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Response of *Conocarpus erectus* seedlings to different levels of salinity and sodicity

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Abstract

Soil salinity and sodicity problems are common in arid and semiarid regions, like Pakistan where annual rainfall is insufficient to leach salts and excess sodium ion out of the rhizosphere. Reclamation is not always an easy and economical approach for efficient use of salt affected soils. Other option is utilization of salt affected soils through growing of salt tolerant plants. So, a study was conducted to evaluate salinity/sodicity tolerance of *Conocarpus Erectus* for its cultivation on waste salt affected soils. Different combination of EC_e (20 to 40 dS m^{-1}) and SAR (20 to100 mmol $L^{-1})^{1/2}$ were tested Data recorded after two years showed that increasing levels of salinity and sodicity had negative impact on all plant growth characteristics i.e. stem diameter, plant height, number of leaves and number of branches/plantbut plant mortality was not observed in any treatment. Maximal percent increase was observed in control having salinity and sodicity level within safe limit. While owning to dual stress of salinity and sodicity minimal percent increase for plant height (44 %), stem diameter (117 %), number of leaves (761.90 %) and number of branches/plant (340 %) was noticed in T_{16} = EC 32.40 dS m^{-1}& SAR 79.60 (m mol $L^{-1})^{1/2}$(mmol $L^{-1})^{1/2}$. Most of parameters showed 50% reduction in growth at T_{11} =EC_e27.34 dS m^{-1}&SAR 81.52 (mmol $L^{-1})^{1/2}$. Generally negative impact on the growth was more intense at higher sodicity levels as compared to salinity.

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Introduction

Salinity and underground brackish water is very common problem in arid and semi-arid regions of the world. Ecological conditions like limited rainfall, more evapo-transpiration and high temperature promote net upward capillary movement of soluble salts from the soil solution causing salinization (Manchanda and Garg, 2008).It has been estimated that more than 8 × 108 ha of land are affected, either by salinity (3.97 × 108 ha) or sodicity (4.34 × 108 ha) around the world (FAO, 2000) and extent of salt affected soils in Pakistan is 6.67 million hectares (Khan, 1998).This large extent of degraded salt affected soils is of a great concern because already limited land resources are insufficient to fulfill the increasing demands for food, fuel and fiber.

Cultivation of conventional agronomic crops on highly salt-affected soils is generally not feasible because yields of such crops are low and physical reclamation of these soils is often prohibitively expensive for poor farmers (Qadir and Oster, 2004).Therefore, more easy and practicable approach for exploiting such ultra-salt affected soil is growing the stress tolerant plants without any prior reclamation. The Most important factor in biosaline agriculture system is selection of suitable plant species having potential to grow and survive under severe stress conditions.

Conocarpus erectus L. is a seaside, evergreen shrub with highly salt-resistant foliage (Hegazy *et al*., 2008). Mostly it is cultivated as ornamental plant in street, yards and park and potted plants are used in bonsai technique (Abohassan *et al*., 2010). The wood of *Conocarpus erectus is* hard and is used to make railroad ties, bulidings, charcoal, fuel. Its bark is composed of 16.5-18.5% tannin and being used in tannery. Leaves are folk remedy for fever, anemia, catarrh, conjunctivitis, gonorrhea and headache (Al-Humaid & Moftah, 2007). Conocrpus is a attractive plant to feed animals (Suleiman *et al.,* 2005).

Conocarpus *erectusis reprted a highly* tolerant plant against different environmental stresses like heat, drought, salt stress, (Hegazy *et al*., 2008).Previously different attempts had been made to exploit the highly salt affected soil by using the conocarpus in Pakistan and Gulf-Arab countries (Shirazi *et al*., 2006, Redha *et al.* 2012).

In a study Asif *et al.* (2014) reported that conocarpus plant can grow successfully up to a salinity stress of 40 dSm^{-1} but when water stress was combined with salinity no plant was survived at 40 dSm^{-1}. Jalaly et al., (2015) evaluated the performance of concocarpus seddling at 0, 5,10,15 and 20 g/ L Na Cl. They reported that poor quality water up to 10 g/L Na Cl can be used directly for growing the conocarpus while brackish water with 15 and 20 g/ L Na Cl can be used alternatively with fresh water to irrigate the conocarpus seedling. In a study, Basim and Ali (2014) applied the four salinity levels of brackish water (fresh water, 3000 ppm, 6000 ppm and 12000 ppm) and three levels of water intervals (one day, two day and three days) to six month old seedlings of conocarpus. They found all the seedlings survive at highest levels of salinity at 12000 ppm but a slight reduction in growth parameters was observed when water interval was elongated to 3 days. Likewise, Shirazi et al. (2006) stated that cocnocarpus at early growth stages demonstrated a high percentage of survival at high salinities. Similarly,Previously most of researchers focused the growth performance of conocarpus under drought and salinity stress but to our knowledge no information is available under saline sodic soil conditions. As approximately 56% of the salt-affected soils of Pakistan are saline-sodic (Mirbahar and Sipraw, 2000) therefore current study was planned with objective to assess performance of conocarpus under saline sodic soil conditions and to determineits suitability for cultivation on waste salt affected soils.

Materials and methods

To study the suitability of conocarpus cultivation on waste salt affected soils as well as to evaluate its salinity/sodicity tolerance potential, a pot experiment was conducted inthe wire house of Soil Salinity Research Institute Pindi Bhattian, Hafizabad. Before salinity/sodicity development normal soil was collected andanalyzed for its physical and chemical properties (Table 1).Desired levels of EC_e and SAR were developed artificially with NaCl, Na_2SO_4, $CaCl_2$, $MgSO_4$ salts using Quadratic Equation (Ghafoor *et al.*, 1988).After calculation and proper weighing, each salt was sprayed separately in solution form. Soil was incubated for a period of seven days through covering with plastic sheet.

In total 16 treatments were planned having different combination of EC_e and SAR i.e. T_1 = EC_e< 4 dS m^{-1}&SAR< 15 (mmol $L^{-1})^{1/2}$, T_2 = 20 EC_e20 dS m^{-1}&SAR 20 (mmol $L^{-1})^{1/2}$, T_3 = EC_e20 dS m^{-1}&SAR 40 (mmol $L^{-1})^{1/2}$, T_4 = EC_e20 dS m^{-1}&SAR 60 (mmol $L^{-1})^{1/2}$, T_5 = EC_e20 dS m^{-1}&SAR 80 (mmol $L^{-1})^{1/2}$, T_6 = EC_e20 dS m^{-1}&SAR 100 (mmol $L^{-1})^{1/2}$, T_7 = EC_e30 dS m^{-1}&SAR 20 (mmol $L^{-1})^{1/2}$, T_8 = EC_e30 dS m^{-1}&SAR 40 (mmol $L^{-1})^{1/2}$, T_9 = EC_e30 dS m^{-1}&SAR 60 (mmol $L^{-1})^{1/2}$, T_{10} = EC_e30 dS m^{-1}&SAR 80 (mmol $L^{-1})^{1/2}$, T_{11} = EC_e30 dS m^{-1}&SAR 100 (mmol $L^{-1})^{1/2}$,T_{12} = EC_e40 dS m^{-1}&SAR 20 (mmol $L^{-1})^{1/2}$, T_{13} = EC_e40 dS m^{-1}&SAR 40 (mmol $L^{-1})^{1/2}$, T_{14} = EC_e40 dS m^{-1}&SAR 60 (mmol $L^{-1})^{1/2}$, T_{15} = EC_e40 dS m^{-1}&SAR 80 (mmol $L^{-1})^{1/2}$, T_{16} = EC_e40 dS m^{-1}&SAR 100 (mmol $L^{-1})^{1/2}$. After establishing the desired levels of EC_e and SAR, soil was filled in glazed pots @ 25 Kg soil per pot. Pots were arranged in Completely Randomized Design (CRD) with three relications. Three months old seedlings of conocarpus having uniform size were transplanted in these pots, keeping one plant in each pot. Fertilizer @ one liter of 1% urea, TSP and SOP was applied at the start and after every six months. All agronomic and plant protection measures were exercised unoformly.

Data regarding growth characteristics i.e. Plant height stem diameter, number of branches per plants and number of leaves per plant was recorded after two years. All plant and soil analysis was carried out following the methods of U.S. Salinity Laboratory Staff (1954).The collected crop data (Raya and Sunflower) was statistically analyzed. The treatment mean comparison was made using Least Significant Difference Test @ 5% Probability (Steel et al., 1997) using STATISTIX 8.1 package software.

Results and discussion

Plant height

Results in Table 4 revealed that dual stress of EC and SAR had negative impact on plant height. Plant height decreased substantially with increasing levels of salinity and sodicity. At the end of study (after two years) maximum plant height of 170 cm was observed in control with 143 % increase over its initial value. While at the same time plant height decreased linearly with increasing levels of EC and SAR. Minimum plant height (89 cm) was observed in T_{16} (EC 32.40 dS m^{-1}& SAR 79.60 (m mol $L^{-1})^{1/2}$).

Table 1. Physical and chemical properties at start of study.

Texture	Sandy Clay Loam
pH_s	7.98
EC_e(dS m^{-1})	2.22
SAR (mmol $L^{-1})^{1/2}$	8.64
Organic matter (%)	0.57
Available P (mg kg^{-1})	8.40
Extractable K (mg kg^{-1})	114.0

When compared with control maximum reduction of 69.64 % in plant height was also observed in T_{16}. One of the most negative impact of salinity on plants is reduced biomass production which might be a one of protective strategies of plants in response to adverse growth condition (Yang *et al.*, 2009). Under salt stress condition plants have to spend vital energy for their survival rather than normal vegetative growth (Lesica & Crone, 2007). Our results are in agreement with earlie findings that conocarpus can tolerate the high salinity and can survive upto 40 dSm^{-1} (Passioura *et al.*, 1992; Asif *et al.*, 2014).

Table 2. Analysis of irrigation water.

EC	0.81 d S m^{-1}
SAR	3.88 (m mol L^{-1})$^{1/2}$
RSC	3.78 me L^{-1}

Stem diameter

Data regarding the stem height also showed a declining trend with increasing levels of EC and SAR (Table 5) which produces the more detrimental effects on highest levels of EC and SAR i.ein T_{16} (EC 32.40 dS m^{-1}& SAR 79.60 (m mol L^{-1})$^{1/2}$). Maximum stem diameter (2.62 cm) was observed in T_1 (control) with 240 % increase over its initial value at transplanting. Minimum stem diameter (1.65 cm) was noted in T_{16} with117 % increase over its initial value. When compared the EC and SAR treatments with control (non saline) maximum reduction of 51.25 % was observe in T_{16}. Salinity not only suppresses the plant growth but also modify its metabolic processes (Maheshwari *et al.*, 2012). Salt stress negatively affect the different plant process like reduced transpiration, photosynthetic activity, gaseous exchange, morpho and anatomical characteristics (Ibrahim *et al.*, 2007).

Table 3. Levels of ECe and SAR to be developed artificially and there actual status (according to laboratory analysis).

	EC_e to be developed (d Sm^{-1})	EC_e observed (d Sm^{-1})	SAR to be developed (m mol L^{-1})$^{1/2}$	SAR observed (m mol L^{-1})$^{1/2}$
T_1	<4	<4	<15	<15
T_2	20	17.30	20	21.42
T_3	20	16.89	40	38.18
T_4	20	18.16	60	54.72
T_5	20	17.86	80	71.46
T_6	20	19.10	100	86.78
T_7	30	26.47	20	18.36
T_8	30	27.84	40	41.78
T_9	30	25.94	60	56.88
T_{10}	30	26.71	80	68.96
T_{11}	30	27.34	100	81.52
T_{12}	40	31.85	20	17.68
T_{13}	40	33.27	40	37.46
T_{14}	40	32.69	60	55.78
T_{15}	40	34.39	80	72.86
T_{16}	40	32.40	100	79.60

Reduced plant growth and stem diameter with increasing the salinity and sodicity stress may be ascribed to disturbance in all above mentioned physiological process.

Number of leaves

Same trend was observed in case of number of leaves, increasing levels of of EC and SAR had drastic effect on number of leaves (Table 6). Maximum number of leaves (803) was recorded in control (T_1) which decreased significantly with increasing level of salinity and sodicity. Minimum number of leaves (362) was noted with highest intensity of EC and SAR i. einT_{16} (EC 32.40 dS m^{-1}& SAR 79.60 (m mol L^{-1})$^{1/2}$). In comparison with control increasing levels EC and SAR negatively affected this parameters and maximum reduction of 70.43 % was observed in T_{16}.Different plants adopt different mechanism to tolerate the salinity such as changes in leaves optical properties (Khatoon *et al.*, 2000) reduced stomata number (Cavusoglu *et al.*, 2007a) changes in stomatal length (Cavusoglu *et al.*, 2008).

Table 4. Effect of different levels of ECe and SAR on plant height (cm) of conocarpus erectus seedlings.

EC (d Sm^{-1})		SAR (m mol L^{-1})$^{1/2}$	Plant height at transplanting	Plant height after two years	% increase over initial value (after two years)	% decrease over control (after two years)
T_1	<4	<15	70.00	170.00	143.00	-
T_2	17.30	21.42	57.00	137.00	140.35	-1.85
T_3	16.89	38.18	58.00	139.00	140.00	-2.10
T_4	18.16	54.72	52.00	122.00	134.62	-5.86
T_5	17.86	71.46	58.00	129.00	122.00	-14.66
T_6	19.10	86.78	62.00	122.00	97.00	-32.53
T_7	26.47	18.36	66.00	155.00	135.00	-5.98
T_8	27.84	41.78	53.00	119.00	125.00	-13.18
T_9	25.94	56.88	62.00	142.00	129.00	-10.04
T_{10}	26.71	68.96	59.66	121.00	103.00	-28.31
T_{11}	27.34	81.52	58.00	103.00	78.00	-45.90
T_{12}	31.85	17.68	62.00	131.00	111.00	-22.41
T_{13}	33.27	37.46	64.00	132.00	106.00	-25.92
T_{14}	32.69	55.78	67.33	125.00	86.00	-40.28
T_{15}	34.39	72.86	70.00	110.00	57.00	-60.16
T_{16}	32.40	79.60	62.00	89.00	44.00	-69.64

Table 5. Effect of different levels of EC_e and SAR on stem diameter (cm) of conocarpus erectus seedling.

EC (d Sm^{-1})		SAR (m mol L^{-1})$^{1/2}$	stem diameter at transplanting	stem diameter after two years	% increase over initial value (after two years)	% decrease over control (after two years)
T_1	<4	<15	0.77	2.62	240.00	-
T_2	17.30	21.42	0.60	2.04	240.00	0.00
T_3	16.89	38.18	0.62	2.07	233.87	-2.55
T_4	18.16	54.72	0.57	2.08	235.00	-2.08
T_5	17.86	71.46	0.69	2.22	222.00	-7.50
T_6	19.10	86.78	0.70	2.09	199.00	-17.08
T_7	26.47	18.36	0.77	2.58	235.00	-2.08
T_8	27.84	41.78	0.53	1.85	240.00	0,00
T_9	25.94	56.88	0.63	2.07	229.00	-4.58
T_{10}	26.71	68.96	0.59	1.82	208.00	-13.33
T_{11}	27.34	81.52	0.76	1.93	153.00	-36.25
T_{12}	31.85	17.68	0.66	1.96	197.00	-17.92
T_{13}	33.27	37.46	0.63	1.96	211.00	-12.08
T_{14}	32.69	55.78	0.73	2.06	182.00	-24.17
T_{15}	34.39	72.86	0.79	1.85	134.00	-44.17
T_{16}	32.40	79.60	0.76	1.65	117.00	-51.25

Less number of leaves at higher intensities of salinity and sodicity can be attributed to reduced photosynthetic activity under saline condition which resulted the senescence of premature leaves and abscission of adult leaves (Munns, 2002).

Number of branches

Data in Table 7 depicted that maximum number of branches (65) was also observed in T_3. While further increase in EC and SAR negatively affected the number of branches. Minimum number of branches (22) was observed in T_{16} with 340% reduction over control. Salt stress rendered unfavorable environment for natural growth and development of plants.

Table 6. Effect of different levels of ECe and SAR on No. of leaves of conocarpus erectus seedlings.

EC (d Sm^{-1})		SAR (m mol $L^{-1})^{1/2}$	No. of leaves at transplanting	No. of leaves after two years	% increase over initial value (after two years)	% decrease over control (after two years)
T_1	<4	<15	30	803	2576.67	-
T_2	17.30	21.42	29	785	2606.90	+1.16
T_3	16.89	38.18	32	845	2540.62	-1.40
T_4	18.16	54.72	27	700	2492.60	-3.26
T_5	17.86	71.46	24	548	2183.33	-15.29
T_6	19.10	86.78	27	590	2085.18	-19.09
T_7	26.47	18.36	33	864	2518.18	-2.29
T_8	27.84	41.78	29	729	2413.80	-6.33
T_9	25.94	56.88	25	604	2316.00	-10.31
T_{10}	26.71	68.96	26	491	1788.46	-30.59
T_{11}	27.34	81.52	35	480	1271.42	-50.65
T_{12}	31.85	17.68	26	611	2250.00	-12.69
T_{13}	33.27	37.46	24	570	2275.00	-11.72
T_{14}	32.69	55.78	27	488	1707.40	-33.76
T_{15}	34.39	72.86	25	340	1260.00	-51.11
T_{16}	32.40	79.60	42	362	761.90	-70.43

The plants under salinity stress exhibited reduced number of branches and leaves, they attain less weight and less stem diameter (Ashraf and Sarwar (2002).

Ionic analysis

A quick glance on (Table 8) data showed that leaves Na^+ contents increased linearly with increasing levels of SAR. Minimum leaves Na^+ contents (2.31 %) was observed in non saline treatment i.e control, which increased remarkably with increasing the sodicity level and maximum Na^+ contents (4.63 %) was observed at highset levels of EC and SAR (EC 32.40 dS m^{-1}& SAR 79.60 (m mol $L^{-1})^{1/2}$).An opposite trend was observed in case of leaves K^+ contents, increasing levels of EC and SAR suppress the leaves K^+ contents. Maximum K^+ contents (0.77 %) was observed in T_2 which decreased significantly with increasing levels of EC and SAR and minimum K^+ contents (0.34 %) was observed in T_{16}.Maximum K^+ /Na^+ (0.31)was also recorded in control which decreased progressively in T_{16} i.e (0.07 %).

Table 7. Effect of different levels of ECe and SAR on No. of branches of conocarpus erectus seedlings.

EC (d Sm^{-1})		SAR (m mol $L^{-1})^{1/2}$	No. of branches at transplanting	No. of branches after two years	% increase over initial value (after two years)	% decrease over control (after two years)
T_1	<4	<15	7	61	771.43	-
T_2	17.30	21.42	7	60	757.14	-1.85
T_3	16.89	38.18	8	65	713.00	7.52
T_4	18.16	54.72	6	50	733.33	-4.93
T_5	17.86	71.46	7	52	643.00	-16.60
T_6	19.10	86.78	6	41	583.33	-24.38
T_7	26.47	18.36	7	60	757.00	-1.82
T_8	27.84	41.78	6	50	733.00	-4.93
T_9	25.94	56.88	8	57	613.00	-20.49
T_{10}	26.71	68.96	9	50	455.56	-40.86
T_{11}	27.34	81.52	6	30	400.00	-48.12
T_{12}	31.85	17.68	7	53	657.14	-14.79
T_{13}	33.27	37.46	9	55	511.11	-33.72
T_{14}	32.69	55.78	5	29	480.00	-37.74
T_{15}	34.39	72.86	7	34	385.71	-49.94
T_{16}	32.40	79.60	5	22	340.00	-55.90

Plants evolved several physiological and anatomical mechanism which enable them to survive under salt stress conditions. Physiological mechanism involve uptake of uptake of specific ions (Flowers & Colmer, 2008). When sodium contents increased in root zone then potassium contents decreased (Saqib *et al.,* 2004) resulting a nutritional imbalance and toxicity of sodium occur (Akram *et al.,* 2007).

Table 8. Effect of different levels of soil EC_e and SAR on Na^+, K^+ and K^+/Na^+ content of conocarpus erectus.

		SAR (m mol $L^{-1})^{1/2}$	Na^+(%)	K^+(%)	K^+/Na^+
T_1	<4	<15	2.31 j	0.72 ab	0.31
T_2	17.30	21.42	2.60 i	0.77 a	0.30
T_3	16.89	38.18	2.64 hi	0.74 ab	0.28
T_4	18.16	54.72	3.26 f	0.69 b	0.21
T_5	17.86	71.46	3.63 e	0.61 cd	0.17
T_6	19.10	86.78	3.86 d	0.52 e	0.14
T_7	26.47	18.36	2.73 hi	0.73 ab	0.27
T_8	27.84	41.78	2.81 gh	0.73 ab	0.26
T_9	25.94	56.88	3.38 f	0.69 b	0.20
T_{10}	26.71	68.96	4.04 c	0.57 cde	0.14
T_{11}	27.34	81.52	4.49 a	0.40 f	0.09
T_{12}	31.85	17.68	2.94 g	0.69 b	0.23
T_{13}	33.27	37.46	3.26 f	0.62 c	0.19
T_{14}	32.69	55.78	3.92 cd	0.56 de	0.14
T_{15}	34.39	72.86	4.28 b	0.43 f	0.10
T_{16}	32.40	79.60	4.63 a	0.34 g	0.07

Conclusions

Results of present study revealed that increasing levels of salinity and sodicity had negative impact on all plant growth parameters of *Conocarpus erectus L* i.e. stem diameter, plant height, number of leaves and number of branches. Furthermore due to dual stress of salinity and sodicity maximum reduction in growth attributes over control was observed in T_{16} having EC 32.40 dS m^{-1}& SAR 79.60 (m mol $L^{-1})^{1/2}$. Leaves sodium contents increased with increasing levels of EC and SAR, while an opposite trend was observed in case of leaves potassium contents. So it can be concluded that *Conocarpus erectus* L. can grow successfully at EC 32.40 dS m^{-1}& SAR 79.60 (m mol $L^{-1})^{1/2}$ as no mortality occur at this salinity and sodicity levels.

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