MANAGING SALTY SOILS AND WATERS FOR AFFORESTATION

by

RAJ K. GUPTA, O. S. TOMAR and P. S. MINHAS

All India Coordinated Research Project on
Management of Salt-affected Soils and Use of Saline Water in Agriculture

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Gupta, Raj K., Tomar, O.S., and Minhas, P.S., (1995). Managing Salty Soils and Waters for Afforrestation. CSSRI Bulletin No. 7/95, Central Soil Salinity Research Institute, Karnal, p. 23

Published by : The Director
Central Soil Salinity Research Institute
Karnal-132001 (INDIA)

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Printed at : National Printers, 20/3, West Patel Nagar, New Delhi-110008

FOREWORD

With ever increasing pressure of human and animal populations, productive use of salt degraded lands has to be given priority for easing out food, fodder and fuel shortages as well as for correcting ecological imbalances. Realising such a need the institute initiated major agro-forestry programmes during the eighties, especially for developing techologies suited for the rehabiltation of salty lands falling under the perview of governmental/ community lands. An outcome of these research efforts has been the development of suitable planting methods alongwith other practices which mitigate the ill effects of salinity / alklainity. In this process, salt tolerant tree species have also been identified. The research efforts are continuing at the institute which have been further strengthened in collaboration with other organisations like NWDB, UPLDC and the State Forest Dept., Haryana. Refining the evolved techniques and their extension to more difficult areas is now in progress.

As a result of sustained research efforts, appropriate technologies for afforestation of salty lands have emerged. In the present compilation, the authors have attempted to scrutinise and update the information on forestry research that could be recommended to user agencies for large scale adoption. Some of the technologies developed at CSSRI have already become popular with the foresters. It is hoped that the new technologies described here, which are more user freindly, will also find acceptance for large scale afforestation of salt-affected soils. I congratulate the authors for their commendable efforts in bringing out this very useful publication.

NKTyagi

N.K. Tyagi
Director

ACKNOWLEDGMENTS

We are grateful to Dr. N. K. Tyagi, Director, CSSRI and Dr. N. T. Singh, former Director for guiding the technical programmes of the project on "Evaluating tree plantations for control of salinity and water table" and extending all facilities and encouragement.

We are also thankful to Shri Ranjit Issar, Joint Secreatry, Dr. S. Subramaniayn, Director (Technology Extension), Dr. Anand Singh, Asstt. Commisioner and other staff of the National Wasteland Development Board, New Delhi for the help and cooperation rendered in providing the funds for the above project. It is only with the timely release funds that various programmes of the project could be implemented as per schedule. Dr. D. C. Das, former Director, NWDB also made many useful suggestions on the first draft of this bulletin.

Thanks are also due to Dr. S. Chinnamani, former Assistant Director General (Agroforestry), ICAR and Mr. Sultan Singh, Conservator of Forests, Haryana for their help and cooperation in implementing the NWDB funded project.

Many of our scientist colleagues at the institute have made untiring efforts and have contributed over the years to the dvelopement of afforestation technologies as are recommended in this bulletin. We appreciate their efforts and extend our sincere thanks, especially to Drs. H.S. Gill and G.B. Singh.

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EXECUTIVE SUMMARY

It is being realised that productivity of nearly 28 million hectares (mha) of forest lands having a crown cover less than 40 percent be enhanced and additional lands, where economic crop production is not possible, be put under tree canopy for correcting ecological imbalance. Some of the salt-affected soils which occupy an area of ~ 10.0 mha could possibly be used as alternate sites for afforestation. Ground water quality underneath salt-affected soils, particularly the saline soils is usually brackish.

Rehabilitation of chemically degraded lands for raising food crops demands additional agricultural inputs on recurring basis. Salty soils can be speedily rehabilitated with phased-out use of inputs through horizontally extensive land use in forestry. In afforestation of salty soils, excess of salts and paucity of water for meeting irrigation needs are the 2 major problems which adversely affect the establishment and growth of tree saplings. Reluctance to develop brackish water aquifers for providing irrigation during hot summers and chilly winters further complicates the afforestation problems in saline areas. For achieving success with new plantations in saline environments, proper selection of tree species, planting methods and the practices which have better control over rootzone salinity are crucial.

Recent researches on relative tolerance/performance of tree species under saline and alkali environments and for the conditions of brackish water irrigation have indicated a fairly large number of tree species which can be utilised for afforestation. Suitable planting methods along with the practices which mitigate the ill-effects of salinity have been explored. It has been recommended that 'sub-surface planting and furrow irrigation method, (SPFIM) is best suited for saline as well as alkali soil conditions. Post-augerholes for piercing through the sub-soil calcareous layers should be advantageously combined with 'SPFIM' under alkali land situations. Further, saline waters of EC_{iw} less than 10 dS/m can be suitably exploited for early tree establishment and growth with SPFIM. In arid regions wherein rainfall is scanty and the sub-soil layers are fairly dry, an irrigation support period of at least 3 years, even if the irrigation water quality is poor, is recomended for better canopy cover and biomass yield.

2. INTRODUCTION

The National Forests Policy (1952) envisages that an area of 110 million hectares (mha) should be under the forests. However, the total area currently under forest cover is only about 65 million hectares. The area of closed forests with more than 40 percent crown cover is about 36 m ha. Burgeoning populations and degradation of land resources seem to be primarily responsible for this sad state of our forest resources. Therefore, corrective measures to improve the productivity of the degraded forest lands (~ 28 m ha) are imperative. Also, possibilities for bringing more lands under tree canopy must be explored.

It is fairly clear that competitive land use patterns do not favour afforestation of fertile lands. Therefore, it is axiomatic that marginal and 'wasted' agricultural lands which are unable to support economic crop production due to constraints of aridity, salinity, low-fertility, extremes of soil pH and of poor quality irrigation waters be allocated for taking up afforestation programmes. All these conditions are although hostile to trees as well, but the hard woody tree species are known to tolerate such stresses better than food crops. Recent, researches have greatly improved our understanding of the biology and management of the forestry plantations in salty soils. It is now very well established that subject to needed changes in technologies, salty soils can be successfully put to alternate land use through afforestation programs. Potentially, tree plantations are at least as economic as some of the cropping alternatives. Therefore, we have attempted to collate the available information on afforestation technologies for salt affected soils and present it in a simpler form such that it can be adopted by growers and concerned forestry staff.

3. HOW DO SALTY SOILS DIFFER FROM NORMAL SOILS ?

Salt-affected soils differ from normal arable soils in respect of two important properties, namely the amounts of soluble salts and the soil reaction. Excess soluble salts adversely influence soil behavior by changing its physico-chemical properties which in turn have a strong bearing on the activity of plant roots and growth of plants.

Salt-affected soils are known by different local terms. They are called *Kallar* or *Thur* in Punjab, *Usar* or *Reh* in Uttar Pradesh, *Luni* in Rajasthan, *Khar* or *Kshar* in Gujarat and Maharashtra, *Chouddu* or *Uippu* in Andhra Pradesh, *Choppan* in Karnataka. The acreage of salt degraded lands is nearly 10 m ha in the country. These soils occur extensively in different agro-ecological and soil zones of the country, particularly the arid, semi-arid and the dry sub-humid regions.

3.1 Sources of Salts

Excess salts may accumulate in the surface horizons of soils mainly due to the following reasons :

- **Secondary salinization associated with waterlogging**
- **High salt content of irrigation water**
- **Release of immobilized salts already precipitated in soils**
- **Atmospheric salt dispositions as in coastal areas**
- **Weathering of soil minerals**
- **Use of fertilizers**

The relative significance of each source in contributing soluble salts to the root zone depends on the natural drainage conditions, soil properties, irrigation water quality, management practices and distance from the coast line. Soluble salts are either neutral in their reaction (e.g. chlorides and sulfates of sodium, calcium and magnesium) or are the soda salts (carbonate and bicarbonates of sodium) capable of producing alkalinity.

3.2. Classification of Salt-affected Soils

Salt affected soils are grouped according to the nature of plant response to the presence of soluble salts and on the basis of management practices required for their reclamation. Unlike the pedogenic system, it is a simple system of classification requiring information on the nature of soluble salts only. Since salts are either neutral or alkaline in reaction, salty soils are grouped into 2 classes:

(i) **Saline soils and**
(ii) **Alkali soils**

3.3 Characteristics of Saline and Alkali Soils

SALINE SOILS

- salts form white efflorescent crust on the soil surface
- soluble salts are usually determined by measuring electrical conductance (EC) and are invariably present in large quantities. EC of the paste extract (ECe) is more than 4 dS/m.
- salts are primarily the chlorides and sulfates of sodium, calcium and magnesium.
- soil paste pH which is a measure of acidity/alkalinity, is less than 8.2.
- Na^+/Cl^- or $Na^+/(Cl^- + SO_4^{2-})$ ratio in paste extracts is less than unity.
- sodium adsorption ratio, $Na/[(Ca+Mg)/2]^{1/2}$ a measure of soil sodicity hazard is variable [may be lesser or greater than 15 $(mmol/L)^{1/2}$].
- gypsum may be naturally present in the soil.

ALKALI SOILS

- pH of the soil paste is greater than 8.2.
- high sodium hazard (SAR or exchangeable sodium percentage more than 15 and 8 for alluvial and black soils, respectively)
- soils have soda type salts (carbonates and bicarbonates of sodium).
- salt encrustation marked with black colour near organic matter spots.
- water especially the rain water does not infiltrate into the soil and stagnates for long periods
- Na^+/Cl^- or $Na^+/(Cl^- + SO_4^{2-})$ ratio exceeds unity.
- A layer of calcium carbonate concretions is usually present in the subsoil (1-1.5m depth). Gypsum usually not detected.

3.4 Ground Water Quality in Salt-affected Areas

Salt-affected soils are generally found in the arid and semi-arid regions of the country. Rainfall is often less than 700 mm in the most of these areas and about 80 percent of the annual precipitation is received during the monsoon season (July to September). In the post-monsoon season, water requirement of the transplanted saplings has to be met either through canal water supplies or through ground water use. In the presence of poor quality under ground waters salinity problems are further complexed.

It has been observed that ground water underneath most saline soils is poor in quality due to excess of salt load or high sodium adsorption ratio(SAR).Many people who think that it is unwise to irrigate the saplings with brackish waters may simply be handing you over a wrong prescription. This is because overcoming water stress is more crucial than salt stress for survival of saplings. Judicious use of brackish waters not only can save the saplings but will also improve their growth.

Ground water quality underneath alkali soils is generally good and could be used for irrigation. In about 15-20% situations ground waters may have high residual alkalinity (concentration of carbonates and bicarbonates in excess of calcium and magnesium, RSC > 4.0 meq/l) and high SAR (SAR >15). Since the use of high RSC and SAR waters creates alkalinity problem, they are termed as 'strongly alkali waters'. Except for the strongly alkali waters which have to be used with some care, all other type of alkali waters can be used safely for irrigation in afforestation programme. Cautions for the safer use of alkali water have been described later in the section on irrigation management.

4. WHY TO REHABILITATE SALTY SOILS THROUGH FORESTRY ?

New obligations emerging out of growing population demand that each parcel of land be best utilized consistent with ecology and the land use capabilities. This means that even the degraded lands including salty soils be either reclaimed for agricultural purposes or put under alternate land uses. Despite the availability of technical know-how, reclamation and management of salty soils is proceeding at a snails pace. This is because marginal farmers and village *Panchayats* who own the salt-affected soils have poor resource endowments. Reclamation of salt affected soils requires additional agricultural inputs such as amendments, fertilizers, water and infra-structure for farm operations and drainage. Requirement of extra resources on recurring basis has been a major bottle neck for the rehabilitation of salty soils on an extensive scale. Therefore, enhancement in the pace of the reclamation of salty soils calls for adoption of strategies which permit horizontally extensive use of salt affected soils with phased-out use of agricultural inputs. This requirement is very well met by setting up afforestation programs, especially on 'wasted' village community and other governmental lands. In other situations, agroforestry or farm forestry can be practiced for speedy rehabilitation of salty soils. Besides providing fuel, fodder and timber, afforestation will also lead to bio-amelioration of salt affected soils. Afforestation of salt affected soils is not only prudent from ecological and environmental considerations but also offers a unique opportunity for relieving pressure on traditionally cultivated lands.

5. PRACTICES FOR AFFORESTATION OF SALT-AFFECTED SOILS

Creation of favorable root environment for proper establishment of tree saplings on salt affected soils and with brackish waters demands for the adoption of special package of practices. Before discussing these practices, we have attempted to present here a comprehensive account of the points which need special considerations for the success of afforestation programs.

- **Identification of the nature of salt problem**
- **Assessment of availability and quality of irrigation water**
- **Selection of suitable tree species**
- **Choice of pitting and planting methods for alkali & saline soils**
- **Soil and water management**
- **Physical and social fencing during initial years**

Both alkali and the saline soils differ in their physical and chemical characteristics and thus nature of constraints for plant growth. Therefore, diagnosis of the nature and magnitude of the problem is must. This can be ascertained by sending the soil and water samples to a nearby soil testing laboratory. Once the causative factors are known, specific instructions for undertaking afforestation programs on such soils may be followed.

5.1 Nursery Production and calendar of activities

For maximum establishment of tree saplings in salty soils, nursery should be of good size, not over grown, of high standards in respect of form and vigor. Saplings should have well developed fibrous root systems, free of root coiling, malformation, disease or mechanical damage. Comprehensive accounts of nursery raising techniques are available in several forestry manuals and texts. Here we intend to describe only those specific features which deserve special attention under saline environment.

- Nursery operations should be aimed at producing nursery stocks of predetermined specifications before the onset of monsoons. Most appropriate period for planting saplings in salty soils is during the rainy season (July-August), though planting can also be undertaken during February-March under aasured irrigated conditions.

- Seed raised nurseries suffer more due to salts.Where ever possible, nurseries raised from stem/root slips should be preferred for salty soils.

- Saplings should be at least 70 -100cm tall. Mortality rates are high in smaller sized saplings.

- Provide for adequate drainage to prevent waterlogging in the potted soil or laid out nurseries. Make 6-8 'punch holes' in the bottom of polythene 'pee bags'.

- Do not raise nurseries on saline/alkali soils. If salty soils are unavoidable, irrigations should aim at minimizing the salt effects. Irrigate nursery bags frequently (2 days interval) with good quality water from the top. Flood irrigation of 'pee bags' with bottom holes when placed in salty beds will cause salts to accumulate in upper parts of the bag. Irrigation from the top (with fountain) will push the salts down and out of the 'pee bags'.

- With saline waters (EC_w > 4 dS/m) leaf injuries can be avoided by irrigating the nursery late in the evening so that saplings adjust themselves to the new salt equilibrium over-night.

- Roots may protrude out of 'punched holes'and fix up in the soil below. To avoid such problems, containers should be shifted and the protruded roots be pruned at regular intervals.

- Plants in polythene tubes/pots are prone to injury during transport to distant saline areas. Care should, therefore, be taken that potted soil neither falls apart nor excessively hardens due to drying. Do not transport saplings which have been irrigated only few days back.

- Use only sorted and hardened /seasoned saplings for field planting

A general calender of activities for raising tree nurseries is given below :

Month	Filling of bags	Seedbed preparation & seeding	Planting cutting	Shifting & grading	Root pruning	Thatching	Weeding	Plant protection
January	✓	✓	–	✓	✓	✓	–	–
February	✓	✓	✓	✓	✓	–	–	–
March	–	✓	–	–	–	–	–	–
April	–	–	–	✓	–	–	✓	–
May	–	–	–	–	–	–	✓	–
June	–	–	–	✓	–	–	✓	–
July	–	–	–	–	✓	–	–	✓
August	–	–	–	–	✓	–	–	✓
September	✓	✓	–	–	✓	–	✓	–
October	✓	✓	–	✓	–	–	✓	–
November	–	–	–	–	–	–	–	–
December	–	–	–	✓	–	✓	–	–

Note: Apply irrigations as per requirements

5.2 Selection of Tree species

Choice of proper tree species depends upon the local agro-climate, land capablity, purpose of planting, tolerance to salinity/ alkalinity and waterlogging/ drought stresses. In general, plantation for fuelwood are rated better for salty soils than the timber wood tree species. In addition to inter- and intragenic variations in salt tolerance of forest tree species, tolerances also vary with the growth stages. It may also be pointed out that besides salt tolerance, socio-economic conditions and the ameliorative role of trees should also be given due consideration in selecting tree species for afforestation programs.

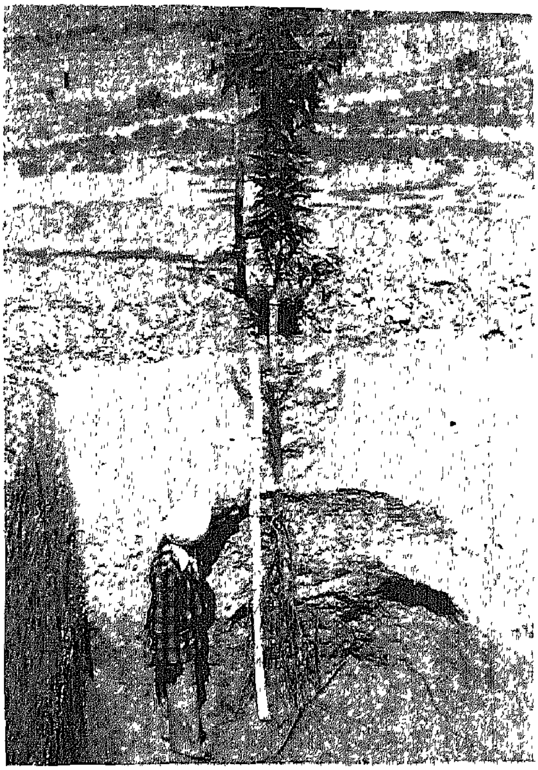
Numerous tree species have been evaluated for their tolerance to saline and alkali conditions. Amongst the principal species of arid and semi-arid regions, some species have been rated better than the others. A short list of consistently better performing species which could be recommended for growing under saline and alkali conditions of soils or irrigation waters, has been presented in the following 3 tables where as agroclimatic requirements of these species are detailed in appendix-I.

Table 1. Recommended tree species for alkali soils.

Soil pH_2 down to 1.2m	Firewood/timber/fruit species	Common name
> 10.0	*Acacia nilotica*	Kikar
	Butea monosperma	Dhak
	Casuarina equisetifolia	Casuarina, Saru
	Prosopis juliflora	Mesquite, Pahari kikar
	Prosopis cineraria	Khejri, Jand
9.0-10.0	*Aegle marmelos*	Bel
	Achras japota	Chiku
	Albizzia lebbeck	Siris
	Carissa carandua	Karonda
	Cassia siamea	Cassia
	Eucalyptus tereticornis	Mysore gum, Safeda
	Feronia limonia	Kainth, Kabit
	Pongamia pinnata	Papri
	Phoenix dactylifera	Datepalm, Khajur
	Psidium guajava	Guava, Amrud
	Sesbania sesban	Dhaincha
	Tamarix articulata	Faransh
	Terminalia arjuna	Arjun
	Zizyphus maurtiana	Ber
	Zizyphus jujuba	Ber
8.6- 9.0	*Azardirachta indica*	Neem
	Dalbergia sissoo	Shisham, Tahli
	Emblica officianalis	Amla
	Grevillia robusta	Silver oak
	Hardwickea binnata	Anjan
	Kajellea pinnata	Balam khira
	Morus alba	Mulburry, Shehtoot
	Moringa ollfera	Sonjna
	Mangifera indica	Mango
	Pyris communis	Pear, Nashpati
	Populus delteoides	Poplar
	Punica granatum	Anar
	Prunus persica	Peach, Aaru
	Tectona grandis	Teak, Sagwan
	Syzium cumuni	Jamun
	Vitis vinifera	Grape, Angur

Note : The alkalinity limits given here refer to pH of the bulk soil in 1:2 suspension

Evaporating water from shallow water table leaves behind white salt encrustation on soil surface. Excess salts are hostile to plant growth.



Alkali soils have poor physical conditions. Reclamation of alkali soils for crop production requires usage of gypsum in high doses. *Kankar* layer restricts deeper penetration of roots. Piercing through *kankars* with auger holes and reclaming only small post-hole volumes of the soil, suffice for afforestation.

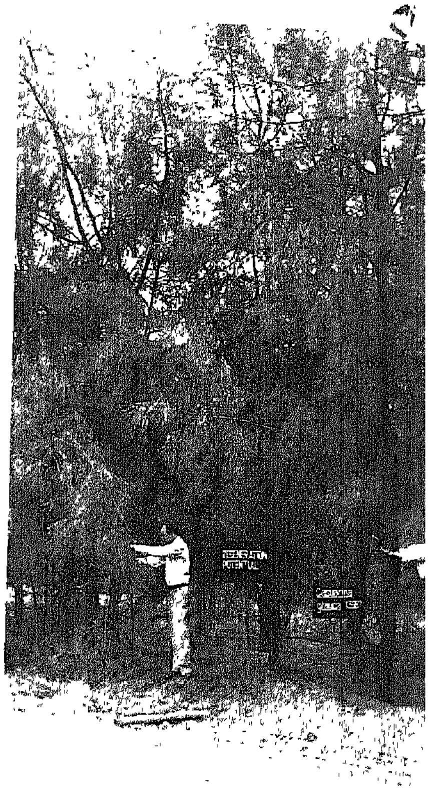
Pruning of coiled and extruded roots is essential for healthy growth of tranplanted saplings.

Auger bore holes being dug into an alkali soil

Salts transported to exposed surfaces and with in the ridges render them susceptible to erosion during monsoons rains and result in growth stagnation of saplings.

Sub-surface planting-cum-furrow irrigation (SPFIM) method enhances tree establishment in waterlogged saline soils.

Prosopis juliflora



Casuarina glauca

Acacia nilotica

All species do not grow well on salt affected soils. Proper choice of tree species in crucial for the success in refforestation.

TABLE 2. Recommended tree species for waterlogged saline soils (ECe in dS/m down below 0.3m).

ECe (dS/m)	Firewood/timber/fruit species	Common name
20-30	*Acacia farnesiana*	Pissi babul, Cassie
	Prosopis juliflora	Mesquite, Pahari kikar
	Pithecellobium dulce	Jangli jalebi
	Parkinsonia aculeata	Jerusalem thorn, Parkinsonia
	Tamarix aphylla	Faransh
14-20	*Acacia nilotica*	Desi kikar
	Acacia penatula	Kikar
	Acacia tortilis	Israeli kikar
	Casuarina glauca	Casuarina, Saru
	Casuarina obesa	Casuarina, Saru
	Casuarina equisetifolia	Casuarina, Saru
	Eucalyptus camaldulensis	River-red gum, Safeda
	Feronia limonia	Kainth, Kabit
	Leucaena leucocephala	Subabul
	Zuziphus jujuba	Ber
10-14	*Callistemon lanceolatus*	Bottle Brush
	Casuarina cunninghamiana	Casuarina, Saru
	Eucalyptus tereticornis	Mysore gum, Safeda
	Terminalia arjuna	Arjun
5-10	*Albizzia caribea*	-
	Dalbergia sissoo	Shisham
	Emblica officianalis	Amla
	Guazuma ulmifolia	-
	Punica granatum	Anar
	Pongamia pinnata	Papri
	Samanea saman	-
< 5	*Acacia auriculiformis*	Australian kikar, Akash mono
	Acacia deami	-
	Acacia catechu	Khair
	Szygium cumini	Jamun
	Salix spp.	Willow, Salix
	Tamarindus indica	Imli

Note: The salinity limits here refer to ECe of the bulk soil.

TABLE 3. Performance ratings of tree species with saline water irrigation(ECiw < 15 dS/m)

Performance	Firewood/timber/fruit species	Common name
Very Promising	*Acacia nilotica*	Keekar
	Acacia tortilis	Israeli kikar
	Acacia farnesiana	Pissi babul, Cassie
	Cassia siamea	Kassod, Cassia
	Capparis decidua	Kair
	Eucalytus tereticornis	Mysore gum, Safeda
	Eucalytus camaldulensis	River-red gum, Safeda
	Melia azedarach	Bakain, Dhrake
	Prosopis juliflora	Mesquite, Pahari kikar
	Prosopis cineraria	Khejri, Jand
	Pithecellobium dulce	Jangali Jalebi
	Phoenix dactylifera	Datepalm, Khajur
	Salvadora persica	Jaal
	Salvadora oleoides	Jaal
	Tamarix articulata	Faranash
	Tamarix troupi	Faranash
	Tamarix ericoides	Faranash
Promising	*Azadirachta indica*	Neem
	Cassia javanica	Cassia
	Casuarina glauca	Casuarina, Saru
		Dalbergia sissoo
Shisham		
	Feronia lemonia	Kainth, Kabit
	Jatropha curcas	Jamalghota
	Punica granatum	Anar
	Tecomella undulata	Rohira, Rajasthani sal
	Zizyphus mauritiana	Ber
	Zizyphus jujuba	Ber
Poor	*Acaua auriculiformis*	Australian kikar, Akash mono
	Bauhinia variegata	Kachanar
	Cassia glauca	Cassia
	Cassia fistula	Amaltas
	Crescentia alata	-
	Pongamia pinnata	Papri
	Szygium cumini	Jamun

5.3 Planting Methods

For planting on normal soils there are several traditional methods of site preparation. Planting methods traditionally used include the

- **pit planting**
- **mound planting**
- **ridge-trench planting**
- **saucer pit planting**
- **post-auger hole planting method**

Choice of planting method amongst other factors importantly depends on the landscape, topography, local drainage, soil and climatic conditions. Of the above methods, pit planting and ridge-trench planting are most commonly practiced on normal soils. In low lying areas where water stagnation is a problem, mound planting or ridge-trench techniques are commonly used while saucer pit method is suited to rainfed condittions. But due to one or the other reason, the methods common to normal soils usually fail in salt affected soils. Therefore, site preparation methods have recently been researched and innovated to enhance the sapling survival and subsequent growth of saplings on salty soils. Merits and demerits of planting techniques for saline and alkali soils have been discussed briefly in the ensuing sections.

Only those planting methods are suited to alkali and saline soils which either eliminate or alleviate the constraints due to salinity and/or alkalinity especially during establishment of plantations. Following are the desired attributes in planting methods suited to salty soils:

- Help replace exchangeable sodium with calcium, down to deeper soil layers.
- Reclaim more soil volume for proper root growth.
- Maintain low salinity in the root zone.
- Reduce water application costs
- Help *in situ* conservation of rain water and at the same time alleviate waterlogging problems
- Help in breaking through the hard *kankar* layer if present.
- Loosens the soil deep into the profile
- Encourage and train deep rooting.
- Cost effective

5.3.1 Pit planting

Pits having dimensions (90 x 90 x 90 cm) meets most of above requirements except for piercing through the hard calcite (*Kankar*) layers usually existing at depths below 1.0 to 1.25 m in alkali soils. *Kankar* pans serve as a physical

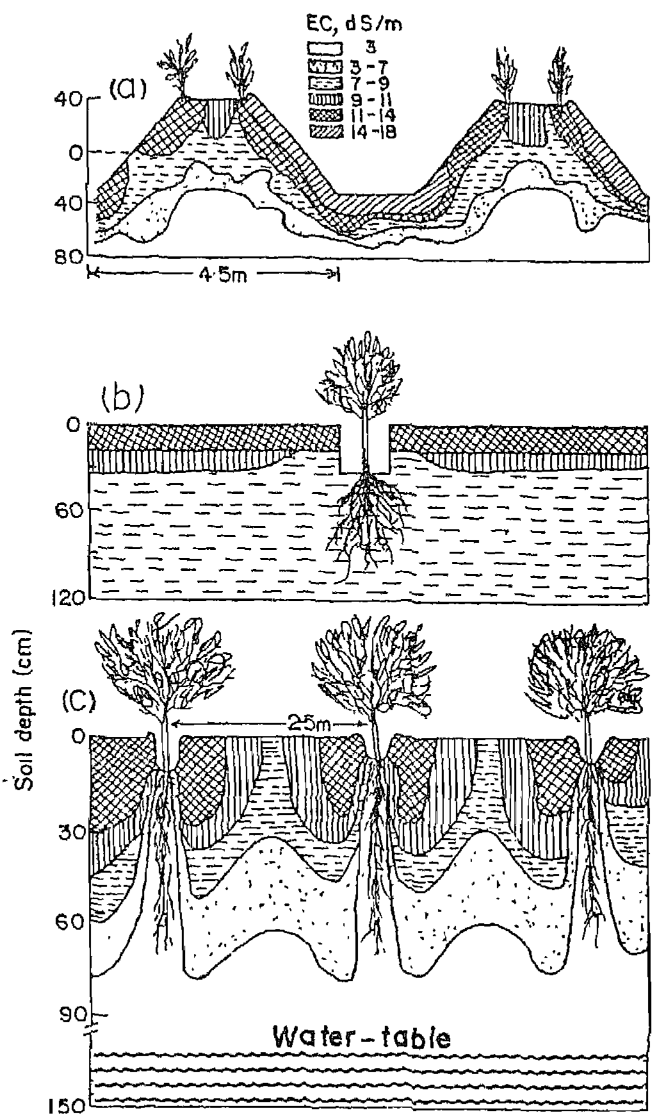


Fig 1. Typical salt distribution patterns under a) Ridge-trench, b) Sub-surface and c) Furrow planting methods in waterlogged saline soils.

impediment for vertical root growth and thus restrict mining of deeper soil layers for water and essential plant nutrients. Since pit planting method is laborious and costly, the recommended pit dimensions are hardly followed. To save labour costs, pit standards are liberalized to 45cm x 45cm x 45cm size under normal soil conditions. It may be noted that 'liberal standards' will not work because they do not overcome/ lease-out the constraints those restrict healthy growth in alkali soils.

With pit planting method salts get mixed up and distributed uniformly in the dug out zone. Even the good soils used for back filling the pits turn saline within few months. Thus pit planting method is an utter failure in saline soils. Salt distribution patterns suggest that salts do not move far away and deep into the profile (Fig. 1). Most of the salts stay closer to the active roots. Consequently the sapling establishment and survival rarely exceeds 25 percent with this method in strongly saline soils. A desirable feature for a successful planting method in saline soil is that it should minimize the salt levels near the active root zone of trees.

5.3.2 Ridge-trench planting

Planting on the ridges is a usual practice for low lying areas for example along the roads, railway lines and canal embankments where water stagnates in burrow pits. In a ridge-trench system, saplings are planted in the center of the ridge or close to edges of the ridge flats in staggered double row planting system. Plants transplanted on ridges in alkali soils suffer from lack of moisture availability due to poor transmissivity of water. On the other hand, ridges prepared of saline soils enhance salt accumulation on exposed surfaces of the ridges. Typical salts distribution patterns in a ridge-trench system followed in a typical saline situation are also included in figure 1. Accumulation of salts on the berms and top of the ridges reduces the stability of ridges and make them highly prone to erosion during monsoon season. Requirements of spot irrigation and frequent repair of ridges enhance the maintenance cost of plantations. Hence, ridge-trench planting method is not suitable for alkali as well as saline soils except in areas where there is water stagnation problem.

5.3.3 Post-auger hole planting

This method was designed to facilitate root penetration through *kankar* layer or hard pans found at some depth in most of the alkali soils. In this method, bore holes of 15-30 cm in diameter are dug to a depth of 120 cm or more such that it pierces beyond the *kankar* layer. For reducing manual labour costs and speed up the operations, tractor driven augers are now available in the market. Main features of this method are:

- Pierces through hard *kankar* layer
- Encourages and trains deeper rooting.
- Does not cause roots to coil or face constriction which adversely affect plant growth

- Improves the penetration of water through the holes thereby, inducing better water storage and its availability
- Ensures deeper reclamation of soil
- Makes the mixing of fertilizers possible even in deeper layers.

Performance of post-auger hole planting method has been observed to be highly satisfactory in field trials. This method has picked-up well with the foresters. Saplings transplanted in post-auger holes have to be spot irrigated. In order to avoid spot irrigation, the post-auger hole technique has been further refined to reduce irrigation costs. First, auger holes of 15-20 cm in diameter are dug and then connected with each other through an irrigation channel. Thus, the post-auger holes are finally positioned in irrigation furrows. Saplings are then planted in boreholes at a depth of 15-20cm from original soil surface. The method is a variant of 'sub surface planting furrow irrigation method' (SPFIM) elaborated in an ensuing section.

Alternately for high value species like fruit trees, pits of 45 x 45 x 30cm size are manually prepared and then post-augered (15-20 cm dia.) beyond the *kankar* layer with a tractor driven auger. The pit-holes are then interconnected with an irrigation channel. Additional benefits accruing from refined post-augur hole method include:

- Ensures easy and uniform application of irrigation
- Provides for larger volume of reclaimed soil for the development of feeder roots during the initial years of growth
- Curtails run off and promotes *in situ* rain water conservation

5.3.4 Sub-surface planting and furrow irrigation method (SPFIM)

In water-logged saline soils, the salinity is usually maximum in the surface layers and decreases with depth down to water-table. To the contrary, soil moisture contents are minimum near the surface and maximum near the water table. Therefore, to encash advantages of low salinity and better soil moisture regimes in sub-surface layers, saplings are planted in 'pee bag' sized holes made at the sill of the 15-20cm deep irrigation furrows, such that roots are exposed in 20-35cm soil layer from original surface. This method abbreviated as SPFIM (Sub-surface planting-cum-furrow irrigation method) has performed very satisfactorily in large scale field trials conducted on highly saline soils.Furrows are subsequently used for irrigating the saplings which helps in pushing the accumulated salts deeper and away from the active rootzone into the bed area between two furrows. Thus, a large volume of soil remains relatively free of salts which greatly improves the survival and growth of tree saplings.

POINTS TO REMEMBER

- ☞ Remember that saline soils may not have hard kanker layer and hencedeep auger holes may not be necessary. Wherever soils have hard layers, it may become necessary to combine the advantage of deep auger holes with SPFIM. If augerholes are to be made, it is preferable that furrows are first opened with a tractor mounted furrow-maker and then auger holes are excavated in these furrows.

- ☞ Channels should be made across the slope to prevent run-off of rain water. Do not allow run-off of sálty water from beds to enter channels during monsoon season. Weak brims of the channels may be repaired if needed to conserve all the rain water at the place.

- ☞ Close both ends of the furrows before the on-set of the monsoons so that rain water percolates at the place in the field and does not flow out of the area through these channels.

5.4 Filling Mixtures

Adequate nutrition is necessary for faster establishment and growth of saplings. Generally salt affected soils are low in organic matter and fertility. In order to provide a more congenial environment around sapling roots, and to furnish a starter dose of nutrients, mixtures of soil, fertilizer, farm yard manures, insecticide etc. are used for back filling of the pits and/or post-auger holes. High pH and exchangeable sodium also necessitates use of chemical amendments. Because of easy availability and subsidized costs, gypsum is mostly used for mixing with the excavated auger holes/pit soil. If pyrites is to be used, it should be applied on the surface only. Recommended back-filling mixture for alkali soils is :

- Gypsum @ 3.5 kg per hole or on the basis of gypsum requirement of the soil excavated by auger.

- Farm yard manure @ 10 kg per hole or 20-25 kg per pit of size 90 x 90 x 90 cm along with urea @ 50 g per hole or pit.

- Zinc Sulphate @ 10 to 15g hole. Most alkali soils are deficient in zinc, it is obligatory to apply it.

- BHC 30 % @ one table spoon per hole to avoid termite attack.

- Additional use ot rice husk @ 5 kg/hole is beneficial in highly-deteriorated alkali soils and other soils with very poor permeability.

- Use of iron sulphate @ 20 g/ hole in soils having $CaCO_3$ content more than 5 % is advocated.

☞ CAUTIONS

- ▲ Saline soils do not require amendments. So application of gypsum may prove counter productive and a waste of costly input. Avoid gypsum usage in saline soils.
- ▲ Phosphatic fertilizers help in mitigating adverse effects of salts on plants. Use diammonium phosphate @ 20 g/hole in saline soils. Dissolution of superphosphate is very poor in saline soils.
- ▲ In waterlogged soils, addition of FYM sets in intense reducing conditions. Saplings may suffer due to root suffocation under such conditions.
- ▲ Non-leguminous tree species like *Eucalyptus* respond to nitrogen application even upto 3 years. Therefore, apply 25 g urea/tree in first 3 years during monsoon season.

5.5 Pitting and Planting of Seedlings

Fully conditioned, robust and fair sized saplings (70-100 cm) with properly pruned roots should be used for planting. If saplings have been in nursery for longer times to generate root coiling, remove bottom 1-2 cm of root system by cutting the polythene bags with a sharp knife. Prepared saplings are so positioned in the pits/holes that root collar is at least one centimeter above sill surface in channels. In arid regions the root collar can be in level with the sill of the channel.

☞ CAUTIONS

- ▲ The back-filled soil in holes/pits is loose and dry. During first irrigation soil settles and caves-in. This dispositions the transplanted saplings. To avoid cave-in injury to roots of young plants irrigate once before transplanting. This will also create better root zone environment by leaching down of the soluble salts.
- ▲ Remove the polythene bag before planting, but don't throw them in pits/ holes.
- ▲ To ensure good contact of roots, pitting is essential. Place the saplings in sized holes and press the soil around sapling with heels.

5.6 Irrigation Management of Field Plantations

As stated earlier, saline and alkali soils are found in arid, semi-arid and hot and dry subhumid regions. In these regions, about 70-80 percent of the total rainfall is received during the months of July-September. Usually monsoons are erratic and periods following them are dry. Though the transplanting work is mostly completed during monsoon season, the saplings may suffer for want of water during the post monsoon period expecially the summers. Young saplings may also suffer from frost injuries during winters. Therefore, provision of supplemental irrigation for early establishment and growth and avoiding froast injuries of saplings is very crucial.

Irrigation schedules, include frequency and quantities of irrigation water required. Until recently, most researches on irrigation schedules were mainly focussed on annual crops. However, these researches have led to development of general guidelines which can be adjusted for tree plantations as well. Like crops, trees also need irrigations to meet their evapo-transpirational demands. Irrigation of tree saplings during the initial two years is an absolute requirement. In arid areas, irrigation support should be continued at least for 3 years. Higher plant population may necessiate further extending the support period.

Irrigation practices for trees on saline and alkali soils should further ensure the following points :

- **Avoid waterlogging and aeration problems**
- **Optimize the availability of moisture in the root-zone**
- **Minimize secondary salinization of the root zone**

Above conditions can be met with recently innovated micro-irrigation (drip/ trickle) systems but the cost and technical know-how involved limit their use in forestry. Therefore, as an alternative, "sub-furrow planting and furrow irrigation method" SFPIM system has been devised which optimizes water regimes of the rooting zone and also help in a better control of salinity. It may be pointed that when water table is within 50 cm during the monsoon season or within 2.0 m during later parts of the year, irrigation may be avoided. This is because capillary rise of water towards surface will suffice irrigation needs of saplings. Irrigation under situations of high water table may preferably be applied for leaching the salts, when accumulated in excessive amounts. Otherwise irrigation may only aggravate aeration problem. Saplings planted on field boundaries meet their water requirements from irrigations applied to crops and hence need no extra water.

5.7 Irrigation with saline / alkali waters

Canal water supplies in many saline areas are usually deficient and allocations for forestry have to face tough competitions with food crops. The problem is further aggravated as routines of canal water supplies to lands earmarked for forestry are either not allotted or fixed in advance. In many situations canal network is not in place to supply water to an outlet in the newly planted area. As a consequence, transplanted saplings have to be spot irrigated with waters transported through tractor attached tankers. This results in deficit irrigation and escalates the costs at the same time. Afforestation programs under such situations can only succeed if the poor quality ground water aquifers are developed and utilized judiciously for irrigating the saplings.

Three categories of problems usually arise upon use of poor quality waters viz., 1) salinity (due to salts) affect water availability to plants, 2) permeability (due to high sodium) affect the rate of water infiltration into soils and 3) specific ion toxicity (due to ions like B, F, NO_3, Na, Cl etc) which affect the physiological processes in sensitive plants. Management alternatives for utilizing poor quality waters should be to improve the soil-water availability to transplanted tree saplings. Practices that are important in the use of poor quality waters have been discussed in subsequent sections.

5.7.1 Irrigation methods for brackish water use

An irrigation method with brackish waters should create and maintain favorable salt and water regimes in the root zone such that water is readily available to plants for their growth. We advocate the use of SPFIM to meet the twin objectives. With this method, irrigation is applied only to furrows. Depending upon plant row spacing, furrows occupy 1/5 to 1/10 of the total land area. Thus, it not only saves irrigation time and labour but less salts are added to the soil profile. The added salts keep on moving towards the inter-row area thus maintaining the salinity of the area below the sill of the furrows at relatively low levels, as shown previously. With SPFIM, saline waters of ECiw upto 12 dS/m in sandy loam and loam soils can be used. In finer textured soils (clay loams), saline waters of ECiw upto 6-8 dS/m can be used with some reduction in tree growth and biomass (Table 3).

5.7.2 Irrigation schedules

A general recommendation for use of brackish waters is to irrigate frequently for better control over the matric (drought) and osmotic (salt) stresses and provide for leaching requirements. Nevertheless, such a practice would demand for additional application of saline water,which results in higher salt loads. The practice of frequent irrigation is advocated for food crops, because it pushes the added salts beyond the shallow root zones of food crops. To the contrary frequent saline irrigations may aggravate salinity problems in deep rooted tree crops. Therefore, irrigate normally for the growth of trees. For this, a monthly irrigation during winter (October-March) and fortnightly irrigations during summer (April-June) are recommended for plantations undertaken with SPFIM method.

Use of waters having residual alkalinity render the soils alkali. Severity of alkalinity problems depend mainly upon the quality and quantity of water used. Since smaller irrigation quantities suffice for the growth of tree saplings with newly developed SPFIM method, alkali waters are unlikely to cause any serious problem unless RSC (residual sodium carbonates) is excessively high (>10 meq/l). Under such situations, a gypsum bag may be kept in irrigation channel to neutralize a part of RSC in the water. With flow irrigation, irrigation schedules and methods for use of alkali waters remain the same as described for saline waters.

☞ CAUTION

Replanting the site in the following year may prove futile and not work the way you expect. Better get your soil and ground water tested for diagnosis of the nature and intensity of the problem. May be the water, you consider unsuitable, is helpful to plantations.

5.8 Stand Tending : Thinning and Pruning

The desired plant to plant and row to row distances are governed by the growth habits of the planted tree species and the purpose for which trees are being grown. In salty soils, it is desirable to plant at relatively closer spacings e.g. 2m x 2m, 2m x 3m or 3m x 3m to ensure good tree stands against mortality due to salinity and alkalinity stresses. Since, salt stressed plants do not grow as vigorously as under normal soil conditions, denser populations compensates for reduced growth of trees. Excess canopies can be pruned/thinned out subsequently. Thinning will also provide for intermediate fuel wood yields and opportunities to retain vigorous plants.

Pruning is done to produce well shaped and clear bolls and in the case of thorny tree species to provide for access to plantations for growing understory crops. The lopped branches also provide for firewood and sometime foliage can be used as a fodder. To be effective, pruning should start early in the life of stands e.g. 2-3 years. Prune only lower 1/3rd portion otherwise it shocks the plants, reduces photosynthetic area, and bio productivity. Activities that are required to performed for raising a good plantation have been listed in calender given below:

Calender of activities for field plantations

Month	Harrowing & levelling	Preparing furrows & pits/auger holes	Back filling	Trans-planting	Inter-culture	Thatching	Pruning & lopping	Plant Protection
January	✓	✓	✓	–	–	✓	✓	–
February	✓	✓	✓	✓	–	–	✓	–
March	–	–	–	✓	–	–	–	✓
April	✓	✓	✓	–	–	–	–	–
May	✓	✓	✓	–	–	–	–	✓
June	✓	✓	✓	–	–	–	–	✓
July	–	–	–	✓	–	–	–	–
August	–	–	–	✓	–	–	–	✓
September	–	–	–	✓	✓	–	–	–
October	–	–	–	–	✓	–	–	–
November	–	–	–	–	–	–	–	–
December	✓	✓	–	–	–	✓	–	–

Note: Apply irrigations as per requirements

5.9 Protection Against Browsing

The plans for afforestation programs should include measures for protection against stray animals and wild life. Much of the afforestation efforts may be of little avail if saplings are not protected against chewing, grazing and nibbling etc. by stray animals and wild life. Some of the suggested control measure against grazing are:

5.9.1 Fencing

Live fencing :Saplings can be protected from the animals by growing either a live fence or the physical barriers are erected for movement of animals. A close hedge of certain species like *Euphorbias, Jatropha, Vitex, Agave, Opentia, Duranta, Gliricidia, Acacia nilotica, Prosopis juliflora* etc., can be raised two to three years in advance around the intended plantations. However live fences only reduce the animal menace and do not eliminate it completely because the gaps will usually be formed one way or the other in due course.

Barbed wire fencing: Fencing posts 2.0 - 3.5m in length preferably of RCC cement are fixed at about 3 - 3.5m distance and 4 to 6 strands of two ply galvanized barbed wire with 4 barbs spaced at 7-10cm apart are then fixed to the poles. Fixing of branches of thorny plants like *Acacia* can further enhance effectiveness of the fence against entry of wild animals.

Trenches: Wherever depth and nature of the soil and finances permit, dug out trenches can also be effective. Normally 3.0m wide trenches of 1.2m depth may prove an effective measure against entry of animals. Excavated soil is used for a ridge on the inner side. As a further safe guard live hedges can be grown on the ridges.

Planting of polarded saplings: Since small sized saplings are well within the reach of stray animals they can be easily browsed. Some of the tree species which could be polarded to heights beyond reach of animals, stand a better chance against browsing. Although pollarding may save part of the cost on fencing but increases nursery, labour and transportation costs.

Chemical methods: Environmentally safe animal repellent are now available in the market. Repellent chemicals penetrate into bark and leaves to produce awful bitter taste and remain effective despite rain. Spray with such chemicals prevent foliage damage. Chemicals such as 'Ro-Pel' repels animals and discourages them from returning. One or 2 sprays in summers may prove effective against animal damage.

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Appendix - I

Some common tree species for afforestation of salt-affected soils

Species	Common name	Rainfall (mm)	Drought resistance	Nitrogen Fixation
Acacia catechu	Khair	200-1500	High	Yes
Acacia fernesiana	Cassie flower	300-700	High	Yes
Acacia nilotica	Desi kikar	200-1500	High	Yes
Acacia pennatula	Vilayati kikar	300-800	High	Yes
Acacia saligna	Gum arabic	350-600	High	Yes
Acacia tortalis	Israeli kikar	100-1000	High	Yes
Achras japota	Chikoo	300-800	Moderate	No
Albizzia lebbeck	Siris	400-1000	Moderate	Yes
Azadirachta indica	Neem	200-1200	Moderate	No
Butea monosperma	Dhak	300-1000	Moderate	No
Callistemon laceolatus	Bottle brush	400-1550	High	No
Cassia fistula	Amaltash	300-850	Moderate	Yes
Cassia siamea	Cassia	350-800	Moderate	Yes
Casuarina equisetifolia	Saru	200-2000	Moderate	Yes
Casuarina glauca	Saru	200-2000	Moderate	Yes
Casuarina obesa	Saru	200-2000	Moderate	Yes
Dalbergia sissoo	Shisham,Tali	500-2000	Moderate	Yes
Eucalyptu comaldulensis	Safeda	400-1500	Moderate	No
Eucalyptus tereticornis	Safeda	400-1500	Moderate	No
Feronia limonia	Kainth	200-1800	Moderate	No
Guajuma ulmifolia	---	200-700	High	Yes
Leuceana leacocephala	Subabul	600-200	Moderate	Yes
Madhuca indica	Mahua	350-750	Moderate	No
Madhuca latifolia	Mahua	350-750	Moderate	No
Melia azedirach	Bakan	300-800	Moderate	No
Moringa oleifera	Sonjana	300-700	Moderate	Yes
Pithecellobium dulce	Janglijalebi	200-1000	High	Yes
Pongamia glabra	Karanj	300-700	Moderate	No
Pongamia pinnata	Papri	300-700	Moderate	Yes
Populus euphratica	Popular	300-700	Moderate	No

Contd.........