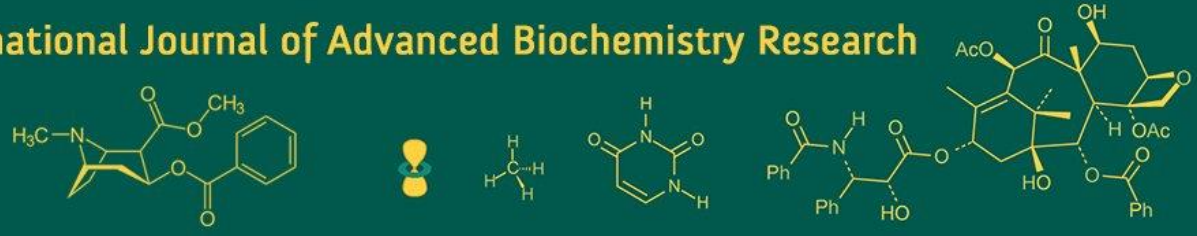
International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(1): 1037-1040
www.biochemjournal.com
Received: 07-10-2025
Accepted: 10-11-2025

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Safety and effectiveness of SV59 for enhancing okra crop production

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DOI: https://www.doi.org/10.33545/26174693.2026.v10.i1Sm.7176

Abstract
The study evaluated the bio-efficacy of SV59 bio-stimulant on growth, yield, and soil nutrient status of okra under field conditions at ZAHRS, KSNUAHS, Shivamogga (December 2023-May 2024). The experiment was laid out in a randomized block design with seven treatments replicated thrice. SV59 was applied as soil drench at 20 and 50 DAS at 0-2.00 L acre^{-1}, with positive and negative controls. Growth parameters, physiological traits, yield attributes, phytotoxicity and soil properties were assessed and analysed using ANOVA (P = 0.05). SV59 at 1.50-2.00 L acre^{-1} significantly enhanced plant height (82.2 cm), leaf area (4170 cm^2), LAI (1.158), total chlorophyll (2.15 mg g^{-1}), fruit weight (10.29 g) and yield (11.75 t ha^{-1}) over control. No phytotoxicity symptoms were recorded. Post-harvest soil showed slight nutrient decline, indicating efficient nutrient uptake. SV59 effectively improved okra growth and productivity without adverse effects; 1.50-2.00 L acre^{-1} is recommended.

Keywords: Okra, bio-stimulant, SV59, phytotoxicity, yield, growth parameters and chlorophyll content

Introduction
Okra (*Abelmoschus esculentus* L. Moench), commonly known as bhendi or lady's finger, is a warm-season crop originating from India and widely cultivated for its immature fruits, which are consumed fresh, canned, or used in soups and stews due to their mucilaginous properties (Siemonsma, 1987) [6]. Among *Abelmoschus* species, *A. esculentus* has significant commercial value due to its rich nutritional profile, including vitamins A, B and C, proteins, carbohydrates, fats, minerals, iron and iodine, making it an important dietary component in regions with nutritional imbalances (Tindall, 1983) [8].

Excessive reliance on chemical fertilizers increases yield quantity but often reduces nutritional quality and impairs long-term soil fertility through nutrient degradation, loss of organic matter, increased acidity and nutrient imbalance (Savci, 2012; Tilman *et al.*, 2002) [5, 7]. Bio-stimulants provide a sustainable alternative by reducing chemical inputs, restoring natural nutrient cycles and enhancing soil organic matter via microbial activity (du Jardin, 2015) [3]. Derived from organic materials with bioactive compounds, bio-stimulants improve physiological processes, nutrient-use efficiency, growth and tolerance to biotic and abiotic stresses (Bulgari *et al.*, 2019) [1]. They typically contain plant hormones (cytokinins, auxins, IAA, IBA), vitamins, amino acids and trace elements (Fe, Cu, Zn, Co, Mo, Mn) and are effective as foliar sprays or soil applications (Calvo *et al.*, 2014) [2].

Okra requires high nutrient inputs for optimal yield. Integrating bio-stimulants can improve fruit quality, post-harvest keeping quality and soil health. The present study evaluated the bio-efficacy of a novel bio-stimulant, SV59, on okra growth, yield and quality while assessing potential phytotoxicity risks. The specific objectives were to: (1) examine the effects of SV59 on growth and physiological parameters, (2) assess phytotoxic effects and (3) determine impacts on yield and quality attributes.

2. Materials and Methods
The field experiment was conducted at Zonal Agricultural and Horticultural Research Station (ZAHRS), Navile, KSNUAHS, Shivamogga, Karnataka, from December 2023 to May 2024.

2.1 Experimental Site
The trial was laid out in Block C-6 at ZAHRS, Navile (13°58' N, 75°34' E, 650 m above mean sea level) in Agro-climatic Zone VII (Southern Transitional Zone), Karnataka.

2.2 Soil Characteristics: Pre-sowing composite soil samples (0-30 cm depth) showed sandy loam texture (Typic Haplustalf, USDA classification), slightly acidic pH, normal electrical conductivity, medium organic carbon, low available N and P, medium K, sufficient Ca and Mg, medium S, high Fe, Cu and Mn and low Zn (Table 1).

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 25ºC)	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

2.3 Climatic Conditions
During the cropping period, actual rainfall (288.8 mm over 13 days) exceeded the 30-year average (163.9 mm) by 124.9 mm, with surplus in January and May and deficits in April. Mean maximum temperatures were slightly above normal (30.8-37.3 °C), minimum temperatures below normal (15.1-22.4 °C) and relative humidity mostly below normal.

2.4 Treatment Details
Seven treatments were tested in a randomized block design with three replications and 3 × 3 m plots at 60 × 60 cm spacing:

- T_1: Control (water spray)
- T_2: SV59 @ 0.50 L $acre^{-1}$
- T_3: SV59 @ 1.00 L $acre^{-1}$
- T_4: SV59 @ 1.50 L $acre^{-1}$
- T_5: SV59 @ 2.00 L $acre^{-1}$
- T_6: Positive control (recommended NPK fertilizer)
- T_7: Negative control

SV59 was applied as soil drench at 20 and 50 days after sowing (DAS).

2.5 Cultural Operations
The field was prepared with deep ploughing, harrowing and incorporation of farmyard manure (25 t ha^{-1}). Okra hybrid cv. Arka Nikita was sown on 31 December 2023. Recommended NPK fertilizer (125:75:63 kg ha^{-1}) was applied with half N and full P and K at sowing and the remaining N at 30-35 DAS. Standard interculture, weed management, irrigation and plant protection practices were followed. Harvesting comprised 26 pickings of tender fruits (8-10 cm).

2.6 Observations and Analytical Methods
Growth (plant height, internodal length, leaf area, leaf area index) and physiological (chlorophyll a, b and total) parameters were recorded non-destructively on three tagged plants per plot at 30, 60 and 90 DAS. Yield and quality attributes were recorded over all harvests. Phytotoxicity was visually scored (0-10 scale) at 1, 3, 5, 7 and 10 days after each application. Post-harvest soil samples were analysed for pH, EC, organic C, available N, P, K and micronutrients using standard methods.

2.7 Statistical Analysis
Data were subjected to analysis of variance (ANOVA) at P = 0.05 following Gomez and Gomez (1984) [4].

3. Results and Discussion
3.1 Morphological Parameters
At 30 DAS, treatments showed no significant differences in plant height, internodal length, leaf area, or leaf area index (LAI) (Table 2). Significant improvements emerged at 60 and 90 DAS, with the highest values in T_5 (SV59 @ 2.00 L $acre^{-1}$): plant height 82.2 cm (11.4% > control), leaf area 4170 cm^2 $plant^{-1}$ (15.6% > control) and LAI 1.158 (15.7% > control). Treatments T_4 and T_3 also outperformed the control, while T_2 showed modest, mostly non-significant gains. The dose-dependent response (3.19-13.53% improvement) is attributed to auxin-and cytokinin-like activity promoting cell division and expansion (Calvo *et al.*, 2014; Bulgari *et al.*, 2019) [2, 1].

3.2 Physiological Parameters
Chlorophyll contents were similar across treatments at 30 DAS but significantly higher in SV59 treatments at 60 and 90 DAS (Table 3). T_5 recorded the highest total chlorophyll (2.26 mg g^{-1} at 90 DAS; 22.2% > control), followed by T_4 and T_3. Enhanced chlorophyll synthesis is linked to trace elements in SV59 that support chlorophyll formation and stability (du Jardin, 2015) [3].

Table 2: Morphological parameters as influenced by application of SV 59 (soil drenching) at 20 and 50 DAS^{+} on okra

Treatment & Dosage	Plant height (cm)			Inter nodal length (cm)			Leaf area (cm^2)			LAI		
	30*	60**	90	30	60	90	30	60	90	30	60	90
	Days after sowing											
T_1: SV 59 @ 0.50 L acre^{-1}	28.6	57.2	76.0	5.0	7.0	7.6	745	1970	3883	0.207	0.547	1.079
T_2:SV 59 @ 1.00 L acre^{-1}	29.6	60.5	79.5	5.0	7.2	7.7	800	2105	4068	0.222	0.585	1.130
T_3: SV 59 @ 1.50 L acre^{-1}	31.2	62.3	81.6	5.2	7.0	7.7	832	2228	4117	0.231	0.619	1.144
T_4: SV 59 @ 2.00 L acre^{-1}	33.4	62.7	82.2	4.9	6.5	7.5	854	2276	4170	0.237	0.632	1.158
T_5: Untreated control	30.5	55.2	73.8	5.2	6.7	7.5	740	1658	3608	0.206	0.461	1.002
S. Em. ±	1.61	1.97	2.28	0.15	0.24	0.12	41.2	146.5	159.6	0.013	0.042	0.047
C.D. (5%)	NS	5.70	6.55	NS	NS	NS	NS	423.4	461.2	NS	0.121	0.136

DAS^{+}-Days after sowing 30*-10 days after first application 60**-10 days after second application

Table 3: Physiological parameters as influenced by application of SV 59 (soil drenching) at 20 and 50 DAS^{+} on okra

Treatment & Dosage	30* DAS			60** DAS			90 DAS		
	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 59 @ 0.50 L acre^{-1}	1.262	0.471	1.735	1.508	0.517	2.025	1.623	0.580	2.205
T_2:SV 59 @ 1.00 L acre^{-1}	1.289	0.485	1.774	1.553	0.545	2.098	1.675	0.608	2.283
T_3: SV 59 @ 1.50 L acre^{-1}	1.317	0.490	1.807	1.570	0.584	2.154	1.712	0.634	2.346
T_4: SV 59 @ 2.00 L acre^{-1}	1.353	0.498	1.852	1.595	0.602	2.197	1.756	0.672	2.428
T_5: Untreated control	1.235	0.445	1.680	1.412	0.482	1.894	1.552	0.535	2.089
S. Em. ±	0.045	0.019	0.063	0.049	0.021	0.068	0.053	0.030	0.085
C.D. (5%)	NS	NS	NS	0.140	0.061	0.197	0.155	0.089	0.246

DAS^{+}-Days after sowing 30*-10 days after first application 60**-10 days after second application

Table 4: Yield and yield components as influenced by application of SV 59 (soil drenching) at 20 and 50 DAS^{+} on okra

Treatment & Dosage	Fruit length	Fruit diameter	Average fruit weight	Number of fruits per plant	Fruits yield per plant	Net plot yield	Yield per hectare
	(cm)	(mm)	(gm)	(Number)	(gm)	(kg)	(tonne)
T_1: SV 59 @ 0.50 L acre^{-1}	11.9	14	9.71	45	437	9.23	10.68
T_2:SV 59 @ 1.00 L acre^{-1}	12.3	13	9.85	47	463	9.37	10.84
T_3: SV 59 @ 1.50 L acre^{-1}	11.5	15	10.03	49	491	9.78	11.32
T_4: SV 59 @ 2.00 L acre^{-1}	11.7	14	10.29	52	535	10.15	11.75
T_5: Untreated control	8.8	15	9.34	45	421	8.94	10.35
S. Em. ±	0.98	0.8	0.21	2.5	13.4	0.24	0.32
C.D. (5%)	NS	NS	0.61	NS	38.7	0.69	0.92

DAS^{+}-Days after sowing

3.3 Yield and Yield Components

Fruit length, diameter and number of fruits per plant showed no significant treatment effects. However, average fruit weight, yield per plant, net plot yield and hectare yield were significantly higher in SV59 treatments. T_5 achieved 535 g plant^{-1} (27.1% > control) and 12.18 t ha^{-1} (17.7% > control), followed by T_4 (11.75 t ha^{-1}). The positive control (T_6) was intermediate (Table 4). Improved yield is attributed to enhanced photosynthate translocation facilitated by SV59's bioactive compounds (Calvo *et al.*, 2014) [2].

3.4 Phytotoxicity

No phytotoxic symptoms (chlorosis, necrosis, wilting, epinasty, hyponasty) were observed at any dose or observation interval after either application (score = 0).

3.5 Post-Harvest Soil Properties

Soil pH remained stable. Slight reductions in organic C, N, P, K and Zn were observed across treatments, reflecting efficient nutrient uptake by the crop rather than degradation. SV59 treatments showed no adverse effects on soil fertility (Table 5).

Table 5: Effect of application of SV 59 (soil drenching) at 20 and 50 DAS^{+} on soil chemical properties and nutrient status after crop harvest

Sl. No.	Particulars	Initial	Final
1.	Soil pH	6.25	6.28
2.	EC (dSm^{-1}at 25^{o}C)	0.17	0.19
3.	Organic Carbon (g kg^{-1})	3.62	3.57
4.	Available Nitrogen (kg ha^{-1})	219.52	206.35
5.	Available Phosphorus (kg ha^{-1})	80.54	69.20
6.	Available Potassium (kg ha^{-1})	225.79	204.44
7	Exchangeable Calcium [cmol(p^{+}) kg^{-1}]	1.80	1.48
8	Exchangeable Magnesium [cmol(p^{+}) kg^{-1}]	0.92	0.71
9	Available Sulphur (ppm)	17.1	16.6
10	Zinc (ppm)	1.44	1.07
11	Iron (ppm)	14.48	10.35
12	Copper (ppm)	0.84	0.78
13	Manganese (ppm)	8.27	8.06

DAS^{+}-Days after sowing

4. Conclusion

Soil drenching with SV59 at 20 and 50 DAS significantly enhanced okra growth, chlorophyll content and yield in a dose-dependent manner, with optimal performance at 1.50-2.00 L acre^{-1} (11.75-12.18 t ha^{-1}; 13.5-17.7% > control). No phytotoxicity was observed, confirming safety. Post-harvest soil analysis indicated sustained fertility through improved nutrient utilisation.

SV59 is a promising bio-stimulant for integrated nutrient management in okra, particularly in nutrient-poor acidic soils of the Southern Transitional Zone. Recommended application is 1.50-2.00 L acre^{-1} with recommended fertilizer dose to maximise yield and sustainability.

5. Competing Interests

The authors declare no competing interests.

6. Authors' Contributions

Renukaswamy N. S. and Ganapathi M. designed the study, performed statistical analysis, wrote the protocol and drafted the manuscript. Kishore S. M. and S. J. Kirankumar managed field and laboratory analyses. Shashikala B. and Jaya Kishore Ankireddypalli conducted literature searches and assisted in data interpretation. All authors read and approved the final manuscript.

7. Ethical Approval

This study did not involve human participants or animals.

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