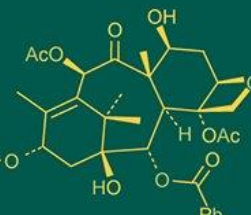
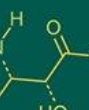
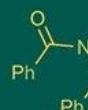


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(9): 430-436
www.biochemjournal.com
Received: 01-06-2026
Accepted: 04-07-2026

Avantika Singh
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

Divya Rana
Division of Vegetable Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

Aniket Sharma
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

Syed Romana Mahmood
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

Atiya Maqbool
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

Rohit Rawat
Department of Vegetable Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Corresponding Author:
Avantika Singh
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

Influence of integrated bioinoculants and bioenhancers on biochemical quality attributes of strawberry (*Fragaria × ananassa* Duch.) cv. winter dawn

Avantika Singh, Divya Rana, Aniket Sharma, Syed Romana Mahmood, Atiya Maqbool and Rohit Rawat

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i9Sf.9863>

Abstract

The present study evaluated the effects of bioinoculants and bioenhancers on the biochemical quality attributes of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn under subtropical conditions. The experiment was conducted in a randomized block design comprising nine treatments, including the recommended dose of fertilizers (RDF) and different combinations of *Azotobacter*, phosphate-solubilizing bacteria (PSB), Jeevamrit, and Amritpani. Key fruit quality parameters, namely total soluble solids (TSS), titratable acidity, and ascorbic acid content, were assessed.

The combined application of Jeevamrit, Amritpani, and PSB (T₈) significantly improved the biochemical quality of strawberry fruits compared with the control and other treatments. Fruits under this treatment recorded the highest TSS (7.98 °Brix) and ascorbic acid content (58.82 mg 100 g⁻¹ fresh weight), along with titratable acidity (1.57%), indicating a favourable sugar-acid balance.

These improvements may be attributed to enhanced microbial activity in the rhizosphere, improved nutrient solubilization, and increased nutrient availability and uptake resulting from the synergistic action of bioinoculants and bioenhancers. The findings demonstrate that the integrated use of bioinoculants and bioenhancers is an effective, sustainable, and eco-friendly approach for enhancing the biochemical quality of strawberry cv. Winter Dawn under subtropical agro-climatic conditions.

Keywords: Bioenhancers, bioinoculants, fruit quality, nutrient management, strawberry, subtropical agriculture

Introduction

Strawberry (*Fragaria × ananassa* Duch.) is one of the most important small fruit crops cultivated worldwide and is valued for its pleasant flavour, attractive colour, and high nutritional quality. Strawberry fruits are rich in vitamins (particularly vitamin C and folate), dietary fibre, organic acids, and a wide range of bioactive phenolic compounds such as flavonoids and other polyphenols, which together contribute to their strong antioxidant and anti-inflammatory activities. These bioactive constituents, including anthocyanins and phenolic acids, play a key role in the health-promoting properties of strawberries (Newerli-Guz *et al.* 2023) [8]. Regular consumption of strawberries has been associated with beneficial effects on human health, including improved antioxidant status and reduced inflammation, with potential protective effects against cardiometabolic disorders (Charoenwoodhipong *et al.* 2024) [2].

Among the nutritional components of strawberry, ascorbic acid (vitamin C) plays a major role in determining fruit quality and antioxidant potential. In addition to vitamin C, phenolic compounds and anthocyanins are major contributors to the radical-scavenging capacity and overall antioxidant activity of strawberry fruits (Cianciosi *et al.* 2025) [3]. The concentration of these bioactive compounds is not constant and varies with cultivar, environmental conditions, and stage of fruit maturity, indicating that both genetic and environmental factors strongly influence strawberry fruit quality (Charoenwoodhipong *et al.* 2024) [2].

From a commercial and consumer point of view, biochemical parameters such as total soluble solids (TSS), titratable acidity, and ascorbic acid content are considered key indicators of strawberry fruit quality.

TSS mainly reflects sugar accumulation, while titratable acidity contributes to flavour balance and overall sensory acceptability. These attributes directly affect consumer preference and market value, and are known to respond to differences in genotype, nutrient availability, and growing conditions (Patel *et al.* 2023) ^[9].

In intensive strawberry production systems, chemical fertilizers are commonly used to achieve high yields and acceptable fruit quality. However, prolonged and excessive use of inorganic fertilizers can negatively affect soil health by altering nutrient balance and soil microbial community structure, reducing soil biological activity, and decreasing nutrient use efficiency, raising concerns regarding the long-term sustainability of strawberry cultivation and environmental safety (Bai *et al.* 2023) ^[1].

In recent years, plant growth-promoting rhizobacteria (PGPR) and other microbial inoculants have emerged as promising biofertilizers that can complement or reduce the use of synthetic fertilizers in sustainable agriculture. These beneficial microorganisms colonize the rhizosphere and enhance plant growth through multiple mechanisms, including solubilizing phosphorus, fixing atmospheric nitrogen, producing phytohormones, and improving nutrient availability, cycling, and uptake, thereby supporting improved soil health and long-term crop productivity while mitigating environmental impacts associated with conventional chemical inputs (Yang *et al.* 2024) ^[17].

Plant growth-promoting bacteria improve plant performance through several mechanisms, such as biological nitrogen fixation, solubilization of insoluble phosphorus compounds, and the production of phytohormones and siderophores that support root development and nutrient acquisition. Their application has been shown to enhance soil fertility and crop productivity while reducing dependence on synthetic fertilizers (Timofeeva *et al.* 2023) ^[16].

Among these microorganisms, *Azotobacter* species are free-living diazotrophs capable of fixing atmospheric nitrogen under non-symbiotic conditions. In addition to nitrogen fixation, *Azotobacter* spp. are known to produce growth promoting substances such as indole-3-acetic acid (IAA), which stimulate root growth and enhance nutrient uptake. Some strains have also been reported to solubilize phosphate, thereby contributing to both nitrogen and phosphorus nutrition in plants (Rathod *et al.* 2025) ^[11].

Phosphate-solubilizing bacteria (PSB) play an important role in improving phosphorus availability in soils where phosphorus is largely present in insoluble forms. These microorganisms solubilize inorganic phosphates through the secretion of organic acids and phosphatase enzymes, thereby converting unavailable phosphorus into plant-available forms. In strawberry, inoculation with PSB and other beneficial bacteria, such as *Azotobacter* and *Azospirillum*, enhances phosphorus uptake, root growth, fruit yield, and overall plant performance, highlighting their potential as sustainable alternatives to chemical phosphorus fertilizers (Singh *et al.* 2024) ^[13].

In recent years, traditional organic bioenhancers such as Jeevamrit and Amritpani have received increasing attention

in sustainable and natural farming systems. These liquid organic formulations, prepared from cow dung, cow urine, jaggery, pulse flour, and soil, are rich in beneficial microorganisms and nutrients. Their application has been shown to stimulate soil microbial activity, enhance enzymatic processes, and improve nutrient mineralization, thereby supporting plant growth and soil health (Kumar *et al.* 2025) ^[5]. Jeevamrit and Amritpani are also believed to act as microbial inoculants that improve nutrient availability and enhance crop productivity under low-input conditions.

In addition to microbial inoculants, organic bioenhancers used in organic and low-input farming systems can stimulate soil biological activity and enhance soil enzymatic processes, thereby increasing the potential for nutrient transformation and supporting sustained nutrient cycling and plant growth in strawberry (Maková *et al.* 2024) ^[7].

The combined application of microbial inoculants and organic bioenhancers may offer synergistic benefits by improving soil biological health while enhancing nutrient uptake by plants. Integrated nutrient management approaches have been reported to improve fruit biochemical attributes, including TSS, titratable acidity, and vitamin content, in several horticultural crops.

Considering the growing emphasis on sustainable horticultural practices and quality-oriented fruit production, the present study was undertaken to evaluate the effects of selected bioinoculants and bioenhancers, applied individually and in combination, on key biochemical quality parameters of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn. The study focuses on total soluble solids, titratable acidity, and ascorbic acid content, with the aim of generating practical information for sustainable nutrient management under subtropical agro-climatic conditions.

Materials and Methods

Experimental Site and Plant Material

The experiment was conducted during the winter season of 2022-23 at the Horticulture Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology & Sciences, Prayagraj, under subtropical agro-climatic conditions. Healthy and uniform runners of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn were used as planting material.

Experimental Design and Treatments

The study was laid out in a Randomized Block Design (RBD) with nine treatments and three replications. The treatments consisted of the recommended dose of fertilizers (RDF), which served as the control (T₀), and different bioinoculant and bioenhancer applications applied individually and in various combinations. Treatments T₁ to T₈ included applications of *Azotobacter*, phosphate-solubilizing bacteria (PSB), Jeevamrit, and Amritpani. The details of the treatment combinations are presented in Table 1.

Table 1: Details of treatments used in the experiment

Treatment	Solutions
T ₀	CONTROL (RDF)
T ₁	<i>Azotobacter</i> @ 400 g/100 m ²
T ₂	PSB @ 400 g/100 m ²
T ₃	Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l
T ₄	Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l
T ₅	<i>Azotobacter</i> @ 400 g/100 m ² + Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l
T ₆	PSB @ 400 g/100 m ² + Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l
T ₇	Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l + Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l + <i>Azotobacter</i> @ 400 g/100 m ²
T ₈	Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l + Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l + PSB @ 400 g/100 m ²

Cultural Practices

Standard agronomic and horticultural practices recommended for strawberry cultivation were uniformly followed for all treatments throughout the crop period. Irrigation, weeding and plant protection measures were carried out as and when required to ensure normal crop growth.

Observations Recorded

Fruit samples were collected at commercial harvest maturity for the assessment of biochemical quality parameters. The biochemical attributes analyzed included total soluble solids (TSS), titratable acidity and ascorbic acid content.

Total soluble solids were determined using a hand refractometer and expressed as °Brix. Titratable acidity was estimated by titration against a standard sodium hydroxide solution and expressed as percentage citric acid. Ascorbic acid content was determined by the 2,6-dichlorophenol indophenol dye method and expressed as mg per 100 g fresh weight.

Statistical Analysis

The recorded data were subjected to analysis of variance

(ANOVA) appropriate for the randomized block design. Treatment means were compared using critical difference (CD) at the 5% level of significance. Statistical analysis was performed using OPSTAT software.

Results

Total Soluble Solids (TSS)

Total soluble solids (TSS) content of strawberry fruits varied significantly among different bioinoculant and bioenhancer treatments (Table 2), and the treatment-wise variation is clearly illustrated in Fig 1. The highest TSS value was recorded in treatment T₈ (Jeevamrit + Amritpani + PSB), which registered (7.98 °Brix). This was followed by treatment T₆ (PSB + Amritpani), which recorded a TSS value of (7.86 °Brix). Both treatments recorded significantly higher TSS compared to the control (T₀), which showed the lowest value of (4.48 °Brix).

Among the individual treatments, Jeevamrit (T₃) recorded a TSS value of (5.87 °Brix), while Amritpani (T₄) recorded (6.01 °Brix). Treatments receiving combined applications of bioinoculants and bioenhancers generally recorded higher TSS values than individual applications.

Table 2: Effect of bioinoculants and bioenhancers on total soluble solids (°Brix) of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn

Notation	Treatment Combinations	TSS (°Brix)
T ₀	CONTROL (RDF)	4.48
T ₁	<i>Azotobacter</i> @ 400 g/100 m ²	5.25
T ₂	PSB @ 400 g/100 m ²	5.57
T ₃	Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l	5.87
T ₄	Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l	6.01
T ₅	<i>Azotobacter</i> @ 400 g/100 m ² + Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l	6.34
T ₆	PSB @ 400 g/100 m ² + Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l	7.86
T ₇	Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l + Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l + <i>Azotobacter</i> @ 400 g/100 m ²	6.64
T ₈	Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l + Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l + PSB @ 400 g/100 m ²	7.98
	F-Test	S
	SE(m)	0.14
	C.D.	0.41
	C.V.	3.80

Values are mean of three replications.

CD = critical difference at 5% level of significance.

S = significant.

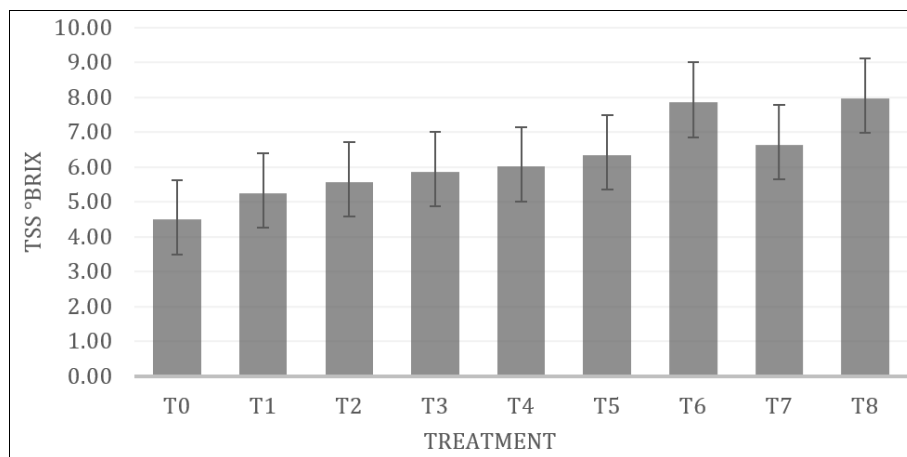


Fig 1: Effect of bioinoculants and bioenhancers on total soluble solids (°Brix) of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn. Values represent mean ± SE (n = 3)

Titrateable Acidity

Titrateable acidity of strawberry fruits showed significant differences among treatments (Table 3), and the treatment-wise variation is clearly illustrated in Fig 2. The lowest titrateable acidity was recorded in the control treatment (T₀) with a value of (0.57%). Higher acidity values were observed in treatments receiving bioinoculants and

bioenhancers.

The highest titrateable acidity was recorded in treatment T₈ (1.57%), followed by T₆ (1.33%) and T₅ (1.30%). Among the individual treatments, PSB (T₂) and Amritpani (T₄) recorded acidity values of (0.93%), while Jeevamrit (T₃) recorded (0.90%) acidity.

Table 3: Effect of bioinoculants and bioenhancers on titrateable acidity (%) of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn

Notation	Treatment Combinations	Acidity (%)
T ₀	CONTROL (RDF)	0.57
T ₁	<i>Azotobacter</i> @ 400 g/100 m ²	0.60
T ₂	PSB @ 400 g/100 m ²	0.93
T ₃	Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l	0.90
T ₄	Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l	0.93
T ₅	<i>Azotobacter</i> @ 400 g/100 m ² + Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l	1.30
T ₆	PSB @ 400 g/100 m ² + Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l	1.33
T ₇	Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l + Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l + <i>Azotobacter</i> @ 400 g/100 m ²	1.17
T ₈	Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l + Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l + PSB @ 400 g/100 m ²	1.57
F-Test		S
SE(m)		0.09
C.D.		0.28
C.V.		15.30

Values are mean of three replications.

CD = critical difference at 5% level of significance.

S = significant.

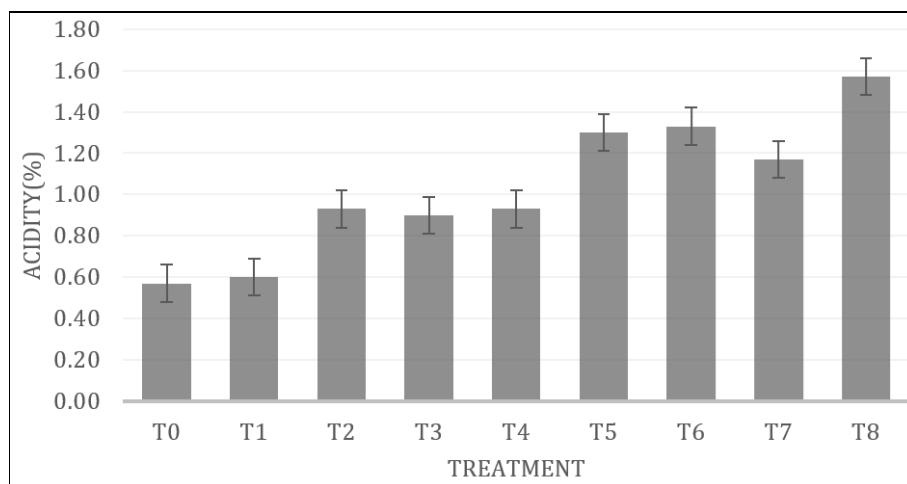


Fig 2: Effect of bioinoculants and bioenhancers on titrateable acidity (%) of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn. Values represent mean ± SE (n = 3)

Ascorbic Acid Content

Ascorbic acid content of strawberry fruits differed significantly among the treatments (Table 4), and the treatment-wise variation is clearly illustrated in Fig 3. The maximum ascorbic acid content was recorded in treatment T₈ (58.82 mg 100 g⁻¹ fresh weight), followed closely by T₆

(58.63 mg 100 g⁻¹). The control treatment (T₀) recorded the lowest ascorbic acid content of (51.97 mg 100 g⁻¹).

Among individual treatments, Amritpani (T₄) recorded an ascorbic acid content of (56.24 mg 100 g⁻¹), while Jeevamrit (T₃) recorded (55.64 mg 100 g⁻¹).

Table 4: Effect of bioinoculants and bioenhancers on ascorbic acid content (mg 100 g⁻¹ fresh weight) of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn

Notation	Treatment Combinations	Ascorbic Acid (mg 100 g ⁻¹ fresh weight)
T ₀	CONTROL (RDF)	51.97
T ₁	<i>Azotobacter</i> @ 400 g/100 m ²	53.08
T ₂	PSB @ 400 g/100 m ²	54.76
T ₃	Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l	55.64
T ₄	Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l	56.24
T ₅	<i>Azotobacter</i> @ 400 g/100 m ² + Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l	56.77
T ₆	PSB @ 400 g/100 m ² + Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l	58.63
T ₇	Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l + Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l + <i>Azotobacter</i> @ 400 g/100 m ²	54.14
T ₈	Jeevamrit (3 times diluted with non-chlorinated water) @ 250 ml/l + Amritpani (3 times diluted with non-chlorinated water) @ 250 ml/l + PSB @ 400 g/100 m ²	58.82
F-Test		S
SE(m)		0.50
C.D.		1.51
C.V.		1.56

Values are mean of three replications.

CD = critical difference at 5% level of significance.

S = significant.

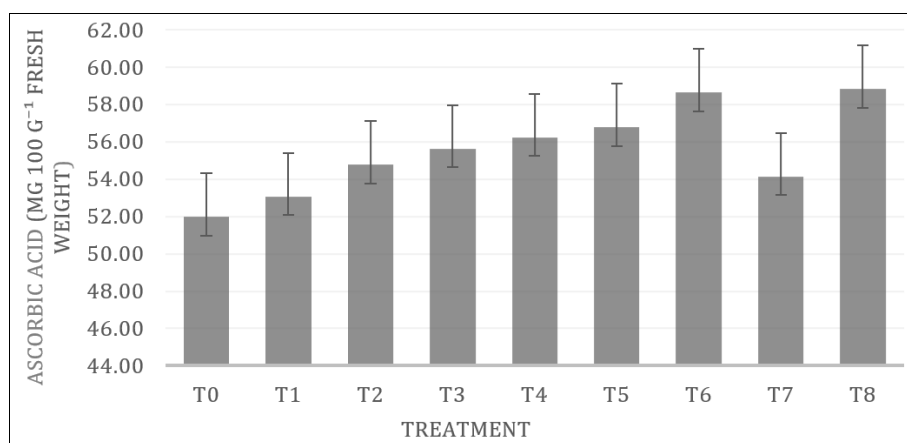


Fig 3: Effect of bioinoculants and bioenhancers on ascorbic acid content (mg 100 g⁻¹ fresh weight) of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn. Values represent mean ± SE (n = 3)

Discussion

The results of the present study clearly indicate that the application of bioinoculants and organic bioenhancers, either alone or in combination, significantly influenced the biochemical quality attributes of strawberry fruits. Among the treatments, combined applications, particularly Jeevamrit + Amritpani + PSB (T₈), consistently showed superior performance in terms of total soluble solids, titratable acidity, and ascorbic acid content, highlighting the synergistic effects of bioinoculants and organic bioenhancers.

Total Soluble Solids (TSS)

The enhancement of total soluble solids under combined bioinoculant and bioenhancer treatments may be attributed to improved nutrient availability and enhanced microbial activity in the rhizosphere, which can stimulate photosynthetic efficiency and carbohydrate metabolism.

Increased availability of phosphorus through phosphate-solubilizing bacteria plays a crucial role in energy transfer and sugar synthesis, while organic bioenhancers such as Jeevamrit and Amritpani may improve soil microbial dynamics and nutrient mineralization. Similar improvements in TSS due to biofertilizer application have been reported in strawberry and other horticultural crops (Kumar *et al.* 2019; Singh *et al.* 2025) [6, 15]. Enhanced TSS content is generally associated with improved sweetness and overall fruit quality, which is a desirable trait from a consumer perspective.

Titratable Acidity

Titratable acidity was observed to increase under bioinoculant and bioenhancer treatments compared to the control. Organic acids are important intermediates in plant metabolism, and their accumulation in fruits is influenced by nutrient uptake and physiological activity during fruit

development. Improved nutrient availability under integrated bio-based treatments may have enhanced metabolic processes, leading to higher organic acid synthesis. Similar trends of increased acidity under biofertilizer and organic input application have been reported in strawberry and other fruit crops. Importantly, the concurrent increase in TSS and acidity under integrated treatments suggests an improved sugar-acid balance, which is a key determinant of flavour quality in strawberries (Quddus *et al.* 2025) ^[10].

Ascorbic Acid Content

The significant increase in ascorbic acid content observed under combined bioinoculant and bioenhancer treatments may be related to improved micronutrient availability and enhanced enzymatic activity involved in ascorbic acid biosynthesis. Beneficial microorganisms are known to influence the uptake of micronutrients such as iron and zinc, which play important roles in enzymatic pathways associated with vitamin C synthesis. Earlier studies have also reported enhanced ascorbic acid content in strawberry fruits following biofertilizer and organic amendment application (Kaur *et al.* 2024) ^[4]. Increased vitamin C content enhances the nutritional value of fruits and contributes to their antioxidant capacity.

Integrated Effect of Bioinoculants and Bioenhancers

The superior performance of combined treatments observed in the present study supports the concept of integrated nutrient management using bioinoculants and organic bioenhancers. Bioinoculants such as *Azotobacter* and PSB improve nutrient availability through biological nitrogen fixation and phosphorus solubilization, while organic formulations like Jeevamrit and Amritpani stimulate microbial activity and nutrient cycling in the soil. The combined use of these inputs creates a favourable rhizosphere environment that supports sustained plant growth and improved fruit quality. Similar synergistic effects of integrating biofertilizers with organic inputs have been reported in strawberry, where organic manure combined with *Azotobacter* significantly influenced fruit quality traits, including TSS and sugar content (Reddy *et al.* 2020) ^[12], and where biofertilizer combinations with *Azotobacter*, PSB, and *Azospirillum* enhanced quality and economic returns (Singh *et al.* 2024) ^[13]. These studies confirm that integrated nutrient management not only improves nutrient availability but also promotes sustainable and low-input horticultural production systems. Overall, the findings of the present study demonstrate that integrated application of bioinoculants and organic bioenhancers can effectively improve the biochemical quality of strawberry fruits while reducing reliance on chemical fertilizers, thereby supporting sustainable strawberry production under subtropical agro-climatic conditions.

Conclusions

The present study demonstrated that integrated application of bioinoculants and bioenhancers significantly influenced the biochemical quality of strawberry fruits cv. Winter Dawn under subtropical conditions. Among the treatments, combined application of Jeevamrit, Amritpani and phosphate-solubilizing bacteria (PSB) resulted in the highest total soluble solids (TSS), indicating improved fruit

sweetness and quality. Treatments receiving combined inputs consistently outperformed individual applications, highlighting the synergistic effect of bioinoculants and bioenhancers on fruit biochemical attributes. The findings suggest that integrated use of organic bioinputs can serve as a sustainable and effective strategy for enhancing strawberry fruit quality while reducing dependence on chemical fertilizers.

Acknowledgements

The authors acknowledge the institutional facilities provided for conducting the experiment and sincerely thank Dr. Samir E. Topno for his academic guidance and valuable suggestions.

Authors' contribution

Conceptualization, methodology, investigation, data curation, formal analysis, and writing-original draft preparation: AS.

Writing-review and editing: SRM and AM.

Investigation, data collection, and technical assistance: DR and AS.

Supervision: RR.

All authors have read and agreed to the published version of the manuscript.

Declarations

Conflict of interest

The authors declare that they have no conflict of interest.

Ethics approval

Not applicable

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

References

1. Bai X, Liu K, Ning T, Deng C, Wang L, Li D, *et al.* Effects of multiple N, P, and K fertilizer combinations on strawberry growth and the microbial community. *PLoS ONE*. 2023;18(11):e0293088.
2. Charoenwoodhipong P, Zuelch ML, Keen CL, Hackman RM, Holt RR. Strawberry (*Fragaria × ananassa*) intake on human health and disease outcomes: a comprehensive literature review. *Critical Reviews in Food Science and Nutrition*. 2024;65(25):4884-4914.
3. Cinciosi D, Forbes-Hernández TY, Regolo L, Alvarez-Suarez JM, Quiles JL, Battino M. Strawberry as a health promoter: an evidence-based review. Where are we 10 years later? *Food & Function*. 2025;16(14):5705-5732.
4. Kaur K, Singh A, Kaur A. Comparative analysis of morphological and biochemical traits in *Fragaria × ananassa* (Cv. Chandler) under varied cultivation systems. *Journal of Scientific Research and Reports*. 2024;30(4):259-265.
5. Kumar P, Chandel RS, Verma SC, Sharma N, Saini S, Bishist R, *et al.* Biostimulation through natural biological inputs on fruiting, nutrient availability and rhizosphere microbiome in legume intercropped 'Sweet Charlie' strawberry (*Fragaria × ananassa* Duch.). *BMC Plant Biology*. 2025;25:1009.

6. Kumar S, Kundu M, Rakshit R. Effect of bio-fertilizer on growth, yield and quality of strawberry (*Fragaria × ananassa* Duch.) cv. Camarosa. Bulletin of Environment, Pharmacology and Life Sciences. 2019;8(Suppl 2):S99-S107.
7. Maková J, Artimová R, Javoreková S, Adamec S, Paulen O, Andrejiová A, *et al.* Effect of application of nitrogen fertilizer, microbial and humic substance-based biostimulants on soil microbiological properties during strawberry (*Fragaria × ananassa* Duch.) cultivation. Horticulturae. 2024;11(2):119.
8. Newerli-Guz J, Śmiechowska M, Drzewiecka A, Tylingo R. Bioactive ingredients with health-promoting properties of strawberry fruit (*Fragaria × ananassa* Duchesne). Molecules. 2023;28(6):2711.
9. Patel H, Taghavi T, Samtani JB. Fruit quality of several strawberry cultivars during the harvest season under high tunnel and open field environments. Horticulturae. 2023;9(10):1084.
10. Quddus MA, Ahmed R, Islam M, Haque ME, Islam MA, Alam A, *et al.* Organic and inorganic fertilizers influence the productivity, fruit quality and nutrient use efficiency of strawberry (*Fragaria × ananassa* Duch.). Scientific Reports. 2025;15:26252.
11. Rathod SG, Shrivastav P, Pednekar J. Screening of *Azotobacter*, *Bacillus*, and *Pseudomonas* species for biofertilizer production. International Journal of Advanced Biochemistry Research. 2025;9(1):293-295.
12. Reddy GC, Goyal RK, Godara AK. Response of organic manure and *Azotobacter* on quality and leaf nutrient status of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn. International Journal of Plant and Soil Science. 2021;33(24):327-332.
13. Singh J, Sharma R, Chandra N, Meeta, Azadpal S. Impact of biofertilizer combinations on quality, yield, and economic returns of strawberry in Central Region of Punjab, India. International Journal of Plant & Soil Science. 2024;36(9):821-833.
14. Singh SR, Zargar MY, Najar GR, Ishaq MI, Hakeem SA. Effect of integrated nutrient supply on yield, fertility and quality of strawberry under rainfed temperate conditions. Journal of the Indian Society of Soil Science. 2012;60(1):79-82.
15. Singh Y, Gupta G, Virkhare U, Kumar M, Nimbalkar P, Kumari S, *et al.* Impact of micronutrients on flowering, yield, and fruit quality attributes of strawberry (*Fragaria × ananassa* Duch) cv. Camarosa under open field conditions. Applied Fruit Science. 2025;67:452.
16. Timofeeva AM, Galyamova MR, Sedykh SE. Plant growth-promoting soil bacteria: nitrogen fixation, phosphate solubilization, siderophore production, and other biological activities. Plants. 2023;12(24):4074.
17. Yang P, Condric A, Scranton S, Hebner C, Lu L, Ali MA. Utilizing plant growth-promoting rhizobacteria (PGPR) to advance sustainable agriculture. Bacteria. 2024;3(4):434-451.