**Effect of Organic Manure and Bio-Fertilizers on the Quality Enhancement of Dragon Fruit (*Hylocereus costaricensis*) (Web.) Britton and Rose**

**ABSTRACT**

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| **Aims:**This study aimed to assess the effects of vermicompost and bio-fertilizers on the quality attributes of Red Skin, Purple Flesh dragon fruit (*Hylocereus costaricensis* L.), focusing on improving fruit size, biochemical composition, and overall fruit quality through sustainable agricultural practices.  **Study Design:**The experiment was conducted using a randomized block design, consisting of eleven treatments with three replications, including a control. The treatments varied in the combination of vermicompost and bio-fertilizers (Azotobacter, VAM, and PSB) applied to dragon fruit plants.  **Place and Duration of Study:**The study was carried out from 2022 to 2024 at the Orchard, Department of Fruit Science, C.S.A. University of Agriculture and Technology, Kanpur, India.  **Methodology:**Eleven treatments were testedT1-Control, T2-Vermicompost @ 0.5 kg/plant, T3-Azotobacter @ 50 g/plant, T4-VAM @ 100 g/plant, T5-PSB @ 50 g/plant, T6-Vermicompost @ 0.5 kg/plant + Azotobacter @ 50 g/plant, T7-Vermicompost @ 0.5 kg/plant + VAM @ 100 g/plant, T8-Vermicompost @ 0.5 kg/plant + PSB @ 50 g/plant, T9-Vermicompost @ 0.5 kg/plant + Azotobacter @ 50 g/plant + VAM @ 100 g/plant, T10-Vermicompost @ 0.5 kg/plant + Azotobacter @ 50 g/plant + PSB @ 50 g/plant and T11-Vermicompost @ 0.5 kg/plant + VAM @ 100 g/plant + PSB @ 50 g/plant. Each treatment was replicated three times.A basal dose of FYM (5 kg/plant), Trichoderma (25 g/plant), and neem cake (50 g/plant) was applied uniformly. Various quality parameters, such as fruit weight, size, pulp-to-peel ratio, and biochemical properties (total soluble solids, total sugars, ascorbic acid, and acidity), were measured to evaluate fruit quality.  **Results:**The application of T₁₁ (Vermicompost @ 0.5 kg/plant + VAM @ 100 g/plant + PSB @ 50 g/plant) resulted in the highest fruit weight (280.50 g), length (9.42 cm), diameter (7.64 cm), and volume (254.98 cm³). T₁₁ also exhibited superior biochemical attributes, including the highest total soluble solids (15.76° Brix), total sugars (9.42%), and ascorbic acid content (14.26 mg/100 g), with the lowest acidity (0.17%) and highest TSS/acid ratio (92.85).  **Conclusion:**The integration of vermicompost with VAM and PSB significantly enhanced dragon fruit quality by improving nutrient availability, optimizing physiological processes, and enhancing fruit size and biochemical attributes. These findings suggest that combining organic amendments and beneficial microbes offers a sustainable approach to improving dragon fruit production in tropical regions. |

**Keywords:**Dragon fruit,Vermicompost,VAM, PSB, Organic nutrition TSS and Fruit quality

**1. INTRODUCTION**

Dragon fruit (*Hylocereus sp.*) is emerging as a commercially significant exotic fruit crop in India due to its high nutritional value, economic potential and adaptability to arid and semi-arid conditions. Rich in antioxidants, vitamins, minerals and dietary fibers, it is widely consumed for its health benefits and is in demand across global markets (Kim *et al.* 2011). The fruit is particularly valued for its red-purple betacyanin pigments, which have applications in pharmaceuticals, cosmetics and the food industry (Priatni and Pradita, 2015).Sustainable production of dragon fruit requires a balanced nutrient management approach. Conventional farming practices relying on chemical fertilizers have led to soil degradation, reduced microbial diversity and environmental concerns (Hennao and Baanate, 2006). Organic farming, integrating organic manures and bio-fertilizers, offers a viable alternative to enhance soil fertility, improve fruit quality and promote ecological sustainability (Babalad *et al.* 2015). Studies indicate that bio-fertilizers like Azotobacter, PSB and mycorrhizae enhance nutrient uptake, improve soil microbial activity and contribute to better fruit yield and quality (Gaskell *et al.* 2007).

The present study evaluates the impact of organic manure and bio-fertilizers on the quality attributes of dragon fruit, emphasizing their role in enhancing fruit nutritional composition, market value and sustainability. Organic amendments, such as vermicompost and farmyard manure, are known to improve soil fertility, enhance microbial activity and facilitate better nutrient uptake, which directly influences fruit physico-biochemical parameters. Similarly, bio-fertilizers like Azotobacter, phosphate-solubilizing bacteria (PSB) and mycorrhizae contribute to improved root development, nutrient availability and overall plant health.Despite the well-established benefits of organic manure and bio-fertilizers, limited research has explored their combined effects on the quality enhancement of dragon fruit under Indian agro-climatic conditions. The integration of these organic inputs not only promotes sustainable production by reducing chemical dependency but also improves postharvest quality, shelf life and consumer acceptability. Therefore, the present study, titled “Effect of Organic Manure and Bio-Fertilizers on the Quality Enhancement of Red Skin, Purple Flesh Dragon Fruit (*Hylocereus costaricensis* L.)”, was conducted to address these knowledge gaps. The findings aim to provide insights into optimizing organic nutrient management strategies to improve the physico-chemical attributes of dragon fruit, thereby enhancing its marketability, nutritional value and sustainability in sub-tropical agro-climatic conditions.

**2. MATERIAL AND METHODS**

Thepresent experiment was conducted from 2022 to 2024 in Orchard, Department of Fruit Science, C.S.A. University of Agriculture and Technology, Kanpur, India,, situated at 25.26° to 26.28° N latitude and 79.31° to 80.34° E longitude, with an altitude of 126.0 m above mean sea level. The soil was well-drained with poor fertility and saline-alkaline conditions.

The annual rainfall is 80–85 cm, primarily received during the northeast monsoon from July to September. Temperatures range from 24°C to 47°C in summer and 5°C to 27.8°C in winter, with relative humidity varying from 35% to 98%. The experiment was laid out using randomized block design with eleven treatments including a control*viz.,* T1-Control, T2-Vermicompost @ 0.5 kg/plant, T3-Azotobacter @ 50 g/plant, T4-VAM @ 100 g/plant, T5-PSB @ 50 g/plant, T6-Vermicompost @ 0.5 kg/plant + Azotobacter @ 50 g/plant, T7-Vermicompost @ 0.5 kg/plant + VAM @ 100 g/plant, T8-Vermicompost @ 0.5 kg/plant + PSB @ 50 g/plant, T9-Vermicompost @ 0.5 kg/plant + Azotobacter @ 50 g/plant + VAM @ 100 g/plant, T10-Vermicompost @ 0.5 kg/plant + Azotobacter @ 50 g/plant + PSB @ 50 g/plant and T11-Vermicompost @ 0.5 kg/plant + VAM @ 100 g/plant + PSB @ 50 g/plant. Each treatment was replicated three times. A basal dose of FYM (5 kg/plant), Trichoderma (25 g/plant) and neem cake (50 g/plant) was applied uniformly across treatments.

Observations recorded included fruit weight (g), fruit length (cm), fruit diameter (cm), fruit volume (cc) using the water displacement method and specific gravity calculated as the weight-to-volume ratio. Pulp weight, peel weight and pulp-to-peel ratio were determined using an electronic balance. Pulp and peel thickness (cm) were measured using a vernier caliper. Quality parameters such as total soluble solids (°Brix) were measured with a hand refractometer, titratable acidity (%) via titration (AOAC, 1984), ascorbic acid (mg/100 g) following AOAC (1990) and total sugars (%) using the Lane and Eynon method as per Ranganna (1987).

Statistical analysis was performed using ANOVA (Panse and Sukhatme, 1985) and mean separation was done via Duncan’s Multiple Range Test (DMRT) at p < 0.05. Correlation and principal component analyses were conducted using XLSTAT software to ensure statistical reliability.

**3. RESULT AND DISCUSSIONS**

The presented pooled data (Table 1) revealed that the highest fruit weight (280.50 g) was recorded in T₁₁ [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)], closely followed by T₁₀ [Vermicompost (0.5 kg/plant) + Azotobacter (50 g/plant) + PSB (50 g/plant)]. In contrast, the control (T₁) exhibited the lowest fruit weight (106.66 g). The significant improvement in fruit weight under organic amendments and bio-fertilizer treatments can be attributed to enhanced soil microbial activity, better nutrient assimilation and improved physiological processes. The combined application of vermicompost and beneficial microbes (VAM, Azotobacter and PSB) likely contributed to increased root proliferation, higher nutrient uptake and improved photosynthetic efficiency, ultimately leading to better fruit development. Vermicompost, rich in essential macro and micronutrients, provides a favourable environment for beneficial soil microbes, further enhancing plant growth and fruit set. The role of VAM in improving phosphorus availability and PSB in facilitating phosphate solubilisation may have played a crucial role in fruit development. These findings align with previous studies by Bhagat and Panigrahi (2020) in strawberry, Verma *et al.*  (2019) and Siddiqua *et al.*  (2023) in dragon fruit, which also reported a significant increase in fruit weight due to the synergistic effects of organic manure and bio-fertilizers. The results reaffirm the potential of integrated organic nutrient management in enhancing fruit quality while promoting sustainable cultivation practices.

The highest fruit length (9.42 cm) was recorded with T₁₁ [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)], while the lowest (6.90 cm) was observed in the control (T₁). The increase in fruit length can be attributed to improved nutrient uptake, enhanced microbial activity and better soil moisture retention due to organic amendments. VAM and PSB facilitated phosphorus availability, promoting cell elongation and overall fruit growth. These findings align with Yadav *et al.*  (2011) in mango, Verma *et al.*  (2019) and Khatun *et al.* (2023) in dragon fruit, confirming the beneficial role of organic and bio-fertilizers in enhancing fruit quality.

The maximum fruit diameter (7.64 cm) was observed in T₁₁ [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)], while the lowest (5.53 cm) was recorded in the control (T₁). Treatments T₂ [Vermicompost (0.5 kg/plant)] and T₃ [Azotobacter (50 g/plant)] also showed moderate increases (5.70 cm and 5.88 cm, respectively). The improved fruit diameter can be attributed to enhanced microbial activity, increased nutrient availability and better soil moisture retention due to vermicompost application. These findings are consistent with Verma *et al.*  (2019), Heerawati *et al.*  (2019) andSiddiqua *et al.*  (2023) in dragon fruit.

The application of T₁₁ [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)] resulted in the highest fruit volume (254.98 cm³) and specific gravity (1.10 g cm⁻³), whereas the lowest values were recorded in the control (T₁) treatment (125.58 cm³ and 0.85 g cm⁻³, respectively). The significant increase in fruit volume and density can be attributed to improved nutrient assimilation, enhanced water retention and increased microbial activity in the rhizosphere, leading to better cell division and expansion.

The combination of vermicompost and bio-fertilizers played a crucial role in improving soil fertility, facilitating better root development and nutrient uptake, which directly influenced fruit growth and quality. The specific gravity, an indicator of fruit density and quality, was also positively affected by enhanced metabolic activities and enzymatic functions due to microbial inoculants. These findings align with the studies of Verma *et al.*  (2019), Kumar *et al.*  (2021) and Siddiqua *et al.*  (2023) in dragon fruit.

The present study revealed that T₁₁ [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)] recorded the highest pulp weight (244.50 g) and peel weight (36 g), whereas the lowest values were observed in the control (T₁) (81.66 g and 25 g, respectively), followed by T₂ [Vermicompost (0.5 kg/plant)]. The significant increase in pulp weight and peel weight can be attributed to the enhanced nutrient availability and microbial activity facilitated by vermicompost and bio-fertilizers. The improved uptake of essential nutrients such as nitrogen, phosphorus and potassium likely promoted better fruit development, leading to an increase in both pulp and peel weights. Furthermore, the presence of beneficial microbes enhanced enzymatic activity and soil organic matter decomposition, which played a pivotal role in improving fruit quality attributes. A higher pulp weight is desirable in commercial fruit production as it contributes to better marketability and consumer preference. The increased peel weight, while secondary, also suggests enhanced structural integrity and fruit development. These results are in accordance with the findings of Bashir *et al.*  (2009) on guava, Verma *et al.*  (2019) on dragon fruit and Kumar *et al.*  (2022) on papaya, emphasizing the positive role of organic amendments in fruit quality improvement.

The highest pulp-to-peel ratio (7.01) was observed in T₁₁ [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)], followed by T₁₀ [Vermicompost (0.5 kg/plant) + Azotobacter (50 g/plant) + PSB (50 g/plant)]. The lowest ratio (3.27) was recorded in the control (T₁) treatment. The increased pulp-to-peel ratio can be attributed to enhanced cell division and expansion facilitated by organic manure and bio-fertilizers, which improved nutrient uptake and mesocarp development. A thicker peel also contributes to reduced postharvest losses by minimizing mechanical damage. These findings are consistent with Kumar and Kumar (2013) in mango, Verma *et al.*  (2019) in dragon fruit and Bhagat and Panigrahi (2020) in strawberry.

The present study demonstrated that the T₁₁ treatment [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)] resulted in the highest pulp thickness (7.27 cm) and peel thickness (0.36 cm). Conversely, the lowest pulp thickness (5.27 cm) and peel thickness (0.25 cm) were recorded in the control (T₁) treatment. The significant increase in pulp and peel thickness can be attributed to the synergistic effects of organic amendments and bio-fertilizers, which improved soil structure, microbial activity and nutrient uptake efficiency. Vermicompost contributed to higher organic matter content, enhancing soil moisture retention and cation exchange capacity, which are crucial for sustained nutrient availability. Additionally, VAM and PSB facilitated better phosphorus solubilization and root proliferation, leading to improved carbohydrate accumulation in the fruit.

A thicker pulp is particularly important for fruit quality as it enhances juiciness and consumer acceptability, while an optimal peel thickness provides better protection against postharvest losses. These findings align with the research of Hazarika *et al.*  (2019) on Assam orange, Verma *et al.*  (2021) on dragon fruit and Siddiqua *et al.*  (2023) on dragon fruit, further supporting the role of integrated organic nutrient management in improving fruit morphology and quality.

The highest fruit yield (3.84 kg/plant) was recorded in T₁₁ [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)], significantly outperforming all other treatments. The lowest yield (0.59 kg/plant) was observed in the control (T₁) treatment.

The increase in fruit yield can be attributed to enhanced microbial activity in the soil, leading to improved nutrient availability, root proliferation and metabolic efficiency in the plant. Vermicompost, combined with bio-fertilizers, facilitated superior protein and carbohydrate synthesis, which directly influenced fruit production. These findings are in accordance with Singh *et al.*  (2010) in strawberry, Hoe (2014) in dragon fruit and Verma *et al.*  (2021) and Siddiqua *et al.*  (2023) in dragon fruit.

The highest TSS (15.76° Brix) was recorded in T₁₁ [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)], followed by T₁₀ [Vermicompost (0.5 kg/plant) + Azotobacter (50 g/plant) + PSB (50 g/plant)]. The lowest TSS (12.86° Brix) was observed in T₁ (Control). The increased TSS content can be attributed to the improved nutrient assimilation and enhanced metabolic processes facilitated by organic manures and bio-fertilizers. These amendments enhanced soil properties, including water retention, aeration and microbial activity, which likely led to better starch-to-sugar conversion, improving fruit sweetness and quality. The results are in accordance with Kirad *et al.*  (2010) in papaya, Khayum (2021) in jamun, Verma *et al.*  (2021) and Heerawati *et al.*  (2021) in dragon fruit and Siddiqua *et al.*  (2023) in dragon fruit.

The highest total sugar content (9.42%) was recorded in T₁₁ [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)], which was significantly superior to all other treatments. The lowest total sugar (8.40%) was observed in T₁ (Control), followed by T₂(8.62%) [Vermicompost (0.5 kg/plant)]. The increase in total sugar content can be attributed to the enhanced nutrient availability and hormonal activity facilitated by organic amendments. The conversion of stored starch into soluble sugars was likely accelerated due to improved metabolic functions and higher enzymatic activity in plants grown under enriched soil conditions. This ultimately led to better carbohydrate synthesis and accumulation in the fruit, enhancing its sweetness and quality. These findings are in agreement with Khayum (2021) in jamun, Verma *et al.*  (2021) and Siddiqua *et al.*  (2023) in dragon fruit.

The lowest acidity (0.17%) was recorded in T₁₁ [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)], which was significantly superior to all other treatments. This was followed by T₁₀ (0.19%) [Vermicompost (0.5 kg/plant) + Azotobacter (50 g/plant) + PSB (50 g/plant)]. The highest acidity (0.29%) was observed in T₁ (Control), followed by T₂ (0.27%) [Vermicompost (0.5 kg/plant)]. The reduction in acidity due to the application of organic manures and bio-fertilizers is likely attributed to their role in enhancing microbial activity, which facilitates the conversion of organic acids into sugars via the glycolytic pathway. This process improves the sugar-acid balance, contributing to a smoother and sweeter taste in dragon fruit. Additionally, the enhanced nutrient availability from vermicompost and bio-fertilizers may have boosted enzymatic activities, leading to greater metabolic efficiency in fruit development. These findings align with the reports of Singh and Varu (2013) in guava, Khayum (2021) in jamun and Siddiqua *et al.*  (2023) in dragon fruit.

The highest TSS/acid ratio (92.85) was recorded in T₁₁ [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)], which was significantly superior to all other treatments. This was followed by T₁₀ (79.13) [Vermicompost (0.5 kg/plant) + Azotobacter (50 g/plant) + PSB (50 g/plant)]. The lowest TSS/acid ratio (43.96) was observed in T₁ (Control). The higher TSS/acid ratio is primarily attributed to the reduced acidity and enhanced sugar accumulation facilitated by the application of organic manures and bio-fertilizers. These amendments improve nutrient uptake, stimulate enzymatic activity and accelerate metabolic processes such as acid conversion into sugars, leading to better fruit sweetness. The findings align with previous studies by Singh *et al.*  (2010) on strawberry, Kumar and Kumar (2013) on mango and Siddiqua *et al.*  (2023) on dragon fruit.

The highest ascorbic acid content (14.26 mg/100 g) was recorded in T₁₁ [Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant)], significantly surpassing all other treatments. The lowest ascorbic acid content (13.43 mg/100 g) was observed in T₁ (Control), followed by T₂ (13.57 mg/100 g) [Vermicompost (0.5 kg/plant)]. The increase in ascorbic acid can be attributed to the enhanced nutrient availability from organic manures and bio-fertilizers, which improved plant metabolism and stimulated enzymatic activity. These amendments facilitated the conversion of acids to sugars and other derivatives through glycolytic pathways, ultimately enhancing vitamin C synthesis in the fruit. The results align with the findings of Khayum (2021) in Jamun, Verma *et al.*  (2021) and Siddiqua *et al.*  (2023) in dragon fruit.

**CONCLUSION**

The present study demonstrated that integrating vermicompost with beneficial bio-fertilizers, particularly VAM and PSB, significantly enhanced the fruit growth, yield and quality attributes of dragon fruit. The highest fruit weight, size, pulp-to-peel ratio and superior biochemical traits, including elevated TSS, sugars and ascorbic acid content, were recorded in Vermicompost (0.5 kg/plant) + VAM (100 g/plant) + PSB (50 g/plant). This treatment also exhibited the lowest acidity and the highest TSS/acid ratio, indicating improved fruit palatability. Additionally, the highest fruit yield per plant in T₁₁ underscores the synergistic effect of organic amendments in optimizing plant physiological responses and soil health. These findings highlight the potential of integrating vermicompost with bio-fertilizers as an eco-friendly and sustainable approach to enhancing dragon fruit productivity under tropical conditions.

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| **Treatments** | **FW** | **FL** | **FD** | **FV** | **SG** | **PW1** | **PW2** | **PPR** | **PT1** | **PT2** | **TSS** | **TS** | **AC** | **TSAC** | **AA** |
| T1 | 106.66 | 6.90 | 5.53 | 125.58 | 0.85 | 81.66 | 25.00 | 3.27 | 5.27 | 0.25 | 12.86 | 8.40 | 0.29 | 43.96 | 13.43 |
| T2 | 147.66 | 7.12 | 5.70 | 166.12 | 0.89 | 120.66 | 27.00 | 4.50 | 5.42 | 0.27 | 13.03 | 8.62 | 0.27 | 47.70 | 13.57 |
| T3 | 166.33 | 7.25 | 5.88 | 180.88 | 0.92 | 137.66 | 28.66 | 4.80 | 5.60 | 0.28 | 13.20 | 8.73 | 0.27 | 49.54 | 13.64 |
| T4 | 198.33 | 7.80 | 6.36 | 204.72 | 0.97 | 168.00 | 30.33 | 5.58 | 6.07 | 0.28 | 13.53 | 8.88 | 0.24 | 55.66 | 13.75 |
| T5 | 183.00 | 7.50 | 6.09 | 192.74 | 0.95 | 153.66 | 29.33 | 5.26 | 5.80 | 0.28 | 13.33 | 8.81 | 0.25 | 53.32 | 13.70 |
| T6 | 213.33 | 8.06 | 6.57 | 213.33 | 1.01 | 182.66 | 30.66 | 6.02 | 6.28 | 0.29 | 13.76 | 8.94 | 0.23 | 59.01 | 13.82 |
| T7 | 241.00 | 8.66 | 7.06 | 234.02 | 1.03 | 208.00 | 33.00 | 6.31 | 6.77 | 0.29 | 14.36 | 9.05 | 0.21 | 69.50 | 13.97 |
| T8 | 229.66 | 8.26 | 6.82 | 227.38 | 1.01 | 197.66 | 32.00 | 6.21 | 6.52 | 0.29 | 14.23 | 9.00 | 0.22 | 63.78 | 13.92 |
| T9 | 260.33 | 8.97 | 7.33 | 247.95 | 1.05 | 226.00 | 34.33 | 6.60 | 7.03 | 0.30 | 14.86 | 9.13 | 0.20 | 73.07 | 14.04 |
| T10 | 271.66 | 9.14 | 7.50 | 251.92 | 1.08 | 236.32 | 35.33 | 6.77 | 7.17 | 0.33 | 15.03 | 9.27 | 0.19 | 79.13 | 14.12 |
| T11 | 280.50 | 9.42 | 7.64 | 254.98 | 1.10 | 244.50 | 36.00 | 7.01 | 7.27 | 0.36 | 15.76 | 9.42 | 0.17 | 92.85 | 14.26 |

**Table 1 Impact of Organic Manure and Bio-Fertilizers on the Qualitative Attributes of Dragon Fruit**

**FW-Fruit weight (g),FL-Fruit length (cm), FD- Fruit diameter (cm), FV- Fruit Volume (cm3), SG- Specific gravity, PW1- Pulp weight (g), PW2-Peel weight (g), PPR- Pulp peel ratio, PT1-Pulp thickness (cm), PT2- Peel thickness (cm), TSS (° Brix), TS- Total sugar (%),AC-Acidity (%), TSAC-TSS: acid ratio, AA-Ascorbic acid (mg/ 100 g)**