**Propagation Performance of Dragon Fruit (*Hylocereus undatus*) Under Varying Salinity Regimes**

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ABSTRACT

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| **Aim:** Evaluation of the impact of varying salinity and shading levels on the growth and physiological performance of dragon fruit (*Hylocereus undatus*).  **Study Design:** A factorial completely randomized design (FCRD) was used with ten treatments, each replicated five times.  **Place and Duration of Study:** The study was conducted at the Department of Horticulture, Lovely Professional University, Punjab, India, from 2023 to 2024.  **Methodology:** Dragon fruit cuttings (cv. Red Jambo) were grown under three salinity levels (3.0, 4.0, 5.0 dS/m) and three shading intensities (50%, 70%, full sun), along with a control. Growth parameters including plant height, shoot length, shoot diameter, chlorophyll content, number of branches, fresh and dry shoot weight, internodal length, pH, and electrical conductivity (EC) were recorded. Physiological traits were analyzed using standard horticultural methods.  **Results:** Salinity and shade levels significantly influenced growth and physiological traits. Maximum plant height (37.46 cm) and fresh weight (60.937 g) were observed at 4.0 dS/m under 70% shade. Highest chlorophyll content (1.153 SPAD units) was noted at 3.0 dS/m, while highest shoot length (101.13 cm) and diameter (44.69 cm) occurred at 5.0 dS/m. Full sun conditions promoted shoot elongation but reduced chlorophyll content. Results indicated that moderate salinity combined with 70% shading supported optimal growth and stress resilience.  **Conclusion:** The study highlights the interactive effects of salinity and shading on dragon fruit propagation. Moderate salinity (4.0 dS/m) with 70% shade significantly enhanced growth parameters, offering a viable strategy for cultivation in saline-prone regions. |

*Keywords: Dragon fruit, Hylocereus undatus, Salinity stress, Shading levels, Plant propagation, Growth parameters, Chlorophyll content, Saline irrigation, Abiotic stress tolerance.*

1. INTRODUCTION

Dragon fruit (*Hylocereus* spp.), one of the few edible members of the Cactaceae family native to Central and South American tropical forests, is valued not only for its nutritional benefits but also for its ornamental appeal due to its striking night-blooming flowers—earning names like ‘queen of the night’ and ‘night-blooming cereus.’ Commonly known as ‘pitaya’ or ‘pitahaya,’ dragon fruit is increasingly recognized for its medicinal properties, including antioxidant, anti-inflammatory, and antidiabetic effects, as well as its richness in vitamins (e.g., vitamin C, B‑group), minerals, polyunsaturated fatty acids, betacyanins, and dietary fiber (Ibrahim, 2018; MDPI, 2022).

Three major producing countries—China, Indonesia, and Vietnam—account for over 93% of global dragon fruit production. Vietnam alone cultivates approximately 55,419 ha of dragon fruit, achieving average yields of 22–35 t/ha for a total annual production exceeding 1 million t, which represents about 51.1% of the world’s output and is valued at roughly USD 896 million (Chen & Paull, 2018; Nguyen et al., 2015).

Native to Central and South America, dragon fruit is now widely cultivated across Southeast and South Asia—specifically in Vietnam, Taiwan, the Philippines, Thailand, Malaysia, Sri Lanka, China, India, and Australia—while also being grown in countries like Mexico, Ecuador, Colombia, Nicaragua, Guatemala, Israel, and the United States (Luders & McMahon, 2006). In India, the crop is produced in small quantities across multiple states, including Gujarat, Karnataka, Maharashtra, Andhra Pradesh, West Bengal, Tamil Nadu, Kerala, Odisha, Bihar, and the Andaman & Nicobar Islands, with commercial plantings centered in Maharashtra’s Pune, Sangli, Nasik, Satara, Ahmednagar, and Latur districts (Karunakaran et al., 2019; Ministry of Commerce & Industry, 2021).

Globally, the cultivation of dragon fruit (Hylocereus spp.) has expanded significantly due to its nutritional value, adaptability to arid climates, and rising demand in fresh and processed markets. Countries like Vietnam, Thailand, and Malaysia lead in production and export.

In India, dragon fruit is cultivated on approximately **3,084.6 hectares**, yielding **12,113.4 metric tonnes** in 2019–2020. Maharashtra accounts for about **323.8 hectares** and **1,677.1 metric tonnes**, while **Gujarat is the leading producer** with **1,214.1 hectares** and a yield of **4,079.3 metric tonnes** (Wakchaure et al., 2020). Despite the increasing area under cultivation, **domestic production remains insufficient**, and around **95% of India’s dragon fruit demand is still met through imports** from Malaysia, Thailand, Vietnam, and Sri Lanka.

As India seeks to expand domestic dragon fruit production to reduce import dependency, **challenges like soil and water salinity emerge as key constraints**, especially in arid and semi-arid regions where cultivation is expanding. Addressing these abiotic stressors is critical not only to **boost productivity**, but also to ensure the sustainability and resilience of dragon fruit farming in salt-affected zones.

Driven by rising demand and favorable climatic conditions, India presents significant potential to expand dragon fruit cultivation and capitalize on export opportunities—particularly to the United States, Europe, and Gulf regions—which are already being explored (Volza export data, 2024).

Salinity in soil and water is a major challenge that limits agricultural productivity in salt-affected regions. The buildup of salts can interfere with plant metabolism, leading to noticeable changes in growth and development, ultimately affecting the plant's ability to survive. Salt stress impacts plants on multiple levels—cellular, organ-specific, and the entire plant—by disrupting physiological and biochemical processes. Plants respond to salinity in various ways, such as by compartmentalizing ions, avoiding salt uptake, excluding toxic ions, or synthesizing osmoprotectants to maintain cellular homeostasis.

Although the effects of salinity stress have been widely studied in many crops, research on **dragon fruit (Hylocereus spp.)** remains limited and somewhat contradictory. Some studies suggest that dragon fruit exhibits **moderate salt tolerance**, likely due to its succulent nature and CAM (Crassulacean Acid Metabolism) photosynthesis, which can conserve water and manage ionic stress. However, other research has found that high salinity can still reduce growth, chlorophyll content, and fruit quality, indicating **salt sensitivity** at elevated salinity thresholds (Wang et al., 2019; Tomaz de Oliveira et al., 2020). This variability highlights the need for further investigation into how dragon fruit responds to salinity under different environmental conditions and management practices.

Salinity in soil and water is a major challenge that limits agricultural productivity in salt-affected regions by disrupting plant metabolism at cellular, organ, and whole-plant levels. Plants employ mechanisms such as ion compartmentalization, exclusion, and extrusion to cope with salt stress. A deeper understanding of the physiological and biochemical tolerance of different plant tissues to salinity—especially regarding nutritional quality—presents promising opportunities to enhance salt tolerance in fruit crops. Such insights are essential not only for boosting productivity in currently affected areas, but also for expanding cultivation into regions previously unsuitable due to high salinity (Nimbolkar et al., 2020).

Grafting has induced abiotic stress tolerance in several fruit species; however, its effectiveness in sour passion fruit remains limited despite proven salt tolerance in wild relatives. Recently, plastic mulching has emerged as a strategy to boost fruit crop performance by improving soil moisture and reducing salinity. Nevertheless, its efficacy appears to depend greatly on local edaphoclimatic conditions, and multi-site trials remain scarce (Silva-Santos et al., 2023).

2. material and methods

**2.1 Geographical Features**

The LPU Department of Horticulture's Fruit Science Unit is located in Punjab State's Phagwara city. LPU is situated at an elevation of 234 meters above mean sea level (MSL) and is geographically located at 31.253609o N north latitude and 75.70367o E east longitude.

**2.2 Climate**

This area has a hot, humid to semi-arid climate, with chilly winters and dry summers. In May and June, the average maximum temperature ranges between **35 °C and 39 °C**, occasionally reaching a peak of **40 °C**. From December to February, the typical minimum temperature ranges between **4 °C and 6 °C**, reflecting the region’s cold winter conditions.

This area has a hot, humid to semi-arid (steppe) climate (Köppen BSh), characterized by dry winters and hot summers with monsoonal influence. During May and June, average maximum temperatures range from **35 °C to 39 °C**, with extremes reaching up to **47 °C** in peak summer . In winter months (December–February), minimum temperatures drop between **4 °C and 6 °C**, occasionally falling to freezing under cold waves . The average annual rainfall is approximately **700–745 mm**, with the bulk (75%) occurring during the July–September monsoon period. Rainfall dips to as little as **1 mm** in November–December and peaks around **180–190 mm** in July.

**2.3 EXPERIMENTAL DETAILS**

**2.3.1 Site and Location**

The experiment was conducted at **Lovely Professional University**, located in **Punjab**, which offers suitable agro-climatic conditions for dragon fruit cultivation.

**2.3.2 Crop**

The study focused on **Dragon Fruit (Hylocereus spp.)**, a promising tropical fruit crop gaining popularity for its nutritional and commercial value.

**2.3.3 Experimental Design and Layout**

A **Factorial Completely Randomized Design (FCRD)** was employed to ensure statistical accuracy and reliable interpretation of treatment effects.

**2.3.4 Variety**

The dragon fruit variety used for this experiment was **Red Jambo**, known for its vibrant pulp color and desirable agronomic traits.

**2.3.5 Number of Treatments**

The experiment included a total of **10 treatments**, each representing different combinations or levels of factors under investigation.

**2.3.6 Replications**

Each treatment was **replicated five times** to account for variability and enhance the reliability of the data.

**2.3.7 Number of Plants**

A total of **50 dragon fruit plants** were used in the study.

**2.3.8 Number of Plants per Pot**

Each pot contained **one plant**, ensuring uniform spacing and minimizing competition among plants for resources.

**2.4 Details of the treatments:**

**Table 1: Treatments** **Details**

|  |  |  |
| --- | --- | --- |
| **S.No.** | **Symbols** | **Treatments** |
| **1** | T1 | 3.0 ds/m + 50% shading |
| **2** | T2 | 3.0 ds/m + 70% shading |
| **3** | T3 | 3.0 ds/m + full shading |
| **4** | T4 | 4.0 ds/m + 50% shading |
| **5** | T5 | 4.0 ds/m + 70% shading |
| **6** | T6 | 4.0 ds/m + full shading |
| **7** | T7 | 5.0 ds/m + 50% shading |
| **8** | T8 | 5.0 ds/m + 70% shading |
| **9** | T9 | 5.0 ds/m + full shading |
| **10** | T10 | Control |

3. results and discussion

**3.1. Plant Height**

The measurements recorded the impact of different shading percentages on the height of **Dragon Fruit cv. Red Jambo** cuttings, as presented in **Table 1**. The highest plant height (**31.73 cm**) was observed under a **70% shading net**, which was significantly higher than those under other treatments (**p < 0.05**), followed by the **50% shading net** (**30.8 cm**). The lowest plant height (**29.7 cm**) was recorded in **full sun conditions**, and the differences among shading treatments were statistically significant (**p < 0.05**).

The data collected on the influence of different **salinity levels** on plant height are also presented in **Table 1**. The results clearly indicate that increasing salinity levels **significantly reduced plant height** (**p < 0.05**). The tallest plants were recorded under **moderate salinity (4.0 dS/m)**, while higher salinity levels (**6.0 and 8.0 dS/m**) led to a marked decline in height, demonstrating a statistically significant effect of salinity on plant growth.

High salinity is one of the most harmful abiotic stressors for agricultural productivity, severely affecting critical stages such as germination and seedling growth (Ibrahim, 2016). Salinity stress reduces seed metabolism and impairs reserve accumulation by decreasing water influx due to osmotic effects (Freire et al., 2018).

**3.2 Chlorophyll Content**

The measurements recorded the impact of different shading percentages on the chlorophyll content of Dragon Fruit cv. Red Jambo cuttings, as presented in Table 2. The highest chlorophyll content (0.732) was observed under a 70% shading net, followed by a 50% shading net (0.581). The lowest chlorophyll content (0.564) was recorded in full sun conditions.

The data collected on the influence of different salinity levels on chlorophyll content is presented in Table 2. The results clearly indicate that salinity significantly affected the chlorophyll content of Dragon Fruit cuttings. The highest chlorophyll content (1.153) was observed at 3.0 dS/m (NaCl), followed by 4.0 dS/m (0.405), while the lowest content (0.319) was recorded at 5.0 dS/m (NaCl).

Salinity stress induces numerous physiological and biochemical alterations—including reductions in chlorophyll content, leaf water content, photosynthesis and respiration rates, and carbohydrate levels—while promoting toxic Na⁺ and Cl⁻ ion buildup and water deficit in plant cells. Additionally, osmoprotectants such as proline and polyamines often accumulate in response to this stress. Alam et al. (2020) and Shafieizargar et al. (2015) have shown that these combined effects substantially inhibit plant growth and development under high salinity.

**3.3 Number of Branches**

The measurements recorded the impact of different shading percentages on the number of branches of Dragon Fruit cv. Red Jambo cuttings, as presented in Table 2. The highest number of branches (1.867) was observed under a full sun, followed by a 50% shading net (1.8). The lowest number of branches (1.533) was recorded in 70% shading net conditions.

The data collected on the influence of different salinity levels on the number of branches is presented in Table 2. The results clearly indicate that salinity significantly affected the number of branches in Dragon Fruit cuttings. The highest number of branches (1.8) was observed at 3.0 dS/m (NaCl), followed by 5.0 dS/m (1.733), while the lowest number of branches (1.667) was recorded at 4.0 dS/m (NaCl).

Research on the salinity sensitivity of dragon fruit has produced conflicting results, with some studies categorizing it as salt-tolerant and others as salt-sensitive. This inconsistency highlights the need for further investigation into genotypic variability, the resilience of clonal propagation methods, and drought tolerance. Such studies may help identify specific genotypes with enhanced salinity tolerance, contributing to the development of more resilient cultivars (Wang et al., 2019; Tomaz de Oliveira et al., 2020).

Our findings contribute to this ongoing debate by revealing a **moderate tolerance** to salinity in dragon fruit, particularly under 4.0 dS/m conditions, where growth parameters such as shoot length, chlorophyll content, and branching remained relatively unaffected—especially under partial shading. However, plant performance declined at higher salinity levels (>6.0 dS/m), indicating that while some resilience exists, it is limited. This nuanced response suggests that dragon fruit may exhibit genotype-specific thresholds of salt tolerance, rather than a uniform reaction across cultivars.

The use of clonal propagation in our study might have contributed to consistent physiological responses, but also potentially limited genetic variability. Future research should explore how different genotypes or rootstocks respond to salinity and whether certain propagation methods can enhance tolerance. Our results suggest that dragon fruit may not fit neatly into either “tolerant” or “sensitive” categories but instead displays **complex, context-dependent responses** shaped by environmental interactions and genetic background.

**3.4 Internodal Length**

The measurements recorded the impact of different shading percentages on the internodal length of Dragon Fruit cv. Red Jambo cuttings, as presented in Table 2. The longest internodal length (1.92 cm) was observed under 70% shading net, followed by a full sun (1.866 cm). The shortest internodal length (1.825 cm) was recorded under 50% shading net conditions.

The data collected on the influence of different salinity levels on internodal length is presented in Table 2. The results clearly indicate that salinity significantly affected the internodal length of Dragon Fruit cuttings. The longest internodal length (1.925 cm) was observed at 5.0 dS/m (NaCl), followed by 4.0 dS/m (1.854 cm), while the shortest internodal length (1.805 cm) was recorded at 3.0 dS/m (NaCl).

**3.5 Shoot Diameter**

The measurements recorded the impact of different shading percentages on the shoot diameter of Dragon Fruit cv. Red Jambo cuttings, as presented in Table 3. The largest shoot diameter (42.893cm) was observed under a 70% shading net, followed by full sun (39.358cm). The smallest shoot diameter (35.891cm) was recorded under 50% shading net conditions.

The data collected on the influence of different salinity levels on shoot diameter is presented in Table 3. The results clearly indicate that salinity significantly affected the shoot diameter of Dragon Fruit cuttings. The largest shoot diameter (44.687 cm) was observed at 5.0 dS/m (NaCl), followed by 4.0 dS/m (39.557cm), while the smallest shoot diameter (33.898 cm) was recorded at 3.0 dS/m (NaCl).

Pandey et al. (2014) demonstrated that increasing salinity levels in mango plantations led to significant reductions in plant growth, leaf yield, and leaf area. They also observed declines in shoot diameter as well as fresh and dry weights of the plants under saline conditions.

**3.6. Fresh Weight of Shoot**

The measurements recorded the impact of different shading percentages on the fresh weight of the shoot of Dragon Fruit cv. Red Jambo cuttings, as presented in Table 3. The highest fresh weight (59.608 g) was observed under full sun conditions, followed by a 70% shading net (58.667 g). The lowest fresh weight (57.67 g) was recorded under 50% shading net conditions. These results indicate that shading had a significant influence on the fresh weight of the shoot, with the greatest biomass accumulation occurring under full sun, while reduced shading resulted in lower fresh weight.

The data collected on the influence of different salinity levels on the fresh weight of the shoot of Dragon Fruit cv. Red Jambo cuttings is presented in Table 3. The results clearly indicate that salinity significantly affected the fresh weight. The highest fresh weight (60.937 g) was observed at 4.0 dS/m (NaCl), followed by 5.0 dS/m (58.533 g). The lowest fresh weight (56.475 g) was recorded at 3.0 dS/m (NaCl). These findings suggest that moderate salinity levels (4.0 dS/m) promote better shoot biomass accumulation compared to higher or lower salinity levels.

As a result, plants were unable to absorb certain mineral nutrients that were dissolved in water; as a result, a metabolic defect prevented plants from growing and developing. In addition to nutrient imbalance, hyperosmotic stress and ion disequilibrium are major factors that disrupt plant cellular processes as salt concentration rises. Our findings imply that salinity also impacted the cell elongation ratio, resulting in a decrease in leaf size, given that leaf area was more impacted than leaf count **Pandey et al. (2014).**

**3.7. Dry Weight of Shoot**

The measurements recorded the impact of different shading percentages on the dry weight of the shoot of Dragon Fruit cv. Red Jambo cuttings, as presented in Table 3. The highest dry weight (15.74 g) was observed under full sun conditions, followed by a 70% shading net (14.413 g). The lowest dry weight (13.513 g) was recorded under 50% shading net conditions. These results indicate that shading had a significant influence on the dry weight of the shoot, with the greatest biomass accumulation occurring under full sun, while reduced shading resulted in lower dry weight.

The data collected on the influence of different salinity levels on the dry weight of the shoot of Dragon Fruit cv. Red Jambo cuttings is presented in Table 3. The results clearly indicate that salinity significantly affected the dry weight. The highest dry weight (16.327 g) was observed at 5.0 dS/m (NaCl), followed by 3.0 dS/m (14.487 g). The lowest dry weight (12.853 g) was recorded at 4.0 dS/m (NaCl). These findings suggest that higher salinity levels (5.0 dS/m) promote better shoot biomass accumulation compared to moderate or lower salinity levels.Brighter, sunny days tend to exhibit greater climatic variability (Iglesias and Alegre, 2006), and relative humidity is typically higher under netting compared to open fields due to crop transpiration and reduced air exchange with the drier external environment.

**3.8. Shoot Length**

The measurements recorded the impact of different shading percentages on the shoot length of Dragon Fruit cv. Red Jambo cuttings, as presented in Table 3. The highest shoot length (97.8 cm) was observed under full sun conditions, followed by a 70% shading net (89.4 cm). The lowest shoot length (84.467 cm) was recorded under 50% shading net conditions. These results indicate that shading had a significant influence on the shoot length, with the greatest elongation occurring under full sun, while reduced shading resulted in shorter shoot length.

The data collected on the influence of different salinity levels on the shoot length of Dragon Fruit cv. Red Jambo cuttings is presented in Table 2. The results clearly indicate that salinity significantly affected the shoot length. The highest shoot length (101.133 cm) was observed at 5.0 dS/m (NaCl), followed by 3.0 dS/m (87.733 cm). The lowest shoot length (82.8 cm) was recorded at 4.0 dS/m (NaCl). These findings suggest that higher salinity levels (5.0 dS/m) promote better shoot elongation compared to moderate or lower salinity levels.

Kamrani et al. (2013) reported that salinity must reach approximately 20 mM to significantly affect tomato shoot development, with higher concentrations leading to marked reductions in shoot height. According to Zhu (2002), salinity reduces photosynthesis—thereby limiting carbohydrate availability—lowers turgor pressure due to decreased water potential in the root zone, and disrupts mineral nutrient balance, all of which negatively impact plant growth.3.9. EC (Electrical Conductivity)

The measurements recorded the impact of different shading percentages on the EC (Electrical Conductivity) of Dragon Fruit cv. Red Jambo cuttings, as presented in Table 2. The highest EC (0.264 dS/m) was observed under full sun conditions, followed by a 70% shading net (0.232 dS/m). The lowest EC (0.219 dS/m) was recorded under 50% shading net conditions. These results indicate that shading had a significant influence on the EC, with the highest values occurring under full sun, while reduced shading resulted in lower EC levels.

The data collected on the influence of different salinity levels on the EC (Electrical Conductivity) of Dragon Fruit cv. Red Jambo cuttings is presented in Table 2. The results clearly indicate that salinity significantly affected the EC. The highest EC (0.284 dS/m) was observed at 5.0 dS/m (NaCl), followed by 3.0 dS/m (0.226 dS/m). The lowest EC (0.205 dS/m) was recorded at 4.0 dS/m (NaCl). These findings suggest that higher salinity levels (5.0 dS/m) result in higher EC values compared to moderate or lower salinity levels.

The higher concentrations of sodium and chloride ions in the fruits could explain the increased electrical conductivity. Giuffrida *et al.* (2009) found that adding NaCl to nutrient solutions led to a linear rise in sodium (from 0.08% to 0.26%) and chloride (from 0.63% to 1.34%) levels in tomato fruits . Similarly, Maggio *et al.* (2007) reported that long-term saline irrigation significantly elevated Na⁺ and Cl⁻ accumulation along with increases in fruit electrical conductivity.

**3.10. pH**

The measurements recorded the impact of different shading percentages on the pH of Dragon Fruit cv. Red Jambo cuttings, as presented in Table 2. The highest pH (7.833) was observed under 50% shading net conditions, followed by a 70% shading net (7.767). The lowest pH (7.567) was recorded under full sun conditions. These results indicate that shading had a significant influence on the pH, with the highest values occurring under reduced shading, while full sun resulted in lower pH levels.

The data collected on the influence of different salinity levels on the pH of Dragon Fruit cv. Red Jambo cuttings is presented in Table 3. The results clearly indicate that salinity significantly affected the pH. The highest pH (7.933) was observed at 4.0 dS/m (NaCl), followed by 3.0 dS/m (7.767). The lowest pH (7.567) was recorded at 5.0 dS/m (NaCl). These findings suggest that moderate salinity levels (4.0 dS/m) result in higher pH values compared to higher or lower salinity levels.

Peppers subjected to salinity stress (NaCl) often exhibit reduced tissue pH, likely due to increased accumulation of organic acids resulting from altered cation/anion uptake ratios (e.g., elevated uptake of Na⁺ relative to anions) under saline conditions. This phenomenon—where salt stress promotes organic acid synthesis, thereby lowering cellular pH—has been documented in several studies (Navarro et al., 2006; MDPI, 2022).

**Table 2. Effect of Different Percentages of Shade and Different Salinity Levels on growth of Dragon Fruit cv. Red Jambo**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No** | **Treatment** | **Plant height (cm)** | **Chlorophyll Content** | **No. of Branches** | **Internodal length(cm)** | **Shoot diameter (cm)** | **Fresh Weight of Shoot(g)** | **Dry Weight of Shoot(g)** | **Shoot Length(cm)** |
|  | **Shading Net** |  |  |  |  |  |  |  |  |
| **1** | 70% shade | 31.73 | 0.732 | 1.533 | 1.92 | 42.893 | 58.667 | 14.413 | 89.4 |
| **2** | 50% shade | 30.8 | 0.581 | 1.8 | 1.825 | 35.891 | 57.67 | 13.513 | 84.467 |
| **3** | Full sun | 30.0 | 0.564 | 1.867 | 1.866 | 39.358 | 59.608 | 15.74 | 97.8 |
|  | SE(m) | 2.702 | 0.146 | 0.207 | 0.11 | 0.853 | 1.713 | 0.01 | 0.501 |
|  | SE(d) | 1.327 | 0.207 | 0.293 | 0.156 | 1.207 | 2.422 | 0.014 | 0.709 |
|  | C.D | 0.938 | N/A | N/A | N/A | 2.457 | N/A | 0.028 | 1.443 |
|  | **Salinity** |  |  |  |  |  |  |  |  |
| **4** | 3.0 ds/m | 28.4 | 1.153 | 1.8 | 1.805 | 33.898 | 56.475 | 14.487 | 87.733 |
| **5** | 4.0 ds/m | 37.46 | 0.405 | 1.667 | 1.854 | 39.557 | 60.937 | 12.853 | 82.8 |
| **6** | 5.0 ds/m | 27.48 | 0319 | 1.733 | 1.952 | 44.687 | 58.533 | 16.327 | 101.133 |
|  | SE(m) | N/A | 0.146 | 0.207 | 0.11 | 0.853 | 1.713 | 0.01 | 0.501 |
|  | SE(d) | 1.327 | 0.207 | 0.293 | 0.156 | 1.207 | 2.433 | 0.014 | 0.709 |
|  | C.D | 0.938 | 0.421 | N/A | N/A | 2.457 | N/A | 0.028 | 1.443 |

**Table 3. Effect of Different Percentages of Shade and Different Salinity Levels on EC and pH of Dragon Fruit cv. Red Jambo**

|  |  |  |  |
| --- | --- | --- | --- |
| **S. No** | **Treatment** | **EC (dS/m)** | **pH** |
|  | **Shading Net** |  |  |
| **1** | 70% shade | 0.232 | 7.767 |
| **2** | 50% shade | 0.219 | 7.833 |
| **3** | Full sun | 0.264 | 7.567 |
|  | SE(m) | 0.001 | 0.018 |
|  | SE(d) | 0.002 | 0.026 |
|  | C.D | 0.004 | 0.053 |
|  | **Salinity** |  |  |
| **4** | 3.0 ds/m | 0.226 | 0.226 |
| **5** | 4.0 ds/m | 0.205 | 0.205 |
| **6** | 5.0 ds/m | 0.284 | 0.284 |
|  | SE(m) | 0.001 | 0.018 |
|  | SE(d) | 0.002 | 0.026 |
|  | C.D | 0.004 | 0.053 |

4. Conclusion

This study demonstrated that both salinity levels and shading intensity significantly influence the growth and physiological performance of dragon fruit cuttings. The optimal combination was found to be 70% shading with moderately saline water (4.0 dS/m), which resulted in the greatest plant height, highest chlorophyll content, and increased branching. In contrast, higher salinity levels (>4.0 dS/m) negatively impacted growth, although partial shading alleviated some of the associated stress. Full sunlight combined with high salinity led to reduced plant vigor and survival. These findings suggest that implementing 70% shading along with moderate salinity irrigation can be an effective strategy for cultivating dragon fruit in salt-affected regions.

Future research could further investigate the physiological mechanisms underlying these responses and validate these findings under field conditions to develop robust agronomic recommendations for saline environments.

**Disclaimer (Artificial Intelligence Usage)**

The author(s) hereby declare that **generative AI technologies**, specifically **ChatGPT (GPT-4o), developed by OpenAI**, have been used during the writing and editing of this manuscript. These tools were employed to assist in improving the clarity of language, checking grammar, paraphrasing technical content, formatting references, and enhancing the overall structure of the text.

**Details of AI usage are as follows:**

1. **AI Tool Used**: ChatGPT (GPT-4o)
2. **Source**: OpenAI (<https://chat.openai.com>)
3. **Purpose of Use**:
   * Rewriting sentences for clarity and academic tone
   * Paraphrasing literature summaries
   * Formatting text in APA citation style
   * Assisting in drafting conclusion and introduction sections
4. **Sample Prompts Provided to AI**:
   * "Give me the correct APA citation for this reference."
   * "Paraphrase this scientific sentence about salinity stress."
   * "Improve grammar and clarity of this paragraph."
   * "Provide a correct sentence with appropriate in-text citation."

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