Haya: The Saudi Journal of Life Sciences (SJLS)
Scholars Middle East Publishers
Dubai, United Arab Emirates
Website: http://scholarsmepub.com/

ISSN 2415-623X (Print)
ISSN 2415-6221 (Online)

Growth of *Conocarpus erecuts* Seedlings in Different Artificially Developed Saline Sodic Soils

Muhammad Arshad Ullah[1*], Muhammad Rasheed[2], Imdad Ali Mahmood[1], Badar-uz – Zaman[1] and Syed Ishtiaq Hyder[1]
[1]Land Resources Research Institute, National Agricultural Research Centre, Islamabad, Pakistan.45500
[2]PMAS - Agronomy Department, University of Arid Agriculture, Murree Road, Shamsabad, Rawalpindi, Punjab 46000, Pakistan

Original Research Article

***Corresponding author**
Muhammad Arshad Ullah

Article History
Received: 06.07.2018
Accepted: 19.07.2018
Published: 30.07.2018

DOI:
10.21276/haya.2018.3.7.3

Abstract: Salinity and bad quality irrigation water is very common problem in Pakistan due to limited rainfall, more evapo-transpiration and high temperature. So, there is need to select salt tolerant plants. In view of that a pot experiment was conducted to study the growth performance and ionic composition of *Conocarpus erectus* L. under saline – sodic conditions. Sixteen treatments i.e. ($T_{1=}$<4(dSm^{-1}) + <15 (mmol L^{-1})$^{1/2}$, $T_{2=}$ 20(dSm^{-1}) + 20 (mmol L^{-1})$^{1/2}$, $T_{3=}$ 20(dSm^{-1}) + 40 (mmol L^{-1})$^{1/2}$, $T_{4=}$ 20 (dSm^{-1}) + 60 (mmol L^{-1})$^{1/2}$, $T_{5=}$ 20 (dSm^{-1}) + 80(mmol L^{-1})$^{1/2}$, $T_{6=}$ 20(dSm^{-1}) + 100 (mmol L^{-1})$^{1/2}$, $T_{7=}$ 30(dSm^{-1}) + 20(mmol L^{-1})$^{1/2}$, $T_{8=}$ 30(dSm^{-1}) + 40(mmol L^{-1})$^{1/2}$, $T_{9=}$ 30 (dSm^{-1}) + 60(mmol L^{-1})$^{1/2}$, $T_{10=}$ 30 (dSm^{-1}) + 80(mmol L^{-1})$^{1/2}$, $T_{11=}$ 30(dSm^{-1}) + 100 (mmol L^{-1})$^{1/2}$, $T_{12=}$ 40(dSm^{-1}) + 20(mmol L^{-1})$^{1/2}$, $T_{13=}$ 40(dSm^{-1}) + 40(mmol L^{-1})$^{1/2}$, $T_{14=}$ 40 (dSm^{-1}) + 60(mmol L^{-1})$^{1/2}$, $T_{15=}$ 40 (dSm^{-1}) + 80(mmol L^{-1})$^{1/2}$ and $T_{16=}$ 40(dSm^{-1}) + 100 (mmol L^{-1})$^{1/2}$) were evaluated in order to assess their effect on plant growth and ionic composition. Results revealed that increasing levels of salinity and sodicity had negative effect on all plant growth parameters i.e. plant height, number of leaves and branches. While owing to dual stress of salinity and sodicity minimum percentage increase over control was noticed in T_{16} having EC (40 dSm^{-1}) and SAR 100 (mmol L^{-1})$^{1/2}$. Results showed that sodium concentration increased with increasing salinity/ sodicity, while potassium in leaf samples was decreased. Maximum K/ Na was depicted in control while minimal at the highest level i.e. T_{16}.

Keywords: Growth, buttonwood (*Conocarpus erectus* L.), soil salinity, potassium status and potassium sodium ratio.

INTRODUCTION

Plants grown under saline soils were subjected to water stress and uptake of water by plants was decreased which ultimately decreased the transpiration rate [1]. Under salt stress plant closed its stomata which protect the plant from dehydration. This condition decreased the uptake of nutrients by plant and slows down metabolism in plant and decreased the chances of plant survival [2]. There are many abiotic stresses for a plant but salinity is a major abiotic stress [3].

Conocarpus erectus can endure different stresses like salinity, drought, heat, water logging, light frosts, diseases and pests [4]. Accumulation of salt is less in *C. erectus* as compared with other plants so it is more efficient in preventing salts from going into the xylem sap [5]. Low salinities increase growth and development in this species, which mainly depend on ion regulation, leaf succulence, and the presence of salt glands in leaf lamina [6, 7]. It has also been reported that *C. erectus* can tolerate high salinities more easily than drought stress as its growth is less affected under high salinities than under mild drought [8]. Buttonwood is a seaside shrub or tree with highly salt-resistant foliage. *Conocarpus sp*. is known as one of salt tolerant forest species and their native habitats are moist. Buttonwood (*Conocarpus erectus L.*), is an evergreen shrub of family *Combretaceae* native to Florida's mangrove forest ecosystem in North America. It is found on the edges of salt flats, rock lands of the Florida Keys, edges of hammocks, borders of fresh and brackish marshes in South Florida. *Conocarpus erectus* is a source of food for wildlife and it also protects the soil during storm and helps to fix dunes. Buttonwood (*Conocarpuserectus L.*) is planted as ornamental plant in yards, streets, parking lots and parks. Buttonwood is reported to be a soft, non-toxic and attractive plant to feed animals because its green residues branches and shoots are used as fodder [9]. The use of economically useful salt tolerant plants in rehabilitation programmed for a saline ecosystem would be a useful option [10].

Conocarpus erectus L. (buttonwood) habitat is moist and mostly grows on shorelines in tropical and subtropical areas around the world [4]. Since the nutrient status of *C. erectus* is very low so it grows very well in the soils that have very low fertility [6]. Mostly, it is planted in parks, streets and yards as ornamental and the potted plants are used to make bonsai [11]. Leaves are useful in preparing some folk medicines, which are tonic for diarrhea, catarrh, fever, conjunctivitis, anemia and diabetes [12]. It is an important source of food and protection for wildlife and prevents erosion [12].

Abiotic stresses like heat, drought, water logging and particularly salt stress affect not only the plant growth but also its metabolic processes [13, 14]. Among physiological adaptations ion homeostasis is an earlier response which involves uptake of specific ions [15] and maintenance of turgor by osmotic adjustments [16]. Anatomical characteristics involved in salinity tolerance are related to changes in stomatal length and width [17], stomata number and cell number of epidermis [17], distance between vascular bundles [17] and leaf thickness.

Water scarcity is the greatest crisis facing humanity in the 21st century and possibly beyond [18]. Nearly every country in the world experiences water shortages during certain periods of the year and more than 80 countries now suffer from serious water shortages [19]. Agricultural production consumes more fresh water than any other human activity. To cope with the scarcity of fresh water for the sustainable development of agriculture, there is increasing awareness among agricultural scientists and planners in the utilization of seawater (at least diluted) for irrigation of crops [20].

However, the high concentration of ionic species in seawater is the main limiting factor in the utilization of seawater for irrigation [21]. Some of the basic variables are pH, electrical conductivity, salinity and hardness [22]. Moreno *et al.*, [23] evaluated the effects of salinity stress on growth and yield of cotton and sugar beet crops. Geng-Mao *et al.*, [24] found that Jerusalem artichoke could be safely grown in salt-affected land with 25 and 50% seawater irrigation.

Studies in south-eastern United States have looked at the role of SLR-induced increases in flooding frequency and groundwater salinity in coastal hydric hammocks of Florida [25, 26], pine rock lands on oceanic islands off Florida's coast [27], coastal marshes of Florida and Louisiana [28, 29], deltaic coasts of Mississippi [30], and tidal swamps in South Carolina [31]. The coastal forest complex of Everglades National Park (ENP) provides a novel setting because even though they lie along South Florida's shoreline, little data exist on salinity regimes, plant distribution, and dynamics of water table. With these, coastal communities are associated rare and tropical plant species at their northernmost limit of distribution [32], making the coastal forests an important site from a conservation standpoint as well. Considering the importance of buttonwood (*Conocarpus erectus* L.*)* a pot experiment was carried out to evaluate the effect of various salinity stress levels on the growth performance and ionic composition of buttonwood (*Conocarpus erectus* L.*).*

MATERIALS AND METHODS

A pot study was conducted to evaluate the growth and ionic concentration of Na, K, and K/ Na of (*Conocarpus erectus* L) under different artificial developed saline- sodic soils at green house of Land Resources Research Institute, National Agricultural Research Centre, Islamabad, Pakistan during, 2015. The soil used for the pot experiment was analysed and having 7.98 $pH_{s,}$ 2.127 ECe (dSm^{-1}), 4.75 SAR (mmol $L^{-1})^{1/2}$, 22.99 Saturation Percentage (%), 0.42 O.M. (%), 7.44 Available P (mg Kg^{-1}) and 97.85 Extractable K (mg Kg^{-1}). Considering the pre- sowing soil analysis the ECe (Electrical conductivity) and SAR (Sodium Absorption Ratio) was artificially developed with salts of NaCl, Na_2 SO_4, $CaCl_2$ and $MgSO_4$ using Quadratic Equation.10 Kg soil was used to fill each pot. 10 seeds of *Conocarpus erectus* were sown in each pot. Fertilizer was applied @75-60-50 NPK Kg ha^{-1}. Treatments were as $T_{1=}$<4(dSm^{-1}) + <15(mmol $L^{-1})^{1/2}$, $T_{2=}$ 20(dSm^{-1}) + 20 (mmol $L^{-1})^{1/2}$, $T_{3=}$ 20(dSm^{-1}) + 40 (mmol $L^{-1})^{1/2}$, $T_{4=}$ 20 (dSm^{-1}) + 60 (mmol $L^{-1})^{1/2}$, $T_{5=}$ 20 (dSm^{-1}) + 80 (mmol $L^{-1})^{1/2}$, $T_{6=}$ 20(dSm^{-1}) + 100 (mmol $L^{-1})^{1/2}$, $T_{7=}$ 30(dSm^{-1}) + 20 (mmol $L^{-1})^{1/2}$, $T_{8=}$ 30 (dSm^{-1}) + 40 (mmol $L^{-1})^{1/2}$, $T_{9=}$ 30 (dSm^{-1}) + 60(mmol $L^{-1})^{1/2}$, $T_{10=}$ 30 (dSm^{-1}) + 80 (mmol $L^{-1})^{1/2}$, $T_{11=}$ 30(dSm^{-1}) + 100 (mmol $L^{-1})^{1/2}$, $T_{12=}$ 40(dSm^{-1}) + 20(mmol $L^{-1})^{1/2}$, $T_{13=}$ 40 (dSm^{-1}) + 40 (mmol $L^{-1})^{1/2}$, $T_{14=}$ 40 (dSm^{-1}) + 60 (mmol $L^{-1})^{1/2}$, $T_{15=}$ 40 (dSm^{-1}) + 80 (mmol $L^{-1})^{1/2}$ and $T_{16=}$ 40 (dSm^{-1}) + 100 (mmol $L^{-1})^{1/2}$. Post- harvest soil analysis was done. Completely randomized deign was applied with three repeats. Data on plant height, number of leaves $plant^{-1}$ and number of branches $plant^{-1}$ at the time of transplanting and after two years were collected. Ionic concentration of Na, K, and K/ Na of soil used in this experiment after two years of transplanting of (*Conocarpus erectus* L) seedlings was determined. The data obtained were subjected to statistical analysis using the STATISTIX statistical software (Version 8.1) and the mean values were compared using least significant difference (LSD) [33].

RESULTS AND DISUSSIONS

Salinity plus sodicity influenced the growth of *Conocarpus erecuts* seedlings (table-1). Plant height is the main growth parameter of this plant to withstand salinity and sodicity stresses. Plant height was the highest (70.00cm) at the time of transplanting at lowest salinity and sodicity stresses i.e. $T_{16.}$ After two transplanting this value was increased to170 showing143% increase over control after two years. T_{16} having the top level of salinity and sodicity attained the bottom position in plant height. Therefore it is resulted that plant height is inversely proportional to salinity plus sodicity. Saline soils have adverse effects on plant growth and cause plant death due to ion toxicity, water stress, ion imbalance, or a combination of all these factors [34]. Salt damage of plants occurs by a combination of several causes, including mainly osmotic injury and specific ion toxicity [35, 36] that affect a variety of physiological and metabolic processes in plants [37].

Number of leaves plant^{-1} showed variations among treatments (table-1).A huge variation of 362 to 803 after two years of transplanting indicated the worst effects of saline sodic soil environment. % decrease over control (after two years) in number of leaves plant^{-1} showed great difference (-70.43 to+1.16) among treatments as mentioned in table-1. Significant anatomical characteristics which plays an important role in salt tolerance include stomatal shape, size, density and orientation [38], increased thickness (succulence) in leaf, root and stem [39], increased vascular bundle area [40], high water use efficiency, low transpiration rate, and low reduction in photosynthetic rate and chlorophyll pigments [41].

Number of branches plant^{-1}is the detrimental parameter in the growth of woody plants. Data regarding number of branches plant^{-1} presented in table-2 influenced the severity of salinity and sodicity stresses. % decrease over control after two years transplanting cleared the picture indicated the range i.e. -55.90 to -1.85 among treatments. % decrease over control was increased as well as the salinity cum sodicity toxicity was increased. Salinity is the most familiar a biotic stresses that effect plant growth and limit the many physiological processes such as photosynthetic rate, mineral distribution and membrane permeability [42]. Different plants respond to salinity in different ways such as changes water balance and its uptake, transpiration, metabolic pathways, exchange of gases, leaves optical properties, ion uptake, respiration and photosynthesis, morpho-anatomical characteristics and balance of hormones [43, 44].

K$^+$ Na$^+$ ratio is the important factor for the determination of salt tolerance in every plant. More K$^+$ Na$^+$ ratio showed more salt tolerance. Data regarding this parameter presented in table-2. T_2 [20(dSm^{-1}) + 20 (mmol L^{-1})$^{1/2}$] showed the highest salt tolerance among other treatments (table-2) due to having the maximum value of K$^+$ Na$^+$ ratio. Na+ stress interferes K$^+$ entry by root cells. When Na$^+$ moves into the cells and gathered to high levels, it becomes harmful to enzymes [45]. Plants have developed different mechanisms to deal with salinity effects [1]. To prevent growth break off, excessive Na has to be expelled or divided up into compartments in the vacuole [45]. In some species, salt concentration can also be reduced by transferring the salts into old leaves or by storing them in the bark or the wood.

Table-1: Influence of salinity plus sodicity on Plant height (cm) and # leaves plant^{-1}of *Conocarpus erecuts* seedlings

Treatment	Plant height (cm) at transplanting	Plant height (cm) after two years	% increase over control (after two years)	% decrease over control (after two years)	# of leaves at transplanting	# of leaves after two years	% increase over control (after two years)	% decrease over control (after two years)
T_1	70.00	170.00	143.00	----------	30	803	2576.67	----------
T_2	57.00	137.00	140.35	-1.85	29	785	2606.90	+1.16
T_3	58.00	139.00	140.00	-2.10	32	845	2540.62	-1.40
T_4	52.00	122.00	134.62	-5.86	27	700	2492.60	-3.25
T_5	58.00	129.00	122.00	-14.66	24	548	2183.33	-15.29
T_6	62.00	122.00	97.00	-32.35	27	590	2085.18	-19.09
T_7	66.00	155.00	135.00	-5.98	33	864	2518.18	-2.29
T_8	53.00	119.00	125.00	-13.18	29	729	2413.80	-6.33
T_9	62.00	142.00	129.00	-10.04	25	604	2316.00	-10.31
T_{10}	59.66	121.00	103.00	-26.31	26	491	1788.46	-30.59
T_{11}	58.00	103.00	78.00	-45.90	35	480	1271.42	-50.65
T_{12}	62.00	131.00	110.00	-22.41	26	611	2250.00	-12.69
T_{13}	64.00	132.00	106.00	-25.92	24	570	2275.00	-11.72
T_{14}	67.33	125.00	86.00	-40.28	27	488	1707.40	-33.76
T_{15}	70.00	110.00	57.00	-60.16	25	340	1260.00	-51.11
T_{16}	62.00	89.00	44.00	-69.64	42	362	761.90	-70.43

Table-2: Influence of salinity plus sodicity on # of branches plant^{-1} and Na, K, and K/ Na of *Conocarpus erecuts* seedlings

Treatment	# of branches plant^{-1}) at transplanting	# of branches plant^{-1} after two years	% increase over control (after two years)	% decrease over control (after two years)	Na^+ Percentage	K^+ Percentage	K^+/ Na^+ Ratio
T_1	7	61	771.43	----------	2.31	0.72	0.31
T_2	7	60	757.14	-1.85		0.77	0.32
T_3	8	65	713.00	-7.52	2.60	0.74	0.28
T_4	6	50	733.33	-4.93	2.64	0.69	0.21
T_5	7	52	643.00	-16.60	3.23	0.61	0.17
T_6	6	41	583.33	-24.38	3.63	0.52	0.14
T_7	7	60	757.00	-1.82	3.86	0.73	0.27
T_8	6	50	733.00	-4.93	2.73	0.73	0.26
T_9	8	57	613.00	-20.49	2.81	0.69	0.20
T_{10}	9	50	455.56	-40.86	3.38	0.57	0.14
T_{11}	6	30	400.00	-48.12	4.41	0.40	0.09
T_{12}	7	53	657.14	-14.79	4.49	0.69	0.23
T_{13}	9	55	511.11	-33.72	2.94	0.62	0.19
T_{14}	5	29	480.00	-37.74	3.92	0.56	0.14
T_{15}	7	34	385.71	-49.94	4.28	0.43	0.10
T_{16}	5	22	340.00	-55.90	4.63	0.34	0.07

$T_{1=}$<4(dSm^{-1}) + <15(mmol L^{-1})$^{1/2}$, $T_{2=}$ 20(dSm^{-1}) + 20(mmol L^{-1})$^{1/2}$, $T_{3=}$ 20(dSm^{-1}) + 40(mmol L^{-1})$^{1/2}$, $T_{4=}$ 20 (dSm^{-1}) + 60(mmol L^{-1})$^{1/2}$, $T_{5=}$ 20 (dSm^{-1}) + 80(mmol L^{-1})$^{1/2}$, $T_{6=}$ 20(dSm^{-1}) + 100 (mmol L^{-1})$^{1/2}$, $T_{7=}$ 30(dSm^{-1}) + 20(mmol L^{-1})$^{1/2}$, $T_{8=}$ 30(dSm^{-1}) + 40(mmol L^{-1})$^{1/2}$, $T_{9=}$ 30 (dSm^{-1}) + 60(mmol L^{-1})$^{1/2}$, $T_{10=}$ 30 (dSm^{-1}) + 80(mmol L^{-1})$^{1/2}$, $T_{11=}$ 30(dSm^{-1}) + 100 (mmol L^{-1})$^{1/2}$, $T_{12=}$ 40(dSm^{-1}) + 20(mmol L^{-1})$^{1/2}$, $T_{13=}$ 40(dSm^{-1}) + 40(mmol L^{-1})$^{1/2}$, $T_{14=}$ 40 (dSm^{-1}) + 60(mmol L^{-1})$^{1/2}$, $T_{15=}$ 40 (dSm^{-1}) + 80(mmol L^{-1})$^{1/2}$ and $T_{16=}$ 40(dSm^{-1}) + 100 (mmol L^{-1})$^{1/2}$

CONCLUSIONS

Increasing levels of salinity and sodicity had adverse influences on plant growth. Salinity cum sodicity minimum percentage increase over control was determined in T_{16} having EC (40 dSm^{-1}) and SAR 100 (mmol L^{-1})$^{1/2}$. Sodium concentration increased with increasing salinity/ sodicity, while potassium in leaf samples was decreased. Maximum K/ Na was measured in control having less level of salinity plus sodicity while minimum was in T_{16} i.e. EC (40 dSm^{-1}) and SAR 100 (mmol L^{-1})$^{1/2}$.

REFERENCES

1. Munns, R. (2002). Comparative physiology of salt and water stress. Plant Cell Environ. 25:239-250
2. Tang, A. C., Kawamitsu, Y., Kanechi, M., & Boyer, J. S. (2002). Photosynthetic oxygen evolution at low water potential in leaf discs lacking an epidermis. *Annals of Botany*, *89*(7), 861-870.
3. Mehboob-UR-Rahman, T. A., Chowdhary, M. A., Iqbal, M. J., & Zafar, Y. (2004). Application of random amplified polymorphic DNA (RAPD) technique for the identification of markers linked to salinity tolerance in wheat (Triticum aestivum l.). *Pak. J. Bot*, *36*(3), 595-602.
4. Hegazy, S. S., Aref, I. M., Al-Mefarrej, H., & El-Juhany, L. I. (2008). Effect of spacing on the biomass production and allocation in Conocarpus erectus L. trees grown in Riyadh, Saudi Arabia. *Saudi J. Biol. Sci*, *15*(2), 315-322.
5. López-Portillo, J. O. R. G. E., Ewers, F. W., & Angeles, G. (2005). Sap salinity effects on xylem conductivity in two mangrove species. *Plant, Cell & Environment*, *28*(10), 1285-1292.
6. Dewir, Y. H., El-Mahrouk, M. E., Naidoo, Y., Belal, E., & Shaik, S. (2014). Effect of diluted seawater irrigation and exogenous proline treatments on growth, chemical composition and anatomical characteristics of conocarpus erectus l. *Journal of Testing and Evaluation*, *43*(4), 1-6.
7. Asif, M., Saqib, M., Yousaf, B., Adnan, M., Yousaf, A., Ali, A., & Sabir, D. (2014). Growth and ionic composition of buttonwood (Conocarpus erectus L.) in response to soil salinity and water stress. *Growth*, *19*.
8. El-Juhany, L. I., & Aref, I. M. (2005). Interactive effects of low water supply and high salt concentration on the growth and dry matter partitioning of Conocarpus erectus seedlings. *Saudi Journal of Biological Sciences*, *12*, 147-157.
9. Suleiman, M. K., Bhat, N. R., Abdal, M. S., & Bellen, R. R. (2005). Testing newly introduced ornamental plants to the arid climate of Kuwait. *Archives of Agronomy and Soil Science*, *51*(4), 469-479.
10. Khan, M. A., & Gul, B. (2006). Halophyte seed germination. In *Ecophysiology of high salinity tolerant plants* (pp. 11-30). Springer, Dordrecht.
11. Tewfik, S. F. A., & El-Wakeel, A. O. (2010). Effect of thinning on the above ground biomass of (Conocarpus erectus L.) trees in the western region

of Saudi Arabia. *Meteorology, Environment and Arid Land Agriculture Sciences*, *21*(1).

12. Al-Humaid, A. I., & Moftah, A. E. (2007). Effects of hydrophilic polymer on the survival of buttonwood seedlings grown under drought stress. *Journal of Plant Nutrition*, *30*(1), 53-66.
13. Ashraf, M. F. M. R., & Foolad, M. (2007). Roles of glycine betaine and proline in improving plant abiotic stress resistance. *Environmental and experimental botany*, *59*(2), 206-216.
14. Maheshwari, D. K., Dubey, R. C., Aeron, A., Kumar, B., Kumar, S., Tewari, S., & Arora, N. K. (2012). Integrated approach for disease management and growth enhancement of Sesamum indicum L. utilizing Azotobacterchroococcum TRA2 and chemical fertilizer. *World Journal of Microbiology and Biotechnology*, *28*(10), 3015-3024.
15. Flowers, T. J., & Colmer, T. D. (2008). Salinity tolerance in halophytes. *New Phytologist*, *179*(4), 945-963.
16. Abou-Leila, B., Metwally, S. A., Hussen, M. M., & Leithy, S. Z. (2012). The combined effect of salinity and ascorbic acid on anatomical and physiological aspects of Jatropha plants. *Australian Journal of Basic and Applied Sciences*, *6*(3), 533-541.
17. Çavuşoğlu, K., Kiliç, S., & Kabar, K. (2008). Effects of some plant growth regulators on leaf anatomy of radish seedlings grown under saline conditions. *Journal of Applied Biological Sciences*, (2), 47-50.
18. Singh, R. (2008). Worldwide water crisis. *Journal of Membrane Science*, *1*(313), 353-354.
19. Jin, Z. M., Wang, C. H., Liu, Z. P., & Gong, W. J. (2007). Physiological and ecological characters studies on Aloe vera under soil salinity and seawater irrigation. *Process Biochemistry*, *42*(4), 710-714.
20. Liu, Y., Yang, S. F., Li, Y., Xu, H., Qin, L., & Tay, J. H. (2004). The influence of cell and substratum surface hydrophobicities on microbial attachment. *Journal of biotechnology*, *110*(3), 251-256.
21. Xiao-Hua, L. O. N. G., Jin-He, C. H. I., Ling, L. I. U., Qing, L. I., & Zhao-Pu, L. I. U. (2009). Effect of seawater stress on physiological and biochemical responses of five Jerusalem artichoke ecotypes. *Pedosphere*, *19*(2), 208-216.
22. Hatzikos, E. V., Tsoumakas, G., Tzanis, G., Bassiliades, N., & Vlahavas, I. (2008). An empirical study on sea water quality prediction. *Knowledge-Based Systems*, *21*(6), 471-478.
23. Moreno, F., Cabrera, F., Fernandez-Boy, E., Giron, I. F., Fernandez, J. E., & Bellido, B. (2001). Irrigation with saline water in the reclaimed marsh soils of south-west Spain: impact on soil properties and cotton and sugar beet crops. *Agricultural water management*, *48*(2), 133-150.
24. Geng-Mao, Z. H. A. O., Zhao-Pu, L. I. U., Ming-Da, C. H. E. N., & Shi-Wei, G. U. O. (2008). Soil Properties and Yield of Jerusalem Artichoke (Helianthus tuberosus L.) with Seawater Irrigation in North China Plain1. *Pedosphere*, *18*(2), 195-202.
25. Desantis, L. R., Bhotika, S., Williams, K., & Putz, F. E. (2007). Sea‐level rise and drought interactions accelerate forest decline on the Gulf Coast of Florida, USA. *Global Change Biology*, *13*(11), 2349-2360.
26. Williams, K., MacDonald, M., McPherson, K., & Mirti, T. H. (2007). Ecology of the coastal edge of hydric hammocks on the Gulf Coast of Florida. In *Ecology of tidal freshwater forested wetlands of the Southeastern United States* (pp. 255-289). Springer, Dordrecht.
27. Ross, M. S., O'Brien, J. J., Ford, R. G., Zhang, K., & Morkill, A. (2009). Disturbance and the rising tide: the challenge of biodiversity management on low‐island ecosystems. *Frontiers in Ecology and the Environment*, *7*(9), 471-478.
28. Donnelly, J. P., & Bertness, M. D. (2001). Rapid shoreward encroachment of salt marsh cordgrass in response to accelerated sea-level rise. *Proceedings of the National Academy of Sciences*, *98*(25), 14218-14223.
29. Reed, D. J. (2002). Sea-level rise and coastal marsh sustainability: geological and ecological factors in the Mississippi delta plain. *Geomorphology*, *48*(1-3), 233-243.
30. Blum, M. D., & Roberts, H. H. (2009). Drowning of the Mississippi Delta due to insufficient sediment supply and global sea-level rise. *Nature Geoscience*, *2*(7), 488.
31. Krauss, K. W., Duberstein, J. A., Doyle, T. W., Conner, W. H., Day, R. H., Inabinette, L. W., & Whitbeck, J. L. (2009). Site condition, structure, and growth of baldcypress along tidal/non-tidal salinity gradients. *Wetlands*, *29*(2), 505-519.
32. Gann, G. D., Woodmansee, S. W., & Bradley, K. A. (2002). *Rare plants of south Florida: their history, conservation and restoration*. Institute for Regional Conservation.
33. Steel, R. G., Torrie, J. H., & Dickey, D. A. (1997). *Principles and procedures of statistics: A biological approach*. McGraw-Hill.
34. Bor, M., Özdemir, F., & Türkan, I. (2003). The effect of salt stress on lipid peroxidation and antioxidants in leaves of sugar beet Beta vulgaris L. and wild beet Beta maritima L. *Plant Science*, *164*(1), 77-84.
35. Nandwal, A. S., Godara, M., Sheokand, S., Kamboj, D. V., Kundu, B. S., Kuhad, M. S., ... & Sharma, S. K. (2000). Salinity induced changes in plant water status, nodule functioning and ionic distribution in phenotypically differing genotypes of Vigna radiata L. *Journal of plant physiology*, *156*(3), 350-359.

36. Di Baccio, D., Navari-Izzo, F., & Izzo, R. (2004). Seawater irrigation: antioxidant defence responses in leaves and roots of a sunflower (Helianthus annuus L.) ecotype. *Journal of plant physiology*, *161*(12), 1359-1366.
37. Silveira, J. A. G., Melo, A. R. B., Viégas, R. A., & Oliveira, J. T. A. (2001). Salinity-induced effects on nitrogen assimilation related to growth in cowpea plants. *Environmental and Experimental Botany*, *46*(2), 171-179.
38. Naz, N., Hameed, M., Ashraf, M., Al-Qurainy, F., & Arshad, M. (2010). Relationships between gas-exchange characteristics and stomatal structural modifications in some desert grasses under high salinity. *Photosynthetica*, *48*(3), 446-456.
39. Hameed, M., Ashraf, M., & Naz, N. (2009). Anatomical adaptations to salinity in cogon grass [Imperata cylindrica (L.) Raeuschel] from the Salt Range, Pakistan. *Plant and soil*, *322*(1-2), 229-238.
40. Ali, I., Abbas, S. Q., Hameed, M. A. N. S. O. O. R., Naz, N., Zafar, S. A. R. A., & Kanwal, S. H. I. A. S. T. A. (2009). Leaf anatomical adaptations in some exotic species of Eucalyptus L'Hér.(Myrtaceae). *Pakistan Journal of Botany*, *41*(6), 2717-2727.
41. Hameed, M., Batool, R., & Ashraf, M. (2014). Photosynthetic response of three aquatic species of Schoenoplectus (Reichenb.) Palla under salt stress. *Wetlands Australia Journal*, *27*(1), 2-11.
42. Qin, J., Dong, W. Y., He, K. N., Yu, Y., Tan, G. D., Han, L., ... & Wang, Z. L. (2010). NaCl salinity-induced changes in water status, ion contents and photosynthetic properties of Shepherdia argentea (Pursh) Nutt. seedlings. *Plant soil environ*, *56*(7), 325-332.
43. Khatoon, A., Hussain, M. K., & Sadiq, M. (2000). Effect of salinity on some growth parameters of cultivated sunflower under saline conditions. *International Journal of Agriculture & Biology*, *2*, 210-213.
44. Ibrahim, M., Akhtar, J., Younis, M., Riaz, M. A., Anwarul-Haq, M., & Tahir, M. (2007). Selection of cotton (Gossypium hirsutum L.) genotypes against NaCl stress. *Soil and Environment*, *26*(1), 59-63.
45. Hasegawa, P. M., Bressan, R. A., Zhu, J. K., & Bohnert, H. J. (2000). Plant cellular and molecular responses to high salinity. *Annual review of plant biology*, *51*(1), 463-499.