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AT THE WORKSHOP

"TREE PRODUCTION FROM SALINE, SODIC & WATERLOGGED SOILS"

FAISALABAD, DECEMBER 1990

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FOREWORD

This work shop was held from December 1 to 6, 1990, at Faisalabad. The objective of the workshop was to present the "state of the art" knowledge concerning the establishment of tree species on saline, sodic and waterlogged sites. The materials covered were both the biological and physical concepts needed to successfully establish trees and shrubs on saline, sodic and waterlogged soils. The workshop was a summarization of knowledge gained from technical journals, recent research, seminars and first hand experiences in problem areas of Australia. These materials were purposely presented in the form of concepts and illustrated by examples from many parts of the world. The workshop materials have been assembled into a manual "A Guide to Tree Planting on Saline, Sodic and Waterlogged Soils" available from The Forestry Planning and Development Project, USAID Islamabad.

Although the concepts of producing trees on saline, sodic and waterlogged sites are basically the same, regardless of geographic location; specific examples of work done by Pakistanis served to reinforce the concepts presented in the workshop. During the course of the workshop, a number of Pakistani scientists volunteered to present papers germane to the workshop objectives. This document represents a compilation of those papers. These papers emphasize both soil and plant relations specific to Pakistan; it was felt that these papers should be made available also.

We thank the authors who gave generously of their time in the preparation and presentation of these papers, and to Tahir Wadood Malik of Winrock International, Islamabad, for compiling/assembling the documents in book form.

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INTRODUCTION OF AUSTRALIAN SALT TOLERANT WOODY SPECIES IN SALT AFFECTED AREA OF SHORKOT IRRIGATED PLANTATION.

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INTRODUCTION

Land in Pakistan is constantly being removed from cultivation due to the twin menace of salinization and waterlogging. The physical-chemical properties of saline soil are adverse for plant growth. These salt affected soils will retard growth or even kill the plants. Besides the toxic effects, the salts render the soil impermeable to water, reduce organic matter & biological activity. According to one estimate, the extent of salt affected arable area in Pakistan is 13 million acres. Out of this, 4.7 million acres is saline, 7.2 million acres saline sodic and 0.96 million acres gypsiferous saline. The reclamation of these areas is very expensive and time consuming and therefore, complete reclamation cannot be achieved within foreseeable future. One of the methods to rehabilitate these areas is growing of salt tolerant trees which also help in biological amelioration of the soil.

Seeds of 26 different tree species and provenances of salt tolerant trees were received from Australian Tree Seed Center of the Commonwealth Scientific and Industrial Research Organization during January and March 1990 for the establishment of a species trial in salt affected areas of Shorkot Plantation. Replications of this species trial will be planted in other parts of Pakistan by other cooperators i.e., Pakistan Forest Institute (PFI), Pakistan Agriculture Research Council (PARC), etc.

REVIEW LITERATURE:

It seems that a lasting solution of salinity and waterlogging problem will take a long time. We may have to learn to live with salinity and find ways to utilize the affected land fruitfully. (Malik et al., 1986).

Bangash (1977) reported that under experimental conditions *Zizyphus jujuba*, *Albizzia lebbek* and *Acacia arabica* were the most salt tolerant of the six species grown under salt concentration which varied from 0.05% to 0.80%. The other species included in the experiment were *Parkinsonia aculeata*, *Prosopis spicigera* and *Rubinia pseudoacacia*. Sheikh (1974) reported that *Acacia arabica*, *Populus euphratica*, *Eucalyptus camaldulensis*, *Eucalyptus robusta* and *Eucalyptus rudis* could be successfully planted on waterlogging and saline sites. Sheikh et al., (1983), reported a planting site

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where pH varied from 8.2 to 9.5 and with an electrical conductivity range (mmhos/cm) from 2.7 to 28.0, the survival after one growing season was 53% for Tamarix articulata, 44% for Eucalyptus camaldulensis and 43% for Prosopis juliflora. (Gogate 1984) studied germination trials of a number of Australian species. Treatments consisted growing species with salts concentrations of 0.2, 0.6 and 1.0%, and electrical conductivities of 2.2, 5.0 and 15.0 (mmhos) respectively. He observed that the germination of seeds of Casuarina cristata was 33%, Casuarina cunninghamiana was 0%, Casuarina obesa was 20%, Melaleuca glomerata was 0% and Acacia nilotica was 30%. He concluded that Casuarina obesa and Casuarina cristata, were the most promising species for saline areas.

MATERIALS AND METHODS:

Nursery phase:

Seeds of 26 species and provenances of Australian salt tolerant trees were sown in the nursery after the required pre-treatment in the month of February and April, 1990. Seeds of Eucalyptus, Casuarina and Melaleucas were first sown in earthen containers and then transferred in polyethylene bags when these were fit for pricking. These plants were grown in the nursery up to September 1990.

Field Planting Phase:

Planting of 21 Australian species and provenances and two indigenous species was carried out in the salt affected areas of compartment No. 53 of Shorkot Irrigated Plantation during September 1990. The soil of this area was found to be salt affected but free from sodicity. Its upper 30 cm layer had pH value varied from 7.9 to 8.4. The quantity of total soluble salts ranged from 0.27% to 2.56%. The planting was done along trenches in holes 23 cm's deep and 2 meter apart, (trenches were dug to carry water to the plants). A complete randomized block design with 3 replications was used. Each plot had five row with five plants per row and the total number of plants was 1,725. Dead seedlings were replaced one month after planting in October, 1990. The details of plant restocking is given in table 2.

RESULTS AND DISCUSSION:

Nursery Phase:

The survival percentage of seedlings after 4 months of sowing and pricking was highest in Casuarina glaua (87%) followed by Casuarina equisetifolia provenance 14194 (84.9%) and Eucalyptus camaldulensis provenance 15441 (83.7%). The seed of Melaleuca cajuputi germinated very well but all the seedlings died later on.

Table 1 gives the germination results:

TABLE 1. SHOWING GERMINATION AND SURVIVAL PERCENTAGE OF VARIOUS SPECIES.

Serial	Seed lot No.	Species	Seeds Germinated	Plants Survived	(%)
1.	17209	Acacia victoriae	250	138	55.2
2.	16484	A. auriculiformis	210	161	76.6
3.	15774	A. sclerosperma	176	100	56.8
4.	15762	A. ampliceps	285	167	58.5
5.	15795	A. saligna	310	220	70.9
6.	11690	A. baileyana	20	-	-
7.	16648	A. salicina	225	143	63.5
8.	14670	A. stenophylla	50	10	38.0
9.	17062	Sesbania formosa	530	134	25.2
10.	15441	Eucalyptus camaldulensis	1598	1338	83.7
11.	15068	E. microtheca	540	341	63.1
12.	14847	E. camaldulensis	1288	484	37.5
13.	15391	E. rudis	1290	566	43.9
14.	15377	E. occidentalis	252	175	69.4
15.	15940	E. robusta	468	45	9.0
16.	17255	Melaleuca bracteata	2550	700	27.4
17.	14878	M. cajuputi	462	-	-
18.	14147	M. leucadendra	2600	1380	53.0
19.	15045	M. halmaturorum	250	100	4.0
20.	15429	M. glomerata	300	156	52.0
21.	14100	Casuarina obesa	200	146	73.0
22.	14194	C. equisetifolia	900	763	84.0
23.	16796	C. obesa	2280	1732	75.9
24.	15941	C. glauca	932	820	87.9
25.	16511	C. cunninghamiana	1740	615	35.3

Field Planting Phase:

It is too early to draw any inference from the field planting of Australian salt tolerant woody species because the plants were transplanted in the field just about 2 months ago. However it will be interesting to note the initial growth and success percentage of field planting.

Table 2. PLANT RESTOCKING AND AVERAGE HEIGHT - DATA

Species	Seed lot	Plants initially Planted (No.)	Plants restocked (No.)	Survival after restocking (%)	Average height (m)
T1 A. ampliceps	15762	75	42	25.92	0.37
T2 A. auriculiformis	16484	75	9	90.00	0.42
T3 A. salicina	16648	75	11	96.00	0.46
T4 A. saligna	15795	75	17	92.59	0.46
T5 A. sclerosperma	15774	75	-	37.00	0.40
T6 A. victoriae	17209	75	35	29.62	0.30
T7 E. microtheca	15069	75	4	92.59	0.61
T8 E. camaldulensis	15411	75	4	96.36	0.98
T9 E. camaldulensis	14847	75	13	96.29	0.79
T10 E. rudis	15391	75	10	92.58	0.53
T11 E. occidentalis	15377	75	25	77.77	0.52
T12 E. melaleucaden	14147	75	2	96.20	0.68
T13 M. bracteata	17255	75	12	96.29	0.40
T14 M. halmaturorum	15045	75	4	77.77	0.34
T15 C. obesa	15796	75	4	100.00	0.40
T16 C. glauca	15941	75	2	96.29	0.57
T17 C. cunninghamiana	16511	75	2	100.00	0.65
T18 C. equisetifolia	14194	75	12	100.00	0.45
T19 C. obesa	14100	75	7	100.00	0.13
T20 S. formosa	17062	75	27	22.22	0.55
T21 M. lanceolata	15387	75	15	100.00	0.32
T22 T. arjuna	-	75	4	100.00	0.37
T23 T. articulata	-	75	9	100.00	0.50

A hundred percent survival was obtained with following Australian species (Table 2) Casuarina obesa, Casuarina cunninghamiana, Casuarina equisetifolia, Casuarina obesa, Melaluca lanceolata. Two indigenous species, Tamarix articulata and Terminalia arjuna also had a hundred percent survival. The rest of the species had survival rates that varied from 25% to 96%.

FUTURE STRATEGY

This experiment will be maintained for a period of at least five years in its present form. Behavior and growth of these tree species will be monitored along with changes in soil chemistry.

ACKNOWLEDGEMENT:

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EFFECTS OF SOIL SALINITY ON THE EARLY DEVELOPMENT OF THREE IMPORTANT FOREST TREE SPECIES AND TWO PROVENANCES OF *ACACIA NILOTICA*

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INTRODUCTION:

Soil salinity is one of the most harmful factors restricting the economic utilizations and development of available land resources in the world. According to a survey reported by Bohn, et al., (1985), as much as one third of all irrigated lands or approximately 70 million hectares in the world, have been estimated to be salt affected. When the problems of non-irrigated semi-arid and humid regions, mine spoils and waste disposal areas are added to this figure, the magnitude of the world wide salinity problem becomes even more impressive.

The distribution of saline-sodic soils is largely restricted to the extremely arid, arid and semi arid zones, where high evaporation rate favors the upward movement and subsequent accumulation of soluble salts in the surface layers of the soil (Raheja, 1968). As most of Pakistan lies in the arid belt the problem of soil salinity has become a great threat to the economy of the country. The problem has not only rendered thousands of hectares unfit for cultivation but it has also adversely affected the productively of our forests and woodlands. An indication of the severity and extent of salinity problems can be gained from the results of a survey conducted by different agencies in Pakistan. This survey found that about 5.72 million hectares have already become victim of salinity and about a half million hectares are being added to that total every year (Sheikh,1974;Choudhry, et al, 1978).

Although some suitable techniques have been developed for growing agricultural crops on these problem soils, there are, however, large tracts of salt affected soils in Pakistan where growing of agricultural crops is neither feasible nor economical (Framji, 1975). Under such conditions an alternative is to utilize these lands for raising forest plantations. Forest trees, apart from giving direct revenue from the sale of timber and other forest produce, also help in mitigating the salinity problem by improving soil condition, through the addition of organic matter, nitrogen and in reducing the soil's salt content.

OBJECTIVES OF THE STUDY

Due to the harsh properties of salt affected soils, crop growth is reduced or completely limited, and any attempts to crop these degraded lands, is usually not profitable (Framji 1975). In

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1975 Framji divided 107 hectares into 3 plots. Plots 1 represented 65 percent of the area, and was reclaimed by leaching or with soil amendments. Plot 2 represented 30 percent of the area, but was partially reclaimed. Plot 3, represented 5 percent of the area, and was the control. The results revealed that on all lands (reclaimed, partially reclaimed and unreclaimed), costs were higher than returns. Under such conditions, the utilization of these lands to raise forest plantations becomes attractive.

Keeping in view the magnitude of soil salinity problem generally in the world, and specifically in Pakistan, a study of effects of soil salinity on the early development of three important forest tree species and two provenances of Acacia nilotica was planned with an objective:

(a) To identify and compare the performance of selected salt-tolerant tree species that can be grown in these problematic soils.

(b) To assess the relative tolerance of selected species and provenances to different concentrations of sodium chloride (NaCl), sodium sulphate (Na_2SO_4) and sodium bicarbonate ($NaHCO_3$).

(c) To compare the establishment and performance of selected provenances of Acacia nilotica, a native species on salt affected soils.

MATERIALS AND METHODS:

Seeds of selected forest tree species and provenances were collected from natural stands through the courtesy of Pakistan Forest Institute, Peshawer. The study was conducted in plastic pots having 25 cm outside diameter by 10 cm height in a greenhouse. The experimental units (Pots) were lined with plastic sheeting to prevent leaching.

A randomized incomplete block design with three replications was used (Table 1). There were five tree species, three kind of salts, and three levels of each salt plus a control. The total number of pots (treatments) in each replication was 50. Therefore, the total number of experimental units for the whole experiment was 150. Randomization was carried out according to a procedure described by Steel and Torrie (1980). Randomization was repeated three times during the study period by rotating the pots to minimize the local effects in the green house.

To establish salinity levels of sodium chloride (NaCl), sodium sulphate (Na_2SO_4) and sodium bicarbonate ($NaHCO_3$) at 0.25, 0.50 and 0.75 percent by weight, three, six and nine grams respectively of each salt were first weighed and then dissolved in small amounts of

distilled water mixed with 1200 grams of pre-weighed commercial plant medium "PEAT-LITE MIX'. The salinity levels of the saturation extract at the initiation of study were measured using the methods described by Richards, et. al. (1969) (Table 2).

The tree seeds selected for the trial were pre-treated using standard techniques to increase germination (Table 3). Ten treated seeds of each of five tree species were sown directly in the experimental pots with the exception of Eucalyptus camaldulensis. Since the seed of Eucalyptus camaldulensis was very small in size and difficult to count, it was sown in the petri-dishes; the seedling were then transferred to experimental pots as they germinated.

Germination capacity of the seed was determined and used to correct the amount of seed planted. After germination each pot was thinned to one seedling. Each plant was marked with black water-proof ink to retain its identity and location for making repeated measurements of height and diameter. Measurements of height and diameter were made at fifteen days intervals.

Soils moisture contents (approximately field capacity) and salinity levels were maintained at constant levels throughout the study by adding distilled water daily. The temperature was maintained at about 78° F during the period of investigation. To prevent plants from breaking and lodging, bamboo plant support sticks were used for support. An insecticide "ISOTOX" was sprayed as needed at the rate of one tablespoon of insecticide to a gallon of distilled water to control damaging insects.

When the plants reached too great a size to be supported by limited food supply in their pots, a final observation was made and the plants harvested. All plant parts were retained for biomass determination. The stems were cut into pieces and placed in paper bags, along with the leaves. The roots cleaned with water over mesh and remaining root materials add to the paper bags. The paper bags labeled and then placed in the drying oven at 70° C for 48 hours or until constant weight was obtained. When the plant tissues were dried properly, they were weighed to the nearest 0.1 mg. Rubber gloves were worn when handling the plants to prevent contamination from body moisture or oils and consequent weighing errors. Oven dried shoot and root weights were separately measured and used to calculate total biomass and shoot-root ratios of each plant.

Analysis of variance (ANOVA) was performed on seed germination, height growth, diameter growth, total biomass production and shoot-root ratio data by using computer programme"SPSSX" for each tree species. To determine significant differences among treatment means the LSD (Least Significant Difference) test was applied at the five percent confidence level (Steel and Torrie, 1980).

Table 1. Details of treatments in each replication

Tree Species	TREATMENTS Salt concentrations 0	0.25	0.50	0.75
T_1	T_1SL_0	$T_1S_1L_1$ $T_1S_2L_1$ $T_1S_3L_1$	$T_1S_1L_2$ $T_1S_2L_2$ $T_1S_3L_2$	$T_1S_1L_3$* $T_1S_2L_3$ $T_1S_3L_3$
T_2	T_2SL_0	$T_2S_1L_1$ $T_2S_2L_1$ $T_2S_3L_1$	$T_2S_1L_2$ $T_2S_2L_2$ $T_2S_3L_2$	$T_2S_1L_3$ $T_2S_2L_3$ $T_2S_3L_3$
T_3	T_3SL_0	$T_3S_1L_1$ $T_3S_2L_1$ $T_3S_3L_1$	$T_3S_1L_2$ $T_3S_2L_2$ $T_3S_3L_2$	$T_3S_1L_3$ $T_3S_2L_3$ $T_3S_3L_3$
T_4	T_4SL_0	$T_4S_1L_1$ $T_4S_2L_1$ $T_4S_3L_1$	$T_4S_1L_2$ $T_4S_2L_2$ $T_4S_3L_2$	$T_4S_1L_3$ $T_4S_2L_3$ $T_4S_3L_3$
T_5	T_5SL_0	$T_5S_1L_1$ $T_5S_2L_1$ $T_5S_3L_1$	$T_5S_1L_2$ $T_5S_2L_2$ $T_5S_3L_2$	$T_5S_1L_3$ $T_5S_2L_3$ $T_5S_2L_3$

* T = Tree species
- T_1 = Acacia nilotica (D.I.Khan)
- T_2 = Acacia nilotica (Shorkot)
- T_3 = Eucalyptus camaldulensis
- T_4 = Prosopis juliflora
- T_5 = Albizia lebbek

S = Kind of salt
- S_1 = Sodium chloride (NaCI)
- S_2 = Sodium sulphate (Na_2SO_4)
- S_3 = Sdium bicarbonate ($NaHCO_3$)

L = Levels of salt
- LO = No salt
- L_1 = 0.25% by weight
- L_2 = 0.50% by weight
- L_3 = 0.75% by weight

Table 2. ANALYSIS OF SOIL SATURATION EXTRACT* SAMPLES

Soil sample	Electrical conductivity mmohs/cm
0.25 percent sodium chloride (NaCI)	04.95
0.50 percent sodium chloride (NaCI)	09.40
0.75 percent sodium chloride (NaCI)	14.00
0.25 percent sodium sulphate (Na_2SO_4)	03.85
0.50 percent sodium sulphate (Na_2SO_4)	06.40
0.75 percent sodium sulphate (Na_2SO_4)	08.60
0.25 percent sod bicarbonate ($NaHCO_3$)	02.50
0.50 percent sod bicarbonate ($NaHCO_3$)	04.95
0.75 percent sod bicarbonate ($NaHCO_3$)	06.20

Saturation extract is a solution extracted from a soil at its saturation percentage. Whereas saturation percentage is the moisture percentage of a saturated soil paste expressed on dry-weight basis.

Table 3: Pre-sowing seed treatments

Tree species	Origin Lat	long	Seed treatment
Acacia nilotica (D.I.Khan)	32°N	74°E	The seed was soaked in hot water for 24 hours and then let cooled for 24 hours at room temperature.
Acacia nilotica (Shorkot)	31°N	72°E	Same as for Acacia nilotica (D.I.Khan).
Eucalyptus camaldulensis	32°N	74°E	No seed treatment was made prior to sowing the seed.
Prosopis juliflora (var.glandulosa)	Unknown		Seed was extracted from pods with forceps and then soaked in conc sulfuric acid (H_2SO_4) for 15 minutes.
Albizia lebbek	Unknown		The seeds were taken from pods by hand and then treated with hot water as described for Acacia nilotica (D.I.Khan) earlier.

RESULTS AND DISCUSSION

1. SEED GERMINATION

Analysis of variance (Table 4) indicated that only salt concentration significantly affected seed germination percentage in *Acacia nilotica* (D.I. Khan source), and *Acacia nilotica* (Shorkot source), at five and one percent levels of confidence respectively. Both salts and concentrations differed significantly in *Prosopis juliflora* and *Albizia lebbek* at five and one percent levels of significance respectively. In *Eucalyptus camaldulensis*, none of the treatments, i.e., salts concentrations and their interactions were found to be significant.

Table 4: Analysis of variance for seed germination of selected forest tree species and provenances as affected by salinity

Tree Species	SOV	DOF	S.S	M.S
Acacia nilotica (D.I.Khan)	Salt	2	886.222	443.111
	Conc	3	3300.778	1100.259
	Salt x Conc	6	1025.556	170.926
	Error	24	6464.667	269.361
Acacia nilotica (Shorkot)	Salt	2	932.722	466.361
	Conc	3	5966.083	1988.694
	Salt x Conc	6	770.167	128.361
	Error	24	3891.333	162.139
Eucalyptus camaldulensis	Salt	2	299.056	149.528
	Conc	3	360.306	120.102
	Salt x Conc	6	170.944	28.491
	Error	24	1723.333	71.806
Prosopus juliflora var.glandulosa	Salt	2	667.056	333.528
	Conc	3	7005.639	2335.213
	Salt x Conc	6	288.278	48.046
	Error	24	1517.333	63.222
Albizia lebbek	Salt	2	1112.000	556.000
	Conc	3	5683.333	1894.444
	Salt x Conc	6	1174.000	195.667
	Error	24	2620.667	109.194

* Significant at five percent significance level
** Significant at one percent significance level
N.S. Non-significant

In general, the most detrimental salts in reducing seed germination percentage were found to be sodium chloride and sodium bicarbonate, whereas sodium sulphate was found to be less harmful than former two salts (Table 5). The harmful effects of sodium chloride and sodium bicarbonate as compared to sodium sulphate on seed germination may be attributed to the effects of the Cl ion, the high osmotic potential of sodium chloride salt, and high pH value of a sodium bicarbonate salt in a saturated solution. Experimental work conducted by Richards et al. (1969) at the U.S Salinity Laboratory indicated, that the osmotic potential of a solution largely depends on the kind of salt and its concentration and electrical conductivity (ECe). A solution of sodium chloride will have less osmotic potential (more negative) than a sodium sulphate salt solution. Hence, it would be more difficult for seeds to absorb water for germination and growth in sodium chloride than in the same concentration of sodium sulphate salt.

Table 5. Means for seed germination percentage of selected forest tree species and provenances in sodium chloride(NaCl),sodium sulphate(Na_2SO_4) and sodium bicarbonate($NaHCO_3$) salts mediums

Tree Species	KIND OF SALT		
	Sodium Chloride (NaCl)	Sodium Sulphate (Na_2SO_4)	Sodium bicarbonate ($NaHCO_3$)
	Germination percent		
Acacia nilotica (D. I. Khan)	64.17(a)	71.83(a)	59.33(a)
Acacia nilotica (Shorkot)	79.92(a)	84.50(a)	72.17(a)
Eucalyptus camaldulensis	80.00(a)	85.17(a)	78.42(a)
Prosopis juliflora var. glandulosa	70.58(b)	76.65(a)	66.17(b)
Albizia lebbek	58.33(b)	68.33(a)	55.34(b)

Means followed by the same letter are non-significant at five percent level of significance according to the least significant difference (LSD) test.

From the above results, it is clear, of the species studied, the most tolerant to soil salinity in seed germination percentage is Eucalyptus camaldulensis. The most sensitive tree species, on the other extreme, was found to be Prosopis juliflora. Reduction in seed germination with the increase in salinity level, and species difference in salinity tolerance, have also been found by Bernstein and Hayward (1958); Bender and Ramati (1967); Sheikh (1966); Kaushik, et al.(1969); Bangash(1977); Muthana et al. (1980) and Blake (1981).

Results obtained by Ayers (1952) demonstrated that excess of salts influenced seed germination by diminishing the absorption rate of water or by facilitating the influx of ions in quantities large enough to make them toxic. Both phenomena result in reduction in seed germination percentage and lower rate of seed emergence.

Another negative effect of excess salt is an augmented osmotic potential of the medium. A lowered osmotic potential of the soil solution will decrease the absorption of water by seeds. Hence, reduction in imbibition of water by seeds, and subsequent retardation of plumule and radicle growth in higher concentration of salt solution, can be attributed to the lesser imbibition rate of water along with superimposed specific ion effect.

According to Repp, et al. (1959) adaptation and resistance of plants in saline soils is due to the resistance capacity of their protoplasm to salt, i.e. to the ability of plants to accumulate the salts in the cellular fluid without causing the death of cells themselves. An increase of salinity levels in the cellular fluid results in an increase of the internal osmotic potential of the plant and hence in a greater capacity to absorb water from saline soils.

2. HEIGHT GROWTH

The meristematic cells at the shoot tip divide rapidly and simultaneously in several planes, retaining the cylindrical form of the stem. The elongation of these upper cells, extending down to several internodes, produces the increase in height. The undifferentiated primary growth produced by the apical meristem subsequently undergoes differentiation with age into the various cell types, such as epidermis, xylem, phloem, etc.

Analysis of variance showed that height growth was significantly affected by different salts with the exception of *Prosopis juliflora*, in which no significant difference was observed among salts (Table 6).

With regard to the concentrations of these salts, significant differences existed in *Acacia nilotica* (D.I. Khan source), *Acacia nilotica* (Shorkot source), *Prosopis juliflora* and *Albizia lebbek* whereas in *Eucalyptus camaldulensis*, no significant difference was found. Significant interactions between salts and their concentrations were noticed in *Acacia nilotica* (D.I. Khan source) and *Albizia lebbek*.

In general, the three salts studied in this experiment were all harmful to plant height development. Sodium chloride and sodium bicarbonate salts appeared to be more or less similar in their detrimental effects in retarding the height growth, whereas sodium sulphate was less harmful (Table 7).

Table 6: Analysis of variance for total biomass production of selected forests tree species and provinces as affected by waterlogging

Tree Species	SOV	DOF	S.S	M.S	F
Acacia nilotica (D.I.Khan)	Treatments	1	64.945	64.945	3.48 N.S
	Error	4	74.764	18.691	
Acacia nilotica (Shorkot)	Treatments	1	7.752	7.752	0.48 N.S.
	Error	4	65.005	16.251	
Eucalyptus camaldulensis	Treatments	1	80.667	80.667	0.67 N.S
	Error	4	0.039	0.001	
Prosopus juliflora var.glandulosa	Treatments	1	1.092	1.092	0.03 N.S
	Error	4	131.513	32.878	
Albizia lebbek	Treatments	1	322.667	322.667	17.23*
	Error	4	74.927	18.732	

* Significant at five perrcent level of significance
N.S. Non-significant

Table 7. Means for height growth of selected forest tree species and provenances in sodium chloride (NaCl),sodium sulphate(Na_2SO_4) and sodium bicarbonate($NaHCO_3$) salts

Tree Species	KIND OF SALT		
	Sodium Chloride (NaCl)	Sodium Sulphate (Na_2SO_4)	Sodium bicarbonate ($NaHCO_3$)
	Height growth(cms)		
Acacia nilotica (D. I. Khan)	1.64(b)	2.25(a)	1.75(b)
Acacia nilotica (Shorkot)	2.39(a)	2.04(b)	2.04(b)
Eucalyptus camaldulensis	5.10(a)	5.54(a)	4.48(b)
Prosopis juliflora var. glandulosa	1.36(a)	1.65(a)	1.48(a)
Albizia lebbek	0.67(a)	0.81(a)	0.67(b)

Means followed by differ significantly at five percent level of significance according to the least significant difference (LSD) test.

According to Bohn, et al. (1985) and Brady (1974), the bicarbonate toxicities usually arise from deficiencies of calcium, iron or other micronutrients caused by the resultant high pH of the bicarbonate solution. It was observed that plants which were subjected to high concentrations of sodium bicarbonate ($NaHCO_3$) salt showed chlorosis symptoms associated with iron (Fe) deficiency. It is interesting to note that both provenances of Acacia nilotica reacted differently in height growth to different levels of salinity. The average height growth of Acacia nilotica (D.I. Khan source) was reduced (about 27 percent) significantly with the increment of salinity, but Acacia nilotica (Shorkot source) was comparatively less affected (about 21.16 percent reduction) to imposed salinity regarding height growth.

As a whole, height growth of all the tree species studied decreased gradually with increase in salinity levels. Reduction in height growth and stem elongation with increased salinity was also observed by Framji (1975); El-Lakamy and Laurd (1983) and Dubinski (1987). It was also observed that selected tree species responded differently in height growth to salinity levels. Differences in height growth of species tolerant to soil salinity has also been reported by Bender and Ramati (1967); Yadav and Singh (1970); Sheikh (1985) and Kretinin et al. (1985). In the present study, the most salt-tolerant and salt resistant tree species, as expressed in height growth, was found to be Eucalyptus camaldulensis. The ability of Eucalyptus camaldulensis to withstand salinity was also reported by Bender and Ramati (1967); Kaushik, et al. (1969); Sheikh (1974); Jackson (1977) and Malik and Sheikh (1983).

3. DIAMETER GROWTH

The increase in thickness of stems and branches in woody plants is brought about by activity of the lateral meristem, which produces xylem and phloem. The self perpetuating unicellular layer of cambium consists of two types of cells, the fusiform initials and the ray initials. The former, typically narrow and elongate, divide in the tangential plane, producing longitudinally arranged elements which give rise to fibers, vessels and other cells of the wood and inner bark. The short cubical ray initials give rise to ray tissue in the xylem and phloem. As a tree increases in diameter, the necessary increase in the circumference of the cambium occurs through radial division of the cambium cells. In most angiosperms, an oblique wall is formed across the center of the initials which cuts off two daughter cells. The initials produced after division elongate and force their way between the cells above and below by a process of intensive growth.

The analysis of variance indicated (Table 8) that tree species selected for this trial responded differently to different levels of soil salinity. Significant differences among salts and their

concentrations were found in Acacia nilotica (D.I. Khan source) and Albizia lebbek. In Acacia nilotica (Shorkot source) and Eucalyptus camaldulensis, significant differences were found in concentrations and salts, respectively, while there were no significant differences among salts and their concentrations in Prosopis juliflora as regards diameter growth.

Table 8: Analysis of variance for diameter growth of selected tree species and provenances as affected by salinity

Tree Species	SOV	DOF	S.S	M.S	F
Acacia nilotica (D.I.Khan)	Salt	2	0.014	0.0068	10.08**
	Conc	3	0.189	0.063	93.24**
	Salt x Conc	6	0.035	0.006	8.61**
	Error	24	0.016	0.0007	
Acacia nilotica (Shorkot)	Salt	2	0.003	0.0014	2.31 N.S
	Conc	3	0.017	0.0056	8.98**
	Salt x Conc	6	0.002	0.0003	0.55 N.S
	Error	24	0.015	0.0006	
Eucalyptus camaldulensis	Salt	2	0.021	0.0105	6.90**
	Conc	3	0.005	0.0016	1.06 N.S
	Salt x Conc	6	0.008	0.0014	0.94 N.S
	Error	24	0.036	0.0015	
Prosopis juliflora var.glandulosa	Salt	2	0.001	0.0005	1.58 N.S
	Conc	3	0.002	0.0007	2.09 N.S
	Salt x Conc	6	0.0009	0.0001	0.45 N.S
	Error	24	0.0080	0.0003	
Albizia lebbek	Salt	2	0.009	0.0045	6.89**
	Conc	3	0.099	0.0332	50.04**
	Salt x Conc	6	0.022	0.0036	5.41**
	Error	24	0.016	0.0007	

* Significant at five percent significance level
** Significant at one percent significance level
N.S. Non-significant

All salts were found detrimental in reducing diameter growth of the tree species studied (Table 9). Sodium chloride and sodium bicarbonate were found to be more harmful in retarding diameter growth than sodium sulphate. This difference in retarding diameter

growth may be similar to that discussed under height growth. There was a gradual reduction in diameter growth with the increase in level of salinity (i.e. amount and concentration of salts). Results obtained by Dubinski (1987) and Szonlagh (1983) indicated that increasing salinity levels decrease the vegetative growth and performance and make plants weak and subject to attack by insects. During the study it was observed that there was a tendency of weak plants to be attacked by insects.

Both provenances of Acacia nilotica reacted differently in diameter growth to various concentrations of sodium chloride, sodium sulphate and sodium bicarbonate salts (Table 9). The Shorkot provenance of Acacia nilotica performed better in sodium chloride salt, whereas the D.I. Khan provenance grew better in sodium bicarbonate. In the sodium sulphate salt, both sources of Acacia nilotica grew comparably in diameter to the control plants.

Table 9. Means for diameter growth of selected forest tree species and provenances in sodium chloride (NaCl),sodium sulphate(Na_2SO_4) and sodium bicarbonate($NaHCO_3$) salts

Tree Species	KIND OF SALT		
	Sodium Chloride (NaCl)	Sodium Sulphate (Na_2SO_4)	Sodium bicarbonate ($NaHCO_3$)
	Diameter growth (mm)		
Acacia nilotica (D. I. Khan)	0.158(b)	0.203(a)	0.165(b)
Acacia nilotica (Shorkot)	0.218(a)	0.210(a)	0.197(a)
Eucalyptus camaldulensis	0.271(a)	0.301(a)	0.242(b)
Prosopis juliflora var. glandulosa	0.115(a)	0.128(a)	0.118(a)
Albizia lebbek	0.119(b)	0.154(a)	0.122(b)

Means followed by different letters differ significantly at five percent level of significance according to the least significant difference (LSD) test.

4. TOTAL BIOMASS PRODUCTION

Analysis of variance of total biomass production (Table 10) indicated that differences in both salts and their concentrations were significant in both provenances of Acacia nilotica (D.I. Khan and Shorkot provenances) and Albizia lebbek. Biomass of Eucalyptus camaldulensis was significantly affected by type of salts while in Prosopis juliflora increased concentrations produced significant differences. Significant interaction between salt and concentration was observed in Acacia nilotica (D.I. Khan source) and Albizia lebbek.

Table 10: Analysis of variable for total production of selected tree species and provenances as affected by salinity

Tree Species	SOV	DOF	S.S	M.S	F
Acacia nilotica (D.I.Khan)	Salt	2	399.183	199.591	7.89**
	Conc	3	3090.463	1030.154	40.71**
	Salt x Conc	6	868.315	144.719	5.72**
	Error	24	607.281	25.303	
Acacia nilotica (Shorkot)	Salt	2	511.639	255.820	8.28**
	Conc	3	419.533	139.845	4.53*
	Salt x Conc	6	183.208	30.5345	0.99 N.S
	Error	24	741.211	30.8838	
Eucalyptus camaldulensis	Salt	2	3471.986	1735.993	7.28**
	Conc	3	1138.734	379.578	1.59 N.S
	Salt x Conc	6	1223.544	203.924	0.85 N.S
	Error	24	5725.520	238.563	
Prosopis juliflora var.glandulosa	Salt	2	2.062	1.031	0.07 N.S
	Conc	3	360.099	120.030	7.64**
	Salt x Conc	6	34.473	5.745	0.37 N.S
	Error	24	376.976	15.707	
Albizia lebbek	Salt	2	215.265	105.633	4.77*
	Conc	3	3834.493	1278.164	56.62**
	Salt x Conc	6	384.198	64.033	2.84*
	Error	24	541.745	22.573	

* Significant at five percent significance level
** Significant at one percent significance level
N.S. Non-significant

Table 11. Means for total biomass production of selected forest tree species and provenances in sodium chloride(NaCl),sodium sulphate(Na_2SO_4) and sodium bicarbonate($NaHCO_3$) salts

Tree Species	KIND OF SALT		
	Sodium Chloride (NaCl)	Sodium Sulphate (Na_2SO_4)	Sodium bicarbonate ($NaHCO_3$)
	Biomass (grams)		
Acacia nilotica (D. I. Khan)	20.19(b)	28.69(a)	22.67(b)
Acacia nilotica (Shorkot)	39.04(a)	38.36(a)	30.73(b)
Eucalyptus camaldulensis	82.29(a)	90.79(a)	67.05(b)
Prosopis juliflora var. glandulosa	20.37(a)	19.80(a)	20.22(a)
Albizia lebbek	21.45(b)	26.20(a)	20.66(b)

Means followed by different letters differ significantly at five percent level of significance according to the least significant difference (LSD) test.

The most harmful salt for reducing total biomass production was sodium bicarbonate. The dramatic effects of sodium bicarbonate salt can be attributed to non-availability of micronutrients as discussed earlier. Average total biomass production indicates that maximum average total biomass was produced by Eucalyptus camaldulensis (80.10 grams) followed by Acacia nilotica (Shorkot source-36.04 grams), Acacia nilotica (D.I. Khan source-23.85 grams), Albizia lebbek (22.77 grams), and Prosopis juliflora (20.13 grams), (Table 11).

Results regarding total biomass production indicated that both provenances of Acacia nilotica reacted differently to different salts. Acacia nilotica (Shorkot source) performed better in sodium chloride salt where as reverse trend was observed in sodium bicarbonate salt. In sodium sulphate salt both sources of this species did not show any difference in performance regarding total biomass production.

The overall results on total biomass indicated that as with other growth variables, there was a gradual reduction in total biomass with the increase in concentration of all salts. This reduction in total biomass production is a result of either reduction in height, diameter, or root growth. West (1978) found that apple plants grown under saline conditions showed less water-uptake as compared to plants in normal soil. Dubinski (1987) reported that salinity reduced plant biomass and vegetative growth in many plants. Similar results were also obtained by Framji (1975) who made typical response curves relating yield of different crops to levels of salinity indicating high yield at low levels of salinity, relativity rapid decrease at medium levels, and slower decrease at high salinity to a level where zero yield was obtained.

5. SHOOT-ROOT RATIO

Half of a woody plant, and often much more, is buried in the earth. Because the soil hides the roots from view, they are the least understood and least appreciated parts of plants. It is, therefore, important to know not only the normal development of above-ground parts but also the development of below-ground parts, i.e. the roots and their relationships with above-ground parts. To learn these relationships, the ratio between above-ground (shoot) and below-ground (root) biomass was computed.

Results of analysis of variance (Table 12) of the shoot-root ratio (shoot biomass divided by root biomass) indicated that both salts and their concentrations significantly affected the shoot-root ratio in Acacia nilotica (D.I. Khan source) and Albizia lebbek. Significant differences among salts and their levels only were observed in Eucalyptus camaldulensis and Prosopis juliflora, respectively. Neither salt treatments nor concentrations significantly affected the shoot-root ratio in Acacia nilotica (Shorkot source).

Table 12. Analysis of variance showing salt x Concentration interaction in total biomass production of Acacia nilotica (D.I.Khan) and Albizia lebbek

Tree Species	SOV	DOF	S.S.	M.S	F
Acacia nilotica (D.I.Khan)	Salts at 0.25% conc.	2	0.6099	0.30495	0.01
	Salts at 0.50% conc.	2	80.72	40.367	1.60
	Salts at 0.75% conc.	2	1186.17	593.085	23.44**
	Conc. at NaCl salt	2	1474.21	737.105	29.13**
	Conc. at Na_2SO_4 salt	2	64.91	32.455	1.82
	Conc. at $NaHCO_3$ salt	2	1882.67	941.335	37.20**
	Error	24	607.28147	25.30339	—
Albizia lebbek	Salts at 0.25% conc.	2	21.0538	10.5269	0.47
	Salts at 0.50% conc.	2	22.4086	11.2043	0.50
	Salts at 0.75% conc.	2	555.9979	277.9989	12.32**
	Conc. at NaCl salt	2	1435.5187	717.7593	31.798**
	Conc. at Na_2SO_4 salt	2	307.7324	153.8662	6.82**
	Conc. at $NaHCO_3$ salt	2	1315.8038	657.9019	29.15**
	Error	24	541.74493	22.57271	—

** Significant at one percent level of significance

Table 13. Means for shoot-root ratio of selected forest tree species and provenances in different kind of salts

Tree Species	KIND OF SALT		
	Sodium Chloride (NaCl)	Sodium Sulphate (Na_2SO_4)	Sodium bicarbonate ($NaHCO_3$)
	Shoot-root ratio		
Acacia nilotica (D. I. Khan)	1.37(b)	1.88(a)	1.40(b)
Acacia nilotica (Shorkot)	2.00(a)	1.92(a)	1.74(a)
Eucalyptus camaldulensis	2.36(a)	2.86(a)	1.66(b)
Prosopis juliflora var. glandulosa	1.49(a)	1.48(a)	1.38(a)
Albizia lebbek	0.99(b)	1.28(a)	0.99(a)

Means followed by different letters differ significantly at five percent level of significance according to the least significant difference (LSD) test.

GMB/maa

All salts were found to reduce the shoot-root ratios in all of the species studied, although the reduction was not significant in Acacia nilotica (Shorkot source). As with other growth parameters, sodium sulphate was found less harmful in reducing the shoot-root ratio than the other two salts. Since, more reduction in height growth, diameter growth, and total biomass production occurred in sodium chloride, and sodium bicarbonate salts than in sodium sulphate, it was expected that more reduction in shoot-root ratio in these salts compared to sodium sulphate salt would also be found, this was confirmed by analysis (Table 13).

As with other growth parameters namely height, diameter growth and total biomass production; shoot-root ratio declined gradually with the increase in concentration of salts studied. Reduction in shoot-root ratio may result either in reduction in the above ground biomass (height,diameter, etc.) or increase in the below-ground biomass (roots). It is unlikely that increment in root development due to soil salinity would result. Chaturvedi, et al. (1986) excavated the root systems of various trees and found that most of the tree species growing under saline condition failed to develop healthy roots. Therefore, results obtained from the present study suggest that there was more reduction in above-ground biomass as compared to below-ground biomass with increasing salinity levels. There was more reduction in shoot development than root development with increasing soil salinity.

Shoot-root ratio in both provenances of Acacia nilotica declined with each increment of salinity. Acacia nilotica (Shorkot source) was however,less affected than Acacia nilotica (D.I. Khan source). In most of the salts studied shorkot provenance did not show any significant reduction in shoot-root ratio even up to the maximum concentration (0.75 percent) while D.I. Khan source tolerated imposed salinity up to 0.50 percent in most cases.

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EXCHANGEABLE SODIUM, ITS EFFECTS ON SOIL CONDITIONS AND PLANT GROWTH

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INTRODUCTION:

Soil salinity and sodicity problems are widespread. There are 380 million hectares of saline and alkali soils on the earth's land surface (Massoud, 1974). This includes the humid regions of Europe as well as arid and semi-arid areas of United States, Australia, Middle East, India and Pakistan, (Yaron, 1981). Of these, 240 million hectares are not strongly saline (Massoud 1974), while 50 million hectares are strongly saline and are located in the South and Southeast Asia (Akbar and Ponnamperuma, 1982).

Pakistan is an agricultural country and most of its population is directly or indirectly dependent on agriculture. Approximately 5.73 million ha of salt affected soils occur in Pakistan (Muhammad 1983), and approximate annual loss of 20 billion rupees had been estimated due to the decrease in agricultural production (Qayyum and Malik, 1985).

Sodium as a specific ion has been shown to have a toxic effect when present in large amounts. It exerts important secondary effects on plant growth by causing adverse structural changes in the soil. The soils tend to become dispersed and puddled, resulting in poor aeration and low water availability.

Exchangeable sodium is the major saline constituent in salt affected soils. Its replacement from the exchange complex is considered important in reclamation of saline sodic and sodic soils. Usually the replacement of exchangeable sodium is done with Calcium (Ca^{++}) from the calcium sources such as Gypsum, calcium carbonate, and either with chemical amendments such as calcium sulphate, sulphur, sulfuric acid, and/or from biological or organic amendments or both. This removal or reduction in exchangeable sodium from the exchange complex is used as a measure of chemical reclamation of saline sodic and sodic soils.

The objectives of this paper are:

1. To familiarize the participants of the Workshop with basic concepts relating to soil salinity/sodicity and the role of Exchangeable sodium in soil exchange system

2. Importance of Exchangeable Sodium in the reclamation of saline and sodic soils.

3. The effects of Exchangeable Sodium on soil conditions and plant growth.

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CHARACTERISTICS AND CLASSIFICATION OF SALINE AND SODIC SOILS:

The saline and sodic soils are classified in the following three classes, (U.S. Soil Salinity Laboratory Staff, 1954).

i) SALINE SOILS. Saline soils have electrical conductivity (Ec) of the saturation extract more than 4 mmhos/cm, exchangeable sodium percentage (ESP) less than 15%, and the pH less than 8.5. These are synonymous to the white alkali and Solonchaks of the Russian classification.

ii) SALINE ALKALI SOILS. These are soils of which Ec of the saturated extract is greater than 4 mmhos/cm and ESP greater than 15%. These soils are the results of combined processes of salinization and alkalization. If the soil has excess salts, pH values rarely go beyond 8.5 but upon leaching the soil may become sodic.

iii) NON SALINE ALKALI SOILS. The Ec of the saturated extract of these soils is less than 4 mmhos, and the ESP, is greater than 15%. The pH varies between 8.5-10.0. These soils are also known as black alkali and solonetz.

EXCHANGEABLE CATIONS.

When a soil sample is placed in a salt solution e.g. Ammonium acetate, NH^+_4 ions are adsorbed by the soil and an equivalent amount of cations is displaced from the soil into the solution. This reaction is called "cation exchange". The cations displaced from the soil are referred to as "exchangeable cations", (U.S. Salinity Laboratory Staff, 1954). The exchangeable cations are determined to know the total cations present in the soil as they have a marked influence on the physical and chemical properties of soils.

CATION-EXCHANGE-CAPACITY (CEC)

The total amount of exchangeable cations that a soil can retain is designated as the cation exchange capacity. It is usually expressed in milliequivalent per 100g of soil. It is convenient to express the relative amount of various exchangeable cations present in a soil as percentage of the cation exchange capacity e.g., the exchangeable sodium percentage is equal to 100 times the exchangeable sodium content divided by the cation exchange capacity of that soil.

$$\text{Exchangeable Sodium Percentage (ESP)} = \frac{Na^+}{CEC} \times 100$$

SODIUM ADSORPTION RATIO

In saline sodic and sodic soils conditions resulting from an accumulation of adsorbed (exchangeable) sodium on exchange sites of soil minerals and organic matter, cause the soil to disperse and become impermeable to water at low salt concentrations. Some salt affected soils with adequate initial permeability also tend to seal or become relatively impermeable during leaching. Such soils generally reveal an excess of exchangeable sodium, which causes the soil to disperse once excess salts have been leached from the soil profile.

Sodium adsorption ratio (SAR) describes a relationship between the soluble sodium and soluble divalent cation which can be used to predict the exchangeable sodium percentage of soil equilibrated with a given solution.

$$\text{Sodium Adsorption Ratio (SAR)} = \frac{(Na^{+})}{[(Ca + Mg/_{2})]^{\frac{1}{2}}}$$

All concentrations in milliequivalent per liter.

Sodic soils tend to have pH values 8.5 or higher, particularly at low salt concentration therefore soil pH in general is not a reliable indicator of soil sodium status (U.S. Salinity Laboratory Staff, 1954).

GAPON'S EQUATION

The SAR is related to the exchangeable ion composition through the exchangeable sodium ratio. The dissolved and exchangeable levels of Na' are estimated by Gapon's equation because of adsorption of Sodium ions on exchange sites.

$$\text{Exchangeable Sodium Ratio (ESR)} = \frac{Na\ x}{Ca\ x + Mg\ x} = K_g.SAR$$

Where x refers to exchange sites and K is Gapon-type constant having an average value of 0.015 for many soils from the Western United States (U.S. Salinity Laboratory Staff, 1954).

The ESR in turn is related to the ESP by the expression:

$$\text{Exchangeable Sodium Percentage (ESP)} = 100 \times ESR/_{1+ESR}$$

Yaron (1981) studied the soils from the Western United States and found that the ESP of the soil and SAR of the soil solution are approximately equal numerically upto ESP levels of 25 to 30. This

is the ESP range of most interest to the irrigation agriculture. Higher ESP levels generally are associated with soils of so slowly permeable that major problems with crop production result

The ESP-SAR relationships have been studied for soils from other areas as well (Sinanuwong and EL-Swaify, 1974) but because of potential errors in experimental ESP determination, the SAR has gained increasing acceptance as the favored parameter for indicating the presence of sodic soil conditions.

EFFECTS OF SODIUM ON SOIL CONDITIONS.

The presence of excessive amount of exchangeable sodium in the exchange complex causes modifications in the soil structure (U.S. Salinity Staff, 1954).

1. The soil may become dispersed and puddled (Fine textured soils are more affected than the coarse textured).

2. Poor aeration and low permeability.

3. If the exchange complex is saturated with more than 40-50% of sodium, it disturbs the nutritional balances of the plants.

4. It also replaces the Calcium and Magnesium from the exchange complex and hence causes deficiency of these nutrients in the soil.

FACTORS THAT MODIFY THE EFFECTS OF EXCHANGEABLE SODIUM ON SOILS.

Saline and Sodic soils vary greatly with respect to their physical properties. Due to this variable behavior, the ill effects of excessive exchangeable sodium may be modified by the following soil characteristics (U.S. Salinity Laboratory Staff, 1954):

1. Texture
2. Surface area and type of clay
3. Potassium status and soluble silicates
4. Organic matter

1. Soil texture. Generally fine textured soils have high moisture retention and low permeability than coarse textured soils. The physical properties of fine textured soils are affected more adversely than the coarse textured soils, e.g., the hydraulic conductivity of the coarse textured soil having an exchangeable sodium percentage of 50, may be as great as that of a fine textured soil having an exchangeable sodium percentage of only 15-20.

2. Surface area and type of clay. Primary soil minerals

(quartz and feldspars) and 1:1 type of clay minerals such as Kaolinite and Illite have external surfaces only. Clay minerals of expanding type such as montmorillonite (2:1), which exhibits inter layer swelling have an internal as well as external surfaces. The external surface area of a soil is related to the texture, whereas the internal surface area is related to the content of the mineral.

Expanding type (montmorillonite) of clays which exhibits more swelling and dispersion are more adversely affected than non expanding type (Kaolinite, Illite) when appreciable amounts of exchangeable sodium is present in the soil surface.

3. Potassium and soluble silicates. The saline sodic soils having high ESP and containing appreciable soluble silicates give relatively low inter layer swelling. This indicates that the sodic soils containing high amounts of these salts constituents are susceptible to the development of adverse physical conditions.

4. Organic matter. The organic matter content has a favorable effect upon soil physical properties. It counteracts the harmful effects of exchangeable sodium on soils and enhances the degree of aggregation and the rate of infiltration of the surface soil (U.S. Salinity Laboratory Staff, 1954). It also improves and prevents deterioration of physical conditions of the soil by interacting with the ion organic cation exchange material, by serving as energy material for microorganisms which promotes stable aggregation of soil particles by decreasing the bulk density of the soil.

CHEMICAL AMENDMENTS USED FOR THE REPLACEMENT OF EXCHANGEABLE SODIUM FROM THE EXCHANGE COMPLEX.

The chemical amendments commonly used in Pakistan for the replacement of exchangeable sodium are as follows (U.S. Salinity Laboratory Staff, 1954):

1. Gypsum ($CaSO_4 . 2H_2O$)

   $2Na\ X + CaSO_4$ ----------$Ca\ X_2 + Na_2SO_4$

2. Acid forming:

   Sulfur and Sulfuric acid

   $2S + 3O_2$ ---------- $2SO_3$

   $2SO_3 + H_2O$ ---------- H_2SO_4

$$H_2SO_4 + CaCO_3 \text{----------} CaSO_4 + CO_2 + H_2O$$

OR

$$H_2SO_4 + 2CaCO_3 \text{----------} CaSO_4 + Ca\ (HCO_3)_2$$

$$2Na\ X + CaSO_4 \text{----------} Ca\ X_2 + Na_2SO_4$$

EFFECTS OF SALINITY AND SODICITY ON PLANT GROWTH.

Generally the crop yield decreases with the increase in soil salinity. For this two possible mechanisms are explained. Firstly the osmotic potential of soil solution increases with addition of salt which makes the volume of soil water less available to plants. (Luken, 1962; Amer et al., 1964; Lunin and Gallatin, 1965). Secondly soil salinity influences the uptake of the macro and micro nutrients (Lunin and Gallatin, 1965) and hence affecting the plant nutrition.

SODIUM-SPECIFIC ION EFFECT

Sodium (Na^+) is a major constituent in saline and sodic soils. Many fruit trees and woody Vines are susceptible to damage from specific ions of Na^+. The toxicity of this element tends to produce distinctive foliar symptoms such as necrotic spot and marginal or tip burn (Bernstein, 1961). Some fruit trees encounter Na^+ ion toxicity at ESP levels as low as 5% (Pearson, 1960; Bernstein, 1967) although many field crops evidence no apparent Na^+ toxicity even at ESP levels of 40 to 60%.

EFFECTS ON BIOLOGICAL NITROGEN FIXATION.

In symbiotic nitrogen fixation, bacteria (Rhizobium) cause the formation of root nodules in the host plants (legumes) and then inhabit these growths where they convert gaseous nitrogen (N_2) to a form useful to the plant. This process has been determined to be sensitive to soil salinity. There are generally two methods whereby salt effects are manifested upon fixation.

First a general osmotic effect in which total soil water potential decreases such that nodules lose water to the soil solution, with resultant damage to the metabolic processes. Second, high levels of soil salts interfere with the metabolism of nodule cortical cells, which prohibits delivery of materials of respiratory origin to nitrogen fixing regions of the plant (Sprent, 1972).

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EFFECTS OF WATERLOGGING ON THE EARLY DEVELOPMENT AND PERFORMANCE OF THREE IMPORTANT FOREST TREE SPECIES AND TWO PROVENANCES OF ACACIA NILOTICA

Zafar Iqbal[4]

INTRODUCTION.

Cultivation and development have progressed simultaneously in Pakistan. Although irrigation by inundation canals has been practiced in this country for several centuries, no record however, exists of rise in water table until 600 B.C. (Raheja, 1968). The area under irrigation has steadily increased during the past seven decades, especially during the British Occupation Period. The dynamic equilibrium between ground water recharge and discharge was altogether destroyed and as a result water tables have risen from 0.15 to 0.61 m per year (WAPDA, 1961; Franklin and Willard, 1973). The problem has not only rendered millions of hectares unfit for cultivation but has also affected our irrigated forests adversely.

Literally, waterlogging refers to a soil that is permanently saturated with water. As commonly used, however, it also implies to instances of temporary saturation and situations were the permanent water table is high enough to reduce significantly the amount of air filled pore spaces in the root zone.

The question arises about the extent and duration of this saturation or the critical depth of water table to classify a particular soil as waterlogged. According to WAPDA (1961), soils with water table less than 1.52 m (five feet) deep should be considered as a waterlogged. Long term investigations carried out at Vaksh Met Station (USSR) by Kovda (1971), showed that on an average the critical depth to the water table can be from 1 m to 3.5 m, depending upon the texture of the soil, climatic conditions and plants to be grown. There are different schools of thought to describe a particular soil as being waterlogged (Anon 1983). One school of thought argues that waterlogged soil should be classified as the three years enveloped area having 0-1.52 m (0-5 feet) water table. A second school advocates that the area having water table less than 1.52 m (5 feet) during winter should be called as waterlogged. A third group defines, the waterlogged soil, as the soil having 0-1.52 m water table depth during summer.

Keeping in view the magnitude of waterlogging, generally in the world and especially in the irrigated areas of Pakistan, the present study was designed with the following objectives:

a) To identify and compare the performance of selected forest tree species under waterlogged conditions.

b) To compare the establishment of selected provenances of *Acacia nilotica* (Kiker), a native species, on waterlogged soils.

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MATERIALS AND METHODS.

The study was conducted in plastic pots having 25 cm outside diameter by 10 cm height size in a greenhouse. Seed of the selected tree species was collected from the native stands and was pretreated before sowing (Table 1). The pots were lined with polyethylene sheeting to simulate waterlogged conditions. A Complete Randomized Block Design with three replicates was used. Ten treated seeds of each of five tree species were sown directly in the experimental pots having Fafard Peat-lite Mix "a plant medium" with the exception of Eucalyptus camaldulensis. Since the seed of Eucalyptus is very tiny and difficult to count, it was first sown in the petri dishes; the seedlings were transferred to the experimental units. Germination capacity was found separately by sowing seeds in the petri dishes and seed germination percentage was calculated after giving allowance for germination capacity.

Table 1: Pre-sowing seed treatments

Tree species	Origin	Lat	long	Seed treatment
Acacia nilotica	(D.I.Khan)	32°N	74°E	The seed was soaked in hot water for 24 hours and then let cooled for 24 hours at room temperature.
Acacia nilotica	(Shorkot)	31°N	72°E	Same as for Acacia nilotica (D.I.Khan).
Eucalyptus camaldulensis		32°N	74°E	No seed treatment was made prior to sowing the seed.
Prosopis juliflora (var.glandulosa)	Unknown			Seed was extracted from pods with forceps and then soaked in conc sulfuric acid (H_2SO_4) for 15 minutes.
Albizia lebbek	Unknown			The seeds were taken from pods by hand and then treated with hot water as described for Acacia nilotica (D.I.Khan) earlier.

When the plants were tall enough and there was danger of

competition, they were thinned to a single seedling per pot. Each plant was marked with black water proof ink to retain its identity. At the conclusion of study plants were harvested and oven dried for the determination of total biomass and shoot root ratio.

Analysis of Variance was performed on seed germination, height growth, diameter growth, total biomass production and shoot to root ratio data. The F-ratio was used to indicate significant difference among treatments. Least Significant Difference (LSD) test was used to establish significant differences among treatment means whenever needed for making comparisons.

REVIEW OF LITERATURE.

Some trees are able to withstand waterlogging. This is of special concern to managers of recreational areas and farm lands subject to flooding and land adjacent to multipurpose reservoirs and canals, where water level fluctuates. Apart from this trees also help in reclaiming waterlogged soil by lowering water table as a result of accelerated loss of water through leaves in the process of transpiration.

Waterlogging effects are generally felt through the plant root system, which physically support the plant and acts as entry point for water, nutrients and oxygen. The presence of excessive moisture in the root zone affects the plant in the three basic ways: through its influence on gas diffusion leading to an oxygen deficient environment, on soil micro flora and on soil temperature.

Despite the numerous changes that occur under waterlogged conditions, oxygen deficits in soil are probably the main cause of arrested root growth, decreased water and ion uptake,hinderance in fluid transport within the plant body and finally limited growth and performance of many sensitive plants (Drew and Lynch, 1980; Barrett-Lennard, 1986). West (1978) grew apple trees and found that water uptake was depressed to 30 percent under O_2 deficient environment.

The soil supports populations of micro-flora which may exert both harmful as well as beneficial influences on plant growth. In well drained soils this population is mainly composed of aerobic organisms which fix atmospheric nitrogen and mineralize organic materials into the useable N forms by plants. On the other hand, under conditions of prolonged waterlogging, these aerobic organisms are replaced by anaerobic forms with the result that nitrogen fixation and mineralization are greatly reduced. Additionally, nitrate and ammonium ions already present in the soil decompose into forms which are unavailable for plant use. Moreover, anaerobic organisms produce chemical compounds, such as sulfides, butyric acid and ethylene which can affect plant growth adversely. Seleskar (1986) observed that waterlogging was responsible for

Seleskar (1986) observed that waterlogging was responsible for inhibiting stem growth. The concentration of ethylene, a hormone known to inhibit stem elongation in plants, was increased fourfold in stems of Scripus americanus under waterlogged conditions.

The low temperature of wet soil is due partially to evaporation and partially due to high specific heat of water. The temperature of the upper few inches of a wet soil is about 6-12°F lower than that of normal soil (Brady,1974). A study conducted by Walker (1969), indicated that in early growth stages, growth rate can be decreased by as much as 39 percent as a result of 1° C temperature drop. Indirectly, cooler soil temperatures will influence the availability of nutrients, soil moisture relations and physiological processes that are more strongly temperature dependent than physical ones. Subsequently, these all will decrease the seed germination, growth and yield of many sensitive plants (Levitt, 1969; Brady 1974).

Since plants vary in their tolerance to waterlogging, selection of different tree species with respect to their tolerance to this suboptimal soil condition has been dealt with experimentally for many years. Sheikh (1974), in various experiments conducted at different sites, concluded that some species of Eucalyptus, Acacia nilotica, Populus euphratica could be planted successfully in partially waterlogged and saline areas. In an earlier study, Sheikh (1966), reported good success of Eucalyptus camaldulensis, Eucalyptus saligna in waterlogged and saline areas of Pakistan.

Results of three years trial in poplar stands by Szonlagh (1983), in Hungary showed that waterlogging and salinity increased the risk of damage from wood borers. Trees growing under such conditions were weak and easily attacked by insects. Malik and Sheikh (1983), in an experiment conducted at Azakhel near Peshawar, reported that out of different tree species tried, the best performance was from by Casuarina equistefolia, Tamarix aphylla, Prosopis juliflora and Eucalyptus camaldulensis. Chaturvedi, et al. (1986), excavated the root systems of different tree species planted on an area subjected to waterlogging and salinity. They found that Eucalyptus treticornis, Albizia lebbek, Dalbergia sissoo, Pongamia pinnata, Albizia procera and Terminalia arjuna developed good superficial root systems rather than long tap roots and grew well on this site.

RESULTS AND DISCUSSION.

(1) SEED GERMINATION. Seed germination percentage of Acacia nilotica (D.I. Khan source), Prosopis juliflora and Albizia lebbek was significantly reduced (17.33, 14.67 and 27.00 percent respectively) by waterlogging. On the other hand, the seed germination percentage of Acacia nilotica (Shorkot source) and Eucalyptus camaldulensis was not affected significantly by waterlogging (Table 2). It is interesting to note that the Acacia nilotica (Shorkot provenance) was found quite resistant (2.34% reduction) to waterlogged conditions compared to the D.I.Khan provenance of that species (17.33% reduction) (Fig.1).

Table 2: Analysis of variance for seed germination percentage of selected tree species and provenances as affected by waterlogging

Tree Species	SOV	DOF	S.S	M.S	F
Acacia nilotica (D.I.Khan)	Treatments	1	450.667	450.667	12.64*
	Error	4	142.667	35.667	
Acacia nilotica (Shorkot)	Treatments	1	8.167	8.167	0.17 N.S
	Error	4	197.333	49.333	
Eucalyptus camaldulensis	Treatments	1	16.667	16.667	0.20 N.S
	Error	4	333.333	83.333	
Prosopus juliflora var.glandulosa	Treatments	1	322.667	322.667	30.25**
	Error	4	42.667	10.667	
Albizia lebbek	Treatments	1	1093.500	1093.500	42.06**
	Error	4	104.000	26.000	

* Significant at five percent level of significance
** Significant at one percent level of significance
N.S. Non-significant

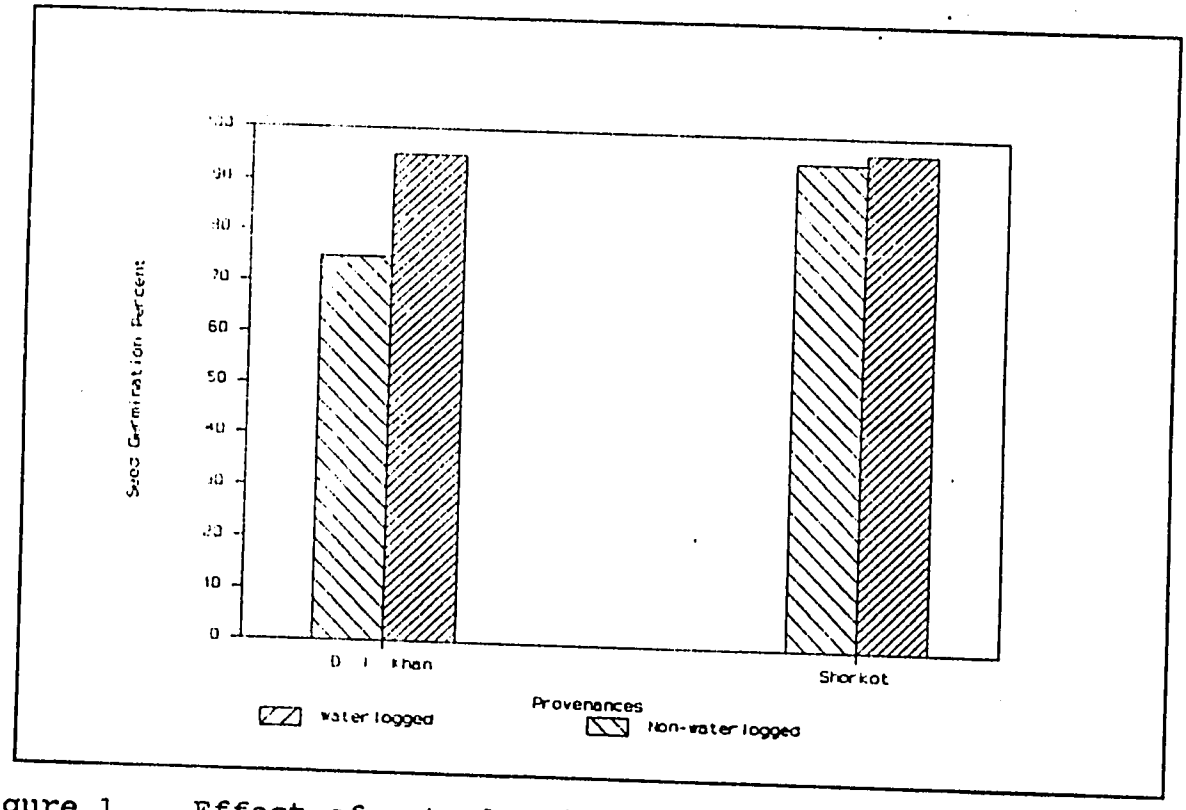

Figure 1. Effect of waterlogging on seed germination percentage of Acacia nilotica

Seed germination percentage of all the tree species studied was higher in the non-waterlogged treatment (94.87%) than in the waterlogged treatment (81.93%) (Table 3). Although some of these results are not significantly different, it is likely that soil waterlogging reduces seed germination. This can be attributed to the deficiency of aeration, low soil temperature and lack of water uptake for germination of seed and normal growth under waterlogged conditions as pointed out by Brady (1974), West (1978) and Barrett-Lennard (1986).

Table 3: Means of germination and gorwth parameters of selected forest trees species and provenances as affected by waterlogging conditions

Parameter	Tree Species	Treatments	
		Non-waterlogged	Waterlogged
Seed germination, percent	Acacia nilotica (D.I.Khan)	93.00(a)	75.67(b)*
	Acacia nilotica (Shorkot)	95.67(a)	93.33(a)
	Eucalyptus camaldulensis	86.67(a)	83.33(a)
	Prosopis juliflora var.glandulosa	100.00(a)	85.33(b)
	Albizzia lebbek	99.00(a)	72.00(b)
Height(centimeters/week)	Acacia nilotica (D.I.Khan)	3.20(a)	2.77(a)
	Acacia nilotica (Shorkot)	2.49(a)	2.41(a)
	Eucalyptus camaldulensis	5.56(a)	5.34(a)
	Prosopis juliflora var.glandulosa	2.13(a)	2.06(a)
	Albizzia lebbek	1.63(a)	0.91(b)
Dia(millimeters/week)	Acacia nilotica (D.I.Khan)	0.23(a)	0.23(a)
	Acacia nilotica (Shorkot)	0.24(a)	0.23(a)
	Eucalyptus camaldulensis	0.29(a)	0.28(a)
	Prosopis juliflora var.glandulosa	0.14(a)	0.13(a)
	Albizzia lebbek	0.19(a)	0.17(a)
Total biomass(Grams)	Acacia nilotica (D.I.Khan)	36.89(a)	30.31(a)
	Acacia nilotica (Shorkot)	43.77(a)	41.50(a)
	Eucalyptus camaldulensis	95.74(a)	88.41(a)
	Prosopis juliflora var.glandulosa	25.65(a)	24.80(a)
	Albizzia lebbek	46.96(a)	32.29(b)
Shoot-root ratio	Acacia nilotica (D.I.Khan)	1.96(a)	2.13(a)
	Acacia nilotica (Shorkot)	1.64(a)	2.06(a)
	Eucalyptus camaldulensis	1.84(a)	2.43(a)
	Prosopis juliflora var.glandulosa	1.57(a)	1.80(a)
	Albizzia lebbek	1.40(a)	1.41(a)

* Means followed by different letters differ significantly.

(2) HEIGHT GROWTH. Analysis of variance indicated that height growth was significantly reduced (23.68%) in *Albizia lebbek* at the one percent level of significance (Table 4). In all other tree species studied, however, height growth was not significantly affected in waterlogged treatment compared to non waterlogged treatment.

Neither provenance of *Acacia nilotica* was significantly affected by waterlogged conditions (Table 3). Comparatively less reduction (3.21%) in height growth was recorded, however, in the Shorkot source than D.I.Khan source (44.69%), (Fig. 2). Average height in the non waterlogged treatment was higher (10.30%) than waterlogged treatment in all the species studied.

Reduction in height growth due to waterlogging has also been reported by West and Taylor (1978), Szonlagh (1983) and Seleskar (1986), all whom related inhibition of stem growth under waterlogged conditions mainly to the accumulation of ethylene in the stem tissue. It is probable that if the plants studied were allowed to grow under waterlogged conditions for a few more years, significant differences in height growth between waterlogged and non waterlogged treatments would have been obvious. Since the study was conducted for a limited period significant differences in height growth were not detected between plants under waterlogged and non waterlogged conditions.

Table 4: Analysis of variance for height growth (cms) of selected forest tree species and affected by waterlogging

Tree Species	SOV	DOF	S.S	M.S	F
Acacia nilotica (D.I.Khan)	Treatments	1	0.273	0.073	6.51 N.S
	Error	4	0.168	0.042	
Acacia nilotica (Shorkot)	Treatments	1	0.011	0.011	0.90 N.S
	Error	4	0.050	0.013	
Eucalyptus camaldulensis	Treatments	1	0.073	0.073	0.24 N.S
	Error	4	1.229		
Prosopus juliflora var.glandulosa	Treatments	1	0.025	0.025	0.06 N.S
	Error	4	1.657	0.414	
Albizia lebbek	Treatments	1	0.778	0.778	42.06**
	Error	4	0.036	0.009	

** Significant at one percent level of significance
N.S. Non-significant

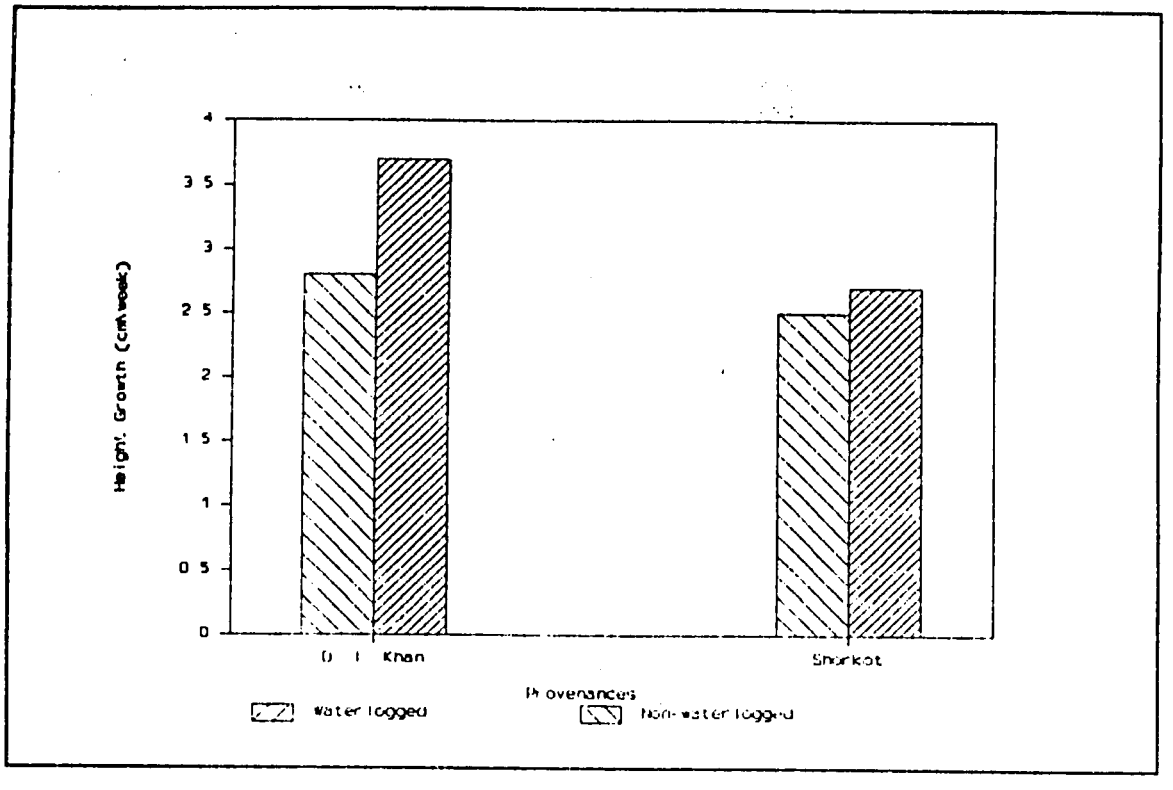

Figure 2. Effect of waterlogging on height growth of Acacia nilotica

(3) DIAMETER GROWTH. The data for diameter growth of the species studied, when subjected to analysis of variance (Table 5) revealed that there was no significant difference between the diameter growth of the species tested.

The average diameter growth of all species studied in waterlogged and non waterlogged pots is given in Table 3. Similarly, as with height growth, diameter growth in non waterlogged treatment was recorded higher (4.55%) than the waterlogged treatment. The only difference between height and diameter growth among species was recorded for Albizia lebbek. Reduction in height growth in this tree species under waterlogged conditions was significant, whereas reduction in diameter growth was non significant. It is also worthy to note that maximum reduction in diameter growth was recorded in Albizia lebbek (about 10.53%)

It is generally believed that diurnal variation in diameter due to shrinkage and swelling caused by water loss during daytime and re-hydration during the night obscure the effects on diameter growth. So despite reduction in height growth of Albizia lebbek, there was no significant difference between waterlogged and non waterlogged treatments regarding diameter growth as compared to height growth. Neither provenance of Acacia nilotica showed any significant difference in diameter growth between

waterlogged and non-waterlogged experimental units. Reduction in diameter growth under waterlogging, when it occurs, can be attributed to the accumulation of ethylene in stem tissue as reported by Szonlagh (1983) and Seleskar (1986).

Table 5: Analysis of variance for diameter growth (mm) of selected forests tree species and provinces as affected by waterlogging

Tree Species	SOV	DOF	S.S	M.S	F
Acacia nilotica (D.I.Khan)	Treatments	1	0.00002	0.00002	0.04 N.S
	Error	4	0.00206	0.00052	
Acacia nilotica (Shorkot)	Treatments	1	0.00015	0.00015	0.17 N.S
	Error	4	0.00360	0.00090	
Eucalyptus camaldulensis	Treatments	1	0.00007	0.00007	0.069 N.S
	Error	4	0.00387	0.00097	
Prosopus juliflora var.glandulosa	Treatments	1	0.00027	0.00027	1.60 N.S
	Error	4	0.00067	0.00017	
Albizia lebbek	Treatments	1	0.00082	0.00082	1.75 N.S
	Error	4	0.00187	0.00047	

N.S. Non-significant

(4) TOTAL BIOMASS PRODUCTION. The results of Analysis of variance for total biomass production given in Table 6 revealed that the total biomass production of Albizia lebbek was significantly reduced (31.30 %) by waterlogging, whereas no significant differences in total biomass production between waterlogged and non waterlogged conditions was detected in all of the other species studied. The significant reduction in biomass in Albizia lebbek is a result of the reduction in height due to water logging as discussed earlier. Since no significant effect of waterlogging on height growth was found in any of the other tree species studied, it is not surprising that no significant effect of waterlogging on the total biomass production was found.

Means for total biomass production are given in Table 3. Maximum average total biomass was produced by Eucalyptus camaldulensis followed by Acacia nilotica (Shorkot source), Albizia lebbek, Acacia nilotica (D.I.Khan source) and Prosopis juliflora.

As for other parameters of growth, total biomass production was generally higher (about 12.73%) in non-waterlogged pots. The reduction in total biomass production due to waterlogging is mainly the result of a

reduction in height growth or diameter growth or both. Results obtained by Szonlagh (1983) and Saleskar (1986) demonstrated that plants growing under waterlogged conditions are stunted, weak and exhibit less growth and produce less biomass compared to plants growing in normal soil. Table 3 also shows that no significant difference in total biomass production for Acacia nilotica between waterlogged and non-waterlogged treatments. There was, however, less reduction in total biomass production in Shorkot source (5.19%) than in the D.I. Khan source (17.84%). However, overall total biomass production was higher in Acacia nilotica (D.I.Khan) than Acacia nilotica (Shorkot) as depicted in Figure 3.

The main causes for reduced growth and production under waterlogged conditions are mainly aeration deficits. These deficits lead to reduced ATP (adenosine triphosphate) production, the ultimate source of energy for plant growth and reproduction; flourishing of anaerobic soil flora resulting in the formation of many injurious and harmful chemical compounds in the soil and finally the low temperature of wet soil, affects all of the temperature depending reactions within soil and plant body.

Table 6: Analysis of variance for total biomass production of selected forests tree species and provinces as affected by waterlogging

Tree Species	SOV	DOF	S.S	M.S	F
Acacia nilotica (D.I.Khan)	Treatments	1	64.945	64.945	3.48 N.S
	Error	4	74.764	18.691	
Acacia nilotica (Shorkot)	Treatments	1	7.752	7.752	0.48 N.S.
	Error	4	65.005	16.251	
Eucalyptus camaldulensis	Treatments	1	80.667	80.667	0.67 N.S
	Error	4	0.039	0.001	
Prosopus juliflora var.glandulosa	Treatments	1	1.092	1.092	0.03 N.S
	Error	4	131.513	32.878	
Albizia lebbek	Treatments	1	322.667	322.667	17.23*
	Error	4	74.927	18.732	

* Significant at five perrcent level of significance
N.S. Non-significant

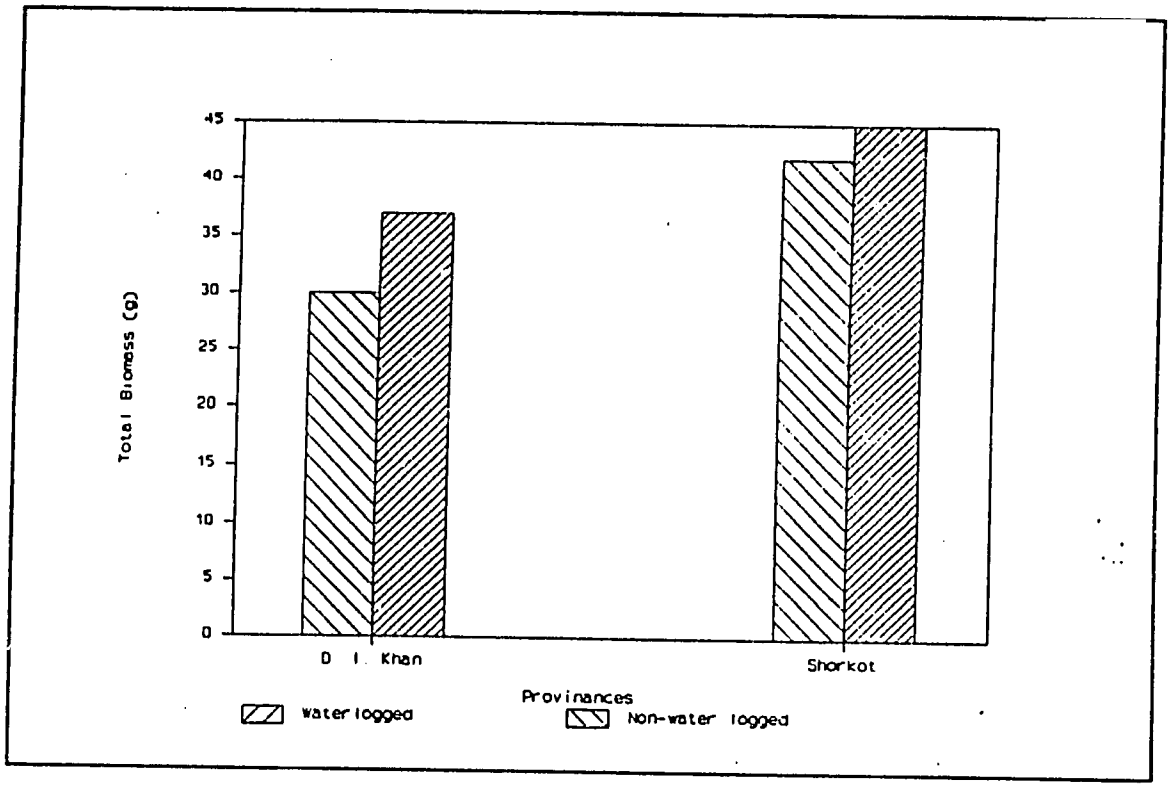

Figure 3. Effect of waterlogging on total biomass of Acacia nilotica

(5) SHOOT-ROOT RATIO. No significant difference was detected in shoot to root ratio for any of the species studied (Table 7). Neither did the two provenances of Acacia nilotica show any difference in resistance to water-logging as far shoot to root ratio is concerned.

Average shoot root ratio for all the tree species is given in Table 3. The differences (not significant) between waterlogged and non waterlogged pots are shown in Figure 4.

In contrast to the results for other growth parameters, such as height, diameter and total biomass production, mean shoot-root ratio (Table 3) was higher in lined pots (waterlogged treatment) than in the unlined pots (non waterlogged treatment). This indicates that despite reduction in height and diameter growth, there was more reduction in root development as compared to shoot development (Table 8). This reduction in root development may be caused by a lack of aeration resulting in the production of ethylene (root and shoot growth inhibitor). Chaturvedi, et al (1980) found that excessive moisture in

the root zone can injure or even kill plants due to reduced development of roots, resistant plant species usually tolerate such adverse conditions (waterlogging) by developing superficial roots rather than long tap roots. However, the idea that waterlogging causes a reduction in root or shoot development has not been reported.

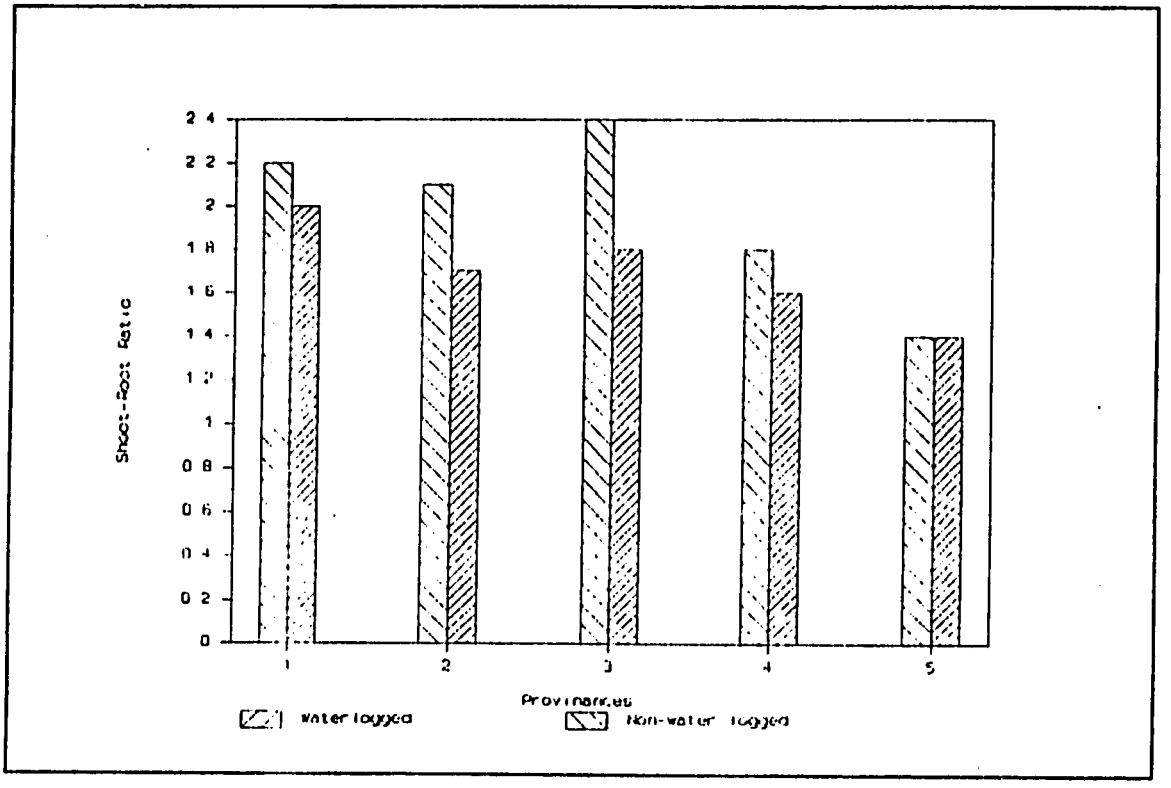

Figure 4. Effect of waterlogging on shoot-root ratio of selected forest tree species

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