PLANTING OF TREES IN SALINE AND WATERLOGGED AREAS PART I. TEST PLANTING AT AZAKHEL

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Salinization and water-logging are concomitant, though the intensity of one or the other, or the proportion thereof, depend upon several factors of land and its management. In Pakistan, being an arid/semi-arid land, and the vast plains of Indus Basin and its tributaries allowing irrigational network, the supplemental irrigation has in due course of time broughtforth with intensive culture in piecemeal form patches of salt-affected soil and placement of water table at zone affectng culture of common agricultural crops and tree plants. This menace of land was realized even long before the creation of Pakistan, and full-fledged Department of Land Reclamation was established to counter-check the malady; nevertheless, it attained alarming proportion and threatened the very basis of economy of Pakistan. Of course, vast physical outlays in the form of SCARP have been the outcome of very serious deliberations, even involving the expertise at international level; all the same, the land management problem still persists and baffles the intelligensia.

The magnitude of work in land renovation is such that it can't entirely be left out to pure physical manipulation. One of the sane approaches is to try introduction of plant cover wherever the conditions, and their possible manipulation permit. In marginal land, or in state land along roads, highways, canals, railway, etc. tree cover is the need of the time from several manifestations. Moreover, it has somewhat ameliorative effect too.

Viewing the concept of introduction of economic trees in such land conditions in its proper perspective, a series of trials and experiments, fortified with controlled work in pot-culture and monitoring of analytical soil data in, chemical laboratories, have been initiated. The results reported in this paper are the outcome of field trials in an innovated culture of several selected tree species in highly abnormal land-strips along Peshawar-Nowshera highway at Azakhel which had defied most of the earlier efforts of tree planting.

Types of Salt Condition of Land and Tree Growth

Soluble salts in soil are the primary sources of indispensable nutritional food for plants; only in higher proportion, and imbalance in its constituents, does it deterioratively affect the capability of land. As naturally distributed in the soil mantel, no untoward ill-effect appears; however, by manipulation, physical or biological, a stream of abnormalities are generated. These salt-based abnormalities, in the context of plant culture, have somewhat been classified for general understanding in order to cope with the situation. These are:-

I. *Saline Soils*

The adverse effect in relation to natural vegetation cover or plant culture appears exclusively from the high soluble salt content, interfering in the plant's physiological function owing to high osmotic potential of soil solution, and, as a consequence of its highly disturbing

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water relation of plant and of favourable associated biological life in intimate contact with the plant in the soil sphere. This type of soil is diagnosed by the saturation extract of soil possessing conduction > 4 mmhos/cm at 25°C, and ESP less than 15. Soil pH is invariably less than 8. Such soils often show water encrustation of salts on the surface, favourable flocculated structure to permit satisfactory internal drainage. The ill-effect on plant culture results primarily from excess soluble salts which disturb usual availability of soil water to plants, and in exceptional cases individual salts may be directly or indirectly proving toxic to plants.

Salt flats world-over are well known, and except for sagebush nothing worth of much consequence covers such lands. However, in places, where irrigational water can be commanded, and a salt balance is allowed to sustain, agricultural crops such as sugarbeets with intermittent culture of sesbania, salt grass and legume, together with rice to allow more delta of water letting salts leach out and extracted in drains, can be practised. Wherever water table has arisen, and a sort of culture is allowed to sustain to keep root zone free of excess salts, and not letting water table in this zone through maintenance of effective drainage, irrigated agriculture is practised. On the contrast, with limited water supply efforts have been in way to put tree cover of some economic value. Tamarix spp. has been quite natural to such soil conditions (7). But there have been observations when plant cover of even this resistant type beyond a limit, such as conductivity of 16 mmhos/cm did not establish as a climax tree cover, proving extreme salt infested soil conditions.

2. *Alkaline Soils*

This toxic condition of soil gradually develops with the exchange process that is always taking place between the soil particles and the soil solution; and when Na^+ dominate in the exchange complex of soil particles over other cations, so much so that it may exceed beyond 15 ESP, soil system disperses and a bad soil develops. Its physical condition deteriorates to such an extent that almost aeration and internal drainage reaches practically to a stage when nothing can be grown in it. Its dragnosis are simple: conductivity to express soluble salt content may be less than 4 mmhos/cm; ESP 715%; and soil pH is always above 8.5.

Such soils are quite difficult to reclaim in large chunk of land in order to put them back to plant culture. It is a long and slow process, and involves vast lay-out of network of drains and expensive rehabilitation irrigated culture. The effort first is to improve the physical condition by replacing Na^+ in the soil particles exchange complex with preferably Ca^{+2} or some other ions in order to open up the land to facilitate aeration and internal drainage. Gypsum treatment is economical and culturally practicable.

In extremes of such soil conditions, the land becomes bare flat; nothing grows in such environs.

3. *Saline-Alkaline Soils*

A soil may develop possession of high soluble salt content and also high ESP. Presence of soluble salts keeps the physical tilth of soil not deteriorating to affect internal drainage and plant aeration. Such soils don't form contiguous long unit of land; but develop in patches, depending on the topography, soil state and past management practices, especially the quality of irrigational water used and drainage system laid and permitted.

Some Practical Aspects of Research Studies Conducted in the Improvement of Land for Plant Culture

Wherever irrigated agriculture had been introduced, this problem arose; and consequently researches in the diagnosis and improvement of cultural management to restore such lands had become a permanent practice. Soil system being heterogenous, and plant growth and its physiology itself being very mysterious, saline-soil agriculture, or agrisilviculture, has been baffling the scientists – agronomists and foresters – alike. There is no such thing as a uniform standard culture applicable under all conditions. In many developing countries in Asia and North Africa, where such land conditions persisted since ages, and there has been increasing pressure on land, presently the far-sighted approach and also economics, permit even to plant up such land with salt tolerant economic tree species alone or in conjunction with agricultural crops, success has been varied even at introduction and initial survival in such extreme conditions (2). As in case of tree culture, the salinity effect may vary at many stages of growth, such as at germination of seed, survival of transplant, adaptation and adjustment at seedling and sapling conditions, and form of growth of plant to yield timber or firewood, or even form a scrub cover to clothe the land. As all over the world, in Pakistan too efforts to effect reclamation of such lands has been in way in many departments and research institutions where soil-plant-water aspect comes in. Kaller grass (*Diplachae fusca*), together with *Sesbania aculeata*, has been a much publicized versatile practice to improve such lands (3, 4); this comes in a principle of ecosystem of plant communities which keep on changing in composition and proportion with changing soil-site conditions. The aforementioned ameliorative plant species are mentioned as cultural pioneers to allow in their succession ultimately these crop plants, or economic trees, which require improved soil conditions. Kaller grass has been identified to be a pioneer crop in such lands; it is also being accepted as a special fodder crop (5) in saline agriculture. The biological approach to improve such land many successful studies have been conducted at NIAB by a competent group of scientists (5).

Besides, though many programmes, initiated in piecemeal form by the research institutions of Irrigation and Agriculture Departments, especially of Punjab, have been in way, concentrated efforts were started in mid-fifties with the launching of Ground Water Development Organization which later got merged with WAPDA. In the latest stages are the many SCARP programmes all over Pakistan, although the efficiency and the extent of recovery of deteriorated land, and, of course, the consequent effect of these vast scale intensive management programme on yields of agricultural crops, is still being heatedly debated (1). Besides the out-lays of very high magnitude in these SCARP programmes, significant part is the choiced plant culture itself which should make an acceptable impact. In it, alongwith agricultural cropping husbandry, agri-silviculture and agri-pasture approach also enter in.

REVIEW OF THE PAST EFFORTS IN THE AREA

Experiment No. 1

The experiment was started on 1971-72 at Adamjee Paper and Board Mills Farm located at Azakhel. The following species were planted in a randomised complete block design replicated 6 times, using 16 plants in a plot:

T_1 *Ailanthus altissima*

T_2 *Albizzia procera*

T_3 *Eucalyptus camaldulensis*

T_4 *Tamarix articulata*

T_5 *E. microtheca*

The area exhibited waterlogged and saline conditions. Water table depth is from 0.6 metres to 1.0 metre. Soil and water were analysed.

Only two species viz., *Eucalyptus camaldulensis* and *E. microtheca* showed a fair percentage of survival and height growth.

Survival % in 1974
(A) 30-3-1974 and (B) 5-1-1976

	T_1		T_2		T_3		T_4		T_5		Total	
Rep.	A	B	A	B	A	B	A	B	A	B	A	B
I	31	–	–	–	56	37	81	–	69	12	237	49
II	6	–	–	–	81	37	75	–	50	12	212	49
III	12	–	–	–	100	25	37	–	69	6	218	31
IV	44	–	6	–	81	56	94	–	75	6	300	62
V	6	–	12	–	69	44	94	–	44	6	225	50
VI	31	–	–	–	94	87	69	–	69	31	263	118
Total	130	–	18	–	484	286	450	–	376	73		
Average	22	–	3	–	81	48	75	–	63	12		

Analysis of variance for 1974 data showed that the survival and height growth is significant. *Eucalyptus camaldulensis, E. microtheca* and *Tamarix articulata* showed identical survival while in height growth *E. camaldulensis* showed the best growth followed by *E. microtheca*.

After 2 years i.e. in 1976, no species except *E. camaldulensis* and *E. microtheca* could survive. The former showed better survival with average height of 2.8 and 1.7 m respectively.

Experiment No. 2

Another study was started on 14th February 1975 on G. T. Road near Azakhel. Following 4 species were planted in 3 replications in a randomised complete block design, using 7 plants of each species in one replication:

T_1 *Eucalyptus camaldulensis*

T_2 *Melia azedarach*

T_3 *Populus euphratica*

T_4 *Salix tetrasperma*

Survival percent on November 1976

	T_1	T_2	T_3	T_4
I	86	–	57	–
II	100	–	86	29
III	29	–	57	–
Total	215	–	200	29

Eucalyptus camaldulensis gave maximum survival followed by *Populus euphratica*. While all plants of Melia died after sprouting, survival of willows was only 10%. Superiority of *E. camaldulensis* was thus amply proved.

Experiment No. 3.

The study was started in February 1975 near Azakhel Bala on G. T. Road. 12 species were planted in a randomised complete block design replicated 4 times using 14 plants in one plot. Following were the survivals recorded on 17-3-1976:

E. camaldulensis	53/56	=	95 %
Tamarix articulata	50/55	=	91 %
E. hybrid	48/56	=	86 %
E. microtheca	41/56	=	73 %
E. melanophloia	35/56	=	62 %
E. crebra	31/55	=	62 %
E. torreliana	24/54	=	44 %
E. robusta	18/56	=	32 %
Acacia cyanophylla	2/28	=	7 %
A. seyal			
A. albida	Nil		
Albizzia procera			

In this experiments also *E. camaldulensis, Tamarix aphylla* and E. microtheca gave the best performance.

Experiment No. 4.

Following 4 species were planted in a randomised complete block design and replicated 5 times using 20 plants in one plot. Planting was done on 6-2-1976. Survival percent recorded on 9-12-1976 is as follows:

	R_I	R_{II}	R_{III}	R_{IV}	R_V	Total	Average
Tamarix articulata	60	60	65	85	85	355	71
Eucalyptus crebra	75	75	95	100	100	445	89
E. microtheca	65	70	100	90	100	425	85
E. camaldulensis	80	75	100	90	100	445	89

The results confirm the superiority of Eucalypts and Tamarix.

Experiment No. 5.

Seven species were planted on 9-2-1977 in a randomised complete block design replicated 8 times, using 5 plants in one replication. Following survival percent was recorded on 12-5-1977

	R_I	R_{II}	R_{III}	R_{IV}	R_V	R_{VI}	R_{VII}	R_{VIII}	Total	Average
A. *Populus euphratica*	80	–	–	20	–	–	–	20	120	15
B. *Taxodium distichum*	–	–	–	–	–	20	20	–	40	5
C. *E. camaldulensis*	20	–	–	–	20	60	20	20	140	18
D. *Casuarina glauca*	40	–	60	60	40	–	20	40	260	33
E. *Tamarix aphylla*	80	40	60	60	60	100	40	80	520	65
F. *E. melanophloia*	–	–	–	–	–	–	–	–	–	–
G. *E. microtheca*	–	–	–	–	–	–	20	–	20	3

Maximum survival was shown by ***Tamarix aphylla*** followed by ***Casuarina glauca***. The Eucalypts did not perform well in this particular experiment as the quality of planting stock was not good but survival of Tamarix was very good.

MATERIAL AND METHODS

The ensuing studies, of which this is the fore-runner study after a series of trial planting of many tree species in the area for screening to choose ones which may have promise, are being established at Azakhel road-side strip at a distance of 27 km from Peshawar on G. T. Road. Azakhel has been a problem area owing to its topographic situation, though at times it was rated very productive agriculture and fruit culture area in the vicinity of the surround of Peshawar basin. This particular area falls in depression spur of drainage gradient towards the Kabul river. The drainage of the road strip in the gradient side is obstructed by embankment of railway line. The main recharge comes from the high lying canal which has caused water-table to gradually rise-up, so much so that at present most of the land is going out of production. To counteract the water table and to stabilize it at a respectable depth, an intercepting drain along the road as well as tubewells have been installed in the area.

The natural vegetation of the belt comprises presently a low scrub to a grassland. The scrub may consist of pure *Suaeda fruticosa*, or may contain the grass *Desmostachya bipinnata*

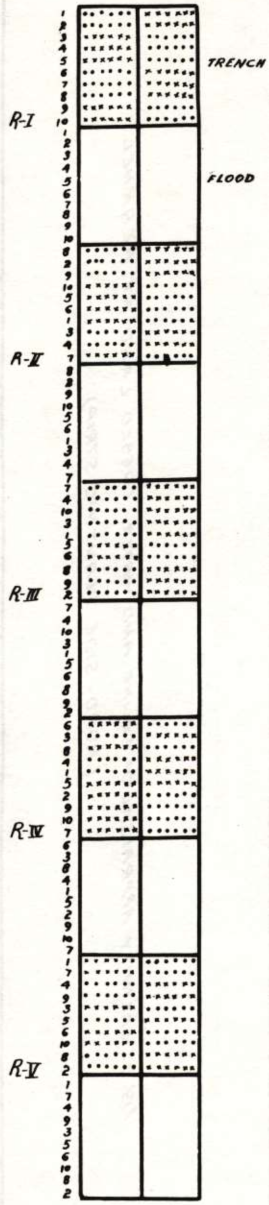
Fig.1 - EXPERIMENTAL PLANTING OF TREE SPECIES AT AZAKHEL WATER LOGGED & SALINE AREA

REFERENCES

1 ... ACACIA CYANOPHYLA
2 ... CASUARINA
3 ... EUC. MICROTHECA
4 ... PARKINSONIA
5 ... PROSOPIS JULIFLORA
6 ... EUC. CAMALDULENSIS
7 ... TAMARIX ARTICULATA
8 ... GLEDITSCHIA TRIACANTHOS
9 ... LEUCAENA LEUCOCEPHALA
10 ... ALBIZZIA PROCERA

GYPSUM .... •

WITHOUT GYPSUM ... x



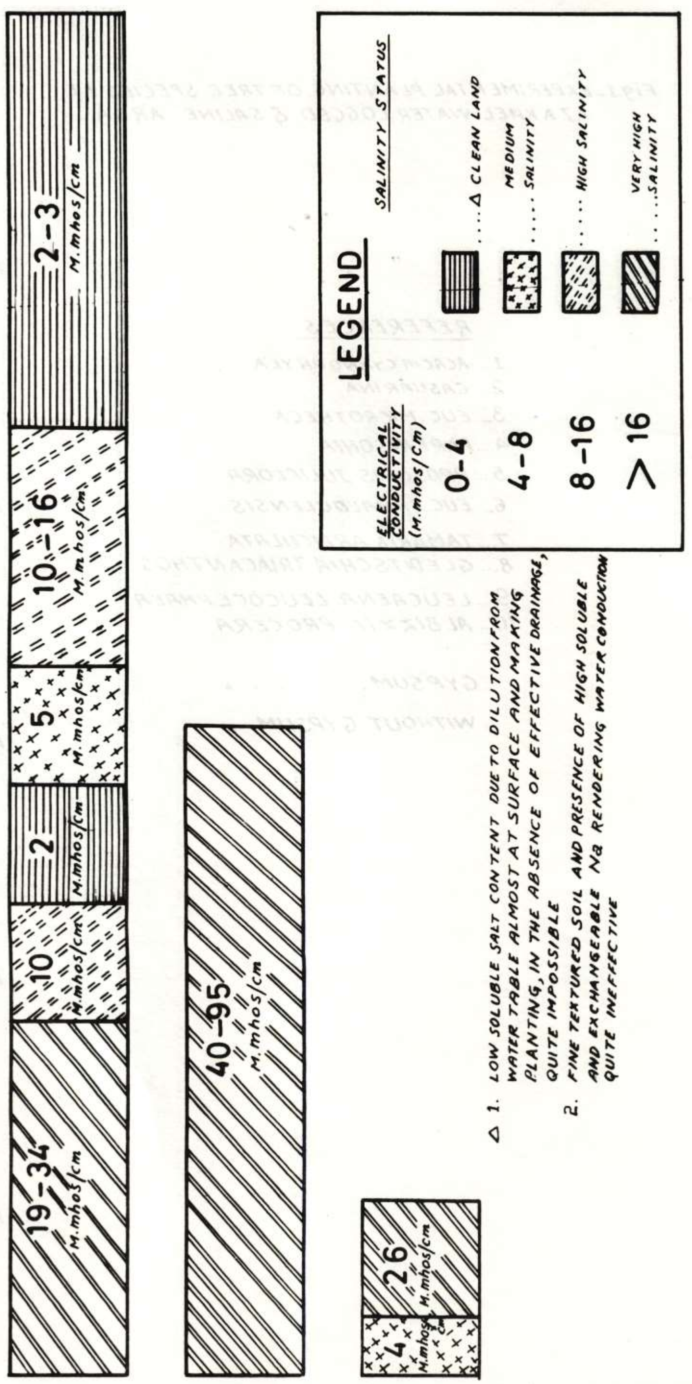


Fig. 2 – SALINITY APPRAISAL OF SALINE AND WATER-LOGGED LAND AT AZAKHEL (ROAD-SIDE PLANTING STRIP)

Δ 1. LOW SOLUBLE SALT CONTENT DUE TO DILUTION FROM WATER TABLE ALMOST AT SURFACE AND MAKING PLANTING, IN THE ABSENCE OF EFFECTIVE DRAINAGE, QUITE IMPOSSIBLE

2. FINE TEXTURED SOIL AND PRESENCE OF HIGH SOLUBLE AND EXCHANGEABLE Na RENDERING WATER CONDUCTION QUITE INEFFECTIVE

in varying proportions, depending upon the different levels of salinity and moisture; it may form *Suaeda fruticosa – D. bipinnata* shrub grassland. Along the road-side, at somewhat raised ground on the slopes, vis-a-vis the level of beds of strip, previously were huge trees of *Tamarix aphylla* which of being old age had been cut, and were intermittently planted with *E. camaldulensis*. There is thick matting of 'dab'; and at places are reeds where the watertable is almost quite at the surface.

In this experimental strip of road-side land, on the experiences of past efforts of planting, a drain, 2' wide and 4'–5' deep, running to a length about 2 km was opened. On the berms of it, the following tree species, at random, were first planted in 1980, and subsequently casualties had been replaced quite frequently almost in all succeeding planting seasons:

1. *Eucalyptus camaldulensis*
2. *E. microtheca*
3. *Acacia tortalis*
4. *Acacia victoriae*
5. *Prosopis juliflora*

Similarly, quite a number of plant species were planted in pits, with their surround kept practically clean, and the surface of plants covered with straw against desiccation of soil in drought periods, in the road-strips between Km 2 and 27 from Peshawar. The observation over a period of plantings of 2–3 seasons helped in arriving at two approaches: (1) all the strip running in length in this belt was surveyed for the assessment of salt status in order to apportionate land with near uniform salt picture, and, viewing the water table and other features of topography, approach for the management and method of planting accordingly; (2) tree species of promise were chosen, and were to be tried in a well-laid out experiment for screening to discern survival, adaptation and apparent qualitative form of growth.

In the experiment under reference, the conductivity of site ranged 2.7–28.0 mmhos/cm. Water table though fluctuated with season but in worst of times at eastern end of the site, its capillary fringe almost saturated the surface; whereas at the other end, being at a slight higher elevation in the limb of this bowl of depression draining the land, it stood at 4 feet.

The experiment was laid out in March, 1980, in the spring planting ideal for most of the plant species to stand transplanting at their dormant period. The design of experiment may be interpreted as a split-split plot randomised complete block type with 10 tree species, of each taken 12 plants planted in 2' x 2' pits as a mid-distance 1½m, splitted randomized half six treated with gypsum (½ kg. per plant pit). The planting was done half in flat and half on the berms of Herring-Bone type drainage trenches leading to main disposal drain. The design is figuratively given in Fig. 1. The tree species tried were:

1. *Gledischia triacanthos*
2. *Prosopis juliflora*
3. *Albizzia procera*
4. *Casuarina equisetifolia*
5. *Tamarix aphylla*
6. *E. camaldulensis*

7. *E. microtheca*
8. *Parkinsonia aculeata*
9. *Leaucaena leucocophala*
10. *Acacia cyanophylla*

The planting stock was uniform, 6–12 months in age and selected from vigorous seedlings of good form. In the succeeding 2 weeks, the casualties were replaced, presuming the cause being the carriage disturbance and transplanting shock. Initially the plants were regularly watered so that the roots got adjusted and there had been possible physiological adaptation of plants. The severity of physiological drought both from the summer harsh desiccating months and the interaction stress from the increased osmotic potential from soluable salts, and also of ionic effect, affected the post-summer survival. Besides, interim periodical observations of condition and survival of plants were observed all through. The final picture of survival, as it stood on 14th July, 1981 is given.

Soil Sampling and Chemical Analyses

54 composited soil samples to a depth of one foot were taken from individual treatments; the sampling was so arranged as to cover the apparent visual observations of condition of plants, and, after detailed analyses, the various parameters might be somewhat indicative of critical demarcation line, beyond which the survival of plant was critically affected.

Soil samples were air-dried, ground, 2 mm mesh sieved, and stored for conducting various laboratory analyses. pH was recorded of saturated paste which was further pressure extracted to yield saturation extract for analysis. Saturation percentage of samples was also determined.

Electrical conductivity and ionic composition such as Co_3^{2-}, HCo_3^{1-}, Cl^{1-}, Ca^{2+}, Na^{+}, K^{1+}, were determined following well-known standard procedures given in references (7).

RESULTS AND DISCUSSION

Peshawar valley forms a basin, and its soil beds are, in general, loess in character and of fine texture to a greater depth. It is a rich soil; and this part of Pakistan is considered an exceptionally productive farming land. Its climate is quite severe with summer temperature 24–36°C, and winter temperature 4–19°C; here merge the continental eastern mediterranean and the sub-continental monsoon. Summers are hot; and winters are severe with frequent frosty nights in December –January months. There is at present a conspicuous change in weather cycles, causing a striking change-over in the intensity and frequency of rain. The average rainfall in the past 3 years recorded at the PFI observatory is 358 mm.

The agriculture, fruit culture – citrus and predominent prunus spp. – blossomed with the introduction of canal irrigational networks. And this brought in its wake the rise of water table, and the concomitant concentration of excess soluble salts in the rhizosphore as a consequence of evaporation, both the scourges appearing simultaneous and gripping the farming land in this basin of Azakhel. The agriculture is disappearing; its place has been taken by a vast stretching ground of poor quality pasture. Tree cover is practically absent except at places where through efforts some stray straggling trees survived. The ground water table has arisen from a considerable depth in areas not commanded by canal irrigation to within few feet. This has gripped a vast area, though the calamity varies from place to place; the area under reference, however, is the hardest hit.

Physiological Behaviour of Plants Grown in Water-logged Areas

The present matted condition of grass cover that we find in whole of Azakhel pasture barren and roadside surround is due to adaptive character of plants in water-logged conditions. The plants put on superficial root system, or by development of specialized roots which are functional in submerged soil. Such roots are slender and much branched. They are massed just below the surface of the soil to enable them to absorb sufficient oxygen from their environment by virtue of their large absorbing surface (2). There are also adventitious roots, penetrating deep, becoming thick to add more inter-cellular space (2). In cases where roots in the absence of requisite oxygen supply die, new roots are found from the base of stem, which are observed to be better adapted to changing conditions. In general herbaceous plants are better able to form adventitious roots than are woody ones (6).

The basic soil requirements of fruit trees are well-drained soils, and are therefore more severely affected by water-logged conditions (7); pears are reported to be slight exceptions, when severe conditions of it caused girdling, split-bark and die-back. Of course, in such plant culture root-stock on which the fruit has been grafted exerts a major influence to adaptation (2). Observations have, in general, shown that in the dormant season plants can escape major injury; however, on intensity of active growth the susceptibility to injury returns. In case of forest tree species, except of mangrove forests, tidal forest, the basic requirements in water-logged conditions are not met with to allow even the very adaptive species to grow normally. The determination of the optimum level of water table, and thereof of the ideal depth of drainage, to screen tree species which can grow, is beset with difficulties, especially in situations as inherent in pockets of arid and semi-arid lands where the situation is also parallely infested with excess soluble salts. In general, the maximum allowable water table is 40–50 cm. in the case of grassland (2).

Specific Characteristics of Tree Species under Trial

1. *Gledischia triacanthos*

It is a very hardy species, though in its native place it is a species of rich and moist bottomlands. This very character was suggestive of a possible adaptative in water-logged-cum-saline land, where instead of becoming a usual tall tree with a spreading crown, it might have become a scraggy tree. It tolerates frost, and, in fact, is a plant of colder climate; but it is tolerant of all sorts of site and environmental conditions. It makes faster growth as a nitrogen-fixing species. It can be transplanted with open roots in winter.

Its wood is, similarly, hard, tough and strong, and quite durable and pods provide excellent fodder.

2. *Prosopis juliflora*

Mosquite is deep-rooted and drought resistant. It is a small thorny tree, not affected by frost. It grows on all sorts of soil conditions; and in its native place it grows in saline flats. It coppices well. Its wood is hard and durable. It is frost tender.

3. *Albizzia procera*

It is otherwise a well-shaped tall tree but is cut back by frost. It thrives well in moist soils, but stands up to a long dry period. It has adapted and grown well in irrigated saline conditions in Sind. Its timber is hard, strong, and quite suitable for a variety of purposes.

4. *Casuarina equisetifolia*

It is primarily an ornamental avenue plant, which is known to take to saline condition but is affected by frost. Being faster in growth, it has also been accepted as an afforestation species of coastal areas for seashore reclamation. It likes sandy graded loose and moist soils; may take salinity but sodium salts affect it badly. It stands partial water-logging and gtrows out long adventitious roots. In the initial planting of open-root or tubed plants, preferably in early spring planting, at the end of summer months, there should be wrenching of roots so that more adventitious roots are set out.

5. *Tamarix aphylla*

It grows into a decent-sized tree from cuttings or otherwise. It is proven to come up well in saline soil and somewhat moist soil conditions. It is a phreatophyte, with a vigorous taproot, transpiring abundantly. It is a natural tree of the tract.

The wood is moderately hard but cracks and splits easily.

6. *E. camaldulensis*

A native of Australia which has practically taken home almost everywhere in all countries. In its soil requirements, some provenances have been known to be salt tolerant and to periodic water-logging conditions.

It is number one species which is on increase amongst the planted species in Pakistan owing to its wide acceptable use as wood, shelterbelt and even as a future source of pulp. It is easy to raise and very quick growing, and has already adapted in a variety of soil conditions in Pakistan.

7. *E. microtheca*

Basically it is the tree of inland arid areas of Australia, and has as much acceptability world-over as a tree of wide-spreading branches its other sister – *E. camaldulensis*. It resists drought, high temperatures and alkaline soils; also grows in partially water-logged conditions. This species has considerable genetic variation. In Pakistan, it has not been well-accepted owing to its inter-locking grain of wood which is difficult to work, and of its spreading character in growth. However, it is a good tree for shelterbelt planting, soil conservation, erosion control and shade.

8. *Parkinsonia aculeata*

It is a drought resistant leguminous tree adaptable to a variety of environmental and soil conditions; such soils as poor, gravelly or sandy alluvial are quite natural of it. It tolerates salinity, but does not take to water-logging.

Its wood is hard and brittle; it is more of an ornamental tree in many countries, and in its native countries used as firewood.

9. *Leucaena leucocephala* (ipil-ipil)

It is a versatile tropical leguminous plant of fame to be used as firewood, nutritious forage, rich fertilizer, and also as a minor timber; besides, its forest tree role as a vegetation cover on hill slopes. It is hardy and drought tolerant; and for this reason, and also for its aggressive root-system, can be a choiced plant for general protection of watersheds when planted on marginal soils. Its root system takes to variety of soils. It also grows on wet and somewhat alkaline conditions.

Its constraint to its popularity may be the content of mimosine in its foliage, which becomes toxic to ruminants when its foliage is consumed in excessive amounts; and secondly at good sites, at times it is turning into a brothersome weed.

10. *Acacia cyanophylla,* Lindl

It is known as blue leaved wattle. A tall shrub growing upto 5 metres in height with drooping branches and ever green linear oblong lanceolate foliage. Flowers, large, golden yellow. The plant is known for its tolerance to saline-alkaline soils.

Survival of Tree species and Salinity Parameters

The behaviour of plants in heterogenous conditions prevailing in 'saline' soils, with fluctuating water table, but after staying close to root-zone of plant seedlings in their initial adaptation trial, has been intriguing the minds of researchers since the very stage when one came across unanswerable anomalies in abstract parameters in the realm of soil-plant relationships. This has been due to several factors, some of which are attributable while others are still lost unanswerable realities pf nature (1, 2). Life itself is mysterious and it has considerable flexibility in adaptation in order to survive and tide over unfavourable environments. As for tree cover in such abnormal habitats, there are aspects such as survival, tolerance, resistance and growth which differ not only from species to species but also at different stages of growth of plants. In general, germination, and in case of practices in some species young transplants, are the most sensitive stages. Thereafter if plants have survived, a satisfactory initial growth in a habitat of complexity of salts and water-table is looked for conditions. In perpetuation the plants may develop with a scrub cover. What is overall desirable is to search for economic species which withstand and develop into timber form. But all these aspects to discern and understand are very quizzical and interest a researcher to look for breaking points. It concerns not only the species under trial, but also the prevaricated behaviour of strains and the practices to which the plants have responded.

The salt regime in the rhizosphere considerably varies with the heterogenity of soil conditions, terrain topography, and placement and seasonal variation of water table; this can be depicted from the figure 2, where salts deposited in the upper layers of soil have been varying in strips influenced by factors enumerated above. Previous plantings have similarly been affected where the salts ranged above 16 mmhos/cm electrical conductivity, and water table was placed fairly below the root-zone. The casualties of various tree species such as *Acacia seyal, A. albida, A. cyanophylla, Albizzia procera, Ailanthus altisimma*, transplanted in packet planting, was on mass scale.

The salt regime and its composition of the experimental area are given. The range of various parameters of salts which are to be used as indicative of bearing in relationship with behaviour of tree species being tested are as follows:

pH (sat. paste);	Electrical conductivity (mmhos/cm)	—Ca^{2+} (meq/L)
8.2 – 9.5	2.7 – 28.0	traces – 16.0
Mg^{2+} (meq/L);	Na^{1+} (meq/L;	K^{1+} (meq/L)
traces – 19.0	25.8 – 766.1	1.7 – 356.8
CO_3^{2-} (meq./L);	HCO_3^{1} (meq./L)	Cl^{1-} (meq/L)
traces – 356.2		7.5 – 83.5
SAR		
21.4 – 685.2		

The survival picture of the tree species under reference at different times during 1980–81 is given in Table. In July 1980, the following species had more than 50% survival after being affected by summer hot months, though watering to individual plant pits was arranged by water-tank carrier:

Tree species	% survival
Tamarix articulata	60
Prosopis juliflora	59
E. camaldulensis	51

Amongst the rest, *E. microtheca* (46%) and *Albizzia procera* (46%) also performed satisfactorily. In August 1980, casualties were removed and the whole experiment was freshly restocked. After restocking, the picture available is being given on survival standing on 7-8-1980. The final survival data recorded after one-and-half year effect, is being presented in Table. The prominent species which considerably resisted the severer salt regime, and also closeness of water-table, are being given as under:

Tamarix articulata	(53 %)
E. camaldulensis	(44 %)
Prosopis juliflora	(43 %)

Leucaena leucocephala performed well in one replication where water table influenced soil conditions, but the plants were severely affected by frost.

Effect of Planting on Slopes of Berms of Trenches

The presumption that planting on slopes of berms in trenches to allow periodical flushing of salts in the root-zone and the removal of affluents by trenches to assist in general drainage did not bring in the desired results. The survival species-wise of 120 of each planted in 5 replications is being given as under:

		Planting	
	Tree species	Trenched	Untrenched
1.	*Acacia cyanophylla*	0	2
2.	*Casuarina equisetifolia*	16	30
3.	*E. microtheca*	4	25
4.	*Parkinsonia*	5	12
5.	*Prosopis juliflora*	17	34
6.	*E. camaldulensis*	12	41
7.	*Tamarix aphylla*	25	39
8.	*Gleditschia triacanthos*	1	11
9.	*Leucaena leucocephala*	3	16
10.	*Albizzia procera*	1	21

It appears quite clearly that trenching had no effect; instead, plants relatively performed much better when planted in flats. It appears that the salts get washed and get accumulated in the pit around the plant and thus increasing the concentration still further.

Effect of Soil Treatment with Gypsum on Improvement of survival of Tree Species

The site is saline-alkaline, as judged from high pH, low soluble Ca^{2+} in spite of being calcareous as the parent character of these loess beds, and high soluble Na^{+}. SAR values are very high. In a split-split plot randomised complete block design, plant pits were treated with ground gypsum (200 gm, 2 mesh screened), equivalent to 300 Kg per acre. Apparently, in the absence of regular irrigation to flush out the soluble salts, the treatment did not slow the desirable effect on the survival of plants.

Species-wise effect, appearing from gypsum treatment, is shown as under:

Tree species	No. of survival of plants Gypsum treated pits	Non-gypsum treated pits	Total out of 120
Acacia cyanophylla	1	1	2
Albizzia procera	14	8	22
Casuarina equisetifolia	32	14	46
E. camaldulensis	27	26	53
E. microtheca	25	4	29
Gleditschia triacanthos	7	5	12
Leucaena leucocephala	13	6	19
Parkinsonia aculeata	17	0	17
Prosopis juliflora	27	24	51
Tamarix aphylla	30	34	64
	193	122	315

Had the gypsum treatment been followed with leaching in the management practice, a more desirable effect on the removal of sodium as well as of soluble salts should have appeared on more survival of sapling transplants under such conditions. Being fine textured land, the presence of excess exchangeable sodium affected movement of water and aeration of roots. This adverse effect of sodium, of course, is moderated by many variables but the most effective is the organic matter content of soils. This aspect is usually covered in the management of such lands when Sesbania is grown and young crop is invariably ploughed in to improve the land.

CONCLUSION

The fore-runner field study to determine the conditions which, when improved by physical, chemical and biological adjustments and amendments might help in the initial adaptation and survival of transplant seedlings, and also to discern behaviour of various possible salt tolerant tree species after being affected by the abnormal salt and underground water conditions of site and of its improvements by cultural methods, brought out some salient features which are pointed out below:

1. The soil-site at Azakhel had been saline-alkaline with predominant soil texture to a depth of 4 feet of silt-clay loam. The infestation of salts in upper beds varied with slight variation in topography; at places where the water table stood near the surface, it diluted the salt content, however, at dry sites the salt content expressed as electrical conductivity of saturated extract, had been 7.25 mmhos/cm^2. The site was densely covered with *Desmostachya bipinnata*.

2. Of the ten tree species whose 6–12 months year old transplants were tried on the site for

establishment, planted either in berm of trenches or in flats, and random treatment given with gypsum, the ones which stood salt condition of this intensity better were: *Tamarix aphylla, E. camaldulensis, Prosopis juliflora* and *Casuarina equisetefolia*.

3. Berm planting on trenches to facilitate washing of salts from the root-zone and of drainage of surface affluent, did not help survival of plants.

4. Gypsum treatment did not improve the plant beds; this could be attributed to ineffective removal of exchangeable soluble sodium salts in the absence of irrigation. This condition, therefore, had no effect on the overall survival of plants of all the tree species tried in this habitat.

The establishment of a tree cover on lands deteriorated with imbalance of soluble salts and encroachment of water table has posed problems which can only be partially solved permitting economics of venture in an encumbersome vast area. The Azakhel belt which at present lies barren owes to this condition primarily to rising water-table in this low basin and absence of effective drainage to keep the rising salts somewhat restricted. The roadside strip is a representative of worst of the area under reference, and the tree plant culture in the absence of intensive management of refurnishing of soil by drainage, flushing of salts by irrigation, removal of dense grass cover and planting with sesbania few times to strengthen the soil tilth cannot be possibly established. The adjacent soil improvement by cultural methods and planting with agricultural crops such as sugar-cane and sugar-beet with periphary of Poplars surrounding the field is a case in point. All this requires soil improvement first before planting with relatively best-known salt tolerant economic tree species.

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