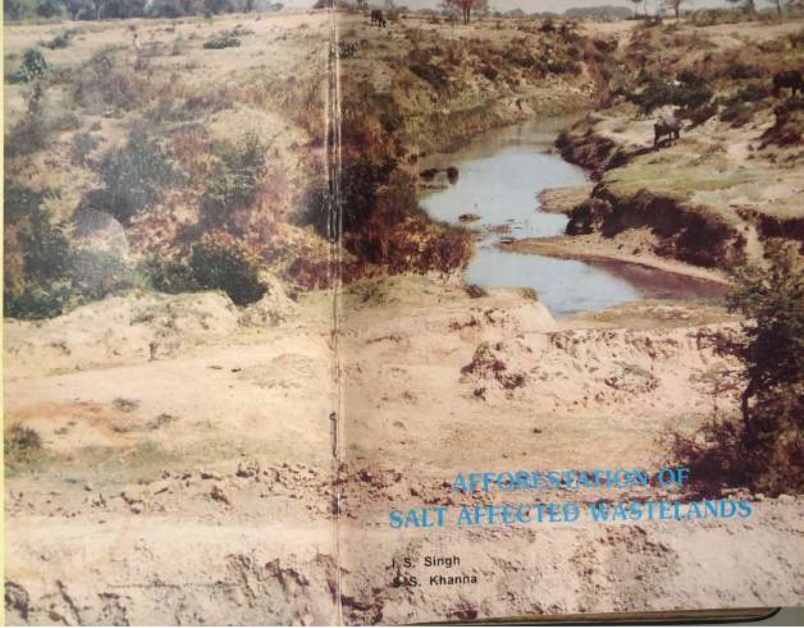

AFFORESTATION OF SALT AFFECTED WASTELANDS

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AFFORESTATION
OF
SALT AFFECTED WASTELANDS

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FOREWORD

Deforestation has been identified as one of the major causes of land degradation. Salt affected degraded lands which cover an area of 8.5 million hectares in our country are most susceptible to the processes of desertification. Inorder to salvage the degraded lands and provide a bulwark against the forces of desertification, it is vital to repose faith on afforestation of degraded lands. While this would enable the conservation of soil and water regime, it would also help to provide basic requirement of fuelwood, fodder, timber, herbal medicines etc. of rural communities.

Of the 43 lakh hectares classified as wasteland in U.P., about 13 lakh hectares is affected by salinity/alkalinity. The forest cover in U.P. is as low as 17.5% of the total geographical area, which is about half of what has been prescribed in the National Forest Policy. It is a cause for grave concern that the forest cover in U.P. is even less than the national average. It is therefore imperative that concerted efforts be made to increase the forest cover and check further denudation of such lands.

The Bulletin describes the package of technology developed by Scientists of the N.D. University of Agriculture and Technology for the benefit of the scientists, planners, foresters and farmers. The time tested technology (TTT) deserves to be applied and replicated at the field level by all concerned associated in this task.

I am happy to see that Dr. I.S. Singh, Professor Horticulture- cum-Officer Incharge, Wasteland Development Project and Dr. S.S. Khanna, Vice Chancellor have done a commendable job in collating all relevant information in a capsule form.

(B.N. Tiwari)
Agriculture Production Commissioner)
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1. INTRODUCTION

As per National Forest Policy, one third area out of the total geographical area (329 million hectares) should be under the forest/tree cover. The recorded forest area of the country and per capita availability (Table 1) is much less than the required National Forest Policy. Because of the heavy pressure of fast growing human (920m) and live stock (470 m) population, the biotic pressure in forest has increased. Reduction in forest area as well as in density has diminished the production capacity of existing forest. This has aggravated the problem of soil erosion, eco-restoration and environmental stability on one hand and meeting the bonafide domestic demands of forest produce such as fuel, wood, fodder and timber on the other.

Table 1. Requirement and availability of forest area.

Area under	Required	Available
Forest/tree cover (%)	33	23.4
Per capita forest area (ha)	0.47	0.09

The demand for fuel and timber wood is expected to rise (Table 2) and supply is inadequate to meet the present requirement. There is acute shortage of fuel wood in the Country and the resultant high prices leads to the practice of burning dry cattle dung cake @ 100 mt annually which could have increased biomass production if diverted for the agricultural fields. The current gap between the demand and supply of fuel, timber and fodder seems to worsen in near future as a consequence of continued deforestation (1.5 million ha/year) and degradation of land.

Table 2. Requirement of fuel and timber wood.

Year	Fuel wood (Million m^3)	Timber (million m^3)
1980	184	26.9
2000 AD	240	64.4

Nearly 53 percent of the total geographical area of the Country is affected by denudation and degradation processes. Salt affected area is about 7 million hectares. The largest area of about 1.3 million hectares exists in Uttar Pradesh which comes to about 18.5 percent of the total salt affected lands of the Country. Majority of these salt affected soils are lying barren and have become ecologically and economically unproductive due to chronic degradation and denudation. Tree biomass production on such degraded lands will play an important role in meeting daily survival needs of the vast majority of the rural house-hold like fuel, fodder, timber and herbal medicines besides calling a hault to further degrdatation of soil, water and environment.

In view of the fact, mentioned above a systematic programme of work was started at the N.D. University of Agriculture and Technology for afforesting the salt affected lands with selective species. Salient research findings are presented in this bulletin.

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2. SITE AND SOIL PROPERTIES

The N.D. University of Agriculture and Technology operates in the eastern districts of U.P. The lands in most of the districts are salt affected. The main campus of the University itself has 1600 hectares of such lands. The land scape varies from gentle slope to highly undulating.

2.1 Soil Properties

The data on physical (Table 3) and chemical (Table 4) properties of soils of the plantation site reveal high bulk density with low permeability and porosity. The soils are very compact and mechanical impedance is caused due to formation of thick kankar pan. Further the soil is characterised by high pH and exchangeable sodium percentage and low organic content.

Kankar of variable sizes ($CaCo_3$ nodules) and density are present all through the depth of profile. A hard Kankar pan of 20-30 cm thickness is found within 1 metre depth of soil profile. The bulk density was found to increase, whereas hydraulic conductivity (permeability) and porosity decreased with soil depth. The pH and ESP of soil increased up to 80 cm depth and declined thereafter. A steady decline in organic carbon from 0.16 to 0.08 percent was also noticed. Salt concentration was recorded maximum at the surface of profile which declined with depth. Area having such type of highly deteriorated sodic soils can not be brought under cultivation unless and untill these are reclaimed. Reclamation of such soil is not only expensive but management of reclaimed soils is further complicated because of high pH both at top and also in lower strata. An endeavour was made to grow forest species on such land.

Table 3. Physical properties of soil.

Depth (cm)	Bulk density (g/cc)	Hydraulic conductivity (cm/hr)	Porosity (%)
0-20	1.60	0.028	36.5
20-40	1.62	0.025	36.2
40-60	1.64	0.022	36.1
60-80	1.72	0.021	34.8
80-100	1.75	0.013	34.2
Average	1.66	0.02	35.5

Table 4. Chemical properties of soil

Depth (cm)	pH	ECE (ds/m)	ESP	Organic carbon (%)
0-20	10.4	24.5	76.0	0.16
20-40	10.6	21.3	82.6	0.13
40-60	10.7	20.5	83.9	0.10
60-80	10.7	18.8	84.2	0.10
80-100	10.6	18.3	83.8	0.08
Average	10.6	20.6	82.0	0.1

2.2 Water table and Water quality

Water table of the farm fluctuates between 3 and 7 metres during the monsoon (July-August) and Summer (May-June) respectively. The ground water of farm area is of good quality (pH 8.5 to 8.7). The water of natural drain passing through the farm is also of good quality and is being used for irrigation purposes.

2.3 Natural Vegetation

The patches of natural vegetation generally consisted of Saccharum species (Kons), *Sporobolus species*, *Butea monosperma* (Dhalk), *Carissa carandas* (wild Karonda), *Bassia latifolia* (Mahua), *Acacia nilotica* (Babul), *Dalbergia sisso* (Shisham) and *Ziziphus mumularia.* These plants are typical of semiarid regions.

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3. SELECTION OF TREE SPECIES

Salt affected soils are degraded lands and possess characteristics that are unfavorurable for plant growth. Therefore selection of plant species for salt affected lands shouid preferably have salt tolerance, prolific deep root system, some degree of drought tolerance, ameliorative effect on soil properties and relatively fast growing.

Reclamation of salt affected for growing of agronomic crops is not only expensive but management of such soils is further complicated because of high pH at top and also in lower strata. Thus area having salt affected soil can not be put to profitable production of cereal crops and hence offer good alternative for afforestation. Most of the trees are phenotypically harder to counter adversities, have forage nutrients, provide vertical drainage through pits, require only spot reclamation and provide sufficient cover to check soil erosion. Taking the advantage of nature of tree, probably it is possible to manage the salt affected soils in a more positive manner than cereal crops.

The fuel and timber species which have shown some degree of tolerance and were found most suitable are given in Table 5 and 6, respectively.

Table 5. Salt tolerance of some soil species.

Species	Common name	Salt tolerance (pH)
Casuarina equisetifolia	Saru	9.5
Cassia siamea		9.2
Eucalyptus tereticornis	Eucalyptus	9.0
Leucaena lecocephala	Subabul	9.0
Prospis juliflora	Prospis	10.0

Table 6. Salt tolerance of some timber species.

Species	Common name	Salt tolerance
Acacia auriculiformis	Babul (Australian)	9.0
Albizia procera	Siras (white)	9.5
Albizia lebbek	Siras (black)	9.3
Acacia nilotica	Babul	9.8
Bassia latifolia	Mahua	9.0
Dalbergia sisso	Shisham	9.5
Tectona grandis	Teak	9.0
Terminalia arjuna	Arjune	9.5

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4. AGROTECHNIQUES

Agrotechniques play an important role in establishment of tree plantation. Considerable research work has been carried out at this University in recent years on various aspects of afforestation. The results are briefly summarised here.

4.1 Cattle Proof Trench

This can be done by digging a trench of 1 metre depth and width. The dug out soil is placed on the inner side of the boundary to raise bund. Among the various species tried, Prospis juliflora was found the most effective live hedge which can be grown on bund at a distance of one metre during rainy season. Biofencing with this species protect the plantation from cattle, check soil erosion, generate biomass and helps in moderating climate.

4.2 Layout of field

Prior to afforestation field could be cleaned and layout plan be prepared by dividing lands into plots of convenient size i.e. 0.5 to 1 hectare. For assured irrigation, boring should be done for construction of shallow cavity tube well.

4.3 Plant spacing

Provision of appropriate or optimum spacing to trees is one of the most important aspects of successful plantation. If the spacing is inadequate the trees will grow poorly and produce small biomass. On the other hand, if the spacing is too wide, there will be wastage of land. The optimum spacing is, therefore, desired so that trees may grow and produce biomass properly. Data presented in table 7 clearly show that plant growth of fuel and timber species are better with wide spacing.

Table 7. Effect of plant spacing on growth of forest species.

Spacing (m)	Growth after 5 years					
	Av. Height (m)			Av. girth (cm)		
	Casuarina	Eucalyptus	Dalbergia	Casuarina	Eucalyptus	Dalbergia
2x2	15.2	9.3	8.6	33.8	22.7	40.3
3x3	16.1	10.5	10.4	39.2	33.4	46.2
4x4	16.8	11.8	11.2	50.2	36.8	48.8

4.4 Pit size and filling mixture

The size of pit varies according to the nature of soil and the size of the trees. In salt affected soil, deep and larger pits are preferred. As far as possible kankar pan must be removed. The pits should be filled up to the height of 10cm above the ground with good soil or the original soil of the pit should be treated with gypsum to provide a more favorurable medium for initial plant growth during the establishment period. Data presented in table 8 and 9 clearly show that plant survival and growth of forest species are better with filling mixture of normal soil+BHC in a pit size of 90 cm^3.

Table 8. Effect of pit size and filling mixture on plant survival

Pit size (cm^3)	Filling mixture*	Survival (%) after 5 years Casuarina	Eucalyptus	Shisham	Arjune
30	– Original soil+Gypsum*+BHC	28.7	20.7	31.8	38.2
	– Normal soil+BHC	35.5	38.0	40.2	50.2
60	– Original soil+Gypsum+BHC	40.3	40.8	41.8	45.5
	– Normal soil+BHC	51.8	70.3	55.6	71.8
90	– Original soil+Gypsum+BHC	58.6	48.2	59.2	54.9
	– Normal soil+BHC	88.5	83.8	90.8	82.8
CD at 5%		4.8	6.3	5.3	6.8

* 1,2 and 3 kg. gypsum 30, 60 and 90 cm^3 pit size respectively.

Table 9. Effect of pit size and filling mixture on growth of forest species.

Pit size (cm^3)	Filling mixture	Av. girth (cm) after 5 years Casuarina	Eucalyptus	Shisham	Arjune
30	– Original soil+gypsum+BHC	22.3	21.5	18.7	15.7
	– Normal soil+BHC	30.1	28.8	25.7	18.2
60	– Original soil+gypsum+BHC	34.2	27.9	26.3	23.7
	– Normal soil+BHC	40.8	37.3	40.5	36.2
90	– Original soil+gypsum+BHC	48.5	45.2	50.7	38.7
	– Normal soil+BHC	68.5	61.8	92.3	70.6
CD at 5%		4.7	3.2	4.9	3.8

4.5 Planting

Appropriate planting techniques play an important role in the successful establishment of plantation. The points to be taken into consideration are :

4.5.1. System of planting

Tree species are normally planted in square system where plant to plant and row to row distance is kept the same. This system is considered to be the simplest of all the systems and is widely adopted in plain.

Contour system of cultivation is more suitable for such undulated topography where the problem of soil erosion is immense. The main purpose of this system is to minimise land erosion and to conserve soil moisture so as to make the slope fit for afforestation.

4.5.2. Season of planting

Planting of forest species is generally done with the onset of mansoon rains from July to September when the soil moisture is high. The ideal time for planting is the month of July. Delayed planting reduces plant survival (Table 10)

Table 10. Influence of time of planting on survival of forest species.

Species		Survival after one year			
		July	August	September	October
1.	*Casuarina equisetifolia*	83.4	79.5	75.6	73.2
2.	*Leucanea leucocephala*	63.8	56.6	38.5	25.3
3.	*Eucalyptus tereticornis*	66.5	58.3	40.8	36.2
4.	*Acacia auriculiformis*	70.8	66.2	49.2	40.8
5.	*Dalbergia sisso*	85.7	84.3	76.7	60.2
6.	*Tectona grandis*	80.3	78.5	59.8	47.8

4.6 Age of seedling

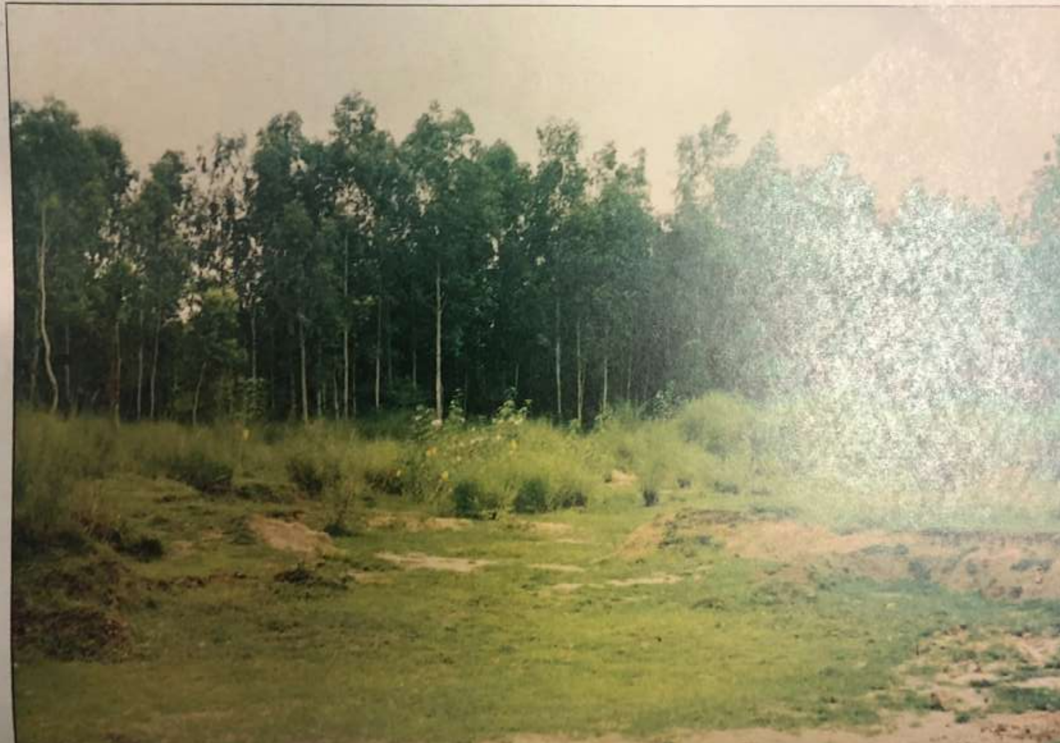
Age of seedling also influences the plant survival. Data presented in table 11 indicate that seedling of one year age had higher percentage of survival than the seedling of 6-month age.

A view of salt affected area

Basin system of irrigation- Provides uniform distribution of water and minimises the movement of salt into pits.

A view of Casuarina plantation (7-year old) in Salt affected lands

7-year old plantation of Cassia siamea in Salt affected land

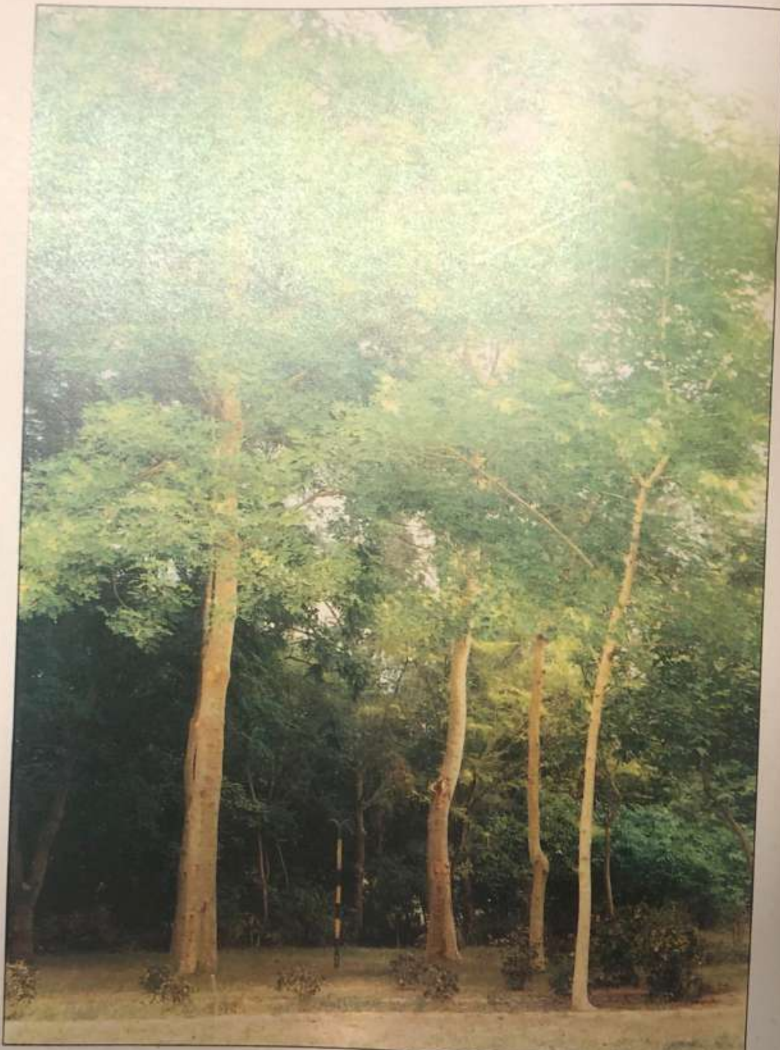


A view of eucalyptus plantation (7-year old) on degraded land

Dalbergia sisso- a timber species in sodic soil (7-year old)

7-year old plantation of teak in sodic soil

7-year old plantation of *Albizia lebbek*



7-year old plantation of Albizia procera in Salt affected soil.

Mahua (*Bassia latifolia*)- an oil bearing tree in sodic soil

Acacia auriculiformis plantation (7-year old)

Acacia nilotica plantation in Sodic soil.

Terminalia arjuna plantation in Sodic soil (7-year old)

Drop spillways- a device to reduce run off velocity and promote sedimentation

Check dam with watershed- a device for water harvesting and control of soil erosion

Table 11. **Effect of age of seedling on survival of some forest species.**

Species		Survival (%) after 12 months of planting	
		6-month old Seedling	12-month old Seedling
1.	*Dalbergia sisso*	47.2	79.6
2.	*Terminalia arjuna*	53.8	86.2
3.	*Casuarina equisetifolia*	70.3	89.8

4.7 Method of planting

Place of sapling (with earth ball) errect in the pit. Planting material should be trained to a single stem. Fill the pit with dugout soil and press gently.

4.8 Irrigation

Salt affected soils suffer from moisture stress particularly during summer when evaporation is very high. As a result, higher concentration of salts may cause plasmolysis and thus ultimately plant dies. Therefore, irrigation of young plantation (upto 2 years) during the summer is essential.

4.8.1 Irrigation system

The irrigation system should be such which could minimise the movement of salt into pits while irrigating the young plantation. Data presented in table 12 and 13 clearly indicate that survival and growth of forest species were better with basin system as compared to strip and bed systems which caused serious damage to the plants. Making of irrigation channels with basin system along the rows of tree plantation also serves as a check for salt movement and soil erosion.

Table 12. Effect of irrigation system on survival of forest species.

Species	Plant survival (%) after 24 months			
	Basin	Strip	Bed	CD at 5%
Casuarina equisetifolia	84.6	60.6	42.0	9.8
Leucaena leucocephala	79.5	49.8	31.3	8.5
Eucalyptus tereticornis	80.2	51.3	33.7	8.2
Dalbergia sisso	91.8	53.3	49.2	9.5
Tectona grandis	86.2	50.8	30.8	7.7

Table 13. Effect of irrigation system on growth of forest species.

Species	Av. height (m) of plant after 24 months			
	Basin	Strip	Bed	CD at 5%
Casuarina equisetifolia	4.0	3.2	2.5	0.6
Leucaena leucocephala	2.8	2.3	1.8	0.3
Eucalyptus tereticornis	4.8	3.7	3.2	0.4
Dalbergia sisso	3.7	3.1	2.2	0.6
Tectona grandis	3.5	2.8	2.2	0.4

4.8.2. **Number of Irrigation**

Number of irrigation during the summer (March-June) influence the plant survival and growth. Data clearly shows that both plant survival (Table 14) and growth (Table 15) were much better under irrigated conditions. Percent survival and growth of plants were found to be the highest with 8 irrigation at fortnightly interval from March to June.

Table 14. Effect of number of irrigation on plant survival of forest species on sodic soil.

No. of Irrigation*	Plant survival (%) after 12-month of plantation				
	Casuarina	Eucalyptus	Leucaena	Dalbergia	Tectona
0	37.3	29.5	28.3	50.5	39.8
4	59.2	44.8	37.9	72.2	70.5
8	88.2	76.5	56.3	96.2	90.5
CD at 5%	6.3	5.1	5.3	4.8	4.3

Table 15. Effect of number of irrigation on plant growth of forest species of sodic soil.

No. of Irrigation*	Av. height (m) after 12-month				
	Casuarina	Eucalyptus	Leucaena	Dalbergia	Tectona
0	1.3	1.5	1.0	1.7	1.3
4	2.9	1.9	1.6	2.5	2.4
8	3.8	2.9	2.4	3.3	3.7
CD at 5%	0.5	0.6	0.4	0.4	0.3

* 0 - No irrigation, 4 - March to June at monthly interval, 8 - March to June at 15 days interval

4.8.3. Period of irrigation

Data in Table 16 clearly shows that Casuarina and Dalbergia species require irrigation upto two years and Eucalyptus and Leucaena upto three for better establishment.

Table 16. Effect of period of irrigation during summer season on survival and growth of forest species.

Period of irrigation*	Plant survival %			
	Casuarina	Eucalyptus	Leucaena	Dalbergia
1st year - 5 irrigation	72.8	60.3	53.5	88.5
2nd year - 5 irrigation	98.2	96.5	90.8	100
3rd year - No irrigation	95.2	55.2	50.8	100

* March-1, April-1, May-2 and June-1.

4.9 Training

In forest species, training is done to obtain maximum height and girth of the main st em. It is therefore necessary that all the side branches of the main stem must be removed from time to time to encourage plant height. (Table 17)

Table 17. Effect of training or removal of side branches on height increment of forest species

Species	Average height (m) of main stem after 24-month		
	With training	Without training	CD at 5%
Casuarina equisetifolia	5.5	3.5	0.8
Eucalyptus	5.0	3.4	1.1
Acacia nilotica	4.8	2.3	0.7
Albizia procera	6.0	4.8	0.6
Acacia auriculiformis	5.5	4.0	0.8
Dalbergia sisso	3.8	1.8	1.2

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5. GROWTH AND PRODUCTIVITY

The growth and productivity of various fuel and timber species were evaluated and results are presented as under :

5.1 Growth of fuel species

The data presented in table 18 a and b showed wide variability in the growth pattern of various fuel tree species at different periods. After 7 years of plantation the height of five tree species ranged from 6.0 m (Prospis juliflora) to 16.8 m (Casuarina equisetifolia). It was also observed that after one year of planting, Eucalyptus grow faster than Subabul. Girth increments were highest with Casuarina followed by Cassia siamea and Eucalyptus. Results indicated that Casuarina was far ahead with respect to both height and girth parameters than the other tree species, hence, this may be considered as the most suitable fuel wood species for the sodic lands.

Table 18. Growth performance of some fuel wood species on sodic soil.

a. Average height (m)

Species	Year after planting						
	1	2	3	4	5	6	7
Casuarina equisetifolia	3.2	4.5	8.8	9.9	12.2	13.9	16.8
Eucalyptus tereticornis	4.8	6.0	8.3	8.9	10.8	11.2	12.9
Leucaena leucocephala	4.6	5.2	5.5	5.9	6.1	6.8	7.3
Cassia siamea	2.5	2.9	4.8	5.4	6.2	7.0	8.2
Prospis juliflora	1.0	1.8	2.6	3.9	4.7	5.2	6.0
b. Average girth - GBH (cm)							
Casuarina equisetifolia	8.7	14.3	26.5	35.3	43.8	50.3	61.2
Eucalyptus tereticornis	7.2	12.8	20.3	27.3	36.6	42.3	49.8
Leucaena leucocephala	7.0	10.7	16.1	22.8	30.3	36.8	40.2
Cassia siamea	9.8	20.8	30.7	37.5	41.2	48.2	55.2
Prospis juliflora	6.9	11.3	15.8	20.7	25.3	28.5	33.4

5.2 Productivity of fuel species

In table 19 the comparative biomass productivity of various fuel species are given. Casuarina produced the highest biomass amongst the various species followed by Cassia, Eucalyptus, Leucaena and Prospis species.

Table 19. **Biomass productivity of 7-year old plantation of some fuel species.**

Species	Biomass productivity (t/ha)	
	Fresh	Dry (oven dry)
Casuarina equisetifolia	202.6	80.8
Eucalyptus tereticornis	117.2	52.2
Leucaena leucocephala	106.8	50.4
Cassia siamea	120.8	57.6
Prospis juliflora	100.2	45.3

5.3 Growth of timber species

Data recorded on average height and girth of some timber species is presented in table 20 a and b. After 7 years of plantation the height of 8 tree species ranged from 6.6 m *(Acacia nilotica)* to 14.7 m *(Albizia procera)* and girth from 37.6 cm *(Bassia latifolia)* to 93.8 cm *(Albizia procera)*. Observations indicated that *Albizia procera* grew faster amongst all the tree species followed by *Dalbergia sisso, Tectona grandis* and *Acacia auriculiformis.* Other species are also making satisfactory growth but they are slow growing.

Table 20. Growth performance of some timber species.

a. Average height (m)

Species	Year after Planting						
	1	2	3	4	5	6	7
Dalbergia sisso	2.5	4.5	6.7	7.8	8.3	9.2	10.5
Tectona grandis	1.8	2.6	3.5	4.8	6.6	7.3	9.0
Acacia auriculiformis	2.1	4.3	5.1	7.3	8.2	9.0	9.8
Acacia nilotica	1.3	2.7	3.2	3.9	4.6	5.3	6.6
Terminalia arjuna	2.6	3.1	3.5	4.3	4.9	6.2	8.1
Bassia latifolia	1.8	3.9	4.7	5.3	5.9	6.9	7.3
Albizia procera	4.1	5.8	7.2	8.6	9.8	11.9	14.7
Albizia lebbek	3.8	4.5	5.6	7.1	7.9	8.8	9.7

b. **Average girth-GBH (cm)**

Species	Year after Planting						
	1	2	3	4	5	6	7
Dalbergia sisso	3.8	4.2	12.2	21.8	40.6	55.3	70.8
Tectona grandis	5.1	10.8	18.2	24.3	38.8	47.3	58.2
Acacia auriculiformis	7.0	10.5	15.8	25.3	33.7	42.6	51.5
Acacia nilotica	5.8	9.8	20.7	32.3	40.2	45.8	50.7
Terminalia arjuna	8.8	18.2	24.4	28.8	37.5	42.8	47.3
Bassia latifolia	6.2	8.8	13.0	21.8	30.2	34.8	37.6
Albizia procera	8.4	17.5	28.9	38.2	50.3	72.8	93.8
Albizia lebbek	6.2	8.2	17.5	23.8	32.3	45.7	56.7

5.4 Productivity of timber species

Relative productivity of 7-year old plantation of timber species is given in table 21. *Tectona grandis* produced highest biomass followed by *Albiza procera, Acacia nilotica* and *Terminalia arjuna* and *Dalbergia sisso. Bassia latifolia* is a slow growing species hence, produced lowest biomass at the age of seven years.

Table 21. Biomass productivity of 7-year old plantation of timber species.

Species	Biomass productivity (t/ha)	
	Fresh	Dry (Oven)
Dalbergia sisso	90.3	44.1
Tectona grandis	215.2	100.6
Acacia auriculiformis	78.6	40.6
Bassia latifolia	40.8	18.2
Terminalia arjuna	104.1	53.4
Albizia procera	180.0	85.1
Albizia lebbek	104.4	42.6
Acacia nilotica	124.8	78.0

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6. SOIL IMPROVEMENT

Observations recorded on litter fall and biomass of weed flora and the changes in soil properties in relation to afforestation are presented below:

6.1 Litter fall

Data presented in table 22 show that *Casuarina equisatifolia* adds 8.2 tonnes of dry matter annually followed by *Cassia siamea, Acacia auriculiformis, Albizia lebbek / leucaena leucocephala* and *Albizia procera* through litter fall.

Table 22. Leaf litter fall of various tree species after 7-year of plantation.

Species		Leaf litter fall t/ha
a.	**Fuel species**	
	Casuarina equisetifolia	8.2
	Eucalyptus tereticornis	1.8
	Leucaena leucocephala	3.8
	Cassia siamea	4.2
	Prospis juliflora	1.2
b.	**Timber species**	
	Dalbergia sisso	2.2
	Tectona grandis	2.8
	Acacia auriculiformis	4.0
	Acacia nilotica	0.4
	Terminalia arjuna	2.7
	Bassia latifolia	1.3
	Albizia procera	3.4
	Albizia lebbek	3.8

6.2 Biomass of Weed flora

The total biomass of Weed flora under various forest species was much higher as compared to those of barren land. Among the various forest species, the biomass of Weed flora under *Leucaena leucocophala* was found to be the highest followed by *Acacia auriculiformis, Bassia latifolia* and *Terminalia arjuna* (Table 23). The most common grasses observed were usar grass, *Eleusive indica, Cynodon dactylon, Dichanthium annulatum, Eragrostis* Panpothi, janava etc.

Table 23. Biomass of Weed flora under various tree species after 5-year of plantation.

Forest species		Biomass of Weed flora Dry wt/t/ha
a.	**Fuel species**	
	Casuarina equisetifolia	1.3
	Eucalyptus tereticornis	2.4
	Leucana leucocephala	5.8
	Cassia siamea	2.5
	Prospis juliflora	1.2
b.	**Timber species**	
	Dalbergia sisso	2.7
	Tectona grandis	2.6
	Acacia auriculiformis	5.2
	Acacia nilotica	1.8
	Terminalia arjuna	2.9
	Bassia latifolia	4.4
	Albizia procera	2.3
	Albizia lebbek	2.5
c.	**Barren land (Control)**	0.9

6.3 Changes in soil properties

Data on organic carbon content, hydraulic conductivity, pH and exchangeable sodium percentage in relation to various forest species were recorded and presented in Table 24.

6.3.1 Organic carbon

The organic carbon content of soil was maximum under *Casuarina equisetifolia* (0.60 percent) followed by *Albizia lebbek, Leucaena leucocephala, Albizia procera / Terminalia arjuna* and *Acacia auriculiformis.*

6.3.2. pH$_2$

The pH of the soil reduced with all forest species under study as compared to those of barren land. Maximum reduction was observed with casuarina plantation followed by *Acacia auriculiformis.*

6.3.3 Exchangeable Sodium Percentage

The exchangeable sodium percentage of soil was also reduced with the plantation of various forest species as compared with the soil of barren land. Maximum reduction in ESP was with Casuarina plantation followed closely by *Acacia nilotica*, *Albizia procera* or *Prospis juliflora*, *Cassia siamea* and *Acacia auriculiformis*.

Table 24. Changes in properties of sodic soil under various forest species after 7-years of plantation.

	Forest species	Soil properties (O-20 cm depth)			
		Organic carbon (%)	Hydraulic conductivity (cm/hr)	pH_2	ESP (%)
a.	**Fuel wood species**				
	Casuarina equisetifolia	0.60	0.32	8.8	47.3
	Eucalyptus tereticornis	0.29	0.16	9.3	58.3
	Leucaena leucocephala	0.57	0.31	9.1	48.8
	Cassia siamea	0.49	0.25	9.0	48.8
	Prospis juliflora	0.52	0.28	9.0	48.5
b.	**Timber species**				
	Dalbergia sisso	0.39	0.27	9.4	58.4
	Tectona grandis	0.42	0.24	9.2	54.7
	Acacia auriculiformis	0.53	0.30	8.9	48.9
	Acacia nilotica	0.49	0.28	9.0	47.8
	Terminalia arjuna	0.56	0.30	9.5	60.2
	Bassia latifolia	0.37	0.18	9.5	60.7
	Albizia procera	0.56	0.29	9.0	48.5
	Albizia lebbek	0.58	0.31	9.0	49.2
c.	**Barren land (Control)**	0.16	0.03	10.4	76.0

The improvement in soil properties indicates the ameliorative influence of various forest species and biomass of weed flora on salt affected soils.

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7. INTEGRATION WITH SOIL CONSERVATION AND WATER HARVESTING

Supplementing afforestation with soil conservation and water management enhances the process of establishment of the forest tree species and rehabilitation of salt affected Wastelands. The measures adopted to control soil erosion and harvesting of rain water for economic utilization of denuded sodic lands are as under :

7.1 Bunding

Bunding is very useful to cut the length of run-off and check running water which helps in checking soil loss improving water regime. This results in more biomass production and an increase in plant growth as compared with unbunded control (Table 25)

Table 25. Effect of bunding on biomass of Weedflora and growth of Casuarina and Eucalyptus plantation.

Bunding	Species	Av. dry wt of	Growth of plant after 3 years	
		Weeds (t/ha)	Av. height (m)	Av. girth (cm)
Bunding	Casuarina	2.2	10.3	27.8
(0.75 Sqm)	Eucalyptus	2.0	8.5	22.2
No bunding	Casuarina	0.8	8.8	25.1
	Eucalyptus	0.7	7.2	20.3
CD at 5%		0.3	1.1	2.4

7.2 Water harvesting

Water harvesting is the real base in water shed management programmes. A well managed watershed support biomass production activity of the area and help in maintaining environmental balance.

Rise in ground Water table (Table 26) due to Watershed has stabilized the growth of forest plantation in term of biomass productivity (Table 27)

Table 26. Mean water levels of dug wells

Year	Water table from ground (m)	
	January-June	July-December
1990	8.1	4.8
1991	7.8	4.5
1992	7.3	4.1
1993	7.0	3.8
1994	6.8	3.1

Table 27. Biomass productivity of forest species with watershed.

Species	Total fresh Biomass/plant (qtls) after 5–years	
	With watershed	Without watershed
Casuarina equisetifolia	2.0	1.8
Eucalyptus tereticornis	1.4	1.2
Dalbergia sisso	1.1	0.9

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8. ECONOMICS

Afforestation of salt affected soils has various direct and indirect gains. Transfer of technology to the field becomes easier if the economic returns are favourable. An attempt has been made to collect the data on cost and benefit involved in afforestation of some fuel species.

8.1 Direct economic gains

It is essential to compare the actual investment and returns and the likely benefits that will accrue from afforestations of salt affected soils to indicate the viability of the technology.

Data presented in Table 28 reveal that the total investment required for growing of fuel species i.e. *Casuarina equisetifolia, eucalyptus tereticornis, leucaena leucoceplala Cassia siamea* and *Prospis juliflora for a period of 7 years (1987-94) is Rs. 28540, 25632, 25632, 25632 and 21272 respectively. The net benefit cost ratio was the highest with* Casuarina *equisetifolia* followed by *Cassia siamea* and *Prospis juliflora.*

Table 28. Cost and return from raising fuel species on sodic lands after 7-years of Plantation.

Species	Total cost (Rs./ha) 1987-94	Gross return (Rs.)	Gross benefit ratio	Net benefit cost ratio	Annuity value (Rs.)
Casuarina	28540	64160	2.24	1.25	5089
Eucalyptus	25632	41760	1.63	0.63	2304
Subabul	25632	40800	1.59	0.59	2117
Cassia siamea	25632	45100	1.76	0.75	2781
Prospis	21272	36640	1.72	0.72	2195

The annuity value in case of *Casuarina equisetifolia* was higher than the other species. Investment of one rupee gives an income of Rs. 1.25 from Casuarina as compared to Rupee 0.63, 0.59, 0.75 and 0.72 from Eucalyptus, Leucaena, Cassia siamea and Prospis species respectively. Although the cost of raising Prospis, Cassia siamea Leucaena and Eucalyptus species are relatively low but the returns are considerably higher from Casuarina.

8.2 Indirect benefits

The indirect benefits from afforestation of salt affected soils are as under :

8.2.1 Impact on environment

The afforestation and improvement of salt affected lands must be viewed as an environmental asset. It must be remembered that an average hectare of woodland consumes 3 tonnes of Carbon dioxide and gives out 2 tonnes of Oxygen. Therefore, afforestation on any available land is very helpful to mitigate the growing pollution of the environment. It is true that in pure economic terms one may say usar plantation is not viable but if the indirect benefits are taken into consideration afforestation of salt affected lands becomes sine qua non.

8.2.2 Saving of animal dung for food production

Animal dung is often used as a source of domestic fuel due to acute shortage of fuel wood. Raising of fuel species like Casuarina, Eucalyptus, Leucaena, Cassia siamea and Prospis on salt affected Wastelands provides 80, 52, 50,57 and 45 tonnes of fuel wood and will thus save about 179, 116, 112, 127 and 100 tonnes of animal dung respectively which on application in the field will add 1.24, 0.80, 0.77, 0.88 and 0.70 tonnes of N+P+K (Table 29). This will finally result in additional production of food grains to the tune of 12.5, 8.1, 7.8, 8.8 and 7.0 tonnes respectively.

Table 29. Animal dung and plant nutrient saving by raising of one hectare plantation of fuel species.

Species	Fuel wood (t)	Animal dung Saving (t)	Sutrient Saving (t)			Increase in food Production (t)
			N	P	K	
Casuarina	80	179	0.62	0.26	0.36	12.5
Eucalyptus	52	116	0.40	0.17	0.23	8.1
Subabul	50	112	0.39	0.16	0.22	7.8
Cassia siamea	57	127	0.44	0.19	0.25	8.8
Prospis	45	100	0.35	0.15	0.20	7.0

- 1 ton of fuel wood replaces about 2.24 tonnes of animal dung cake.
- 1 ton of animal dung cake supplies about 3.5 kg N, 1.5 kg P_2O_5 and 2.0 kg K_2O.
- 1 ton of animal dung is estimated to increase about 70 kg of food grains production.

8.2.3 Soil fertility improvement

Amelioration of soil through leaf litter fall and weed flora is very helpful in improving fertility status and physico-chemical properties of the salt affected soil.

8.2.4 Employment generation

Afforestation of salt affected lands ensures the employment for the rural people on long term basis and has thus improved their well being. A large number of people have been trained in nursery production and afforestation techniques and quite of them have got employment in various organisation.

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9. CONSLUSION AND FUTURE STRATEGIES

9.1 Conclusion

1. Possibilities of raising forest species on salt affected wastelands have been examined. Results indicated that it is possible to grow forest species economically on such soils provided the agrotechniques developed by the university are followed.

2. Tree biomass production on salt affected wastelands has an important role in meeting daily survival needs of the vast majority of rural household like fuel wood, fodder and timber etc. besides, calling a hault to further degradation of soil, water and environment.

3. Integration of plantation with soil conservation measures and Water harvesting, ensures faster reclamation and rehabilitation of salt affected Wastelands.

9.2 Future strategies

1. Systematic survey and preparation of consolidated salt affected wasteland maps are needed for judicious planning of afforestation programme.

2. Data on biomass production and on cost-benefit ratio different forest species on sodic soils should be generated for easy transfer of technology on large scale.

3. Collection of detailed data on the amount of litter production, its decomposition rate, nutrient recyling, nitrogen fixation of both leguminous and nonleguminous tree species and their influence on physico-chemical properties of soil and environmental ecology are needed.

4. There is need for development of forest based cropping system on salt affected soils or sustainable land use and balance of natural ecosystem.

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