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ROOT MORPHOLOGY AND SEEDLING GROWTH OF THREE MALVACEOUS SALT TOLERANT PLANTS AT SALINE RHIZOSPHERE

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ABSTRACT

The effects of salinity were studied on root morphology and seedling growth in thirty five day old *Gossypium hirsutum*, *Kosteletzkya virginica* and *Thespesia populnea* under different concentrations of sea salt solution i.e. non saline control (EC_{iw}: 0.4 $dS.m^{-1}$), 0.5% sea salt (EC_{iw}: 6.2 $dS.m^{-1}$), 1.0% sea salt (EC_{iw}: 12.95 $dS.m^{-1}$). Results showed that primary root length was reduced in *K. virginica* at 1.0% sea salt, while it remained almost unaffected in the other two plants at this salinity in comparison to control. Number of secondary roots increased in *G. hirsutum* and *T. populnea* but in *K. virginica* they show a slight decrease. All the three plants showed promotion in the length of secondary roots at 0.5% salinity. Number of tertiary roots was enhanced in *T. populnea* at 0.5% salinity level, whereas the other two plants exhibit inhibition of tertiary roots. Root biomass was increased in *G. hirsutum* at 0.5% salinity but decreased at higher salinity. *K. virginica* and *T. populnea* showed decrease with the increasing salinity. Fresh and dry shoot biomass and plant height showed a gradual decrease in response to increasing salinity in all the three species. The number of leaves decreased gradually in *K. virginica* and *T. populnea* as the salinity of the rooting medium increased, whereas, in *G. hirsutum*, the number of leaves decreased under saline condition but the number of leaves were more or less same under two salinity levels. Leaf area per plant of *K. virginica* and *G. hirsutum* gradually reduced with increasing salinity. In *T. populnea* leaf area increased at 0.5% salinity and decreased at 1.0% salinity level. *T. populnea* showed more uptake of Na^+ and K^+ under non saline condition as compared to the other two plants. Uptake of Na^+ increased with increasing salinity in all the three plants. K^+ concentration increased in roots of *T. populnea* and *G. hirsutum* and decreased in *K. virginica* at 0.5% salinity. At 1.0% salinity level K^+ concentration substantially decreased in all the three plants.

The results showed that K. *virginica* was comparatively more tolerant under saline condition, where as *G. hirsutum* showed the comparatively least tolerance. Over all salt tolerance during growth of above mentioned three plants at higher level of salinity show that *G. hirsutum* was more tolerant, where as *K. virginica* showed the least tolerance at seedling stage.

Key Words: Root morphology, seedling growth, *Gossypium hirsutum*, *Kosteletzkya virginica*, *Thespesia populnea*.

INTRODUCTION

Healthy plant growth depends on acquisition of water and mineral nutrients. The water and essential nutrient are taken up from soil solution. The structure and morphology of roots vary according to plant species and function (Eames and Mac Daniels, 1947). The soil or rhizosphere is not always homogeneous but mostly differ in physical and chemical composition. The ability of roots to adapt and acquire soil resources enables the plant to survive and grow in diverse environment. The growth of root system is affected by both the external as well as internal factors under different environments (Fitter, 1999). Seedling root growth and development during early stages could affect the development of root system during the later growth stages of the plant, which ultimately affect the growth and yield (Leskovar *et al*., 1995; Lynch, 1995). According to Marschner (1986) external factors change the shoot: root ratio and growth of the shoot may be regulated by the root born phytohormones under unfavorable soil conditions. Casimiro *et al.* (2003) showed the environment at rhizosphere also influences number and placement of lateral roots.

Salinity is wide spread in the world and limits the plant growth and development. Growth of plant roots is altered under saline conditions. Two population of Aalfalfa exhibited differences in extension of roots under low and high salinity levels (Vaughan, *et al.*, 2002). Root formation and development has shown a decreased with increasing salinity and the root diameter was also changed (Muhammad *et al*., 1999).

Salt stress in the root zone can alters the root morphology and ultimately the potential of plant to exploit the soil resources. Salinity is reported to adversely affect root morphology, growth, lateral root formation and rate of their development (El-Saidi, 1997). According to Barber and Silberbush (1984) morphology of root under saline condition will be dependent upon the soil profile and will affect the development of total surface area of root system. Stresses reduce growth, volume and extent of soil exploration of root system. In case of its declines, the supply of water and nutrients to shoot is reduced which results subsequent reduction in biomass production.

Salinity affects the plants physiologically in two ways. One is by lowering the osmotic potential of the soil solution which may stop the absorption of water by the roots causing dehydration; the other physiological effect is

nutritional which is caused by the presence of toxic concentrations of sodium in the system (Epstein, 1972). Osmotic adjustment in plants may occur by accumulation and compartmentalization of inorganic as well as organic solutes under saline conditions. (Wyn Jones, 1981; Dracup *et al.,* 1988). K:Na selectivity is an important criterion of salt tolerance. Many salt tolerant varieties maintain high K^+: Na^+ ratio (Gorham *et al*., 1985, Flowers *et al*., 1977; Khan *et al.,* 1987; Sahito *et al.,* 2013).

In view of the above, seedling growth, root morphology and uptake of Na^+ and K^+ by three salt tolerant Malvaceous species under the saline environment was undertaken to investigated.

MATERIALS AND METHODS

A – Root Morphology

Plastic bags having fine basal pores for leaching water were filled with 6.5 Kg of non saline sandy loam soil. Three seeds of above mentioned plants were sown in each bag and irrigated with non saline tap water. After the establishment of seedling they were thinned to only one seedling in each bag. Saline irrigation started from fifth day after germination. Out of thirty bags, ten were irrigated with tap water (EC_{iw}: 0.4 $dS.m^{-1}$), ten irrigated with 0.5% sea salt solution (EC_{iw}: 6.2 $dS.m^{-1}$) and remaining ten were irrigated with 1.0% (EC_{iw}: 12.95 $dS.m^{-1}$). The seedlings were irrigated twice a week with 500 ml of non saline water or sea salt solutions with about 40% leaching percentage. Bags containing thirty-five days old seedlings were placed on a plastic tray having perforated sieve bottom. Plastic covers of bags were removed gently cutting by razor blade, and root system was washed under water tap so that the only soil was removed and roots were not broken. The plant was divided into root and shoot. A photostat of each root was made on a graph paper. Length of primary roots, number of secondary roots, total length of secondary roots and number of tertiary roots were recorded.

B - Growth of Thirty Five Days Old Seedlings and Estimation of Na^+ and K^+ Uptake in Roots

Height, number of leaves, their total area, fresh and dry biomasses of above mentioned seedlings were recorded. Root samples of the three replicates were collected for the mineral estimation (Na^+ and K^+).

Mineral Estimation

Roots were dried in hot air cabinet and 0.5g of dry sample was taken in china crucible and placed in oven for making ash. Solution of ash was made in 50ml of de-ionized water. Concentration of Na^+ and K^+ was determined in samples using flame emission spectrophotometer (Model Coleman SI-Ca; Perkin-Elmer, Oak Brook, III., USA).

Statistical Analyses

Data were subjected to analysis of variance (ANOVA).The follow up of (ANOVA) include least significant difference (LSD) which was calculated as out lined in Gomez and Gomez (1984). Duncan's Multiple Range Test (DMRT) was also used to compare the treatment means (Duncan, 1955).

OBSERVATION AND RESULTS

Root morphology and seedling growth

Root morphology

Photostat images of roots taken from thirty five days old seedlings of three above mentioned plants, developed under irrigation of non saline control and 0.5% and 1.0% sea salt concentrations are presented in (Figure 1). Salinity changed the root morphology of all the three plants and longitudinal (elongation) as well as horizontal (initiatiation) root growth was effected. The effect was more pronounced at the highest salinity level.

Length of primary root

The data for the plants roots irrigated with non saline or saline sea salt concentrations is given in (Table 1). *G. hirsutum* has the longest primary roots under non saline control than that of *T. populnea* and *K. virginica*. There appears slight increase in primary root of *K. virginica* at 0.5% (EC_{iw}: 6.2 $dS.m^{-1}$), whereas. *G. hirsutum* and *T. populnea* showed some decrease in their length. Sea salt concentration of 1.0% (EC_{iw}: 12.95 $dS.m^{-1}$) caused inhibition in root elongation of *K. virginica,* but in other two plants the root length showed slight increase over that of 0.5% sea salt solution though still remaining less than non saline control in *G. hirsutum*.

Number of secondary roots

The effect of salinity on number of secondary roots is presented in (Table 1). In control plants *T. populnea* showed the highest number of secondary roots followed by *K. virginica* and *G. hirsutum*. The development of

secondary roots was promoted in *T. populnea* and *G. hirsutum*, at 0.5% (EC_{iw}: 6.2 $dS.m^{-1}$) sea salt in comparison to control, where as in *K. virginica* there appeared decrease in them. Under 1.0% ($EC_{iw:}$ 12.95 $dS.m^{-1}$) salinity number of secondary roots decreased in all the three plants.

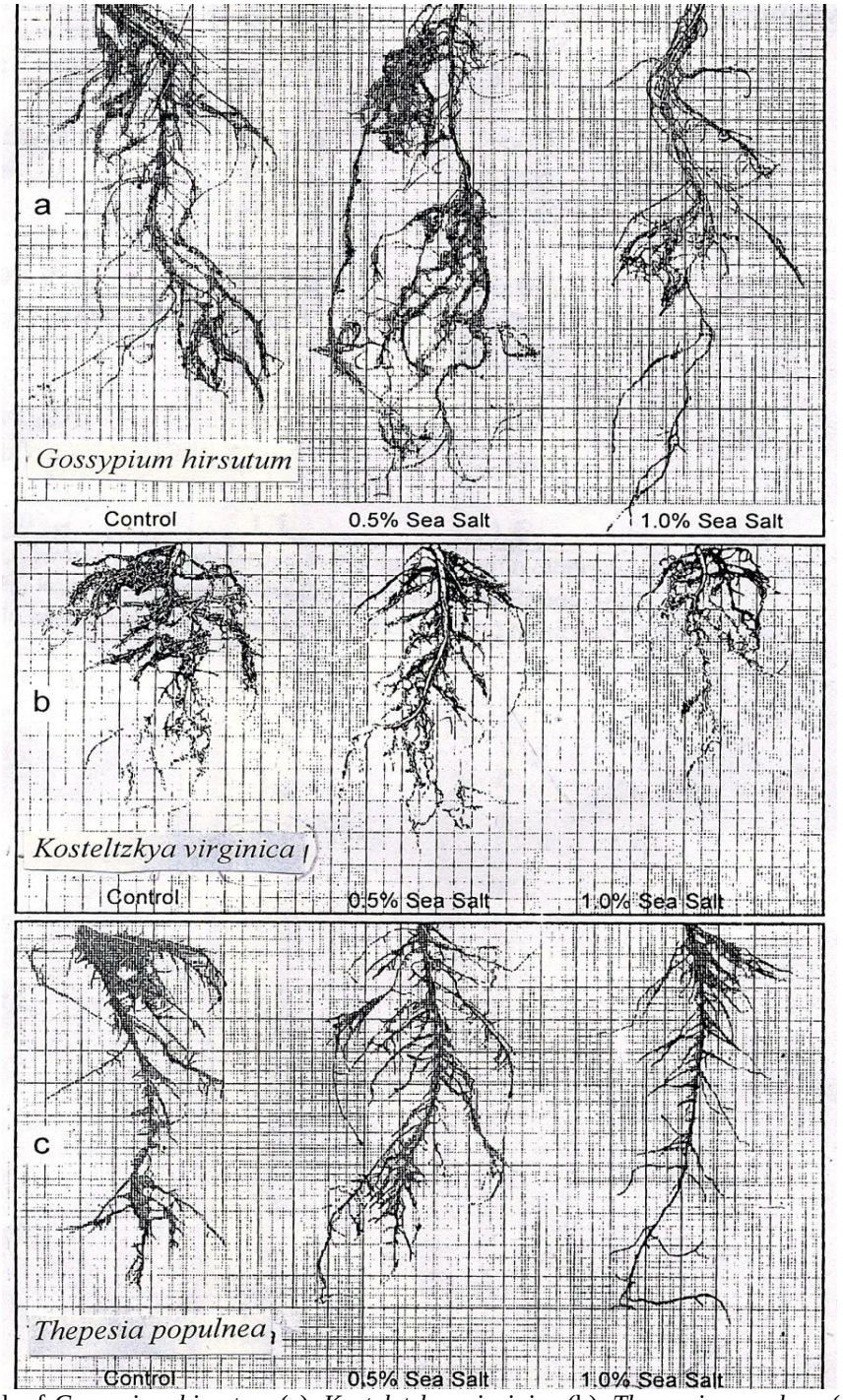

Fig. 1. Root growth of *Gossypium hirsutum* (a), *Kosteletzkya virginica* (b), *Thespesia populnea* (c) under irrigation with water of various concentrations of sea salt.

Total length of secondary roots

G. hirsutum showed the longest total length of secondary roots in non saline medium, where as *K. virginica* and *T. populnea* occupied second and third position (Table 1). The elongation of secondary roots was promoted over

control at lower salinity 0.5% (EC_{iw}: 6.2 $dS.m^{-1}$) sea salt in all the three plants. The decrease in total length of secondary roots at 1.0% ($EC_{iw:}$ 12.95 $dS.m^{-1}$) sea salt concentration in all the three plants was in order of *K. virginica* > *T. populnea* > *G. hirsutum* respectively.

Table 1. Root system of *G. hirsutum*, *K. virginica* and *T. populnea* under irrigation with different sea salt concentrations.

Treatment	*G. hirsutum*				*K. virginica*				*T. populnea*			
	*PRL (cm)	NSR	TLSR (cm)	NTR	PRL (cm)	NSR	TLSR (cm)	NTR	PRL (cm)	NSR	TLSR (cm)	NTR
Control (EC_{iw}: 0.4 $dS.m^{-1}$)	37.7 a ± 0.64	84.3 a ± 6.74	416.1 a ± 112.21	348 a ± 79.84	23.2 a ± 1.22	116 a ± 8.50	404.86 a ± 53.8	723 a ± 155.08	32.13 a ± 2.06	124.6 a ± 5.70	374.75 a ± 36.09	252 a ± 91.51
0.5% (S.S) (EC_{iw}: 6.2 $dS.m^{-1}$)	33.3 a ± 0.302 (-11.58)	90 a ± 5.70 (+ 7.14)	442.8 a ± 41.10 (+6.4)	223 ab ± 13.02 (-35.9)	25.6 a ± 3.07 (+10.3)	112 a ± 11.14 (-3.4)	442.6 a ± 6.8 (+9.3)	709 a ± 109.7 (-1.89)	28.3 a ± 4.32 (-11.9)	156 b ± 12.12 (+ 24.1)	398.7 ab ± 31.31 (+ 6.25)	328 ab ± 79.16 (+ 30.3)
1.0% (S.S) (EC_{iw}: 12.95 $dS.m^{-1}$)	36.8 a ± 1.51 (-2.29)	68.6 a ± 5.70 (-18.57)	353.06 a ± 50.74 (-15.15)	166 b ± 7.80 (-52.29)	19 a ± 2.11 (-18.1)	78.6b ± 2.60 (-32.18)	209.1 b ± 22.9 (-48.3)	344 b ± 33.05 (-52.4)	32.33 a ± 3.01 (+ 0.62)	119 b ± 14.73 (-5.3)	261.03 b ± 31.35 (- 30.34)	136 b ± 30.57 (-45.7)
$LSD_{0.05}$	5.78	20.4	289	162.36	5.78	28.47	117.60	385.50	6.50	24.775	114.17	152.34

*PRL (Primary root length), NSR (Number of secondary roots), TLSR (Total length of secondary roots), NTR (Number of tertiary roots).
Means followed by different letters in a column differ significantly at 95% probability level according to new Duncan's Multiple Range Test
Figures in parentheses indicate % promotion (+) and reduction (-) over control.

Table 2a. Fresh root biomass of *G. hirsutum, K. virginica and T. populnea* under irrigation with various sea salt concentrations.

	Fresh root biomass (g)		
Treatment	*G. hirsutum*	*K. virginica*	*T. populnea*
Control	6.77 a	4.52 a	3.97 a
(EC_{iw}: 0.4 $dS.m^{-1}$)	± 1.18	± 1.07	± 0.38
0.5% (S.S)	7.47 a	4.03 ab	2.87 ab
(EC_{iw}: 6.2 $dS.m^{-1}$)	± 0.55	± 0.24	± 0.43
	(+10.27)	(-11.01)	(-27.73)
1.0% (S.S)	3.86 b	1.25 b	2.02 b
(EC_{iw}: 12.95 $dS.m^{-1}$)	± 0.86	± 0.33	± 0.48
	(-42.9)	(-68.87)	(-49.17)
$LSD_{0.05}$	1.6	2.82	1.496

Table 2b. Dry root biomass of *G. hirsutum, K. virginica and T. populnea* under irrigation with various sea salt concentrations.

	Dry root biomass (g)		
Treatment	*G. hirsutum*	*K. virginica*	*T. populnea*
Control	0.74 a	0.20 a	0.35 a
(EC_{iw}: 0.4 $dS.m^{-1}$)	± 0.07	± 0.03	± 0.01
0.5% (S.S)	0.77 a	0.16 ab	0.27 a
(EC_{iw}: 6.2 $dS.m^{-1}$)	± 0.03	± 0.02	± 0.04
	(+3.97)	(-20.53)	(-20.97)
1.0% (S.S)	0.36 b	0.03 b	0.03 b
(EC_{iw}: 12.95 $dS.m^{-1}$)	± 0.04	± 0.00	± 0.01
	(-50.8)	(-83.44)	(-89.95)
$LSD_{0.05}$	0.101	0.153	0.084

Means followed by same letter in a column differ significantly at 95% probability level according to New Duncan' s Multiple Range Test. Figures in parentheses indicate % promotion (+) and reduction (-) over control.

Table 3a. Fresh shoot biomass (g) of *G. hirsutum, K. virginica* and *T. populnea* under irrigation with various sea salt concentrations.

Treatment	*G. hirsutum*	*K. virginica*	*T. populnea*
Control	14.85 a	5.7 a	10.53 a
(EC_{iw}: 0.4 $dS.m^{-1}$)	± 1.47	± 1.08	± 1.57
0.5% (S.S)	10.4 b	2.67 b	6.32 ab
(EC_{iw}: 6.2 $dS.m^{-1}$)	± 0.48	± 0.58	± 1.20
	(-29.8)	(-53.09)	(-39.95)
1.0% (S.S)	6.65 b	0.95 b	3.78 b
(EC_{iw}: 12.95 $dS.m^{-1}$)	± 1.05	± 0.30	± 0.84
	(-55.2)	(-64.46)	(-64.1)
$LSD_{0.05}$	2.16	2.48	4.28

Table 3b. Dry shoot biomass (g) of *G. hirsutum, K. virginica and T. populnea* under irrigation with various sea salt concentrations.

Treatment	*G. hirsutum*	*K. virginica*	*T. populnea*
Control	2.16 a	0.86 a	1.46 a
(EC_{iw}: 0.4 $dS.m^{-1}$)	± 0.4	± 0.19	± 0.31
0.5% (S.S)	1.42 b	0.41 b	0.92 ab
(EC_{iw}: 6.2 $dS.m^{-1}$)	± 0.417	± 0.10	± 0.32
	(-34.59)	(-52.36)	(-37.19)
1.0% (S.S)	0.85 b	0.08 b	0.55 b
(EC_{iw}: 12.95 $dS.m^{-1}$)	± 0.136	± 0.03	± 0.18
	(-60.4)	(-80.8)	(-62.3)
$LSD_{0.05}$	0.684	0.426	0.815

Means followed by same letter in a column differ significantly at 95% probability level according to New Duncan' s Multiple Range Test. Figures in parentheses indicate % promotion (+) and reduction (-) over control.

Table 4. Seedling height of *G. hirsutum, K. virginica* and *T. populnea* under irrigation with various sea salt concentrations.

	Seedling height (cm)		
Treatment	*G. hirsutum*	*K. virginica*	*T. populnea*
Control	23.0 a	26.5 a	28.8 a
(EC_{iw}: 0.4 $dS.m^{-1}$)	±0.50	±1.44	±1.64
0.5% (S.S)	17.8 b	17.6 b	21.6 b
(EC_{iw}: 6.2 $dS.m^{-1}$)	± 1.76	± 2.17	± 1.64
	(-22.4)	(-32.07)	(-24.8)
1.0% (S.S)	15.3 b	6.3 c	16.8 b
(EC_{iw}: 12.95 $dS.m^{-1}$)	± 1.53	± 1.46	± 1.59
	(-33.3)	(-76.2)	(-41.62)
$LSD_{0.05}$	2.7	5.96	6.53

Means followed by different letters in a column differ significantly at 95 % probability level according to New Duncan's multiple range test. Figures in parenthesis indicate % promotion (+) or reduction (-).

Table 5. Number of leaves per plant in *G. hirsutum, K. virginica* and *T. populnea* under irrigation with various sea salt concentrations.

Treatment	*G. hirsutum*	*K. virginica*	*T. populnea*
Control	14a	29a	12a
(EC_{iw}: 0.4 $dS.m^{-1}$)	± 1.15	± 2.60	± 0.0
0.5% (S.S)	8b	14b	11a
(EC_{iw}: 6.2 $dS.m^{-1}$)	± 0.58	± 3.48	± 0.58
	(-41.8)	(-51.7)	(-13.5)
1.0% (S.S)	8b	7b	9a
(EC_{iw}: 12.95 $dS.m^{-1}$)	± 0.58	± 0.88	± 0.33
	(-46.5)	(-75.8)	(-29.7)
$LSD_{0.05}$	1.631	8.86	3.647

Table 6. Leaf area per plant (mm^2) in *G. hirsutum, K. virginica* and *T. populnea* under irrigation with various sea salt concentrations.

Treatment	*G. hirsutum*	*K. virginica*	*T. populnea*
Control	33468.6a	16866.2a	24362.33 a
(EC_{iw}: 0.4 $dS.m^{-1}$)	± 3305.7	± 428.5	± 3952.9
0.5% (S.S)	28215.5a	9691.8 b	30893.7a
(EC_{iw}: 6.2 $dS.m^{-1}$)	± 1230.7	± 1357.9	±2257.8
	(-15.69)	(-42.5)	(+26.81)
1.0% (S.S) (EC_{iw}: 12.95 $dS.m^{-1}$)	15531.9a	1539.1c	9376.8 b
	± 1086.8	± 497.45	± 2313.43
	(-53.59)	(-90.87)	(-61.51)
$LSD_{0.05}$	7374.71	3013.71	10201.9

Means followed by different letters in a column differ significantly at 95 % probability level according to New Duncan's Multiple range test.

Table 7. Uptake of Na^+ and K^+ in *G. hirsutum, K. virginica and T. populnea* roots grown at various salinity levels. Figures in parenthesis are % promotion or reduction.

	G. hirsutum		*K. virginica*		*T. populnea*	
	Na^+ meq/l	K^+	Na^+ meq/l	K^+	Na^+ meq/l	K^+
Control	1.78 a	5.56a	1.78 a	4.786 a	3.96 a	6.46 a
(EC_{iw}: 0.4 $dS.m^{-1}$)	± 0.03	± 0.57	± 0.09	± 0.33	± 0.46	± 1.10
0.5% (S.S)	2.37 b	5.6 a	2.62 b	2.36 b	6.17 b	7.78 a
(EC_{iw}: 6.2 $dS.m^{-1}$)	± 1.72	± 3.25	± 0.11	± 0.25	± 0.33	± 0.36
	(+33.6)	(+0.6)	(+47.1)	(-50.4)	(+56.0)	(+20.3)
1.0% (S.S)	3.68 b	4.8 a	3.30 c	1.41 c	8.26 b	5.47 a
(EC_{iw}: 12.95 $dS.m^{-1}$)	± 3.68	± 2.82	± 1.91	± 0.82	± 0.50	± 0.56
	(+107.4)	(-11.9)	(+85.3)	(-70.2)	(+108.7)	(-15.3)
$LSD_{0.05}$	2.26	1.59	0.39	0.835	2.139	2.559

Means followed by different letters in a column differ significantly at 95 % probability level according to the New Duncan's Multiple Range Test.

DISCUSSION

Though there appear small difference in length of primary and secondary roots and number of secondary and tertiary roots of *G. hirsutum* under the irrigation of control (non saline), 0.5% (EC_{iw}: 6.2 $dS.m^{-1}$) and 1.0% (EC_{iw}: 12.95 $dS.m^{-1}$) sea salt solution, these differences are statically non significant. Whereas, in *K. virginica* significant differences appear towards reduction in number of secondary and tertiary roots and length of secondary roots at irrigation of 1.0% (EC_{iw}: 12.95 $dS.m^{-1}$) sea salt solution. In *T. populnea* significant differences were found in number of secondary and tertiary roots and length of secondary roots under saline condition as compared to control. Root growth of cotton is usually inhibited under salinity but different cotton varieties show variable tolerance (Akhter and Azhar, 2001; Reinhardt and Rost, 1995; Noor *et al.*, 2001; Gohar *et al.*, 2003). Others have shown that the effect of salinity on root length remains non significant in some cotton genotypes even at (EC: 23.8 $dS.m^{-1}$) though root biomass was considerably reduced (Hosseini and Thangane, 2007). In the present study primary roots of *G. hirsutum* were shorter but comparatively thicker at 0.5% (EC_{iw}: 6.2 $dS.m^{-1}$) salinity as compared to those in control. Kurth *et al.* (1986) showed that when the cotton roots were subjected to various salinities, cell length decreased but the cells became wider with the increasing salinities and at 150 mM NaCl, the roots attained twice the cross sectional areas of the control, therefore, the roots were considerably short and

conical throughout their length. Their studies also indicated that the rate of cell production was not much affected. In *K. virginica* primary root length increased at low salinity but decreased at high salinity. Salt stress had shown non significant effect on root elongation in *Spartina patens* as well (Wu *et al*., 1998). Cramer *et al.* (1986) showed that KCl at 50 mM concentration inhibited the root of cotton to lesser extent than did NaCl, indicating that this inhibition was partly ion specific. Rios-Gomez *et al* (2010) showed that decrease in primary root length or number of secondary roots in *Prosopis laevigata* was ion specific. Some others have also shown that, root elongation of melons is adversely effected due to osmotic as well as ionic reasons under saline condition (Yermiyahu *et al.,* 1997).

Under non saline condition *G. hirsutum* had longest primary roots. *T. populnea* and *K. virginica* occupied the second and third position. At 0.5% (EC_{iw}: 6.2 $dS.m^{-1}$) sea salt concentration *G. hirsutum* and *T. populnea* showed 11.58 and 11.9% reduction respectively. *K. virginica* showed 10.3% promotion. The effect of salinity was more pronounced on primary root length of *K. virginica* as compared to *G. hirsutum* and *T. populnea* at 1.0% (EC_{iw}: 12.95 $dS.m^{-1}$) sea salt.

The comparative performance of root growth of three above mentioned plants under non saline control and different concentrations of sea salt irrigation is given below:

Under control

Length of primary roots	*G. hirsutum* > *T. populnea* > *K. virginica*
Number of secondary roots	*T. populnea* > *K. virginica* > *G. hirsutum*
Total length of secondary roots	*G. hirsutum* > *K. virginica* > *T. populnea*
Number of tertiary roots	*K. virginica* > *G. hirsutum* > *T. populnea*

Under 0.5% sea salt irrigation

Length of primary roots	*G. hirsutum* > *T. populnea* > *K. virginica*
Number of secondary roots	*T. populnea* > *K. virginica* > *G. hirsutum*
Total length of secondary roots	*G. hirsutum* > *K. virginica* > *T. populnea*
Number of tertiary roots	*K. virginica* > *T. populnea* > *G. hirsutum*

Under 1.0% sea salt irrigation

Length of primary roots	*G. hirsutum* > *T. populnea* > *K. virginica*
Number of secondary roots	*T. populnea* > *K. virginica* > *G. hirsutum*
Total length of secondary roots	*G. hirsutum* > *T. populnea* > *K. virginica*
Number of tertiary roots	*K. virginica* > *G. hirsutum* > *T. populnea*

It appears that changes due to salinity occurred only for second and third position in number of tertiary roots between *T. populnea* and *G. hirsutum* at 0.5% (EC_{iw}: 6.2 $dS.m^{-1}$) sea salt irrigation and between total length of secondary roots and number tertiary roots of all the three plants at 1.0% (EC_{iw}: 12.95 $dS.m^{-1}$) sea salt irrigation. The comparative performance on other parameters of roots in all the three plants under saline water irrigation was similar to that of non saline control.

The finding for inhibition in lateral root initiation in cotton grown at saline soil has been reported in literature (Gohar *et al.* 2003). Rubinigg *et al.* (2004) also reported the inhibition in the number of lateral roots under saline condition. According to Shalhevet *et al.*, (1995) lateral root initiation is more sensitive to salinity than the extension of roots. Redistribution of the Auxin in *Arabidopsis* roots was reported to regulate the formation and growth pattern of lateral roots under salt or water stress (Galvan-Ampudia and Testerink, 2011). Rubinigg, *et al.* (2004) reported that primary root length was not affected in *Plantago maritima* under lower level of salinity, whereas the lateral root length was stimulated at lower salinity level and was reduced at higher salinity of 200 mM NaCl. Gersani *et al.* (1993) reported that the length of tap root, initiation and length of lateral roots, total root dry weight and surface area (contributed mainly by the primary lateral roots as compared to main roots) inhibition, accompanied with the decrease in carbon accumulation and increase in the rate of respiration in *Opuntia ficus-indica* roots with increase in salinity level. It was suggested that carbon assimilates were used for adjustment to high salinity rather than root surface area.

It might be noted that above mentioned study of comparative performance of roots is for growth period of thirty five days only in a plastic bag of eighteen inches height. Their growth pattern in field could be different. Furthermore the pattern of further growth of roots would also depend upon life form (e.g. trees, shrubs, herbs) of

the species.

Regarding the biomass of roots under various salinity levels, *G. hirsutum* seedlings showed promotion at low salinity but inhibition at higher salinity levels as compared to control. Jafri and Ahmad (1994). *K. virginica* and *T. populnea* seedlings showed reduction at both the salinity levels. Blits and Gallagher (1990 b) showed that the growth of *K. virginica* in terms of fresh and dry root biomass remained unaffected at low salinity and was inhibited at NaCl concentration higher than 85 mol m^{-3} An inhibition has been reported beyond control, in root dry biomass of *Atriplex patula* (Unger, 1996), and in fresh and dry weight of Bermuda grass (Pessarakli and Touchane, 2006).

All the three plants showed a gradual decrease in shoot biomass with increase in salinity of root medium. Decrease in shoot weights of different cultivars of cotton has been reported (Jafri and Ahmed, 1994; Gohar *et al.*, 2003; Ibrahim *et al.*, 2007). Reduction in shoot biomass was associated with reduction in leaf area and chlorophyll content of cotton genotypes which ultimately effects photosynthesis (Akhtar *et al.*, 2010). Inhibition of growth have been reported in salinized cultures of *K. virginica* (Blits *et al.* 1993) and decrease in dry weight and RGR of salinized callus of *K. virginica* (Li, *et al.*, 2006). Blits and Gallagher (1990) reported decrease in shoot biomass of *K. virginica* as well, under saline environment and showed that reduction in shoot biomass was partly due to reduced leaf area per plant and decrease in production of new leaves in NaCl treated *K. virginica* plants.

Adverse effect of salinity was more pronounced on shoot as compared to roots in all the three plants in present study. Brugnoli and Bjorkman (1992) reported decreased in relative growth rate, assimilation rate and leaf area per dry weight of cotton under saline condition and mainly the reduction in growth was due to the decreased allocation of carbon to leaf growth as compared to the root growth. Relatively lesser inhibition of root development as compared to shoot development has also been attributed to more accumulation of Na^+ in the shoot than in the roots (Jaffri and Ahmed, 1994).

Decrease in shoot height under salinity has been reported in different cotton genotypes (Basal, 2010). Jafri and Ahmad (1995) exhibited delay in leaf development and decrease in leaf area in *G. hirsutum*. Inhibition in leaf size and number of leaves and seedling growth and alteration in different physiological characteristics under salt stress have been reported in *K. virginica* (Zhou *et al*., 2010) and Shoot elongation of *Spartina patens* (Wu *et al.*, 1998). Salinity led the two phase growth response. The first phase response of salinity is reduction in root and leaf growth which is considered an osmotic effect and the second phase response is due to internal injury (Munns, 2002), where adverse effect of salinity are more pronounced on leaf growth as compared to root growth.

Increase in uptake of Na^+ in all the three species was proportional to increase in the salinity of the rooting medium. In *G. hirsutum*, K^+ uptake was not much affected by salinity up to certain level (0.5%, EC_{iw}: 6.2 $dS.m^{-1}$ sea salt) but slightly increased, at 1.0% (EC_{iw}: 12.95 $dS.m^{-1}$) salinity it decreased. Jafri and Ahmed (1994) have also reported increase in the uptake of Na^+ with increasing salinity in different cotton cultivars including *G. hirsutum* cv. NIAB 78, and decrease in uptake of K^+ at 1.0% salinity and suggested that higher affinity for K^+ in *G. hirsutum* managed to keep the higher K^+/Na^+ ratio even at 1.0% salinity in spite of greater Na^+ uptake. Some studies have shown that a high level of potassium in plants is also associated with salt tolerance (Volkmar *et al.*, 1998). In *G. hirsutum* the salt tolerance is related in part to root based K^+/Na^+ selectivity (Laüchli and Stelter, 1982). Ruan *et al.* (2005) showed that K^+/Na^+ ratio was lower in roots of *K. virginica* and it increased from root to leaves. In *T. populnea* K^+ content increased at 0.5%, (EC_{iw}: 6.2 $dS.m^{-1}$) sea salt and slightly decreased at 1.0% (EC_{iw}: 12.95 $dS.m^{-1}$) sea salt level which shows a greater affinity for K^+ and maintainance of high K^+/Na^+ ratio in root under saline condition Halophytes show diversity of growth responses to increasing salinity and show different mechanisms of uptake and regulate cellular Na^+, K^+ and Cl^- and formation of compatible solutes to adjust the external water potential (Flower and Colmer, 2008).

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