EFFECT OF WATER-LOGGING AND SALINITY STRESS ON SINDHRI MANGO (MANGIFERA INDICA L.) SEEDLINGS

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Abstract. Mango is considered the major fruit crop in Sindh, Pakistan. The expected yield targets have not been achieved due to waterlogging and salinity problems. For this study, we investigated the effects of waterlogging and salinity on the growth and development of mango rootstock seedlings. The treatments were arranged, and the rootstock seedlings were grown in controlled (without waterlogging and salinity) and waterlogged conditions. In the water-logging treatments, plants were waterlogged with fresh and saline water from EC 2, 4, 6, 8, and 10 (dSm-1). In addition to growth parameters, the concentrations of Na+, K+, Ca2+, and Mg2+ in leaf tissues were also determined. The results obtained from the study indicated that, compared to control, the mango seedlings under waterlogging with fresh water and 2, 4, 6, 8 and 10 EC (dSm-1) saline water showed a significant decline in the studied growth parameters and displayed 25, 20, 37, 27, 0, and 31% more Na+ and 36, 45, 50, 54, 63, and 68% lower K+ in leaf tissues over control seedlings, respectively. The overall result suggested that the Sindhri mango rootstock is highly susceptible to both water-logging and salinity stress. Such knowledge in terms of specific-genotype responses to resistance and tolerance to waterlogging and salinity stress is important for Sindhri plantation rootstock management under environmental conditions.
Keywords: *waterlogging, salinity, mango, rootstock, growth, development*

Introduction

Mango (Mangifera indica L.) belongs to the family Anacardiaceae. This commercial fruit tree grows in several countries of the world including the Philippines, Indonesia, Malaysia, Thailand, Burma, Sri Lanka, India, Mexico, Brazil, Bangladesh, and Pakistan. In Pakistan, mango is considered as the 1stmajor fruit-producing tree, grown onan area of 93.42 thousand hectares with a production of 915.7 thousand tons. In the Sindh province, mango is grown on an area of 500,000 acres and its production 1.5 million tons with 20 percent in 2020 (Shah, 2020). Currently, the mango industry in Sindh is facing some severe problems including a declination in number of trees due to sudden death of trees, Die-back, pests, and infestations like powdery mildew, malformation, anthracnose, leaf blight, fungal diseases, etc. (Fateh et al., 2006; Khanzada et al., 2006).

In addition to these, the environmental factors such as waterlogging, salinity, shortage of irrigation water, and use of poor-quality groundwater are also considered as significant threats to mango orchards in the Sindh. Some of the observation has indicated that mango orchards, particularly in lower Sindh, are under abiotic stress (Jilani et al., 2010). Among the abiotic stresses the waterlogging and salinity are considered serious threat to the plants. Generally, under salt-stress environment, plants faces the problem of high salt concentrations, which create physiological drought and ionic toxicity as well. Mango plant height and leaf area drastically reduce due to salinity. Mango generally accumulates 2.5 to 3.0 times more salt than guava, the high

accumulation capacity creates bearing difficulty in mango and thus results in a reduction of fruit yield (Dubey et al., 2007).Among different varieties being cultivated in the area a few mango polyembryonic varieties are found tolerant to salinity, differences among rootstocks in response to salinity found in fruit species, and these differences are imperative for selecting appropriate germplasm against such stress conditions (Hassan and Catlin, 1984).

Mango plants uptake toxic ions in a large quantity under water-logged conditions (Hebbara et al., 2002). The young mango tree has been reported to be sensitive to salinity (Abo-Rekab et al., 2014), therefore it can be assumed that the mango plants are more susceptible to salinity under water-logged conditions. But there is no study performed to confirm the hypothesis. Planning the study that can answer the significant salinity effects in the presence of waterlogging on mango plants would be beneficial to mango cultivars. Therefore, this study was designed to address the issue being faced by the mango farmers in the field.

Materials and Methods

A pot experiment was conducted in a greenhouse with no control of light or temperature at the Center for Bio-Saline Agriculture, Department of Soil Science, and Sindh Agriculture University Tandojam. The details of the experiment are given below: Sindhri mango is a highly adaptable variety, higher in production compared to other varieties in Sindh, has higher tolerance, and is imported by other countries. Economic benefits local farmers. Six-month-old Sindhri mango rootstock seedlings along with earthen bolls were transferred into holes for drainage. These plastic pots were placed in large cement pots, containing saline water as per treatment plan. Saline water treatments were developed by dissolving NaCl: CaCl2 salts in normal canal water. T1=control (without water-logging and salinity), T2=water-logging with freshwater, T3=water-logging with 2 EC (dSm-1) water, T4=waterlogging with 4 EC (dS m-1) water, T5=waterlogging with 6 EC (dSm-1) water, T6=waterlogging with 8 EC (dSm-1) water, and T7=waterlogging with 10 EC (dSm-1) water.

Data on the following traits were collected four months after the stress was applied. Plant height (cm), number of green leaves (per plant), branch length (cm), stem girth (cm), leaf length and width (cm), stem dry weights (g plant-1), leaf dry weights (g plant-1), tap root length (cm), and root dry weight (g plant-1). And then fully expanded top mature leaves were sampled for the analyses of Na+, K+, Ca2+, and Mg2+. Leaves were dried at 680 °C, powdered, and digested; Na+ and K+ were determined by a flame photometer; Ca2+ and Mg2+ were determined by titration methods, the same work done by Baloch et al. (2017). The plant data were subjected to statistical analysis, using appropriate statistical procedure and Statistix 8.1 software used for data analysis. Means separation was done by LSD.

Results and Discussion

Effect of water logging and salinity stress on the height of Sindhri mango seedlings

The effect of waterlogging and salinity stress on the height of mango rootstock seedlings is given in *Table 1*. The results indicated that, compared to the control and plants waterlogged with freshwater treatments, the plants waterlogged with saline water

stress at 2, 4, 6, 8 and 10 EC (dS m-1) were significantly ($p<0.05$) shorter in height. Compared to control treatments, the mango plants under waterlogged conditions with fresh and saline water (2, 4, 6, 8 and 10 EC (dS m1) grew slowly by 26, 29, 38, 39, 43, and 43% respectively.

Table 1. *Effect of water logging and salinity on the height (cm) ofSindhri mango seedlings*.

Water logging and salinity treatments	Initial height (cm)	Final height (cm)	Net increase in height (cm)	% increase overtime
Control (without water logging and salinity)	77.50	88.23	10.63±2.73	13.70
Water logging with freshwater	59.17	65.40	6.23±0.54	10.53
Water logging with 2 EC (dS m-1) water	57.30	62.60	5.30±0.45	9.24
Water logging with 4 EC (dS m-1) water	53.83	54.33	0.50±0.25	0.92
Water logging with 6 EC (dS m-1) water	53.33	53.50	0.16±0.16	0.31
Water logging with 8 EC (dS m-1) water	50.00	50.17	0.16±0.16	0.33
Water logging with 10 EC (dS m-1) water	49.83	50.00	0.16±0.16	0.33

Effect of water logging and salinity on the no of green leaves developed on the Sindhri mango seedlings

The data on the number of green leaves developed on mango seedlings as influenced by waterlogging and salinity are given in *Table 2*. It is evident from the results that the mango seedlings grown under waterlogged conditions with fresh and salinity-treated (2, 4, 6, 8, and 10 EC (dS m-1)) water had 16, 52, 66, 83, 100, and 100 % fewer leaves than the control.

Table 2. *Effect of water logging and salinity stress on the number of green leaves developed on Sindhri mango seedlings.*

Water logging and salinity treatments	Initial number of green leaves (plant-1)	Final number of green leaves (plant-1)	Net increase green leaves (plant-1)	% increase / decrease over time
Control (without water logging and salinity)	36.67	59.33	22.66±1.45	64.93
Water logging with freshwater	35.33	49.33	14.00±7.00	18.86
Water logging with 2 EC (dS m-1) water	33.00	28.00	-5.00±0.57	-13.46
Water logging with 4 EC (dS m-1) water	26.33	20.00	-6.33±1.20	-22.01
Water logging with 6 EC (dS m-1) water	27.67	9.67	-18.00±2.51	-84.33
Water logging with 8 EC (dS m-1) water	25.33	0.00	-25.33±0.33	-100
Water logging with 10 EC (dS m-1) water	23.33	0.00	-23.33±1.858	-100

Effect of water logging and salinity stress on branch length of Sindhri mango rootstock

The data for the effect of water-logging and salinity on the branch length (cm) are given in *Table 3*. The results showed that mango seedlings compared to control the plants grown in waterlogged condition with fresh water, and saline water (2, 4, 6, 8 and 10 EC (dS m-1) had 34, 38, 42, 68, 69 and 73 % of decrease in branch length, respectively.

Table 3. *Effect of water logging and salinity on branch length of Sindhri mango seedlings.*

Water logging and salinity treatments	Initial branch length (cm)	Final branch length (cm)	Net increase branch length (cm)	% increase overtime
Control (without water logging and salinity)	5.07	8.40	3.33±0.26	65.78
Water logging with freshwater	4.30	5.50	1.20±0.20	27.90
Water logging with 2 EC (dSm-1) water	4.17	5.20	1.03±0.17	24.8
Water logging with 4 EC (dSm-1) water	4.27	4.80	0.53±0.08	12.5
Water logging with 6 EC (dSm-1) water	2.63	2.63	0.00±0.00	0
Water logging with 8 EC (dSm-1) water	2.60	2.60	0.00±0.00	0
Water logging with 10 EC (dSm-1) water	2.23	2.23	0.00±0.00	0

Effect of water logging and salinity on stem girth of Sindhri mango seedlings

The results related to the effect of water-logging and salinity on stem girth of mango rootstock sindhriseedlings are presented in *Table 4*. The data show that compared to control, the seedlings grown under waterlogged condition with fresh and saline water (2, 4, 6, 8 and 10 EC (dS m-1)) displayed 9, 12, 20, 33, 35 and 46 %of reduction in stem girth, respectively.

Table 4. *Effect of water logging and salinity on stem girth (cm) of Sindhri mango seedlings.*

Water logging and salinity treatments	Initial stem girth (cm)	Final stem girth (cm)	Net increase stem girth (cm)	% increase overtime
Control (without water logging and salinity)	1.07	1.80	0.73±0.06	68.75
Water logging with freshwater	1.03	1.63	0.60±0.05	58.06
Water logging with 2 EC (dS m-1) water	1.10	1.57	0.46±0.03	42.42
Water logging with 4 EC (dS m-1) water	1.17	1.43	0.26±0.03	22.85
Water logging with 6 EC (dS m-1) water	1.13	1.20	0.20±0.03	5.88
Water logging with 8 EC (dS m-1) water	1.17	1.17	0.00±0.00	0
Water logging with 10 EC (dS m-1) water	0.97	0.97	0.00±0.00	00

Effect of water logging and salinity on leaf length and leaf width of Sindhri mango seedlings

The effect of waterlogging and salinity on the length (cm) of fully mature top leaves shown in *Table 5* indicates that there was a significant effect of waterlogging and salinity on leaf length. The plants waterlogged with fresh 2, 4, 6, 8 and 10 EC (dS m-1) water showed -0.6, 8, 8, 10, 21, and 37 % smaller leaves, respectively, over control. The data on the effect of waterlogging and salinity on the width (cm) of leaves shown in Table 5 indicate that there was significant effect of waterlogging and salinity on leaf width. It is evident from the results that the plants waterlogged with fresh 2, 4, 6, 8, and 10 EC (dS m-1) water had 7, 23, 21, 27, 30, and 27 % narrow leaves, respectively, over control.

Table 5. *Effect of water logging and salinity on leaf length and leaf width of Sindhri mango seedlings.*

Water logging and salinity treatments	Leaf length (cm)	Leaf width (cm)
Control (without water logging and salinity)	16.23±1.05	5.36±0.26
Water logging with freshwater	16.33±0.41	4.96±0.17
Water logging with 2 EC (dS m-1) water	14.80±1.23	4.11±0.21
Water logging with 4 EC (dS m-1) water	14.83±0.93	4.20±0.30
Water logging with 6 EC (dS m-1) water	14.53±0.33	3.86±0.33
Water logging with 8 EC (dS m-1) water	12.76±0.31	3.70±0.28
Water logging with 10 EC (dS m-1) water	10.16±0.44	3.90±0.45

Effect of water logging and salinity on stem dry weight (g plant-1) of Sindhri mango seedlings

The stem dry weight (plant-1) of mango seedlings was also significantly ($p<0.05$) affected by waterlogging and salinity (*Table 6*). The mango seedlings under waterlogged conditions with fresh and saline water (2, 4, 6, 8 and 10 EC (dS m-1)) showed 32, 40, 45, 50, 49, and 62 % lower stem dry weights, respectively, over control.

Table 6. *Effect of water logging and salinity on stem dry weight (g plant-1) of Sindhri mango seedlings.*

Water logging and salinity treatments	Stem dry weight (g plant-1)

Control (without water logging and salinity)	30.53±8.61
Water logging with freshwater	20.56±1.93
Water logging with 2 EC (dS m-1) water	18.16±2.81
Water logging with 4 EC (dS m-1) water	16.66±0.78
Water logging with 6 EC (dS m-1) water	15.03±1.26
Water logging with 8 EC (dS m-1) water	15.53±0.38
Water logging with 10 EC (dS m-1) water	11.46±2.08

Effect of water logging and salinity on leaf dry weight (g plant-1) of Sindhri mango seedlings

Both water-logging and salinity treatments remained significantly effective in reducing the leaf dry weight of grafted mango seedlings (*Table 7*). The leaf dry weight obtained from control treatment plants was 16.80g (plant-1), while the plants established in a fresh waterlogged condition produced 10.73 g of leaf dry weight (plant-1). The treatments where seedlings were waterlogged with fresh and saline water at 2, 4, 6, 8, and 10 EC (dS m-1) gave 36, 64, 70, 71, and 77% lower leaf dry weights, respectively, than the control.

Table 7. *Effect of water logging and salinity on leaf dry weight (g plant-1)of Sindhri mango seedling.*

Water logging and salinity treatments	Leaf dry weight (g plant-1)
Control (without water logging and salinity)	16.80±0.46
Water logging with freshwater water	10.73±3.63
Water logging with 2 EC (dS m-1) water	6.03±0.80
Water logging with 4 EC (dS m-1) water	6.20±1.44
Water logging with 6 EC (dS m-1) water	4.93±0.29
Water logging with 8 EC (dS m-1) water	4.80±0.41
Water logging with 10 EC (dS m-1) water	3.80±0.61

Effect of water logging and salinity on root length of Sindhri mango seedlings

The effects of waterlogging and salinity on the root length of grafted mango seedlings also remained significantly ($p<0.05$) adverse to the plants (*Table 8*). It is evident from the data that the waterlogging of plants without salinity had a 37 percent shorter root system, whereas the seedlings grown under waterlogging with fresh and saline water (2, 4, 6, 8, and 10 EC level (dS m-1)) showed 44, 46, 46, 46 and 60% shorter roots over control, respectively.

Table 8. *Effect of water logging and salinity on root length of Sindhri mango seedlings.*

Water logging and salinity treatments	Root length (cm)
Control (without water logging and salinity)	48.33±2.33
Water logging with freshwater	30.00±1.15
Water logging with 2 EC (dS m-1) water	27.00±1.52
Water logging with 4 EC (dS m-1) water	26.00±2.64
Water logging with 6 EC (dS m-1) water	25.66±2.33
Water logging with 8 EC (dS m-1) water	25.66±2.85
Water logging with 10 EC (dS m-1) water	19.33±1.20

Effect of water logging and salinity on root dry weight (g plant-1) of Sindhri mango seedlings

The data show that the mango seedlings established in water-logging and salinity treatments showed significantly ($p<0.05$) lower root dry weight than the control. Treatments plants compared to controls produced 32, 44, 47, 62, 65, and 74% decreases in root dry weight, depending on salt concentration in treatments (*Table 9*).

Table 9. *Effect of water logging and salinity on root dry weight of Sindhri mango seedlings.*

Water logging and salinity treatments	Root dry weight (g plant-1)
Control (without water logging and salinity)	28.46±1.73
Water logging with freshwater	19.23±1.86
Water logging with 2 EC (dSm-1) water	15.86±1.56
Water logging with 4 EC (dSm-1) water	14.93±1.67
Water logging with 6 EC (dSm-1) water	10.76±0.75
Water logging with 8 EC (dSm-1) water	9.70±0.25
Water logging with 10 EC (dSm-1) water	7.16±0.67

Effect of water logging and salinity water on Na+ content determined in the leaf tissues of Sindhri mango seedlings

The data related to Na+ content of leaf dry matter obtained from mango seedlings grown in different water-logging and salinity treatments are given in *Table 10*. Generally, plants grown in waterlogged salinity had more Na+ in their leaf tissues. With increasing EC (dS m-1) of water compared to control, seedlings grown in 2, 4, 6, 8, and 10 EC water had 25, 20, 37, 27, 0, and 31 more Na+ in their leaf tissues, respectively.

Table 10. *Effect of water logging and salinity water on Na+ content determined in the leaf tissues of Sindhri mango seedlings.*

Water logging and salinity treatments	Na+ % in Leaf tissue
Control (without water logging and salinity)	0.03±0.01
Water logging with freshwater	0.04±0.01
Water logging with 2 EC (dSm-1) water	0.05±0.01
Water logging with 4 EC (dSm-1) water	0.08±0.01
Water logging with 6 EC (dSm-1) water	0.11±0.01
Water logging with 8 EC (dSm-1) water	0.11±0.01
Water logging with 10 EC (dSm-1) water	0.16±0.01

Effect of water logging and salinity K+ content determined in the leaf tissues of Sindhri mango seedlings

The effects of waterlogging and salinity treatments on the K+ content of grafted mango seedlings are shown in *Table 11*. The data indicated that the seedlings grown in freshwater treatments were less affected; compared to control seedlings grown in 2, 4, 6, 8, and 10 EC (dS m-1) water, they had 36, 45, 50, 54, 63, and 68% less calcium than the plants grown in normal conditions.

Table 11. *Effect of water logging and salinity K+ content determined in the leaf tissues of Sindhri mango seedlings.*

Water logging and salinity treatments	K+ % in leaf tissue
Control (without water logging and salinity)	0.22±0.35
Water logging with freshwater	0.14±0.00
Water logging with 2 EC (dSm-1) water	0.12±0.00
Water logging with 4 EC (dSm-1) water	0.11±0.01
Water logging with 6 EC (dSm-1) water	0.10±0.00
Water logging with 8 EC (dSm-1) water	0.08±0.00
Water logging with 10 EC (dSm-1) water	0.07±0.00

Effect of water logging and salinity on Ca+ in the leaf tissues of Sindhri mango seedlings

Compared to the control (without waterlogging and salinity), in the treatments where mango seedlings were grown in freshwater and saline water, the concentration of Ca+ in leaf tissues was 28, 42, 57, 71, and 85% less depending on the salt concentration in the treatments (*Table 12*).

Table 12. *Effect of water logging and salinity on Ca+ in the leaf tissues on Sindhri mango seedlings.*

Water logging and salinity treatments	Ca+ % in leaf tissue
Control (without water logging and salinity)	0.07±0.00
Water logging with freshwater	0.05±0.01
Water logging with 2 EC (dSm-1) water	0.04±0.01
Water logging with 4 EC (dSm-1) water	0.03±0.01
Water logging with 6 EC (dSm-1) water	0.02±0.01
Water logging with 8 EC (dSm-1) water	0.02±0.01
Water logging with 10 EC (dSm-1) water	0.01±0.00

Effect of water logging and salinity on Mg2+ in the leaf tissues of Sindhri mango seedlings

The Mg2+ in the leaf tissue of grafted mango seedlings was also significantly affected ($P<0.05$) by waterlogging with fresh and saline water, as shown in *Table 13*. The data show that, compared to the control, the seedlings grown in fresh and saline water showed the Mg2+ in leaf tissues was 33, 50, 50, 66, 66, and 83% decreased.

Table 13. *Effect of water logging and salinity on Mg2+ in the leaf tissues of Sindhri mango seedlings.*

Water logging and salinity treatments	Mg2+ % in leaf tissue
Control (without water logging and salinity)	0.06±0.01
Water logging with freshwater	0.04±0.00
Water logging with 2 EC (dSm-1) water	0.03±0.00
Water logging with 4 EC (dSm-1) water	0.03±0.00
Water logging with 6 EC (dSm-1) water	0.02±0.00
Water logging with 8 EC (dSm-1) water	0.02±0.00
Water logging with 10 EC (dSm-1) water	0.01±0.00

In present study, an economically important mango fruit tree (Mangifera indica L.) which has high commercial value was tested for its tolerance to waterlogging and salinity levels of 2, 4, 6, 8 and 10 EC (dS m-1). Generally, mango seems to be salt-sensitive in nature (Elsheery et al., 2020; Duran et al., 2003). It has been reported by some researchers that the salt-tolerance and sensitivity of mango may vary with grafted scion. Grafted mango varieties tolerant to salinity have shown ability to retain Na+ in their rootstock tissues rather than sending Na+ to scion tissues. This fruit tree is commercially grown in Sindh province, particularly in lower parts, which are facing the problem of salinity and waterlogging. One year old mango seedlings already grafted with scion of most commercial variety Sindhri, were used in this study. The results obtained from the study indicated that the mango (Mangifera indica L.) seedlings grafted with Sindhi scion were largely affected by both waterlogging and salinity. Generally, the plants grown in a salt and waterlogging stress environment showed leaf burning symptoms on both older and younger leaves of the scion; in severe cases, there was total scion leaf fall and even the death of seedlings. Similar symptoms have also been observed by some other workers, including Duran et al. (2003). Adverse effects of waterlogging and salinity were observed on almost all recorded traits. Particularly, these effects were larger on the seedling's height (*Table 1*), number of green leaves (*Table 2*), branch length (*Table 3*), etc. Similar effects have also been observed by Duran et al. (2003). This suggests that both salinity and waterlogging largely influence the growth and development of mango seedlings. It is also evident from the reports of other workers that waterlogging and salinity are adverse to plants at the most sensitive stage of seedling development (Schmutz, 1999).

The grafted mango seedlings grown in fresh 2, 4, 6, 8, and 10 EC (dS m-1) standing water showed significant reductions in stem girth (*Table 4*), length, and width of fully mature leaves (*Table 5*), over control. This indicates the ability of the stem of a mango rootstock, to protect the stem of the scion from salt damage caused by the accumulation of salts. This study also indicates that the mango seedlings grown in both salinity and waterlogging treatments had lower stem (*Table 6*) and leaf dry weights (*Table 7*). The results of this work coincide with others that demonstrate a positive influence of salinity on mango growth (Schmutz, 1999). This study also indicates the adverse effects of waterlogging and salinity on the root system (*Tables 8* and *Table 9*). Generally, the seedlings grown in waterlogging and salinity treatments had shorter root systems and displayed lower root dry weight, which was possibly due to the unavailability of oxygen to the plant, which might have disturbed the respiration process in plants (El-Nashar, 2013).

The higher concentration of Na+ and Cl- medium has produced a rise in the concentrations of Na+ in scion leaves (*Table 10*) and a progressive decrease in the K+ concentration (*Table 11*). Some researchers have also stated that the significant decrease in K+ caused by high Na+ in waterlogging and salinity conditions is a well-known competitive process and mechanism in sensitive plants; they have also suggested that there is an absence of such a salt-tolerance mechanism in sensitive mango rootstocks. The concentrations of Ca2+ (*Table 12*) and Mg2+ (*Table 13*) in the leaf sap were also significantly affected by waterlogging and salinity treatments. Similar findings have also been reported by other researchers in different plant species under NaCl stress. Finally, this study suggests that mango seedlings are very sensitive to salt and waterlogging environments. Thus, care must be taken to plant mango orchards in waterlogged and salt-affected areas.

Conclusion

Mango (Mengifera indica L.) seedlings are easily artificially grafted. Sindhri is highly susceptible to salt and flooded environments. Salinity severely affected the growth and development of Sindhri mango seedlings. Therefore, our study suggested that the mango orchards must be grown carefully to avoid flooding and salinity contaminated fields.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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