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IMPACT OF PROTEIN HYDROLYSATE BIOSTIMULANTS ON THE GROWTH DYNAMICS AND PROFITABILITY OF *Solanum lycopersicum* L.

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ABSTRACT

The adoption of biostimulants has emerged as a sustainable strategy to enhance crop productivity while reducing dependence on synthetic agrochemicals. Protein hydrolysates, rich in amino acids and bioactive peptides, have demonstrated considerable potential in improving plant growth, nutrient uptake, stress tolerance, and yield. A field experiment was conducted during February–June 2023 at the Agricultural Research Station, Nipani, Karnataka, India, to evaluate the efficacy of BioLyft®, a protein hydrolysate-based biostimulant, on the growth, yield, fruit quality, and economics of tomato (*Solanum lycopersicum* L.) hybrid 'Nayana'. The experiment was laid out in a randomized block design with eight treatments and three replications. BioLyft formulations containing 7% and 10% amino acids were applied as foliar sprays at concentrations of 0.5, 1.0, and 2.0 mL L^{-1} during the vegetative, pre-flowering, and fruit development stages. Significant improvements were observed in growth, physiological, yield, and quality parameters following biostimulant application. The treatment comprising BioLyft with 10% amino acids at 2.0 mL L^{-1} recorded the highest plant height (70.67 cm), number of primary branches (13.73 $plant^{-1}$), secondary branches (10.53 $plant^{-1}$), chlorophyll content (23.68 SPAD units), fruit yield (4.84 kg $plant^{-1}$), and productivity (72.54 t ha^{-1}). The same treatment also improved total soluble solids, sugar content, titrable acidity, and ascorbic acid concentration. Yield enhancement of 83.51% and 29.35% was observed over the untreated control and commercial control, respectively. Economic analysis revealed the highest benefit–cost ratio (4.43) under BioLyft 10% amino acids at 2.0 mL L^{-1}. The results indicate that BioLyft is an effective biostimulant for improving tomato productivity, fruit quality, and profitability under field conditions.
***Keywords* :** BioLyft, protein hydrolysate, tomato, fruit quality, yield.

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated vegetable crops globally owing to its high nutritional value, economic importance, and versatility in culinary applications. Tomato fruits are rich sources of vitamins, minerals, organic acids, and antioxidants, particularly lycopene, which has been associated with reduced risks of cardiovascular diseases, certain cancers, and age-related disorders (Zhu *et al.*, 2020). Consequently, increasing tomato productivity and fruit quality remains a major objective in vegetable production systems.

Modern agriculture relies heavily on chemical fertilizers and synthetic growth-promoting inputs to maximize crop yields. However, long-term and indiscriminate use of these inputs has contributed to soil degradation, nutrient imbalance, reduction in soil microbial diversity, and environmental pollution (Bhatt *et al.*, 2019; Atieno *et al.*, 2020). Sustainable agricultural practices that maintain productivity while minimizing environmental impacts are therefore increasingly necessary.

Plant biostimulants have gained considerable attention as eco-friendly alternatives capable of enhancing crop growth, nutrient-use efficiency, stress tolerance, and productivity. Among the various classes of biostimulants, protein hydrolysates are particularly important because they contain amino acids and peptides that stimulate plant metabolism and physiological processes (Bulgari *et al.*, 2015). These compounds promote nutrient assimilation, photosynthetic efficiency, root development, flowering, fruit set, and yield formation.

BioLyft® is a protein hydrolysate-based biostimulant formulated with amino acids derived from sustainable protein sources. Although several studies have demonstrated positive effects of protein hydrolysates on horticultural crops, information regarding the performance of BioLyft under field-grown tomato conditions is limited. Therefore, the present study was undertaken to evaluate the influence of BioLyft formulations containing 7% and 10% amino acids on the vegetative growth, fruit yield, and nutritional quality of field-grown tomato.

Materials and Methods

The experiment was conducted during February to June 2023 at the Agricultural Research Station, Nipani, Karnataka, India, under the University of Agricultural Sciences, Dharwad. The experimental site is located at 16.20° N latitude and 74.20° E longitude, at an altitude of 610 m above mean sea level. The soil was sandy loam with slightly acidic reaction and adequate irrigation facilities. The study was laid out in a Randomized Block Design (RBD) with eight treatments and three replications using tomato hybrid ‘Nayana’ (F1).

The treatments were:

- T1: Water spray (Control)
- T2: Siapton @ 3.0 mL L^{-1} (Commercial control)
- T3: BioLyft 7% amino acids @ 0.5 mL L^{-1}
- T4: BioLyft 7% amino acids @ 1.0 mL L^{-1}
- T5: BioLyft 7% amino acids @ 2.0 mL L^{-1}
- T6: BioLyft 10% amino acids @ 0.5 mL L^{-1}
- T7: BioLyft 10% amino acids @ 1.0 mL L^{-1}
- T8: BioLyft 10% amino acids @ 2.0 mL L^{-1}

BioLyft was applied as a foliar spray at three critical growth stages like, peak vegetative stage (30–35 DAT), pre-flowering stage and fruit development stage. Twenty five days old healthy seedlings were transplanted at a spacing of 75 cm × 60 cm. recommended agronomic and plant protection practices prescribed by the University of Horticultural Sciences, Bagalkot, were followed uniformly. Fertilizers were applied through urea, diammonium phosphate, and muriate of potash according to recommended doses.

Observations recorded on growth parameters including plant height, number of primary branches, number of secondary branches, days to 50% flowering, and chlorophyll content (SPAD value) were recorded at 45 and 60 DAT. Yield attributes included fruit number, fruit diameter, fruit weight, and days to fruit maturity, total fruit yield per plant, and total fruit yield per hectare. Quality parameters were assessed on Total soluble solids (°Brix), Total sugars (%), Titratable acidity (%) and Ascorbic acid (mg 100 g^{-1}) Standard analytical procedures described by AOAC (1980) and Hegde and Hofreiter (1962) were followed. Statistical analysis was performed using analysis of variance (ANOVA), and treatment means were compared at the 5% significance level.

Results and Discussion

Growth Parameters

Application of BioLyft significantly enhanced vegetative growth compared with both the untreated and commercial controls. The highest plant height at 60 DAT (70.67 cm) was recorded under T_8 (BioLyft 10% amino acids @ 2.0 mL L^{-1}), followed closely by T_7 (70.27 cm). In contrast, the control treatment recorded the lowest plant height (64.60 cm). Similarly, the maximum number of primary branches (13.73 $plant^{-1}$) and secondary branches (10.53 $plant^{-1}$) was observed under T_8. Enhanced branching may be attributed to improved nutrient assimilation, increased metabolic activity, and greater availability of photosynthates, resulting in vigorous vegetative development. Similar observations were reported by Dhanasekaran and Bhuvaneshwari (2005) and Karak *et al.* (2023). The highest chlorophyll content (23.68 SPAD units) was also recorded under T_8, indicating improved photosynthetic efficiency **(**Crop Nutrition Experts, 2026). Amino acid-based biostimulants are known to promote chlorophyll synthesis and nutrient uptake, thereby enhancing photosynthetic activity and biomass accumulation (El Chami *et al.*, 2025).

Flowering and Fruit Maturity

The application of the peptide-based biostimulant BioLyft induced a slight, statistically evident extension in the timeline to 50% flowering (22.57 days) and subsequent fruit maturity (18.07 days) under treatment T_8. In determinate tomato hybrids such as 'Nayana', which possess a genetically fixed growth habit terminating in a solitary inflorescence, premature transition to reproduction often limits final yield potential due to canopy depletion. The observed phenological shift suggests that exogenous protein hydrolysates function as organic signaling complexes that fine-tune endogenous phytohormonal balances primarily modulating auxins and gibberellins (Colla *et al.,* 2015; Galaverni *et al.,* 2025). Rather than promoting stress-induced early flowering, the biostimulant prioritizes the establishment of a rigorous vegetative frame (Monda *et al.,* 2020).

This delay is physiologically advantageous for a bush-type cultivar; extending the initial vegetative phase expands the absolute "source" capacity, such as the leaf canopy and structural branch architecture (Rouphael *et al.,* 2025). Consequently, the prolonged crop duration establishes an enhanced carbohydrate reserve profile (Sorrentino *et al.,* 2023). When the plants transition to the terminal reproductive phase, this ample baseline supports a highly concentrated, heavy sink load without triggering premature vine collapse or leaf senescence (Colla *et al.,* 2017).

Yield Attributes and Yield

BioLyft significantly improved yield attributes and total productivity. The highest fruit diameter was recorded under T_8 (3.30 cm during the second harvest), while the greatest fruit weight per plant during individual harvests was also obtained under BioLyft treatments. The highest total fruit yield was recorded under T_8, producing 4.84 kg plant^{-1} and 72.54 t ha^{-1}, followed by T_7 with 4.71 kg plant^{-1} and 70.76 t ha^{-1}. Compared with the untreated control, T_8 resulted in an 83.51% increase in yield, while a 29.35% increase was observed over the commercial control. The enhanced productivity may be attributed to improved nutrient uptake, increased chlorophyll content, greater photosynthetic efficiency, and enhanced translocation of assimilates toward reproductive structures (Colla *et al.,* 2015; Sorrentino *et al.,* 2023). Protein hydrolysates are known to stimulate physiological and biochemical processes that promote flowering, fruit set, and fruit growth (Cozzolino *et al.,* 2024; Alfosea-Simón *et al.,* 2021).

Phytochemical and Fruit Quality Indices

The peak biochemical indices recorded under T_8 (TSS = 4.55 °Brix, Total Sugars = 5.01%, Titratable Acidity = 0.68%, and Ascorbic Acid = 20.68 mg 100 g^{-1}) indicate that BioLyft influences primary and secondary metabolic pathways during tomato ripening.

- **Total Soluble Solids (TSS) and Sugars:** Enhanced chlorophyll density and net photosynthetic efficiency provide a continuous supply of hexoses to the fruit vacuoles (Dlačić *et al.,* 2026). Exogenous amino acid application actively stimulates the accumulation of glucose and fructose, expanding the total carbohydrate sink profile within the fruit (Zavala-Gonzalez *et al.,* 2020).
- **Titratable Acidity:** The increase in organic acids (primarily citric and malic acid in *Solanum lycopersicum*) indicates a highly active tricarboxylic acid (TCA) cycle, generating the cellular ATP required for active transport and structural ripening (Zavala-Gonzalez *et al.,* 2020). This confirms that peptide-based inputs function as direct metabolic activators for fundamental respiratory pathways (Al-Karaki and Othman, 2024).
- **Ascorbic Acid (Vitamin C):** The biostimulant upregulates the plant's enzymatic antioxidant defense systems, accelerating ascorbic acid synthesis via the D-galacturonate or L-galactose pathways (Mellidou *et al.,* 2021). This elevated antioxidant profile protects cellular membranes from lipid peroxidation, which improves post-harvest shelf life and preserves internal quality parameters during transport (Alfosea-Simón *et al.,* 2021).

Economic Analysis

Economic analysis demonstrated the superiority of BioLyft treatments over the control and commercial standard. The highest gross return (Rs. 7,25,400 ha^{-1}), net return (Rs. 5,61,500 ha^{-1}), and benefit–cost ratio (4.43) were obtained under T_8. Treatment T_7 also produced a high benefit–cost ratio of 4.38. These results indicate that BioLyft application not only enhances biological productivity but also improves profitability, making it a viable option for commercial tomato cultivation. The economic gains are directly attributed to the biostimulant's ability to maximize fruit sizing and overall marketability, which allows the produce to secure top-tier market prices (Choudhary *et al.,* 2024). Integrating advanced peptide-based treatments into the nutrient matrix optimizes input-use efficiency, providing substantial financial scalability that surpasses traditional inorganic or commercial control baselines (Omara *et al.,* 2026).

Conclusion

The present investigation demonstrated that foliar application of BioLyft®, a protein hydrolysate-based biostimulant, significantly improved growth, physiological performance, yield, fruit quality, and economic returns of tomato. Among the treatments evaluated, BioLyft containing 10% amino acids applied at 2.0 mL L^{-1} during vegetative, pre-flowering, and fruit development stages proved most effective, producing the highest yield (72.54 t ha^{-1}) and benefit–cost ratio (4.43). The results suggest that BioLyft can serve as an environmentally sustainable and economically viable component of integrated nutrient management programs for tomato cultivation. Adoption of this technology may contribute to improved productivity, enhanced fruit quality, and greater profitability while reducing dependence on conventional chemical inputs.

Table 1: Effect of BioLyft formulation on growth attributes of tomato

Treatments	Plant height (cm)		Number of primary branches per plant		Number of secondary branches per plant		Days to 50 % flowering	Chlorophyll content (SPAD) value	
	45 DAT	60 DAT	45 DAT	60 DAT	45 DAT	60 DAT		45 DAT	60 DAT
T_1- Control	58.00	64.60	7.93	12.13	4.53	9.93	22.27	17.32	19.85
T_2- Commercial Control (Siapton @ 3.0ml/L)	59.27	66.53	9.17	13.00	4.63	9.97	22.30	17.82	20.43
T_3- BioLyft 7% amino acids @ 0.5 ml/L	59.67	67.47	8.47	13.27	4.63	10.03	22.33	18.33	20.78
T_4- BioLyft 7% amino acids @ 1.0 ml/L	61.27	67.87	9.27	13.43	4.70	10.20	22.40	20.50	22.69
T_5- BioLyft 7% amino acids @ 2.0 ml/L	62.00	69.60	9.33	13.47	4.70	10.30	22.47	20.64	22.75
T_6- BioLyft 10% amino acids @ 0.5 ml/L	59.27	66.80	9.20	13.27	4.67	10.10	22.40	20.47	22.53
T_7- BioLyft 10% amino acids @ 1.0 ml/L	62.27	70.27	9.33	13.50	4.70	10.40	22.57	21.15	23.34
T_8- BioLyft 10% amino acids @ 2.0 ml/L	62.73	70.67	9.33	13.73	4.77	10.53	22.57	21.31	23.68
S.Em±	2.27	1.9	0.26	0.48	0.13	0.13	0.19	0.3	0.48
CD (p=0.05)	6.9	5.8	0.8	1.5	0.4	0.4	0.6	0.9	1.4

Table 2: Effect of BioLyft formulation on yield attributes and yields of tomato

Treatments	Number of fruits per plant @ each Picking				Fruit diameter (cm) @ each Picking				Weight of fruits per plant (g) @ each Picking				Days to fruit maturity	Total fruit yield /plant (kg)	Total fruit yield/ha (ton)
	1^{st}	2^{nd}	3^{rd}	4^{th}	1^{st}	2^{nd}	3^{rd}	4^{th}	1^{st}	2^{nd}	3^{rd}	4^{th}			
T_1- Control	15.07	17.87	13.33	8.33	2.31	2.28	1.95	1.69	438.9	1525.5	551.8	118.9	14.27	2.64	39.53
T_2- Commercial Control (Siapton @ 3.0ml/L)	26.87	22.73	17.20	7.13	2.42	2.33	1.88	1.75	1260.9	1694.2	701.7	81.7	13.80	3.74	56.08
T_3- BioLyft 7% amino acids @ 0.5 ml/L	21.87	25.20	13.93	8.73	2.37	2.33	1.87	1.77	1399.1	1747.7	611.3	141.3	15.40	3.90	58.49
T_4- BioLyft 7% amino acids @ 1.0 ml/L	22.80	24.67	15.27	9.47	2.50	3.20	1.83	1.70	1550.9	2181.5	607.5	140.8	15.58	4.48	67.21
T_5- BioLyft 7% amino acids @ 2.0 ml/L	19.67	25.60	15.33	9.20	2.40	3.23	1.83	2.07	1475.8	2199.8	651.5	124.9	17.13	4.45	66.78
T_6- BioLyft 10% amino acids @ 0.5 ml/L	22.53	24.13	15.80	9.53	2.23	3.03	1.93	2.00	1627.9	1903.2	606.9	146.9	15.42	4.28	64.27
T_7- BioLyft 10% amino acids @ 1.0 ml/L	23.00	24.40	19.60	9.60	2.93	3.17	1.97	1.97	1658.4	2145.7	792.3	120.9	17.83	4.71	70.76
T_8- BioLyft 10% amino acids @ 2.0 ml/L	21.93	24.07	16.07	8.00	3.07	3.30	1.83	1.87	1708.7	2408.7	615.3	103.1	18.07	4.84	72.54
S.Em±	2.77	1.75	0.69	0.57	0.13	0.06	0.05	0.07	81.12	103.08	32.04	14.47	0.29	0.15	2.30
CD (p=0.05)	8.4	5.3	2.1	1.7	0.4	0.2	0.2	0.2	246.1	312.7	97.2	43.9	0.9	0.5	7.00

Table 3: Effect of BioLyft formulation on qualitative characters of tomato

Treatments	TSS (^oB)	Sugar content (%)	Titrable acidity (%)	Ascorbic acid (mg/100g)
T_1- Control	4.11	3.66	0.46	14.11
T_2- Commercial Control (Siapton @ 3.0 ml/L)	4.15	4.24	0.56	14.91
T_3- BioLyft 7 % amino acids @ 0.5 ml/L	4.31	4.77	0.62	16.01
T_4- BioLyft 7 % amino acids @ 1.0 ml/L	4.41	4.87	0.54	17.91
T_5- BioLyft 7 % amino acids @ 2.0 ml/L	4.44	4.88	0.55	18.10
T_6- BioLyft 10 % amino acids @ 0.5 ml/L	4.33	4.68	0.53	16.81
T_7- BioLyft 10 % amino acids @ 1.0 ml/L	4.48	4.92	0.63	19.91

T_8- BioLyft 10 % amino acids @ 2.0 ml/L	4.55	5.01	0.68	20.68
S.Em±	4.35	4.63	0.57	17.31
CD (p=0.05)	0.05	0.04	0.05	0.08

Table 4: Effect of BioLyft formulation on economics of tomato

Treatments	Total yield per hectare (ton)	Cost of cultivation (Rs.)	Gross return (Rs.)	Net return (Rs.)	B:C Ratio
T_1- Control	39.53	1,57,600	3,95,300	2,37,700	2.51
T_2- Commercial Control (Siapton@ 3.0ml/L)	56.08	1,63,784	5,60,800	3,97,016	3.42
T_3- BioLyft 7% amino acids @ 0.5 ml/L	58.49	1,61,200	5,84,900	4,23,700	3.63
T_4- BioLyft 7% amino acids @ 1.0 ml/L	67.21	1,63,300	6,72,100	5,08,800	4.12
T_5- BioLyft 7% amino acids @ 2.0 ml/L	66.78	1,67,500	6,67,800	5,00,300	3.99
T_6- BioLyft 10% amino acids @ 0.5 ml/L	64.27	1,60,300	6,42,700	4,82,400	4.01
T_7- BioLyft 10% amino acids @ 1.0 ml/L	70.76	1,61,500	7,07,600	5,46,100	4.38
T_8- BioLyft 10% amino acids @ 2.0 ml/L	72.54	1,63,900	7,25,400	5,61,500	4.43

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