***Review Article***

**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

One of the most sought-after fruits, dragon fruit (Hylocereus spp.), is just now beginning to reveal its nutritional and medicinal advantages. It belongs to the Cactaceae family of crops. The fruit is endemic to Central and South American tropical and subtropical forest environments. One of the few edible crops in the Cactaceae family is dragon fruit. It also has an ornamental quality due to its beautiful night-blooming blooms, which may explain some of its regional names, such as "belle of the night," "queen of the night," and "night blooming cereus." The term "Pitaya" or "Pitayaha" is used in popular culture **(Ahmad *et al.*, 2016).**

Three major nations—China, Indonesia, and Vietnam—produce more than 93% of the dragon fruit consumed worldwide. With 55,419 hectares and an average production of 22–35 metric tonnes (MT)/hectare (ha) each year, Vietnam alone produces more than half (51.1%) of the world's output. Over 1 million dragon fruit metric tons, worth USD 895.70 million, are produced in Vietnam **(Chen and Paull, 2018)** and estimated at 353.19 million tonnes, reflecting a slight decline of 0.65% compared to 355.48 million tonnes in 2022–23. Expanded to 28.98 million hectares in 2023–24, up from 28.44 million hectares in the previous year. Increased by 2.29%, reaching 112.73 million tonnes, driven by higher yields in mango, banana, lime/lemon, grapes, and custard apple.

Native to North, Central, and South America, dragon fruit is widely grown in nations including Vietnam, Taiwan, the Philippines, Thailand, Malaysia, Sri Lanka, China, India, and Australia **(Luders and McMahon, 2006)**. Additionally, Mexico, Ecuador, Colombia, Nicaragua, Guatemala, Israel, and the United States cultivate it. Dragon fruit is produced in small quantities in various Indian states such as Gujarat, Karnataka, Maharashtra, Andhra Pradesh, West Bengal, Tamil Nadu, Kerala, Odisha, Bihar, and the Andaman & Nicobar Islands, with commercial cultivation notably taking place in Maharashtra districts like Pune, Sangli, Nasik, Satara, Ahmednagar, and Latur (Babar et al., 2021).

In India, dragon fruit is cultivated on approximately 3,084.6 hectares of land, yielding 12,113.4 metric tonnes in the year 2019–2020. In Maharashtra, about 323.8 hectares are dedicated to dragon fruit cultivation, with a production of 1,677.1 metric tonnes during the same period. Gujarat stands as the leading producer, with 1,214.1 hectares under cultivation and an estimated yield of 4,079.3 metric tonnes (Wakchaure et al., 2020). Despite this, domestic production remains insufficient, and around 95% of India's dragon fruit demand is met through imports from countries such as Malaysia, Thailand, Vietnam, and Sri Lanka. Given the rising demand and favorable climatic conditions, there is significant potential for expanding dragon fruit cultivation in India, along with promising opportunities for export to markets in the United States, Europe, and the Gulf region (Waghmare et al., 2021).

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 harmful salts, or actively pushing them out. Gaining a deeper understanding of how different plant tissues tolerate salt—both physiologically and biochemically—offers promising opportunities to improve salt tolerance in fruit crops, especially in terms of their nutritional value. This knowledge is not only essential for increasing productivity in areas already affected by salinity but also for expanding cultivation into regions currently unsuitable due to high salt levels (Nimbolkar et al., 2020).

Grafting has been shown to induce abiotic stress tolerance in several fruit species. However, this propagation technique has not been particularly effective for sour passion fruit, despite the salt tolerance observed in its wild relatives. Recently, plastic mulching has emerged as a strategy to enhance the performance of fruit crops. Nevertheless, according to Sun et al. (2015), there is still a lack of research conducted across diverse edaphoclimatic conditions. The advantages of cultivating various fruit species using primarily saline irrigation remain a subject of ongoing debate.

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 stays between 35 and 390 degrees Celsius, reaching a maximum of 40 degrees. From December to February, the typical winter temperature stays between 4 and 60 degrees Celsius. The average rainfall in this area ranges from 1 mm in November through December to 180 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, followed by a 50% shading net (30.8 cm). The lowest height (29.7 cm) was recorded in full sun conditions.

The data collected on the influence of different salinity levels on plant height is presented in Table 1. The results clearly indicate that salinity significantly affected the height of Dragon Fruit cuttings. The maximum plant height (37.46 cm) was observed at 4.0 dS/m (NaCl), followed by 3.0 dS/m (28.4 cm), while the lowest height (27.48 cm) was recorded at 5.0 dS/m (NaCl).

High salinity is the most harmful abiotic stressor to agricultural output, leading to losses at the most crucial stages of plant development, including germination and seedling growth **(Ibrahim, 2016).** Due to the decreased influx of water produced by the osmotic response, salinity stress lowers seed metabolism and prevents reserve buildup **(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).

Reduced chlorophyll, leaf water content, photosynthesis, respiration rates, and carbohydrates are among the physiological and biochemical changes brought on by salinity stress, which also causes hazardous Na+ and Clion buildup in cells and water deficiencies. Proline and polyamines might occasionally rise as a result. **Alam et al. (2020) and Shafieizargar et al. (2015)** both state that these alterations collectively hinder the growth and development of plants. Plant growth and development can be seriously hampered by high salt concentrations close to the roots.

**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).

**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).

Mangoes are cultivated in salt, plant growth, leaf yield, and leaf area all decline. Additionally, they noticed that as salinity increased, shoot diameter, fresh and dry weights of plants decreased **Pandey et al., (2014).**

**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.

Salinity must reach 20 mM to have an impact on tomato shoot development, according to **Kamrani et al. (2013),** who also noted that higher salinity dramatically reduces shoot height. Salinity reduced photosynthesis, which in turn limited the supply of carbohydrates needed for growth; it reduced turgor in expanding tissues due to lowered water potential in root growth medium; it disrupts the mineral supply, either in excess or insufficiently; and it changed the concentrations of certain ions in the growth medium, which may have a direct effect on growth, **Zhu (2002).**

**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 help to explain the increased electrical conductivity. Higher sodium and chloride concentrations were anticipated in tomato fruits cultivated in high salinity environments, and comparable outcomes have been documented in the past. **(Giuffrida et al., 2009 and Maggio et al., 2007)**

**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.

The lower pH values observed in red pepper plants treated with NaCl as opposed to control plants may be the result of higher concentrations of organic acid, most likely brought on by a higher ratio of inorganic cation/anion uptake **(Davies, 1964)**

**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 research demonstrated that how salty the water is and how much shade there is greatly affects how well dragon fruit cuttings grow and function. The best results were seen when the plants got 70% shade and water with a moderate amount of salt (4.0 dS/m), leading to the tallest plants, the greenest leaves, and more branches. When the water was saltier than 4.0 dS/m, the plants didn't grow as well, but some shade helped reduce the stress. Exposing the plants to full sun when the water was very salty led to weaker plants and fewer surviving. The study suggests that using 70% shade and watering with moderately salty water could be a good way to successfully grow dragon fruit in areas with salty conditions. These findings provide useful advice for improving how dragon fruit is grown when facing environmental stresses, helping them establish better, grow stronger, and produce more.

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