Pak. J. Bot., 35(5): 949-959, 2003.

GROWTH AND DEVELOPMENT OF COTTON ROOTS AT VARIOUS SOIL TEXTURES UNDER SALINE CONDITIONS

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Abstract

The effect of sandy and clayey loams was studied on the growth and development of roots of cotton seedlings at different soil salinity levels. Plastic bags were filled with soils of different textures and made saline with 0.4 % (EC 4.44 dS/m in sandy loam, 5.45 dS/m in clayey loam) and 0.8 % (EC 8.2 dS/m in sandy loam, 9.05 dS/m in clay loam) dilutions of sea salt. Seven days old seedlings were transplanted in these plastic bags and allowed to grow for forty days. The soil was later washed out from the roots very carefully leaving undamaged root system at sieve, which was examined thoroughly. Roots were found thicker in clayey loam as compared to sandy loam, but in both the cases root thickness decreased with an increase in salinity. Primary roots were longer in sandy loam in control and 0.4 % soil salinity, but at 0.8 % soil salinity it was longer in clayey loam. Number of secondary roots was comparatively more in sandy loam at 0.4 % salinity treatment, but at 0.8 % salinity treatment it was more in clayey loam. Average length of secondary roots was longer in clayey loam. Tertiary root development was much more in clayey loam but decreased with the increasing salinity in both the soil textures. Root and shoot biomass, height of seedlings and number of leaves were comparatively more in clayey loam. Salinity did affect the shoot growth but over all it was much better in clayey loam, in above mentioned range of salinity than that of sandy loam

Introduction

Soil solution is the most important immediate source of nutrients for absorption by the roots. Since the mineral elements essential for the growth of plants are taken from the soil solution, absorbing organs (roots) are reported to penetrate through the whole mass of the soil bringing the large possible surface into intimate contact with the soil matrix (Epstein, 1971). Soil textures present a variety of mineral environment for absorption from roots and they also differ in their resistance to root penetration. Mechanical impedance refers to the resistance offered by the soil matrix against root development: it permits root elongation only to the extent that the root pressure exceeds the mechanical impedance (Boone & Veen, 1982; Nadian *et al.*, 1996). Changes in mechanical impedance through the rooting zone can modify root growth and distribution (Shierlaw & Alston, 1984). Salinity has been reported to affect the root growth, lateral root formation and the rate of their development (El-Saidi, 1997). The cotton plant has, in general, a fairly slender tap root, the size of which depends on the soil environment, such as physical texture, fertility, soil temperature and the amount of moisture (Afzal, 1969).

Root morphology is said to be dependent upon the total surface area of root system that is exposed to salinity (Barber & Silberbush 1984). It is further governed by the soil texture and the degree of salinity in rhizosphere. The effect of different soil textures supplemented with different levels of salinity have been investigated on the morphology of cotton roots in present studies.

Materials and Methods

Since cotton is quite susceptible to salinity at germination stage and it is not possible to obtain good sized healthy seedlings at soil of higher salinities (Abdullah & Ahmed, 1986), hence the seeds were, to start with, sown at non saline soils of various textures and the seedlings obtained were exposed to various levels of salinities at later stages. Cotton seeds (*Gossypium hirsutum* L. cv. Nayab-78) were germinated in non saline soils of different textures (*i.e.* sandy and clayey loams) kept in small plastic bags and irrigated with tape water to obtain the seedlings of the same size for all salinity treatments. Seven days old seedlings were transplanted in large plastic bags containing the soil of same textures in which seedlings were raised. The soil was irrigated up to field capacity level with solutions of 0.4 % sea salt (EC 4.44 dS/m in sandy loam, 5.45 dS/m in clayey loam) and 0.8 % sea salt (EC 8.2 dS/m in sandy loam, 9.05 dS/m in clay loam). Farmyard manure (FYM) was mixed in 9:1 ratio. The seedlings were irrigated with just sufficient amount of non-saline water at regular intervals to avoid water logged conditions. Three replicates were made each for control (non-saline) and salinity treatments in both the kinds of soil in order to study growth of root system. Plastic bags containing forty days old seedlings were placed on a plastic tray having perforated sieve bottom, and root system was cleaned without damage by washing out soil particles under tap water. The roots without any soil particles were dried on a blotting paper and photosate were made on graph paper, length and diameter of tap roots were measured. Numbers of secondary and tertiary roots were counted. Number of leaves, plant height and biomass of seedlings grown under various salinity levels were also noted to correlate with the root growth.

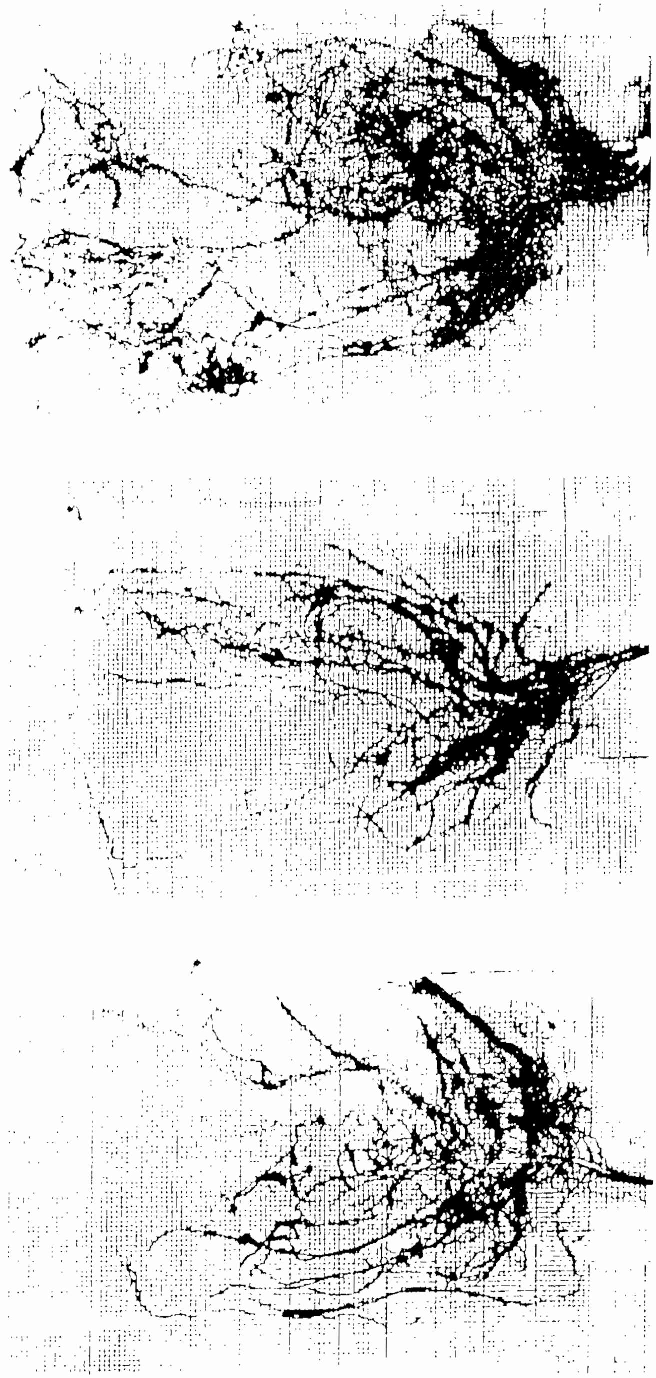
Statistical analysis of the data was carried out as outlined by Little & Hills (1975) and Gomez & Gomez (1976). Data were analyzed using a computer program Costat 3.03. Mean separation of data was carried out using Duncan's Multiple Range test (Duncan, 1955).

Results

***a) Root biomass*:** Growth of cotton seedlings in term of root biomass production at different soil textures and different salinity levels is presented in Figs. 1 & 2. It showed non-significant reduction in fresh weight and significant ($P<0.05$) reduction in dry biomass production, with increase in soil salinity in both the soil textures. Root biomass is more in clayey loam as compared to that of sandy loam.

b) Diameter of primary root: Primary root thickness of cotton seedlings grown in different soil textures and salinity levels is presented in Table 1. The diameter of primary root in clayey loam was greater than that in sandy loam irrespective of saline or non-saline conditions. In sandy loam root thickness significantly ($P<0.05$) decreased in saline soil as compared to the control but there was no difference in root thickness between different salinity levels. In clayey loam, there was a significant ($P<0.05$) decrease in root thickness with increase in the soil salinity level.

***c) Primary root length*:** Primary root length of forty days old cotton seedlings grown in different soil textures and salinity levels are given in the Table 1. Average primary root length decreased with increase in soil salinity in sandy loam. In clayey loam primary root



Sandy loan (Control)
Root biomass (g)
Fresh wt. 10.16
Dry wt. 0.53

Sandy loan (0.4 % sea salt)
Root biomass (g)
Fresh wt. 5.08
Dry wt. 0.42

Sandy loan (0.8 % sea salt)
Root biomass (g)
Fresh wt. 4.53
Dry wt. 0.33

Fig. 1. Root growth of forty days old seedlings grown in sandy loam amended with various levels of soil salinity.

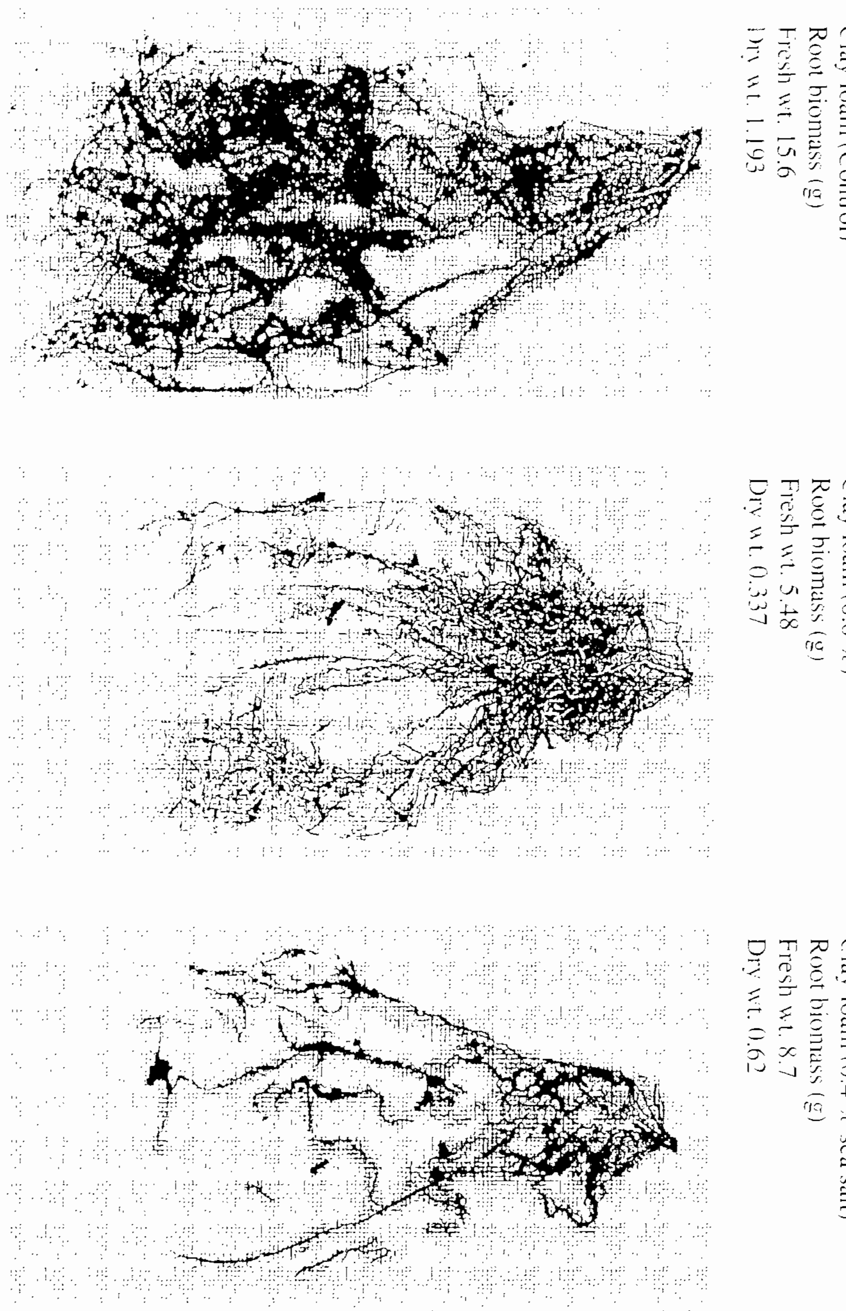


Fig. 2. Root growth of forty days old seedlings grown in clayey loam amended with various levels of soil salinity.

Table 1. Development of root system of cotton seedlings under different soil texture at various salinity levels.

Treatments	Primary root thickness		Primary root length		Number of sec. roots		Number of tertiary roots	
	Sandy loam	Clayey loam	Sandy loam	Clayey loam	Sandy loam	Clayey loam	Sandy loam	Clayey loam
Control	0.55 a	0.77 a	42.85 a	39.50 a	52.00 a	52.00 a	467.50 a	644.00 a
	±0.05	±0.025	±5.350	±4.5	±4	±1.0	±14.5	±73
0.4 %	0.40 b	0.65 a	39.00 ab	27.70 a	56.50 a	43.50 ab	285.50 b	437.50 b
(Sea Salt)	0	±0.050	±3.100	±1.899	±3.5	±6.5	±11.5	±14.5
	(-27.273)	(-16.129)	(-8.985)	(-29.873)	(+8.654)	(-16.346)	(-38.390)	(-32.065)
0.8 %	0.41 b	0.50 b	21.35 b	27.30 a	28.00 b	33.50 b	244.50 b	282.50 b
(Sea Salt)	±0.009	0	±3.649	±0.799	±6	±2.5	±63.5	±7.5
	(-25.455)	(-35.484)	(-50.175)	(-30.886)	(-46.154)	(-35.577)	(-47.701)	(-56.134)
$LSD_{0.05}$	0.132	0.145	18.657	12.861	20.828	18.281	171.866	194.[illegible]

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

Figures in parentheses indicate % promotion (+) and reduction (-) over control.

length decreased in saline soil as compared to control (non-saline) but there was no difference in primary root length at two soil salinity levels. In non-saline and 0.4 % saline treatment the primary root length is more in sandy loam than in clay loam, but it is more in clay loam at highest salinity level.

***d) Number of secondary roots*:** Number of secondary roots in forty days old cotton seedlings in both the textures remained almost same under control (non-saline) conditions. In sandy loam, number of secondary roots increased in 0.4 % salinity treatment but decreased in 0.8 % saline treatment as compared to control. In clay loam there is a gradual significant decrease ($P<0.05$) in the development of secondary roots with the increasing soil salinity level. The number of secondary roots is comparatively more in 0.4 % saline treatments in sandy loam than that in clay loam, but it is more in clayey loam in 0.8 % saline treatment than that in sandy loam.

***e) Length of secondary roots*:** Length of secondary roots decreased in saline soil as compared to non-saline soil in both the soil textures (Fig. 4). In non-saline and 0.4 % saline clayey loam secondary roots were longer than those at these salinity levels in sandy loam. The bulk of secondary roots of longer length arise from 1st five centimeters of tap root (from ground level) in clay loam, whereas in sandy loam they keep on arising up to ten centimeters. Secondary roots are longer in sandy loam than the secondary roots in clayey loam at highest salinity level.

***f) Number of tertiary roots*:** There is a gradual significant decrease ($P<0.05$) in number of tertiary roots with increase in soil salinity level in both the soil textures (Table 1). Number of tertiary roots is more in clayey loam as compared to the sandy loam.

***g) Shoot biomass*:** Shoot biomass showed significant reduction ($P<0.001$) with increasing salinity levels in both the soil textures. In clayey loam seedlings showed more fresh and dry shoot biomass production at all soil salinity levels than those in sandy loam (Fig. 3).

***h) Plant height*:** Height of forty days old seedlings, significantly decreased ($P<0.001$) with increase in soil salinity level in both the soil textures (Fig. 5). Plant height was more in clayey loam as compared to the plant height in sandy loam at all salinity levels.

***i) Number of Leaves per plant*:** The number of leaves per plant significantly decreased ($P<0.01$) in saline soil in both the soil textures. Number of leaves per plant was greater in clayey loam in non-saline as well as in 0.4 % salinity level than the number of leaves per plant in non-saline sandy loam.

Discussion

Reduction in root biomass, primary root thickness, primary and secondary root length and the development of the tertiary roots was noticed at saline soil as compared to control (non-saline soil) in both the soil textures, except that of development of secondary root at 0.4 % salinity level in sandy loam. Salinity affects the root growth by inhibiting their initiation and development. Initiation of lateral roots is comparatively less affected by the salinity, whereas their elongation seems to be the most sensitive process (Waisel, 1991). Inhibition of the subsequent growth of lateral roots would reduce the horizontal spread of the root system of salt affected plant and compel them to depend on the deep soil layers for supply of water and nutrients (El-Saidi, 1997).

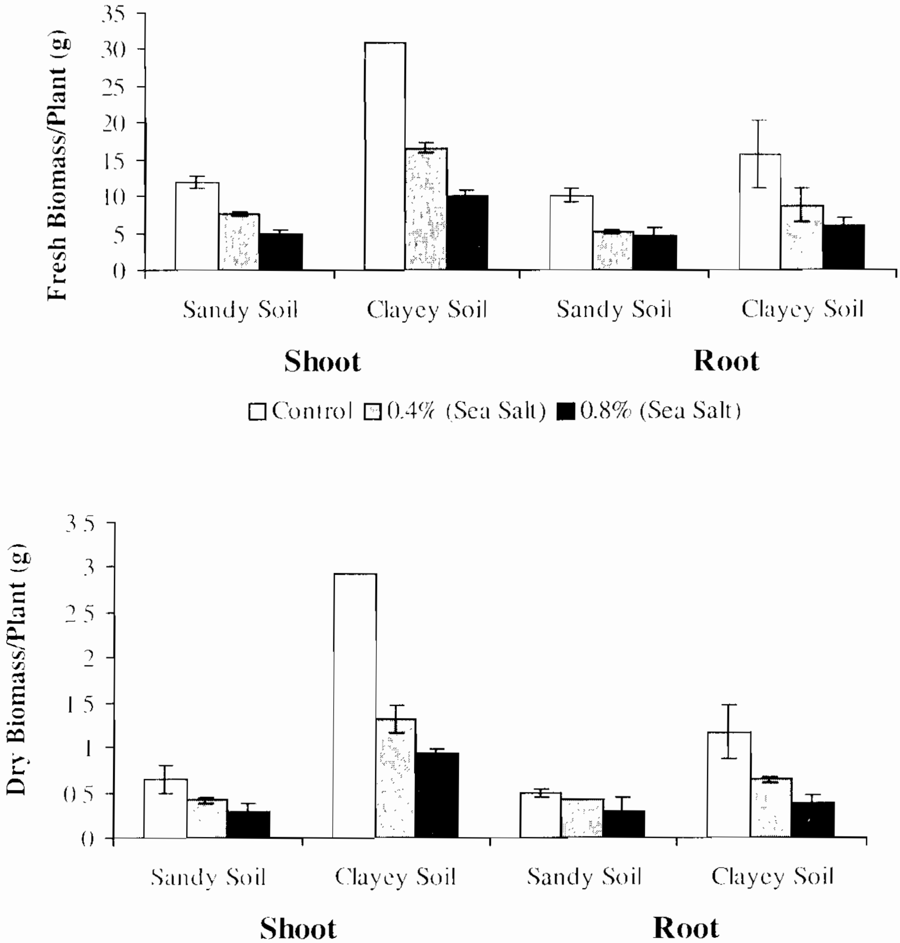


Fig. 3. Biomass of cotton seedlings under different soil textures at various soil salinity levels.

Soil texture had marked effect on root morphology of plants. In sandy loam primary roots are longer than those in clayey loam in control (non-saline) and 0.4 % soil salinity level. Soil compaction is known to reduce root elongation (Barley, 1965; Taylor & Ratliff, 1969). Montague *et al.* (2001) are of the opinion that position of localized soil compaction determines root and subsequent shoot growth responses. Primary roots in clayey loam in present investigation were found thicker, secondary roots longer with significant increase in the formation of tertiary roots. The change in the morphology of cotton seedlings grown in clayey loam was probably caused by the higher mechanical impedance of clayey loam due to more compactness, as compared to the sandy loam. The pressure exerted by the soil particles on the large elongating primary roots probably stimulates the formation of small tertiary roots which are able to grow between soil particles (Gross, 1977; Veen, 1982).

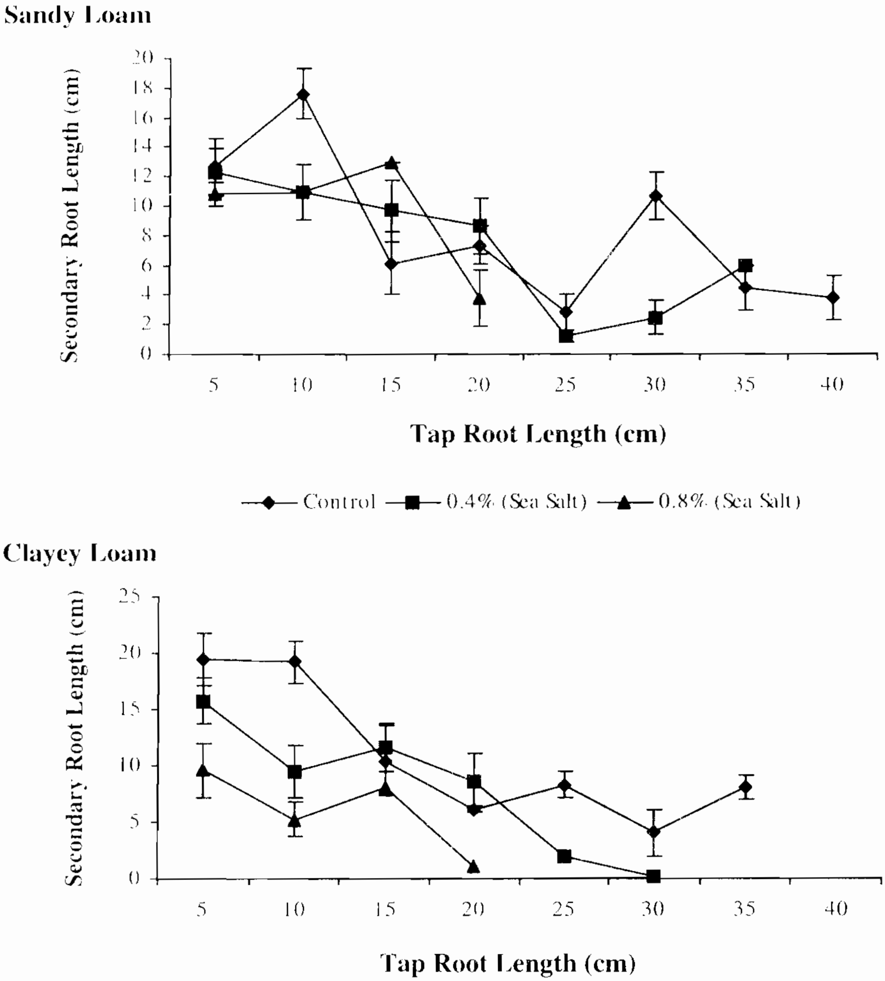


Fig. 4. Average length of secondary roots of 40 days old cotton seedlings in soils of different textures amended with various levels of soil salinity.

There appear reductions in plant height, number of leaves and shoot biomass under saline conditions in both the soil textures. Plant growth in glycophytes is generally reduced by the salinity even at lower level (Greenway & Munns, 1980). The reduction in growth is the consequence of several physiological responses, including ionic imbalance, water status (physiological drought), stomatal behavior, photosynthetic efficiency, carbon allocation and utilization (Flowers *et al.*, 1977; Greenway & Munns, 1980; Munns & Termatt, 1986; Munns, 1993). Salinity influences several vital processes of plant growth such as nutrient uptake (Alam, 1990; Yang *et al.*, 1990), protein and nucleic acid synthesis (Hurkman & Tanaka, 1987; Hurkman *et al.*, 1988), photosynthesis (Hasio, 1973), hormonal balance, enzyme activities and their interactions (Reddy, 1985).

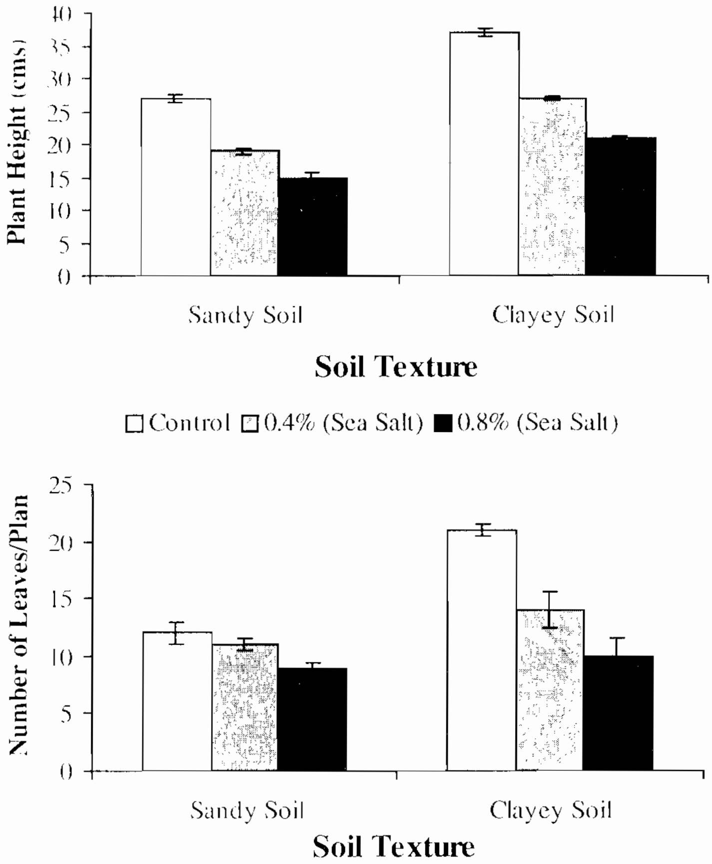


Fig. 5. Plant height and number of leaves per plant of cotton seedlings in soils of different texture and amended with various levels of soil salinity.

Soil texture had significant effect on seedling growth. There was 35.11 % promotion in fresh biomass of roots, 61.35 % promotion in fresh biomass of shoot, 29.1 % promotion in plant height and 41.46 % promotion in number of leaves in clayey loam as compared to the sandy loam under non-saline condition. Significant promotion was also observed in all the above-mentioned parameters in both the salinity levels in clayey loam in comparison with sandy loam.

Clayey loam appears to be promoting root as well as shoot growth even under different salinity levels. Availability of essential mineral elements for plant growth and capability of moisture retention is higher in clay. However, higher concentrations of salt under clayey loam (beyond the salinity levels taken for present investigations) could be inhibitory for plant growth since it is capable of retaining salts in greater concentrations in soil matrix in comparison with sandy loam due to obvious differences in textures.

References

Abdullah, Z. and R. Ahmed. 1986. Salinity induced changes in the reproductive physiology of cotton plants. In: *Prospects for Biosaline Research*. (Eds.): R. Ahmed & A.S. Pietro. Univ. Karachi, Karachi, p. 125-137.

Afzal, M. 1969. The root system of cotton. In: *The Cotton Plant in Pakistan*. Pak. Cent. Cotton Commi., Karachi, p. 36-46.

Alam, S. M. 1990. Effect of salinity stress on growth, yield and chemical composition of rice. *Pak. J. Sci. Ind. Res.*, 33: 292.

Barber, S.A. and M. Silbarbush. 1984. Plant root morphology and nutrient uptake. In: *Roots, Nutrient and Water Influx and Plant Growth*. (Eds.): S.A. Barber and D.R. Bouldin. American Society of Agronomy: Medicine, p. 65-87.

Barley, K.P. 1965. The effect of localized pressure on the growth of the maize radical. *Aus. J. Biol. Sci.*, 18: 499-503.

Boone, F.R. and B.W. Veen. 1982. The influence of mechanical resistance and phosphate supply on morphology and function of maize roots. *Neth. J. Agric. Sci.*, 30: 179-192.

Duncan, D.B. 1955. Multiple range and multiple F-test. *Biometrics*, 11: I-42.

El-Saidi, M.T. 1997. Salinity and its effect on growth, yield and some physiological processes of crop plants. In: *Strategies for Improving Salt Tolerance in Higher Plants*. (Eds.): P.K. Jaiwal, R.P. Singh and A. Gulati, Oxford & IBH Publishing, New Delhi, p. 111-127.

Epstein, E. 1971. The media of plant nutrition. In: *Mineral Nutrition of Plants: Principles and Perspectives*. (Ed.): Epstein. E., John Wiley, New York, p. 29-49.

Flowers, T.J., P.F. Troke and A.R. Yeo. 1977. The mechanism of salt tolerance in halophytes. *Ann. Rev. Plant Physiol.*, 28: 89-121.

Gomez, K.A. and A.A. Gomez. 1976. *Statistical Procedures for Agricultural Research with Emphasis on Rice*. International Rice Res. Ins., Los Banos, Phillipines, 294 pp.

Greenway, H. and R. Munns. 1980. Mechanism of salt tolerance in non halophytes. *Ann. Rev. Plant Physiol.*, 31: 149-190.

Gross, M.J. 1977. Effects of mechanical impedance on root growth in barley *Hordium vulgare* L. *J. Exp. Bot.*, 28: 96-111.

Hasio, T.C. 1973. Plant response to water stress. *Ann. Rev. Plant Physiol.*, 24: 519-534.

Hurkman, W.J. and C.K. Tanaka. 1987. The effect of salt on the pattern of protein synthesis in barley roots. *Plant Physiol.*, 83: 517-524.

Hurkman, W.J., C.H.K. Tanaka and F.M. Dupont. 1988. The effect of salt stress on poly peptides in membrane fractions from barley roots. *Plant Physiol.*, 88: 1263-1273.

Little, T.M. and F.J. Hills. 1975. *Statistical Methods in Agricultural Research*. Univ. California. 242 pp.

Montague, K.D., J.P. Conroy and B.J. Atwell. 2001. The position of the localized soil compaction determines root and subsequent shoot growth responses. *J. Exp. Bot.*, 52: 2127-2133.

Munns, R. 1993. Physiological processes limiting plant growth in saline soils, some dogma and hypothesis. *Plant Cell & Environ.*, 16: 15-24.

Munns, R. and A. Termatt. 1986. Whole plant responses to salinity. *Aust. J. Plant Physiol.*, 13: 143-160.

Nadian, H., S.E. Smith, A.M. Alston and R.S. Murray. 1996. The effect of soil compaction on growth and P uptake by *Trifolium subperraneum*: interactions with mycorrhizal colonisation. *Plant Soil*, 182: 39-49.

Reddy, M.P. 1985. Sodium chloride salinity induced metabolic changes in bajra *Pennisatum typhoids*. Ph. D. thesis, Gujrat University, Ahmedabad

Shierlaw, J. and A.M. Alston. 1984. Effect of soil compaction on root growth and uptake of phosphorus. *Plant Soil*, 77:15-28.

Taylor, H.M. and L.F. Ratliff. 1969. Root elongation rates of cotton and peanuts as a function of soil strength and soil water content. *Soil Sci.*, 108: 113-119.

Veen, B.W. 1982. The influence of mechanical impedance on the growth of maize roots. *Plant & Soil*, 66: 101-109.

Waisel, Y. 1991. Adaptation to salinity. In: *Physiology of Trees*. (Ed.): A.S. Rahavendro, John Willey, New York, p. 359-383.

Yang, Y.W., R.J. Newton and F.R. Miller. 1991. Salinity tolerance in sorgham. I. Whole plant responses to sodium chloride in *Dorghum bicolor* and *Sorghum halepenes*. *Agron J.*, 30: 775.