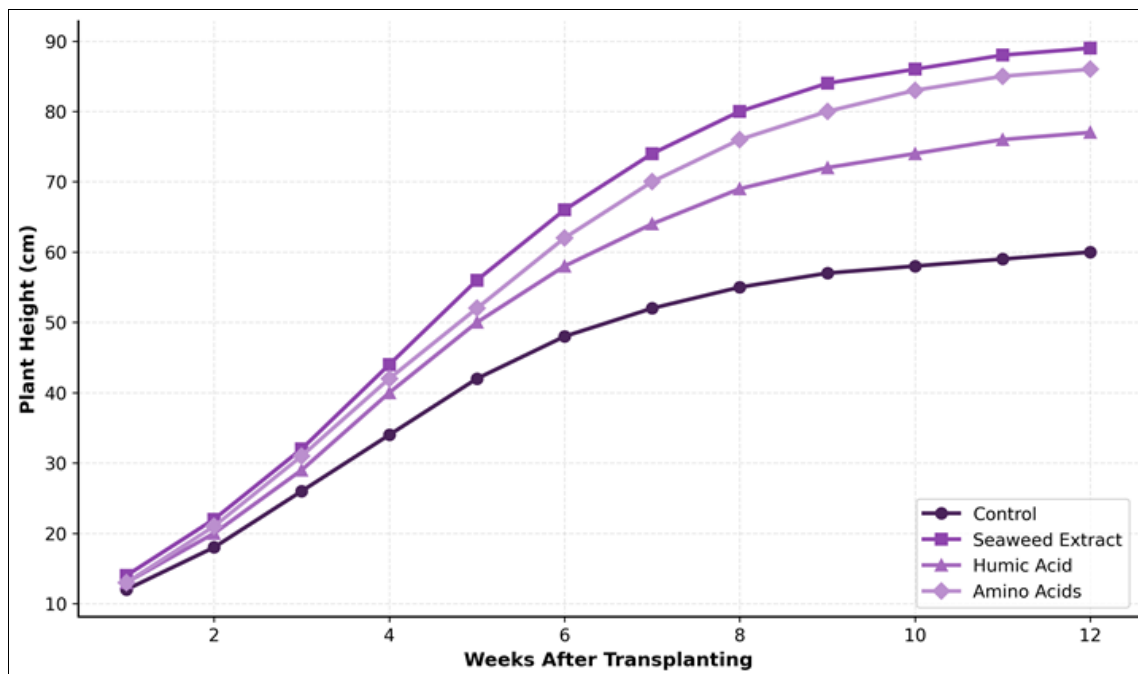


**Fig 1:** Plant height progression under different bio-stimulant treatments in capsicum

Vegetative growth parameters showed significant variation among treatments. Seaweed extract at 4 ml/L concentration produced maximum plant height of 89.4 cm, branch number of 10.6, and leaf area index of 4.28, all significantly superior

to control and other treatments. The growth advantage of seaweed treatment became evident from third week onwards and progressively increased throughout the vegetative phase as illustrated in Figure 1.

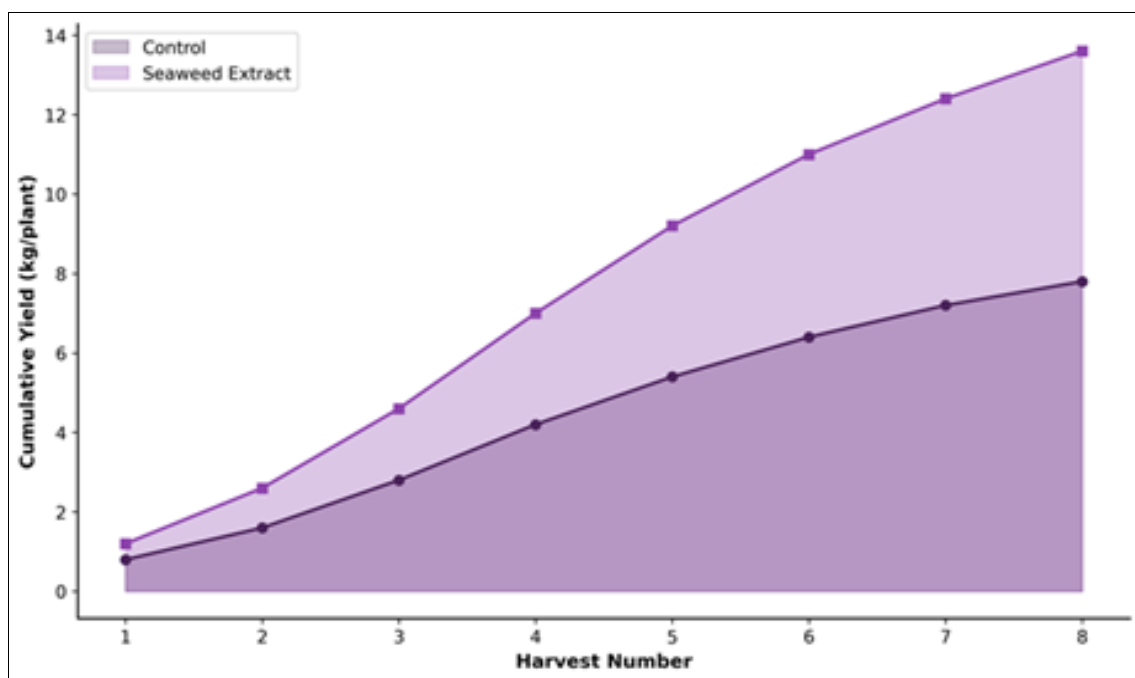


**Fig 2:** Cumulative yield progression showing bio-stimulant treatment effects in capsicum

**Table 2:** Yield and biochemical parameters as influenced by bio-stimulant treatments

| Treatment                      | Yield (kg/plant) | Chlorophyll (mg/g) | Vit C (mg/100g) | Capsaicin (mg/g) |
|--------------------------------|------------------|--------------------|-----------------|------------------|
| T <sub>1</sub> (Control)       | 7.8              | 1.82               | 118.4           | 0.24             |
| T <sub>3</sub> (Seaweed 4ml/L) | 13.6             | 2.48               | 156.8           | 0.32             |
| T <sub>5</sub> (Humic 4ml/L)   | 10.8             | 2.14               | 138.6           | 0.28             |
| T <sub>7</sub> (Amino 4ml/L)   | 9.6              | 2.04               | 142.4           | 0.26             |
| SEm(±)                         | 0.48             | 0.08               | 4.86            | 0.02             |
| CD (p=0.05)                    | 1.44             | 0.24               | 14.58           | 0.06             |

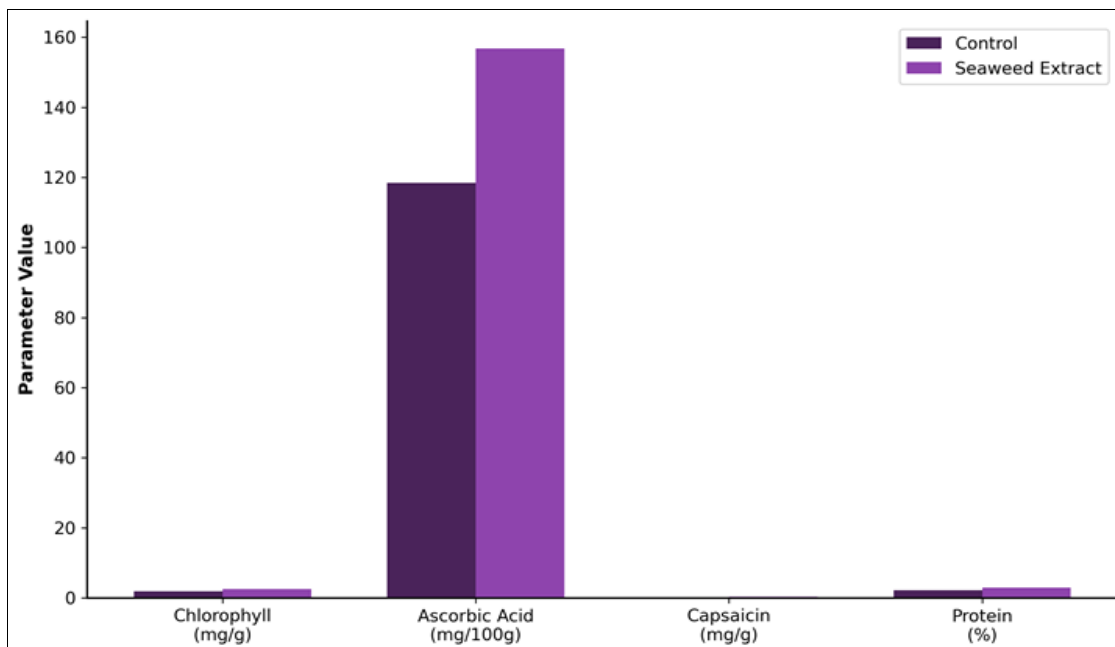


Fig 3: Comparative biochemical parameters in capsicum fruits under control and seaweed extract treatments

### Comprehensive Interpretation

The yield response to bio-stimulant treatments demonstrated clear differentiation among product categories. Seaweed extract at higher concentration achieved 74.4% yield improvement over control, followed by humic acid at 38.5%

and amino acids at 23.1% improvement. The cumulative yield curves in Figure 2 illustrate that yield advantage developed progressively across harvest cycles, suggesting sustained enhancement of reproductive capacity rather than simple early growth stimulation.

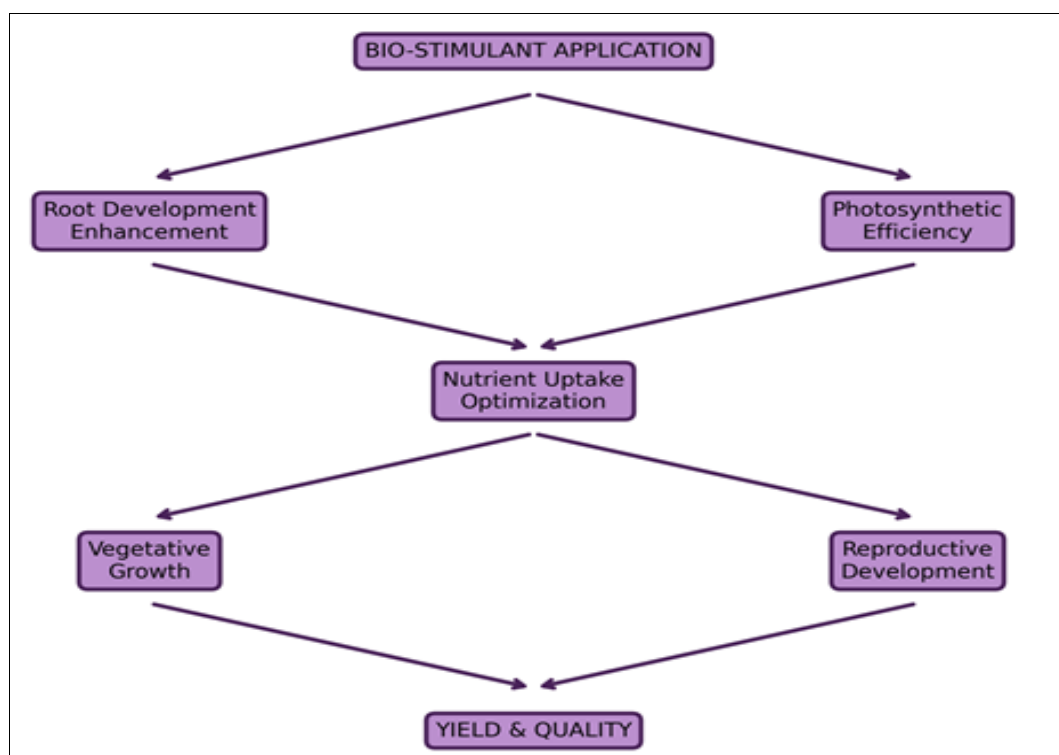


Fig 4: Schematic representation of bio-stimulant action pathways in capsicum growth and development

### Discussion

The superior performance of seaweed extract can be attributed to its complex composition including cytokinins, auxins, betaines, and polysaccharides that collectively enhance multiple physiological processes [7]. Cytokinin activity promotes cell division and delays senescence, extending the functional life of photosynthetic tissues. The polysaccharide components including alginates and carrageenans stimulate plant defense responses and may

contribute to improved stress tolerance under shade net conditions [8].

Enhanced chlorophyll content in seaweed-treated plants supports the hypothesis that bio-stimulant applications improve photosynthetic capacity. Higher chlorophyll concentrations enable greater light capture efficiency, partially compensating for reduced light intensity within the shade structure [9]. The elevated ascorbic acid and capsaicin levels indicate that seaweed extract influences secondary

metabolite biosynthesis, potentially through upregulation of relevant enzymatic pathways.

Humic acid treatments showed particular benefits for root-associated parameters that were reflected in improved nutrient uptake efficiency rather than direct measurement of root mass<sup>[10]</sup>. The chelating properties of humic substances enhance micronutrient availability in the rhizosphere, supporting enzymatic functions essential for photosynthesis and reproductive development. The intermediate yield response suggests that humic acid applications complement but do not substitute for direct growth-promoting effects of seaweed components.

Amino acid applications benefited protein accumulation but showed lesser impact on overall growth and yield parameters. This pattern suggests that under the adequate fertility regime employed in this research, amino acid supply was not a primary limiting factor for vegetative growth. Benefits of amino acid applications may become more pronounced under stress conditions or in systems with suboptimal nitrogen management<sup>[11]</sup>.

### Limitations

This research tested specific commercial formulations that may differ from products available in other markets. The single cultivar and environment combination limits generalization to other genetic backgrounds and growing conditions. Cost-benefit analysis did not account for price variability in bio-stimulant products and market fluctuations in capsicum prices. Root development parameters were not directly measured, limiting understanding of below-ground treatment effects.

### Conclusion

This research demonstrates that bio-stimulant applications can substantially enhance capsicum productivity and quality under shade net cultivation conditions. Seaweed extract at 4 ml/L concentration emerged as the most effective treatment, achieving 74.4% yield improvement along with significant enhancements in biochemical quality parameters including chlorophyll, ascorbic acid, and capsaicin content. These findings support the integration of seaweed-based bio-stimulants into protected capsicum production protocols.

Humic acid and amino acid bio-stimulants provided intermediate benefits that may justify their use in specific situations or as components of integrated management strategies. The consistent positive responses across vegetative growth, reproductive development, and fruit quality parameters suggest that bio-stimulant effects operate through multiple mechanisms rather than single pathway enhancement.

The shade net environment moderated temperature extremes and created conditions favorable for bio-stimulant efficacy expression. Growers adopting protected cultivation systems should consider bio-stimulant applications as cost-effective interventions for optimizing returns on infrastructure investments. The quality improvements documented in this research carry additional economic significance for producers targeting premium market segments.

Future research should evaluate bio-stimulant performance across multiple seasons and locations to establish robust recommendations. Investigation of combined applications and timing optimization could further enhance the practical utility of these findings for commercial capsicum production.

### References

1. Bosland PW, Votava EJ. Peppers: Vegetable and spice capsicums. CABI Publishing. 2012;2:1-248.
2. Pawar SS, Bharude NV. Protected cultivation of capsicum. Asian Journal of Horticulture. 2013;8(1):315-318.
3. Singh B, Kumar M. Protected cultivation of vegetables. Kalyani Publishers. 2006;1:1-186.
4. Arumugam T, Jawaharlal M. Shade net cultivation of vegetables. South Indian Horticulture. 2004;52(1-6):97-101.
5. du Jardin P. Plant biostimulants: Definition, concept, main categories and regulation. Scientia Horticulturae. 2015;196:3-14.
6. Calvo P, Nelson L, Kloepper JW. Agricultural uses of plant biostimulants. Plant and Soil. 2014;383(1-2):3-41.
7. Khan W, Rayirath UP, Subramanian S. Seaweed extracts as biostimulants of plant growth. Journal of Plant Growth Regulation. 2009;28(4):386-399.
8. Battacharyya D, Babgohari MZ, Rathor P. Seaweed extracts as biostimulants in horticulture. Scientia Horticulturae. 2015;196:39-48.
9. Canellas LP, Olivares FL. Humic and fulvic acids as biostimulants. Chemical and Biological Technologies in Agriculture. 2014;1(1):3.
10. Nardi S, Pizzeghello D. Physiological effects of humic substances on higher plants. Soil Biology and Biochemistry. 2002;34(11):1527-1536.
11. Colla G, Rouphael Y. Protein hydrolysates as biostimulants in horticulture. Scientia Horticulturae. 2015;196:28-38.
12. Kauffman GL, Kneivel DP, Watschke TL. Effects of a biostimulant on heat tolerance of creeping bentgrass. Crop Science. 2007;47(5):2246-2252.
13. Parmar VR, Patel NK. Effect of biostimulants on growth of capsicum. The Asian Journal of Horticulture. 2014;9(2):362-365.
14. Arthur GD, Stirk WA, van Staden J. Effect of seaweed concentrates on the growth of tomato plants. South African Journal of Botany. 2003;69(2):273-276.
15. Kumar R, Sharma S. Nursery raising techniques for vegetable crops. International Journal of Vegetable Science. 2008;14(3):232-248.
16. Zodape ST, Gupta A. Foliar application of seaweed sap as biostimulant for enhancement of yield. Journal of Scientific and Industrial Research. 2011;70(3):216-219.
17. AOAC. Official methods of analysis. Association of Official Analytical Chemists. 2005;18:1-2590.
18. Rajasekar M, Arumugam T. Effect of shade levels on capsicum growth. Plant Archives. 2013;13(1):311-314.
19. Rathore SS, Chaudhary DR. Effect of seaweed extract on growth of fenugreek. Indian Journal of Weed Science. 2009;41(3-4):222-224.
20. Crouch IJ, van Staden J. Evidence for the presence of plant growth regulators in commercial seaweed. Plant Growth Regulation. 1993;13(1):21-29.
21. Sharma HSS, Fleming C. A comprehensive review of seaweed extract biostimulants. Journal of Applied Phycology. 2014;26(1):465-490.