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Short Communication

Impact of bio-stimulants on organically cultivated strawberries (*Fragaria* × *ananassa* Duch.)

Bhujel S.[1], Bhowmick N.[1*], Rai S.[2], Layek S.[2] and Mostafa Md.[2]

[1]Department of Pomology & Post Harvest Technology, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar - 736 165, West Bengal, India

[2]Directorate of Cinchona & Other Medicinal Plants, Mungpoo, Darjeeling - 734 313, West Bengal, India

[*]Corresponding author Email: nileshbhowmick@gmail.com

ABSTRACT

The present study evaluated the effect of different foliar-applied biostimulants on growth, yield and fruit quality of organically cultivated strawberry cv. Festival under protected conditions in the Darjeeling Himalayan region during a single growing season (2021-22). Four biostimulants seaweed extract, humic acid, fulvic acid and amino acid were applied either once (30 days after transplanting, DAP) or twice (30 and 60 DAP), along with a water sprayed control in randomized block design with three replications. Foliar application of humic acid at 4 gL^{-1} twice (30 and 60 DAP) significantly enhanced vegetative growth, flowering duration, fruit set, yield and biochemical quality. The highest fruit yield (650.10 g $plant^{-1}$), total soluble solids (9.73 °Brix) and ascorbic acid content (50.48 mg 100 g^{-1}) were recorded under this treatment, along with reduced titratable acidity. The findings indicate that humic acid applied twice during early growth stages can be effectively integrated into organic strawberry production systems in the Darjeeling Himalayan region for improving productivity and fruit quality.

Keywords: Biostimulants, fruit quality, humic acid, organic cultivation, Strawberry,

INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) is a high value soft fruit crop widely cultivated in temperate and subtropical regions due to its nutritional richness and consumer preference. In recent years, strawberry cultivation has gained importance in the hilly regions of northern West Bengal, including the Darjeeling Himalayas, owing to favorable agro-climatic conditions and increasing demand for organically produced fruits. However, organic strawberry production often faces challenges related to nutrient availability, plant vigor and yield stability.

Inorganic systems frequently rely on synthetic fertilizers and pesticides, which may contribute to environmental problems such as nutrient runoff and soil damage (Gomiero et al., 2011). Bio-stimulants are a combination of peptides and free amino acids, produced by chemical or enzymatic hydrolysis of the organic matrix of plant or animal origin, with a wide range of compositions (Maini, 2006). Biostimulants, including humic substances, seaweed extracts and amino acid-based formulations, have emerged as promising tools for improving plant growth, nutrient uptake and stress tolerance under sustainable farming systems. These compounds act at low concentrations and influence physiological processes such as photosynthesis, hormonal regulation and nutrient assimilation. Previous studies have reported positive effects of biostimulants on growth and yield of strawberry under different production systems; however, information on their performance under organic cultivation in the Darjeeling Himalayan region remains limited. The use of biostimulants, which are known to improve plant growth and stress tolerance, has emerged as a viable technique for optimizing both inorganic and organic strawberry production (Chakraborty et al., 2023; Al-Shatri et al., 2019). Therefore, the present investigation was undertaken to evaluate the response of strawberry cv. Festival to foliar application of selected biostimulants during a single growing season under protected organic conditions.

The experiment was conducted during the 2021-22 growing season under polyhouse conditions at the Directorate of Cinchona and Other Medicinal Plants, Mungpoo, Darjeeling, West Bengal (26°58′ N latitude, 88°22′ E longitude; 1200 feet above mean sea level).

Strawberry cv. Festival plants were transplanted on raised beds during the first week of September 2021 at a spacing of 45 × 30 cm. Organic cultivation practices were followed, and well-decomposed farmyard manure was applied during bed preparation.

Four biostimulants namely, seaweed extract, humic acid, fulvic acid and amino acid were applied either once at 30 days after transplanting (DAP) or twice at 30 and 60 DAP, along with a water-sprayed control. The treatments *viz*., T_1: control (water spray) at 30 + 60 DAP, T_2: seaweed extracts 4 mL/L at 30 DAP, T_3: humic acid 4 g/L at 30 DAP, T_4: fulvic acid 4 g/L at 30 DAP, T_5: amino acid 4 mL/L at 30 DAP, T_6: seaweed extracts 4 mL/L at 30 + 60 DAP, T_7: humic acid 4 g/L at 30 + 60 DAP, T_8: fulvic acid 4 g/L at 30 + 60 DAP and T_9: amino acid 4 mL/L at 30 + 60 DAP were evaluated in randomized block design with three replications. Standard cultural practices were followed throughout the crop period.

Growth parameters, flowering and fruiting attributes, yield and fruit biochemical characteristics were recorded using standard procedures. Data were statistically analyzed using analysis of variance (ANOVA), and treatment means were compared using the least significant difference (LSD) test at $P \leq 0.05$.

Foliar application of biostimulants significantly influenced growth, yield and fruit quality of strawberry (Tables 1&2). Among the treatments, humic acid applied at 4 gL^{-1} twice (30 and 60 DAP) resulted in the maximum plant height, number of leaves and root length. The positive impact of humic acid might be due to the boosting of hormonal activity in plants, resulting in improved plant growth (Nardi et al.,

Table 1 : Effect of biostimulants on vegetative growth of strawberry cv. Festival

Treatment	Plant height (cm)		Length of petiole (cm)		Increment (%) of shoot petiole	No. of leaves		Root length (cm)	No. of runners/ plant	Days to emergence of first flower bud	Flowering Duration (days)
	30DAP	60DAP	30DAP	60DAP		30 DAP	60 DAP				
T_1	16.32^{e}	18.25^{c}	11.52^{b}	12.26^{d}	6.42^{c}	4.75^{f}	7.81^{d}	18.34^{e}	6.93^{f}	102.05^{ab}	76.67^{e}
T_2	16.75^{de}	18.31^{c}	11.66^{b}	13.04^{cd}	11.44^{a}	5.28^{de}	8.00^{d}	19.55^{de}	9.17^{d}	97.82^{bc}	80.55^{de}
T_3	18.30^{c}	18.82^{bc}	13.03^{a}	13.09^{cd}	0.46^{f}	5.90^{bc}	8.30^{bcd}	19.76^{cde}	10.36^{c}	82.32^{e}	85.75^{cd}
T_4	17.86^{cd}	18.61^{c}	13.01^{a}	13.06^{cd}	0.38^{f}	5.59^{cd}	8.23^{cd}	18.83^{de}	10.27^{c}	87.55^{de}	82.55^{cde}
T_5	16.53^{de}	18.28^{c}	11.64^{b}	12.80^{cd}	9.96^{b}	5.07^{ef}	8.00^{d}	18.60^{e}	7.93^{e}	108.85^{a}	79.29^{de}
T_6	18.93^{abc}	18.98^{bc}	13.23^{a}	13.44^{bc}	1.58^{e}	6.00^{bc}	8.73^{bc}	21.96^{ab}	12.10^{b}	93.35^{cd}	94.24^{ab}
T_7	20.07^{a}	21.30^{a}	13.98^{a}	15.58^{a}	11.83^{a}	6.80^{a}	9.65^{a}	22.07^{a}	14.63^{a}	98.82^{bc}	98.33^{a}
T_8	19.84^{ab}	20.31^{ab}	13.91^{a}	14.52^{ab}	4.38^{d}	6.09^{b}	8.99^{ab}	21.40^{abc}	12.10^{b}	94.35^{bcd}	96.30^{a}
T_9	18.31^{bc}	18.84^{bc}	13.17^{a}	13.24^{cd}	0.53^{f}	5.88^{bc}	8.41^{bcd}	20.34^{bcd}	11.13^{c}	86.55^{de}	88.30^{bc}
S.Em±	0.5	0.53	0.36	0.37	0.18	0.16	0.22	0.56	0.3	2.66	2.44
LSD ($P \leq 0.05$)	1.52	1.6	1.08	1.13	0.55	0.48	0.71	1.69	0.9	7.98	7.32

Means with the same letter do not significantly differ from each other

Table 2 : Effect of bio-stimulants on fruiting behaviour and yield attributes of strawberry cv. Festival

Treatment	Duration of fruiting (days)	Fruit set (%)	Total fruits/plant (Nos.)	Fruit weight (g)	Fruit diameter (cm)	Yield (g/plant)
T_1	69.81^{e}	65.25 (53.91)^{de}	23.2^{f}	16.36^{e}	2.00^{e}	379.55^{d}
T_2	76.27^{de}	74.52 (59.74)^{b}	25.4^{ef}	18.23^{cd}	2.70^{d}	463.04^{c}
T_3	78.08^{cd}	72.67 (58.54)^{bc}	28.3^{cd}	16.87^{de}	2.00^{e}	477.42^{c}
T_4	76.32^{de}	61.39 (51.61)^{ef}	26.6^{de}	17.09^{de}	2.50^{d}	454.59^{c}
T_5	72.20^{de}	64.38 (53.39)^{de}	24.7^{ef}	18.23^{cd}	2.00^{e}	450.28^{c}
T_6	86.82^{b}	57.60 (49.40)^{f}	27.9^{cd}	20.75^{a}	3.60^{a}	578.92^{b}
T_7	94.10^{a}	80.78 (64.09)^{a}	32.9^{a}	19.76^{abc}	3.30^{bc}	650.10^{a}
T_8	89.77^{ab}	60.62 (51.16)^{ef}	32.4^{ab}	19.96^{ab}	3.50^{ab}	646.70^{a}
T_9	84.07^{bc}	68.51 (55.90)^{cd}	30.2^{bc}	19.10^{bc}	3.20^{c}	576.82^{b}
S.E.m±	2.27	2.68	0.78	0.51	0.07	14.79
LSD ($P \leq 0.05$)	6.82	5.69	2.35	1.55	0.23	44.36

Figures in the parenthesis are the angular transformed value. Means with the same letter do not significantly differ from each other

2002). Enhanced vegetative growth under humic acid treatment may be attributed to improved nutrient uptake, stimulation of root growth and modulation of endogenous hormone activity, particularly auxins and cytokinins. Humic acid treatment stimulates photosynthetic pigments, which enhance plant photosynthesis because of increased petiole length (Abbas et al., 2012). The present study found that biostimulants effectively increased fresh and dry biomass in strawberry plants. This aligns with the findings of Ranasingha et al. (2024), who also observed increased fresh and dry biomass in strawberries with the application of amino acid based biostimulants.

Nitrate reductase, glutamate dehydrogenase, and glutamine synthetase are enzymes involved in nitrogen assimilation pathways that were stimulated by various humic substances (Hernandez et al., 2015). Additionally, flowering behavior was positively influenced by humic acid treatment. Plants that received humic acid twice showed earlier flowering and longer flowering durations, which led to better fruit set and a higher number of fruits per plant. This increase in flowering and fruiting with humic acid application has been linked to enhanced photosynthesis and improved carbon and nitrogen metabolism.

Yield attributes showed significant variation among treatments. The highest fruit yield (650.10 g plant^{-1}) was recorded with humic acid applied at 30 and 60 DAP. The application of humic acid may significantly boost plant respiration, photosynthesis, and hormonal activities, resulting in more flowering and thereby improving fruit production significantly (Chen & Aviad, 1990), followed closely by fulvic acid applied twice. Seaweed extract applied twice resulted in the highest individual fruit weight and fruit diameter, likely due to the presence of cytokinin like compounds that enhance sink strength and assimilate partitioning. Seaweed extracts have been shown to increase cytokinin generation. Cytokinins are plant hormones that drive cell reproduction, differentiation, and resource mobilization (photo assimilation) to “sink” tissues such as fruits. Increased cytokinin levels can improve fruit sink strength, allowing for a greater accumulation of sugars and other substances, resulting in increased fruit weight (Rana et al., 2022).

Applying biostimulants notably enhanced fruit quality parameters (Table 3). Fruits from plants treated with humic acid showed the highest levels of total soluble solids, total sugars, and reducing sugars, while having the lowest titratable acidity. Similarly, in terms of biochemical observations, humic acid is known to improve photosynthesis; therefore, improvement of TSS was observed as a result of its application

Table 3 : Effect of bio-stimulants on TSS, total sugar, reducing sugar, ascorbic acid content, titratable acidity of strawberry fruits of cv. Festival

Treatment	TSS (°Brix)	Total sugar (%)	Reducing sugar (%)	Titratable acidity (%)	Ascorbic acid content (mg/100 g)
T_1	7.05^{f}	3.32^{e}	2.47^{c}	0.743^{a}	36.83^{e}
T_2	7.45^{def}	3.74^{cd}	2.56^{c}	0.633^{b}	41.88^{d}
T_3	7.90^{cde}	3.87^{bcd}	2.81^{b}	0.582^{cd}	45.51^{bcd}
T_4	7.64^{def}	3.80^{cd}	2.58^{c}	0.601^{bc}	44.74^{bcd}
T_5	7.39^{ef}	3.62^{de}	2.50^{c}	0.694^{a}	43.18^{cd}
T_6	8.45^{bc}	3.99^{bc}	2.92^{ab}	0.503^{e}	46.10^{bc}
T_7	9.73^{a}	4.46^{a}	3.06^{a}	0.401^{f}	50.48^{a}
T_8	8.97^{b}	4.15^{ab}	2.90^{ab}	0.502^{e}	48.01^{ab}
T_9	8.13^{cd}	3.94^{bcd}	2.86^{ab}	0.554^{de}	47.13^{ab}
S.E.m±	0.23	0.11	0.08	0.023	1.27
LSD (P≤0.05)	0.68	0.32	0.22	0.049	3.78

Mean with the same letter does not significantly differ from each other

(Liu et al., 1998). Moreover, humic acid treatment significantly boosted ascorbic acid content, possibly due to improved nutrient availability and metabolic activity during fruit growth. The use of amino acids supplies essential precursors for chlorophyll synthesis, which can increase pigment concentrations and enhance photosynthesis rates (Draie, 2019).

Overall, the results clearly demonstrate that foliar application of humic acid at critical growth stages can enhance both productivity and fruit quality of organically grown strawberry under hill conditions.

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