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INFLUENCE OF NACL-INDUCED SALINITY ON GROWTH CHARACTERISTICS OF DRAGON FRUIT (*HYLOCEREUS* SPP.)

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ABSTRACT

The present experiment was conducted at the Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra) during 2023–24 and 2024–25. The pot experiment was laid out in a Factorial Completely Randomized Design (FCRD) with three replications, comprising two factors: four genotypes (*Hylocereus undatus, H. polyrhizus, H. megalanthus* and *H. costariscensis*) and four salinity levels (control, 50, 100, and 200 mM NaCl). Among the genotypes, *H. megalanthus* required the minimum number of days to sprout, whereas *H. costariscensis* took the maximum days, indicating significant genotypic variation in sprouting behaviour. The maximum number of secondary cladodes was recorded in *H. polyrhizus*, while *H. costariscensis* exhibited the highest shoot diameter. In contrast, *H. megalanthus* recorded the minimum number of secondary cladodes and pooled shoot diameter. Increasing salinity levels significantly reduced vegetative growth, with maximum secondary cladodes and shoot diameter under control conditions and minimum values at 200 mM NaCl. Interaction effects revealed the highest shoot diameter in *H. costariscensis* under control conditions and the lowest in *H. megalanthus* at 200 mM NaCl. However, genotype × salinity interactions were non-significant for days to sprouting and number of secondary cladodes.

Key words : Dragon fruit, Genotype, Abiotic stress, Salinity; Growth.

Introduction

Dragon fruit (*Hylocereus* spp.) is an emerging fruit crop in India that has gained considerable attention due to its attractive appearance, high nutritional value, and economic profitability. It is an herbaceous, perennial, climbing cactus belonging to the family Cactaceae and is valued for its low maintenance requirements and adaptability to diverse agro-climatic conditions. The fruits are rich in vitamins, minerals, antioxidants,and dietary fibre, making them increasingly popular among health-conscious consumers. Cytogenetically, most *Hylocereus* species are diploid (2n = 22), whereas *Hylocereus* (*Selenicereus*) *megalanthus* is tetraploid with a chromosome number of 2n = 44 (Lichtenzveig *et al.*, 2000). Economically important species include *H. undatus* (white-fleshed pitaya), *H. polyrhizus* (red-fleshed pitaya), *H. costariscensis* (violet-red flesh), and *H. megalanthus* (yellow pitaya) (Jadhav *et al.*, 2021). Originally native to North, Central, and South America, dragon fruit is now cultivated in several countries including Vietnam, Thailand, Malaysia, China, Australia, and India (Luders and McMahon, 2006). In India, cultivation has expanded rapidly across states such as Gujarat, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, and West Bengal, with the total cultivated area exceeding 3,000 ha (Babar *et al.*, 2021). In Maharashtra, commercial cultivation is mainly concentrated in districts such as

Pune, Sangli, Nashik, Satara, Ahmednagar and Latur.

Climate change–induced abiotic stresses, particularly soil salinity, pose a major threat to sustainable agricultural production worldwide. Salinity affects nearly 20% of global agricultural land, with approximately 932 million hectares classified as salt-affected soils (Nellemann, 2009; FAO, 2021). In India alone, about 6.73 million hectares are affected by salinity (Singh, 2009), with arid and semi-arid regions being the most vulnerable. High salinity disrupts water uptake due to osmotic stress and causes ionic toxicity, leading to impaired physiological processes, reduced growth, and yield losses (Munns, 2002; Oliveira *et al.*, 2011). In fruit crops, salinity stress adversely affects seed germination, vegetative growth, nutrient uptake, yield, and fruit quality, and prolonged exposure can result in plant mortality (Kakade *et al.*, 2019). Although, management practices such as leaching and improved irrigation methods have been suggested, their large-scale adoption is often limited due to high costs and practical constraints (Singh *et al.*, 2018). Therefore, the identification of salt-tolerant genotypes remains one of the most sustainable and economically viable approaches for salinity management.

Dragon fruit, despite being drought tolerant, exhibits variable responses to salinity stress. Some studies have reported tolerance up to moderate salinity levels (Barcenas-Abogado *et al.*, 2002; Ortiz *et al.*, 2014), whereas others have documented significant growth reduction and plant mortality under saline conditions (Cavalcante *et al.*, 2007; Sousa *et al.*, 2021). These contrasting findings suggest strong genotype-dependent responses and highlight the need for systematic evaluation of different *Hylocereus* species under saline environments.

Considering the expanding cultivation of dragon fruit in salinity-prone regions and the lack of systematic studies on genotype-specific salinity tolerance, the present investigation was undertaken to evaluate the response of different *Hylocereus* genotypes to salinity stress. The study aims to assess morphological changes in dragon fruit genotypes under varying salinity levels, thereby contributing to the identification of salt-tolerant genotypes for sustainable cultivation in saline environments.

Materials and Methods

The pot experiment was conducted at the Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra) during 2023–24 and 2024–25. The experiment was laid out in a Factorial Completely Randomized Design (FCRD) with three replications, comprising two factors: four dragon fruit genotypes (*Hylocereus undatus, H. polyrhizus, H. megalanthus* and *H. costariscensis*) and four salinity levels (control, 50, 100 and 200 mM NaCl) (Table 1). Mature, healthy, and disease-free dragon fruit cuttings measuring 25 ± 4 cm in length and 15 ± 2 cm in girth were collected from the mother block orchard. The cuttings were shade-dried for ten days and treated with 0.25% copper oxychloride prior to planting. Each cutting was planted in earthen pots filled with a mixture of black soil and well-decomposed farmyard manure.

Salinity stress was imposed through irrigation using saline water prepared with laboratory-grade sodium chloride (NaCl). The required quantities of NaCl were calculated based on its molecular weight to obtain the desired salinity levels. The electrical conductivity (EC) and pH of the saline solutions were measured after preparation. During the initial three months (December to March), irrigation was applied once weekly, which was

Table 1 : Treatment details of experiment.

Factor A		
Genotypes	G_1	*Hylocereus undatus*
	G_2	*Hylocereus polyrhizus*
	G_3	*Hylocereus megalanthus*
	G_4	*Hylocereus costariscensis*
Factor B		
Salinity levels	S_1	0 mM
	S_2	50 mM
	S_3	100 mM
	S_4	200 mM

S. no.	Treatment ID	Combinations
1	T-01	G_1S_1
2	T-02	G_1S_2
3	T-03	G_1S_3
4	T-04	G_1S_4
5	T-05	G_2S_1
6	T-06	G_2S_2
7	T-07	G_2S_3
8	T-08	G_2S_4
9	T-09	G_3S_1
10	T-10	G_3S_2
11	T-11	G_3S_3
12	T-12	G_3S_4
13	T-13	G_4S_1
14	T-14	G_4S_2
15	T-15	G_4S_3
16	T-16	G_4S_4

increased to twice weekly during the final two months (April and May). Initially, 300 mL of irrigation water was applied per pot per irrigation, which was later increased to 500 mL as plant growth progressed.

The number of days to sprouting was recorded by daily visual observation of each cutting after salinity treatment, noting the day when initial sprouting occurred. The number of secondary cladodes per plant was counted manually at the end of the experiment. Shoot diameter of newly formed cladodes was measured at the midpoint using a vernier caliper and expressed in millimetres, and the mean value was calculated. The data obtained were subjected to statistical analysis following standard procedures described by Panse and Sukhatme (1985).

Results and Discussion

Dragon fruit exhibited notable alterations in shoot development when exposed to salinity stress. New shoot production remained stable up to 50 mM salinity, with only a slight reduction at 100 mM NaCl compared to the control. However, at higher salinity levels (200 mM NaCl), shoot production declined markedly, indicating that severe salinity exerts a strong inhibitory effect on vegetative growth. This reduction may be attributed to osmotic stress and ionic toxicity, which impair water uptake, nutrient transport, and meristematic activity, ultimately restricting shoot initiation and development. The pooled mean data (Table 2) revealed significant genotypic variation in the number of days required for sprouting. *Hylocereus megalanthus* (G_3) recorded the minimum number of days to sprout (28.83 days), indicating early sprouting behaviour, whereas *H. costariscensis* (G_4) required the maximum time (32.91 days). This indicates that sprouting behaviour in dragon fruit is predominantly under genetic control. Early sprouting in *H. megalanthus* may be attributed to efficient mobilization of stored carbohydrates, rapid activation of meristematic tissues, and favourable endogenous hormonal balance. In contrast, delayed sprouting in *H. costariscensis* may reflect slower physiological activation during the initial growth phase. Similar genotypic differences in sprouting behaviour have been reported by Dano *et al.* (2020). The pooled effect of salinity on number of days to sprout was non-significant, suggesting that dragon fruit cuttings possess inherent tolerance to salinity during the sprouting stage. This tolerance may be related to the succulent nature of the cuttings, which enables maintenance of internal water balance under saline conditions. The genotype × salinity interaction was also non-significant, further confirming that sprouting is largely genotype-dependent.

Table 2 : Effect of different salinity levels on different genotypes and their interactions on no of days to sprout.

Treatments	**Number of days to sprout**		
	2023 -2024	**2024 -2025**	**Pooled mean**
Genotypes (G)			
Hylocereus undatus (G_1)	27.50	30.17	28.83
Hylocereus polyrhizus (G_2)	29.08	33.33	31.20
Hylocereus megalanthus(G_3)	24.67	27.08	25.87
Hylocereus costariscensis(G_4)	30.58	35.25	32.91
S.E.±	**1.596**	**1.220**	**0.866**
C.D. at 5%	**NS**	**3.516**	**2.507**
Salinity levels (S)			
Control (S_1)	27.50	28.42	27.95
50 mM (S_2)	26.92	34.58	30.75
100 mM (S_3)	28.67	30.67	29.66
200 mM (S_4)	28.75	32.17	30.45
S.E.±	**1.596**	**1.220**	**0.866**
C.D. at 5%	**NS**	**3.516**	**NS**
Interaction (G X S)			
G_1S_1	27.33	27.33	27.33
G_1S_2	26.67	34.00	30.33
G_1S_3	28.00	29.33	28.66
G_1S_4	28.00	30.00	29.00
G_2S_1	31.33	28.33	29.83
G_2S_2	25.33	37.00	31.16
G_2S_3	29.00	33.33	31.16
G_2S_4	30.67	34.67	32.66
G_3S_1	20.33	24.67	22.50
G_3S_2	23.33	28.67	26.00
G_3S_3	28.00	26.00	27.00
G_3S_4	27.00	29.00	28.00
G_4S_1	31.00	33.33	32.16
G_4S_2	32.33	38.67	35.50
G_4S_3	29.67	34.00	31.83
G_4S_4	29.33	35.00	32.16
S.E. ±	**3.192**	**2.441**	**1.733**
C.D. at 5%	**NS**	**NS**	**NS**

Secondary cladode production is a critical determinant of canopy development, photosynthetic surface area, and biomass accumulation in dragon fruit. The data presented in Table 3 showed significant variation among genotypes for number of secondary cladodes. *Hylocereus polyrhizus* (G_2) produced the maximum number of secondary cladodes (4.73), followed by *H. costariscensis* (G_4) (4.20), while *H. megalanthus* (G_3) recorded the minimum (3.32). These results clearly indicate superior branching ability in *H. polyrhizus*. The superior performance of *H. polyrhizus* may be attributed to its higher vegetative vigour, efficient assimilate partitioning, and enhanced lateral growth capacity. Increased cladode production also reflects better regulation of apical dominance and higher endogenous growth regulator activity, which promote lateral bud initiation. Similar genotypic variation in shoot production among dragon fruit species has been reported by Dano *et al.* (2020), who observed superior shoot proliferation in red-fleshed genotypes. Salinity significantly influenced secondary cladode production. The maximum number of secondary cladodes was recorded under control conditions (5.05), followed by 50 mM NaCl (4.47), whereas the minimum was observed at 200 mM NaCl (2.89). The progressive reduction in cladode number with increasing salinity indicates the inhibitory effect of salt stress on shoot initiation and development. High salinity levels adversely affect water uptake, nutrient transport, and ionic balance in plants, leading to reduced meristematic activity and impaired initiation of new shoots. Salt-induced osmotic stress disrupts cell division at the shoot apex and reduces the formation of new cladode primordia, ultimately lowering cladode number (Mishra *et al.*, 2025). These findings are in agreement with Sousa *et al.* (2021), who reported that salinity stress significantly reduces shoot development in dragon fruit by impairing root function and nutrient uptake. Kokani *et al.* (2024) further observed that shoot production remains relatively stable under mild salinity but declines sharply at higher salt concentrations. The pooled genotype × salinity interaction for this trait was non-significant, indicating a similar response pattern of genotypes to increasing salinity levels.

Table 3 : Effect of different salinity levels on different genotypes and their interactions on no of secondary cladode.

Treatments	Number of secondary cladodes		
	2023 -2024	**2024 -2025**	**Pooled mean**
Genotypes (G)			
Hylocereus undatus (G_1)	3.41	3.95	3.68
Hylocereus polyrhizus (G_2)	4.51	4.96	4.73
Hylocereus megalanthus(G_3)	3.19	3.44	3.32
Hylocereus costariscensis(G_4)	3.95	4.45	4.20
S.E. ±	**0.102**	**0.141**	**0.098**
C.D. at 5%	**0.296**	**0.407**	**0.283**
Salinity levels (S)			
Control (S_1)	4.75	5.34	5.05
50 mM (S_2)	4.03	4.91	4.47
100 mM (S_3)	3.49	3.56	3.52
200 mM (S_4)	2.79	2.99	2.89
S.E. ±	**0.102**	**0.141**	**0.098**
C.D. at 5%	**0.296**	**0.407**	**0.283**
Interaction (G X S)			
G_1S_1	4.22	5.29	4.76
G_1S_2	3.52	4.50	4.01
G_1S_3	3.24	3.03	3.14
G_1S_4	2.65	2.97	2.81
G_2S_1	5.65	6.35	6.00
G_2S_2	5.07	5.80	5.43
G_2S_3	4.10	4.27	4.18
G_2S_4	3.23	3.43	3.33
G_3S_1	3.93	4.29	4.11
G_3S_2	3.48	4.27	3.88
G_3S_3	3.17	2.67	2.92
G_3S_4	2.19	2.53	2.37
G_4S_1	5.21	5.44	5.33
G_4S_2	4.06	5.07	4.56
G_4S_3	3.43	4.27	3.85
G_4S_4	3.11	3.03	3.07
S.E. ±	**0.205**	**0.282**	**0.196**
C.D. at 5%	**NS**	**NS**	**NS**

The data shown in Table 4 revealed significant differences among genotypes, salinity levels, and their interaction for shoot diameter. Among the genotypes, *Hylocereus costariscensis* (G_4) recorded the maximum pooled shoot diameter (41.43 mm), whereas *H. megalanthus* (G_3) recorded the minimum (31.93 mm), indicating marked genotypic variation in structural growth. Shoot diameter is an important indicator of mechanical strength, vascular development, and assimilate transport capacity. The enhanced shoot diameter observed in *H. costariscensis* may be attributed to higher rates of cell division and enlargement in cortical tissues, efficient photosynthate accumulation and stronger vascular differentiation. This structural robustness enables the genotype to sustain vigorous vegetative growth and withstand stress conditions. Similar genotypic differences in shoot diameter among dragon fruit species have been reported by Abirami *et al.* (2021). Salinity exerted a significant negative effect on shoot diameter. The maximum pooled shoot diameter was recorded under control conditions (39.39 mm), followed by 50 mM (38.19 mm) and 100 mM NaCl (36.35 mm), while the minimum was observed at 200 mM NaCl (31.74 mm). This progressive decline reflects the adverse impact of salinity on structural growth. Salinity stress reduces shoot diameter by inducing osmotic stress, ionic toxicity, and hormonal imbalance, which collectively inhibit cell division and elongation. Reduced availability of growth-regulating hormones such as auxins, gibberellins, and cytokinins under saline conditions limits cell expansion and stem thickening (Zhu, 2001). These findings are consistent with reports by Zhang *et al.* (2016) in tomato and Ahani *et al.* (2018) in sea buckthorn, who observed significant reductions in stem diameter under salinity stress.

The pooled genotype × salinity interaction showed that G_4S_1 (*H. costariscensis* under control conditions) recorded the maximum shoot diameter (44.70 mm), whereas G_3S_4 (*H. megalanthus* at 200 mM NaCl) recorded the minimum (25.14 mm). This interaction indicates that *H. costariscensis* exhibits superior adaptability and structural resilience under saline conditions, while *H. megalanthus* is more sensitive to high salinity stress. Shoot diameter decreased significantly with increasing salinity, indicating the adverse impact of salt stress on structural growth. The maximum shoot diameter under control conditions reflects optimal physiological functioning, including efficient water uptake, nutrient availability and cell expansion. Mild salinity (50 mM) caused only a slight reduction, suggesting partial tolerance at lower salt levels. shoot diameter was significantly influenced by both genotype and salinity levels. Increasing salinity resulted in a progressive reduction in shoot diameter, Among the genotypes, *Hylocereus costariscensis* (G_4) consistently exhibited superior shoot diameter under both control and saline conditions, indicating better structural strength and adaptability. In contrast, *Hylocereus megalanthus* (G_3) showed greater sensitivity to salinity stress, particularly at higher salinity levels (S_4). The findings from this study are consistent with the results reported by Al rahman *et al.* (2017), who observed that salinity stress adversely impacts stem girth by limiting water and nutrient uptake, leading to inhibited cell growth and reduced expansion. In both studies, it was noted that the osmotic stress caused by increased soil salinity restricts water availability, disrupts nutrient balance and induces oxidative stress through reactive oxygen species. These physiological disturbances hinder cell division and elongation, leading to slower stem thickening. Roy *et al.* (2014) also found that graded levels of NaCl salt affected the plant height, stem diameter, number of leaves, leaf area and survivability of mango. Significant reduction in growth parameters (shoot length, number of leaves, leaf area, fresh and dry weight etc.) under salinity stress was also observed by Perez Tornero *et al.* (2009), Tsai *et al.* (2015), Shiyab *et al.* (2003) and Sharma *et al.* (2013) in *citrus microphylla*, pink wax apple, Sour orange and *Citrus jambhiri*, respectively.

Table 4 : Effect of different salinity levels on different genotypes and their interactions on shoot diameter (mm).

Treatments	**Shoot diameter (mm)**		
	2023 -2024	**2024 -2025**	**Pooled mean**
Genotypes (G)			
Hylocereus undatus (G_1)	34.91	37.16	36.03
Hylocereus polyrhizus (G_2)	35.84	36.71	36.28
Hylocereus megalanthus (G_3)	31.10	32.76	31.93
Hylocereus costariscensis (G_4)	40.53	42.34	41.43
S.E. ±	**0.411**	**0.374**	**0.315**
C.D. at 5%	**1.183**	**1.077**	**0.911**
Salinity levels (S)			
Control (S_1)	38.41	40.37	39.39
50 mM (S_2)	37.47	38.91	38.19
100 mM (S_3)	35.61	37.10	36.35
200 mM (S_4)	30.88	32.60	31.74
S.E. ±	**0.411**	**0.374**	**0.315**
C.D. at 5%	**1.183**	**1.077**	**0.911**
Interaction (G X S)			
G_1S_1	38.48	40.50	39.49
G_1S_2	37.50	40.44	38.97
G_1S_3	34.42	36.00	35.21
G_1S_4	29.23	31.71	30.47
G_2S_1	37.98	38.49	38.23
G_2S_2	36.59	36.98	36.78
G_2S_3	35.89	37.27	36.58
G_2S_4	32.92	34.11	33.51
G_3S_1	34.29	35.98	35.14
G_3S_2	33.89	35.11	34.50
G_3S_3	32.23	33.65	32.94
G_3S_4	23.97	26.31	25.14
G_4S_1	42.90	46.50	44.70
G_4S_2	41.90	43.12	42.51
G_4S_3	39.91	41.46	40.68
G_4S_4	37.41	38.27	37.84
S.E. ±	0.821	0.748	0.630
C.D. at 5%	2.366	2.073	1.822

Conclusion

The current research revealed significant changes in dragon fruit shoot development when subjected to salt stress. As salinity levels increased, shoot production progressively declined. Nevertheless, new shoot formation persisted up to 50 mM NaCl with only a marginal reduction compared to the control, indicating a degree of tolerance to mild salinity. However, higher salinity levels resulted in a marked suppression of shoot initiation, reflecting the adverse effects of osmotic stress and ionic toxicity on vegetative growth. The results showed that sprouting in dragon fruit was mainly influenced by genotype, with *Hylocereus megalanthus* exhibiting early sprouting, while salinity had little effect at this stage. In contrast, vegetative growth parameters, particularly number of secondary cladodes and shoot diameter, were significantly reduced with increasing salinity, with severe inhibition observed at 200 mM NaCl. Among the genotypes, *Hylocereus polyrhizus* recorded the highest secondary cladode production, indicating superior branching ability, whereas *Hylocereus costariscensis* consistently exhibited greater shoot diameter under both saline and non-saline conditions, reflecting better structural adaptability. *Hylocereus megalanthus* was comparatively more sensitive to high salinity, particularly in terms of shoot growth.

Overall, the study highlights pronounced genotypic variation in salinity response and identifies *Hylocereus polyrhizus* and *Hylocereus costariscensis* as promising genotypes for cultivation under moderate salinity conditions, contributing to sustainable dragon fruit production in salt-affected areas.

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