SELECTION OF SUITABLE TREE SPECIES FOR SALINE AND WATERLOGGED AREAS *

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ABSTRACT

Thirty five tree species were planted to determine their suitability for salt tolerance under waterlogged conditions. Analysis of the soil of the experimental site indicated that it was dispersed and varied from saline to saline-sodic in chemical composition with salinity in water. Performance of species was determined on the basis of their survival and height growth. Local species, such as, *Tamarix aphylla*, *Acacia modesta* and *Acacia nilotica* as well as exotic species, such as, *Acacia stenophylla*, *Acacia ampliceps*, *Casuarina obesa*, *Eucalyptus camaldulensis*, *Prosopis chilensis*, *Prosopis siliquestrum* and *Prosopis alba* exhibited high survival rates. *Eucalyptus camaldulensis* had higher height growth as compared to other species.

INTRODUCTION

The salinity and waterlogging have become alarming problems in Pakistan, adversely affecting the production of agricultural crops and tree growth. Millions of hectares of farmlands have been salinized due to faulty irrigation practices and lack of proper drainage over long periods of time. The introduction of canal irrigation system in Pakistan initially increased agricultural production but upset the dynamic equilibrium between ground water recharge and discharge resulting in decrease in production. The percolation of seepage from irrigation canals and irrigation water increased the natural ground recharge. This recharge being far greater than the actual discharge, caused a rise in water table. Continuous rise in water table reduced the drainage capacity of soil and the evaporation of water increased the accumulation of salt near and above the top soil.

It is estimated that about 6.3 million hectares of land has been affected and 40,000 hectares are being added each year through the spread of waterlogging and salinity (Hussain and Attaullah, 1989).Reclamation of such lands is generally done through engineering practices. However, new avenues to prevent further damage are being explored. All over the world, foresters are trying to reclaim waterlogged and saline areas by planting trees. Because of transpiration and evaporation processes, trees act as large water pumps and help in lowering water table to reclaim the land. The planting of suitable species to control or reduce waterlogging and salinity has been successfully carried out in many parts of the world.

Australian tree species and shrubs like *E. camaldulensis*, *Acacia auriculiformis*, *Rhizophora* species, *Prosopis tamarugo*, *Casuarina*

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equisetifolia and *Melaleuca quinquenervia* have been successfully introduced in the subtropical and tropical zones and several of these have potential for planting on salt affected sites (Midgley et al. 1986). Brendan (1990) reported that species like *E. camaldulensis*, *E. occidentalis*, *E.sargentii*, *Melaleuca halmaturorum* and *Casuarina obesa* performed exceedingly well in saltland revegetation programme in South Australia.

Species like *Prosopis juliflora*, *Eucalyptus hybrid* and *Acacia nilotica* can be grown successfully in sodic soils by treating the soil of the planting pit with gypsum and farm yard manure alongwith application of small dose of nitrogenous and phosphatic fertilizer (Yadav, 1980). McKinnell and Horisetijono (1991) indicated that Acacia species like *Acacia ampliceps*, *A.holoserica*, *A. auriculiformis* performed better on highly alkaline soil in tree species screening trials in West Timor, Indonesia. *E. camaldulensis*, *E. tereticornis*, *E. occidentalis* were also found the most salt-tolerant species amongst 19 frost resistant Eucalyptus species screened for salt tolerance under glasshouse conditions (Marcar, 1989).

A number of studies have been carried out in Pakistan over the years. Ahmad (1961) has discussed in detail the performance and method of planting of various species in saline areas. He concluded that *E. botryoides*, *E. maculata*, *E. albens*, *E. grandis*, *E. camaldulensis*, *E. gomphocephala*, *Bischoffia javanica*, *Erythrina indica* etc. were successful at Rakh Pir Sabz and Pakhowal in Punjab. Similarly, Sheikh (1966) also reported that planting of Eucalyptus could solve the problem of afforestation in waterlogged area in Pakistan. He observed that *E. camaldulensis*, *E. tereticornis* and *E. citriodora* were quite successful in saline and waterlogged area. Qadri (1968) recommended planting of *E. robusta* and *E. botryoides* for waterlogged and saline sites.

E.camaldulensis, *E.rudis*, *E. occidentalis*, *E. sargentii*, *E. kondininensis*, *Casuarina glauca* and *Melaleuca* species have also been recommended for testing by others (Pryor, 1967). Recently, *E. camaldulensis*, *Tamarix aphylla*, *E. microtheca*, *Casuarina cunninghamiana* were found to grow well in saline and waterlogged areas by Malik and Sheikh, 1983; Hussain and Attaullah, 1989.

A number of species like *Prosopis pallida*, *P. tamarugo*, *P. chilensis*, *P. articulata*, *P. juliflora*, *E. camaldulensis*, *E. occidentalis*, *E. sargentii*, *E. lazophleba*, *E. kondininensis*, *E. spathulata*, *Casuarina equisetifolia*, *C. glauca*, *C. cristata*, *C. obesa*, *Tamarix aphylla*, *T. stricta*, *T. articulata* and *T. gallica* have been recommended to rehabilitate saline sites (Anon, BOSTID report 1990). In addition *Acacia nilotica*, *A. ampliceps*, *A. holoserica*, *Leucaena leucocephala*, *Albizzia lebbek*, *Cassia siamea*, *Pongamia pinnata* and *Terminalia arjuna* have shown promise when planted in these problematic areas.

Afforestation of salt-affected soils offers the possibilities of both utilizing and ameliorating these degraded lands. But this has proceeded slowly because many suitable tree species have not yet been identified so far which could be introduced on a large scale. With the introduction of Eucalyptus, Acacias, Casuarinas and Prosopis species from Australia and other countries, fresh attempts were made in Pakistan Forest Institute (PFI) to find out suitable species for the waterlogged and saline areas. This paper presents the results of recent studies in this regards.

MATERIALS AND METHODS

Seed of different species and seed sources of Acacias, Eucalyptus, Prosopis etc. were procured from Australia, Chile, Peru, USA and Holland. Seed of remaining species used in the experiment were locally collected (Table 1). One year old seedlings of 35 species were planted in randomized complete block design with 20 replications. Each replication had 3 plants per species planted in August, 1989 at 2 x 1 m spacing at Risalpur under non-irrigated conditions.

Prior to the establishment of this trial, adjacent area was planted with various tree species from March, 1986 to July, 1989. An area of 5 ha was selected which included both planted as well as unplanted areas and divided into 53 rectangular grids of 30 x 25 meters size. Three composite soil samples were collected at the surface (0-15 cm) from each sample point in May, 1990. In July, 1990 soil and water samples were also collected up to the depth of 180 cm at the time of installing PVC pipes to monitor variation in water table. In all, thirty sample points were located in planted and 23 in the unplanted areas. Sample points in the unplanted areas were treated as control.

Using standard methods, physical and mechanical analysis of top soil (0-15 cm) and bottom soil (15-180 cm) samples were carried out. Water samples were also analysed for physical characteristics. Surface soil samples were again collected in November, 1990 to find out if any change had occurred in it during the past 6 months.

Table 1. Origin of seed of different tree species of the trial

Sl. No.	Species	Seed lot No.	Origin of seed (Latitude, Longitude, Elevation)
1.	*Acacia victoriae*	17209	Lake Josceline, Western Australia (18^0 6'S; 124^0 24'E; 65 m)
2.	*A.stenophylla*	14670	Cow creek, Western Australia (184^0 1'S; 128^0 21' E; 240 m)
3.	*A.radiana*	1013/81	Arara, Distr; Ein-Hazeva, Israel (13^0 47' N; 35^0 12' E; 100m)
4.	*A.aneura*	13740	Holland
5.	*A.sclerosperma*	15790	Sanford River, Meka, Western Australia (27^0 25 S; 116^0 56' E; 320 m)
6.	*A.nilotica*	--	Pakistan Forest Institute,Peshawar (34^0 01' N; 71^0 34' E; 350 m)
7.	*A.ampliceps*	15741	Wolfe Creek Crater, Western Australia (19^0 10' S; 127^0 48' E; 360 m)

8.	*A.cyclops*	--	Pakistan Forest Institute,Peshawar (34^0 01′ N: 71^0 34′ E; 350 m)
9.	*A.saligna*	15795	Murchison River, Western Australia (27^0 51′ S; 114^0 37′ E; 180 m)
10.	*A.albida*	1394/84	Marina Dakhar Dept Tivaoune Reg.de Thies Senegal (15^0 06′ N; 16^0 32′ W)
11.	*A.modesta*	--	Pakistan Forest Institute,Peshawar (34^0 01′ N; 71^0 34′ E; 350 m)
12.	*A.adsurgen*	14091	Gunbarella, Western Australia (24^0 50′ N; 125^0 01′ E; 440 m)
13.	*Prosopis glandulosa* Var.*Torreyana*	1473/84	La Sauceda Coale Romas Arizpe Coahuila, Maxico (25^0 51′ N; 101^0 19′ W; 1010 m)
14.	*P.juliflora*	1214/83	Cananez, Sonona, Mexico ($24^0$13′ N; 104^0 28′ W; 890 m)
15.	*P.pallida*	1338/84	La Pinilla Ocucaje Ica, Peru ($14^0$13′ S; 75^0 40′ W; 413 m)
16.	*P.alba*	1574	San Pedro attacana EL Loa, Chile (22^0 54′ S; 68^0 12′ W; 2000 m)
17.	*P.cineraria*	1087/82	Bhiwani (Hissan) Haryana, India (28^0 45′ N; 76^0 10′ E; 250 m
18.	*P.chilensis*	1419/84	Liamari 4 Region combarbala Pama, Chile (31^0 09′ S; 71^0 04′ W; 650 m
19.	*P.siliquestrum*	1578/76	Losloras I. Copiapo, Chile (27^0 01′ S; 70^0 05′ W; 1000 m)
20.	*E. crebra*	--	Pakistan Forest Institute,Peshawar (34^0 01′ N; 71^0 34′ E; 350 m)
21.	*E.microtheca*	15067	Carnarvon Basin (1), Western Australia (23^0 30′ S; 114^0 0′ E; 15 m)
22.	*E.robusta*	--	Washington, USA
23.	*E.camaldulensis*	15441	De Grey River, Western Australia (20^0 19′ S; 119^0 15′ E; 100 m)
24.	*Leucaena leucocephala*	--	Pakistan Forest Institue,Peshawar 34^0 01′ N; 71^0 34′ E; 350 m)
25.	*Casuarina obesa*	15796	Murchison River (27^0 51′ S; 114^0 37′ E; 180 m

26.	*C.cunnighamiana*	13508	Holland
27.	*C.montana*	--	Nowshera (34^0 12′ N; 70^0 04′ E; 350 m)
28.	*Syzygium cumini*	--	Pakistan Forest Institute, Peshawar (34^0 01′ N; 71^0 34′ E; 350 m)
29.	*Dalbergia sissoo*	--	Pakistan Forest Institute, Peshawar (34^0 01′ N; 71^0 34′ E; 350 m)
30.	*Tamarix aphylla*	--	Nowshera (34^0 12′ N; 70^0 04′ E; 350 m)
31.	*Ceratonia siliqua*	--	Pakistan Forest Institute, Peshawar (34^0 01′ N; 71^0 34′ E; 350 m)
32.	*Albizzia procera*	--	Pakistan Forest Institute, Peshawar (34^0 01′ N; 71^0 34′ E; 350 m)
33.	*A. lebbek*	--	Pakistan Forest Institute, Peshawar (34^0 01′ N; 71^0 34′ E; 350 m)
34.	*Tecoma undulata*	--	Pakistan Forest Institute, Peshawar (34^0 01′ N; 71^0 34′ E; 350 m)
35.	*Zizyphus mauritiana*	--	Pakistan Forest Institute, Peshawar (34^0 01′ N; 71^0 34′ E: 350 m)

RESULTS AND DISCUSSION

Survival percentage recorded in February, 1990 ranged from 35-97% but the survival data collected in December, 1990 showed reduction in it and varied from 8-87% (Table 2). This decrease in the survival percentage can be attributed mainly to hot and dry summer conditions of that year.

Of local species, highest survival percentage was exhibited by *Tamarix aphylla* (83%) followed by *Acacia modesta* (77%) and *Acacia nilotica* (73%). Exotic species such as *Prosopis chilensis*, *Prosopis siliquestrum* and *Prosopis alba* showed 87%, 85% and 80% survival respectively. *Acacia stenophylla* (77%) and *Acacia ampliceps* (75%) showed best survival results amongst exotic Acacias. Australian seed source No.15441 of *Eucalyptus camaldulensis* and No.15796 of *Casuarina obesa* had highest survival amongst all Eucalyptus and Casuarina species with 70% and 72% survival respectively. *Acacia adsurgen* (8%) and *Acacia cyclops* (17%) were found to be the most salt-sensitive species in the study.

On the basis of height growth data recorded in December, 1990, *Eucalyptus camaldulensis* (No.15441) had maximum growth rate as compared to other species with average height of 3.56 m. *Tecoma undulata* had minimum height of 0.1 m Other species like *Leucaena leucocephala*, *Acacia nilotica* and *Acacia ampliceps* also showed higher height growth than other local and exotic tree species (Table 2). Considerable variation was also observed within all species.

Because of a number of missing values in the height growth data, a general linear model procedure was used for statistical analysis, which showed highly significant differences between the species.

Table 2. Survival % and height growth data of different tree species

Sl. No.	Species/Seed source		Survival %		Average Ht. (m)		Range (m)
			Feb.90	Dec.90	Feb.90	Dec.90	
1.	*Acacia victoriae*	(17209)	55	37	0.26	1.44	0.4-3.0
2.	*Acacia stenophylla*	(14670)	85	77	0.29	2.25	0.4-4.2
3.	*Acacia raddiana*	(1013/81)	65	58	0.32	1.43	0.6-3.1
4.	*Acacia aneura*	(13740)	55	27	0.23	0.45	0.2-0.6
5.	*Acacia sclerosperma*	(15790)	57	32	0.33	2.23	0.7-3.5
6.	*Acacia nilotica*	(Local)	85	73	0.55	3.34	0.3-5.3
7.	*Acacia ampliceps*	(15741)	87	75	0.32	3.11	0.8-4.1
8.	*Acacia cyclops*	(Local)	72	17	0.24	1.01	0.2-2.7
9.	*Acacia saligna*	(15795)	75	60	0.40	2.06	0.4-3.6
10.	*Acacia albida*	(1394/84)	62	50	0.35	2.09	0.4-4.2
11.	*Acacia modesta*	(Local)	97	77	0.33	1.09	0.4-2.0
12.	*Acacia adsurgen*	(14090)	35	8	0.22	0.70	0.3-1.1
13.	*Prosopis glandulosa*	(1473/84)	85	77	0.49	1.93	0.9-3.1
14.	*Prosopis juliflora*	(1214/83)	78	72	0.48	2.92	0.5-5.0
15.	*Prosopis pallida*	(1338/84)	72	62	0.85	3.00	0.6-4.2
16.	*Prosopis alba*	(1574/86)	93	80	0.75	2.83	0.6-5.8
17.	*Prosopis cineraria*	(1087/82)	68	67	0.28	1.72	0.4-3.0
18.	*Prosopis chilensis*	(1419/84)	92	87	0.77	2.67	0.9-4.7
19.	*Prosopis siliquastrum*	(1578/76)	95	85	0.55	1.88	0.3-3.9
20.	*Eucalyptus crebra*	(Local)	57	43	0.47	2.35	0.3-7.0
21.	*Euc. microtheca*	(15067)	67	58	0.43	2.31	0.4-4.6
22.	*Eucalyptus robusta*	(USA)	77	65	0.65	2.89	0.4-7.2
23.	*Euc. camaldulensis*	(15441)	80	70	1.04	3.56	1.1-7.0
24.	*Leucaena leucocephala*	(Local)	85	62	0.80	3.51	0.6-4.8
25.	*Casuarina obesa*	(15796)	85	72	0.44	1.37	0.3-2.6
26.	*Cas. cunninghamiana*	(13508)	70	63	0.56	1.94	0.2-3.7
27.	*Casuarina montana*	(Local)	70	63	0.79	2.58	0.2-4.5
28.	*Syzygium cumini*	(Local)	67	57	0.36	1.14	0.4-1.8
29.	*Dalbergia sissoo*	(Local)	60	47	0.33	1.92	0.4-3.2
30.	*Tamarix aphylla*	(Local)	97	83	0.56	2.10	0.2-4.1
31.	*Ceratonia siliqua*	(Local)	62	33	0.27	0.84	0.3-1.7
32.	*Albizzia procera*	(Local)	72	45	0.43	1.69	0.2-5.3
33.	*Albizzia lebbeck*	(Local)	63	28	0.24	1.08	0.3-2.7
34.	*Tecoma undulata*	(Local)	48	32	0.29	1.42	0.1-2.2
35.	*Zizyphus mauritiana*	(Local)	57	48	0.33	2.31	0.9-3.5

On the basis of average height growth, ten species are recommended for future test planting. They are listed in the Table on next page.

Ranking	Species/seed source	Average Height (m)
1	*Eucalyptus camaldulensis* (15441, Australia)	3.56
2	*Leucaena leucocephala* (Local)	3.51
3	*Acacia nilotica* (Local)	3.34
4	*Acacia ampliceps* (15741, Australia)	3.11
5	*Prosopis palida* (1338/84, Peru)	3.00
6	*Prosopis juliflora* (1214/83, Mexico)	2.92
7	*Eucalyptus robusta* (USA)	2.89
8	*Prosopis alba* (1574/86, Chile)	2.83
9	*Prosopis chilensis* (1419/84 Chile)	2.67
10	*Casuarina montana* (Local)	2.58

Physical analysis of water showed that salinity level was higher in the unplanted areas as compared to planted area (Table 3).

Table 3. Physical Analysis of Water Samples

Water salinity level	Planted areas	Un-planted areas
July, 1990	pH 7.09 - 8.19 EC 1.00 - 6.00	7.74 - 9.01 1.10 - 9.50
November, 1990	pH 7.59 - 8.80 EC 1.00 - 5.50	7.79 - 9.50 1.75 - 8.00

Analysis of soil samples were carried out for pH and electric conductivity (E.C) of soluble salts only because it was not possible to analyse them for Exchangeable Sodium Percentage (ESP) due to non availability of equipment. The pH and EC of surface soil samples collected in May, 1990 indicated that the soil in planted area ranged from normal to saline-sodic, whereas in the unplanted areas it was mostly sodic and saline-sodic. Bottom soil samples in both areas was normal. Mechanical analysis of surface and bottom soils indicated dispersal though texture varied from silt-loam to sandy loam

(Table 4). The presence of fine clay contents influenced the soil texture and worked as cementing agent hindering water infiltration.

Table 4. Soil analysis data of surface and bottom soil samples collected in May, 1990

Physical & mechanical analysis	Planted area Surface soil (0-15cm)	Planted area Bottom soil (1.8m)	Un-planted area Surface soil (0-15cm)	Un-planted area Bottom soil (1.8m)
pH at 25^0C	7.44-10.04	7.54-8.50	8.91-10.44	8.00-8.50
E.C.(mmohs/cm)	0.55- 8.50	0.40-2.00	3.40-14.00	0.30-2.00
Texture class	Sandy-loam, Loamy-sand, Loam	Sand, Silt-loam, Loamy-sand, Sandy-loam	Sandy-loam, Loamy-sand, Loam	Sandy-loam, Sand, Loamy-sand, Loam, Silt, Silt-loam
Soil type	Normal pH < 8.5 EC < 4.0	Normal pH < 8.5 EC < 4.0	Sodic pH > 8.5 EC < 4.0	Normal pH < 8.5 EC < 4.0
	Saline pH < 8.5 EC > 4.0		Saline sodic pH > 8.5 EC > 4.0	
	Sodic pH > 8.0 EC < 4.0			
	Salin sodic pH > 8.5 EC > 4.0			

Physical and mechanical analysis of soil samples collected in November, 1990 showed some changes in pH, EC and texture in six months. However, no definite conclusion for these changes can be drawn at this early stage (Table 5). These changes may have occurred due to flooding of uneven sites on account of unusual and intermittent heavy rains and probably transported the surface salts from higher to the lower sites particularly in the unplanted areas. Changes in the planted areas may be attributed to the development of the tree roots which increased the initial infiltration capacity of soil.

CONCLUSION

At this early stage of the study, result demonstrate that local tree species like *Tamarix aphylla, Acacia nilotica, A. modesta* and exotic species such as *Acacia ampliceps, A. stenophylla, Prosopis glandulosa, P. juliflora, P. alba, P. chilensis, P. siliquestrum, E. camaldulensis* and *Casuarina obesa* have great potential to survive under saline and sodic soil conditions provided the soil is properly worked and weed competition decreased. Certain species have promising growth rates at 1.5 years age. The species which have shown better survival and growth should further be tested under saline-sodic and waterlogged conditions.

Table 5. Comparison of surface soil data collected in May and November, 1990.

Physical & mechanical analysis		Planted area	Un-planted area
pH at 25°C	May,90	7.44 - 10.04	8.91 - 10.44
	Nov,90	7.97 - 9.82	8.25 - 10.22
E.C(mmohs/cm)	May,90	0.55 - 8.50	3.40 - 14.00
	Nov,90	0.44 - 6.50	0.75 - 8.00
Texture class	May,90	Sandy-loam, Loamy-sand, Loam	Sandy-loam, Loamy-sand, Loam
	Nov,90	Loam, Silty-clay loam, Clay-loam	Loam, Silty-loam, Silty-clay loam, Clayey-loam, Silty-clay
Soil types	May,90	Normal, Saline, Sodic, Saline-sodic	Sodic, Saline-sodic
	Nov,90	Same	Same

In the present trial only one seed source of each species have been tested. It is recommended that selected range of provenances of promising species be tested as part of the species selection process for saline and waterlogged sites so that more meaningful recommendation can be made.

The reason for changes in pH, electric conductivity of soluble salts (EC) and texture of soil in six months would be too early to conclude. The trial should be continued for about five years to make final conclusions.

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