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Effect of different salinity levels and month of exposure on vegetative growth of bougainvillea (*Bougainvillea peruviana* L.)

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Abstract
The present investigation was conducted to study the Effect of different salinity levels on vegetative growth of bougainvillea (*Bougainvillea peruviana* L.) at Horticulture Polytechnic, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat during March, 2023 to May, 2023. The experiment consists of six treatments of different salinity levels *i.e.* I_1: Best available water (Control), I_2: 3.0 dSm^{-1}, I_3: 6.0 dSm^{-1}, I_4: 9.0 dSm^{-1}, I_5: 12.0 dSm^{-1} and I_6: 15.0 dSm^{-1} with four repetitions in completely randomized design. Among different levels of salinity, best available water (I_1: Control) showed the maximum plant height (45.39 cm), number of leaves (64.79), stem girth (1.15 cm), number of branches per plant (2.77) and leaf area (27.94 cm^2) in the month of March (M_1). Thus, as the month of exposure and salinity increased, all vegetative parameters decreased. Overall vegetative growth parameters of bougainvillea plants remain acceptable up to the salinity level 9.0 dSm^{-1}. Thus, bougainvillea plant has been found to be a moderate salt tolerant crop.

Keywords: Bougainvillea, salinity, month of exposure and vegetative parameters

Introduction

Bougainvillea (*Bougainvillea peruviana* L.) is a perennial ornamental plant belongs to family Nyctageniceae and is a native to Brazil. The first generic name as bougainvillea was published by De Jussieu, A. L. (1789) [4] in his work '*Garden Plantarum*'. It is a shrubby climber and one of the most important ornamental plant in tropical and sub-tropical gardens. Due to high popularity and use in gardening, bougainvillea is called as 'Glory of the tropics' in the tropical countries. The plant grows well in various climatological zones and also in almost all types of soil. They are grown as climbers, bush, hedges, topiaries, on pergolas, trees, pot plant and bonsai *etc*. Bougainvillea bracts are available in almost all colour shades like red, magenta, mauve, purple, orange, white and yellow *etc*. Attractive variegation in leaves is added beauty for its attraction. It is drought and pollution tolerant (Kumari *et al.*, 2022) [8] and can be planted in the industrial regions and in the areas where other ornamental flowering plants do not easily survive well.

Salinity is the amount of concentrated soluble salts in soil moisture around the root zone of plants. These soluble salt concentrations, due to their high osmotic pressure have an effect on plant growth by inhibiting root water uptake. Salinity can also have an impact on plant growth because high salt concentrations in soil solutions interfere with proper absorption of critical nutrients of the plants (Tester and Davenport, 2003) [12]. The inhibition of plant growth, development, senescence and death of the plants are the common symptoms of damage by salt stress condition. Under saline stress condition, primary injury is growth inhibition which leads to other symptoms (Jouyban, 2012) [7].

Salinity does not necessarily negatively affect floriculture and nursery crops. Salt stress reduces the length or quantity of internodes. Proper management of salinity can make it an environmentally friendly alternative to chemical growth regulators by restricting stem length (Shillo *et al.*, 2002) [11]. Plants have evolved different mechanisms to deal with the challenges produced by high salinity levels including ion homeostasis, osmotic adjustment and metabolic adjustment, which are the key variables related with salt stress tolerance in plants (Liu *et al.*, 2021) [9]. Salinity can be controlled by combining saline and irrigation water, minimizing salt stress during the vital phase of plant growth.

Materials and Methods

The present investigation was carried out at Horticulture Polytechnic, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat during March, 2023 to May, 2023. The experiment consists of 6 treatments of different salinity levels *i.e.* I_1: Best available water (Control), I_2: 3.0 dSm^{-1}, I_3: 6.0 dSm^{-1}, I_4: 9.0 dSm^{-1}, I_5: 12.0 dSm^{-1} and I_6: 15.0 dSm^{-1} with four repetitions in completely randomized design. Potting mixture which includes soil, sand, leaf mould and vermicompost were filled with the ratio of 1:1:1:1. One rooted cutting of bougainvillea plant was placed in the centre of the bag and irrigated immediately with normal water (Best available water). Plants were irrigated with normal tap water up to successful establishment and there after the plants were irrigated as per irrigation treatments. The sea water was collected from nearest seacoast *i.e.* Dandi sea shore, which is having EC value 55 dSm^{-1} and was diluted with Best Available Water (BAW) of farm which is having EC value 1.7 dSm^{-1} as per the treatments. The desired EC level of irrigation water was calculated as per treatments. All vegetative parameters were recorded at months of March (M_1), April (M_2) and May (M_3).

Results and Discussions

1. Plant height (cm)

The data given in Table 1 show that plant height was significantly increased with the different levels of saline irrigation water, month of exposure and their interaction effect. In case of salinity, the maximum plant height (45.39 cm) was observed in plants irrigated with I_1 (BAW-control). While, the lowest plant height (32.83 cm) was noted in I_6 (irrigation with 15.0 dSm^{-1} water). For the month of exposure, the maximum plant height (42.71 cm) was observed in March (M_1). Whereas, the minimum plant height (39.00 cm) was recorded in May (M_3). The interaction effect through different levels of salinity and month of exposure were found significant for plant height of bougainvillea. The maximum plant height (45.69 cm) was recorded in treatment combination I_1M_1 which was statistically at par with treatment I_1M_2 (45.44 cm), I_1M_3 (45.12 cm) and I_2M_1 (45.56 cm). However, the minimum plant height (28.00 cm) was found in treatment combination I_6M_3 *i.e.* 15.0 dSm^{-1} and May month. As salinity and exposure duration increased, plants experience cumulative physiological constraints that resulting in decreased height as they struggle to cope with the combined stresses of osmotic imbalance, nutrient deficiency and impaired hormone regulation. This is also supported by Dlamini *et al.*, (2019) [6] in tuberose and Badawy *et al.*, (2023) [2] in *Jatropha curcas.*

2. Number of leaves

The perusal of the data related to the number of leaves (Table 2) was significantly decreased with increased salinity levels of irrigation water, month of exposure and their interaction effect. In case of salinity, the maximum number of leaves (64.79) followed by I_2 (55.60). While, the minimum number of leaves (12.10) were observed in treatment I_6 (irrigation with 15.0 dSm^{-1} water). For the month of exposure, the maximum number of leaves (58.92) was observed in the first month (March). Whereas, the minimum number of leaves (23.19) was recorded in the third month (May). The interaction effect through different levels of salinity and month of exposure were found significant for number of leaves of bougainvillea. The maximum number of leaves were recorded in treatment combination I_1M_1 (85.06). Whereas, no leaves (0.00) were noticed in treatment combination I_6M_3 *i.e.* 15.0 dSm^{-1} and May month. As salinity level increases with month of exposure, plants experience dehydration stress and causing them to close their stomata to conserve moisture. Closed stomata limit gaseous exchange, including carbon dioxide intake needed for photosynthesis. With reduced photosynthesis, decrease in carbohydrate production hinders growth and leads to leaf abscission. The cumulative effects of water stress, reduced photosynthesis and tissue damage contribute to a decrease in the number of leaves in plants. Similar results related to decrease in leaves were recorded by Devit and Morris (1987) [5] in flowering annuals and Badawy *et al.*, (2023) [2] in *Jatropha curcas.*

Table 1: Effect of different salinity levels and month of exposure on plant height (cm) in bougainvillea

Treatment	Plant height (cm)			
Month Salinity	**March (M_1)**	**April (M_2)**	**May (M_3)**	**Mean (I)**
I_1: Control/BAW	45.69	45.37	45.12	45.39
I_2: 3.0 dSm^{-1}	45.56	43.56	42.50	43.87
I_3: 6.0 dSm^{-1}	44.44	42.50	42.31	43.08
I_4: 9.0 dSm^{-1}	43.62	41.44	39.94	41.67
I_5: 12.0 dSm^{-1}	41.25	40.19	36.12	39.19
I_6: 15.0 dSm^{-1}	35.69	34.81	28.00	32.83
Mean (M)	42.71	41.31	39.00	
	I	M	I × M	
SEm ±	0.43	0.30	0.74	
CD at 5%	1.21	0.86	2.10	
CV %	3.61			

Table 2: Effect of different salinity levels and month of exposure on number of leaves in bougainvillea

Treatment	Number of leaves			
Month Salinity	March (M_1)	April (M_2)	May (M_3)	Mean (I)
I_1: Control/BAW	9.25 (85.06)	8.21 (67.06)	6.53 (42.25)	8.00 (64.79)
I_2: 3.0 dSm^{-1}	8.93 (79.31)	7.16 (50.81)	6.09 (36.69)	7.39 (55.60)
I_3: 6.0 dSm^{-1}	8.27 (67.94)	6.71 (44.56)	5.44 (29.12)	6.81 (47.21)
I_4: 9.0 dSm^{-1}	7.59 (57.25)	6.47 (41.44)	4.78 (22.44)	6.28 (40.37)
I_5: 12.0 dSm^{-1}	6.40 (40.56)	5.65 (31.50)	3.02 (8.62)	5.02 (26.89)
I_6: 15.0 dSm^{-1}	4.88 (23.37)	3.66 (12.94)	0.70 (0.00)	3.08 (12.10)
Mean (M)	7.55 (58.92)	6.31 (41.38)	4.43 (23.19)	
	I	M	I × M	
SEm ±	0.03	0.02	0.05	
CD at 5%	0.08	0.06	0.14	
CV %	1.65			

3. Stem girth (cm)

The evaluated data for stem girth (Table 3) as influenced due to different salinity levels, month of exposure and its interaction effect were found significant. In case of salinity, Treatment I_1 (BAW-control) had maximum stem girth (1.15 cm). While, treatment I_6 (irrigation with 15.0 dSm^{-1} water) showed minimum stem girth (0.55 cm). For the month of exposure, the maximum stem girth (1.03 cm) was recorded in March (M_1). Moreover, the minimum stem girth (0.65 cm) was recorded in May (M_3). The interaction between salinity levels and month of exposure was found significant. The maximum stem girth (1.41 cm) was recorded in treatment combination I_1M_1. Whereas, the minimum stem girth (0.38 cm) was reported in treatment combination I_6M_3 *i.e.* 15.0 dSm^{-1} and May month. Increased salinity triggers water imbalance in plant cells that prompts them to accumulate ions like sodium and chloride. This leads to a decrease in cell turgor pressure and inhibits cell expansion particularly in the stems. As a result, plants experience stunted growth and reduced stem girth. Similar results were in agreement with the findings of Naseri Moghadam *et al.*, (2019) [10] in *Narsicuss tazetta* L. and Badawy *et al.*, (2023) [2] in *Jatropha curcas.*

4. Number of branches per plant

The data given in Table 4 clearly indicated that the number of branches per plant in bougainvillea as affected due to different levels of saline irrigation water, month of exposure as well as their interaction effect and they were found significant. In case of salinity, maximum number of branches per plant (2.77) was recorded in treatment I_1 (BAW-control). While, the minimum number of branches per plant (1.00) was observed in I_6 (irrigation with 15.0 dSm^{-1} water). For the month of exposure, the maximum number of branches per plant (2.67) was observed in March (M_1). Whereas, the minimum number of branches per plant (1.59) was noticed in May (M_3). In the interaction effect between various levels of saline irrigation water and month of exposure to saline irrigation water, the number of branches per plant was recorded significantly highest in treatment combination I_1M_1 (3.00) which was statistically at par with I_2M_1 (2.94). Moreover, the lowest no branches per plant were observed in treatment I_6M_3 *i.e.* 15.0 dSm^{-1} and May month. Elevated salinity disrupts the hormonal balance in plants, particularly auxin which regulates branching. Excess salts inhibit auxin transport and distribution which leads to suppressed branching. Moreover, salt accumulation can damage vascular tissues which impair nutrient transport essential for branch development. Similar results related to decrease in number of branches per plant was observed by Chauhan and Ambast (2014) [3] in marigold and Badawy *et al.*, (2023) [2] in *Jatropha curcas.*

Table 3: Effect of different salinity levels and month of exposure on stem girth (cm) in bougainvillea

Treatment	Stem girth (cm)			
Month Salinity	March (M_1)	April (M_2)	May (M_3)	Mean (I)
I_1: Control/BAW	1.41	1.05	0.98	1.15
I_2: 3.0 dSm^{-1}	1.27	0.82	0.74	0.94
I_3: 6.0 dSm^{-1}	1.17	0.70	0.62	0.83
I_4: 9.0 dSm^{-1}	0.84	0.68	0.61	0.71
I_5: 12.0 dSm^{-1}	0.83	0.65	0.59	0.69
I_6: 15.0 dSm^{-1}	0.65	0.61	0.38	0.55
Mean (M)	1.03	0.75	0.65	
	I	M	I × M	
SEm ±	0.008	0.005	0.001	
CD at 5%	0.02	0.01	0.04	
CV %	3.24			

Table 4: Effect of different salinity levels and month of exposure on number of branches per plant in bougainvillea

Treatment	Number of branches per plant			
Month Salinity	March (M_1)	April (M_2)	May (M_3)	Mean (I)
I_1: Control/BAW	1.87 (3.00)	1.80 (2.75)	1.75 (2.56)	1.80 (2.77)
I_2: 3.0 dSm^{-1}	1.85 (2.94)	1.78 (2.69)	1.71 (2.44)	1.78 (2.69)
I_3: 6.0 dSm^{-1}	1.83 (2.87)	1.69 (2.37)	1.62 (2.12)	1.71 (2.46)
I_4: 9.0 dSm^{-1}	1.76 (2.63)	1.67(2.31)	1.39 (1.44)	1.61 (2.12)
I_5: 12.0 dSm^{-1}	1.75 (2.56)	1.58 (2.00)	1.22 (1.00)	1.51 (1.85)
I_6: 15.0 dSm^{-1}	1.58 (2.00)	1.22 (1.00)	0.70 (0.00)	1.71 (1.00)
Mean (M)	1.77 (2.67)	1.62(2.19)	1.40 (1.59)	
	I	M	I × M	
SEm ±	0.01	0.01	0.02	
CD at 5%	0.03	0.02	0.05	
CV %	2.23			

5. Leaf area (cm^2)

The statistical data on leaf area (Table 5) of bougainvillea plant revealed that there were significantly influenced by different levels of salinity, month of exposure to saline irrigation water and their interaction effect. In case of salinity, the maximum leaf area (27.94 cm^2) was observed in plants irrigated with I_1 (BAW-control). While, the minimum leaf area (17.65 cm^2) was noted in treatment I_6 (irrigation with 15.0 dSm^{-1} water). For month of exposure, March (M_1) had the maximum leaf area (33.42 cm^2). In contrast, the minimum leaf area (8.70 cm^2) was recorded in May (M_3) month. In the interaction effect of different levels of saline irrigation water and month of exposure, leaf area was significantly highest in the treatment combination I_1M_1 (36.75 cm^2) which was statistically at par with I_2M_1 (35.80 cm^2). Whereas, the lowest leaf area was reported in treatment combination I_6M_3 (0.00 cm^2) *i.e.* 15.0 dSm^{-1} and May month. Increased salinity disrupts the osmotic balance within plant cells which leads to water loss and reduced leaf turgor pressure. This results in wilting and decreased leaf expansion, ultimately reducing leaf area. Moreover, high salt concentrations hinder photosynthesis by affecting chlorophyll synthesis and enzyme activity that diminishing the production of carbohydrates that essential for leaf growth. Salt-induced oxidative stress damages leaf tissues and accelerates leaf senescence and shedding. Similar results were reported by Dlamini *et al.*, (2019) [6] in tuberose and Asgari and Diyanat (2021) [1] in rose.

Table 5: Effect of different salinity levels and month of exposure on leaf area (cm^2) in bougainvillea

Treatment	Leaf area (cm^2)			
Month Salinity	March (M_1)	April (M_2)	May (M_3)	Mean (I)
I_1: Control/BAW	6.10 (36.75)	5.90 (34.38)	3.62 (12.66)	5. 21 (27.94)
I_2: 3.0 dSm^{-1}	6.02 (35.80)	5.59 (30.76)	3.42 (11.28)	5.01 (25.95)
I_3: 6.0 dSm^{-1}	5.95 (34.98)	5.57 (30.54)	3.26 (10.18)	4.93 (25.23)
I_4: 9.0 dSm^{-1}	5.94 (34.75)	5.55 (30.39)	3.26 (10.18)	4.92 (25.10)
I_5: 12.0 dSm^{-1}	5.62 (31.17)	5.37 (28.33)	2.89 (7.92)	4.62 (22.47)
I_6: 15.0 dSm^{-1}	5.24 (27.04)	5.13 (25.91)	0.70 (0.00)	3.69 (17.65)
Mean (M)	5.82 (33.42)	5.52 (30.05)	2.86 (8.70)	
	I	M	I × M	
SEm ±	0.03	0.02	0.05	
CD at 5%	0.08	0.06	0.15	
CV %	2.22			

Conclusion

On the basis of the results obtained from the present investigation, it can be concluded that increased salinity levels caused reduction in all vegetative attributes. Overall, growth parameters of bougainvillea plants remain acceptable up to the salinity level 9.0 dSm^{-1}. Thus, bougainvillea plant has been found to be a moderate salt tolerant crop.

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