Afforestation of Arid Lands

Editors

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PREFACE

Arid lands are referred to as lands where there is an acute deficiency of water, predominantly because they receive only a meagre amount of rainfall. The problem of shortage of moisture is further compounded by high temperature, which determines many features of soils, flora and fauna.

Arid lands occupy about 2900 million ha of land i.e. approximately 19.5 per cent of the total land area of the globe. These lands predominantly occur in Africa, Arabia and South and Central Asia, North America and Australia. Indian arid lands are the part of the Indo-Iranian desert ecosystem. In India, area under hot desert is 31.7 million ha which is about 10 per cent of the country s geographical area. About 80 per cent of this area lies in Rajasthan and Gujarat. The remaining area is in Punjab, Haryana, Maharashtra, Karnataka and Andhra Pradesh. Arid lands in India are in severe state of degradation, lying barren bereft of vegetation owing to serious constraints of climate and soil coupled with intense biotic pressure. It is the most thickly populated desert in world having 61 persons per km^2 as against 3 persons per km^2 in other deserts of the world. There is very high livestock density in the region. As against 1:0.5 ratio of human and animal population at the national level, the ratio is 1:2 in Indian arid zone, which indicates the gravity of pressure on the natural resources. The skewed relationship of demand and supply is obvious from the acute shortage of fuel wood to the extent of about 2 million tonnes per annum and chronic deficiency of fodder to the tune of 12 to 16 million tonnes annually.

The climatic and edaphic conditions in the region are very hostile. The terrain conditions are such that 58 per cent of the area is covered with stabilized and unstabilized sand dunes which suffer from serious problem of wind erosion. Most of the area consists of shallow sandy soils underlain with hardpan. There are

areas covered with rocky and semi-rocky sites. A substantial area of arid lands suffers from salinity and alkalinity problems including the saline rann of Kachchh and Luni basin. Climate of the region is very adverse. During summers, the maximum air temperature reaches as high as 50°C; the soil temperature goes upto 70-75°C. Minimum temperature drops below the freezing point creating conditions of frost during the winters. Region suffers from severe moisture deficiency, the mean annual rainfall varying from 100 to 500 mm, 90 per cent of which is received in period of July to September with very high coefficient of variation in quantity and duration. The number of rainy days varies from 10 to 18. Low relative humidity and high wind velocity (usually 20 to 30 km per hour and occasionally as high as 130 km per hour) result in high evapotranspiration (7 to 13 mm per day in summer, 5.3 to 6.4 mm per day in monsoon and 1.8 to 2.9 mm per day in winter).

Vegetation cover in the region is very sparse largely comprising mixed xeromorphic thorn forests or scrub vegetation. The species growing are few in number and slow in growth. Excessive livestock population causes high grazing pressure in the region adversely affecting the growth of any form of vegetation and enhancing the pace of desertification.

The Indian arid ecosystem is highly fragile having poor natural resources but large liabilities causing severe impediments in desert development programmes. Afforestation on massive scale is the only way to improve living conditions and productivity in arid region. In consonance with this view, the forestry activities have been the core of desert development programmes. Various forestry activities include sand dune stabilization, shelterbelt plantations, plantations along canals, roads and railway tracks, silvipastoral plantations, etc. However, the planting practices/ techniques in vogue are not matching to the needs and challenges of forestry in the region. The areas where gaps have been vast are collection of superior quality and genetically improved seeds and techniques of raising and handling healthy seedling stock, planting techniques such as soil working, moisture and nutrient management, spacing, pruning, lopping, suitability of provenances and species, plant protection measures, irrigated forestry, silvipastoral plantations,

agroforestry models, etc. To take stock of the available knowledge, to identify the gaps and to priorities the thrust areas of forestry research in arid regions, a seminar "Afforestation of arid lands" was held in January, 8th and 9th, 1991 at AFRI, Jodhpur. Based on the selected papers presented and discussions held during the seminar, this book has been compiled which contains chapters pertaining to state of the art presented by the practising foresters and scientists, status of forestry research and technology covering aspects such as seed, nursery, plantation forestry, forestry on refractory sites, moisture and nutrient management, agroforestry, forest protection, etc.

It is hoped that this book would be useful for practising foresters, researchers, students of forestry and all those who have concern for arid land development.

Jodhpur
26, May, 1993

A.P. Dwivedi
G.N. Gupta

1

PERFORMANCE OF VARIOUS TREE SPECIES IN CANAL SIDE PLANTATIONS OF I.G.N.P. STAGE-II IN WESTERN RAJASTHAN

A.K.Upadhyaya

Introduction

Irrigated plantations in the arid zone of Rajasthan using water from Bhakhra canal were raised as early as in 1961 (Mathur, 1961 and Singh, 1963). However, afforestation activities in stage-I area of Indira Gandhi Nahar Project(I.G.N.P.) were stepped up considerably from 1973-74 onwards. In stage-II area (620-1458 R.D. of main canal and it's distribution systems) afforestation activity started in 1987. Since then 24,285 ha area has been planted in a short span of three years. Various plantation activities are namely, canal side, block, sand dune stabilisation, pasture development, road side and environmental plantations. The canal side plantations have gained top priority because of the need to protect canal from wind eroded sand deposition. Assessment of the growth performance

of different species in these irrigated plantations is very important in order to choose right kind of species suiting the site conditions for meeting the desired objectives of speedy protection of canals and to increase the forest produce from the land in order to meet requirements of fuel, fodder, timber and other forest products.

This paper reports the results of initial growth studies of seven main species used in canal side plantations in I.G.N.P. stage-II.

Materials and Methods

The study area lies in Jaisalmer district in north-western part of Rajasthan. Climate is arid hot where maximum temperature reaches 48°C and minimum 0°C. Mean annual rainfall is 160 mm. Strong winds of 40 km hr^{-1} velocity often predominate, particularly during summer months causing sand movement of very high magnitude. Soils of the area are loose sand lacking soil profile development and at places have underlying gypsum layer. Deficiencies of nitrogen and phosphorus are often encountered in these soils.

Under canal side plantation activity, strips of 100 metre depth on either sides of the main canal and branches, 50 metre on either sides of minors and subminors were planted at a spacing of 3m x 2m. The spacing has been changed to 3m x 3m in recent plantations. Depending upon the topography, mode and method of water application to the plantations varied. (1) Where the ground level was higher than the water level in canal and terrain was undulating, irrigation was done by using engines and quick coupling light galvonised steel pipes of 100mm diameter with riser outlets of 25mm at suitable intervals and on these riser outlets P.V.C./ rubber pipes of 25mm diameter are fixed to carry water to plants; (2) Where the ground was flat having its level higher than water level in canal, furrow irrigation using engines was adopted. Furrow was 30 cm deep, 30 cm wide at the bottom and 40 cm at the top. Plants were planted on lip of furrows. (3) Where terrain was undulating and its level lower than the water level in canal, spot irrigation was done using P.V.C. hose pipe and quick coupling light galvonised steel pipes. (4) Where the terrain was flat having lower level than the water level in the canal, basin irrigation was practised, the basin size being 0.20 to 0.50 ha depending on degree of level and type of soil.

Under first two categories plants with less water requirement like *Prosopis cineraria, Tecomella undulata, Ziziphus mauritiana* and *Acacia tortilis* were planted. On other two sites *Dalbergia sissoo, Acacia nilotica* and *Eucalyptus camaldulensis* were planted. The sites, where trials were conducted are given in table 1.

Table 1. Locations where data were recorded

S. No.	Name of the site
1.	1406–12 R.D., L.H.S., I.G.M.C.
2.	1430–38 R.D., L.H.S., I.G.M.C.
3.	1445–50 R.D., L.H.S., I.G.M.C.
4.	1452–58 R.D., L.H.S., I.G.M.C.
5.	50–60 R. D. , L.H.S., Sagarmal Gopa Shakha.
6.	70–80 R. D. , L.H.S., Sagarmal Gopa Shakha.

R.D. = Relative Distance, where 1 R.D. = 300 metre.
L.H.S. = Left hand side
I.G.M.C. = Indira Gandhi Main Canal

Representative sample plots of size 300 m^2 were taken in triplicate for each age group of different plantations. Growth observations were recorded at six months interval. Mean annual increment (MAI) was calculated by felling a representative sample tree outside the plot for each replicate.

Results and Discussion

RELATIVE GROWTH PERFORMANCE

The maximum growth in height, collar girth (GBH) and MAI were attained by *Eucalyptus camaldulensis* followed by *Dalbergia sissoo, Acacia nilotica, Ziziphus mauritiana, Tecomella undulata* and *Acacia tortilis* (Table 2). Minimum growth was found in *Prosopis cineraria.* Performance of two indigenous species namely *Ziziphus mauritiana* and *Tecomella undulata* was better than *Acacia tortilis*, which has been reported as fast growing species under rainfed condition (Muthana and Arora, 1973). The results indicate that the indigenous species cannot be treated slow growing under irrigated conditions. Lack of adequate data has caused belief that *Prosopis cineraria, Tecomella undulata* and *Ziziphus mauritiana* have excessively slow growth rate. *Prosopis*

Table 2. Initial growth rate and M.A.I. of different species in canal side plantations in stage – II area of I.G.N.P.

Tree species	Height (m)			Girth (cm)				M.A.I. m^3ha^{-1}
	First year	Second year	Third year	First year (Collar)	Second year (collar)	Third year		
						Collar	G.B.H.	
Dalbergia sissoo	1.35	5.95	9.00	11	24	33	27	18.1
Eucalyptus camaldulensis	3.98	6.98	11.38	19	36	47	36	49.7
Acacia nilotica	2.10	3.75	6.80	16	28	33	28	16.2
Tecomella undulata	0.69	1.83	3.70	66	14	25	16	7.5
Prosopis cineraria	0.65	2.10	3.45	2.5	13	20	15	5.0
Ziziphus mauritiana	0.93	2.47	5.60	7	18	30	24	13.6
Acacia tortilis	1.10	1.63	3.60	7	10	19	10	6

Table 3. Proposed management and harvesting schedule for different species in canal side plantation.

Watering schedule		Fertiliser application	Species and their average composition		Silvicultural operations			Harvesting age (years)	Expected growth		Remarks
YR.	Freq.		Species	%	Prunning age (years)	Thining at age (years) I	Thining at age (years) II		G.B.H. (cm)	Height (m)	
1	9	Basal dose	*D. sissoo*	25	2	8	15	25	120	16	Quantum of
2	9	of D.A.P.,	*E. camaldulensis*	10	–	–	–	9;coppice 8yr	50	20	irrigation 100 liters/ irrigation for
3	6	25 gms per plant.	*A. nilotica*	25	2	6	11	15	70	16	first three species
4	6	Three dose	*P. cineraria*	10	3	10	20	50	100	13	and 40 liters/
5	3	of urea 25	*T. undulata*	15	2	8	18	40	120	16	irrigation for
6	3	gm/plant	*Z. mauritiana*	10	–	6	11	25	70	12	remaining species.
7	2	each in 1st	*A. tortilis*	5	–	6	11	15	70	12	
8	2	2nd and 3rd year									

cineraria and *Tecomella undulata* were reported to attain a height of 2.8 m and 3.1 m , respectivley in 14 years under rain fed conditions at Jodhpur.

The MAI in the present study was, for *E. camaldulensis dulensis* 49.7 m^3 ha^{-1}, *D. sissoo* 18.1 m^3 ha^{-1}, *A. nilotica* 16.2 m^3 ha^{-1} and P. cineraria 5.0 m^3 ha^{-1}. According to earlier reports the MAI varied 5 to 38 m^3 ha^{-1} in various provenances of *E. camaldulensis* (Hamel, 1985). At an exceptionally good site in Zimbabve MAI of 65.5 m^3 ha^{-1} was recorded by Barrett and woodvine (1971). For *Dalbergia sissoo* Lerche and Khan, 1971 reported MAI of 2.5 m^3 ha^{-1} at average site and 9.0 m^3 ha^{-1} at potentially good site. According to IBRD (1979) MAI of *A. nilotica* varied from 6-8 m^3 ha^{-1} in canal side plantations of U.P.

The growth performance and MAI of *Ziziphus mauritiana, Tecomella undulata* and *Prosopis cineraria* clearly indicate that they respond well to irrigation. These desert species requiring less water after their establishment, should be given at least 30- 40% weightage in canal side plantation activities in stage-II.

Based on growth parameters, local requirements of fuelwood, fodder and timber and availability of water the future management plan for canal side plantation activities in stage-II area of I.G.N.P. is proposed in table 3.

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2

WATERSHED MANAGEMENT IN RIVER VALLEY PROJECT AREAS OF RAJASTHAN

K.B.L Mathur

INTRODUCTION

Construction of big dams to generate power and increase area under irrigation has been an important developmental activity in post independent India. The dams constructed at very high costs are naturally very important to the economy of our country and as such we have to maintain them for perpetuity. However, in early sixtees itself a feeling developed that unless soil conservation works in the catchment of river valley projects are undertaken these big reservoirs may soon be silted up. Realising this fact, Government of Rajasthan took up watershed management in the catchment areas of Chambal River Valley Project as early as 1962. The programme was taken up by Forest Department ; so initially the soil conservation works were confined to forest areas only but by 1964 the programme was extended to agricultural lands too. The soil conserva-

tion works in the catchment of River Valley Projects got a further boost when the programme was extended to Dantiwara RVP in 1969 and to Mahi RVP in 1970.

When Rajasthan Forest Department took up soil conservation works in the catchment of River Valley Projects, the discharge of silt was of the order of 24 of 72 ha metre per 100 sq. km. The object was to reduce this discharge and bring it to the level of 0.62 to 1.65 ha metre per 100 sq. km. The endeavour of Forest Department was to treat all the area in 10 years. But the area to be treated was large and the available financial resources were too meagre. Therefore, out of 22,620 sq. km. the catchment area, only an area of 2044 sq. kms could be treated by 1988-89 (Table 1)

Table 1 : Detail of work done in RVP

Name of RVP	Total catchment area (sq. km.)	Catchment area which falls in Rajasthan (sq.km.)	Catchment area in which work has been done up to 1988-89 (sq. km.)
Chambal	26944.00	4108.80	1270.51
Dantiwara	2828.80	2035.20	445.98
Mahi (Kadana)	32280.00	16476.17	328.06
Total	62052.80	22620.16	2044.55

From table 1 it is clear that though we started quite early yet we are far from our target of covering all the areas in the catchment of RVPs. So the government of India has decided that soil conservation works should be taken up only in very high priority areas which too will be determined and decided at the level of Government of India. Accordingly the following watersheds are receiving top priority and the ongoing and future programmes will be taken up only in these watersheds (Table 2)

Table 2 : Priority watersheds in different RVP

S. No.	Name of watershed	Area in ha			
		Agriculture	Forest	Waste land	Total
A. Chambal					
1.	Baisakhiya Nala	68.50	2092	1329.5	3490
2.	Para Peepli	11.30	280	1000	2410

3.	Karab Ka Khal	150	2355.8	244.7	2750.5
4.	Nagdara	3000	–	710	3710
5.	Bhutiya Khal	15000	800	1192	3492
6.	Jamunia	1290	440	1190	2920
7.	Chand Baori	130	–	500	630
8.	Parajhar	200	3526	700	4426
9.	Gopalpura	1000	680	3600	5280
10.	Mandawara	2060	330	250	2640
11.	Mandawara	400	190	1330	1920
12.	Gangobi 'A'	800	1375	1000	3175
13.	RPS Watershed	–	3420	250	3670
14.	Dorai	400	3640	–	4040
15.	Gangobi 'B'	500	1350	1236	3086
16.	Dhawan Dhob	–	2978	310	3288
17.	Chomahla	–	–	–	3075
18.	Kharkheda	1260	300	465	2025
19.	Dabla	1025	–	600	1625
20.	Rajpura	750	1950	510	3210
21.	Jawda	907	643	850	2400
22.	Arnod	2000	540	–	2540
23.	Ambapani	80	1620	–	1700
24.	Vasad	–	–	–	3125
25.	Unchabardiya	1590	475	1135	3200
B Dantiwara					
1.	Kui Sangna	855	1650	765	3300
2.	Aamthala	2025	1775	475	4275
3.	Vajna	1450	1700	560	3750
4.	Chandela	3000	3335	315	6650
5.	Bharja	1035	304	1610	2949
6.	Kivarli	840	462	1200	2502
7.	Siyava	508	800	800	2108
8.	Bhansasing	–	940	2385	3325

9.	Santpur	300	330	995	1625
10.	Manpur	1440	479	180	2099
11.	Gaodka	1246	895	134	2275
12.	TalwaronKaNeka	1464	705	55	2224
13.	Panchdeval	398	324	203	925
C. Kadana (Mahi)					
1.	Dabariya	1560	1000	605	3165
2.	Mangarh	820	200	90	1210
3.	Shergarh	1460	500	440	2400
4.	Sajjangarh	2450	1200	445	4095
5.	Borbator	1580	700	595	3075
.6.	Sagwa	2216	1425	450	4091
7.	Nayagaon	500	375	1925	2800
8.	Ghatiya	1947	1155	851	3953
9.	Tejpur	3237	390	919	4546

Nature of treatment given to different types of lands

The soil conservation and afforestation works which are being done on three different types of legal lands are as follows :-

(I) FOREST LAND

In this type of land, which is under the ownership of Forest Department we are spending @ Rs. 2250/- (approx.) per ha as follows :-

Ist year	Fencing	Rs. 1000
	Soil working	Rs. 650
	Total	Rs.1650
2nd Year	Planting & Sowing in trenches	Rs. 600
	Grand Total	Rs.2250

In the first year, the fencing cost includes excavation of trench along fencing wall and also sowing of *Prosopis juliflora* on the trench and construction of *Pacca* check dams in nala along fencing wall. In second year, planting of 200 saplings in one has of area is done. 60 to 70 trenches of size 3m x 0.60m x 0.45 m per ha are also made. In planting preference is given to Churel *(Holoptelea integrifolia)* and *(Azadirachta indica)*.

In forest area, some times there may be opposition to fencing and all the area can not be closed. In such cases we do not go in for fencing and planting of saplings and instead carry out some engineering works like construction of check dams, gully control structures and silt detention dam (SDD). In such type of treatments we spend @ Rs. 600 per ha. It is proposed that a trench along the boundary of the area be dug and sowing of *Prosopis juliflora* should be undertaken which in due course will act as a live fence of the area. In addition sowing of *Prosopis juliflora* seeds are proposed in notches all over the area.

(II) WASTE LANDS

In this type of area we are spending funds @ Rs. 800/- per ha. The treatment includes livehedge fencing and sowing of *prosopis juliflora* on trench and by notches. Engineering structures like check dams, gully control structures and silt detention dams are also undertaken.

(III) AGRICULTURE LANDS

In this type of land we are spending approx. Rs. 600 per ha on construction of graded and contour bunds. Then we are spending another Rs. 350/- per ha on construction of diversion channel, spill ways, cut offs and nala training works, etc. Finally we spend another Rs. 50/- per ha on sowing of seeds of desibabul *(Acacia nilotica)* on bunds. In this way we are spending an amount of Rs. 1000/- per ha for treating the agricultural lands.

Silt Studies

Rajasthan Forest Department is simultaneously carrying out silt studies in watersheds under treatment. Silt monitoring stations, in principal nallas have been established and the discharge of silt is measured in rainy season. So far 44 gauging stations have been established. In addition, The Department has also established observatories to record temperature, rain fall, etc. At present the Department is maintaining two observatories. One of these observatories is also approved by Meteorological Depart-

ment Govt. of India's Pune Centre and the work in this observatory is done strictly as per guidelines issued by the Meteorological Department.

Benefits

The soil conservation and afforestation works in River Valley Projects have resulted in a number of direct and indirect benefits. Some of these can be mentioned as follows :-

1. The soil and water conservation measures have increased the of yield crops which are grown on the treated land. These measures have also enabled farmers to have two crops from the same land.
2. Engineering structures like silt detention dams constructed in treated areas have helped in improvement of water table in adjoining area. This enables farmers to irrigate their agricultural lands.
3. The soil and water conservation measures and also closures of treated area have helped in the production of grass. The grass so produced has been very helpful in fighting famine conditions in Rajasthan.
4. The funds spent on soil and water conservation in River Valley Projects have helped in generation of employment to 29.64 lakh man days from 1974-75 to 1987-88.

Evaluation of Project

The evaluation of this project was done in 1967 - 68 by Evaluation Department of Rajasthan Government. Subsequently the evaluation of works is being done by Forest Department. The evaluation studies show that soil and water conservation measures definitely help in reduction of silt discharge and the tree planting works have been quite successful. The measures have also brought a change in the cropping pattern and the yield of agricultural crops per ha has increased.

Management Plans

Since only very limited funds are available for soil conservation purposes, we have to use these funds in a very careful and scientific manner. This is possible only if works are executed strictly as per management plans prepared on scientific lines. The Department, is therefore, enforcing that these management plans should be prepared well in time and got approved by Goverent of India.

OGRANISATIONAL SET UP

In Rajasthan, the soil and water conservation works in River Valley Projects in all the three categories of land viz. forest land, agriculture land and wasteland are under the over all control of Forest Department. The work is looked after by an Indian Forest Service Officer of the rank of Chief Conservator of Forests who is called Director, Project (Soil Conservation). The Directorate has got 3 Soil Conservation Divisions each headed by a Soil Conservation Officer. One of these divisions is looking after the catchment of Chambal River Valley Project and the other two are respectively looking after Dantiwara River Valley Project with headquarters at Abu Road and Kadana River Vally Project with headquarters at Banswara. In addition there is a cell for silt monitoring located in the office of the Director. This cell is headed by a Senior Research Officer who is responsible for collection and analysis of silt data. Every officer mentioned above has also been provided with supporting field staff.

Problems

1. **Grazing** : In Rajasthan we have a high livestock population which is responsible for considerable damage to forests. It will be seen that in catchment of river valley projects a lot of livestock specially sheep has almost permanently settled. Natural regeneration in the Forest is adversely affected; it is also degrading the forest land. An early solution to the problem must be found out so that further damage to forests does not take place.
2. **Quarrying of stones :** It will be seen that a lot of quarrying of stones is done in the catchment of river valley project area. This activity disturbs the soil completely and helps in soil erosion.
3. **Maintenance of old works:** Government of India gives funds to the Directorate only for 5 years. After this period, the Directorate does not get funds from any source. So it has become a problem to maintain the works which have been carried out in the past. It is high time that staff and funds are

given to the Directorate for looking after the works done in the past.

4. **Revision of norms of work :** It will be seen that we are spending very little amount per ha on soil conservation works. The treated area, therefore, can not check the silt so effectively. Government of India must, therefore, give more funds per ha to Forest Department to effectively carry out all the soil conservation works in the area which is taken up for treatment. It is proposed that for forest land Rs. 3000 per ha instead of Rs. 2250 per ha where fencing and planting is possible and in other areas where fencing and planting is not possible Rs. 1000 per ha instead of Rs. 600 per ha be allocated. In wastelands Rs.1500 per ha instead of Rs. 800 per ha and in agricultural land Rs. 1500 per ha instead of Rs. 1000 per ha should be allowed.

5. **Establishment cost :** It will be seen that the salaries of the staff working in the project are increasing every year with the result that cost of employing the same staff is going up. Government of India has fixed up a formula that only 30 per cent of the allocation can be utilised to meet the establishment costs. This is creating difficulty because Government of India is not correspondingly increasing the total budget allocation which is more or less fixed at Rs. 1.5 crores. Under the circumstances we have to reduce the staff ever year which again is posing too many problems. The problem can be solved if Government of India increases the budget allocation by 10 percent every year.

From the above it is clear that lot of good work has been done by Forest Department in checking soil erosion in the catchment of river valley projects. If these works were not carried out, perhaps the reservoirs constructed at very high costs would have been considerably silted up and the life of dams of national importance would have been shortened by now. But then the work done so far is only a drop in the ocean and from the figures given earlier a lot still remains to be done. Government of India should, therefore, provide funds tto State Government in a big way to help treat the remaining catchment area of the above mentioned reiver valley projects. Also there are some more river valley projects in the state which too require similar treatment. Government of India should help the State for treatment of catchment areas of these river valley projects too.

3

AFFORESTATION OF ARID LANDS WITH SPECIAL REFERENCE TO GUJARAT

R.L.Java

Indian Council of Agricultural Research (ICAR) has identified and divided the Gujarat State into eight agro-climatic zones. These zones have been formed taking into consideration the rainfall pattern, topography, cropping pattern and the climate. Of the eight agro-climatic zones, four can be considered under the category of arid and semi-arid areas on the basis of uncertain and erratic rainfall, less vegetative cover and less productivity of soil. These are:

(1) Dry zone of North Gujarat.

(2) Arid zone of North-West Gujarat.

(3) Arid-cum-dry zone of North Saurashtra.

(4) Bhal and coastal zone.

DRY ZONE OF NORTH GUJARAT

This zone extends to an area of about 22,98,690 ha. It covers all the 10 talukas of Sabarkantha, the only taluka of Gandhinagar, 5 North-eastern talukas of Banaskantha and 9 eastern talukas of Mehsana district. This

zone receives average annual rainfall of 625-875 mm. The rainfall is erratic and fluctuates from year to year. There are no major irrigation projects and major source, of irrigation in this tract are tube-wells and open wells. The underground water has been over exploited for irrigation, consequently the permanent water table has gone down to 30 metres. Some of the deep borewells have been drilled to a depth of 300 to 660 metres (Report of the Expert Committee of ICAR).

ARID ZONE OF NORTH-WESTERN GUJARAT

This zone extends over an area of 57,46,280 ha approximately, covering all the 9 talukas of Kutch, Malia taluka of Rajkot, 3 talukas of Surendranagar-Halvad, Dasada and Dhrangadhra, Sami and Harij talukas of Mehsana, Viramgam taluka of Ahmedabad and 6 north-western talukas of Banaskantha district. Most of the tract falls in drought prone area of the state.

The average annual rainfall in the zone varies from 250 to 500 mm. It is also not dependable, and is erratic. The zone is also not very rich in underground water resources, consequently only 11% of the area is under irrigation.

The soils of the area are mainly sandy, low in fertility, poor in organic matter and saline to a great extent.

ARID-CUM-DRY ZONE OF NORTH SAURASHTRA

This zone extends over an area of 34,96,690 ha approximately. It spreads over all the talukas of Jamnagar, 9 non-coastal talukas of Rajkot, 6 eastern talukas of Surendranagar and 7 talukas of Bhavnagar district. Large parts of the zone constitute drought prone areas of the state. The average rainfall of the zone varies from 400 to 700 mm. There are no major irrigation projects in the area. Underground water resource is poor.

BHAL AND COASTAL AREA

The Bhal lies on the two sides of the Gulf of Cambay where the terrain is flat. It extends to two talukas each of Bhavnagar, Ahmedabad and Bharuch districts and Khambhat taluka of Kheda district. It spreads over 9,67,900 ha area approximately. There is a wide fluctuation in the rainfall of the zone. The area is by and large flat with the outfall resulting in stagnation of water over vast stretches during rainy season. The soils are generally clayey in texture with an impervious sub-soil layer which prevents easy percolation of water. The soils are saline to a greater extent.

Afforestation technology in different zones of the State

Each zone has its own special features, topographic, climatic and biotic which vary making it difficult for raising plantations in these areas. Taking into account these factors special treatment has to be provided.

These special features of each zone are discussed below:

1. The dry zone of North Gujarat has a high population of cattle goats and sheep. Cattle-proof permanent fencing is therefore, necessary to protect the plantations from damage by them.
2. The arid zone of North-West Gujarat has typical loose sandy soil with less moisture content. The rainy days are limited and are interspersed with long dry spells. Many parts have saline soils.
3. The arid-cum-dry zone of North Saurashtra has highly degraded areas and has scrub vegetation. Adverse biotic factors like damage due to grazing is common. Low moisture content in the soil and long dry spells are special features of the zone.
4. The Bhal and coastal areas have special features and are unique in their ecological problem. Soils are Severely saline/alkaline and hence can sustain those species which are salinity tolerant.

Guiding Considerations For The Afforestation Technology For The Various Zones

1. THE DRY ZONE OF NORTH GUJARAT

Scarce rainfall poses problems because of the ill-distribution & non-dependability. This makes selection of species difficult and species which could bear low rainfall and long dry spells are generally preferred.

Moreover, the cattle population of the area is double that of the human population. Protection of forest vegetation against grazing is therefore a serious problem in the zone. It gets aggravated in drought years when heavy lopping of the branches takes place which not only restricts growth of the trees but also results in large scale mortality of the vegetation.

The most important need in the zone is for fodder. The scarce tree growth in the area also makes fuelwood a scarce commodity. Hence stress

should be laid on raising grass, fodder and fuelwood species, in these tracts.

Moreover, the pressure of cattle takes a heavy toll of the vegetation.

2. ARID ZONE OF NORTH WEST GUJARAT

The entire zone is situated on the inland fringes of the two Ranns which are annually inqundated by the water during monsoon months. Ingress of sea water in this manner over millions of years, has created inherent salinity in the soils. Consequently, the choice of species is restricted only to a few species which are salt tolerant.

3. ARID-CUM-DRY ZONE OF NORTH SAURASHTRA

Due to poor agriculture in the zone, cattle rearing including sheep, goat and camel husbandry is quite common. The scarce fodder resource and practice of free and unrestricted grazing leads to a heavy pressure of grazing in the area. Hence, experience shows that it is very difficult to raise those species which are susceptible to grazing and allied damages like lopping etc.

There is a general shortage of the fuelwood in the area. This limits the choice of species to only those few which are mostly coppicing and can also stand up to this type of biotic pressures.

4. THE BHAL AND COASTAL AREA ZONE

The saline/alkaline nature of the soil is a challenge for tree growing, only species tolerant to saline conditions can come up. In addition to the need for fodder and fuelwood, the most important need of the zone is to imporve the condition and texture of the soil.

Choice of Species for the various Zone.

Taking the prevailing geo-physical and biological considerations, the choice of species which can withstand the local conditions is naturally restricted.

1. THE DRY ZONE OF NORTH GUJARAT

Trees	*Azadirachta indica, Madhuca indica, Pongamia pinnata, Holoptelea integrifolia, Albizia lebbeck, Butea monosperma, Ziziphus species, Anogeissus latifolia, Acacia species, Salvadora persica.*

Shrubs/ Herbs	*Cassia auriculata, Xanthium strumarium, Holarrhena antidysenerica, Helicteres isora, etc.*

2. THE ARID ZONE OF NORTH WEST GUJARAT

Trees	*Acacia nilotica, Acacia senegal, Azadirachta indica, Acacia tortilis, Ficus species, Prosopis cineraria, Commiphora mukul, Ailanthus excelsa, Phoenix sylvestris, Salvadora species.*
Shrubs/ Herbs	*Cassia auriculata, Balanites aegyptiaca, Carissa carrandus, Capparis aphylla, Prosopis juliflora,* etc.

3. ARID-CUM-DRY ZONE OF NORTH GUJARAT

Trees	*Cassia species, Acacia nilotica, Acacia senegal, Azadirachta indica, Ficus species, Prosopis cineraria, Ailanthus excelsa, Ziziphus species, Acacia tortilis,* etc.
Shrubs/ Herbs	*Cassia auriculata, Balanites aegyptica, Carissa carandus, Capparis species, Prosopis juliflora.*

4. BHAL AND COASTAL AREA ZONE

Trees	*Prosopis cineraria, Acacia nilotiaca, Salvadora species, Acacia tortilis,* etc.
Shrubs/ Herbs	*Balanites roxburghii, Ziziphus nummularia, Capparis decidua, Cassia auriculata,* etc.

4

FOREST DEVELOPMENT IN KACHCHH (GUJARAT)

Y.R.C. Reddi

Back ground

Kachchh is the largest district in Gujarat State comprising a geographical area of about 41,147 km^2. It is situated in the North-western part of the State and is bounded on North and North-West by Pakistan, on the North-East by Rajasthan, on the East by Banaskantha and Mehsana Districts, on the South-East by Surendranagar District, on the South by the Gulf of Kachchh and Rajkot District and on the South-West and West by the Arabian Sea.

The tract constitutes a unique ecosystem with diverse environmental conditions. It can be divided into the following zones.

1. The Northern zone comprising of Great Rann.
2. The Eastern zone comprising of Little Rann.
3. The Central zone comprising of hills interspersed by plains.
4. The Southern and Western Coastal Border plains.

Status of Forest Areas

In contrast to the vast geographical area of the district, comprising of 41,147 km^2, forest area in the district is only 2881 km^2 forming barely 7% of the total area. The forest areas are mostly confined to undulated plains with few hillocks therein. The vegetation comprises of thorny species such as Gorad (*Acacia senegal*), Baval (*Acacia nilotica*), Hermo (*Acacia leucophloea*), Khijado (*Prosopis cineraria*) Pardeshi baval (*Prosopis juliflora*) Khari jar (*Salvadora persica*) Mithi jar (*Salvadora oleoides*) on the main land and Cher (*Avicinnia officinalis*) Karad (*Rhizophora mucronata*) etc. in the mangroves. By and large density of crop is low and trees are stunted.

Constraints For Development

The tract in general has the following adverse conditions.

1. Inherent salinity at all depths in majority of the areas.
2. Erratic and scanty rains with uneven distribution.
3. Non-availability of suitable water for forestry works.
4. Very high wind velocity along the desert and coastal borders.
5. Shallow and poor soils in the hilly and undulating areas of the district.
6. Large cattle, sheep and goat population.

Thus climatic, edaphic and to some extent biotic factors pose a great challenge for undertaking afforestation works.

Objectives of Forest Management

Considering the adverse factors to which the tract is subjected to, the following objectives are identified for forest development.

1. Stabilisation of the desert sands from North and North-East.
2. Stabilisation of the coastal sands from South and South-West.
3. Afforestation of the barren hills with shallow soil to check soil erosion and promote percolation of water to charge the sub-soil water.

4. Afforestation of the barren saline plains to improve the sites and produce fuelwood to meet the local requirement.
5. Management of the grass reserves to improve the quantity of grass which has degraded as a result of over grazing. This will supply fodder to the cattle specially during drought periods which are of recurring nature in this district.
6. Wherever feasible to raise economically profitable species essentially for the production of small timber and fuelwood to meet the requirement of local people to the extent possible.
7. Protection and improvement of mangroves.
8. Management of wildlife.

Forest Organisation

The forest area of Kachchh falls under the administrative control of the Conservator of Forests, Kachchh Circle. The circle is divided into two territorial divisions namely Kachchh east and west and an Extension Division for Social Forestry. Each division is headed by Dy.Conservator of Forests who organises and executes various developmental works.

Implementation of afforestation scheme

Keeping in view the objectives outlined above, various afforestation schemes with emphasis on soil and moisture conservation are implemented in the district. Rainfall being the most limiting factor, efforts are made to undertake water harvesting techniques by way of percolation tanks, check dams, etc. Soil and moisture conservation measures in the form of gradonies, contour trenches in the hilly and undulating areas and 'T' trenches and ordinary trenches are undertaken in suitable areas. The choice of species for the desert conditions is limited. The species tried for afforestation are Baval (*Acacia nilotica*), Neem (*Azadirachta indica*), Soo-baval (*Leucaena leucocephala*) Nilgiri (*Eucalyptus hybrid,*) Poudeshi baval (*Prosopis juliflora*), Israili baval (*Acacia tortilis*), Gugal (*Commiphora mukul*), Cher (*Avicinnia officinalis*), etc. In the Rann areas and also other refractory areas seed sowing of *Prosopis,* Deshibaval and in some cases Neem and Israili baval has given encouraging results particularly when the seed has been sown on the mounds formed out of the dug up soil from the trenches formed around the plantations as

protection measure. The schemewise physical achievements during the period from 1985-86 to 1989-90 are given below:-

Community Forestry Programme

With the advent of Community Forestry Programme aided by the World Bank, the aforesaid objectives are being realised through farm forestry and plantations on road-side strips, railway strips and village common lands.

Efforts are also being made to promote tree consciousness among the people through farm forestry, kisan and school nurseries and also through the introduction of wood saving devices in the form of smokeless chulas and improved crematoria.

The species tried under this programme are Nilgiri, Neem, Deshi baval, Israili baval, *Prosopis*, Siras, *Casuarina*, Soo-baval, *Ailanthus* , etc.

The physical achievements under Community Forestry Programme during the period from 1985-86 to 1989-90 are given in tables 1 & 2.

Results

The success of afforestation activity depends largely on the timely and adequate rainfall. Unfortunately in Kachchh district there have been consecutive droughts and in the recent past the year 1987-88 was the worst when no rainfall was received. Again the sites being deficient in nutrients and also saline the choice of species is confined to mostly thorny species which to some extent withstand drought and also the salinity. Considering these limitations the results achieved during the year of fair amount of rainfall are encouraging. Seed sowing done on the mounds formed out of the dug up soil from the trenches has given good results. Where it has been possible to provide support irrigation plants have been sustained. This is particularly so in case of strip plantation under the Social Forestry and the coastal border plantations. Farm Forestry Programme has started taking roots in the area which is expected to provide small timber to the needy and in turn farmers would get additional income from tree farming.

Table 1 : Physical achievement under community forestry programmes.

S. No.	Scheme	Physical achievement in ha					
		1985–86	1986–87	1987–88	1988–89	1989–90	Total
1.	Afforestation on desert border	497	255	–	155	155	1062
2.	Plantation on coastal border	200	40	50	60	–	350
3.	Mangroves plantation	100	–	150	250	250	750
4.	Soil and moisture conservation and afforestation in denuded area	200	160	–	160	–	520
5.	Rural fuelwood plantation	1488	1280	–	1800	1400	5968
6.	Fuel wood and small timber plantation	29	100	–	100	100	329
7.	Irrigated plantation	5	–	7	20	20	52
8.	Plantation of medicinal plants	10	10	–	10	10	40
9.	Plantation of minor forest produce	–	10	–	10	10	30
10.	D.P.A.P. Scheme	876	–	14	610	68	1568
11.	Scarcity	–	–	–	785	–	785
12.	R.L.E.G.P	–	–	–	600	–	600
13.	Compensatory plantation	–	–	–	500	600	1100
	Total	3405	1855	221	5060	2613	13154

Table 2. Physical achievements under community forestry programme

S.No.	Component	Physical achievement in ha					
		1985–86	1986–87	1987–88	1988–89	1989–90	Total
1.	Road-side plantation	170	70	21	95	85	441
2.	Railway side plantation	10	6	–	15	–	31
3.	Canal side plantation	20	–	15	5	–	40
4.	Village wood lot (irrigated)	25	–	30	34	25	114
5.	Village wood lot (rain-fed.)	215	374	–	310	150	1049
6.	Rehabilitation of degraded forest area	10	–	–	–	–	10
7.	(R.D.F.L. under C.F.P.)	55	550	157	364	105	1231
8.	R.D.F.L. (Spl. comp., plan.)	–	2	14	157	50	223
9.	N.R.E.P.	7	36	11	10	150	214
	Total...	512	1038	248	990	565	3353
10.	Crematoria	1	2	2	2	2	9
11.	Smokeless Chulas	8	8	10	100	100	226
12.	Farm Forestry (Seedling supply in lakhs)	52.40	48.62	20.95	81.45	64.67	268.09

Fodder Supply

During the years of good rainfall, grass produced in the rakhals incharge of the department is harvested and stored in the Godowns and Ganjis and supplied to the revenue department during the year of scarcity. Due to inadequate and erratic rainfall it has not been possible to undertake introduction of more nutritive grasses on a sustained basis.

Mangrove Forests

The largest area in the state under Mangroves is in Kachchh district which is to the tune of 582.85 km^2 incharge of the Department. These areas are mostly confined to Southern and Western coastal creeks of the district. They consist of mainly Cher (*Avicinnia officinalis*) and Karod (*Rhizophore mucronata*). The areas are not harvested but the leaves are allowed to be collected during the scarcity period to meet the demand of fodder for cattle in the coastal area. Cher in its natural belt regenerates profusely while it is difficult to regenerate it artificially as optimum conditions of growth are required to be maintained. At present annually an area of 250 ha of suitable blanks is planted mostly by seed sowing of Cher (*Avicinnia officinalis*).

Wild Life

Although Kachchh is deficient in forest resources it is better placed in respect of wild life. Considering the important fauna met within the tract, two sanctuaries viz. Narayan-sarovar, Chinkara sanctuary and the Kachchh Desert Wild Life Sanctuary have been constituted. These areas form habitat for a variety of wild animals, the important among them being wild Ass, Chinkara, Panther, Nilgai, Wild boar, Hyeana and a host of bird life which include Flamingo (Migratory bird) Great Indian Bustard, Grey patridge, Common Sandgrouse, etc.

Conclusion

As stated earlier the plantation activity of the department greatly depends on adequate rainfall which is low and erratic in this area. Droughts are frequently faced while years of good rainfall are rather rare. Other limitation is the poor soils with various degrees of salinity. Moreover, there is a large population of live stock which mostly depends for grazing on waste lands and forest lands. All these factors in a combined

way pose a formidable task to the forester for undertaking successful afforestation programme. Therefore, main emphasis is laid on soil and moisture conservation works, water harvesting, seed sowing, etc. Stump and strike planting of species, which respond to these can also be tried. Choice of species also will have to be from those which are useful and also can withstand drought, saline conditions, grazing, hacking, etc. Wherever feasible support watering if provided ensures sustenance of the plants which would otherwise wither away due to harsh climatic conditions. Grass harvesting and storage by individuals and institutions to meet their requirement during the years of scarcity would have to be undertaken sooner or later. Similarly stall feeding of livestock would lessen the problems of soil erosion and the damage to the vegetation in general and tree crop in particular. No doubt these suggestions are made with ease while their implementation is difficult. If we have to protect and improve the forest and waste lands, these measures are required to be implemented.

Research is another important aspect which can offer practical solutions for various problems faced in the area. So far very little work has been done in this regard. It is therefore necessary to draw up various experiments and undertake nursery and field trials particularly in respect of seed collection and storage, regeneration of various species including grasses, suitability of species for different soils and their tolerance to various degrees of salinity, the effect of watering on soils and its effect on growth of various species, soil and moisture conservation measures, water harvesting techniques, etc.

5

NOTES ON AFFORESTATION OF ARID LANDS OF KACHCHH DISTRICT IN GUJARAT STATE

A.P. Jethwa

Setting

Two third area of the district is occupied by the desert and one third by the sea. The track comprised variety of land and water, plains and hills, desert and non desert trees and bare lands along with varying bird and animal life. The land is at present in a retrogressive stage of biotic succession due to total neglet and abuse of the basic principal of land use.

Rainfall is scanty and irregular. Mean annual rainfall of the region for last 10 years is 346 mm. Number of rainy days in a year averages 10 S_2 to 15 days. The distribution of the rainfall over area is uneven. Due to scanty rainfall this district witnessed famine and scarcity conditions for 7 years out of 10 years. Maximum temperature goes beyond 45^0 C in May where as minimum temperature reaches 1^0 C in December.

None of the Kachchh rivers are perennial. All the streams are seasonal, retaining water for few days after rainfall. Starting from the

central uplands they find their way over short courses either north to the Rann of Kachchh or South to the Arabian Sea and Gulf of Kachchh. Sub soil water is the only permanent way of water supply. But it is also not sufficient, the water is usually salty.

Kachchh forest areas fall under "6 B Northern Tropical Thorn Forests" sub type Desert thorn forests.

Objectives of Forest Management

Objects of forest management are

(1) Stabilization of the desertic sand dunes from North and North-East, constituting the great Rann of Kachchh.

(2) Stabilization of the coastal sand dunes from South and South-West.

(3) Regeneration of degraded forest areas through natural regeneration or afforestation with diverse and indigenous species with focus on providing fuelwood, fodder, grass, small timber, M.F.P. etc. to the local village community.

(4) Stopping the process of retrogression of forests and reversing it back toward progression to achieve adequate vegetative cover.

(5) Management of grass reserves so as to improve the quality of grass which is also degraded.

(6) Improving the socio-economic conditions of local people.

(7) Stabilization of the ecological balance through dynamic natural process.

(8) Generating the employment opportunities for the rural poor.

Species composition

(1)	Neem	—	*Azadirachta indica*
(2)	Babul	—	*Acacia nilotica*
(3)	Israeli babul	—	*Acacia tortilis*
(4)	Boradi	—	*Ziziphus spp.*
(5)	Pillu	—	*Salvadora spp.*

(6)	Mithi–Amali	—	*Ingadelsis*
(7)	Gugeal	—	*Comiphora spp.*
(8)	Kharek	—	*Phoenix spp.*
(9)	Amala	—	*Emblica officinalis*
(10)	Amali	—	*Tamarindus indica*
(11)	Gundi	—	*Cordia dichotoma*

TECHNIQUE OF PLANTATION

The forest areas are generally slopy and undulating and in such area the soil is also very shallow and are liable to erosion if vegetation cover is not there, such area is tackled under S.M.C. scheme in form of contour trenches, sapar trenches, check dams, van-tala-vadi and gullyplugging etc.

(1) Contour trenches -

Contour trenches of size 2m x 0.45 m x 0.30 m are prepared at 2m apart and pits of size 30 cm^3 are to be dug in between two lines.

No. of trenches per Ha = 500

No. of pits per Ha = 1000

Six months old container seedlings raised in 15 x 25 x 200 P.B. will be planted on both ends of the trench and also in pits. Seed sowing of Prosopis, Babul, Israil Babul etc. will be done on the excavated earth of contour trenches. Grass seed sowing and swards (thumada) will be planted on the trench to protect the soil erosion.

(2) Sapar Trenches:

Contour trenches of size 9 m x 0.45 m x 0.30 m are prepared at 1 m apart in square (as per the above design) and pits of size 30 cm^3 are to be dug in between four trenches seed sowing of *Prosopis*, Babul, Israil babul etc. will be done on the excavated earth of contour trenches.

(3) Van-talavadi :-

Van-talavadi is prepared in every five ha plantation area. Rain water will be collected in van-talavadi. After rainy season 50% plantation area will be watered with support irrigation wherever water is available.

Natural low lying area is selected for Van-talavadi in which minimum excavation is required.

Approximate qty. of excavation: 450 cm to 485 cm seed sowing of Prosopis, Babul, I.Babul, Neem etc. will be done on the excavated earth of talavadi.

(4) Check dams :-

Small nalas are selected for preparation of rubble checkdams or earthen checkdams. Size of the checkdams varies due to depth and width of the nalas.

(5) Support irrigation by earthen pots :-

The district has very limited water facilities. Because of the adverse climatic factor, the number of rainy days on an average vary 2 to 15, so survival percentage is decreased due to extreme hot and hot winds. In summer support irrigation by earthen pots has given excellent results in the plantations.

Earthen pots of the specific size (As per design) are got prepared by earthen pot makers. It costs upto 30 np. to 50 np. per piece, capacity is 2 litres.

After last weeding soil working earthen pots are burried near plant (10 to 12 cm away) slanting towards roots and 2cm top is kept open, watering in earthen pots will be done by manual labour once in 30 days. Roots will get direct moisture from drop hole of earthen pot hence there will be no water waste and water is utilized fully for growth of the plant. One labour would be employed for 2 to 3 ha of plantation and monthly irrigation will be done from Nov. to June.

6

SEEDING AND AFFORESTATION PROGRAMME IN BET AREAS OF GREAT RANN OF KACHCHH

A. K. Varshney

Introduction

Great Rann of Kachchh is situated in North of Kachchh District. It extends in an area of 1.64 million ha of the total area of 4.11 million ha of the District. The bet areas between Mori bet and Shakti bet are typical land forms created by uplifting sea bed above the water level. This is evident from soil texture. The surface deposits of salts of appreciable thickness are present. The upper layer of soil is about 1 to 2 cm thick, made of salty clay deposition due to high wind in the areas. The sub-surface layer is a coarse sand with high proportion of mollusces shells.

Regarding the vegetation of the Great Rann of Kachchh, it is devoid of any type of vegetation except certain patches of grass land available. The main grass cover is of *Heleochlos setulosa.* The other associate

perennial grasses are *Sporobolus marginatus* and *Desmostachys bipinnata.* Moreover, good population of *Prosopis cineraria* has also been noticed. One climber i.e. *Cocculas* Spp. on *Prosopis cineraria was also seen. Prosopis juliflora* has also found as other associate tree spp. in this area.

Looking into the harsh and typical conditions in the area, particularly highly salty dust storms, it is desirable that soil and vegetation should be the least disturbed. Therefore, the efforts were put to introduce suitable grass spp. in the area alongwith the trials to improve the natural grass cover supplemented by sowing the seeds of grasses and tree spp. and planting the seedlings of some tree spp. as shelter belt plantations. Therefore, the main objectives of these trials were:

(a) to exploit the existing natural grass cover through development plan of this bet area to obtain the grass stock at the time of scarcity and drought occurring in Kachchh district frequently.

(b) to explore the feasibility to check the speed of desertification through seeding and afforestation of grasses and tree spp.

Materials and Methods

In order to evaluate the regeneration of natural grass cover and adaptability of some grass spp. in the area, five field trials were conducted in bet areas between Mori bet and Shakti bet. Total 5 ha of land was selected and 5 blocks of area 1 ha each was demarcated by digging of 5 x 1 x .5 m^3 trenches on all the sides. The dug out soil from these trenches was put inside the plot. The seeds of *Prosopis juliflora, Acacia nilotica* and *Acacia auriculiformis* were dibbled on the soil in three rows and inside of these trenches. The trials were started from 30th June and completed on 13th July, 1988.

Each block of 1 ha area was then numbered serially and separate experiment was conducted. Soil analysis of each block was done in Soil Test Laboratory, Bhuj (Table - 1). Following field trials were undertaken

Table 1 pH

S. No.	Plot No.	Place	pH of soil	Electrical conductivity of salt (milimos/ CM)	% Org. C	Available phosphorus (KM/ HA)	Available Potash KG/ HA.	Type of soil
1.	1	Bet area of Great Rann of Kachch.	7.4	25	0.20	21	128	
2.	2		7.4	50	0.20	24	97	
3.	3		7.5	35	0.19	21	102	Sandy
4.	4		7.3	4	0.22	29	112	
5.	5		7.4	45	0.25	27	102	

PLOT NO. 1: CUTTING OF OLD GRASS CLUMPS AND TREE PLANTING:

In this plot, the grass cover had been lying unutilised in the area. Consequently, the grass clumps had become very old and less productive. In order to activate the growth in these old clumps, they were cut upto the ground level and the cut material was used as a mulch on the trenches. Total 400 pits of 30 x 30 x 10 cms size were dug in the empty patches of this plot nearby the grass and tree cover. 200 seedlings of *Azadirachta indica,* 100 seedlings of *Prosopis juliflora,* and 25 seedlings of each of *P.cineraria* and *Sueda fruiticosa* and 50 seedlings *of Phoenix* spp. were planted at the spacement of 2m x 2m. Further the seeds of *Prosopis cineraria* were dibbled in some parts of the empty patches in the plot. Seedlings were watered manually after plantation.

PLOT NO. 2: SHELTER-BELT PLANTATION:

In this plot, 2500 pits of size 30 x 30 x 30 cms at the spacement of 2m x 2m were dug. The gypsum was added in 1000 pits and the imported good soil was put in the remaining 1500 pits. The seedlings of *Prosopis juliflora* were planted and subsequently they were watered manually as well as mulching was carried out.

PLOT NO. 3: CLEARING OF THE SITE AND RESEEDING WITH SUITABLE GRASS SPP

In this plot, natural grass clumps and other vegetation and debris were completely cleared. They were used as a mulch material on the trenches. Inside the plot, 100 m long ridges and furrows at 0.5 x 0.5 m spacement were prepared. On the ridges, 20,000 pallets of *Cenchrus ciliaris* and *Sporobolus marginatus* were dibbled at 1 m apart.

PLOT NO. 4: BURNING OF OLD GRASS CLUMPS

Here, the old grass clumps of 1/4th area was burnt in the plot to add organic matter and remaining grass clumps of 3/4th area were uprooted and they were dibbled on the trenches as a mulch. After clearing the sites, 100 m long ridges and furrows were prepared at spacement of 0.5 x 0.5 m. On these ridges, the pellets of *Cenchrus ciliaris* and *C. satigerus* were dibbled at 0.5 m apart in two parts of the area.

PLOT NO. 5: SOWING OF SEED PELLETS OF *PROSOPIS JULIFLORA* IN NATURAL GRASS COVER

In this plot, 100 ridges and furrows were prepared at 1 m apart in natural grass cover area. The pellets of *Prosopis juliflora* were dibbled on these ridges at 1 metre apart.

Results and Discussion

The observations were recorded three times at different interval during last one year. The parameters like height of the plant, survival percentage of the seedlings and germination percentage of the seeds were taken into account to obtain the results of these experiments. In general, the significant findings were reported from these trials. The results of different plots were discussed as follow:

PLOT NO. 1:

(a) The germination of the seeds of *Prosopis juliflora* and *Acacia nilotica* was noticed on the trenches dug across boundary of this plot. The growth and development of the seedlings of *P. juliflora* were recorded as highest against other species of *Acacia*. The average height of these plants was noticed as 1.5 metre.

(b) New culms and slips were sprouted from the old clumps which were cut before monsoon. The growth and development of grasses (*Heleochlos setulosa* and *Sporobolus marginatus*) were activated freshly from the culms after receiving rainfall. The height of these grasses was recorded as 0.75m on average and they were grown upto the stage of inflorescence effectively.

(c) The survival percentage of the seedlings planted in this plot was recorded as follow:

1	*Sueda fruiticosa*	90%
2	*Prosopis juliflora*	60%
3	*P. cineraria* Prosopis	40%
4	*Azadirachta indica*	30%

Of these, *Sueda fruticosa* thrived well under these natural conditions which favoured for its multiplication through-out the plots.

(d) The germination of the seeds of *Prosopis cineraria* was also recorded as 35%

PLOT NO. 2:

(a) The seeds of *Prosopis juliflora* sown on trenches gave best result. Some plants have attained the height of 2m. No germination of seeds of *Acacia nilotica* was noticed on the trenches of this plot.

(b) The survival percentage of the seedlings of *Prosopis juliflora* was recorded as 35%. The average height of the plants was noticed as 1m. The seedlings planted with gypsum put in pits showed better results than the seedlings planted with imported good soil put in the pits. The casualities were noticed in very saline patches of the plot.

PLOT NO. 3

(a) The results of seed sowing of *Prosopis juliflora* was found best on trenches.

(b) The germination of the pellets of grass seeds of *Cenchrus ciliaris* and *Sporobolus marginatus* was recorded as 60%. The latter performed better in terms of its growth and development.

PLOT NO. 4

(a) The germination of the seeds of *Prosopis juliflora* was noticed on trenches.

(b) No sprouting of the grass from culms was noticed in 1/4th part of the old grass of the plot which was burnt. In the remaining part of the plot the germination of the grass pellets of *Cenchrus ciliaris* and *C setigerus* was noticed only 12%.

PLOT NO. 5

1. The germination of seeds of *Prosopis juliflora* and *Acacia nilotica* was noticed on the trenches better on good soil as compared to the saline patches of the trenches.

2. The pellets of the seeds of *Prosopis juliflora* gave better results in good part of the plot where they produced 30% seedlings. However, no germination/or sprouting of seedlings from these pellets was noticed in saline patches of the plot.

Thus it is evident on the basis of these results that the germination of seeds of *Prosopis juliflora* gave the best results on the trenches. It is due to the facts that the salts get washed away from the soil on the trenches and thereby the seeds get favourable environment for its proper germination and consequently good growth and development of the seedlings was noticed. Further new grass culms sprouted after receiving rainfall since the growth is activated in the favourable environment. The grass has attained the flowering stage and subsequently the regeneration of natural grass cover may occur from the seeds dispersed from this area to other parts. Moreover, the seedlings of *Prosopis juliflora* and *P. cineraria* have performed better due to adaptability of these plant species to such areas and they gave better results except in very saline and poor soils. The seedlings of *Sueda fruiticosa* has also thrived better since they got natural environment which suited them for multiplication in entire plot and nearby. Basically this plant absorbs salts from the soil and consequently plays its role in reducing the salt status of the soil. Last but not the least, the pellets of seeds of *Sporobolus marginatus* and *Cenchrus* spp have also produced satisfactory results under prevailing conditions of the sites.

7

AFFORESTATION ON ARID LANDS

S. K. Tembe

Arid zone in the broadest sense may be defined as zone experiencing a chronic water deficit. These areas are characterised by sparce and highly variable precipitation, extreme variations of diurnal and annual temperatures and high evaporation conditions. The crop or pasture production in this zone, therefore, must aim at using the available water most efficiently. The areas of the North West. Indian arid zones are one of the most dustiest places in the world. Observations indicate that the dust blows up to the distance of 20 to 30,000 feet. This dust is the main cause for not allowing the precipitation to occur inspite of the good atmospheric humidity. The arid zones in India occupies an area of 3.2 lakh sq km of hot desert mostly in Rajasthan, Gujarat, Haryana and Karnataka and cold desert of 0.7 lakh sq.km. of Ladakh. The hot desert has abundance of sunshine, land of soils capable of responding to management, well adapted grasses, shrubs and trees and considerable ground water reserve. Thus water and hot land are the principal limiting factors. Indian desert has the largest population and the main source of income to the population is agriculture & animal husbandry. Increasing population of both human & animal and decrease in land potential has deteriorated the land and soils.

Unproductible areas are put under agriculture which get eroded. The wind velocity is extremely high in these areas and as such more and more areas are degraded. Therefore, it is necessary not to disturb the ecological balance further and proper land use pattern adopted. The main reasons for aggravating the unfavourable consequences of aridity are -

(1) Diminishing grazing areas and increase in cattle population.

(2) Most of the land in arid zone is only fit for forestry but still it is increasingly brought under cropping.

(3) Though vast extent of land is shown as barren and uncultivable wasteland only a small section is under forests as seen from table below :

	Land use category	Area in million Ha.			
		India		Arid zone	
		Area	%	Area	%
1.	Forests	65.90	21.54	0.53	1.88
2.	Barren & uncultivable and non agricultural areas	46.20	15.10	6.70	23.85
3.	Other uncultivated lands excluding fallow	32.50	10.62	5.42	19.30
4.	Fallow lands	20.20	6.60	3.30	11.72
5.	Net area sown	141.20	46.14	12.20	43.25
	Total reported land for utilization	306.00		28.10	
	Total geographical area	328.00		31.90	

South West Rajasthan and North Gujarat (Kachchh) represent more or less same vegetation in the arid zones. The broad groups being (i) *Calligonum polygonoides* - extreme arid areas only (ii) *Prosopis cineraria - Capparis decidua, Ziziphus, Salvadora* - most common in Rajasthan and Kachchh. This vegetation characterises 150 to 400 mm rain with 9 to 11 dry months. *Acacia nilotica* is common on western Kachchh with *Acacia senegal* in bouldery areas. *Prosopis juliflora* has now spread over quite a good portion of southern Rajasthan and north and NE Kachchh due to its wide adaptibility to severe climatic conditions and almost has become a local species.

Planting techniques

Silvicultural problems demand (i) a careful study regarding the selection of tree species both indegenous and exotic, (ii) the production of seedling stock which deals with nurseries, (iii) Silvicultural characteristic of species selected, (iv) soil working, weeding and cultural operations (v) protection against diseases and animals.

The local tree species are the best indicator for selection of species for planting work. The local species of the arid zone are not only a few but are extremly slow growing and therefore it becomes necessary to introduce tree species of higher growth rate and of better resistance to drought and cold. Many species of *Acacia* and *Eucalyptus* were tried in the CAZRI Jodhpur. The best suited was *Acacia tortilis* from Israel. Next to this was *E. camaldulensis*. Local species like *Acacia nilotica, Prosopis cineraria* and *A. senegal* were also found suitable. In Gujarat Arid Zone also *Acacia tortilis, Acacia nilotica, Prosopis cineraria* etc. were suitable and *Prosopis juliflora* has almost taken Kachchh dist. as its home and become almost indigenous spp. This has proved very successful in the most adverse areas. In irrigated sites, species like *Casuarina equisetifolia, Albizia lebbeck*, and *Pithecalobium dulce* are tried in Kachchh by GEDA successfully. In between the planting lines palatable grasses are planted which also provide wind protection. Where soil depth is shallow shrubs like *Jatropha curcus, Cassia auriculata* and grasses may be planted. Wind velocity is very high in this region, specially southern or South Western coasts salty winds blow almost throughout the year. It becomes, therefore, necessary to plant wind/shelter belts in the plantations by providing irrigation. Species like *Leucaena leucocephala, Eucalyptus* hybrid, *Casuarina equisetifolia* and *Sesbenia* spp can be raised successfully.

Production of seedling stock is done at a suitable place taking into account the planting site and availability of water. Water being scarce commodity many a times nurseries have to be started at a long distance from the planting site. Earthen, metallic or polythene containers are used in raising required seedling stock. Containers are arranged in standard sized beds dug up in the ground. The bottom can be cemented or a thick polythene sheet spread on the bottom and containers arranged to check the water losses and also prevent roots penetrating in the ground. Larger sized polythene bags give better survival and growth rate of the seedlings (20 x 30 cm size instead of 15 x 20 cm). The soil mixture of sand+soil and farmyard manure is filled in the bags in 1:1:1 ratio. Properly treated fresh

seeds are then sown in the bags. A shade on top and south & west side may be given to protect from blowing hot winds in summer. Pots are shifted at regular intervals and roots clipped, if penetrated out. In the later stage the watering is reduced and seedlings hardened for the planting sites. Regular insecticides and fertilizer doses to be given to get strong and healthy seedlings. Root shoot cuttings may also be grown in polythene bags for assured results. *Albizia lebbeck, Prosopis juliflora, Dalbergia sissoo* and *Commiphora mukul* cuttings can be raised and planted successfully.

A lot depends on the proper planting technique. It is necessary to take all precautions to arrange planting on the on-set of monsoon so as to get maximum advantage of available moisture to plants. The planting stock should be 1 or 2 year old and healthy. The size of pit or trench, ridge etc. depends on the site and soil conditions in the area.

In the most adverse conditions at Lakhara velara area of Kachchh, the use of drip irrigation is done in the simple form using species like *Prosopis juliflora, Albizia lebbeck, Acacia tortilis, Acacia nilotica, Pongamia pinnata, Casuarina equisetifolia, Jetropha curcus* and *Azadirachta indica.* The results are quite encouraging.

In the hilly or undulating areas pits of 60 x 60 x 60 cm^3 size with a crescent shaped ridge across the local slope give better results. Staggered contour ridge cum trenches each 2 m long and 60 m x 60 m cross section can be a success. In rocky areas planting of tree species may only be taken up in such patches where the depth of soil of about 43 cm has accumulated. In such patches presprouted stumps can give better result in 60 x 60 x 60 cm^3 pit and sowing seeds of *Acacia senegal* or *Prosopis juliflora* on the ridges.

Flat areas could be ploughed and pits of 30 x 30 x 30 cm^3 size dug in the decided spacing and planting done. If water source is available best results are obtained by giving watering to plants by drip irrigation and good species like *Azadirachta indica, Casuarina, Leucaena, Albizia, Eucalyptus, Pongamia pinnata* can be planted in adverse areas. GEDA has obtained good results with support irrigation facilities to plantations in desert lands.

In undulating areas pits of 60 x 60 x 60 cm^3 may be dug and a crescent shaped mound formed across the local slope. Staggered contour ridges cum trenches each 2 m long and 60 cm x 60 cm cross section could also

give good results. Seedings of *Acacia nilotica* or *Prosopis juliflora* can be planted on ridges.

In rocky areas planting of tree species may be taken up only if the depth of soil is 43 cm. Pits of 60 x 60 x 60 cm^3 may be dug and pre-sprouted stump planted.

Planting is followed by weeding and soil working operations which are very important to conserve available moisture and provide better aeration to the soil, which in turn help the plant to grow vigourously. In the initial stages the seedlings are surrounded with all sorts of weeds. They are to be removed to help the plant to get all available nutrients and moisture for their growth. Adding a dose of manure or fertilizer and soil amendments further hastens the growth of the plants. The mulching improves organic matter in the soil, which is very poor in arid zones. Preservation of organic matter in the soil is very essential in desert areas but unfortunately all litter and dung is burnt by people thereby degrading the soil further. Therefore weeding, soil working and mulching at proper time is essential for success of plantation. It is found by experience that minimum 2 weedings and thorough soil working give excellent results. The first soil working in July+August and second in January/February give best results. This should be done for three consecutive years to get sizable height and diameter growth of the spp. Thus soil working plays key role in successful afforestation specially in arid zone.

Successful plantation is not enough because it is carried out on sites exposed to various biotic factors. The large cattle population in the arid zone, which is let loose to graze causes considerable damage. The animals grazing on almost bare land surface, are attracted by planted areas and cause heavy damage to plantations. To overcome this social awareness is required to be created, specially in the rural population. The importance of growing trees and protecting the already growing ones is to be stressed. Audio- visual aids can be of great importance in this field. Women social workers can play vital roles in this field as most of the cutting and collection of fuel is done by women. The use of improved chulas or biogas (Gobar gas) in the rural sector can bring down consumption of fuel and also give very good organic manure for their fields. Similarly the use of solar energy must be popularised to bring down pressure on the fuelwood. We spent quite a bulk of our budget on "protection of plantation" and still get limited success. In China large scale afforestation programmes are done successfully with the help of students and villagers. A love for trees

has to be created in the minds of people. Unless a social awareness is created in the people our afforestation works will have limited success. There must be a feeling of owning the trees in the minds of public and then only real success of afforestation programme will be achieved. The social forestry wing is already going ahead in this line with some degree of success.

The plantations in form of silvi-pastoral system should be raised in arid zone. This consists of raising tree crops of fodder value in wide spacing of 3 m x 2 m and raising of palatable grasses (*Cenchrus ciliaris* and *Cenchrus setigerus*) in the wide strip between the tree crop. In an experiment by CAZRI in Kachchh district the demonstration plots with *Acacia tortilis* and *Azadirachta indica* were raised and *Cenchrus setigerus* and *Cenchrus ciliaris* seeds sown in the 3 m wide strip. It has given very good results. The grasses attained height up to 2 meters. More and more areas can be covered by Govt. agencies and also encouraged in private sectors. It can play vital role in the development of dry runn of Banni in Kachchh. As agriculture & animal husbandry are main source of income for the people it becomes very necessary to raise and supply sufficient quantity of palatable grasses and fodder material for their use. The degraded grazing lands must be first improved by this system to reduce burden on forests for both fuel and fodder.

Thus the afforestation on arid lands is a herculean task and needs dedicated efforts to achieve success. The modern techniques, suitable species, public awareness and popularising the use of non-conventional energy sources are four pillars on which the successful structure of tree planting programme in aridlands rests.

8

FORESTRY IN ARID ZONES OF PUNJAB

B. C. Bala

Punjab is a small state constituting 1.5 per cent of the total geographical area and 2.5 per cent of population of India. It is situated between 29° 33'N to 32° 32' N latitude and 73° 55' E to 76° 55' E longitude. Total geographical area of the state is 50,362 km^2 which can broadly be classified into three main zones, viz; submountainous tract locally known as kandi area, central fertile plains and south western arid areas adjoining the states of Haryana and Rajasthan.

Kandi area is the most backward area of the state because of its rugged terrain, non-availability of irrigation facility and severe soil erosion during rains. The central plains are the fertile and densely populated. The arid zone comprising of parts of Bhatinda,Faridkot,Ferozepur and Sangrur districts is an extension of the Rajasthan desert. The main features of this zone are discussed below :-

Climate

The major chunk of rainfall in Punjab is received through monsoons, which move along the outer Shiwaliks. The arid zone is situated on the south west of the State and by the time the clouds reach this zone they get

exhausted of rain water. The rainfall in this region is erratic. Rainfall(mm) for Bhatinda district, a representative station of the zone for the last 5 years is 306(1984), 396(1985), 289(1986), 131(1987) and 527mm (1988).

Except for 2-3 weeks in late July and early August, moisture availability in the region is deficient. Strong and desiccating south westerly winds during summer months and westerly chilly winds during winters create climatic conditions which adversely affect the plant and animal life. Mean monthly maximum & minimum temperatures during 1988 at Bhatinda are (Table 1) :

Table 1 Mean monthly maximum and minimum temperature (°C) at Bhatinda

Month	Maximum	Minimum
January	25.2	1.4
February	28.8	2.4
March	34.2	7.4
April	42.2	12.0
May	47.7	20.0
June	46.7	24.0
July	40.6	24.0
August	38.0	21.0
September	39.5	20.4
October	34.6	13.8
November	32.0	5.2
December	26.6	3.2

Source : Statistical Abstract of Punjab, 1989

Facilities of Irrigation

The depth of water table varies from 1 to 30 m. The ground water exploration has been done upto 300 m depth to find out possibility of tubewell installation. The quality of water varies from unsuitable to marginally suitable for irrigation. Provision of canal irrigation for agriculture has proved a boon and converted most of the areas in this tract into a green belt. However, excessive canal irrigation has resulted in acute water logging in some of the earstwhile arid areas of Faridkot and Ferozepur districts, where low lying lands which were previously giving good

agricultural yields have been rendered unfit for agriculture. In such tracts, many patches above the water logging level have been successfully planted with eucalypts. Water logging is moving across the arid areas of Faridkot and Ferozepur districts towards the Punjab-Rajasthan border.

Afforestation Techniques

AREAS AND SPECIES SUITABLE FOR PLANTING

There are scattered chunks of areas having sand-dunes, sand bars and some areas above the level of canal-water which cannot be irrigated by canals. These areas are privately owned and are not suitable for agriculture. Farmers are encouraged to plant suitable economic tree species like *Acacia nilotica* and *Ailanthus excelsa* on such areas.

The area under the control of the Forest Department in this arid zone mostly comprises the strips along roads, railway lines, canals, drains, etc. There are few block areas which are very small in size. So for as the strips along canals are concerned, successful plantations of various species like *Eucalyptus* hybrid, *Acacia nilotica, Dalbergia sissoo, Azadirachta indica, Morus alba, Albizia lebbeck* etc. have been raised except where the area is at unusually higher level than the canal water. However great difficulty is being experienced in afforesting areas along roads, railway lines and drains. *Acacia nilotica, Cassia siamea, Albizia lebbeck, Azadirachta indica and Ailanthus excelsa* are grown with reasonable success in these areas. *Acacia tortilis* has been found to be most successful in extremely hot and dry conditions and also because the species is not browsed.

NURSERY TECHNIQUE

The nurseries are set up along canals or distributories where irrigation is possible. The plants are raised in polythene bages of size 20 cm x 12.5 cm and 150 guage. Bigger bags are used for raising tall plants. Polythene bags are filled with a mixture of good loamy soil and placed in beds. Seeds of *Acacia nilotica, Albizia lebbeck, Acacia tortilis* and *Ailanthus excelsa* are sown in polythene bags during March/April. Soaking of seeds of *Acacia nilotica* in water for 24 hours before sowing accelerates germination. Hand watering to plants is done regularly till they grow to about 20 cm height after which flow-irrigation 1-2 times a week is sufficient. One weeding and hoeing to plants is done every month in order to eliminate competition for nutrients and light. After the plants are more than 30 cm tall, shifting is done once a month to contain the root system in bags. The

plants attain a size of about 60cm by the first week of July which is considered suitable for planting. The seeds of *Azadirachta indica* ripen during June- July and their viability being very short, are sown immediately after ripening. The plants take one year in the nursery to grow to plantable size.

ADVANCE EARTH WORK

The area to be planted up is cleared of weeds and pits of size 50cm x 50cm x 40cm are dug at a spacing of 3m x 2m, the distance being 3m between rows and 2m from pit to pit in the row. These operations are carried out during the period from January to March. The dug out soil is kept in the form of heaps along the side of pit for filling back at planting time.

PLANTING

The dug up soil is filled back in the pits immediately before planting because this weathered soil acts as mulch. With the onset of rains, normally during the first week of July, planting of nursery raised seedlings is started. One hand watering is immediately provided to plants after planting the pits. Efforts are made to complete the planting in the first two weeks of rains so that the plants get maximum benefit of the growing season.

Along roads and canals emphasis is laid on planting avenue line with shady and ornamental trees like *Cassia siamea, Albizia lebbeck, Ailanthus excelsa, Azadirachta indica*, etc.

WEEDING, HOEING AND WATERING

After planting two weedings/hoeings are provided in the first year one after about one month of planting and the other during January-February. Deep hoeing of soil in pits helps in absorption of scarce rain water and gentle pressing of soil with khurpa after hoeing reduces the incidence of loss of soil water due to evaporation. Hand watering is done to plants along canal, distributories and minors as per requirements subject to availability of funds. Tankers are also used for watering the plants at important sites along roads to produce better results.

PROTECTION

Application of aldrin alongwith first watering protects the plants against termite in affected areas. Barbed- wire fencing is done at problematic sites to protect the plantations against grazing and browsing.

Brush wood fencing to individual plants is done in areas near habitations and also in single line planting. The plants of *Acacia nilotica, Cassia siamea, Azadirachta indica*, and *Albizia lebbeck* are covered with dry grasses for protection against frost during the chilly period from December to February. The areas along strips of roads, railways and canals are declared as protected forests under Indian Forest Act, 1927. Plantations raised along these areas are protected against illicit felling/lopping and illicit grazing under the said Act.

MAINTENANCE

The plantations are maintained up to three years. The failed plants are re-stocked in second and third year during rainy season. One weeding is also done during second year depending upon the availability of funds. Fencing wherever provided is maintained for three years. To obtain long and clean bole for quality timber, pruning is done in *Acacia nilotica* and *Morus alba* plantations during the third and subsequent years. Training of *Cassia siamea* plants is also done for 3 years.

The above technique has resulted in raising of successful plantations in dry areas of the state.

9

SAND DUNE AFFORESTATION IN TAMILNADU

R. Sundararaju

Tamil Nadu is situated in the South eastern corner of peninsular India lying between 8° 5' and 13° 4' north latitude and 76° 15' and 80° 20' east longitude. The dry zone tract occurs almost in all the areas excepting parts of coastal plains, high Western Ghats and river alluviums. In this dry tract, which covers about 15000 ha in Rameswaram and Nazereth in Tirunelveli, besides high temperatures and low precipitation, the problem is aggravated by shifting sands, high desiccating winds, formation of dunes and low moisture retentivity. Hence experiments were conducted to know the suitability of species and the silviculture techniques that give good establishment with an over all objective of arresting the expansion of sand dunes, reduce wind erosion and provide green clothing.

The tract comprises coastal sand dunes with an annual average rain fall of 450 mm. The diurnal temperature range between 30-38°C and wind velocity of 40-50 km per hour are recorded. The depth of the water table varies between 40-50'm. The soil is pure sand with very low amounts of organic matter.

Experiment No 1.

This experiment was conducted at Thangachimadam in Rameswaram. 10 species were raised to study their comparative performance for sand dune afforestation. These are;

1. *Casuarina equisetifolia.*
2. *Eucalyptus camaldulensis*
3. *Acacia planifrons*
4. *Acacia mellifera*
5. *Acacia auriculiformis*
6. *Acacia senegal*
7. *Casuarina junghuniana*
8. *Acacia leucophloea*
9. *Tecomella undulata*
10. *Acacia tortilis*

The above 10 species were planted at 2.5m x 2.5m spacing on 30.12.83 in a simple randomised block design with 3 replications and 100 plants in each plot. Data were recorded from the centre 36 plants.

Results & Discussion

The average height and survival of the species tried for the last 4 consequtive years is given in table 1.

It can be observed from the table 1 that *Casuarina equisetifolia* showed a good growth rate followed by *Casuarina junghuniana* and *Tecomella undulata.* Among the *Acacias, Acacia senegal* proved well regarding survival and growth rate, where as the same for *Acacia leucophloea* is poor indicating that it is not suited to sandy tracts.

Experiment No. 2.

In another experiment, three species *Acacia senegal, Acacia mellifera, Acacia planifrons* were raised at Theni sand dune. Six month old seedlings were planted on 26.10.83 at 2m x 2m spacing. The experiment consists of 4 treatments with 8 replications having 32 sub-plots in all. In each sub-plot 49 plants were planted, wherein data from 25 plants were

Table 1. Comparative performance of different tree species on coastal sand dunes

Sr. No.	Species	1985 March		1986 March		1987 March		1988 March	
		Survival (%)	Ave. Ht. (m)	Survival (%)	Ave. Ht. (m)	Survival (%)	Ave. Ht. (m)	Survival (%)	Ave. Ht. (m)
1.	*Casuarina equisetifolia*	98.00	2.34	92.56	2.71	87.00	3.48	86.93	3.61
2.	*Acacia planifrons*	89.33	0.59	68.43	0.70	66.63	1.19	65.66	1..26
3.	*Eucalyptus camaldulensis*	94.00	1.19	83.26	1.50	74.93	1.98	76.00	2.01
4.	*Acacia mellifera*	99.00	0.74	49.86	0.74	47.16	1.39	48.33	1.44
5.	*Acacia auriculiformis*	93.26	1.32	63.80	1.52	52.76	1.95	52.66	2.00
6.	*Acacia senegal*	98.00	0.90	97.20	0.92	97.20	1.46	98.00	1.51
7.	*Casuarina junghniana*	100.00	1.29	96.26	1.52	95.33	2.55	96.33	2.57
8.	*Acacia leucophloea*	86.06	0.35	40.66	0.43	30.50	0.74	33.33	0.78
9.	*Tecomella undulata*	97.00	1.48	95.33	1.69	95.33	2.13	95.26	2.28
10.	*Acacia tortilis*	81.46	0.81	73.10	0.92	69.40	1.26	68.66	1.31

	Acacia senegal				Acacia mellifera				Acacia planifrons			
	S1A	S1B	S2A	S2B	S1A	S1B	S2A	S2B	S1A	S1B	S2A	S2B
Survivals (%)	97.5	98	94.5	84	97	99	90	80	94	99	75	73.5
Mean Ht. (m)	1.61	1.66	1.08	1.02	1.38	1.39	0.81	0.61	1.26	1.27	0.47	0.38

recorded excluding the outer rows as surrounds. The treatments are as follows. Factorial design with split treatments was adopted.

S1 25 kgs of silt mixed with sand at the time of planting.

S2 Control (Planting in the original sand pit)

A Shading with palmyra leaves in the initial stages of growth.

B Control (No shading).

Annual height measurements and survival was recorded till March 1986.

Table 2. Influence of different treatments on survival and height growth of trees on coastal sand dunes.

	Acacia senegal			
	S1A	S1B	S2A	S2B
Survival (%)	97.5	98	94.5	84
Mean Ht.(m)	1.61	1.66	1.08	1.02
	Acacia mellifera			
	S1A	S1B	S2A	S2B
Survival (%)	97	99	90	80
Mean Ht.(m)	1.38	1.39	0.81	0.61
	Acacia planifrons			
	S1A	S1B	S2A	S2B
Survival (%)	94	99	75	73.5
Mean Ht.(m)	1.26	1.27	0.47	0.38

It can be seen from the table 2 that among the three species *Acacia senegal* responded well regarding mean height is concerned. Though all the three species are showing good survival percentage when 25 kg of silt is added to the pit at the time of planting, *Acacia senegal* showed significant increase in growth rate. The treatment of providing shade with palmyra leaf during the initial stages of growth doesn't seem to have significant effect either on growth rate or on survival percentage. The performance of *Acacia mellifera* is in between *Acacia senegal* and *Acacia planifrons*.

Conclusion

Based on the above study it is evident that *Casuarina equisetifolia* and *Casuarina junghuniana* come up fairly well and can be recommended for afforestation of sand dunes. Among Acacias, *Acacia senegal* proved well. Mixing of 25 kg of silt in the pit at the time of planting helps in good establishment.

10

APPLICATION OF DEVELOPED TECHNOLOGIES IN ARID ZONE FORESTRY AND FUTURE PRIORITIES

R.S. Bhandari

In India, forest covers about 22 percent of the land area whereas for the prosperity and well being of any nation, 33 percent of its land area should be under forest cover. In Rajasthan, the forest area is only 31092 sq km, which is about 9.08 percent of the total land area. The situation is worse in the nine desert districts of western Rajasthan-Jodhpur, Jaisalmer, Barmer, Jalore, Pali, Nagaur, Sikar, Jhunjhunu, Churu, Bikaner and Ganganagar. In these districts, the forest area is only 2 percent of the total land area.

The Thar is the most thickly populated desert of the world and nurtures a large population of livestock. This arid land is supporting life beyond its carrying capacity. With increasing population, more land is being brought under cultivation resulting in further deterioration of the land. Due to unscientific removal of vegetation cover, overgrazing and rodents menace, the area has suffered severe degradation and soil erosion; thereby giving rise to desertification. One of the important measures for combating this menace is afforestation. There are several problems facing

systematic effort to improve this vegetative cover which include extreme climatic conditions, low and erratic rainfall, hot winds called *'LOO'*, poor soil and shifting sand dunes.

India was fortunate in having a nature lover as the first Prime Minister, Jawahar Lal Nehru. His concern for wildlife permeated most of the development projects in keeping with Article 48 of the Constitution which enshrines :- "The State shall endeavour to protect and improve the environment and safeguard the forest and wildlife of the country." For the first time in 1951, grave concern was raised regarding the march of the Thar. A need was felt for proper investigation, planning and research in the desert region. Consequently, the Desert Afforestation Research Station was set up at Jodhpur in 1952. This Organisation was further expanded in stages. In 1960, the Central Arid Zone Research Institute came into being. With earnest and untiring efforts of various scientists, systematic knowledge and technical knowhow is now available for afforestation on moving sand dunes and improvement of pastures. In addition to this, trials on exotic species revealed usefulness of certain species viz. *Acacia tortilis, Dichrostachys glomerata, Colophospermum mopane* and *Eucalyptus camaldulensis. Acacia tortilis* has performed very well in sandy areas. It has helped to stabilise dunes in these areas. Similarly, *Eucalyptus camaldulensis* has done well in Rajasthan canal area. Grafted *'Ber'*, (*Gola, Sev* and *Umnan*) varieties developed by C.A.Z.R.I. are also popular in farm forestry programme.

Till 1951, the State Forest Department had confined its activities to management and protection of existing forests. The State Forest Department made a humble beginning towards desert afforestation in 1958 by taking up afforestation on a limited scale in canal command areas of Rajasthan canal in Ganganagar district. Later, during the year 1970-71 large scale afforestation works were taken up in desert districts under Desert Development Programme and Rural Works Programme. But due to paucity of funds this work received a major set back. The first systematic and concerted effort towards afforestation in the desert region was made in 1978 when a separate Directorate of Afforestation and Pasture Development was created for the nine desert districts of the State with its headquarters at Jodhpur.

The major forestry schemes being implemented here are sand dune fixation work, silvipastoral plantations, village fuelwood plantation, shelterbelt plantation, rehabilitation of degraded forests, afforestation on

barren hills, re-seeding of old pastures and farm forestry. By the end of financial year 1989-90 an area of 13,900 hectare has been covered under the aforesaid schemes at a cost of Rs. 71 crore. The details of physical targets achieved under various schemes are given below :–

1. Sand dune stabilization	38,400 ha
2. Silvi pastoral plantation	45,720 „
3. Village fuelwood	17,316 „
4. Afforestation on barren hills	20,687 „
5. Canal side plantation	6,089 „
6. Roadside plantation	18,398 Rkm.
Total	**1,28,212 Hectare** **18, 397 Rkm.**

Till 1983, Rs. 4/- per plant was provided to farmers in this region as subsidy for raising plants in their private fields. In addition to this, free saplings were supplied. This scheme was discontinued in 1984 by the State Government. Now plants raised in nurseries are supplied at a subsidised rate of 10 paise for thorny plants and 20 paise for other plants. During the current year, plants have been distributed to farmers, private and Government Institutions. At present, each Panchayat Samiti in the desert districts has one or more nurseries. In addition, subsidies are being given for decentralised *'Kisan Nurseries'*. An ambitious afforestation programme is also underway in Rajasthan canal command area in districts of Ganganagar, Bikaner, Jodhpur and Jaisalmer. An eco-task force is also carrying out afforestation programme in canal command area near Bajju of Bikaner district since 1983.

These forestry schemes have helped in preventing the march of desert and mitigating the sufferings of local people. These areas have already begun providing much needed fuelwood and grass. The carrying capacity of pastures have increased considerably. Now sufficient stocks of grass can be stored to face famine. Besides, these schemes have provided gainful employment to local people living in remote areas of this region.

As water in this region is scarce, it is essential to develop water harvesting techniques. There is a need to breed and select water efficient and drought resistant plants. A watering schedule showing optimum quantity of water for each plant need to be worked out by the Arid Forest Research Institute, Jodhpur. This Institute can also work on making use of local trees, grasses and other flora as agro-industrial material, reclamation of saline areas through afforestation by using salinity tolerant flora and other physical measures, exploitation of desert trees, plants and grasses, management practices to be adopted for reclaimed sand-dunes and wildlife management in the developed forest areas.

11

SOME ASPECTS OF PLANTATION FORESTRY RESEARCH IN WESTERN RAJASTHAN

J.C. Tewari, L.N. Harsh and J. Venkateswarlu

Introduction

The arid tract of Rajasthan has the very high degree of human and animal interference by way of large scale lopping of trees and exhaustion of range resources, which in turn significantly contributes to the process of desertification. Further, hostile climatic conditions in the region also do not support the much required regeneration of natural vegetation. Thus the establishment of forest stands in this region is of vital importance, both for stabilizing the soil conditions as well as for meeting the growing demand of ever-increasing human and livestock population for fuel, top feed and shade. However, to go for large scale plantation is not an easy task. Improved species of tree/grass, well organised sustainable water bodies and on-farm rain-water harvesting techniques assume greater significance in the arid region.

In this paper an effort is made to summarise the R&D activities of Central Arid Zone Research Institute, Jodhpur for development of plantation forestry in arid western Rajasthan.

Setting

The arid region of India lies between 24° to 29°N latitude and 70° to 76°E longitude, covering an area of 3,17,909 km^2 involving seven states viz., Rajasthan, Gujarat, Punjab, Haryana, Maharashtra, Karnataka and Andhra Pradesh. Of these seven states, Rajasthan alone accounts for 62% of the total hot arid region of India.

The arid area of western Rajasthan, better known as Thar desert, occurs between Aravalli ranges on the east and Sulaiman Kirthar range on the west (Rode, 1964). The sand covered Thar desert extends for 640 km from north-west to south-east with an average width of 300km from west to east.

The climate is characterized by extremes of temperature,ranging from below freezing point in winter, to as high as 48°C in summer and low and erratic rainfall ranging from below 120 mm in extreme west to 375 mm eastward. About 90% of total rainfall is received during rainy season (July to September). The mean monthly wind speed ranges from 7.3 km/hour (December) to 20 km/hour (May). There are instances when it suddenly exceded 100 km/hour (Pramanik and Harisharan, 1952).

The soils are generally sandy to sandy loam in texture. The consistency and depth vary according to the topographical features (Kaul, 1963b; Gupta, 1968). The infilteration rate is very high ranging from 7 to 15 cm/hour. In general, they are poor in organic matter(0.04 - 0.12%) and nitrogen (0.02 to 0.07%) and low to medium in phosphorus content (0.05 to 0.10%).

Due to large human (i.e. over 13 million) as well as livestock (i.e. over 23 million) population, the biotic stress in entire arid tract of western Rajasthan is of very high order (Mann and Muthana, 1984). Due to this ever increasing biotic stress, the requirement of woody biomass is ever increasing. For instance, it increased by 178% from 1951 to 1971. According to a recent estimate the fuel wood requirement at present is more than 52 lac tonnes and the projected requirement for 2001 is around 68 lac tonnes, whereas availability of fuel wood at present is only 7 lac tonnes (Anonymous, 1987). As a result of this rapid increase in the demand for

forest produce, the natural vegetation is suffering from acute biotic interference, and whatever forest lands exist in these areas, are gradually shrinking due to over exploitation.

Forest Cover and Vegetation Types

According to government statistics, Rajasthan state has a total surface area about 34 million ha, of which 3.1 million ha is under the forest of one type or other (Anonymous, 1987). The arid tract in the state is spread over an area of 20.9 million ha, which accounts for more than 61% of its total geographical area. However, area classified under forest cover is only 0.5 million ha which is 2.3% of total arid region of Rajasthan. In whole Rajasthan state, on the hectare basis the ratio of Man: forest is 1:0.09, while the same for arid tract is 1:0.03. However, recent satellite data revealed that in Rajasthan state, forest cover has gone down to 0.60 million ha. Further, the condition in arid western Rajasthan is far more serious and at present only degraded and scattered forest vegetation exists in the region.

Classified as Tropical Thorn Forests by Champion and Seth (1968), the forest vegetation of arid western Rajasthan is very sparse and consists of scattered trees, shrubs and grasses. Satyanarayan (1963) classified the vegetation of the region into five formation types on the basis of land forms.

(1) **Mixed xeromorphic thorn forest** : These are the plant communities growing on the hills and consists mainly :

   (a) *Acacia senegal- Anogeissus pendula* community

   (b) *Euphorbia caducifolia* community.

(2) **Mixed xeromorphic woodlands :** It occurs on sandy soils with kankar pan at varying depths. The common tree species are, namely : *Salvadora oleoides, Prosopis cineraria, Acacia nilotica var. indica, Capparis decidua and Ziziphus nummularia*

(3) **Dwarf semi/shrub desert :** The plant communities of this formation type are mainly dominated on flood plains and river beds. The common species are; *Salvadora persica, Tamarix decidua* and *Acacia nilotica*

(4) **Psamophytic scrub vegetation** : The plant communities of this formation type occur on aeolian deposits or stabilized sand dunes where the soils are very deep. The common plant species are; *Calligonum polygonoides, Acacia jacquemontii, Calotropis procera* and *Aerva persica.*

(5) **Succulent and halophytic plant community** : This type is found on low lying depressional and saline areas. The common species are; *Haloxylon salicornicum, Suaeda fructicosa and Salsola foetida.*

Evaluation and Selection of Species

The local tree species of the region besides being meagre in number are extremely slow growing and it, therefore, becomes necessary to introduce the species of relatively higher growth rates and at the same time tolerant to drought and frost from isoclimatic regions of the world (Kaushik et al 1969). During 1956-1988, 103 species of *Eucalyptus*, 73 species of *Acacia* and 170 species of other genera from Israel, Australia, USA, USSR, Chile, Peru, Sudan, Zimbabwe, etc. were introduced in Jodhpur (deep sandy soil; mean annual rainfall 366 mm) and Pali (shallow soils ranging from 15 to 23 cm in depth with overlying hard calcareous pan; mean annual rainfall 411 mm).

Table 1 Promising exotic species of *Acacia* for arid tract

Species	Country of origin	Survival (%)	MAI	
			Ht (cm)	DBH (cm)
A. tortilis	Israel	100	45.7	1.2
A. raddiana	Israel	100	44.8	1.0
A. senegal	Kenya	16	32.3	1.4
A. ciliata	Israel	50	61.8	0.5
A. aneura	Australia	85	34.7	0.4
A. salicina	Australia	100	26.8	0.5

In general, performance of *Eucalyptus camaldulensis* and *E. terminalis* was found to be better than any other *Eucalyptus* species in both the locations. Among the *Acacia* species those that have shown promise are set in Table 1 in order of their performance. Excepting *A. cyclopsis* and *A. ligulata*, others have flowered and produced viable seeds. *A. tortilis* has proved to be most promising introduction having a mean annual increment rate in height and dbh around 78 cm and 1.1cm at Jodhpur and 77.2 and 0.7 cm at Pali, respectively. The performance of species has been particularly good on shifting dunes and skeletally soils (Mann and Muthana, 1984). However, the farmers are not able to accept this tree as its undergrowth of arable crops had not been comparable with that under *Prosopis cineraria*, a climatic climax species of arid region. Among the species of other genera which have potential to adapt in climatic conditions of this tract are given in Table 2. All these species have flowered and produced viable seeds.

Table 2 Performance of certain promising miscellaneous exotic species in arid tract

Species	Country of origin	Survival (%)	MAI	
			Ht (cm)	DBH (cm)
Prosopis juliflora	Israel	31	65.8	1.7
Prosopis juliflora	Chile	33	46.1	1.2
Brasiletta mollis	Italy	100	41.0	0.5
Colophospermum mopane	Zimbabwe	83	29.3	0.6
Ziziphus spinachristics	Israel	100	17.9	0.4
Dichrostachys nutans	Israel	91	21.5	0.4

Nursery Technique

The technique of raising seedlings in nurseries which has been standardized at CAZRI, Jodhpur (Kaul and Ganguli, 1963) is as follows

(1) A well balanced potting mixture containing equal proportion of sand, clay and farm yard manure is essential for seed sowing.

(2) Cylindrical metallic containers of 6.9 cm in diameter and 22.9 cm long have been found to be most suitable for raising seedlings or polythene bags of similar size can be used.

(3) The watering is done on alternate days during cold period and regularly during hot period. 9 litres of water at a time per set of 50 polythene bags was found to be effective as well as economic. The seedling grown in poly pots when kept on

cemented beds require 29.8% less watering as compared to those kept on earthen beds. Recently, use of polymers with nursery mixture was found to save 30% water (Muthana and Harsh, 1986).

(4) To facilitate quicker germination pre-treatment of seeds by sulphuric acid, soaking of seed in water which had previously been brought to boiling point, manual scarification etc. has been beneficial not only in improving germination percentage but in reducing germination time as well (Table 3). For certain tree species, some relationship was found between collection period of seeds and germination percentages. Kaul and Manohar (1966) observed, if seeds collected at the stage when pods just begin to turn bronze in colour, the germination percentage can be maximized in case of *Acacia senegal.*

In Jodhpur conditions, majority of tree and shrub species seeds are sown in February and seedlings are ready for field transplantation by last week of June. However, seeds of few other species like *Simmondsia chinensis, Parthenium argentatum* etc. respond best to sowing period of October and November.

Planting Technique And Choice Of Species In Relation To Habitat

The arid region is characterized by considerable heterogenity of land forms and soils viz., sand dunes, sandy plains, shallow soils, rocky areas and saline patches. Planting techniques for afforesting different habitats have been standardized at CAZRI Jodhpur. The details of these techniques have given recently by Harsh *et al,* (1989) and they are summarized in Table 4.

Shelterbelt Plantations

The mix of tree and shrub species planted across the wind direction helps in reducing the wind speed and controlling wind erosion. Kaul (1969) suggested five row shelterbelts of pyramidal shape for arid conditions of western Rajasthan.

Shelterbelts consisting of a row of tall trees viz., *Acacia tortilis, Tamarix articulata* and *Azadirachta indica* flanked by two rows (one on each side) of smaller trees like *Acacia senegal, Prosopis juliflora* etc. with two rows (one on each side) of shrubs like *Aerva tomentosa, Ziziphus*

Table 3. Characteristics of some arid zone tree species

Name of tree species	Time of collection	No. of seeds /100 gm	Pretreatment if any	%
Acacia tortilis	Nov.–Feb.	195	50 % Concentrated Sulph. acid 30 min. in Summer & 40 min in winter	90 to 95%
A. senegal	Aug.–Sept.	86	Soking in water for 24 hour	70%–75%
A. aneura	Mar.–April	659	50% Conc Sulph. acid with 15 min.	60%
A. jaccumontii	Mar.–April	126	40 min. in Sup. acid	80%
A. albida	–	143	30 min in Sulp. acid	90%
A. catechu	Dec.–Feb.	415	24 hour Soaked in water	
A. nilotica	May–June	79	60 min. Soked in water	90%
Prosonis cineraria	May–June	231	15 min. Soaked in water	50%
P. juliflora	April–Nov.	202	–	75%
Azadirachta indica	June–July	27	–	50%
Tecomella undulata	April–June	800	–	70%
Dalbergia sissoo	April	256	–	60%
Hardwickia binata	June–July	56	–	95%
Dichrostachys nutans	Dec.–JAn	453	15 min	85%
Colophospermum mopane	Dec.–Jan.	25	–	95%
Leucaena leucocephala	Nov.–Dec.	425	15 min	75%
Albizia lebbek	Dec.–Aug.	118	–	80%
Parkcinsonia aculeata	Feb.–July	160	45 min	

Table 4. Planting techniques and suitable plant species for different land forms

Land form		Planting/Afforestation techniqu	Suitable tree/Shrub grass species
Sand Dunes	1.	Protection from biotic interference by angle iron post with barbed wire.	*Colophospermum mopane, Acacia tortilis, Citrullus colocynthis, Prosopis cineraria, P. juliflora and Lasiurus sindicus*
	2.	Establishment of microwind breaks by brushwood in chess board from at the specing of 5 apart in right angle of wind direction.	
	3.	Afforestartion of treated dunes either by direct sedling of by transplanting nursery raised seedlings.	
Sandy plains	1.	Planting should be done in pits of 45 cm^3 specing of 5x5 m.	*Acacia tortilis, Ziziphus mauritiana, Azadirachta indica* and *Albizia lebbek*
	2.	Around the pits saucer shaped structures about 30 cm in height and 1 m in dia should be constructed to harvest maximum rain water.	
Shallow Soils	1.	Planting should be done in pit size of 60 cm^3	*Eucalyptus tesselaris, E. melanophoia, E. camaldulensis, Acacia nilotica* and *Z. mauritiana*
	2.	The hard calcarious layer below the soil surface should be broken by clowbar to facilitate root growth of tree species.	
Rocky areas	1.	Preparation of staggered contour trenches with a cross section of 60x40 cm tominimize water erosion	*Acacia tortilis, A. senegal, Prosopis juliflora* and *Euphorbi* asp.
Saline patches	1.	Planting should be done in raised beds having a height of 1m and a width of 70 cm.	*Prosopis juliflora, P. pallida P. tamarugo, P. chilensis* and *Atriplex* spp.

spinachristi, Calligonum polygonoides were found to be very effective for arid region (Mann, 1985). Shelterbelts reduced the wind velocity by 20-46% on the leeward side upto 2H to 10H range during monsoon period (H = height of shelterbelt). Similarly, soil loss was also considerably reduced and as a consequence of which total grain production increased considerably (Gupta et al, 1984). Rajasthan State Forest Department has covered so far about 38,000 row km area under shelterbelt, road side, railway line and canal side plantations since 1978 by adopting the technology developed at CAZRI, Jodhpur(Mathur and Govil, 1988).

Silvicultural Studies

Silvicultural studies on some promising arid zone tree species viz., *Acacia tortilis, A. senegal, Albizia lebbeck, Prosopis cineraria, Tecomella undulata* and others have been conducted. The important findings of these studies are as follows:

(1) **Seedling age** : Six to nine month old seedlings showed relatively very high order of establishment as compared to 18 to 24 month old seedlings.

(2) **Planting time:** The best time for planting of seedlings in the field is first fortnight of July as compared to other periods.

(3) **Soil working and method of reboisment:** Transplanting of seedlings showed better results than the direct sowing. The soil working of 60 cm^3 half filled pits with a crescent shape ridge along the local slope gave a high rate of establishment.

(4) **Spacing:** When planted at a spacement of 1.6 x 1.6 m, the crown of planted trees touched each other within a period of seven years and thus thinning is required after this period.

(5) **Irrigation, cultural operation and fertilization :** Studies on water and fertilizer requirements of seedlings of all the species under nursery conditions showed that watering alternate days at the rate of 2 litres per G.I. tube or polythene bag with fertilizer application of 1g urea or 1g DAP (per 20 seedlings) was found to be ideal for promoting the growth of seedlings. Weeding significantly promote the growth of different tree species, however, different levels of watering did not significantly affect the height growth.

Tree Improvement

In addition to introduction and evaluation of fast growing tree species from isoclimatic regions of the world, there is an urgent need for screening of fast growing lines of indigenous tree species as they are highly adaptable for this region. Tree improvement work on *Prosopis cineraria* and *Tecomella undulata,* two native species of arid western Rajasthan, is in progress (Solanki et al, 1986). In *P. cineraria* out of eleven progenies, PC 5 attained a height of 2m and above in a period of three years. In normal case under field conditions, *P. cineraria* grows relatively very slow (i.e. it attains a height of 60-80 cm only in a period of three years). In case of *T. undulata,* TV 109 having maximum number (23) of trees attaining more than 2 m height in same period and thus this line is maintaining its superiority over other selected lines.

Agroforestry

People in arid regions of India are growing arable crops alongwith trees since time immemorial. Trees on agricultural fields act as an insurance against frequent crops failures, a common phenomenon in arid region. The integration of trees with agricultural crops/grasses is commonly known as agroforestry and the practice is very well suited to broaden the scope of plantation forestry, especially in arid region. Various tree-grass combinations provide opportunities to suit different eco-systems. The forage production under different trees is given in Table 5. Likewise, *Acacia albida* and *Prosopis cineraria* when planted with agricultural crops (cluster bean and moong bean) in a spacement of 5 x 5 m, 10 x 5 m, 10 x 10m, it was found that *P. cineraria* did not interfere with grain production at any stage, however during third year cluster bean yield was adversely affected when grown with *A. albida.* In wider spacing (10*10m) cluster bean yield was 1280 kg/ha which declined to 650 kg/ha and 760 kg/ha in spacings of 5 x 5m and 5 x 10m, respectively (Shankarnarayan et al, 1987). Such systems have better scope to bring more and more land under tree cover to enhance the overall productivity of arid lands.

Table 5 Forage production under different tree species

Species	Total forage (t/ha)	% grass
Prosopis cineraria	1.5	74.8
Tecomella undulata	1.5	53.7
Albizia lebbek	1.4	57.9
Zizipus sp.	1.0	87.5
Acacia senegal	0.6	52.5

Future Research Needs

Although considerable techniques for afforestation, tree improvement, agroforestry etc. exist, systematic research geared on the holistic approach is still in its infancy. The future line of research, especially in the context of plantation forestry should involve following points:

(1) To review and summarise existing knowledge regarding the most important tree and shrub species of arid regions. For each species information should be collected regarding its extent and distribution, silvical characters, ecological amplitude, the site in which it occurs, growth data and regeneration behaviour, solely and in association with arable crops.

(2) To develop standard system for classifying sites suitable for plantations. The system developed must be such as to take account the successional development and soil fertility and it must be adaptable to both large and small area under varying intensities of past land use.

(3) To standardize aireal seeding technique for large scale afforestation as well as agroforestry techniques.

(4) To standardize intensity, frequency and seasonality of lopping for potential fodder tree species.

(5) To monitor factors affecting tree establishment, growth and vegetative as well as reproductive phenologies.

(6) To improve more and more indigenous tree species in order to develop seed banks of fast growing trees.

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12

ROLE OF MANAGEMENT TECHNIQUES FOR AFFORESTATION IN ARID REGIONS

R.S. Mertia

Introduction

The Indian desert, particularly Jaisalmer district is characterised by low and erratic rainfall (150mm average of 20 years), very high temperature with a mean maximum value of 44.1°C observed in June, 1987 and very high evaporation values ranging from 5.4 to 19.1 mm day^{-1} (Table 1). The soils of the region are sandy, having water storage capacity of 36 mm in 60 cm profile. Substantial fraction of water percolates into the sub-stratum due to high infiltration rate (15-20 cm hr^{-1}), most of which fails to rise to the root zone owing to low unsaturated hydraulic conductivity (Singh, 1982; Singh and Bhati, 1985). Hence this water is not used by trees and shrubs in their early establishment. Deficiency of moisture and extremes of temperatures in arid regions cause heavy mortality of tree and shrub seedlings and thus adversely affect their early growth and establishment.

Pressure on vegetation based resources has increased many folds, more fuel wood, minor timber, bush wood and lopped tops are required. This warrants large scale plantation of trees and shrubs, particularly in arid regions. Earlier studies conducted at Central Arid Zone Research Institute, Jodhpur, have shown that the use of sub-surface moisture barriers, water harvesting from slopes, soil amendments and mulching improve the moisture regime of soil by increasing water supply, checking deep drainage and evaporation losses (Gupta, 1980; Singh *et al*, 1988 and Dass et al. 1988). However, information lacks on the effect of gravel mulch on moisture, early growth and establishment of fodder trees and shrubs in extreme arid regions. Results of such study are presented here.

Material And Method

A field study was conducted during 1987 and 1988 at CAZRI's sub-station, Chandan, in the Jaisalmer district of western Rajasthan. Nursery raised seedlings of top feed species, *Prosopis cineraria, Ziziphus mauritiana, Colophospermum mopane* and *Dicrostaychis cineria* were planted in monsoon season, 1987 at 5 x 10 M and 10 x 10 M spacing. Treatment of gravel mulch was imposed after planting. The experiment was replicated two times in split plot design. Irrigation of 15 litres of water per plant was given at an interval of fortnight. Observations on soil moisture storage and plant growth in height were recorded.

Result and Discussions

Table 1 shows data on weather conditions during the growth period of the tree seedlings. Rainfall during 1988 was higher (234.7 mm) than in 1987 (32.0 mm). Mean maximum temperature varied from 26.1°C to 44.1° C & 25.7° C to 43.3°C during the year 1987 and 1988 respectively. Pan evaporation values were highest during May and June.

Table 2 shows variation in moisture retention in the soil profile of 40 cm. There were quick losses of moisture in control as compared to gravel mulch. Under mulch the moisture storage was considerably high even after eight days of irrigation as compared to control.

Table 1. Mean monthly values for climatic parameters at Chandan (Dist: Jaisalmer) in 1987 and 1988.

Month	Total Rainfall (mm)		Mean Maximum Temp. (°C)		Mean Pan Evap (mm)		Mean RH (%)					
							1987			1988		
	1987	1988	1987	1988	1987	1988	*I	**II	*I	**II		
January	–	2.0	26.1	26.2	7.5	7.5	81	61	77	47		
February	–	–	27.7	27.6	7.6	9.0	71	55	59	44		
March	–	1.5	34.4	36.1	9.5	8.7	60	37	62	42		
April	–	2.0	31.2	39.8	8.8	9.5	41	27	60	39		
May	12.5	–	41.5	43.3	10.6	18.4	62	33	55	20		
June	–	14.2	44.1	43.2	16.8	19.1	77	33	69	32		
July	9.5	86.8	40.9	38.4	16.2	12.2	76	47	88	49		
August	10.0	128.2	39.5	37.1	15.3	10.2	77	48	94	65		
September	–	–	40.0	38.9	14.2	11.6	71	40	84	47		
October	–	–	32.7	35.9	11.3	8.5	60	28	75	26		
November	–	–	30.0	31.4	7.2	6.9	60	31	69	34		
December	–	–	26.3	25.7	5.8	5.4	57	36	74	51		

* Recorded at 0730 hours ** Recorded at 1430 hours

Table 2 Effect of gravel mulch on retention of soil moisture (mm).

Treatment	Soil Profile	Available *moisture (mm)		
		12.5.88	15.5.88	17.5.88
Mulch	0–15	9.06	6.93	4.80
	15–40	8.37	5.83	4.60
	Total	17.43	12.76	9.40
Control	0–15	6.35	5.22	3.21
	15–40	7.75	4.39	3.95
	Total	13.10	9.61	7.16

* Irrigation was done on 9.5.88

Table 3 shows increase in height of four species. Effect of conserved moisture due to gravel mulch has been clearly reflected in increase in height of tree and shrub species. However, maximum increment has been observed in *Ziziphus mauritiana* under gravel mulch.

Table 3 Effect of gravel mulch on growth of fodder trees and shrubs (height in cm).

Species	Treatments	
	Control	Mulch
Prosopis cineraria	88.60	113.28
Ziziphus mauritiana	129.66	163.48
Dicrostaychis cineria	93.14	112.94
Colophospermum mopane	71.19	90.17

To conclude, gravel mulch proved very effective in checking moisture losses due to high PET in this region. Gravels are easily available in this region while digging pits and can be applied as mulch. Gravel mulch is more stable against strong winds, which prevail for long periods in this region.

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13

PROVEN TECHNOLOGY OF SAND DUNE STABILIZATION-A STEP TO COMBAT DESERTIFICATION

Z.D. Kavia and L.N. Harsh

Under the Operational Research Project of the Central Arid Zone Research Institute, Jodhpur a cluster of five villages (Gram Panchayat, Manaklao) was adopted. In village Basni Karwad, an area of sixteen hectare was taken for sand dune stabilization to arrest drifting sand by planting suitable exotic trees and grasses. The programme was carried out in two phases to demonstrate the technology of sand dune stabilization to farmers and State Government officials so that they may take up this programme on a large scale to check sprawling desert. The sand dune infested sixteen hectare land, owned by a farmer, was selected. In 1975, eight hectare land was brought under the programme. Remaining eight hectare was taken in 1978. Following steps were involved in this sand dune stabilization demonstration :

Fencing of Area

In this area, biotic interferences were of very high order. Therefore, protective measures were taken before planting. Fencing with five strands of barbed wire and angle iron posts spaced 6 m apart was carried out. Locally available thorny bushes viz. *Ziziphus nummularia* and *Prosopis juliflora* were used as protective barriers along with the barbed wire so that direct interference of human as well as livestock population could be minimised.

Erection of Micro windbreaks

Locally available materials such as *Leptadenia pyrotechnica* (*Kheemp*) and *Crotalaria burhia* (*Sinia*) were used to erect micro-wind breaks against the wind direction which generally blows from south west direction to north east direction. The micro windbreaks were erected at right angle to wind direction. These bushes were cut and buried vertically downward in the form of parallel rows at the spacing of 2-5 m apart depending upon the position. These windbreaks were closer on the top of the sand dune and windward side and spaced wider on lower side and depressions.

Revegetation of Sand Dune

(a) The trees were planted in the strips across the wind direction. For the plantation of tree seedlings, pits of 60x60x60 cm^3 at a distance of 5x5 m^2 were dug on the top of sand dune. There were 7 rows of seedlings. Trees were planted in the same fashion to right and left hand side of top rows by keeping a gap of 50 m. Between these gaps sowing of *Cenchrus ciliaris* grass was done. Thus, entire tree plantation and grass cover was over 4.5 and 3.5 ha area, respectively.

(b) **Choice of species :** Exotic tree species from isoclimatic regions viz. *Acacia tortilis, Prosopis juliflora, Colophospermum mopane* and *Dichrostachys nutans* were planted on sand dune. These species are highly resistant to browse and frost and are fast growing.

(c) **Nursery raising :** Seedlings of *Acacia tortilis* and *Prosopis juliflora* were raised in the nursery of CAZRI in metallic (galvanised) iron tubes (size 6-8 cm in diameter and 22.5 cm long). These tubes proved quite useful during transportation and transplanting as the roots of seedlings were not disturbed in entire process. Six months old seedlings were used for field transplanting.

(d) **Planting :** Planting was done after the onset of monsoon (July-August) when the sand becomes wet and wind velocity is reduced considerably. Seedlings were planted deep enough so that plant roots may be able to utilise sand dune moisture quickly. Further by deep plantation at initial stage of seedlings establishment, root will not be disturbed by blowing of sand due to high wind velocity.

(e) **Watering :** During planting, watering as a practice was not followed. Only during prolonged drought spells in rainy season and during summer season seedlings were irrigated which was necessary for their survival.

Rodent and Pest management

Sand dune provides a good shelter to rodents. In sandy soils gerbils can prepare their burrow easily. Rodents not only damage crops and vegetables but also damage tree seedlings at initial years of growth. To avoid this risk rodent control measures were regularly taken. For this, zinc phosphide (2%) and oil (1%) mixed with bajra was used as grain poison bait. Damage of seedlings by termite was another problem. Therefore, BHC powder (10%) at the rate of 50 gm per pit was applied at time of planting.

Gap Filling

Afforestation on the sand dune with all measures resulted in 90% survival of the seedlings. The gaps were filled up by planting the seedlings in rainy season during the successive years after 1976 and 1977, respectively.

Basin Preparation and Weeding

During rainy season, care was taken to harvest the maximum rain water. Accordingly around each seedling saucer shaped basin (Thala) of 60 cm diameter was created and in the slopy side across the slope crescent

shape ring was constructed. These operations proved to be quite useful for better plant growth.

After planting, tree seedlings require special care at least, for first three years for their better growth. Accordingly two weeding operations were done each year to arrest the competition between tree and weed species.

Table 1. Cost benefit of sand dune stabilization programme

	Item	Expenditure/Returns (Rs./ha)
A.	Expenditure	
	Fencing cost*	1964
	Land preparation (mulching)	50
	Digging of pits	56
	Refilling of pits & planting	42
	Seedlings (including 10% casualities)	125
	Preparation of crescent shape structure around pits	68
	Grass seed	25
	Grass sowing	100
	Irrigation	20
	Pesticides	5
	Weeding	45
	Tree & grass cutting	500
	Total Rs.	3000
B.	Returns	
	Grass Production + *Acacia tortilis* + *Prosopis juliflora*	12649
	Net return (B–A)	
	Rs. 12649 – Rs. 3000	9649
	Returns from per ha land	77192

* Cost of fencing during 1975.

Trimming of Plants

During initial growth of plants seedlings were trimmed to remove side branches which were spreading over ground. It was done for quicker

Table 2. Grass production from stabilized sand dunes (3.5 ha area)

Features	YEAR						Total
	1976	1977	1978	1979	1980	1981	
A. Forage Production :							
Production per ha(q)	5	10	15	25	15	5	–
Production from 3.5 ha (q)	17.5	35.0	52.5	87.50	52.5	17.5	5.00
Sale of grass Rs. 10/q.	175	350	525	875	–	–	–
Rs. 20/q.	–	–	–	–	1050	350	3325.00
B. Grass Seed Production :							
Production per ha (kg)	10	15	25	40	15	5	–
Production from 3.5 ha (kg)	35	52.50	87.50	140	52.5	17.5	385.5
Sale of seed Rs. 5/-per kg	175	262.5	437.5	700	–	–	2275
Rs. 10/- per kg	–	–	–	–	525	175	–
Total Returns (Rs.)	350	612.5	962.5	1575	1575	525	5600.00

Note : Grass completes its life after 6 years and requires rennovation.

Table 3. Returns form tree components of stabilized sand dune

(*Acacia tortilis* : No. of trees = 1750)

Feature	YEAR						Total
	1976	1977	1978	1979	1980	1981	
A. Pod Production* :							
Per tree (kg)	2.00	4.00	5.00	7.00	10.00	10.00	
Total production (kg)	3500	7000	8750	12250	17500	17500	
Sale of pods @ Rs. 0.50/kg	1750	3500	4375	6125	8750	8750	33250.00
B. Leaf Production :**							
Per tree (kg)	–	–	–	–	–	5	
Total production (kg)	–	–	–	–	–	8750	
Sale of leaves @ Rs. 0.50/kg	–	–	–	–	–	4375	4375.00
C. Fuel Production :							
Per tree (kg)	–	–	–	–	–	90	
Total production (kg)	–	–	–	–	–	1575	
Sale of fule wood @ 30/-q	–	–	–	–	–	47250	47250.00
Total returns (Rs.)	1750	3500	4375	6125	8750	84875	84875.00

* Pod production starts from 5th year, ** Leaf & fuel taken after 10 years of plantation.

Table 4 : ***Prosopis juliflora*** (total no. of tree = 270)

Feature	YEAR						Total
	1976	1977	1978	1979	1980	1981	
A. Pod Production :							
Per tree (kg)	1.0	1.5	3	5	5	7	
Total production (kg)	273	409	819	1365	1365	1911	
Sale of pods @ Rs. 0.50/kg	136.5	204.5	409.5	682.5	682.5	955.5	3071.00
B. Fuel Production :							
Per tree (kg)	–	–	70	–	–	–	
Total production (kg)	–	–	119.10	–	–	–	
Sale of fuel wood @ 40/- tree	–	–	7644.0	–	–	–	7644.00
Total returns (Rs.)							10715.00

pole growth so that stem can get maximum strength to withstand the high wind velocity.

Economics of sand dune stabilization

Constant efforts made from 1975 to 1985 resulted in a green belt of vegetation over naked soil which was problematic to the owner of sand dune and also for neighbouring farmers. Most unproductive sand dune which was considered as wasteland has become remunerative to the owner. Eight ha land brought under tree cover in first phase of plantation is now in a position to give the net returns of Rs. 77192 (Table 1 to 4)

Thus, the transfer of technology has shown a path to combat the desertification of 54% of land of the eleven arid districts of western Rajasthan. State Government has initiated the sand dune stabilization programmes under social and farm forestry schemes and that has given good employment to the local folks for combating desertification.

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RESEARCH PRIORITIES IN ARID ZONE FORESTRY

G. N. Gupta

Deserts occupy about 29 million km^2 area world over (Baumer and Bensalem, 1985). In India, area under hot desert is 31.7 million ha which is 12% of the country's geographical area. Sixty one per cent of this area is in Rajasthan, 19.6 per cent in Gujarat and remaining 20.4 per cent in Punjab, Haryana, Maharashtra, Karnataka and Andhra Pradesh. Whatever may have been the factors, climatic or geographic to set in the process of desertification, the over-exploitation of the vegetation has been recognised as the immediate cause of rapid expansion of the desert in India. Therefore, revegetation on large scale is the only way to halt the process of desertification and improve living conditions in the arid zones. Thus forestry assumes an important role to play in desert reclamation. However, the forests and forestry situation in arid zone of India is very disappointing. While constraints in raising successful plantations are serious and several, the forestry practices in vogue are obsolete and not matching to the challenges the forestry faces in this region. Thus there is need to develop technology for desert afforestation. This requires indepth studies on various aspects of arid zone forestry. As such the research needs are several in arid zone forestry. However, for speedy development of tech-

nology with limited research facilities available in terms of man and material, it is important to identify the priority areas of forestry research in arid zones. This chapter highlights the research priorities in arid zone forestry.

Problems in Arid Zone Forestry

According to the Government of Rajasthan, 1985, forest area in the arid zone of Rajasthan is 2.61% of the total geographical area, which is 0.04 ha per capita forest area against the national average of 0.11 and world average of 0.80 (FSI, 1989). Further the well stocked forest area is negligibly low. The forests are largely in degraded condition with hardly any productivity. The average annual production per hectare is 0.5 m^3 in India as against 1.9 in USSR, 3.0 in USA, 2.5 in Japan and 3.5 in U.K. (FSI, 1989). Such information for Indian arid zone is not available. The scenario on the demand side is frightening. The Indian desert is most densely populated having 61 persons km^2 as against 3 persons per km^2 in other deserts of the world. The human population of the arid zone of Rajasthan is 13.4 million, the fuelwood demand of which is to the tune of 2.35 million tonnes per annum (Govt. of Rajasthan, 1985). Only 10% of this demand is met from the recorded production from forest leaving a gap of 1.65 million tonnes per annum. The fuelwood demand is so alarming that *Calligonum polygonoides* is vanishing fast from its native habitats (sand dunes) owing to indiscriminate removal of its roots for fuel, causing serious threat to the stability of sand dunes. To feed the 23.4 million cattle population of the region, the estimated minimum requirement of fodder is about 26 million tonnes as against anticipated total fodder production of 10 to 14 million tonnes from all sources, leaving a chronic deficiency of 12 to 16 million tonnes annually. The fodder supply has to be enhanced by improving the productivity of fodder trees in silvi-pastoral or silvicultural systems for the present productivity of already dwindled grasslands (Common Property Resources) is dismally low (300 to 500 kg/ha), producing 2.3 million tonnes annually.

The increase in population and change in their ethos from conservation to materialism has increased the demand of wood for agricultural implements, housing, furniture and panelling, pulp and paper and other industrial and domestic uses. There is no data available on the total demand of such wood in Indian arid zone. The demand, however, is undoubtedly several times more than the wood produced in this region.

The disappearance of Rohida (*Tecomella undulata*) one of the best furniture wood, popularly known as *marwar* teak, is the glaring example and a pointer to the gravity of the timberwood situation in the region. Thus, the demand of wood and other forestry produce is several times higher than the capacity of the forests in the region to supply them. This obviously leads to over exploitation of the natural vegetation aggravating the desertic conditions. Thus the situation calls for intensifying High Biomass Yielding Forestry (HBYF) on better sites and conservation forestry on refractory sites.

There are severe constraints in achieving above objectives. The climate is hostile. Rainfall in the region is very low and erratic. Mean annual rainfall is about 100 mm in the northwest (Jaisalmer) to 450 mm in eastern districts of Rajasthan. Coefficient of variation with respect to annual rainfall is as high as about 65% (a measure of uncertainity of rains). The region experiences extreme temperatures reaching as high as 50°C in the summer and as low as near freezing point in winter. The potential evaporation during summer is 7 to 9 mm per day. Strong hot winds of velocity 20 to 30 km per hour blow in the summer months, particularly May & June.

Soils of arid region are loose sand which are structureless, deficient in nutrients (particularly nitrogen), poor in moisture retention capacity and lacks microbial activity. Soil depth in the region is very shallow varying from 15 to 75 cm. Sand dunes are dominant formations covering 58 per cent of the arid region in Rajasthan. The proportion of moving sand dune is particularly very high and their stabilization is a big challenge. Other waste lands in the region are rocky and semi rocky sites, gravelly soils and saline and alkali soils. These poor edaphic conditions pose serious limitations in tree establishment.

The tree planting activities are further handicapped due to lack of scientific methods of raising and managing the plantations. The prevailing forestry practices are obsolete and inadequate requiring updating.

Research Areas Requiring Priority

IRRIGATED PLANTATIONS

Indira Gandhi Nahar Project (IGNP), one of the biggest canal project, is expected to bring about transformations in the living of inhabitants of 11 per cent of the arid region of western Rajasthan. The IGNP area spreads

over 25 lakh hectares of the Indian desert of which about 12 lakh hectare is cultivable command area (Khullar and Soni, 1990). The total length of the canal is 649 km, of which stage-I comprises 204 km of Rajasthan feeder, 189 km Rajasthan main canal and 2880 km branches, distributaries and minors. Irrigated plantations have been started since 1973-74 in stage-I area and since 1987 in stage-II area, as canal side, road side, shelterbelt, block and *abadi* plantations, primarily to protect the canals from siltation and also protect, roads and habitations from the windblown sand. These plantations are also expected to supply fuel and fodder to the local inhabitants.

However, these plantations have not generated results in commensurate with the amount of precious water used because of the lack of scientific methods of raising, managing and harvesting the irrigated plantations. At places the faulty irrigation practices have resulted in large scale mortality of particularly the *abadi* plantations of *Acacia nilotica, Eucalyptus camaldulensis* and *Dalbergia sissoo* in stage- I area (Gupta, 1990). These plantations raised in 1973-74, were irrigated for initial 8 to 10 years and the discontinuation of irrigation thereafter resulted in heavy plant mortality. An average rise of 0.5 metre in water table in the stage-I area of IGNP has been reported due to indiscriminate use of water (Mathur, 1990). The problem is likely to be more severe in stage-II where thick deposits of kankar, bentonite, gypsum, rocky strata and hardpan exist in the subsoil layers.

Given the suitable technology, the IGNP area could meet the fuel, fodder and wood demand of the whole of the Rajasthan state besides aiding to the food stocks of the state and influencing the ecology of the Thar desert. Therefore, indepth studies on irrigated plantations in IGNP area merit top priority for speedy technological advances in irrigated forestry. The irrigated plantations are also being raised in the states of Gujarat, Haryana and Punjab. The research areas requiring priority are :

Studies on water management in forestry/agroforestry /silvipastoral systems to maximise yields and water use efficiency without deteriorating the soil productivity. Investigations on methods, frequency and quantity of irrigation at varying growth stages and age of different tree species in relation to biomass yield and soil characteristics.

Nutrient management studies in different forestry systems to maximise the production of wood and other economic produce by tapping fully

the genetic potential of species. Besides studying rates, forms, methods and periods of applying different nutrients, nutrients recycling studies in different plantations at their varying age should be studied to workout nutrient budgeting in the irrigated plantations.

Tree improvement studies to develop genetically improved strains to yield the produce, matching to the input management. The research efforts should aim at stepping up the genetic potential of the species.

To develop suitable production systems (silvicultural, silvipastoral, agri-silvicultural etc.,) for maximising the yields and economic returns without imparing ecology of the area. Identification of tree species or combination of species suitable for different site conditions. Package of silvicultural practices for better growth and quality of the produce.

For uncommand areas of IGNP, sand dune stabilisation studies with limited use of water, early establishment and growth of trees, shrubs and grasses merit priority.

Studies to develop effective shelterbelts along canals, roads, farms, habitates etc.

Tillage management studies to improve yield, moisture use efficiency and soil health.

Studies on harvesting techniques, harvesting cycles, post harvest technology and their economics.

Seepage of water from canal has caused water logging at several places along the canal. To reclaim these areas, studies are required to drain out these water logged areas effectively and economically. Studies on species selection, soil management and silvicultural practices to raise and manage plantations on water logged soils need attention.

Forestry under rainfed conditions

The important forestry activities in the arid region are, sand dune stabilization, shelterbelt plantations, fuel and fodder plantations, silvipastoral plantations, block plantations near water points, etc. However, the forestry practices have not been perfected for different types of activities, with the result these activities have not witnessed desired success. To lend technical support to these tree planting activities, research priorities are highlighted as under :

Seed research

Non-availability of the seeds of high physiological and genetic quality is often a bottleneck in forestry development. This, particularly holds true for arid areas where the recurring famines and droughts result in not only the poor quality of seeds but poor seed yield owing to poor seed setting or no seed setting at all. And, at times seeds stored for very long periods have to be used for raising plantations. Therefore, there is need to evolve package of practices for collection and extraction of good quality seeds and storage techniques to maintain quality for long periods. The yield of seeds per tree also need to be kept high to meet seed requirements for raising plantations and also to meet the needs of local population which use the seed of several species as food. The areas in seed research, deserving priority are:

Identification and delineation of seed production areas. Seed collection techniques requiring research on time of collection, maturity indicators, seed bearing age, tree characters such as form of trunk, the branching habit, strength and texture of wood, crown size, etc., methods of seed collection, extraction and cleaning for different tree species. Little is known about the biology and reproduction of arid zone genera like *Boscia, Cadaba, Capparis, Crataeva* and *Salvadora*. Research programme is suggested on biology, phenology and reproduction of these genera. Another aspect requiring research is on seed storage for longer periods without deteriorating the quality. Aspects such as pre storage treatments and; treatments and environmental conditions during storage need to be studied. Systematic research on treatments to promote seed germination of arid zone tree species need to be undertaken and documented. The research to improve seed setting in *Anogeissus* species merit priority to increase seed production of this species. Similarly, seeds of some of the species is used as food or for extracting oil; their yield need to be increased.

Nursery Research

The success in tree establishment in arid zone depends on the quality of nursery stock used. Prevailing practice in the field is to use the mixture of sand, clay soil and farm yard manure as substrate for raising seedlings. There are a few studies on suitability of potting mixtures, material and size of containers and watering (Kaul and Ganguli, 1962, Gupta, 1990).

However, considering the multiplicity and the nature of waste lands in arid region (such as sand dunes, rocky & semi rocky sites, shallow soils) and adverse climatic conditions, there is need to produce healthy seedlings of good vigour suited to different sets of conditions. Research programmes need to be persued on size of poly pots, potting mixtures including inorganic fertilizers, insecticides and pesticides, to control diseases and pests, ways of raising seedlings of different tree species (seed sowing, cuttings, root/shoot cuttings, harmonal and other cultural treatments to promote better germination, watering (to impart drought without hampering growth), conditioning of the seedlings (root pruning, time of sowing, shade conditions, etc.) to suit to the field conditions of different types of waste lands when outplanted. Another aspect of nursery research needing attention is depth of sowing, seed treatment, size and nature of nursery beds etc.

Plantation Establishment

High mortality and slow initial growth in the establishment phase are the major constraints (owing to climatic, edaphic and biotic factors) in afforesting arid lands. Plantation establishment is the most crucial stage and the survival and initial growth of plants will determine the success of plantation. Therefore, package of practices for better initial growth and establishment of trees for different site conditions such as sand dunes, sandy plains, shallow skeletally soils, rocky and semi rocky sites, saline and alkali soils, degraded hills, etc. are of paramount importance. Priority research areas on plantation establishment are as follows :

Moisture management

Moisture is the prime factor limiting growth and establishment of trees in arid regions. The plantations have to be raised with the limited rainwater available in the region. Therefore, there is need to undertake research on in-situ and ex-situ moisture harvesting techniques, its conservation and efficient utilization. Studies need to be undertaken on different water conservation techniques to reduce runoff losses, tillage practices to facilitate better moisture recharge and storage of soil profile, use of different types of surface mulch and weeding techniques to prevent evaporative losses of moisture, use of soil amendments to improve moisture retention and storage, methods to check deep percolation losses, use of anti transpirants and other methods to reduce unproductive transpira-

tion losses, etc. It is a common practice to apply water through small containers during initial 2-3 years of establishment. To utilize this scarce and precious water efficiently, studies should be conducted to findout the number, quantity, timings and methods of watering to maximise water use efficiency of different tree species. Through these studies crucial stages of plant growth should be identified for watering them.

Planting techniques

Surface layer in arid regions dry rapidly due to intense radiations and long dry spells, often resulting in heavy mortality of newly planted seedlings. The growth conditions of rooting zone also vary with the type of site (sand dunes, rocky or semi rocky sites, hill slopes, saline and alkali soils, shallow soils, sandy plains etc). Accordingly planting techniques will also vary. To perfect the planting techniques for different site conditions and for different tree species, studies need to be carried out on pre-plant soil operations (size of pits, ploughing, harrowing, etc.), time of planting, age and size of seedlings, depth of planting, spacing, tree geometry, etc.

Choice of tree species

The practice in vogue is to plant *Acacia tortilis* on sand dunes *Prosopis cineraria* on sandy plains, *Acacia senegal* and *Prosopis chilensis* on semi rocky and skeletally soils. However, considering the heterogenity and inhospitability of sites and societal needs for wood and related produce, indepth studies on suitability of tree species and shrubs should be undertaken for different site conditions. Species suitability for specific purpose such as shelterbelt plantations of different types, sand dune stabilization, fuelwood plantations, fodder plantations, agroforestry and silvipastoral plantations, etc need to be investigated. Tree species suitability criteria should be based on the anatomical features and biochemical and physiological traits through growth performance has to be the over riding consideration. There are a large number of indigenous shrubs, which need to be tried on different sites for promoting them for fuel and fodder production.

Nutrient management

The arid zone soils have poor fertility status. They are particularly poor in organic matter and nitrogen, and have medium level of phosphorus. The effects of low fertility become complex under moisture stress conditions. To improve nutrition of newly establishing plantations research on nutrient management under stress conditions to improve the early growth merits priority. Fertilizer use studies such as response of different tree species to inorganic fertilizers; influence of different rate, forms, methods and frequency of applications on nutrient availability, uptake and tree growth are the important areas of research. Studies on biofertilizers for their role in tree nutrition deserve high priority.

Plantation management and protection

Once the plantations are established, their scientific management in the subsequent years is important for higher biomass yield and good quality of produce. The studies are required on various aspects of silvicultural practices for arid zone tree species and shrubs, such as pruning, optimum plant density at different age, weeding and intercultural operations, intensity and frequency of lopping in fodder and fuel wood species. In order to maximise biomass yield without deteriorating soil productivity, studies on raising different tree mixtures and shrubs need to be undertaken. To safeguard the plantation from the attack of pests and diseases, investigations need to be carried out to find out suitable methods of protection (chemical, biological or cultural) to prevent the occurrence of such attacks. In the cases, where attack has already occurred suitable methods of immediate control should be devised. All the pests which infest the plantations, their life cycle and mode of attack need to be studied. Indian arid zone has a very high cattle population which freely moves into the forest areas. To protect the plantations from these animals and wild life, suitable cost effective fencing materials and other ways of protection need to be investigated. Rodents population is also very high in arid regions, which causes serious damage to the plantations. Practical, cost effective and efficient methods of their control need to be evolved.

Tree improvement

The indigenous species of trees and shrubs in arid region of India are slow growing unable to produce the required biomass. In order to match

the needs of higher biomass yielding trait and adaptability to adverse conditions of different sites and climate, identifying and evolving ideal plant types merit a priority research area which may have activities namely.

Selection : In nature there is tremendous variation in the genetic potential of the tree species. This variation need to be assessed by undertaking field studies. And the genetic material from the tree with best growth and other desirable characters (plus tree) should be selected and tested at the research farm. From this, the best provenance should be selected for planting.

The provenance trials in respect of *Acacias* should be undertaken from the seed materials collected from different parts of the country and other parts of the world having similar climatic conditions. Provenance trials of *Prosopis* species, *Tecomella undulata, Azadirachta indica, Albizia* species and other important species of arid region need to be undertaken.

Breeding: The selected trees (plus trees) be subjected to breeding process to combine the favoured characters such as high biomass yield, drought tolerance (the phenotypical features such as deep and profuse root system, physiological and biological characteristics imparting drought hardiness), salinity and alkali tolerance for trees to be planted on such soils, resistance to insect pests and diseases, etc. The studies on *Prosopis cineraria* and *Tecomella undulata* should receive priority to induce fast growing trait in them without deteriorating the quality of wood and fodder. To enhance fodder production, the species of trees and shrubs need to be improved for maximising yield of good quality fodder. The other species of importance are *Acacia nilotica, Salvadora oleoides, Azadirachta indica, Dalbergia sissoo* (for irrigated conditions), etc.

Introduction trials : Earlier experience has shown that the exotic species like *Prosopis juliflora, Acacia tortilis, Eucalyptus* sp. etc. have exhibited good performance and have naturalised in this area. Further attempts to explore the possibility of introducing the suitable exotic species of trees and shrubs should be made. *Atriplex* species have scope for introduction on saline and alkali soils. The species which have shown promise are *Eucalyptus camaldulensis, Eucalyptus terminalis, Acacia aneura, Acacia raddiana Colophospermum mopane, Dichrostachys glomerata* (CAZRI, 1988).

Wind erosion and its control

Wind erosion is a serious problem in arid regions which manifests in the form of sand movement and dust storms. The phenomenon assumes alarming proportions in summer months when the wind velocity of 30-40 km per hour are common and the moving sand dunes engulf habitations, roads, railway tracks, agricultural fields, canals, wells, etc. The whole atmosphere remains charged with dust. The hot winds charged with sand particles injure the standing crops reducing their yields. Trees and shrubs play vital role in checking sand movement by stabilizing the sand dunes and sandy plains when planted on them. Trees when planted as shelterbelts along agricultural fields not only prevent sand deposition but also protects agricultural crops from dessicating hot winds and increase the crop yields. Shelterbelts along roads and railway tracks are essential to facilitate smooth and comfortable journey besides preventing sand deposition. Around habitations shelterbelts are essential to make them livable. However, shelterbelts around fields and habitations have not been very common due to difficulty in their establishment and maintenance and high costs which may be attributed to lack of suitable and cheaper technology. There are some shelterbelts along roads but all of them are not very effective due to lack of sufficient knowledge on their design. There is some information on raising shelterbelts (Kaul, 1969). However, indepth studies need to be undertaken on composition and design of shelterbelts and their influence on aerodynamics, sand movement, environmental parametres and supply of goods to masses. Studies on raising and managing shelterbelts along agricultural farms and their impact on crop yields should receive priority.

Sand dune stabilization is another important approach to control wind erosion. Indeed it is complementary to shelterbelt plantations because the unstabilized sand dunes are the major source of sand involved in the wind erosion phenomenon. Economically and socially acceptable technology to stabilize these moving sand dunes is urgently required to control wind erosion and also to improve ecology of these sand dunes. *Calligonum polygonoides* is the naturally growing shrub on the sand dunes. Other vegetations occurring on sand dunes are *Aerva psuedotomentosa, Leptadenia pyrotechnica* etc. *Citrullus colocinthis, Lasiurus sindicus, Calotropis procera,* etc. Removal of *Calligonum polygonoides* for fuel at a very fast pace has left these sand dunes naked subject to wind erosion. The prevailing technique of stabilizing sand dunes is comprised of fencing

the dunal area, mulching of *Aerva psuedotomentosa* or other bushes as micro-windbreaks, planting grass slips or seeds and afforesting tree species. The species suggested for planting on sand dunes are *Acacia tortilis, Prosopis juliflora, Calligonum polygonoides, Colophospermum mopane, Prosopis cineraria, Ziziphus nummularia, Parkinsonia aculeata* and *Cordia rothi* (Kaul, 1985). However, this aspect needs further studies not only to identify some more useful species of trees, shrubs and grasses which find favour from the farmers who own large areas of sand dunes, but also to improve the techniques of their establishment to improve their growth and yield.

Research efforts are particularly required on shrubs which in combination with suitable strains of grasses and trees could be easily and quickly established. Studies on phenology, regeneration and propagation should be undertaken in detail to promote their cultivation on large scale. Studies such as method, depth age, time and geometry of planting are required for plant establishment on active sand dunes. Wherever water is available, the methods of utilizing this limited water to its maximum efficiency needs attention. Studies on use of suitable amendments and moisture conservation methods should seek place in research priorities. Plant geometry on sand dunes to prevent movement of sand is an important aspect of research.

Basic rhizosphere studies

Poor supply of moisture and nutrients and lack of microbial activity are the major constraints in establishment and growth of trees in arid regions. In dry zones, application of inorganic fertilizers have shown influence on tree growth. However, under water stress conditions response to inorganic fertilizer is uncertain and they may not provide long term solution on economic as well as ecological grounds. Therefore, research on use of biofertilizers in arid zone forestry need to be undertaken on a priority basis. Mycorrhizal research has a tremendous scope as the earlier studies have shown its influence on nutrients and water uptake of plants (Miller, 1987; Michelsen and Rosendahl, 1989; Tarafdar and Rao, 1990). There is need to screen different VAM fungi for their tolerance to high temperature, moisture stress, salinity and alkalinity and their usefulness in imparting drought resistance to trees; and improving their growth by optimizing moisture and nutrient supply. Research to find suitable protocols for identification and multiplication of mycorrhizal fungi should

be undertaken to facilitate availability of useful strains on a commercial scale.

Research on Frankia and Rhizobium is another important area deserving priority. Different biological, physical and physico- chemical aspects of nitrogen fixation should be studied to improve nutrition of arid zone trees.

Agroforestry

With the growing population and number of cattle heads at an alarming pace, pressure on land for producing adequate food as well as fodder and fuel is increasing. Obviously the land productivity per unit of time and area needs to be enhanced by improving the land use system. The situation calls for growing multipurpose trees and crops in an integrated system which shall maximise yield without deteriorating the resource base. In arid zones, where famines and droughts and consequent crop failures are common, the integration of agriculture, forestry and animal husbandry will provide security for food, fodder and fuel and reduce the element of uncertainity. A few studies have shown beneficial relationship between trees and crops (Shankarnarayan, 1987). However, indepth studies on suitability of different perennial and annual crops and their combination to identify the most suitable system for different sets of climatic and edaphic conditions need priority. Research has to be undertaken to develop package of management practices for different systems and their ecological and social impact.

Natural Regeneration

Natural regeneration of trees and shrubs in arid regions is very poor. There is need to study causes of failure of natural regeneration at different site conditions. The biotic factors are so intense in arid region that the forest floor is grazed clean and the plants are browsed severely hampering the regeneration process. The adverse climatic conditions such as strong winds (which remove the surface soil along with seed), high temperature and low rainfall causing unfavourable conditions of the surface layer do not allow germination of fallen seeds and growth of the germinated plants. Therefore, studies to improve surface soil conditions, by cultural, physical, chemical or biological methods should be undertaken. Studies on coppice management such as time and age of coppicing should be under-

taken. All possible and practical ways of improving natural regeneration should be investigated.

Basic social and economic studies

The technology, howsoever advanced it may be, will not be useful unless it takes into account the ground realities of social needs and economic implications. Therefore, studies need to be undertaken to compute demand of different types of forestry produce, economics of raising different plantations, tree mixtures, silvipastoral systems, etc. In IGNP command area, many irrigated plantations are nearing maturity, which require information on optimum age of felling, techniques of harvesting, processing, marketing, etc. Studies, in detail, are required on post harvest technology of arid zone tree species and shrubs including their utilization. Volume and biomass tables of different tree species are needed not only from commercial point of view but for academic use as well. Social and market surveys need to be undertaken to rationalise the demand and supply of wood and other minor and major forest produce. Research is required to promote the market support system of the seeds of species such as *Salvadora oleoides, Capparis decidua, Azadirachta indica, Acacia senegal,* etc.

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15

AFFORESTATION IN INHOSPITABLE SITES - A CASE OF AFFORESTATION ON A SAND DUNE IN JHALANA AREA

G.S. Nathawat , Anita Nag and Archana Mathur

Introduction

According to national forest policy, 33 per cent of the available land of the country should be under forest cover. At present forest area in Rajasthan is only 9 per cent of the total land area, of which only 3 per cent is dense forest and remaining 6 per cent is covered with scattered trees, bushes and grasses. Even these shrinking forests are under anthropogenic and zoogenic stresses. In order to meet the fuel, fodder, timber and other wood requirement of the growing population and to improve the quality of environment we have to regenerate the degraded lands and expand existing forests through conservation and afforestation. An attempt was made by the university students to afforest a barren sand dune at Jhalana near Jaipur. This dune is surrounded by degraded hills having intensive quarring activity. With the result the area is having high load of suspended particulate matter (SPM) and is under heavy biotic influences. The paper

reports the success of this attempt and influence of plantation on microclimate.

Setting

The Jhalana area (afforested area) is about 7km south-east of Jaipur which lies 75° 55"E longitude and 26° 55" N latitude. It consists of rocky mountain, semi-rocky material on foot hills, which is further followed by sand dunes and open land. Thakur Fateh Singh (1899), the then Prime Minister of the Jaipur State had mentioned about tiger hunt by Prince of Wales in (1875) in this area. Presence of tiger in this area indicates that it had luxuriant vegetation in the late 19th century. Now the hill slopes facing the city is deforested and further degraded by quarring activities. The soil from the denuded hill slopes erodes down with rains and accumulates in the form of mobile sand dunes in the foot-hills by the action of westerly winds. The climate of the area is semi-arid, maximum temperature in summer ranges between 42° C to 45° C, wind speed varies between 7-43 km/hr. The total rainfall in the year 1988 was 527 mm. The soil pH varies from 7.25 to 8.15 (Papriwal, 1988).

Condition before Plantation

Prior to plantation the sand dune was absolutely barren. It is situated in the centre of a girdle shaped mountain range. This sand dune has steep slopes and was devoid of any vegetation. All around this dune, extensive quarring activity and crushing units had further made the area inhospitable for plant growth. Due to quarring activity the barren rock surfaces are exposed to sun- light and the increased radiations further disturb the heat balance and changed the microclimate. The crushing units were releasing huge quantities of suspended particles which were deposited in this loose sand as there was no escape route in this closed system of mountain ranges.

Plantation

Along with the mountaineering activity, the students of the university of Rajasthan, Jaipur did the plantation on this sand dune. *Acacia tortilis* was planted in the months of July-Sept. Approximately 300-400 plants were planted by each group at an interval of 10 days during the rainy season during the years 1982-85. In all about 20,000 plants were planted. The forest department, Government of Rajasthan supplied the saplings

and water tankers during the plantation as well as in the post- plantation periods. Despite the hostile local conditions the survival of plants was 60-70%. The plantation was done from the top of the sand dune downwards. Crescent shaped small embankments were made at right angles to the slope to retain rain water flowing down-hill (Plate 1). The surviving plants showed good growth and subsequently changed the micro-climate which promoted the growth of indigenous plant species whose propagules could reach this area. Many herbaceous plants and grasses appeared as undergrowth in this area. This vegetation cover stabilised the sand and further promoted the regeneration of plant species. Today the mobile dune has changed into a stabilised sand-dune with good tree canopy of 15'-20' high and abundance of ground vegetation (Plate 2).

Jaipur Development Authority (JDA) adjudged this plantation as the best plantation in Jaipur and awarded cash prize of Rs. 15,000/- to the Aravalli Mountaineering Club, University of Rajasthan, Jaipur in 1984.

Study of tree composition and ground vegetation

METHODOLOGY

The quantitative parameters viz., density, frequency, etc, were computed for each species (Misra, 1968). Quadrats were laid down at random on the dunes. The formulae used are as follows :

$$\text{Frequency (\%)} = \frac{\text{Total number of quadrats of occurrence}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individuals of the species}}{\text{Total number of the quadrats studied}}$$

$$\text{Abundance} = \frac{\text{Total number of individuals of the species}}{\text{Number of quadrats of occurrence}}$$

pH of soil sample was estimated by using pH meter (Global Model No. DPH 500). Line transact method was adopted for tree count.



Figure 1. Saplings coming out of the barren sand dune. (September, 1983).

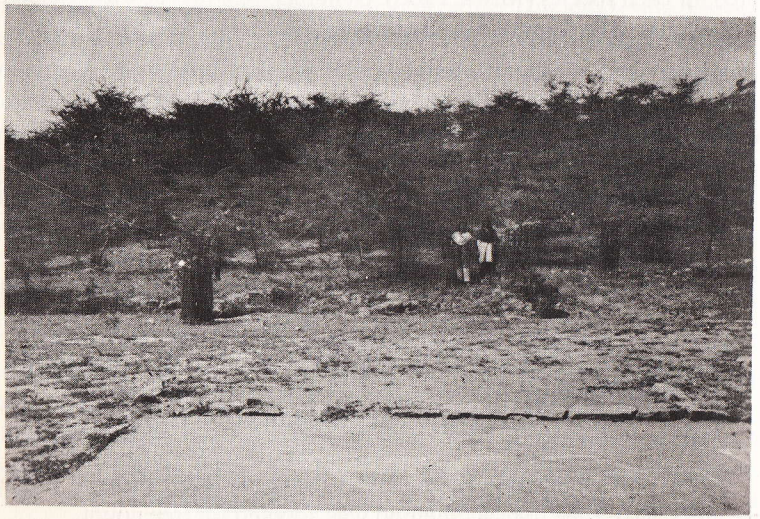

Figure 2. A tortilis plant completely covering the sand dune with good under growth (August, 1990).

Observations

With the plantation the loose sand of the sand dune could resist wind erosion and the herbaceous vegetation started appearing.

As the plants of *A. tortilis* gained in height the microclimate of the area started changing making it possible for other indigenous species to invade, the pioneers in this direction are *Acacia senegal* willd., *Holoptelea integrifolia* (Roxb.) Planch., *Dichrostachys cinerea* (Linn.), *Maytenus emarginata*(Willd.).

Litter from these plants improved the organic matter of the soil and increased its moisture retention capacity. Under the shade of these trees now mosses and *Riccia* species are also seen.

The tree composition on this sand dune after afforestation is given in Table 1.

Table 1 Vegetation composition (%) on the sand dune after afforestation.

Name of Plant	Percentage
Acacia tortilis (Heyne)	67.16
Acacia senegal (Willd)	13.21
Holoptelea integrifolia (Roxb.)	8.92
Dichrostachys cinerea (Linn.)	6.40
Maytenus emarginata (Willd.)	4.31

The underground flora consists of *Calotropis procera* (Ait.) *R. Br., Leptadenia pyrotechnica* (Forsk.) Decne, *Cocculus pendulus, Cenchrus catharticus Del. Indigofera tinctoria* (Linn.), *Boerhaavia diffusa* (L.) Linn., *Sericostoma pauciflorum Stocks., Saccharum bengalense Refz., Cynodon dactylon* (Linn.) *Pers., Cyperus rotundus Linn. Tribulus terristris Linn., Tragus biflorus* (Roxb) *Schutt., Heliotropium marifolium Refz., Dactyloctenium aegyptiacum* (Linn.) *P.P. eauv., Eragrostis ciliaris* (Linn.) *R. Pr., Digitaria ciliaris Pers., Panicum notatum Retz., Digitaria adscendens* (HBK) Henr. The frequency, density and abundance values are given in Table 2.

The highest frequency of the plants in the study area are : *Dactyloctenium aegyptiacum* (100%), *Cenchrus catharticus* (90%), *Cyperus rotundus* (90%), *Digitaria adscendens* (90%), *Cynodon dactylon* (70%),

Tragus biflorus (70%), *Tephrosia purpurea* (60%), *Boerhaavia diffusa*(60%) and *Saccharum bengalense* (60%). The maximum density is observed in *Dactyloctenium aegyptiacum* (27) and *Cyperus rotundus* (20.5). The most abundant species in the study area are *Dactyloctenium aegyptiacum* (27) and *Cyperus rotundus*(22.78).

Table 2 Ground Flora in the afforested area

Name of plant	Frequency	Density	Abundance
Dactyloctenium aegyptiacum (Linn.) P.P. eauv.	100%	27.0	27.0
Cenchrus catharticus Del.	90%	6.4	7.11
Cyperus rotundus Linn.	90%	20.5	22.78
Digitaria adscendens (HBK) Henr.	90%	13.6	15.1
Tragus biflorus (Roxb) Schutt.	70%	3.8	5.43
Cynodon dactylon (Linn.) Pers.	70%	6.4	9.14
Tephrosia purpurea (L.) Pers.	60%	1.3	2.16
Boerhaavia diffusa (L.) Linn.	60%	0.9	1.5
Saccharum bengalense Refz.	60%	2.6	4.33
Panicum notatum Retz.	40%	5.2	13.0
Tribulus terristris Linn.	30%	0.4	1.33
Sericostoma pauciflorum Stocks.	20%	0.2	1.0
Heliotropium marifolium Refz.	20%	0.3	1.5
Digitaria ciliaris Pers.	20%	0.2	1.0
Indigofera tinctoria (Linn.)	20%	0.2	1.0
Eragrostis ciliaris (Linn.) R. Pr.	10%	0.1	1.0
Calotropis procera (Ait.) R. Br.	10%	0.1	1.0

Impact of Afforestation

The plantation on the mobile sand dune has greatly helped in the regeneration of vegetation and also helped in improving the environment. The growth of trees has created such a microclimate which could support under growth. Once mobile sand dune has now completely stabilised. The roots of plants could hold the soil; and the canopy cover, by reducing the wind velocity; has decreased the carrying capacity of the wind. The

underground vege[illegible] cover also helped in checking or reducing soil erosion. The dead decaying parts of the plants have increased organic matter of the soil and thus improved moisture retention capacity. The plantation provided food and shelter to micro and macro organisms. The pH of the soil has now decline to 7.07 from 7.86. The wild life found in the area are rabbit, rats, arthopods, birds and reptiles etc.

It has also improved the land scape and aesthetic beauty even in such a hostile [illegible]nment.

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16

SALVADORA OLEOIDES - A PROMISING TREE FOR THAR DESERT

R.S. Mertia and I.C. Gupta

Introduction

Thar desert of India is unique among the Great deserts of the world. Spread over 27.833 mha area in Rajasthan, Gujarat, Haryana and Punjab, the maximum area of 19.615 mha occurs in Rajasthan alone. Out of a total of 19.615 mha area of Thar desert in Rajasthan, 10.683 mha area consists of wind eroded wastelands. Sandy wastelands cover 70.5% area (Kolarkar *et al.* 1989). The land use classification of Jaisalmer is : sandy waste 21.8%; sandy waste with open scrub lands 24%; saline waste 2.3% ; rocky and stony waste 1.4% ; rocky and gravelly waste 16.1% and rocky gravelly with open scrub lands 22.3% (Sen and Lal, 1986).

Jaisalmer district is characterised by high temperature exceeding 47.5 ^{o}C in summer. The mean annual maximum temperature is 34°C, potential evapotranspiration 2069 mm and rainfall is 180 mm. In such hyperdesertic conditions, *Salvadora oleoides, Salvadora persica, Prosopis cineraria, Ziziphus mauritiana, Tamarix dioca, Acacia senegal* and *Acacia nilotica* are some of the xerophytic trees commonly occurring in Jaisalmer district

(Mertia, 1990). Since *Salvadora oleoides* has been considered as the climax vegetation of the region and because it is a very important source of non-edible oil, finding valuable use in soap industry, its large scale plantation may generate income apart from reclaiming desert and improving its environment.

Distribution

S. oleoides occurs widely in Punjab, Gujarat and Rajasthan (western) in India and Sindh and Baluchistan in Pakistan. The species is in abundance in duny regions near Indo-Pakistan border in the west covering Murhar - Mehrana, Harrao and Jalavia particularly on the slopes and longitudinal dunes associated with *Ziziphus mauritiana. S. oleoides* has been reported to be very common in the erstwhile Jaipur state and also in Trans - Indus hills ascending from 800 m to 1000 m in salt range. It also occurs near the coast of Gujarat and also along tidal creeks in district Thana of Maharashtra state. In Jaisalmer, the species grows on dunes and interdunal plains, alluvial plains, ranns, buried pediments and *khadins.* Although, *Salvadora persica* has been reported to be a plant with wider distribution compared to *Salvadora oleoides* in dry climates and on saline soils (Gupta and Saxena, 1968), in Jaisalmer district, the later has wider distribution. Even in ranns *S. persica* has lower frequency and density (Table 1). *S. oleoides* occurs in the peripheries of all the four major ranns of Jaisalmer district viz. Pokaran, Lawan, Jhalaria and That (Shankar and Kumar, 1987). The soil analysis of Pokaran rann has been presented in Table 2. The occurrence of *S. oleoides* in all the habitats particularly in ranns and khadins (low lying depressional zones in the piedmonts of the district plateau where runoff is embanked for the entire rainy season) shows that it is facultative halophyte which has remarkable tolerance to aridity, salinity and waterlogging.

Propagation

The seed germination takes from 4 to 6 days. For higher germination, rind of seed is to be removed. The ripened cuttings of 50-70 cm length are preferred for raising nursery. Its rate of growth is slow in the early stage but accelerates after proper establishment (Gupta & Saxena, 1968).

Table 1 Frequency and density of S. *oleoides* compared to other tree species in Jaisalmer district.

Species	Dunes and interdunes		Alluvial plains		Ranns		Khadins		Buried pediments	
	F*	D	F	D	F	D	F	D	F	D
S. oleoides	7.09	16.0	10.0	35.0	57.1	261	60	103	28.57	30
S. persica	–	–	–	–	42.8	19	–	–	–	–
P. cineraria	8.66	10.0	20	75	14.3	7	60	154	21.43	10
Z. mauritiana	6.30	10.0	70	90	14.3	40	30	63	69	80
T. dioca	–	–	–	–	50	67	–	–	–	–
A. nilotica	–	–	–	–	–	–	20	13	–	–

* F = Frequency of occurrence (%) , D = Density of population per ha.

Plant Succession

It is a very slow process in the hyperdesertic regions but it does take place. In various geomorphological formations, *S. oleoides* occurs as dominant species forming climax vegetation in the following sequence of plant successional trend :

- Sandy alluvial plains — *P.cineraria- S. oleoides*
- Sandy plains — *S. oleoides- P. cineraria*
- Sand dunes — *S. oleoides- P. cineraria*
- Rocky plains — *A. senegal - E. caducifolia - S. oleoides*

In ranns it is primarily associated with *Tamarix aphylla,* unlike its association with in similar other situations (Gupta and Saxena, 1968).

Uses

The seeds of *S. oleoides* contain about 40-50 percent of the oil (fat) in the kernel. It is a valuable source of non-edible oils which have good commercial value in soap and allied industries. In fact oil mills based upon *S. oleoides* are coming up very fast. One oil mill located in Gujarat is being run by one private organisation under social forestry programme. The seeds are used in the treatment of rheumatism. In addition to fatty acid,

the seeds also contain an ethereal oil. The leaves of the tree are used as purgative and also in the cure of the cough. The leaves are a good fodder for camels. These are also used as antidote for all poisons. The fruits are acrid-sweet in taste and aphrodiasic. The ripe fruits of the tree are edible and consumed fresh.

Table 2 Analysis of the soil of Pokaran rann.

Depth (cm)	Mechanical composition (%)				pH_2	EC_2 (dSm^{-1})
	Clay	Silt	Fine sand	Coarse sand		
0–5	16.4	21.6	9.8	12.2	7.6	22.9
5–10	20.1	24.2	43.7	11.2	7.7	14.5
10–20	26.6	25.8	37.4	11.2	7.3	19.8
20–40	26.2	26.2	34.2	12.4	7.4	21.8
40–60	16.2	26.2	44.2	12.4	7.4	22.8
60–80	6.6	6.8	65.6	19.0	7.6	19.8

Economics

A grown up tree of *S. oleoides* carries from 25 to 35 kg fresh fruits which can be plucked by one man in two days. The dried fruits from one tree yield about 3 kg of oil which is marketed at Rs 30/- per kg. The systematic plantation with *S. oleoides* at a spacing of 8m x 8m, totalling 144 trees in one hectare, could thus generate an income of about Rs 40,000 per hectare on the wasteland.

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17

INFLUENCE OF ALKALINITY ON THE GROWTH OF TREE SEEDLINGS

A.K. Dwivedi and R.J. Srivastava

Introduction

India has got 7 million ha of salt affected land occurring in as many as 14 states of the country. The state of Uttar Pradesh has an area of about 1.15 million ha. Alkaline soils are generally not amenable for crop production but offer greater scope for afforestation. The growth and development of a plant is markedly influenced by soil characteristics such as pH, EC and E.S.P. The soil pH significantly affects the availability of several ions and thus affects the growth and development of the plant. The success of afforesting alkaline soils lies in identifying the tree species tolerant to such conditions. The degree of tolerance amongst the species differs according to varying abiotic stresses of the soil. Hence, a sand culture experiment was conducted to find out the relative performance of certain forest species as influenced by varying pH simulated artificially.

Materials and Methods

Forest tree species viz. *Acacia nilotica, Prosopis juliflora, Acacia leucophloea, Acacia auriculiformis,* and *Casuarina equisetifolia* were taken for the sand culture experiments carried out at State Forest Research Laboratory, Kanpur. The experiment was continued for a complete year. The treatments were comprised of six levels of pH; 7,8,9,10,11 & 12. pH 7 served the purpose of control. Each treatment was replicated 8 times in completely Randomised Design. Each pot contained about 15 kg of washed sand and a polythene sheet was lined between sand and inner walls of earthen pot just to avoid direct contact of nutrient solutions. Due care was taken in planting the seedlings of equal heights and vigour. The seedlings were supplied with complete nutrient solutions (Hoagland and Arnon, 1950) at the rate of 200 ml. per day per plant in summer and alternate days in winter season. After a month when the plants were established, the pH of the nutrient solution was maintained with the help of Na_2CO_3 and NaOH solutions prior to its addition to the pots.

The growth parameters e.g. height and stem diameter at 10cm height were recorded initially before starting the treatments. The plants were harvested after one year after recording the growth parameters and data on biomass of different plant parts were collected.

Results and Discussion

The height of the plants increased with advancing growth periods in all the species at all the pH levels except at pH 12 where all the plants died in case of *Acacia leucophloea* and *Casuarina equisetifolia* (Table 1). In the case of *A. nilotica* and *P. juliflora*, the plant height was found the same from pH 7 to pH 11. The height of plants declined with increase in pH of growth medium upto pH 9 in all the species except A. leucophloea.

The plant diameter increased with age of the plants in all the species but at decreasing rate with increasing pH values. It was at par from pH 7 to 11 in case of *A. nilotica* and *P. juliflora*. The decline in plant diameter after pH 10 in case of *C. equisetifolia* was not significant. However, reduction in plant diameter at pH 12 was highly significant in all the species.

Total biomass production continued to decrease in all species with increasing pH of the sand culture upto 10 (Table 2). However, the drastic decrease in biomass yield over control was from pH 11 onwards in all the

Table 1. Growth parameters of different forest tree species as influenced by varying pH under pot culture conditions.

Species	*Acacia nilotica*				*Prosopis juliflora*				Acacia leucophloea			
	Height (plant cm)		Dia at 10 cm height (cm)		Height (plant cm)		Dia at 10 cm height (cm)		Height (plant cm)		Dia at 10 cm height (cm)	
pH levels	Initial	After One Year	Initial	After One Year	Initial	After One Year	Initial	After One Year	Initial	After One Year	Initial	After One Year
7	43.0	145.9	0.36	1.19	32.4	160.1	0.35	1.05	40.0	48.40	0.28	0.46
8	42.7	142.5	0.35	1.13	32.9	157.0	0.35	1.00	48.0	52.40	0.29	0.46
9	42.2	143.0	0.38	1.09	30.7	138.8	0.34	0.99	39.2	57.00	0.35	0.61
10	44.5	141.9	0.36	1.09	30.0	137.8	0.36	0.94	39.2	43.8	0.32	0.41
11	45.8	135.3	0.36	1.08	30.6	131.2	0.35	1.01	30.8	46.0	0.24	0.52
12	46.2	65.4	0.38	0.55	30.7	67.9	0.33	0.50	39.0	–	0.29	–

Table Contd...

Species	*Acacia auriculiformis*				*Casuarina equisetifolia*			
	Height/(cm)		Dia at 10 cm height (cm)		Height/(cm)		Dia at 10 cm height (cm)	
pH levels	Initial	After One Year	Initial	After One Year	Initial	After One Year	Initial	After One Year
7	48.6	89.8	0.32	1.00	48.8	230.0	0.32	1.53
8	45.9	86.5	0.35	0.94	45.2	223.0	0.29	1.48
9	44.8	81.4	0.31	0.90	38.4	218.0	0.22	1.64
10	46.4	72.6	0.33	0.90	50.5	216.0	0.32	1.46
11	41.5	64.5	0.25	0.81	51.2	183.0	0.30	1.30
12	38.4	48.5	0.28	0.62	49.0	–	0.32	–

Height is mentioned as (plant cm) in upper part of table while in lower part it is mentioned as cm.

Table 2. Biomass production of different forest tree species as influenced by varying pH under pot culture condition

Species	*Acacia nilotica*		*Prosopis juliflora*		*Acacia leucophloea*		*Acacia auriculaeformis*		*Casuarina equisetifolia*	
pH Levels.	Biomass (g per plant)	% reduction over control	Biomass (g per plant)	% reduction over control	Biomass (g per plant	% reduction over control	Biomass (g per plant	% reduction over control	Biomass (g per plant)	% reduction over control
7	111.6	–	187.4	–	27.9	–	68.6	–	180.9	–
8	103.4	7.40	166.9	10.9	24.4	12.8	59.3	13.5	173.6	04.1
9	98.6	11.7	162.9	13.0	23.2	17.1	56.2	18.1	151.4	16.3
10	96.7	13.3	146.8	21.7	21.6	22.5	46.8	31.7	144.4	20.2
11	83.5	25.2	140.5	25.0	18.8	32.7	38.6	43.7	127.1	29.6
12	14.6	86.9	12.9	93.1	–	–	17.8	73.9	–	–

species except in *A. leucophloea* and *C. equisetifolia* where all the plants died at pH 12.

The reduction in growth and total biomass accumulation with increase in pH of sand culture from 7 to 12 could be attributed to increase in concentration of OH^- ions and increased corrosiveness upon cells or tissues of roots inhibiting cell division (Truog, 1967). In the present study also, it was observed that root development was adversely affected by higher pH specially at pH 11 & 12. Further, with rise in pH above neutral onwards, the availability of phosphorus declines adversely affecting the metabolic activities of plants since phosphorus is an essential component of the genetic material of the cell nucleus. Similarly the availability of other anions such as NO_3^- and SO_4^- to the plant roots may also be restricted due to increase in OH^- (Thompson and Troech, 1978). The availability of Fe, Mn, Cu and Zn is also reduced to a greater extent due to increase in pH of growth medium. Some researchers have advocated that increase in pH leads to imbalance in the availability of plant nutrients which ultimately causes toxic effects and retards plant growth.

On the basis of aforesaid findings and with an allowance of about 25 percent reduction in total biomass production over control, it was concluded that tolerance to pH of the tree species could be arranged in the order : *Prosopis juliflora* > *Acacia nilotica* > *Casuarina equisetifolia* > *Acacia auriculiformis* > *Acacia leucophloea.*

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18

AFFORESTATION AND ITS EFFECT IN SALT AFFECTED SOILS

H.S. Gill, J.S. Samra, Gurbachan Singh and I.P. Abrol

Introduction

About 40 per cent of the barren salt affected soils of India are confined to the Indo-Gangetic plains in the states of U.P.,Haryana and Punjab. High soil sodicity is reported (Abrol and Bhumbla, 1971; Bhumbla, 1977) to be the major cause for impairing their productivity. Since these soils have formed under the influence of sodium carbonate, its hydrolysis imparts high pH and ESP which in turn adversely affect the physico-chemical and the biological conditions of the soils. In addition, presence of indurated calcic horizon (hard pan) around one meter depth is another severe barrier that hinders root development. Considering a vast scope for raising tree crops on such soils, available research information is inadequate. A careful review of most of the past researches on the afforestation of salt affected soils indicate that a few tree species can be grown successfully in highly sodic soils by adopting appropriate management practices. But lack of systematic experimental evidences concerning adaptability and tolerance of the species to varying degree of soil sodicity impair successful

planning and planting operations. In several of the investigations in India and abroad, tree species were found greatly differing in their tolerance to soil salinity and sodicity conditions. Therefore, a critical evaluation of the tolerance limits can never be made. Moreover, suitability of a tree species is also to be decided in view of the local agro-climatic conditions, purpose and nature of afforestation operations including the pertinent soil factors.

Tree Planting in Alkali Soils

In early sixties, it was suggested (Khan and Yadav, 1962) that successful afforestation of the salt affected soils has rather limited prospects unless the soil conditions are ameliorated to a desired level by adopting appropriate techniques. Forest departments of U.P., Haryana and Punjab have made several attempts to plant trees on such soils but without much success. But later it was suggested (Pande, 1967) that the soils can be afforestated using soil replacement technique which involves replacement of soil from a pit of 90 cm each in depth and diameter by normal soil from another site of good and productive soil. But Yadav *et al.* (1972) concluded while studying suitability of a few forest tree species in a highly alkaline (pH 10) soil that saplings planted in pits refilled with mixture of original sodic soil, gypsum on 50 percent GR basis and 24 kg FYM were at par with the good soil for growth and survival percentage. Recently a new technique commonly called augerhole method has been developed by Abrol and his associates at the Central Soil Salinity Research Institute.

Relative tolerance and growth response of *Eucalyptus tereticornis* Syn. (hybrid) and *Acacia nilotica*(L.) Willd. ex. Del. (babul) to selected methods of site preparation was evaluated in a highly alkaline soil (Table 1) by Gill *et al.* (1985). In one experiment, method of planting trees was compared with planting of the said species in augerholes of selected dimensions (dia. X depth) where as effect of different refilling mixtures used for augerholes of the same dimensions(15 cm dia. X 120 cm depth) on their survival and growth was investigated in the other. Results indicate (Table 2) that survival of both, *Acacia* and *Eucalyptus*, remained about cent per cent in different types of augerholes and the pit throughout their growth span of 48 months. However, notable differences were found developed due to various mixtures used for refilling of the augerholes.

Table 1. Soil characteristics of the experimental field

Profile depth (cm)	pH*	ECe* (ds/m)	Calcium carbonate (%, <2mm)	Concretions (%, v/v)	ESP	Sand	Silt	Clay
0–15	10.4	4.24	1.12	0.5	97	56	27	16
16–27	10.1	1.64	0.52	2.3	97	49	33	18
28–46	10.1	1.12	0.60	3.6	98	46	32	21
47–87	10.0	1.12	0.86	5.7	98	56	21	22
88–139	10.0	1.07	6.38	32.8	94	50	26	17
140–200	9.8	0.70	9.75	7.5	72	63	16	11

* Measured in 1 ; 2 Soil & Water Suspension

Table 2 Effect of site preparation method and filling mixtures on the performance of given tree species in a highly alkali soil

Auger hole/pit dimensions (cm)	*Eucalyptus tereticornis*			*Acacia nilotica*		
	Survival (%)	Height (m)	Girth * (cm)	Survival (%)	Height (m)	Girth* (cm)
		Experiment–I				
10 X 120 (T–1)	100	6.80	29.0	100	6.23	32.2
10 X 180 (T–2)	100	7.63	34.5	100	6.22	34.7
15 X 120 (T–3)	100	7.27	32.6	100	6.67	34.7
15 X 180 (T–4)	88	8.30	37.2	100	6.64	37.7
90 X 90 (T–5)	100	7.93	35.0	100	7.10	41.4
LSD (0.05)	NS	NS	NS	NS	NS	NS
		Experiment–II				
OS (M–1)	0	–	–	6	5.84	15.0
OS + 3Kg gypsum (M–2)	32	4.31	16.8	94	5.48	29.5
OS + 6Kg gypsum (M–3)	66	5.34	22.6	100	5.49	31.2
OS + 3Kg gypsum + 8Kg FYM (M–4)	81	6.85	36.2	88	5.91	35.4
Sand+8 Kg FYM + 3kg gypsum (M–5)	88	7.94	36.6	100	5.81	38.9
LSD (0.05)	40	1.69	9.6	22	NS	NS

* Circumference of stem at one m height above ground level.

Source : Gill (1985).

Data further indicate that mixing of gypsum alone either 3 kg or 6 kg with original soil (OS) significantly improved the survival of *Eucalyptus* although it was inferior to the mixture of gypsum and 8kg FYM with OS or sand. In *Acacia*, gypsum levels and its combination with FYM and sand did not differ much. This demonstrates relatively higher tolerance of *Acacia* to sodicity hazard of the soil. Results also conclude successfulness of augerhole technique which needs lesser dose of amendments than the pit method; previously recommended for alkali soils. It is evident from table 2 that percentage increase in girth of *Acacia* is 3-4 times more than *Eucalyptus* between 24 and 48 months of the growth period. Further,

crown growth of *Acacia* was more profuse and encouraging than that of *Eucalyptus*. For maintenance of proper balance between the crown and the bole, undesirable growth of shoots on the stem of *Acacia* trees was lopped after 16 and 42 months of planting. Moisture content of potential firewood value ranged 25-30 percent. Fuelwood yield (Table 3) in the pit treatment was higher than in the augerhole technique.

Table 3 Fuel wood yield (t/ha) by lopping of ***Acacia*** at 16 & 42 Months after planting.

Treatment	Months			Treatment	Months		
	16	42	Total		16	42	Total
	Experiment–I				Experiment–II		
T–1	2.21	4.79	7.00	M–1	0.00	0.78	0.78
T–2	2.54	5.98	8.52	M–2	1.08	4.96	6.04
T–3	2.67	4.66	7.33	M–3	1.28	5.12	6.40
T–4	3.05	6.01	9.06	M–4	1.83	7.07	8.90
T–5	4.07	6.57	10.61	M–5	2.48	7.15	9.63
LSD (0.05)	1.00	NS	NS	LSD (0.05	1.05	1.90	2.31

Source : Gill (1985).

In another experiment it was found that *Casuarina equisetifolia* L. holds a promise for afforestation of alkali soils (Gill and Abrol, 1984). Its percent survival stood cent per cent after 15 months of planting in augerholes refilled with original alkali soil. But mixture of gypsum alone or in conjunction with FYM resulted in significantly more height growth (Figure1) than the OS treatment and its mixture with gypsum. Other species which performed satisfactorily was *Prosopis juliflora*(Sw.) DC.(Mesquite bean). It accumulated significantly higher biomass (Table 4) than other species. Other species that performed fairly include *Albizia lebbeck*(L.) Benth. (Siris) and *Azadirachta indica* Juss. (Neem). Growth of *Syzygium fructicosum* DC. (Jamoa) and *Dalbergia sissoo* Roxb. (Shisham) was not satisfactory although survival percentage of the latter species remained 100 after 24 months of planting. Species which failed to grow include *Populus deltoides* Bartr. (Poplar), *Morus indica* var. *alba* L.(Shahtoot) and *Syzygium cumini* Wall. (Jamun).

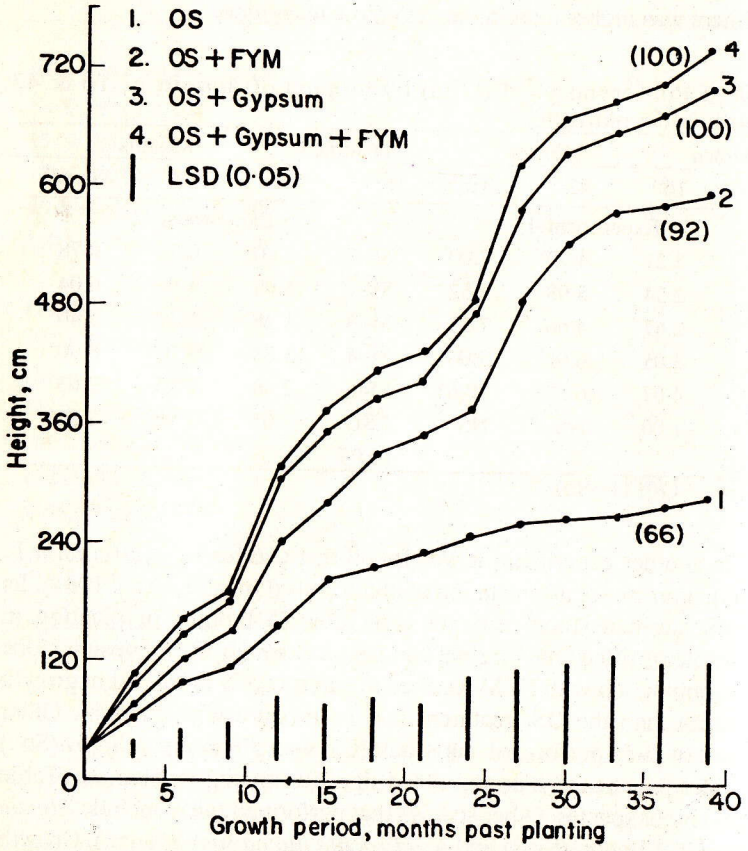

Figure 1.

Table 4 Performance of selected tree species in a highly alkali soil.

Tree species	Survival (%)	Height (cm)	Dry matter (g) Root	Dry matter (g) Shoot
Populus deltoides Bartr. (Popular)	0	–	–	–
Morus indica var. *alba* L. (Shahtoot)	0	–	–	–
Syzygium cumini Wall. (Jamun)	0	–	–	–
Syzygium fructicosum DC. (Jamoa)	50	73	254	260
Azadirachta indica Juss. (Neem)	63	109	118	266
Albizia lebbeck (L.) Benth. (Siris)	69	208	1775	3044
Dalbergia sissoo Roxb. (Shisham)	100	106	149	165
Prosopis juliflora (Sw.) DC. (Mesquite)	88	330	2662	11908

Saplings were planted in augerholes refilled with a mixture of original alkali soil, 3kg gypsum and 8kg farm yard manure(FYM) Observations made after two years of planting

Source : Gill (1985).

Alkali or sodic soils are poorly permeable and allow very little rain water to infiltrate. This causes loss of excellent quality of rain water from the area. Large amounts of run-off also erode huge amounts of nutrients-rich surface soil. Since many research findings indicate that tree plantations help in soil and water conservation, therefore, afforestation of sodic soils may be a useful practice on this account as well. Areas where ensured irrigation is a limitation for successful cultivation of agricultural crops, growing trees which are deep rooted and can meet their water requirements from the deeper horizons help in overcoming drought conditions more easily.

Planting trees in Saline Soils

Amelioration of saline soils involve leaching of soluble salts from the active root zone with good quality irrigation or rain water. But in India such soils occur generally in areas where good quality water is not easily available and the ground waters are mostly unsafe to use because of their high soluble salts content. In many soils where the monsoon rain results in sufficient leaching of the soluble salts, sometimes high water table becomes another problem that subsequently causes salinity development. But where water table is not a problem and soils are light textured, even

highly saline waters can be used for successful growth of trees (Gill *et al.*, 1985). A comprehensive list of tree species for their relative tolerance (Table 5) to salinity hazard of the soil (Abrol and Gill, 1983) is presented. In saline soils, planting of tree species on raised beds is generally preferable when the water table is near to the surface. This provides an additional soil space for the growth and proliferation of tree root systems. But high salinity of ground water causes failure of such approach. Choice of the tree species is thereby the most crucial factor while afforesting saline soils beside the management practices which also have their overwhelming role in successful growth and establishment of plantations on the saline soils. Data are inadequate to generalize and demarcate tree species for specific conditions of soil salinity, however, on the basis of their relative performance and a few systematic studies the given list is compiled for the users.

Table 5 Tree species and their relative tolerance to soil salinity.

Sr. no.	Botanical name	English/common name
	Highly tolerant	
1.	*Tamarix articulata* Vahl.	Tamarisk, *Athel, Farash*
2.	*Tamarix gallica* L.	Tamarisk, *Farash*
3.	*Casuarina equisetifolia* L.	Austrlian pine, beefwood
4.	*Casuarina glauca* L.	Casuarina
5.	*Casuarina cunninghamiana* Mig.	River-Oak, She-Oak
6.	*Prosopis juliflora* (Sw.) DC.	Mesquite, *Pahari babul*
7.	*Acacia nilotica* (L.) Willd. ex. Del.	*Babul, desi Kikar*
8.	*Acacia decurrens var. mollis* Lindl.	Green and Silver wattle
9.	*Acacia catechu* Willd.	*Khair,* Jerusalem thorn
10.	*Ziziphus jujuba* Lamk.	*Ber, Kool,* chinese date
11.	*Ziziphus spina-vulgaris* Willd.	Christ's thorn, *Nubk tree*
12.	*Butea monosperma* (Lamk.) Taub.	*Palas, Dhak,* Flame of forest
13.	*Ailanthus excelsa* Roxb.	*Maharukh,* tree of heaven
14.	*Terminalia arjuna* (Roxb.)Wight & Arn.	*Arjun tree, Kaku*
15.	*Capparis aphylla* Roth.	*Ker, Kerro, Kureal*
	Moderately tolerant	
1.	*Acacia cyanophylla* Willd.	Blue wattle
2.	*Acacia decurrens var. dealbata* Link.	Black and silver wattle
3.	*Parkinsonia aculeata* L.	Parkinsonia, Horse bean
4.	*Eucalyptus camaldulensis* Dehn.	Rever red gun, Green gun
5.	*Eucalyptus citriodora* Hook.	Tree lemon
6.	*Eucalyptus tereticornis*	Blue gum, Bastard gum
7.	*Azadirachta indica* Juss.	*Neem*
8.	*Albiza lebbeck* (L.) Benth.	*Siris*
9.	*Dalbergia sissoo* Roxb.	*Shisham, Tahali, Sissu*
10.	*Leucaena leucocephala* (Lamk.) de Wit.	*Ipil-ipil, Subabul*
11.	*Populas euphratica* L.	Poplar, Willows
12.	*Pinus halepensis* Mill.	Aleppo fir, Jerusalem pine
13.	*Bauhinia alba* vaf. *candida* L.	Bullhoff tree, *Kachnar*

Source : Abrol and Gill (1983)

Effect on Soil Properties

Ameliorative Effect : *Acacia* and *Eucalyptus* plantations were noted to have considerable ameliorative effect on the soil properties. Both the soil pH and EC were found to be reduced. Reduction was more in the surface layer and it decreased with depth to almost a negligible level at 60 cm depth. The soil organic carbon content increased to about double the initial value with *Eucalyptus*. The increase was about three times under *Acacia* plantation. The effect of *Acacia* on the increase in soil organic matter content was notably more than that of *Eucalyptus*. However, both the species effected a nearly similar changes in the soil pH and EC. The greater increase in organic carbon in the soil under *Acacia* plantation is ascribed to greater additions of litter to the soil. The water infiltration rates of the soil also improved with growth of *Acacia* and *Eucalyptus* plantations.

Micro-Climate Modifications: The mean air temperature under the *Acacia* canopy was found to be lower by 2-5^0 C during summer and higher by 2-4^{0}C during winter than in the neighbouring open area. Similar observations were made in respect of the *Eucalyptus* canopy but the magnitude of the modifying effect was less than that of the canopy of *Acacia*. The effect of tree plantations during the summer months was that of blanketing type but it was of the sheltering type during winter months. Tree plantations tend to modify the thermal status of the environment by their sheltering effect through cutting insolation and by their blanketing

effect in restricting the outflow of heat, thereby keeping the ground warmer during winter and cooler during summer seasons respectively.

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EFFECT OF PROSOPIS JULIFLORA IN THE RECLAMATION OF SALT AFFECTED SOILS OF BHAL REGION

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Introduction

Salt affected soils are extensively distributed both on the coastal and inland areas of Gujarat. Bhal region located in the vicinity of Gulf of Khambhat consists of an area of 0.54 million hectares having wide range of salinity and sodicity. *Prosopis juliflora* has been grown in semi-arid regions including the little Rann of Kutch. The plantation is getting momentum in recent years particularly on waste and marginal lands owing to grave energy crisis. Being a salt and drought tolerant tree, its cultivation has potential for planting on waste and salt affected lands. Therefore, a study was undertaken to find out the effect of *Prosopis juliflora* plantation and agricultural crops on the reclamation of saline sodic soils.

Materials and Methods

The study area is situated between 21°45" and 22°55" N latitude and 71°30" and 73°15" E longitude in Gujarat, The area is plain and slightly elevated above the highest tides in the Gulf of Khambhat. Owing to its marine origin, large parts of the plain are saline and sodic. Ground water table fluctuates between 1 to 3 m. Generally water table remains at the capillary fringe for most of the period in the year. Ground water salinity ranged from 0.4 to 36 dSm^{-1} and sodium adsorption ratio varied from 1 to 62. The area receives an average annual rainfall of 550 to 750 mm mainly in the period of July to September. The evaporation of an open water surface exceeds the precipitation even during wet season and net saturation deficit prevails in the post monsoon period. The analysis of soil was carried out as per standard methods described in USDA handbook No. 60 (Richards, 1954).

Table 1 Physico-Chemical characteristics of soil (Typic Chromusterts).

Soil characteristics	Soil depth (cm)			
	0–30	30–60	60–90	90–120
(i) Mechanical separates (%)				
Coarse sand	18.8	10.2	13.2	14.8
Fine sand	20.8	8.2	7.5	9.4
Silt	14.4	33.6	30.8	21.9
Clay	45.9	48.0	48.4	53.8
Texture	Clayey	Clayey	Clayey	Clayey
(ii) Infiltration rate (cm/hr)	0.19	0.04	0.02	0.02
EC_e (dSm^{-1})	1.85	2.66	3.96	6.05
pH_e	8.5	8.1	8.0	8.2
ESP	19.6	28.0	32.5	35.4
Lime (%)	6.2	6.5	7.9	8.0

Results and Discussion

The ECe and pH increased with soil depth (Table 2). The salinity was higher in upper horizon of soil under *Prosopis* plantation as compared to fallow plot in the post monsoon period. However, no differences in ECe and pH of subsurface soil under *Prosopis* plantation and fallow plot were

observed. This situation probably owes to the fact that the rate of upward movement of soil water is higher under *Prosopis* soil than barren. The rapid water loss through transpiration in the plantation area develops steep upward gradient for water movement through soil capillaries carrying larger quantities of salts in upper horizons as compared to fallow plot for specified period under similar set of atmospheric and soil conditions. The depletion of salts from soil due to *Prosopis* plantation was not observed owing to shallow saline underground water which provides constant source of salt for moving water under present situation. In absence of shallow saline aquifer, the analysis of soils for $EC_{2.5}$, $pH_{2.5}$ and ESP are presented in tables 3,4 and 5, respectively. The data on $EC_{2.5}$ showed that the total salt concentration decreased under *Prosopis* as compared to fallow and under crops. The decrease was observed at all depths and also during different intervals of sampling. The $EC_{2.5}$ at surface decreased from 0.60 to 0.22 dsm^{-1}. The $pH_{2.5}$ of soil also decreased from 8.4 to 7.6 upto 30 cm depth of soil sampling. After 30 cm depth, no decrease in $pH_{2.5}$ values was observed (Table 4). The ESP values decreased from 15.0 to 6.5 at 0-5 cm depth and from 18.5 to 7.0 at 5-15 cm depth.

Table 2 Effect of *Prosopis juliflora* plantation on chemical properties of soil in presence of shallow aquifer

Depth of soil (cm) and date of sampling	Fallow		Under *Prosopis* spp.	
	EC_e dSm^{-1}	pH_e	EC_e dSm^{-1}	pH_e
7.12.84				
0–30	1.83	7.7	1.92	7.7
30–60	2.66	7.8	2.73	7.8
60–90	2.35	7.8	3.29	7.8
90–120	3.98	7.9	4.23	7.9
28.1.85				
0–30	1.85	7.7	1.97	7.7
30–60	2.66	7.8	2.76	7.8
60–90	3.25	7.8	3.25	7.8

90–120	4.10	7.9	4.23	7.9
1.3.85				
0–30	1.92	7.7	2.02	7.7
30–60	2.76	7.8	2.88	7.8
60–90	3.12	7.8	3.12	7.8
90–120	3.98	7.9	3.98	7.9
2.4.85				
0–30	1.97	7.7	1.99	7.7
30–60	2.88	7.8	2.83	7.7
60–90	3.00	7.8	3.08	7.8
90–120	3.49	7.9	3.49	7.8
10.7.85				
0–30	1.98	7.8	1.99	7.8
30–60	2.92	7.9	2.83	7.9
60–90	4.96	7.9	4.90	7.9
90–120	4.90	7.9	4.90	7.9

Shah and Vora (1965) reported that *Prosopis juliflora* plantation caused decrease in the salinity and sodicity considerably in absence of shallow saline aquifer. Similar result was also observed by Agarwal *et al* (1976). Sharma *et al* (1990) observed increase in salt concentration while slight decrease in pH under tree cover as compared to bare soil. The mechanism involved in the removal of salts from upper soil layers in absence of shallow aquifer may be that in summer months due to solar heat the salts generally rise to the ground by capillary fringe and accumulate on the surface. But in the case of soils under *Prosopis juliflora*, the plant roots exert a marked influence on soil for their demand of water in dry months. As a result the capillary rise was adversely affected.

Table 3 : Effect of ***Prosopis juliflora*** plantation on $EC_{2.5}$ (dSm^{-1}) of soil in the absence of shallow aquifer

Sampling dates	Depth (cm)					
	0–5	5–15	15–30	30–45	45–60	60–90
F	0.60	0.40	0.45	0.52	0.87	2.66
July, 87						
P	0.45	0.29	0.34	0.45	0.94	2.23
F	0.53	0.35	0.40	0.52	1.20	2.59
Feb, 88						
P	0.29	0.19	0.23	0.35	0.72	2.14
F	0.50	0.35	0.38	0.50	1.00	2.55
Oct, 88						
P	0.24	0.17	0.17	0.28	0.63	2.10
F	0.65	0.55	0.48	0.52	1.00	2.45
June, 89						
P	0.38	0.32	0.30	0.30	0.89	2.00
F	0.67	0.60	0.42	0.53	1.20	2.52
Dec, 89						
P	0.22	0.20	0.25	0.32	0.95	2.12
C	0.40	0.35	0.35	0.48	0.57	1.18
April, 89						
S	0.34	0.38	0.63	0.44	0.58	1.66
Oct., 89						
S	0.34	0.31	0.60	0.49	0.65	1.70

F : Bare Soil; P : ***Prosopis juliflora***; C : Cotton crop; S : Sorghum crop.

Table 4 : Effect of ***Prosopis juliflora*** plantation on $PH_{2.5}$ of soil in absence of shallow aquifer.

Sampling dates	Depth (cm)					
	0–5	5–15	15–30	30–45	45–60	60–90
F	8.4	8.5	8.5	7.5	7.6	7.3
July, 87						
P	7.7	7.6	7.6	7.5	7.4	7.3
F	8.2	8.4	8.4	7.6	7.5	7.3
Feb, 88						
P	7.6	7.8	7.7	7.7	7.7	7.4
F	8.1	8.3	8.2	7.6	7.6	7.3
Oct, 88						
P	7.6	7.6	7.6	7.6	7.7	7.6
F	8.6	8.3	8.5	8.6	8.6	8.6
June, 89						
P	7.6	7.7	7.7	7.6	7.6	7.8
F	8.2	8.2	8.3	8.6	8.6	8.9
Dec, 89						
P	7.5	7.5	7.6	7.6	7.6	7.8
C	8.4	8.4	8.6	8.7	8.7	8.8
April, 89						
S	8.3	8.5	8.5	8.6	8.7	8.7
Oct., 89						
S	8.4	8.3	8.6	8.5	8.7	9.1

F : Bare Soil; P : *Prosopis juliflora;* C : Cotton crop; S : Sorghum crop.

Table 5 : Effect of ***Prosopis juliflora*** plantation on ESP of soil in absence of shallow aquifer.

Sampling dates	Depth (cm)					
	0–5	5–15	15–30	30–45	45–60	60–90
F	15.0	18.5	24.0	27.3	29.5	32.0
July, 87						
P	10.0	13.5	16.0	18.5	32.9	26.1
F	10.0	15.5	20.5	24.0	26.5	29.5
Feb, 88						
P	8.5	10.5	13.9	16.1	20.2	25.0
F	7.0	13.0	17.5	20.5	24.5	26.0
Oct, 88						
P	6.5	8.2	10.0	13.2	16.1	21.9
F	9.5	13.5	16.8	20.0	23.5	25.0
June, 89						
P	7.0	8.0	9.5	13.5	16.5	20.5
F	9.0	13.0	16.7	20.0	23.2	25.0
Dec, 89						
P	6.5	7.0	8.5	13.5	16.8	20.5
C	9.0	12.5	16.8	20.0	23.0	23.5
April, 89						
S	9.2	13.0	16.5	18.9	21.6	23.0
Oct., 89						
S	9.0	12.5	16.8	18.7	21.3	23.0

F : Bare Soil; P : Prosopis juliflora; C : Cotton crop; S : Sorghum crop.

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CASUARINA EQUISETIFOLIA FOR COASTAL DRY AREAS

G. Venkatachalam

Introduction

The Casuarina once cultivated as a windbreak and cover crop in the coastal belt and wastelands, is now being cultivated as a cash crop which fetches definite income with minimum expenditure. The farmers cultivate this crop to escape from the vagaries of monsoon, rising prices of inputs, labour and other factors.

The Casuarina, once mainly used as a fuel is now used as a building material and in paper and rayon industries.

Cultivation Practices In South Arcot District

The Casuarina comes up in almost all types of soils upto pH 9.5. It does not come up in alkaline patches and swampy lands. The ripened fruits

are collected from the plantations aged about 5 years and no selection is made i.e. the seeds are collected almost from all trees. The fruits are dried and the seeds begin to shed while decay and they are collected carefully. The seeds collected are sown in the raised sand beds of convenient sizes and covered with straw or dry *Casuarina* leaves. Periodical watering (sprinkling water from tin sprinkling thumb) is done to maintain optimum moisture. The sowing is done during March-April. The robust and taller seedlings are used for planting and the weaker seedlings are replanted in second nursery for further growth.

SEASON & PLANTING

Dry : September-October (During North-East monsoon)

Wet : December-January

Seed rate : 4500-5000 seedlings/acre

Spacing : 3 x 3 (in parallel rows)

Preparation of the Field

One or two ploughings are given during south west monsoon and Farm Yard Manure at the rate of 10 m. tonnes per acre is applied. Final ploughing is done after application of Farm Yard Manure.

Planting

Ropes marked at 3' spacing with palmyrah leaf or cloth piece is used for planting in a neat row. First a shallow pit is made (to a depth of 4" - 6") to avoid sliding soil in the holes at 3 feet apart. Then, pits are made with crow bar to a depth of 10" having 2" dia. Naked Casuarina seedlings of 45 to 60 cm height is placed in the holes - one if robust seedling or two if they are lean and lanky. This is followed by pot watering and the soil is filled in the pit manually. In heavy clay soils, sand is filled in the holes and the planting is done as said above. Top filling is done two times, 1st at 30th day and 2nd at 60th day to maintain the population.

Irrigation

Pot watering is done for a week and when required in dry lands upto establishment. In the fields which can be irrigated, irrigation is done at 15 days interval.

After Cultivation

Mammooty (spade) hoeing and weeding after 65-70 days and second weeding is done in 4th month. Third hoeing is done in the 6th month, if necessary. In general, hoeing is done to control the weeds and light earthing up for the moisture recaptiveness of the soil.

In the 15th month, side pruning is done to a height of 4 feet to facilitate erect growth. Thinning is done if two plants are found in one hole leaving the healthy one. No manuring or plant protection is done. Irrigation is done at monthly intervals - where there is facility for it.

Harvest

After completion of 5 years, the trees are cut out.

Yield

Dry : 20 M.Tonne/acre.

Irrigated : 30 M.Tonne/acre.

Difficulties Experienced at Growth Phase

Heavy mortality is noticed at the two and half year age of the crop, amounting up to ⅓ of the total population in dry land conditions. Sporadic casualities are noticed in irrigated condition too at the age of two and half year to three year of age. Reasons for this are unknown. Mealy bugs(white spongy adherence in the terminal portions) and other insects are found to attack the Casuarina, but the damage due to them is negligible. Economics is of raining *Casuarina equisetifolia* is given in table 1.

Table 1 Economics of raising *Casaurina equisetifolia.*

	Cost of Cultivation/acre	
	Dry	Wet
	Rs.	Rs.
Preparation of land	200.00	200.00
Manuring	600.00	600.00
Seed materials C @ Rs. 15/- per thousand) (Including gap filling	100.00	90.00
Planting	200.00	250.00
Pot watering (Irrigation)	450.00	1000.00
Hoeing and weeding (seedlings)	400.00	1100.00
Pruning & thinning	225.00	225.00
Harvesting	1200.00	1600.00
Clearing the land (removal of side roots, etc)	660.00	750.00
Total expenses	4035.00	5815.00
Return from the produce	12,000.00	18,000.00
Net Profit	7,965.00	12,185.00

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NURSERY TECHNIQUES OF SOME SPECIES SUITABLE FOR ARID REGIONS

P.E. Bedell, B.Gurudev Singh, T.Dhanushkoti, N.P. Mahadevan and S.N. Vijayachandran

Within the arid zones of the world, there are many degrees of dryness, and varied environmental features such as widely spaced plants, highly specialized vegetation and characteristic soils. The essential factor, however, is the insufficient rainfall combined with excessive heat and strong winds which necessitate plants growing in these areas to adapt themselves to these conditions for their survival.

Rapid elongation of taproots is common in arid lands. In fact any plant, whose rate of root penetration is sufficiently quick, to keep ahead of progressive drying of the soil from surface down is potentially capable of growing in such natural habitats. This characteristic feature if absent in species would exclude it from many arid areas.

Extensive superficial root systems are another important feature of arid zone vegetation. The extent of branching of the root system, and number and length of root hairs, differ considerably in different species, and these have an important bearing on the relative efficiency of the root system. This enables the plant to absorb the small amount of moisture contained in a large mass of soil. The extensiveness of the root systems in proportion to that part of the plant above ground is an important adaptation in desert plants.

Before an afforestation scheme is taken up, it is necessary to study the environmental constraints and climatic records of the area. The single most important climatic factor is the amount of rainfall and its distribution over time during the rainy season. If the timing of the rains is such that the total rainfall occurs within a day or two, instead of a number of weeks, the afforestation scheme can be ruined.

Other factors to be considered are whether the rainfall when it occurs is torrential or a gentle spread out rain. The latter is more likely to soak into the soil than the former. The season in which the rains occur is also important. Some areas have two rainy seasons, others have only one either in the summer months or in the winter months. It has been observed that a tree species which grows well in a region where the rain falls during the winter is not able to adapt well to an area where it rains during the summer months, even though the amount of rainfall is the same.

The next step in an afforestation scheme of desert areas would be to make a list of suitable tree species and the water needs of each. The following trees are reported to be doing well in arid areas:

(1) Low rainfall sites (200-500 mm mean annual precipitation) *Prosopis juliflora, Ziziphus mauritiana, Balanites roxburghii, Acacia senegal, Parkinsonia aculeata.*

(2) Medium rainfall sites (500-900 mm) *Acacia nilotica, Cassia siamea, Azadirachta indica, Tamarix articulata, Eucalyptus globulus.*

Another point of consideration is whether a nursery effort is necessary for a given species or whether revegetation can be accomplished in some other way. In some areas in the past, direct seeding has been attempted, as it was cheaper to scatter seeds on the planting site rather than establish a nursery and maintain it for a time, and transfer the saplings to the planting site. In some cases, direct seeding was attempted by feeding

pods of certain trees to cattle and allowing the cattle to graze on the land. The cattle deposit their manure containing the seeds on the ground, and sometimes a very effective direct seeding operation has been observed to take place in some African countries. But such direct seeding methods require large quantities of seeds. It is necessary to collect good quality seeds.

The best seeds come from strong healthy parent trees. Fully ripened seeds are collected directly from the trees either by picking them, or by spreading tarpaulin under the trees to catch the seeds as they fall. In most species it is the fruits that are collected and the seeds are extracted. The method followed for extraction depends upon the type of fruits. The seeds from dehiscent pods can be extracted by gently pounding or beating the fruits placed in bags. Most of the *Acacias* and *Cassia siamea* seeds can be extracted by using this method. Some fruits such as *Balanites roxburghii* have to be deshelled and soaked in water to remove the pulp and extract the seeds. Some seeds like *Ziziphus mauritiana* must be soaked to soften the pulp and then the remaining hard shell can be cracked with a hammer to remove the seed. Some like *Parkinsonia aculeata* can be deshelled easily by hand.

Seeds after extraction have to be air dried and stored in containers such as mud jars, boxes and bags. Care must be taken to keep the containers off the floors and away from walls. This practice will help to keep insects and dampness away from seed containers. Proper air circulation must be ensured around the containers. Each seed lot must be labeled properly indicating name, location, date of collection, date of storage and quantity of seeds. Once the water supply is fixed, the area fenced or protected in some way and seeds processed, nursery activities can begin.

If open rooted stock is being raised, the soil should be fertilized by adding nutrients. Open rooted plants draw large amount of nutrients out of the soil and special fertilizing efforts should be made, particularly when spading the beds for a new crop. Nitrogen and phosphorus are fertilizers of particular importance. Compost, animal manure and green manure upto 90% per hectare can help to build good soil structure.

For potted plants, good results have been achieved by mixing plain sand with sieved cattle manure at a ratio of 1:1. Seeds planted in the pots should be protected against sunburn and excessive heat by slightly countersinking or burying the rows of pots. The earth dug out for this

operation can be used to build a ridge against the outside pots, thus creating a little shade for them. The earth should be watered daily for two weeks before sowing the seeds. Regular and gradual prewatering in small amounts allows the water to mix evenly and thoroughly with the soil. The top 20 cm of the soil should be moist. Prewatering causes weed seeds in the soil to germinate and become visible before tree seeds are sown. Then all the germinated weeds can be removed.

Seeds of many species require pretreatment before sowing. Based on some experiments carried out in the laboratory, the following pretreatments are recommended for the suggested species.

	Name of species	Pre-treatment
i)	*Acacia albida* Del.	Soak in hot water for 24 hours
ii)	*Acacia senegal* (L.) Willd.	Soak in hot water for 12 hours
iii)	*Albizia lebbeck* (L.) Bth.	Soak in cold water for 24 hours
iv)	*Anogeissus latifolia* Wall.	No pretreatment required
v)	*Azadirachta indica* A. Juss.	No pretreatment required
vi)	*Balanites roxburghii* Planch.	Soak in warm water for 12 hours
vii)	*Cassia siamea* Lam.	Soak in hot water for 24 hours
viii)	*Casuarina equisetifolia* Forest & Forest L.	No pretreatment required
ix)	*Dalbergia sissoo* Roxb.	No pretreatment required
x)	*Parkinsonia aculeata* L.	Soak in cold water for 48 hours
xi)	*Prosopis juliflora* (Sw) DC	Soak seeds in boiling water for 48 hours
xii)	*Tamarindus indica* L.	Soak in hot water for 48 hours
xiii)	*Ziziphus maurtiana* Lam.	No pretreatment required

Most seeds have to be laid flat and pushed into the soil with the thumb and covered over with fine soil about three times their smallest diameter. Generally, one or two seeds are placed in a pot depending upon the germination rate. In open rooted seeding, extra seeds have to be used.

Watering is relatively easy if plans have been made carefully. Even such improvements as water storage tanks beside the nursery beds are useful. Adequate amount of water must be added at regular intervals. Water must be added gradually so that it does not form puddles or run off before it has a chance to soak in. Plants should be watered daily. Seeds should be watered as soon as they have been sown and covered with soil.

And watering should be done twice a day for at least the first month. Plants should receive about 5 mm of water at each watering. The top 20 cm of soil in the pot or bed must be kept moist. Young nursery plants should be weeded once in every ten days.

Young plants need to be thinned out before root competition becomes too severe. When there are too many plants in crowded condition, root development becomes poor. The best time is when the plants are between 10 and 15 cm tall.

Root pruning prevents the developments of a root system outside the pots. This is done generally after 6 to 8 weeks. All plants in pots have to be moved once in a month and the outside root cut off and the pots set back in place.

The general rule of thumb for judging whether a sapling is the right size for transplanting is that the above ground portion of pot stock should not be less than 0.2 m and not more than 1.0m tall. Open rooted stock should have between 1.5 m and 2.0 m of growth above the ground.

Before transplanting, the plants have to undergo hardening off, which is a gradual reduction in watering rates during the last few weeks in the nursery. This lessening of water helps the plants to prepare for the less steady water supplies that they are likely to receive at the planting site. About 4 to 6 weeks before moving time, water is reduced to once a day. If the plants do not begin to wilt, the amount of water can be reduced even further.

However, before transportation, relatively heavy watering should be resumed at least three days prior to lifting to planting sites. The objective of this last period of watering is to have the soil evenly moist. This cannot be accomplished by heavy watering at the last minute.

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BIOTECHNOLOGY AS RELATED TO ARID ZONE FORESTRY

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Abstract

Rapid and high frequency *in vitro* multiple shoots and subsequent plantlets were developed in several plant species of arid forestry viz. *Anogeissus acuminata, A.pendula, A.latifolia, A.sericea* var. *nummularia, A.sericea* var. *sericea, Calligonum polygonoides* and *Withania coagulans.* In *Prosopis cineraria, Tecomella undulata, Acacia senegal, Maytenus emerginata, Balanites aegyptiaca, Zizyphus nummularia* and *Z. mauritiana* in vitro multiple shoots were induced at the high rate by using nodal shoot segments from mature trees, but root induction in differentiated shoots were not very high in few species. *Dipcadi erythraeum* - an endemic and endanagered plant is differentiated into plantlet from cultures *in vitro.*

Various explants (cotyledonary nodal segment and epicotyl of *Anogeissus* spp., nodal and apical shoot segments from mature plants) of 1.5-2.5 cm in length were placed on Murashige and Skoog's (MS) basal medium supplemented with inorganic and organic addenda. Various growth regulators (auxins IAA, IBA, NAA and 2, 4-D and cytokinins; kinetin and BAP) were added from 0.1- 5.0 mg/l either alone or in combination to induce multiple shoots. Differentiated shoots could be further multiplied on fresh medium. Isolated shoots were rooted on MS basal and MS half strength basal salts medium with various concentrations of IAA, IBA and NAA.

Plantlets of *Anogeissus* spp., *Calligonum polygonoides, Withania coagulans* and *Dipcadi erythraeum* were transferred into pots.

INTRODUCTION

The economy of the people of Rajasthan is greatly dependent on the forest wealth in many ways for fuel, food, fodder, timber, drugs and other commerical products. The pressure of growing population has however caused the over-exploitation of the forests to a disastrous proportion. A large scale plantation of priority plants for afforestation of degraded forest and wasteland could be the solution to ensure future sufficiency in biomass.

Plant biotechnology has opened up the door to (1) rapid clonal multiplication of genetically uniform plants from the elite material, (2) the selection of novel and improved varieties using somaclonal variation, (3) the development of new hybrid by means of protoplast fusion, (4) production of virus free plants by meristem culture, (5) the production of biological active compounds for pharmaceutical industry, (6) maintaining viability of valuable germplasm over a number of years by cryopreservation and (7) the use of recombinanat DNA to introduce new genetic material into plant cells to develop drought, cold, salts, disease, pests and herbicide resistant plants.

Commercial application of forest trees tissue culture is presently limited to micropropagation of Poplars, Red-wood, Sequoia, Eucalyptus, Radiata pine, Sandal wood, teak, bamboos and some other species (Mascarenhas et al., 1981; Biondi and Thorpe, 1981; Lakshmi Sita et al., 1982; Thorpe and Biondi, 1984; Powledge, 1984; Haissig et al., 1987; Radojevic, 1988; Nadguada et al., 1990). The work done in our country has been reviewed extensively (DBT, 1989; Mascarenhas and Muralidharan, 1989; Shekhawat and Johri, 1991).

This paper deals with the micropropagation of some important forest plants of semi-arid and arid regions of Rajasthan. The plant species included are *Anogeissus acuminata, A.pendula, A.latifolia, A.sericea* var. *nummularia, A.sericea* var. *sericea, Acacia senegal, Balanites aegyptiaca, Calligonum polygonoides, Dipcadi erythraeum, Maytenus emarginata, Prosopis cineraria, Tecomella undulata, Withania coagulans, Ziziphus nummularia* and *Z.mauritiana*. These plants are important source of fuel, fodder, vegetables, biomass, timber and medicine etc. In addition these species are important component of desert ecosystem and have impact on biological life in many ways.

Prosopis cineraria, Tecomella undulata, Maytenus emarginata, Acacia senegal, and *Ziziphus* spp. are highly cross pollinated. Therefore, selected and tested plants were used for clonal multiplication. *Anogeissus* spp., *Calligonum polygonoides, Withania coagulans* are slow growing and natural propagation is mainly by seeds with very low percentage of seed germination and high rate of seedling mortality.

Therefore these plants were selected for micropropagation using various explants.

Materials and Methods

Fruits of *Anogeissus acuminata, A.pendula, A.latifolia, A.sericea* var. *nummularia, A.sericea* var. *sericea* and *Acacia senegal* were collected from Mount Abu, Ranakpur, Udaipur, Kailana (Jodhpur) and Supka (Nagaur). Fruits wall were removed mechanically and viable seeds were inoculated aseptically on MS medium (Murashige and Skoog, 1962). Seedlings were used a source of explants in *Anogeissus* spp. and *A.senegal*. Explants (axillary bud, apical bud and nodal shoot segment) were taken from mature plants in *Prosopis cineraria, Tecomella undulata, Calligonum polygonoides, Maytenus emarginata, Balanites aegyptiaca, Ziziphus* spp. and *Withania coagulans*. Surface sterilized explants were cut into segments and placed aseptically on medium. Cultures were incubated at 26± 2°C temperature, 2000- 3000 lux intensity of light for 12 h photoperiod and 60-65% relative humidity. Various media were tested to select appropriate medium for the establishment and multiplication of cultures. Auxins viz., IAA, IBA, NAA and 2, 4-D and cytokinis;

kinetin and BAP were added in the media from 0.1-5.0 mg/l either alone or in combinations for the induction of callus, its differentiation, direct multiple shoot induction, multiplication and root induction. Arginine (10-50 mg/l), adenine sulphate (10- 15 mg/l) were used in culture medium for *P.cineraria, T.undulata, A.acuminata* and *A.sericea.* Yeast extract (500 mg/l) and coconut milk 10-15% were supplemented in the MS medium to develop cultures of *Dipcadi erythraeum.* Agar (0.6-0.8%) gelling agent added in the media.

Multiple shoots induced in *Anogeissus* spp. from cotyledonary nodal segment and epicotyl were subcultured for further multiplication on fresh MS medium with IAA (0.1 mg/l) + BAP (0.5-2.5 mg/l). Differentiated shoots were subcultured on root induction medium (MS half strength + IBA, 0.5-2.0 mg/l). *P.cineraria, T.undulata, M.emarginata, B.aegyptiaca, Ziziphus* spp. and *W.coagulans* multiple shoots induced on MS + IAA 0.01-0.1 mg/l + BAP 0.5-5.0 mg/l medium were subcultured for further multiplication on comparative lower cytokinin medium (BAP 0.25-2.5 mg/l).

Isolated shoots were inoculated on half strength basal salts of MS medium with IBA / NAA at various concentrations (0.5-2.5 mg/l) alone or with Kn (0.1-0.5 mg/l) for root induction. Callus cultures of *Dicadi* were raised from bulb, scale and leaf segments on MS medium supplemented with 2, 4-D coconut milk/NAA + BAP. Callus differentiating medium was MS + BAP / MS + NAA + BAP). Direct shoot primordias induced on MS + IAA + NAA + higher BAP. Differentiated shoots of *Dipcadi* were subcultured for root induction on MS full and half strength basal salts with IBA / NAA.

Plantlets with well developed root and shoot were carefully taken out from the culture vessels and washed thoroughly. Finally plantlets were transferred into earthen and plastic pots containing various soil mixtures with or without varmiculite. Pots were covered by polythene bags to check the excess loss of water. Plants were hardened under semicontrolled conditions.

Results and Discussions

Out of the various media used MS basal medium was found the most ideal for the establishment, differentiation and multiplication of cultures for all the plant species. Micropropagation of all the plant species undertaken were obtained in three steps : (i) Multiple shoot induction from the explant used, (ii) Further multiplication of shoots from subcultured shoot or original explant, and (iii) Root induction from isolated shoots and subsequent transfer into pots.

Cotyledonary nodal shoot segment was found the best explant for the multiple shoot induction in *Anogeissus* spp. and *Acacia senegal* whereas nodal shoots segment were found most ideal in *Prosopis cineraria, Tecomella undulata, Calligonum polygonoides, Mayytenus emarginata, Balanites aegyptiaca, Withania coagulans, Ziziphus nummularia* and *Z.mauritiana.*

Anogeissus acuminata-multiple shoots (20-25 shoots/culture) were obtained on MS medium supplemented with IAA 0.1 mg/l + BAP 1.0-2.5 mg/l within 4-5 weeks. Subcultured shoots further multiplied the best on this medium (MS + IAA 0.1 + BAP 0.5-1.5 mg/l). Differentiated shoots rooted on half strength MS salts supplemented with IBA (0.5-1.5 mg/l) within 3-4 weeks. Root induction was achieved in 90-95% shoots. *A.pendula* cotyledonary nodal segment induced 15-20 shoots on MS medium incorporated with IAA (0.1 mg/l) + BAP 1-2.5 mg/l. Further multiplication of shoots was obtained on MS medium with lower strength BAP (0.5-1.0 mg/l). On half strength MS medium with IBA (1.5 mg/l) + Kn (0.1 mg/l) the shoots rooted.

A.latifolia- multiple shoots were obtained from cotyledonary nodal segment as well as from the epicotyl segments on shoot induction medium (MS + IAA 0.1 mg/l) + BAP (1.5-2.5 mg/l) but frequency of shoot induction was less from epicotyl (3- 4 shoots) as compared to cotyledonary (15-20 shoots). Subcultured shoot could be further multiplied on fresh medium. Differentiated shoot rooted while subculturing on hormone free MS & half strength MS medium but addition of IBA in the medium induced strong and viable roots.

A.sericea va. *nummularia*-cotyledonary nodal segment induced 10-12 shoots on shoot induction medium (MS + IAA 0.1 + BAP 2.0-3.0 mg/l) within 3-4 weeks. Original explant induced enhanced multiple shoots (15-20) upto 5 passages on fresh shoot induction medium. Subcultured shoots rooted the best on MS half strength basal salts medium with IBA / NAA within 3-4 weeks.

A.sericea var. *sericea* - ascorbic acid, citric acid and adenine sulphate were added in the MS medium. Requirement of cytokinin (BAP) was high

as compared to other species of *Anogeissus*. Maximum 10-12 shoots were induced from cotyledonary nodal segment on MS medium + IAA + BAP (2.5-3.5 mg/l) + addenda. Subcultured shoots multiplied on the fresh shoot induction medium. Original explant could be subcultured upto 5-6 successive culture for multiple shoot induction. Incorporation of IAA / IBA in the MS half strength medium induced roots in the subcultured shoots.

Acacia senegal - shoots were induced on the MS basal medium + IAA + BAP + Addenda within 4-5 weeks. Isolated shoots could be further multiplied on the same fresh medium. Subcultured shoots rooted on MS half strength basal medium with IBA + NAA but percentage root induction was less than *Anogeissus* spp.

Prosopis cineraria - nodal shoot segment induced 10-12 shoots on MS medium with IAA 0.1 mg/l + BAP 2-5 mg/l + addenda within 3-4 weeks. Original explant could be used upto 4-5 successive cultures for the multiple shoot induction in the fresh shoot induction medium with low BAP 1.0 mg/l. Sporadic root induction observed in the subcultured shoot on MS + NAA + Kn/MS + IBA + Kn medium.

Tecomella undulata – apical and nodal shoot segments induced multiple shoots on MS medium IAA (0.01-0.1 mg/l) + BAP 1.5-2.5 mg/l within 3-4 weeks. Subcultured shoot further multiplied on lower BAP medium (MS + IAA 0.01 mg/l + BAP 0.5-1.0 mg/l). Root induction was observed from the cultures which were kept on MS liquid medium + IBA (10-25 mg/l) with filter paper bridge for 24 hr followed by subculture on hormone free medium.

Maytenus emarginata - adventitious shoots were induced from the nodal shoot segment on MS medium supplemented with IAA + NAA + BAP within 4-5 weeks. Shoot primordias were subcultured and multiplied best on MS + IAA + Kn (0.5-1.0 mg/l) / MS + IAA + BAP (0.25-0.5 mg/l). Multiplication rate was very high (60-80 shoots per culture) in this species.

Ziziphus nummularia - nodal shoot segments found better than apical shoot buds for multiple shoot induction. Combined Kn + BAP proved useful along with IAA for the multiple shoots. Original explant and subcultured shoots could be further multiplied on MS + IAA 0.01 mg/l + BAP 1.5 mg/l + Kn 1.5 mg/l. Isolated shoots rooted on MS medium with IAA + IBA + NAA within 4 weeks.

Calligonum polygonoides - multiple shoots were regenerated from explants within a week. Each explant produced 18-20 shoot buds. When these shoot-buds were attained a length of 1-2 cms these were subcultured on MS + BAP (0.5 mg/l) + NAA (0.1 mg/l). On this medium 35-40 shoots from each shoot bud were proliferated within one week. After 4 weeks when these shoots became 2-3 cms they were transferred on rooting medium (IBA 0.5 mg/l + NAA 0.1 mg/l). About 60 shoots were rooted on this medium within a period of 2 weeks.

Balanites aegyptiaca - multiple shoots were regenerated from mature explants within 9-10 days. Each explant produced 5 to 6 shoots. When these shoots were attained a length of 3-4 cm they were sub-cultured on MS + BAP (0.5 mg/l) and IAA (0.01 mg/l) on this medium 9 to 11 shoots were proliferated within a week.

Withania coagulans - callus was induced on MS medium with 2,4-D + Kn/NAA + Kn from leaf and stem segments. Shoots were induced from the nodal shoot segment on MS + IAA + BAP medium. Further multiplication of shoots was obtained on MS medium + IAA + BAP + GA_3. Viable roots were induced in subcultured shoots on MS half strength medium with supplemented with IAA / IBA (0.5-1.0 mg/l) within 3-4 weeks.

Dipcadi erythraeum - direct multiple shoot induction was achieved from bulb explant. Scale segments differentiated into shoots via callus on MS medium + 2, 4-D + coconut milk. Leaf tissues developed adventitious buds on MS medium + IAA + NAA + BAP. Isolated shoots rooted on half strength MS medium incorporated with IAA / NAA / IBA within 4-5 weeks.

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GENETIC IMPROVEMENT OF TREE SPECIES SUITABLE FOR ARID ZONE

K. R. Solanki

Introduction

There is a wide gap between the demand and supply of forest produce. The maximization of production per unit area to narrow down this gap can only be possible by artificial plantations(man- made forests). Any scheme on afforestation, however, requires, in addition to other, correct choice of species, seeds of genetically improved populations and proper silvicultural treatment. It is in this context that tree breeding assumes importance.

Importance of seed

The quality of seeds used for afforestation is of utmost economic importance. Forest trees are extensively heterogeneous in quality and seeding ability. Often the prolific seed bearers are inferior genotypes. The

silviculturist's practice of thinning and eliminating the undesirable type results in a limited improvement only. He aims to provide the most advantageous environment, while the breeder aims at production of types having superior heritable nature i.e. superior genotypes.

Although there has been a definite trend towards greater usage of phenotypically superior trees as seed source, yet the recourse to the use of genetically superior seed in majority of forestry operation is still in its infancy.

The application of genetics and breeding principles vis-a-vis certified seed has already yielded a green revolution in agriculture. With the growing general acceptance of plantations as a better alternative to regeneration, there is a wide realisation to exploit hereditary principles to tailor trees to produce maximum biomass.

Use of certified seed in afforestation programme has remained neglected which as a matter of fact is of greater importance in forestry than agriculture because of the long life span of tree; as the mistake of having used poor quality seed cannot be rectified soon. Recently it has been realised that superior quality seed will repay many times its initial cost. This has resulted in the collection of seed now only from seed stands, plus trees, or from specially established plantation or seed orchards.

Choice of species:

In arid zone, because of climatic factors, limitations of moisture and inhibition in soils the choice is limited whereas areas to be afforested are very large. Care should be taken that species grown have multipurpose utility and have consideration of energy, social and economic aspect and special emphasis on the locality aspect (Bhimaya, 1977). Plantation of fast growing nitrogen fixing leguminous trees for amelioration of wastelands, providing nutrition for ages and serving as renewable energy sources in the highly degraded lands and environmental set up would be advantageous for the afforestation work.

Numerous workers have identified different tree species depending upon their use such as for fuel, fodder, on different types of soils in arid zone (Ganguli *et al* 1964; Deb Roy & Pathak 1974; Deb Roy *et al.* 1980; Muthana and Shankarnarayan 1977).

Preferred indigenous tree species in the arid areas are *Prosopis cineraria, Acacia senegal, Ziziphus* sp., *Capparis decidua, Tecomella*

undulata and *Salvadora oleoides. Acacia tortilis* an exotic from Israel for sand dune stabilization, *Prosopis juliflora*, suitable for fast biomass production, *Acacia nubica* for sand dune stabilization, *Colophospermum mopane* and *Dichrostachys glomerata* for fodder purpose. *E. camaldulensis* are few exotics suited for low rainfall area. Indigenous tree species suited to better rainfall areas of arid zone are *Azadirachta indica* and *Albizia lebbeck*. Under irrigated conditions, planting of *Dalbergia sissoo, Acacia nilotica* sp. *indica* and *Leucaena leucocephala* have been found useful (Mann and Muthana, 1984).

Introduction of exotics

Plant introduction from isoclimatic regions of the world is an important part of tree improvement programme. At CAZRI 115 species of *Eucalyptus*, 65 species of *Acacia* and 82 miscellaneous species of 44 genera from Australia, Israel, U.S.A., U.S.S.R., South Rhodesia, Chile, Peru, Sudan, Kenya, Arizona, Venezuela, Mexico, etc. have been introduced. Out of these, 16 species of *Eucalyptus*, 12 species of *Acacia* and 12 miscellaneous species of 8 genera have been found promising (Muthana et al., 1978). Out of 82 miscellaneous exotic and indigenous species introduced, the most promising ones in order of their preference are: (1) *Prosopis juliflora* (Israel) (2) *Prosopis juliflora* (Chile) (3) *Pittosporum phyllyraeoides* (4) *Brasilettia mollis* (5) *Colophospermum mopane* (6) *Aclansonia digitata* (7) *Prosopis alba* (8) *Ziziphus spinachristii* (9) *P. juliflora* (Venezuela) (10) *Dichrostachys glomerata.*

Exploitation of available genetic variability

In multipurpose trees simultaneous improvement in more than one character is needed. The information available from other trees improvement programme cannot be applied as such in arid zone trees because in arid zones the plant density is generally very low. The basic steps are same i.e. understanding patterns and extent of variation *in situ.* collection of variability, partitioning of variability into genotypic and environmental components, identification of superior genotypes and establishment of seed orchards. Our achievements in tree improvement programme are summarised below :-

(a) *Prosopis cineraria* : Surveys of western Rajasthan were undertaken during 1983,1984 and 1989. Morphological data on 191 trees from

natural stands from eleven districts of Rajasthan revealed high amount of variability for collar diameter followed by height and canopy diameter. There was variation for pod characteristics and biochemical traits and the ranges were 5.26 cm for pod length, 1-17 for seeds/pod, 2.0 - 7.4 g for 100 seed weight, 8.05 -15.05% for crude protein, 0.83 - 4.67% for reducing sugars, and 6.04 -15.83% for total sugars (Kackar *et al.*, 1986, Gupta *et al.*, 1984). Evaluation of 70 single plant progenies upto six months in nursery showed significant differences among progenies for root and shoot characteristics. Genotypic coefficient of variation, heritability and genetic advance were generally high at one month stage and showed decreasing trend with growth (Kackar, 1988).

Inter-relationship of ten mother trees with their juvenile progenies and mature progenies for height suggested that the selection of plus trees in natural stands was desirable, but selection of progenies of seedling stage was not likely to be effective (Kackar, 1988).

The heritability estimates and correlation studies for height over years upto the age of five years from half-sib plant progenies trial revealed that heritability values tend to stabilize at the age of three years and second year data may be reliably used to predict the performance of families in third, fourth or fifth year (Solanki *et al.*, 1984). Two more progeny trials have been established during 1984 and 1989. The information gathered from progeny trials regarding genetic parameters and relationships is being used to identify genetically superior genotypes at an early stage. Using seeds of good genotypes seedling seed orchard comprising of 156 plants has been established. Many of the trees in the orchard are showing exceptionally good growth and in 4.5 years the best tree attained height of 5.70 m (Table 1).

Table 1.Height, dbh and collar diameter of 4–5 year old *P. cineraria* in seed orchard

Character	Population mean	Best tree
Height (cm)	221.0	570.0
dbh (cm)	4.0	14.1
Collar diameter (cm)	4.4	16.3

For bringing plus trees together it was felt necessary to have vegetative propagation technique. Through systematic attempts air layering technique was standardized. Maximum rooting and better establishment

was observed using twigs of 10-15 mm diameter treated with Seradix B-3 and covered with clay in the month of July-August (Solanki et al., 1984). Using this technique a clonal seed orchard has been established.

However, for a large scale clonal propagation emphasis was given for standardizing tissue culture technique. Method for *in vitro* regeneration and multiplication of this species using axillary buds and root segments as explants has been standardized (Kackar et al., 1989 a,b)

(b) *Tecomella undulata* : This species, also known as Marwar Teak or Rohida is very important timber tree of Indian arid zone. The wood is tough,strong and durable, and lapachol in heart wood provides fungal and termite resistance. The wood takes fine polish and is highly prized for furniture and carving.

Systematic surveys were undertaken during 1983 and 1986 for studying variability *in situ* and collection of germplasm. Maximum frequency of this species was observed in interdunal areas of Barmer district. Coefficient of variability for tree height, d.b.h. basal diameter and canopy diameter was also maximum in this district (Jindal et al., 1985a, 1987b). Besides morphological characters, variation in chemical components and quality traits of leaves was also analysed. In 113 leaf samples collected from Barmer, wind variations were observed with respect to NDF, ADF, cellulose, hemicellulose, lignin and silica, (Jindal et al., 1987 a).

Observations on height of two year old seedlings of juvenile progenies in nursery upto 4 months revealed significant differences among progenies and there was a decreasing trend in heritability and genetic advance with growth period. Correlation of juvenile height at different stages with mean height of one year old progenies in field was non significant implying that screening for height at initial stages may not be appropriate (Jindal et al., 1990).

In the progeny trial comprising of 11 progenies, wide variations in height, dbh and collar diameter between and within progenies was observed. Within progeny there was segregation for flower colour suggesting the outcrossing nature of the species. Our observations showed that birds visit the flowers for nectar and may be acting as pollinators. Studies show that fruit set varies from 0.64% for selfing to 3.93% for cross pollination indicating the presence of self compatibility. Apomixis - an important mechanism for fixing heterotic advantage and ensuring multiplication was found to be absent (Jindal *et al.*, 1985 b).

Seedling seed orchard has been established. The goal is to produce quality seeds i.e. a source for plants with straight, clear cylindrical and solid bole with upright branching habit. These parameters were given due consideration while selecting genotypes for seed orchard.

(c) *Acacia* species : Genetic studies have been undertaken on both indigenous and exotic Acacias.

In *Acacia nilotica* ssp. *cupressiformis* our observations show that some plants which managed to survive, grow very well and their growth is better than many of the arid zone trees like *T. undulata* and *P. cineraria.* Hence if the species is protected and given limited water in the first year of its establishment it may turn out to be promising agroforestry tree.

Germplasm of *A. senegal,* arabic gum producing species, has also been evaluated indicating variation *in situ* for various traits was observed (Solanki *et al.*, 1985). One of the collections from Nigeria showed exceptionally good vegetative growth. Progeny trials have been established at Jodhpur (sandy, deep soil) and Bhopalgarh (rocky habitat) for identifying better gum producing trees.

In *A. tortilis*, an exotic tree species showing good performance in Indian arid zone, plus trees were identified from the existing plantations and the seeds of individuals trees were used to establish progeny trials at Jodhpur and Pali. At three years age twenty promising trees were selected and mean performance of traits of selected trees was found to be better than the population mean particularly for tree volume. Analysis of multilocation data for variance components of height suggested that the components tend to stabilize after three years and hence three years may be the earliest age for selection for tree height in this species(Solanki *et al.*, 1989). A seed orchard of *A. tortilis* using seeds of twenty selected trees has been established at Jodhpur, Chandan and Bikaner.

Vegetative propagation of *P. cineraria*

Air layering technique for vegetative multiplication of *P. cineraria* trees has been standardized. Maximum rooting and better establishment were observed in the twigs of 10-15 cm diameter treated with Seradix B-3 and covered with clay in the month of July and August. Using this technique, a clonal seed orchard has been established.

Conclusion

From the foregoing discussion it is revealed that trees are an important constituent of arid zone ecosystem and provide/satisfy many needs of desert dwellers. Work undertaken on genetic improvement brings out clearly that variability for almost all the silvicultural characters is available in the Thar desert. Genetic studies reveal that there is a possibility of selection of plus or elite trees keeping in view the objectives and needs of a particular zone. However, considering the long span and extreme climatic conditions, systematic efforts through proper planning and testing the material through multilocational trials are required so that genetic potential is realised to the maximum.

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24

ROLE OF PLANT TISSUE CULTURE IN ARID-LAND AFFORESTATION

K.G. Ramawat

The great Indian desert is one of the thickly populated deserts of the world and also with a high density of cattle heads. These biotic factors exert tremendous pressure on its scarce vegetation for feed, fodder, timber, fuel, etc. The important plant species of the region are listed in Table 1. The predominant plants of desert are shrubs with a few tree species found scattered all over the arid and semi arid regions. Because of the pressure on these plants, a few plant species are confined only to the protected areas.

Most of the species are cross pollinated and thus produce heterozygous seed material (e.g. *Prosopis species*). There are various problems with these plants viz. poor seed setting(e.g. *Commiphora*

wightii, Calligonum polygonoides), short seed viability (*Anogeissus* species, *Ephedra foliata, Tecomella undulata*) or seed raised plants are not true to parents due to cross pollination (*Phoenix dactylifera, Aegle marmelos, Ziziphus* species), and these are affected by insect pests and termites. Resultantly, the natural regeneration has come to a halt due to one or several of these factors, including biotic interference. Whatever available, is of poor quality in terms of growth and nutrition. There is a great need, not only to make the people aware of consequences of deforestation but also to preserve the germplasm of these plants, to develop technology for their improvement and propagation. In common, conventional methods of propagation are time consuming, labour oriented and not well effective in some cases. Therefore, plant tissue culture is recommended for such plant species.

Plant Tissue Culture:

In-vitro culture of plant parts forms an excellent system to study various aspects of plant metabolism and morphogenesis. The aseptic growth of tissue requires a balanced combination of mineral salts, organic substances, growth hormones and an energy source. There are several media recommended for plant tissue culture but the basic concept remains the same and the media differ in their quantitative composition of salts. The *in-vitro* system can be used for organogenesis leading to plantlet formation, clonal multiplication of plants of proven characteristics (Fig. 1), production of virus free plants, development of haploids by anther or pollen culture, regulation of secondary mutabilities production and lastly, genetic engineering and modification of plant cell for improvement.

Organogenesis : In callus cultures organogenesis has been reported in several species, yet it is difficult to differentiate many trees through this method e.g. *Prosopis* species. It is possible to obtain a large number of plants through callus differentiation but it poses the risk of somatic variation. In most cases, callus morphogenesis is a manifestation of cytokinin v/s auxin balance in the medium, where high cytokinin favours shoot formation. In some cases manipulation of medium salts and carbon source have been found necessary for organogenesis.

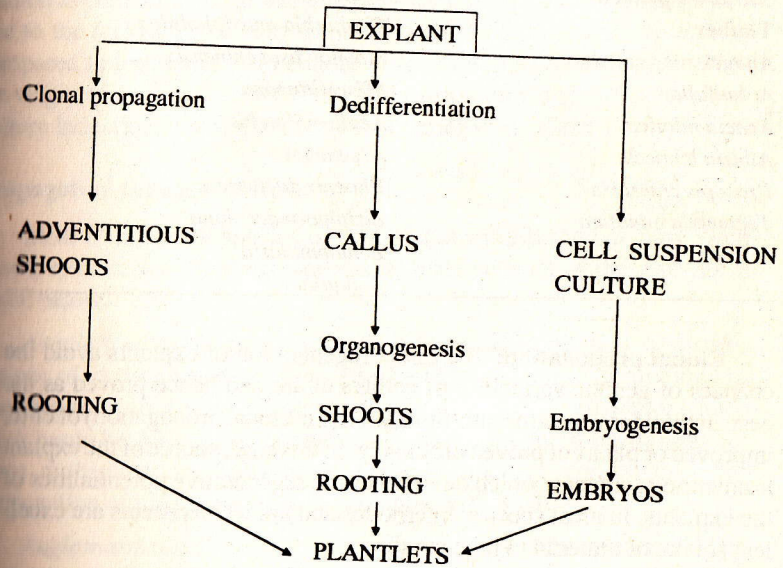

Figure 1. Schematic presentation of various lines obtaining plantlets through *in-vitro*.

Table 1 Important plant species of arid and semi-arid regions; most of them have been grown in culture.

Fuel	**Medicine**
Acacia nilotica	*Balanites aegyptiaca*
A. senegal	*Capparis decidua*
Prosopis cineraria	*C. aphyla*
P. juliflora	*Commiphora wightii*
Caligonum polygonoides	*Ephedra foliata*
Calotropis procera	*Euphorbia spp.*
Salvadora persica	**Wax and oil**
Timber	*Euphorbia antisiphalitica*
Anogeissus pendula	*Simmondisia chinensis*
A. latifolia	***Miscellaneous***
Acacia nilotica	*Aegle marmelos*
Albizia lebbeck	*A. senegal*
Prosopis cineraria	*Phoenix dactylitera*
Tecomella undulata	*Ziziphus mauritiana*
	Z. nummularia
	Z. jujuba

Clonal propagation: The direct regeneration of explants avoid the chances of genetic variability of callus culture and hence proved as the best method for vegetative multiplication (i.e. clonal propagation) of elite, improved or plants of proven efficiency. In this case, source of the explant is an important factor which determines the regenerative potentialities of the explants. In most species, internodes and apical meristems are excellent source of material to regenerate.

Embryogenesis: In certain cases, embryogenesis has been reported from callus or directly from explant. Embryogenesis from explant reduces the chances of variation and can be categorised as an efficient and quick method for obtaining large scale *in-vitro* produced somatic seeds. Unfortunately, this has been achieved in a very limited number of tree species as compared to organogenesis achieved in tree species. The mechanisms and factors governing embryogenesis are still not well understood.

Improvement: It is a matter of debate that whether cultures undergo a genetic or epigenetic change during growth or not. But for any cell improvement programme, using mutagenic treatments or normal cell selection, variation within cell population is an important factor to be

exploited. For all the studies concerning improvement, we require a callus or cell suspension culture system. Without this it is not possible to manipulate the cell or plant.

Production of haploids through anther or pollen culture is the quickest method for obtaining homozygous plants but haploids from only a few tree species have been obtained through this technique. Almost 30 years have passed since the discovery of haploids through anther and pollen culture but the main success remain, confined to Solanaceous plants. Similar to this, secondary mutabilities production in tree species is less studied as compared to the same work in herbaceous plants. This may be due to the fact that it is easy to grow the herbaceous plants *in-vitro* as compared to tree species. In culture of tree species (Gymnosperms too) the origin of explant and medium composition play a significant role in culture induction, maintenance and regeneration of tissues.

Propagation through *in-vitro*:

Most of the plant species of arid and semi-arid regions have been grown in culture by various workers. A brief account of these plants is given below.

Acacia species *(Leguminosae) viz. A. senegal, A. nilotica, A. tortilis,* are one of the important components of arid land. Plantlet formation has been reported in *A. koa* (Skolmen and Mapes, 1987). However, much work has to be done for regeneration and development of technology for mass multiplication. Subsequently, the technology can be used for propagation of high gum producing plants (*A. senegal*).

Aegle marmelos (Rutaceae) is a fruit tree and the plant is sacred. Plant is distributed throughout northern India but not cultivated widely. Differentiation has been achieved through callus morphogenesis and through nodal explants, cotyledons, hypocotyls, petioles, leaves, and even roots. Large number of plantlets have been transferred to field. It was recommended that this plant may be adaped for social forestry (Arya *et al.*, 1981; Bhati *et al.*, 1989).

Albizia lebbeck (Leguminosae) is commonly used as shade tree on road side plantations. This is well adapted to semi-arid regions as compared to *Cassia* sp., *Dalbergia sissoo, Eucalyptus* sp., etc. Regeneration of shoots from hypocotyl and stem explants have been reported (Ramawat and Arya, 1982). The explants maintain polarity and frequently produce

plantlets. Embryogenesis and haploids production have also been achieved (Gharyal and Maheshwari, 1981; Gharyal *et al.*, 1983).

Azadirachta indica(Meliaceae) is potentially one of the most valuable among all arid-zone trees (Anonymous, 1980). Plant is used for animal feed, fuel, shade, medicine, and insecticide. Wide variations are known in seed propagated plants. Somatic embryogenesis has been reported from Zygotic tissues cultured on B-5 medium containing cytokinins. On transfer to hormone free medium embryos develop into seedlings (Muralidharan and Mascarenhas, 1987). Further they reported development of transgenic plants using *Agrobacterium tumefaciens* (Naina *et al.*, 1989).

Balanites aegyptiaca (Simaroubaceae) is known to contain steroids and has been used in Indian system of medicine. Cultures were raised from stem explants and maintained on MS medium. Callus cultures are fast growing in this species and produce diosgenin and related steroids (Suthar *et al.*, 1981). Shoot formation was observed in callus cultures grown on medium with high concentration of cytokinin, osmoticum and increased incubation temperature (unpublished results).

Cocculus pendulus (Menispermaceae) is a lianas, growing wild and scattered on trees of arid land. Plant is known to contain antitumor alkaloids. Attempts have been made in our laboratory to raise cultures and develop technology for its regeneration and drug production. Explants produce intense brown substance in culture and becomes necrotic (unpublished).

Commiphora wightii (Burseraceae) is one of the most important drug plants of arid region of India. Resin obtained from plant is used in medicines and perfumary. Conventionally, plant is propagated through cuttings. So far, all attempts to regenerate through callus have failed.

Ephedra species (Ephedraceae): There are two species of *Ephedra*, *E. foliata* which grows in the Thar desert, and *E. gerardiana* which grows in the cold desert of Leh. Plant is known to contain alkaloid amine, ephedrine. Attempts have been made to develop high alkaloid yielding clones by medium manipulations and to differentiate the tissues (Ramawat and Arya, 1976; Arya and Ramawat, 1988). It would be of interest to obtain a fusion product of these two species, a hybrid rich in alkaloid and can withstand the high temperatures and dry conditions of desert.

Parthenium argentatum (Asteraceae) is known to contain rubber and is well adapted in arid lands. The plant can be grown on waste land where other crops fail to grow. Technologies are available for tissue culture, rubber production and regeneration through *in-vitro* techniques (Radin *et al.*, 1981; Staba and Nygaard, 1983). The plant has been recommended for cultivation in rural areas of desert for the uplift of the people (Khoshoo, 1982).

Phoenix dactylifera (Palmae): In case of date palm tissue culture is the most suitable method to propagate the plants of proven quality. Since it is a cross pollinated and dioecious crop, quality and sex can not be assured by seed raised plants. Technology is available to propagate the plant through somatic embryogenesis (Tisserat, 1981; Raj Bhansali, personal communication). However, variation and abnormalities in embryos have been observed and this needs further observations till the maturity of plants. This may have serious consequences if the proportion of abnormal embryos is high in the cultures.

Prosopis species (Leguminosae) are the predominant plant component of Thar desert. A few reports describe *in-vitro* growth of these multipurpose trees. Callus culture and development of shoot primordia have been obtained in three species namely *P. alba, P. chilensis,* and *P. tamarugo* (Jordan, 1988). Goyal (1982) developed a method for obtaining plants of *P. cineraria* through axillary and terminal bud culture (Goyal and Arya, 1984). However, the frequency of regeneration was very low and repeatability is uncertain. Wide range of germplasm is available within each species of genus *Prosopis*. It will be of interest to develop plants which are salt resistant, without thorn, and with desired nutritional characters.

In our laboratory, three species of *Prosopis* viz. *P. cineraria, P. tamarugo* and *P. juliflora* were selected to establish *in-vitro* regeneration and exploitation of somatic cell genetics and fusion. Different explants viz. stem segments, axillary buds, inflorescence segments, cotyledons and hypocotyls have been used to obtain continuously growing callus. Cultures have been raised and maintained in *P. cineraria and P. tamarugo*, but all attempts to obtain continuosly growing callus of *P. juliflora* have failed. Axillary bud elongation was observed in all the three species on several treatments of growth hormones. Such shoots on transfer to suitable rooting medium develops roots. Multiple shoot formation has been obtained in *P. tamarugo* (unpublished). It appears that the response is tissue

specific and medium factors affect the system marginally. Therefore, a careful selection of tissues is an important factor (Nandwani and Ramawat, 1989).

Tecomella undulata (Bignoniaceae), commonly known as teak of Marwar, was the main source of timber in western Rajasthan till recently. But at present, plants are no more available to be felled except in few protected fields. Stem explants, hypocotyls and anthers produce callus on various media supplemented with an auxin. Stem explants produce shoot buds on medium with reduced salt strength and containing cytokinins. Large number of embryo like structures have been observed on media containing low levels of auxin. So far, these structures have not developed into bipolar structures and instead produced callus (unpublished).

Ziziphus species (Rhamnaceae): Tissue culture is always helpful in propagation of elite plants but in case of improved varieties of *Z. mauritiana* (viz. Seb, Gola, Mundiya, etc.), an improved scion is grafted over wild stock. It appears, that the improved fruit characters are linked with poor root-growth. In such conditions tissue culture can not improve upon the characters. However, it may be helpful in propagation of elite plants developed by selection. Preliminary investigations show that it is possible to raise plantlets through auxiliary bud culture (Goyal and Arya, 1985). Still more studies are required to make the technology highly reproducible with different genotypes.

Future Prospects

Wide genetic variation within a species exists in the plants of the desert. It requires a careful selection of plants of desired characters and tissue culture can be useful in their multiplication. It is clear from the ongoing account that in most of the cases, feasibility to regenerate plants through *in-vitro* technique has been demonstrated. It requires further experimentation to perfect the technology for mass multiplication of the chosen material. Since most of them are heterozygous, anther or pollen cultures can be raised to develop homozygous lines for improvement. Similarly, selection for physiological characters can be made and plants of superior characters can be multiplied e.g., selection of high gum producing lines of *A. senegal*. Cell and protoplast technology is of great promise for incorporating desired characters.

In nut-shell, tissue culture technology holds great promises for the multiplication and improvement of plants of Thar desert.

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25

EFFECT OF AUXINS ON ROOTING BRANCH CUTTINGS OF *TAMARIX APHYLLA*

Mohinder Pal and H.C.S. Bhandari

Introduction

Tamarix aphylla (L.) is a medium sized tree which can tolerate extremes of temperature, drought, salty soils, poor quality water and even ordinary frosts(Bostid, 1980; Singh, 1982). It is a valuable species for stabilizing sand dunes because it grows fast and resists being buried by shifting sands. It sheds twigs abundantly, forming a compact litter that improves the water holding capacity of sand. It is outstanding for use as shelterbelts in arid zones. *Tamarix* wood is hard and durable. It burns reasonally well. The wood is mostly used for firewood although it is useful for carpentary, ploughs, furniture and for the manufacture of fruit boxes also (Bostid, 1980). It is, thus a very important afforestation species for arid zones.

Although *Tamarix* produces abundant seeds, the seeds lose viability within a few days. Therefore, vegetative propagation using rooted branch cuttings is very important for establishment of its plantations. This investigation was, therefore, undertaken to study the effect of auxins on rooting hard-wood branch cuttings of *Tamarix aphylla.*

Material and Methods

About one year old branches of healthy trees of *Tamarix aphylla*(L.) were collected from the lower portions of crown. These were made into 20 cm. long cuttings after excising their apical parts and leaves. The cuttings were treated with 50, 100 or 200 mg/l concentration of IAA (indole-3-acetic acid), IBA (indole-butyric acid) or NAA (L-naphthylacetic acid) for 24 h by dipping their basal 4 cm portion in the auxin solution. Control cuttings were treated similarly with distilled water. After the treatment, the cuttings were planted in earthen pots containing forest soil : farm-yard manure and sand in 1:1:1 ratio, with 20 cuttings per treatment. These were exposed to the environmental conditions prevailing at Dehra Dun during the period of investigation. The cuttings were maintained by regular watering. These were planted on 2nd July and the rooting and sprouting data were recorded after 6 weeks.

Results

Rooting data are presented in Table 1. Almost all control as well as auxin treated cuttings rooted within 6 weeks of planting. IAA did not affect the number of roots produced per rooted cutting, but 200 mg/l IBA and 200 mg/1 NAA decreased the number. 100 mg/l IAA and all concentrations of IBA increased root elongation, whereas NAA was ineffective in this regard. 100 mg/l IBA increased the number of buds that sprouted while 200 mg/l NAA decreased it. 200 mg/l IBA as well as NAA exhibited inhibitory effect on shoot elongation.

Table 1 Rooting response of branch cutting

Treatment (mg/l)	Percent Rooting	Mean root number per rooted cutting	Mean root length (cm)	Average number of shoots	Mean shoot length (cm)
Control	90	4.8	7.1	12.4	6.3
IAA-50	90	4.3	7.7	11.0	6.0
IAA-100	100	4.6	8.4	12.2	7.0
IAA-200	90	4.0	8.0	11.1	7.1
IBA-50	100	4.2	12.3*	13.4	7.5
IBA-100	100	4.2	15.3*	15.5*	6.5
IBA-200	90	3.6*	10.3*	10.9	4.5
NAA-50	100	5.0	7.0	11.6	6.0
NAA-100	90	4.4	8.1	11.3	6.2
NAA-200	90	3.2*	6.9	8.6*	4.4*

within a column, the mean values followed by sign* differ significantly from the respective control at P = 0.05

Discussion

The high per cent rooting of cuttings even without auxin treatment shows that *Tamarix aphylla* is an easy-to-root species.

In such species, more profuse adventitious root formation can be achieved by exogenous application of auxins (Nanda, 1970; Nanda and Kochhar, 1985). But the exogenously applied auxins failed to increase the number of roots produced per rooted cutting in this species. In fact, 200 mg/l concentration of IBA and NAA lead to reduction in the number of roots produced per cutting. This may be due either to the adequate endogenous contents of auxins or to inadequate contents of sugars and/or auxin synergids which are necessary for increased production of adventitious roots in response to auxin application (Nanda, 1970; Pal, 1989).

Strong stimulatory effect of IBA on root elongation and significant promotive effect of 100 mg/l IBA on bud sprouting shows that this auxin can be used to boost growth of adventitious roots formed on branch cuttings of *Tamarix*.

Enhancement of adventitious root growth by auxin treatment of branch cuttings in several other easy-to-root species has already been reported (Nanda, 1970; Pal, 1980). Rapid growth of adventitious roots is very essential for the speedy establishment of vegetative propagules, which infact determines the survival of such plants because under arid conditions adequate soil moisture, which is very essential during initial stages of establishment of rooted branch cutting, may be available only for very brief periods. Thus, by enhancing adventitious root growth, IBA in turn would increase the growth as well as survivability of rooted cuttings.

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26

USE OF MULCHES IN DRY LAND AFFORESTATION PROGRAMME

S.B. Singh and K.G. Prasad

Introduction

Scientific awareness and the will to achieve the greater production with ecological balance are the need of the day. Soil is one of the basic necessities for production which can react negatively or positively depending upon its management.

It is estimated that nearly 36% of world's land area consists of arid and semi-arid regions. In India, an area of 3.87 lakh km^2 is occupied by arid zones(Krishnan, 1977); out of which 1.96 lakh km^2 (62%) is located in Rajasthan (Kaul, 1970). Due to lack of soil moisture, potential fertility of such areas is not utilized as soil nutrients remain immobile resulting in poor plant growth. Further, the water in arid zone is scarce which calls for its judicious and wise use.

Some studies in India have shown that use of sub-surface moisture barriers, soil amendments, water harvesting, contour and graded bunds, scooping and growing of suitable species (Gupta, 1980; Gupta and Gupta 1983; Kaul, 1965, 1983; Ahuja 1977; Kaul and Chakravarty 1968 ; Mathur, 1980; Muthana, 1980) may be helpful for dry zone afforestation. These techniques prevent run-off and percolation losses. To check evaporational loss of water from the soil is no less important. One way to check the evaporational loss of soil moisture is the use of mulches. This communication reviews the results of some workers who have used mulches in their studies.

Effect of Mulching on Soil Temperature

Gupta *et al* (1987, 1988) studied the effect of coir pitch mulch application on soil temperature under *Tectona grandis, Eucalyptus camaldulensis, Tamarindus indica* and *Casuarina equisetifolia* plantation sites and noted a reduction of 0.5° C to 6.0° C temperature. They also observed variations in soil temperature due to different soil conditions (Table 1).

Table 1 Decrease in soil temperature (°C) at 5 cm depth due to mulch under different soil and vegetation (Gupta ***et al*** 1988).

Vegetation	Alkaline soil	Non saline soil	Saline soil
T. grandis	–	0.9	–
E. camaldulensis	0.5	4.0	6.0
T. indica	0.5	3.0	6.0
C. equisetifolia	3.0	3.0	5.0

Gupta and Muthana (1985) compared the soil temperature under different soil management practices. The soil temperature decreased by 1to 2° C due to soil management practices (soil barrier + water harvesting + F.Y.M.). When the above treatments accompanied dry weeds as mulch, 3° to 8°C reduction in soil temperature was recorded. Bansal *et al* (1971),Parihar and Arora (1980), Gupta (1980, 1983) have also reported reduction in soil temperature due to mulch applications.

Effect on Soil Moisture

Due to mulching, loss of water through evaporation is reduced resulting in higher soil moisture. Gupta *et al* (1988) studied the soil moisture under different plantations and noted 25% higher moisture in surface (0-25 cm) and 30-32% in subsurface (25-75 cm) under mulch than control treatment. Increase in soil moisture due to mulch application has also been reported by Gupta and Muthana (1985). Palanivel and Ramanathan (1981) compared soil moisture under different mulching material (Maize straw, sugarcane trash, cumbu straw) of agricultural crops and noted an increase of 5.2% moisture in surface (0-20 cm), soil. At lower depth (20-40 cm) however, soil moisture differed slightly in mulch treatment and control (Table 2).

Table 2 Soil moisture content under different mulches

Mulches	Soil moisture (%)			
	Flowering Stage		Harvesting Stage	
	Soil layers (cm)			
	0–20	20–40	0.–20	20–40
Control	14.5	20.6	13.9	19.5
Maize straw	18.7	20.6	18.2	19.7
Sugarcane trash	19.7	20.5	19.1	19.0
Cumbu straw	18.7	20.6	18.1	20.1

It is seen from above findings that different mulching materials have different capacity to conserve the soil moisture and therefore, there is need to evaluate different mulching materials for use in forestry and their effect on growth and development of tree species.

Effect of Mulches on plant Growth

Soil temperature plays vital role in seed germination and seedling growth. Reduction in soil temperature due to mulching, as discussed earliar, may delay the seed germination and seedling growth of those species which require comparatively higher temperature. Probably this was the reason that Gupta and Muthana (1985) reported a decrease in germination of *Acacia tortilis* seeds due to mulch application because the temperature requirement of *A. tortilis is* high (Harlevy and Orshan, 1972).

The capacity of mulch to conserve moisture in soil depends upon the material being used. A number of workers have used different types of mulching materials in their studies taking agricultural species as test crop. Sharma *et al* (1981) have reported production of 66.9 and 79.6 q/ha of pea due to mulching with F.Y.M. and pine needles, respectively against the production of 55.5 q/ha in control. Table 3 summarises the effect of some mulching materials on the production of agricultural crops.

Table 3 : Effect of mulches on crop production

Mulch used	Crop tested	% increase over control	Reference
Black polythene	Moong	78	Ghosh and Deb (1980)
White polythene	Moong	75	Ghosh and Deb (1980)
Straw	Moong	85	Ghosh and Deb (1980)
Black polythene	Soyabean	65	Ghosh and Deb (1980)
White polythene	Soyabean	55	Ghosh and Deb (1980)
Straw	Soyabean	73	Ghosh and Deb (1980)
F.Y.M.	Pea	21	Sharma *et al* (1981)
Straw	Pea	41	Sharma *et al* (1981)
Cumbu Straw	Sorghum*	67	Palnivel and Ramanathan (1981)
Sugarcane trash	Sorghum*	101	Palnivel and Ramanathan (1981)
Maize straw	Sorghum*	70	Palnivel and Ramanathan (1981)

The increased root weight due to mulch application has also been inferred by Chaudhary and Parihar (1974), Millard (1975), Mehara (1978), Singh *et al* (1989, 1990).

The effect of coir pith and gravel mulching was studied by Singh *et al* (1988) on a number of plant species. They noted tremendous response of trees to mulch applications. (Table 4).

Table 4 : Effect of coir pith and gravel mulches on plant height (cm). (Singh *et al* 1989).

Species	Coir pith			Gravels		
	Control	Treated	% increase	Control	Treated	% increase
A. nilotica	25.9	50.7	49	51	100	50
A. planifrons	19.2	40.9	53	43	65	54
E. camaldulensis	27.5	43.1	36	64	98	35
T. indica	18.0	20.4	12	18	23	22
A. lebbeck	10.7	9.3	–	45	102	59
P. pinnata	18.4	18.7	2	29	33	12
A. indica	10.2	16.3	–	22	35	37
P. pterocarpum	18.1	33.4	84	43	82	48
E. cumuni	17.1	16.9	–	29	32	9
A. leucophloea	11.7	14.9	21	44	74	46
C. pentandra	–	–	–	60	88	32

Grewal and Abrol (1984) noted the biomass production of *Eucalyptus tereticornis, Acacia nilotica* and *Parkinsonia aculeata* at two years of age to be 295, 175 and 281 (g/tree) in control plants against the values of 365, 219 and 314, respectively, for plants receiving grass mulch.

The effect of similar mulch may vary in different types of soil because of variation in moisture holding capacity of the soils. Studying the effect of coir pith mulch at different salinity and alkalinity levels, Gupta *et al* (1988) have reported 7 to 19% higher plant height in treated plants as compared to control ones (Table 5).

Table 5 : Effect of similar mulch (coir pith) under different soils on plant height (cm)

Species	Soil conditions	Height under		
		Control	Treated	% increase
		Saline (dS/m)		
E. camaldulensis	1.5	90	103	13
T. indica	3.0	63	72	13
C. equisetifolia	6.0	95	117	19
		Alkaline (pH)		
E. camaldulensis	7.2	83	94	12
T. indica	8.2	54	58	7
C. equisetifolia	9.7	111	136	18

Ram *et al* (1981) studied the effects of depth of water and rice husk mulch on the yield of maize and wheat crops and reported reduction in grain and straw yields with decrease in water depth without mulch but mulch application increased the yield of both. While taking the depth of irrigation, Singh *et al* (1988, 1989, 1990) have tried to select some mulching materials and their application methods for vegetating the area. Singh *et al* (1990) saw the effect of mulch (rice husk, Jalshakti, pine needles, hare droppings, F.Y.M. and no mulch) treatments on height and bio-mass production of *Eucalyptus* (Table 6). They observed higher plant height and more biomass production of *Eucalyptus* under mulch treatments, though the response varied with the nature of mulching material.

Table 6 : Effect of irrigation and mulches on Eucalyptus height and bio-mass production.

Irrigation regimes(%)	Control	Rice husk	Jalshakti	Pine needles	Hare dropping	F.Y.M.	Mean
			Plant height (cm)				
100	112.8	121.5	117.8	140.8	130.3	152.0	129.2
75	106.3	116.3	104.0	129.3	112.3	133.5	117.0
50	97.5	109.0	94.5	103.8	111.0	113.5	86.0
Mean	105.5	115.6	105.4	124.6	117.8	133.0	
			Total biomass (g plant^{-1})				
100	29.65	36.26	25.55	39.89	27.66	38.45	32.91
75	19.60	30.92	24.75	33.21	20.11	26.08	25.77
50	14.70	27.54	14.63	24.88	18.76	22.36	20.47
Mean	21.31	31.57	21.64	32.49	22.17	28.96	

In another experiment (Singh *et al* 1989) conducted at 120, 100, 80 and 60% irrigation levels, it was observed that all species under test (Table 7) responded to use of mulching material, though the response was better when pine needles were applied on the surface as compared to their mixing with soil. It was also noted (Singh *et al* 1989) that mulch applications increased the water use efficiency of the plants, particularly under higher soil moisture stress conditions.

Table 7 Effect of soil mixed and surface applied mulch materials at different levels of irrigation

Species	M. azedarach			A. falcateria			A. auriculiformis		
treatment	NM	MM	SM	NM	MM	SM	NM	MM	SM
				Plant Height (cm)					
I-120%	63.7	73.5	81.1	41.2	64.2	56.5	55.0	69.0	77.1
I-100%	59.7	62.7	61.7	43.0	50.0	68.7	47.0	57.7	60.5
I-80%	48.5	49.2	72.7	38.5	36.0	56.7	46.2	53.5	54.2
I-60%	55.0	72.0	83.5	27.7	30.0	54.0	51.5	55.7	56.7
				Water use efficiency (mg/L)					
I-120%	483	667	869	330	528	287	283	403	284
I-100%	734	713	738	366	543	599	259	336	274
I-80%	705	769	1067	414	669	934	199	269	287
I-60%	814	1153	1425	710	665	1393	204	384	309
				Bio-mass production (q/plant)					
I-120%	20.1	28.8	34.2	13.8	23.3	16.4	8.8	16.1	24.7
I-100%	25.3	24.6	26.5	12.6	18.7	20.7	12.1	13.2	17.1
I-80%	19.4	21.2	29.4	12.2	13.65	25.6	8.4	10.7	8.4
I-60%	16.9	23.7	29.6	12.2	12.3	28.8	6.2	10.7	9.5

Singh *et al* (1990) added N and P through urea and single superphosphate in the soil equal to amounts (160 Kg N and 80 Kg P_2O_5 ha^{-1}) being added in mulching material (F.Y.M.) and tested the response on *Eucalyptus* plant under three irrigation regimes (100, 75 and 50% of total evaporation).

They noted 3.2 and 19.8% higher plant height and 22.7 and 57.5% more biomass production through the fertilizer nutrients at 75 and 100% irrigation as compared to 50% irrigation regime. Whereas same values under mulch treatment were 5.0 and 41.6% and 23.4 and 59.6%, respectively (Table - 8).

Table 8 Comparision of N and P through F.Y.M. as mulch and fertilizers in soil on growth of ***Eucalyptus*** at 20th week of treatment

Source	Control			Fertilizer			F.Y.M.		
Irrigation%	100	75	50	100	75	50	100	75	50
Height(cm)	145	125	116	151	130	126	170	126	120
Biomass (g plant $^{-1}$)									
Root	6.40	5.56	4.36	6.46	5.36	4.36	6.43	5.13	4.10
Leaf	12.54	10.48	9.03	15.55	11.79	8.52	14.92	14.57	12.24
Branch	21.04	16.78	11.11	20.98	14.35	12.78	24.49	15.74	12.38
Total	39.98	32.82	24.50	42.99	31.50	25.66	45.84	35.44	28.72

Authors have conducted an experiment at Morni hills (Haryana) at site having 10-40% slope including mulch treatments (control,pine needle and local shrub as mulches) with and without N(0 and 60 Kg N ha^{-1}) and P(O and 20 Kg P_2O_5 ha^{-1}). Though it is too early to arrive at any conclusion, it has been observed after 9 months that mulch treatments are superior (Table 9).

Table 9 Relative growth rate of pine after 9 months of mulch treatments

Treatments	Control	Pine needles	Shrub	Mean
N_0 P_0	18	21	24	21
N_0 P_{20}	19	25	26	23
$N_{60}P_0$	22	18	31	24
$N_{60}P_{20}$	29	31	36	32
Mean	22	24	29	

Singh *et al* (1990) saw an increase of 49, 75 and 116% due to F.Y.M. mulch and 70, 157 and 125% due to pine needles mulch in N uptake as compared to control treatments at 100, 75 and 50% irrigation levels, respectively. At 100, 25 and 50% irrigation levels 47, 46 and 52% increase in P uptake was recorded when F.Y.M. was used as mulch and 51, 31 and 19% increase when pine needle was used as mulch. Corresponding values for K uptake were 86, 97 and 95% when F.Y.M. was used and 90, 63 and 65% when pine needles were used, at 100, 75 and 50% irrigation levels, respectively (Table 10).

Table 10 : Effect of mulching on nutrient uptake of ***Eucalyptus*** (mg/plant)

Mulch	Control			F.Y.M.			Pine needles		
Irrigation%	100	75	50	100	75	50	100	75	50
Nitrogen	77	49	32	115	86	69	131	126	72
Phosphorus	47	28	21	69	41	32	71	39	25
Potassium	308	243	194	584	396	321	574	478	378

From the above works it is clear that mulching is beneficial in dry zones for afforestation programme. Locally available mulch materials which are cheaper should be found to reduce the cost of application. Gupta and Mohan (1980) have worked out the economics of afforestation of dry zone and concluded that large scale tree plantations in such region are possible. Similar views have been given by Muthana(1980).

Having accepted that soils of dry zone are comparatively drier, there is necessity to adapt right technology including very correct choice of plant species for such area. There is need of appropriate research to develop these areas of the country for the benefit of mankind with due consideration of conservation of the environment. Initially, the inputs may be very high and work may be challenging but such development will provide immense benefit in long run.

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27

A NEW TECHNOLOGY FOR AFFORESTATION WITH SCARCE AND POOR QUALITY WATERS IN DESERT AREAS

I.C. Gupta, N.D. Yadav, P.M. Singh and B.D. Sharma

Introduction

Ground waters constitute the major source of supplemental irrigation in desert areas but, unfortunately, it is scarce and saline in nature. It has been established that plants are adversely affected by high salinity, more conspicuously at germination and early stages of plant growth. In later stages, the major factor inhibiting the afforestation in desert areas is scarce availability of irrigation water. Though poor quality of irrigation water is also a factor, its effect depends upon tolerance of specific plant species. Thus, the inevitable need of good quality irrigation water for plants, particularly at nursery stage, and their establishment in the field with

scarce available water necessitates working out suitable techniques to utilize the best available irrigation water in desert areas.

Material and Methods

Jalshuddhi: The device (Figure 1) is a double walled earthen pot - a coupling of two earthen pots of different diameters and heights joined at the base such that the bottom of inner pot is open. The diameter of outer pot is approximately 25 cm at the top and 18 cm at the base whereas the diameter of inner pot on top and at the base is 15 ± 1 cm, respectively. The height of outer pot is 30 cm while that of inner one is 27 cm. The saline water is filled up in the annular space between the two pots. The circular surface of water is capped with funnel shaped transparent polythene sheet such that it is embedded upto 2.5 cm depth in the soil contained in the polythene bag (Dia 15 cm, height 25 cm) placed in the internal pot.

Principle of working : The device works on simple principle of condensation. The water evaporates from the annular space and condenses on the polythene cap. The wall of the cap being slanting towards inner pot, the condensed droplets slide down in the soil of inner pot. Thus, moisture is supplied to the soil of inner pot through the condensate which is completely free of soluble salts.

Method of use : The outer surface of external pot is made impervious by curing with cement or painting with some enamel paint, and saline water is filled up in the annular space between the pots. A polythene bag filled with nursery mixture is placed in the inner pot and the seed is sown in this polythene bag. The polythene bag is used in inner pot so as to avoid direct seepage of saline water to the soil. The funnel shaped polythene cap is now placed on the twin-pots such that its margin is around the brim of outer pot and the central portion is embedded in the polythene bag of inner pot. Care has to be taken to ensure that the margin of this cap around the brim of outer pot is air tight otherwise condensation will not take place effectively. The saline water once filled will keep on providing fresh water (15 to 20 ml per day in May/June) to the seed for about ten days.

Jaltripti : It is same as 'Jalshuddhi' without polythene cap and the height of inner pot also is 30 cm in this device (Figure 2).

Principle of working :

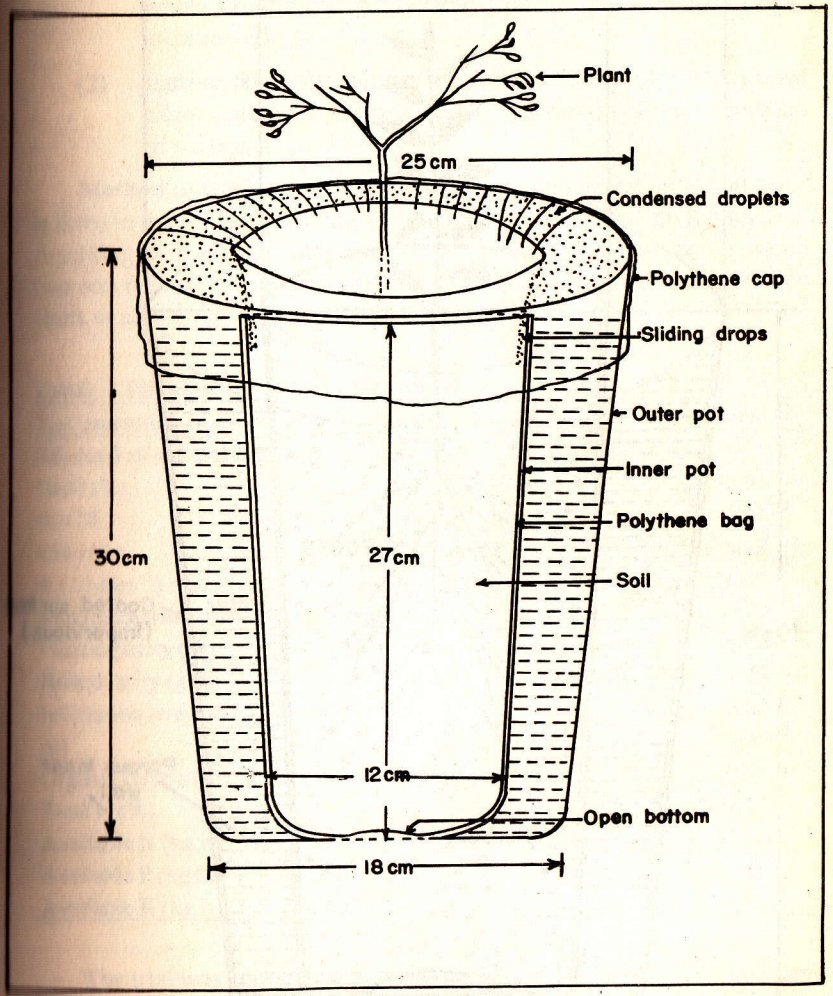

Figure 1. Interaction of trees and crops in an agroforestry system.

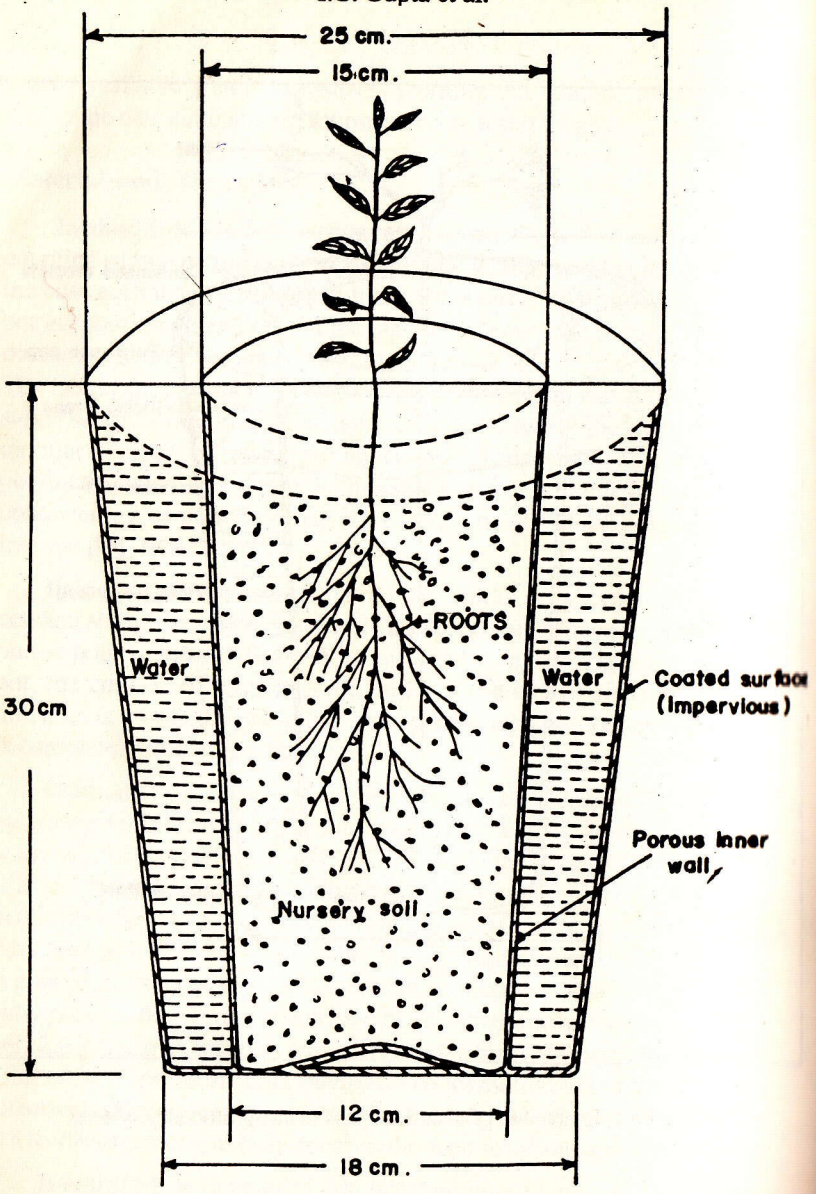

Figure 2. Section of double walled earthen pot.

(1) Soil moisture tension and plant roots create a suction force which draw moisture inwards from the neighbouring high-moisture zones.

(2) Earthen pots have many micropores in their walls which do not allow water to flow freely but allow its seepage in the direction of suction.

Method of use : At the place where planting is to be done 'Jaltripti' is fixed in the soil such that the brim of the pots is in line with the surface. A sapling (with soil) is transplanted to the inner pot. The space between two pots is filled with water and surface of water is covered by a polythene sheet or earthen lid to avoid direct evaporational loss.

Table 1 Physico-chemical characteristics of soil

Soil properties	Value
Mechanical composition	
Sand (%)	92.92
Silt (%)	1.91
Clay (%)	5.17
E.C. (dSm^{-1})	0.17
Maximum water holding capacity (%)	21.70
Field capacity (%)	8.00
Bulk density ($g\ cm^{-3}$)	1.40
Infiltration rate ($cm\ hr^{-1}$)	8.00
pH	7.90
Organic carbon (%)	0.11
Total N (%)	00.014
Available N ($kg\ ha^{-1}$)	110.00
Available P ($kg\ ha^{-1}$)	10.50
Available K ($kg\ ha^{-1}$)	120.00

The trial was conducted on coarse sandy soil with very low moisture retention capacity (75 cm per metre depth of soil) and moisture content at 1/3 and 15 bars being only 8.0 and 2.1%, respectively, classified as typic camborthid according to Seventh Approximation System. The other information about the soil is given in Table 1. The EC of irrigation water used was 1.8 dSm^{-1}. Pits of 50 cm diameter and 60 cm depth were dug by tractor driven auger hole. There were five treatments : T_1-control i.e.

planted with the usual practice; T_2-application of pond sediments in pits as a 5 mm thick barrier at 60 cm depth; T_3-Jalshakti (a granular, organic, superabsorbent polymer) at 5 g/pit, mixed with soil and filled in the pits; T_4-lining of bentonite at the base as well as on the sides of pit and T_5-Jaltripti.

About two month old Neem (*Azadirachta indica*) seedlings raised in the nursery of the Station, in polythene bags containing a mixture of 1:1:1 of pond sediments, sand and farm yard manure were planted in October, 1987 in a randomized block design with four replications. The irrigation was applied @ 3 litres per plant per treatment whenever the moisture content went below field capacity in 'Jaltripti'. Plants were not disturbed for measuring the soil moisture content but in simulated system soil moisture measurements were made and according to their moisture content, water was applied to the plants. A total of 39 irrigations @ 3 litres per plant per treatment were applied during the thirteen months period from October, 1987 to November, 1988. During this period, there was 185 mm of rainfall. On three days the minimum temperature fell to about 0°C. Observations of growth parameters were recorded and data were analysed statistically. Survival percentage of the plants was also noted. For observing the moisture distribution in different techniques, soil samples were taken and moisture was determined gravimetrically.

Results and Discussion

The survival of plants in 'Jaltripti' was 100 per cent whereas in all other treatments 25 per cent of the plants did not survive. It was observed that the plants in 'Jaltripti' were almost not affected by frost, unlike the plants of other treatments due to regular moisture availability to the plants.

Gupta (1986) reported that ber (*Ziziphus mauritiana*) seedlings raised in the treatments conserving maximum moisture in pits (moisture barrier + water harvesting + pond sediments) were least affected by frost.

Growth characteristics

The results reveal (Table 2) that 'Jaltripti' is the device that gives the best growth with respect to the growth parameters studied. This may be attributed to controlled sub-surface watering. Muthana and Kolarkar (1984) have also reported better plant growth with limited sub-surface watering over conventional surface watering. A better growth of ber

(*Ziziphus rotundifolia*) in 'Jaltripti' has also been reported earlier (Gupta et al., 1988).

Table 2 Growth parameters of Neem (*A. indica*) as affected by different treatments.

Treatments	Height of plants (cm)	Collar diameter (cm)
T_1 (Control)	62.3	1.07
T_2 (Pond sediments)	34.0	0.76
T_3 (Jalshakti)	46.3	0.94
T_4 (Bentonite)	65.1	1.11
T_5 (Jaltripti)	100.0	1.83
S. Em ±	13.8	0.20
C.d. at 5%	30.1	0.44

Burman *et al.* (1986) have reported an application of 30 litre water per week or 47 litre water per fortnight per plant for optimum growth of Neem plants under arid conditions at Jodhpur during the period, 24th September, 1985 to 22nd July, 1986. The growth achieved with watering of 30 litre per plant weekly or 47 litre per plant fortnightly was almost comparable whereas in the latter case about 400 litre of water was saved during the establishment of the seedling. Considering this information, the monthly requirement with 47 litre fortnightly works out to 94 litre per plant. In our study, during thirteen months, only 39 waterings of 3 litre each were given over and above the rainfall received during the period. Taking on an average even four waterings per month of 3 litre each, the monthly water requirement comes as 12 litre. This shows saving of about 90% water by the use of 'Jaltripti' without compromising with the growth of plants.

Moisture distribution : The soil samples for moisture determination were collected at two intervals viz. 24 hours and 8 days after application of 3 litre irrigation water in Jaltripti as well as in other treatments. The data regarding the moisture content at different vertical and horizontal distances are given in Table 3.

Table 3 : Moisture distribution(%) pattern in different techniques

Depth (cm)	Treatment									
	Control		Pond sediment barrier		Jalshakti		Bentonite barrier		Jaltripti	
	24 h	8 d	24 h	8 d	24 h	8 d	24 h	8 d	24 h	8 d
					Main					
0–15	6.80	1.30	7.00	1.08	7.00	3.50	7.00	1.00	6.80	6.80
15–30	4.00	0.90	4.60	0.98	5.10	3.15	4.60	1.44	6.00	7.00
30–45	2.03	1.00	2.00	1.00	3.10	1.98	2.00	1.80	4.50	5.50
45–60	1.90	0.90	2.00	1.00	2.00	1.00	2.00	1.30	1.00	4.00
					15 cm*					
0–15	6.00	1.00	5.80	1.00	5.20	1.17	5.00	0.69	1.05	1.00
15–30	4.20	1.00	4.10	1.00	3.00	1.00	2.90	0.98	1.00	1.05
30–45	1.80	1.00	1.69	1.05	1.70	1.00	2.70	1.15	2.00	3.00
45–60	1.80	0.90	1.70	1.00	1.80	1.00	2.00	1.00	2.00	3.15
					30 cm*					
0–15	1.20	0.70	1.00	0.65	1.00	0.90	1.00	0.80	1.00	1.00
15–30	1.00	0.80	0.86	0.90	0.86	0.80	0.90	0.96	1.05	1.80
30–45	1.00	0.80	0.76	1.00	0.80	1.00	1.00	1.00	2.00	3.00
45–60	0.95	0.83	0.80	0.80	0.80	1.00	1.00	1.00	1.00	3.00

* Horizontal distance from plant

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28

ROLE OF SOIL MANAGEMENT PRACTICES IN AFFORESTING DRY LANDS

G.N. Gupta & Premlal

With the heavy removal of tree cover, soil component of the environment has suffered the most. On hill slopes and valleys there has been massive loss of physical body of the soil itself leaving behind truncated soil devoid of productivity. In plains too continuous exposure of barren lands to rainwater, heat and trampling by animals and human beings have rendered the soil shallow, compact and impoverished in nutrients and moisture. Such soils fail to support plant growth and the task of vegetation establishment on wastelands of arid and semi-arid areas becomes further more difficult due to very hostile climate (low rainfall and high temperature) and heavy biotic pressure. Soil management practices to optimise nutrients and moisture supply and aeration, particularly, in the top soil layer which affects initial development of plants are very essential for

successful tree planting on drylands. Influence of fertilizer and moisture management practices on tree establishment is discussed in this paper.

Tree Establishment on Skeletally Degraded Dry Land

Field experiments to investigate the influence of moisture and nutrient management were carried out on a forest land representing drastically degraded scrub jungle in Coimbatore Forest Division of Tamil Nadu. Though mean annual rainfall of the area is 850 mm., most of it is received through north-east monsoon (October to December) in a few heavy showers, with the result, soil profile remains dry for most part of the year. The soil has abundant coarse fragments in the subsurface layer and plenty of boulders on the surface. The subsurface layer is poor in available phosphorus (7.7 to 18.4 kg P_2O_5 ha^{-1}). This situation often results in heavy mortality of seedlings.

Table 1 Effect of N, P and water conservation on survival of *Eucalyptus tereticornis* on a degraded dry land

	W_0	W_1	Mean	C.D.	(0.05)
P_0	69	87	78[b]	(W)	NS[a]
P_{10}	77	81	79[b]	(N)	7
P_{20}	74	72	73[b]	(P)	NS
Mean[c]	73	80	–	(W x N)	9
N_0	83	84	84[d]	(W x P)	12
N_{30}	63	76	70[d]	(N x P)	NS
	P_0	P_{10}	P_{20}	(W x N x P)	16
N_0	84	86	80		
N_{30}	71	72	65		

a Not significant
b Mean of four treatments (2N x 2 water harvesting
c. Mean of sixtreatments (2N x 3 Phosphorus)
d. Mean of six treatments (2 water harvesting x 2 Phosphorus)

An experiment was laid in randomised block design with treatments of moisture conservation (No moisture conservation and in situ moisture conservation by making bunds in chequer board design around each tree) and fertilizer applications comprised graded doses of nitrogen (0 & 30 kg N ha^{-1} as urea) and phosphorus (0,10 & 20 kg P_2O_5 ha^{-1} as single super phosphate) in triplicate. The tree growth recorded after a year indicated tremendous response of *Eucalyptus camaldulensis* to water conservation and phosphate application. The water conservation treatment improved the plant survival from 69 to 87% (Table 1). Whereas, application of nitrogen alone adversely affected plant survival and reduced it from 83 to 63%. The various treatments had tremendous influence on tree growth. The tree height increased from 128 to 176 cm due to water harvesting and 128 to 163 cm due to phosphate (Table 2). The combination of two had complementary effect and improved the tree height to 205 cm. The total above ground biomass increased about 3 times due to the water conservation treatment and nearly 2½ times due to the application of 10 kg P_2O_5 ha^{-1} (25 g single super phosphate per plant) (Table 3). Combining two treatments improved the total biomass to more than four fold. There was decline in biomass yield due to preplant application of nitrogen. Root growth improvements were also significant due to these treatments. The phosphate application increased the root weight by 2.5 times. Combining 10 kg P_2O_5 ha^{-1} and water conservation increased the root weight nearly seven folds (4.39 q ha^{-1} as compared to 0.66 q ha^{-1} in control).

Table 2 Influence of moisture, nitrogen and phosphorus on height of *E. tereticornis* (1 year old) on a degraded dry land due to various treatments

Treatments	W_0	W_1	Mean	C.D. at 5%	
P_0	128	176	152	W	11
P_{10}	163	205	184	N	NS
P_{20}	167	181	174	P	14
Mean	153	187	–	W x N	NS
N_0	151	187	169	W x P	20
N_{30}	155	187	171	W x P	NS
	P_0	P_{10}	P_{20}	W x N x P	28
N_0	153	180	169		
N_{30}	146	188	179		

P_0, P_{10} and P_{20} : 0,10 and 20 kg P_2O_5 ha^{-1}
N_0 and N_{30} : 0 and 30 kg N ha^{-1}
W_0 and W_1 : No water harvesting and water harvesting
NS : Not significant

Table 3 Influence of moisture, nitrogen and phosphorus on total dry biomass production (q ha^{-1}) of *E. tereticornis* (1 year old) on a degraded dry land due to various treatments.

Treatments	No water harvesting	Water harvesting	Mean		C.D. at 5%
P_0	3.61	9.99	6.80	W	2.26
P_{10}	8.68	14.75	11.72	N	NS
P_{20}	9.45	11.30	10.38	P	2.77
Mean	7.24	12.01	–	W x N	NS
N_0	7.26	11.25	9.26	W x P	3.92
N_{30}	7.23	12.77	10.07	W x P	NS
	P_0	P_{10}	P_{20}	W x N x P	5.55
N_0	7.22	11.25	9.30		
N_{30}	6.38	12.18	11.45		

In the subsequent season, response of 11 tree species of social forestry importance to above management practice was studied at the same site. Thus the experiment comprised 11 tree species and two management levels i.e. no management and management practice (water conservation technique + 25 g urea and 25 g single super phosphate per plant). Due to the management practice, the growth improvements were dramatic in 7 species. During the one year period of tree establishment, the increase in biomass varied from 5 to 22 folds (Table 4). The quantum of increase was 22 folds in *Eucalyptus camaldulensis,* 18 folds in *Acacia nilotica,* 5 folds in *Peltophorum pterocarpum,* 22 times in *Ceiba pentandra* and 6 folds in *Acacia leucophloea.* The root growth improvements were also tremendous due to the management treatment (Table 4). The increase varied from 2 times in *Peltophorum pterocarpum* to 12.5 times in *Eucalyptus camaldulensis.*

Table 4 Total biomass yield (q ha^{-1}) of one year old tree as affected by management practice

Tree species	Above ground biomass		Root biomass	
	Without management	With management	Without management	With management
A. nilotica	0.61	10.84	0.27	2.39
A. planifrons	1.76	9.97	0.41	3.60
A. leucophloea	0.59	7.45	0.63	4.30
E. camaldulensis	0.66	14.44	0.48	5.95
P. pterocarpum	3.59	18.13	3.29	6.68
C. pentandra	0.33	7.11	0.24	2.58
D. indica	0.22	1.13	0.29	0.86
E. cumini	0.25	2.42	0.25	0.86
T. indica	0.10	1.13	0.14	0.52
A. lebbeck	0.61	2.95	0.67	2.13
A. indica	0.26	0.60	0.19	0.47
C.D. 5%	Species	Management	Sp. X Management	
	6.22	3.90	5.52	

Tree establishment on impervious clay loam soil of a dry region

Another field study was conducted on an impervious clay loam soil having moderate to strong angular blocky structure and moist firm to very firm consistency. Thus, hardness coupled with dryness owing to poor moisture recharge of soil posed severe mechanical impedance to the growing roots of newly planted seedlings causing their mortality, often at a collosal scale. Influence of coirpith mulching coupled with application of 25 g each of urea and single super phosphate per plant was studied on tree establishment on this soil.

Dry conditions were so severe at this site that the moisture content values in the surface layer were in the range of 3.9 to 5.5% causing heavy mortality of seedlings (Figure 1). Of the ten tree species tried only *Peltophorum pterocarpum, Acacia nilotica* and *Acacia planifrons* maintained 60 to 65 percent survival. The management treatment improved the

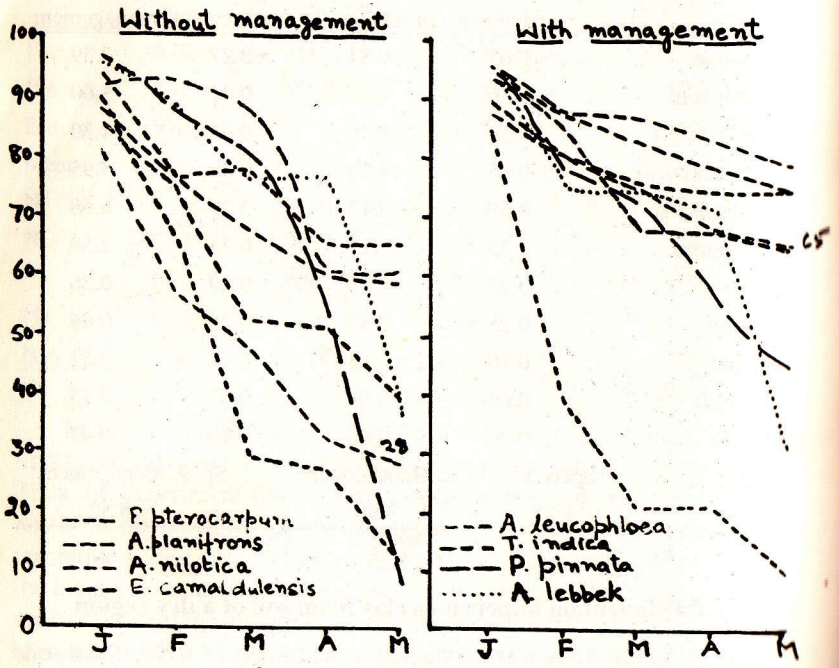

Figure 1. Effect of soil management on plant survival on a dry impervious soil.

survival of *E. camaldulensis* from 28 to 65%; *P. pterocarpum* from 67 to 79%; *A. nilotica* from 57 to 75% and of *A. planifrons* from 67 to 75%.

All other species but for the above four died completely or remained stunted even after 18 months of planting. The management treatment improved the plant height of *E. camaldulensis* from 50 to 93 cm, *Acacia nilotica* from 42 to 93 cm, *Acacia planifrons* from 35 to 84 cm, and *Peltophorum pterocarpum* from 30 to 61 cm (Table 5). These tree species registered appreciable growth increments in no management treatment too, indicating their ability to grow on such hard impervious soil.

Table 5 Height of 18 months old plants as affected by management practice.

Tree species	Without Management	With Management
P. pterocarpum	35	84
E. camaldulensis	50	93
A. nilotica	42	88
A. planifrons	29	61
CD (5%) Management		8
Species		14
Management x Species		19

The management treatment had tremendous influence on biomass accumulation, enhancing on average, 13 times the total above ground biomass and 6 times root biomass yield (Table 6). The quantum of response to management was maximum in *E. camaldulensis* (17 times increase) followed by 13.7 times in *Acacia planifrons*, 13 times in *P. pterocarpum*, 10 times in *Acacia nilotica*. The increase in root biomass was 17.5, 4.7, 2.5 and 6.3 times, respectively.

Table 6 Effect of management practice on biom ass accumulation (kg ha^{-1}) by one year old trees.

Tree species	WithoutManagement	With management	Mean		CD (5%)
	Total above ground biomass				
P. Pterocarpum	20.4	265.1	142.8	M	25.0
E. camaldulensis	13.1	222.5	117.8	Sp	93.3
A. nilotica	16.7	162.9	89.8	M x Sp	132.0
A. planifrons	8.3	113.3	60.8		
Mean	14.6	190.9			
	Root biomass				
P. Pterocarpum	30.6	75.6	53.1		
E. camaldulensis	9.4	164.3	86.9		
A. nilotica	7.5	47.5	27.5		
A. planifrons	5.6	26.3	15.9		
Mean	13.3	78.4			

Tree establishment on cracking clay soil (vertisol) in a dry region

At a site of cracking clay soil (vertisol), response of various tree species to the coirpith mulching and applications of nitrogen and phosphorus was studied during the initial establishment. It is seen that tree species varied significantly in their response to these treatments. All the ten species have responded to the mulching treatment except *Acacia leucophloea* and *Eucalyptus camaldulensis* (Table 7). The application of 25 g single super phosphate per plant has significantly improved the initial growth of the tree species except *Acacia leucophloea* and *Eucalyptus camaldulensis, Casuarina equisetifolia* and *Tamarindus indica* (Table 7). The preplant application of nitrogen has been detrimental to the initial growth of all the tree species except *Acacia planifrons.*

The combination of mulching and phosphate application greatly improved the growth of tree species. The magnitude of increase has been

Table 7 : Effect of coirpith mulch, nitrogen and phosphorus on biomass accumulation (g plant^{-1}) during tree establishment on dry vertisol

Tree species	M_0	M_1	C.D. 5%	N_0	N_{25}	C.D. 5%	P_0	P_{25}	C.D. 5%
A. nilotica	13.3	23.5	8.2	32.7	4.2	8.2	0.6	36.3	8.2
A. planifrons	46.1	172.8	40.6	84.1	134.8	40.6	42.8	176.0	40.6
A. leucophloea	1.5	2.0	6.7	2.3	1.2	6.7	0.7	2.8	6.7
E. camaldulensis	18.7	24.4	7.9	24.4	18.7	7.9	23.3	19.9	7.9
C. equisetifolia	7.7	22.9	6.0	21.3	9.3	6.0	15.9	14.8	6.0
C. pentandra	16.4	47.9	10.3	44.3	20.1	10.3	11.4	52.9	10.3
A. lebbeck	10.7	17.9	5.2	23.5	5.2	5.2	2.5	26.1	5.2
T. indica	2.2	5.9	2.1	4.1	4.0	2.1	3.4	4.7	2.1
A. amara	22.4	32.4	8.8	36.9	17.9	8.8	13.6	41.3	8.8
A. indica	13.8	16.0	2.8	21.6	8.1	2.8	11.0	18.7	2.8

M_0 and M_1: No mulching and mulching

N_0 and N_{25}: No Nitrogen and 25 g urea/plant

P_0 and P_{25} : No Phosphorus and 25 g single super phosphate/plant

several folds in *Acacia planifrons, Acacia nilotica, Ceiba pentandra* and *Albizia lebbeck.*

Above studies indicate that proper soil, moisture and fertilizer management practices are vital for the successful afforestation of dry wastelands. While these studies are only indicative, and highlight the importance of soil management practices in eco- restoration of wastelands, the site specific studies should be carried out for developing package of practices for each species.

The studies also indicate that while phosphate application and moisture conservation is vital for plant establishment on dry lands, the application of nitrogen should not be done unless water supply is ensured.

29

GROWTH AND DRY MATTER PRODUCTION IN RESPONSE TO APPLICATION OF TREE SEED OIL CAKES AS FERTILIZER IN DALBERGIA SISSOO SEEDLINGS

Adarsh Kumar, Uma Singh and P.S. Rawat

Introduction

Dalbergia sissoo Roxb., an important member of the leguminaceae family is the principal tree species of the forests in arid and semi–arid regions in India. On account of its strength, elasticity and durability, it is classed as one of the four primary timbers besides teak, sal and deodar. The species is most suitable for plantation on the sides of roads, canals, railways and on barren community lands in the villages. Though, considered a slow growing tree, under favourable conditions it grows fairly fast in the early stages of growth (Anon, 1968). The use of fertilizer has

been found to boost the growth of seedlings (Anon, 1977). However, due to their high costs, the use of inorganic fertilizer has still not become a common practice especially in case of forest tree plantation. Conventional organic manures like FYM have also some limitations. This calls for a cheaper alternative source of plant nutrients in the form of non-conventional organic manure. In this context, tree oil cakes (a by-product of oil extracting industries) have been found promising (Uma Singh & Gurumurti, 1984). Some studies have recently been carried out at Forest Research Institute, Dehradun indicating favourable effect of such cakes on the growth of various species, viz. *Tectona grandis* and *Pinus elliottii* (Bhatnagar and Gupta, 1977), *Acacia nilotica* (Uma Singh, 1984). In the present study, the effect of some deoiled tree cakes in context with inorganic nitrogen fertilizer on the growth and biomass production of *Dalbergia sissoo* seedlings has been evaluated and compared.

Material and Method

Healthy seeds of *Dalbergia sissoo* soaked in distilled water for over night were sown directly in 63 experimental earthen glazed pots at the rate of 3 seeds per pot. Potting medium consisting of forest soil and black sand in 1:1 ratio was mixed thoroughly. On the 5th day after sowing the seeds, 80 percent germination was recorded. Experiment was initiated in the month of July. When the seedlings attained the height of 12-15 cm, they were thinned to retain only one healthy seedling in each pot. Care was taken to have seedlings of almost equal height. The experimental pots were treated with deoiled cakes of castor, karanj, neem, mahua and sal meal. The last 7th group of pots was kept as control. Only tap water was given throughout the investigation.

The doses of conventional and non-conventional fertilizers were standardized so as to keep the uniform nitrogen supply to all the pots (equivalent to 100 kg N/ha). Nitrogen content of different cakes and the quantity of cake applied per pot is given in Table 1. Per cent nitrogen (N) content in cakes was analysed by Kjeldahl's method (Piper, 1966), phosphorus (P) by Colorimetric method (Vogel, 1961) and potassium (K) was determined by Flame Photometer (Hutton & Nye, 1958).

Table 1 NPK content in different cakes (%) and fertilizer quantity per pot at 100 kg N/ha

Conventional and Nonconventional fertilizers	NPK per cent in different cakes			Fertilizers quantity/Pot (in gm)
	N	P	K	
Nitrogen ($NH_4 NO_3$)	28	–	–	0.5
Castor	4.6	0.7	1.0	3.7
Karanj	5.4	0.9	1.2	3.1
Neem	5.2	1.0	1.4	3.3
Mahua	3.5	0.8	1.8	4.8
Salmeal	1.9	0.6	1.5	8.9

The soil in each pot (except control) was excavated around the seedlings upto the depth of 5 cms and was thoroughly mixed with the respective fertilizers (conventional and non-conventional) and then refilled in the same pot. The fertilizers were supplied only once at the beginning of the experiment. Experimental pots were regularly watered as and when required with 200 ml of water so as to avoid flowing out of the applied fertilizers from the pots. All the replicates of treatment of fertilizers and control were arranged in the glass house conditions, on the basis of complete randomized block design. Observations on height increment were recorded at monthly intervals, while the counting of leaves, branches and fruits was done at the end of the experiment.

Experiment was concluded after 12 months of initiation. On the completion of the experiment, the seedlings were taken out of the pots with intact root system. The roots were thoroughly washed with tap water to remove soil particles. Shoot and root portions of seedlings were separated. The roots were air dried in shade for two hours to remove the surface moisture. Shoots and roots were then kept in oven at 80° C for their dry weight determination till the constant weight was obtained.

Results and Discussion

(a) Growth and Development: The data on average height increment, root length, number of branches and fruits under different treatments are furnished in Table 2.

Table 2 Average height increment of shoot, root length, number of branches and fruits of *Dalbergia sissoo* seedlings under different fertilizer treatments

Treatment	Shoot height (cm)	Root length (cm)	No. of Branches	No. of fruits
Nitrogen	128.2	35.1	14.0	–
	(23.1)	(–15.8)	(215.8)	
Castor	143.9	37.2	19.5	–
	(38.2)	(–10.8)	(103.1)	
Karanj	138.4	40.4	15.6	–
	(32.9)	(–3.1)	(62.5)	
Neem	135.9	42.4	20.5	3
	(30.5)	(1.7)	(113.5)	
Mahua	146.9	46.1	18.5	2
	(41.1)	(10.5)	(92.7)	
Salmeal	133.0	46.9	11.5	3
	(27.8)	(12.5)	(19.8)	
Control	104.1	41.7	9.6	–
	*	N.S.	***	

Note : Figures in parenthesis show increase over control.

* Significant at 5%

*** Significant at 0.1%.

It is indicated that all the cakes and inorganic nitrogen gave significantly more height increment as compared to the control (Table 2). The best height increment was recorded with mahua cake (146.9 cm, 41.1%), followed by castor (143.9 cm, 38.2%), karanj (138.4 cm, 32.9%), neem (135.9 cm, 30.5), sal meal (33.0 cm, 27.8%), nitrogen (128.2 cm, 23.1%) and control (104.1 cm).

The length of tap root increased from 41.7 cm under control to 46.9 cm (i.e. 12.5% more) under sal meal. Mahua (46.1 cm, 10.5%) and neem cake (42.4 cm, 1.7%) also gave better results than control (41.7 cm). However, root development was adversely affected by Karanj (40.4 cm, –3.1%), castor (37.2 cm,–10.8%) and nitrogen (35.1 cm, –15.8%) as compared to control.

The efficacy of treatments with regard to number of branches was in the order : neem (20.5, 113.5%) > castor (19.5, 10.3%) > mahua (18.5

Table 3. Oven dryweight of shoots (stem, branches and leaves), roots and fruits of *Dalbergia sissoo* under different fertilizer treatments

Treatment	Stem	Branches	Leaves	Root	Fruit	Total dry wt. of shoot + root + fruit.
Nitrogen	6.9	1.2	2.6	4.5	–	15.2
	(40.8)	(20.0)	(242.1)	(40.6)		(53.5)
Castor	8.4	2.2	2.3	5.9	–	18.8
	(71.4)	(120.0)	(202.6)	(84.4)	–	(89.9)
Karanj	7.4	2.4	1.7	5.5	–	17.0
	(51.0)	(140.0)	(123.7)	(71.9)	–	(71.7)
Neem	6.9	1.3	1.9	6.1	0.07	16.3
	(40.8)	(30.0)	(150.0)	(90.6)		(64.6)
Mahua	12.0	1.8	2.9	8.7	0.15	25.5
	(144.0)	(80.0)	(281.5)	(171.9)		(157.6)
Salmeal	8.1	1.9	2.4	6.4	0.12	18.9
	(65.3)	(90.0)	(215.8)	(100.0)		(90.9)
Control	4.9	1.0	0.76	3.2	–	9.9
	*	*	*	*	S.A.N.D.	*

Note : Figures in parenthesis show increase over control

* Significant at 5% S.A.N.D. Statistical analysis not done due to insufficient data.

92.7%) > karanj (15.6, 62.5%) nitrogen (14.0, 45.8%) > salmeal (11.5, 19.8%) > control (9.6). The results are significant at 0.1% level of probability. The maximum number of fruits were produced due to *neem* (3.0) and salmeal (3.0) treated plants followed by mahua (2.0). Other treatments failed to produce fruits.

(b) Dry matter production : The maximum dry weight (12.0 gm i.e. 144.9% more than the control) of stem is produced by mahua cake followed by castor (8.4 gm, 71.4%), salmeal (8.1 gm, 65.3%), Karanj (7.4 gm, 51.0%), neem (6.9 gm, 40.8%), nitrogen (6.9 gm, 40.8%) and control (4.9 gm) (Table 3). Dry weight production by the neem cake treated plants was at par with inorganic nitrogen treated plants. Branch dry weight of treated plants was also significantly better as compared to the plants under control, in the following order : Karanj (2.4 gm, 140.0%) > castor (2.2 gm, 120%) > salmeal (1.9 gm, 9.0%) > mahua (1.8 gm, 80.0%) > neem (1.3 gm, 30.0%) > nitrogen (1.2 gm, 20.0%) > control (1.0 gm). The trend in dry weights of leaves is found in the order of mahua (2.9 gm, 281.5%) > nitrogen (2.6 gm, 242.1%) > sal meal (2.4 gm, 215%) > castor (2.3 gm, 202.6%) > neem (1.9 gm 150%) > karanj (1.7 gm, 123%) > control (0.76 gm). All the treated plants produced significantly better results in root dry weights as compared to the control, the best result being in mahua (8.7 gm, 171.9%) followed by sal meal (6.4 gm, 100%), neem (6.1 gm, 90.6%), castor (5.9 gm, 84.4%), karanj (5.5 gm, 71.9%), nitrogen (4.5 gm, 40.6%) and control (3.2 gm).

The sequence of dry weight of fruits under various treatments was in the order of mahua (0.15 gm) > salmeal (0.12 gm) > neem (.07 gm).

With regard to total dry matter production also, all the cake fertilizers and inorganic nitrogen have given significantly better results than control, the best being mahua cake which produced maximum total dry weight of 25.5 gm i.e. 157.6 percent more than the control. The performance of other treatments is in the order of castor (19.0 gm, 91.9%), salmeal (18.9 gm, 90.9%), karanj (17.0 gm, 71.7%), neem (16.3 gm, 64.6%), nitrogen (16.0, 61.6%) and control (9.90 gm).

(c) Efficacy of cake fertilizers vis-a-vis inorganic nitrogen :While reviewing the data in the preceding paras, it is clearly seen that the cake fertilizers have performed remarkably better than the treatment of inorganic nitrogen in respect of both growth and development of the seedlings as well as dry matter production. In height increment, the performance of

inorganic nitrogen was much inferior than that in cake fertilizers. In case of root development, the treatment of inorganic nitrogen gave negative results indicating 15.8% lesser growth of tap root than even control. Similarly, in total dry matter production, it has ranked last amongst all fertilizer treatments.

It has been reported in earlier studies also that nitrogenous fertilizers do not have much favourable effect on leguminous tree species and in some cases they may act adversely (Kushalappa, 1981, Uma Singh, 1986). The leguminous plants are more adapted to biological nitrogen through nitrogen fixing system of root nodules rather than absorbing the external nitrogen applied in the soil (Postgate, 1978).

On the other hand, deoiled tree cakes being organic fertilizers have many advantages over inorganic fertilizers. It has been seen that the dissolution of minerals and detoxication of harmful substances in the soil take place at increased rates in the presence of organic fertilizers (Jha and Rathor, 1984). The nutrients are released slowly thus making them available for plants for longer period. Leaching of plant nutrients is also reduced considerably in the presence of organic substance in the soil. These functions of organic fertilizers may be directly or indirectly responsible for creating proper growth conditions (Kaul and Sharma, 1981).

Table 4 Effect of different deoiled tree cakes on different growth parameters of *Dalbergia sissoo* seedlings.

Parameters	Highest response over control (percent)	With use of deoiled cake
Average height increment (cm)	41.0%	Mahua cake
Root length (cm)	12.2%	Salmeal cake
Number of branches	112.9%	Neem cake
Number of fruits	3.0	Salmeal at par with neem
Dry weight of stem (gm)	142.9%	Mahua cake
Dry weight of root (gm)	174.3%	Mahua cake
Dry weight of leaves (gm)	278.9%	Mahua cake
Dry weight of branches (gm)	14.6%	Karanj cake
Total dry weight	156.6%	Mahua cake

(d) Performance of various tree cakes : In the present investigation though the cakes were applied on the basis of equal quantity of nitrogen content in them, the response by the plants to different cakes was different (Table 4). Such differential response may be attributed to certain growth stimulating factors, other than nitrogen, present in the individual cakes, such as holding of nutrient ions to serve as nutrient reservoir, providing favourable pH, aeration and improving other physical and chemical properties of the soil.

Conclusion

The above results conclusively suggest that the application of deoiled tree-cakes, as organic fertilizer, enhances the growth and biomass production of *Dalbergia sissoo* seedlings. Among various tree-cakes, *mahua* has been found the most effective in this regard. It is also brought out that *D. sissoo* being a leguminous species, does not respond well with the use of inorganic nitrogen fertilizer. The study has proved the good potentiality of deoiled tree-cakes as an effective and much cheaper source of plant nutrients.

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GROWTH AND COVER DENSITY OF KHEJRI (*PROSOPIS CINERARIA*) IN ARID ZONE

R.P. Dhir, S.K. Saxena and J.R. Sharma

Khejri (*Prosopis cineraria*) is the most prominent tree of the arid zone. Insensitivity to drought because of its very deep root system, tolerance to extremes of temperatures, amenability to logging, nutritious nature of its foliage and pods, utility value of the wood, resistance to the widespread termite menace and many other qualities make this a venerated and highly useful tree species of the desertic tract. Investigations have shown that the stand of the tree does not interfere with crop husbandry. In fact, the growth of crops and natural vegetation has been found better under the canopy of the tree than in the intervening space (Saxena, 1980). It is, therefore, not surprising that desert dwellers not only maintain but consciously promote the stand of Khejri in their agricultural holdings. The present exclusive status of Khejri in arid zone is attributable to its adaptability to environmental setting on one hand and to the selective

management on the other. A compilation of the available information on various aspects of the precious tree has been made by CAZRI in the year 1980 (CAZRI, 1980). The growth and stand of this tree is not uniform over the entire region. A number of edaphic characteristics as well as mean annual rainfall seem to exercise control in this respect. The present paper describes the growth of Khejri in relation to salinity and depth of soil and goes further to show the current cover density based on remote sensing techniques.

Growth in relation to edaphic characteristics

SOIL TEXTURE

The sandy texture is dominant in soils of arid zone, yet there are sizeable areas particularly in Pali, Jalore, Nagore and Jodhpur, where medium and fine textured soils co- occur with sandy soils. This situation affords an excellent setting for growth comparison of Khejri tree. The information in this respect is summed up in Table 1. It will be seen that sandy to sandy loam soils permit an optimum stand as well as growth of Khejri. Increasing clay content thereafter leads to reduction particularly so in respect of growth with clayey soils showing very sparse cover and very poor growth. Though soil physical condition could have some moisture availability in lower part of soil profile the major contributing factor. Because of very high water holding capacity (32-43%), rainfall in most years is able to wet the upper part only. The relatively dry sub-soil of clayey lands is not favourable for survival during the prolong dry period. Many such lands in Asop in Jodhpur Dist., Merta City area in Nagore are lying nearly tree less whereas not far away in Degana-Khunkhuna the sandy soils possess some of the finest areas of Khejri.

Table 1 Growth of Khejri in relation to texture of soil

Soil texture	Growth of Khejri
Sandy-loamy sand	Optimum stand as well as growth
Sandy loam	Optimum stand as well as growth
Loam	Somewhat restricted stand and growth
Clay loam	Somewhat restricted stand and considerably reduced growth
Clay	Sparse stand and very poor growth

SOIL DEPTH

Surface soil in arid zone is dry for 9 to 10 months in a year. Therefore, a deep root system is a pre-requisite for survival and growth. However, many soils have root restricting layer at some depth. The results of observations made course of surveys are summed up in Table 2. The best growth is achieved on sites with deep soils and pervious strata. Soils with soft lime nodules during the sub-soil or sub-strata are also no hindrance to root system of Khejri. However, thick, hard, lime concretionary strata, particularly indurated ones permit penetration of root system at occasional weak zone only. Therefore, growth and stand get adversely affected, the magnitude depends on depth of occurrence (Table 2). Presence of such a strata below 80-100 cm depth only slightly affects growth but thereafter the decline is very rapid with decreasing depth. The sandy soils in Luni, Mandore and Osian Blocks of Jodhpur, Kalyanpur area of Barmer, or Alai-Deh area of Nagore are only some examples of this situation. Soils with a thickness of 20 to 40 cm above indurated strata as occur in Kolu area, Pokaran - Phalsund - Shivana or Bap - Nokha area have very sparse stand and highly stunted growth. The gravelly - rocky plains have growth of Khejri only along runnels and in depressions.

Table 2 Soil depth and growth of Khejri

Soil depth	Growth of Khejri
Very deep soils with pervious sub-strata	Optimum stand and growth
Very deep soils with soft lime nodules in sub-soil and sub strata	Optimum stand and growth
Very deep but with strongly developed lime concretionary strata at 80–100 cm depth	Optimum stand but somewhat restricted growth
Same as above but with concretionary strata at 40 cm depth	Greatly reduced stand as well as growth DBH is often 20 to 30 cm only
Same as above but depth of 20 cm.	Very sparse stand and extremely poor growth, DBH is often 10 to 20 cm. only

Gravelly, rocky plains and exposed kankar pans	Well grown trees found only in runnels and depressions

SOIL SALINITY

Khejri may not put up a grand growth in adverse habitats, but its survival is remarkable. In soils with profile ECe in range of 4-8 dSm^{-1}, growth is affected to some extent. Whereas with ECe in range of 18 dSm^{-1} or so there is a drastic reduction. Presence of a non-saline aeolian hummock permits some growth even in highly saline situations.

Growth in relation to mean annual rainfall

The growth and stand of Khejri is the finest in the 400 to 450 mm rainfall zone and deep sandy soils of Nagore, Sikar and Jhunjhunu. Here, the lands look a woodland. With decreasing rainfall, the density and growth decline. But even the 250 to 300 mm rainfall zone possesses an appreciable stand of Khejri though with much less growth, except in aerable location like younger alluvial plains, nadis or well irrigated lands (Shankar, 1980). Below 200 mm rainfall isolyet, the stand also greatly declines. Here good growth/stand is confined to interdunal depressions, nadis and foot plains of hills. Prakash and Gupta (1976) have reported an unusually dense stand of Khejri in 100 mm or so rainfall zone of Jaisalmer, This is associated with existence of good quality water at shallow depth.

Current cover density

Though wide-spread occurrence of Khejri is a common knowledge, quantitative data on distribution and growth is scarce. One exercise has been made by Shankar (1980) wherein a large number of sites were studied for density of Khejri and based on this data a generalized map was prepared employing large extrapolation. However, many sampling sites were situated in grazing lands, 'orans' or 'birs'. The data were collected in tunes of number of trees per hectare and since the common life- form of Khejri in such situations is of the prostrate, shrubby or bushy, this alone does not convey an idea of the crown cover. Besides, as indicated above large scale generalisation obscured substantial variability which does exist in field related to site specific exploitation or management care. Therefore, need for factual measure of abundance still remains. The present approach is a step in this direction.

Remote sensing satellites carry advanced radiometers with radiometeric levels ranging from 128 in IRS - IA to 1024 in NOAA. Therefore, these are able to record even small differences in radiation reflected from land. Further, it has been shown that ratioing of radiance in red and infrared bands is able to maximise the reflectance contrast between green vegetation and other materials. Therefore, a number of spectral vegetation indices based on red-infrared reflectance have been developed to represent apparent surface greenness and empirical relationship has been found between them and vegetation characteristics like photosynthetic activity, biomass production, leaf area index, vegetation water content and so on. Tucker and Justice (1986) could find an effective use of normalised difference vegetation index(NDVI) (IR-R)/(IR+R) very useful in monitoring seasonal advancement and retreat of vegetation in Sahara region. Likewise, Heute Jackson (1987) found NDVI quite sensitive to biomass changes in low range of abundance.

METHODOLOGY

NOAA data, because of its small ground resolution (= 1 Km), was preferred for this regional mapping because it offsets the need for generalisations otherwise necessary in satellite data of better ground resolution. Further, first week of December was chosen as the period of data for a number of reasons. Firstly, that Kharif crops are harvested and even left over crop residues are also grazed out well before this period. *Ziziphus*, which grows in sizeable areas is also cut for dry fodder. The crop in irrigated areas is young enough as to cause minimum interference. The mapping of Khejri, an annual feature, only regimes in late December and, therefore, maximum foliage of Khejri does exist. The NOAA data was processed for NDVI and displayed on image display work-station. The data was linearly stretched for enhancement of range of NDVI values.

RESULTS

A map derived from colour out put is shown in Figure 1. The original colour out put showed even subtle variations both on spatial and cover density scales. However, to simplify the map these have been ignored.

The results show that maximum cover density is present in Degana, Didwana, Kuchaman, Parbatsar areas of Nagore and again around Sikar. It is quite possible that some pockets as near Osian of this class are due to presence of irrigated fields. Despite these shortcomings, the cover density of Khejri has been shown in a convincing manner. It also vividly

shows the decrease in cover density from east to west with decreasing mean annual rainfall. The large patch of sparse cover near Kalyanpur and again Kolu, Pokaran, Phalsund area is due to the presence of shallow soils which indeed are a poor habitat for growth of Khejri.

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COMBATING DESERTIFICATION THROUGH AFFORESTATION

Rajiv K. Sinha

"Forests precede men, desert follow them"- said Chateaubriand, the 18th Century French philospher. The vestiges of Harappan civilization which stand in a barren desert today is an evidence to prove it. Faced with grave ecological problems, like population explosion, environmental pollution, depletion of rain forests, degradation of productive lands and desertification it has become a compelling need for mankind to restore the deserts back to forest and avert the unforseen ecological disaster which might strike the present human civilization.

Deserts are part of that arid zone on earth which comprise nearly one third of earth's surface. They are of two types in India- (1) The hot arid land covering about 3,000,000 Km^2 of western Rajasthan, Gujarat, South-western Punjab, Harayana, parts of Karnataka and Andhra Pradesh and (2) The cold arid land of Ladakh and North- West India covering 1,000,000 Km^2. The major part of arid land in Rajasthan is a hot desert

and is characterized by long history of human settlements. The present paper discusses about some of the strategies to be adopted to fight desertification in Rajasthan through afforestation.

Afforestation in Rajasthan desert which suffers from water-stress and salinity and where temperature often rises to 51°C in summers and sand storms blow high is indeed a challenging task. The ecosystem of the region is extremely fragile, with poor scanty vegetation amongst increasing human and livestock population. It suffers from a great population pressure for meeting the basic needs of local inhabitants. The producers are unable to maintain a balance with the consumers and this has threatened the estabilisation of the entire desert ecosystem. To add to the misery of the desert is their over exploitation for mineral resources. This has resulted into large scale soil erosion. This, along with the shifting sand-dunes of the desert are the major factors in their expansion i.e. desertification. To combat desertification, sustain the human & livestock population and maintain an ecological balance in the region, afforestation is the only answer.

The Strategy

Scientific selection of fast growing multipurpose plants with higher biomass; seggregation of pasture and energy plantations from the green wood; management of water resources and conservation through peoples participation are some of the strategies needed for the success of any afforestation programme.

Multipurpose plants would provide all the basic needs-food, fodder, fuel, fibre, fertilizer and timber to the poor inhabitants. Besides, such plants should also work as "Sand- binders" and "Wind-breakers" which is an important requirement in the desert environment. Scientifically these plants should-

(1) Be less transpiring to conserve water

(2) Have higher efficiency of photosynthesis and avoid photorespiration, (C_4 plants are suitable).

(3) Be capable of growing in impoverished soil, saline soil, higher temperature and water-stress conditions and survive the extreme storms and sand blows.

(4) Work as a "natural pollutant sink" to absorb toxic gases from the atmosphere.

There are plants already existing in nature possessing a good number of the above qualities and only need to be identified. Others can be produced through selective breeding programme. Neem (*Azadirachta indica*), Jojoba (*Simmondsia chinensis*), Khejri (*Prosopis cineraria*), Rohida (*Tecomella undulata*), Ber (*Ziziphus nummularia*), Dhadun (*Sesbania grandiflora*), Amla (*Phyllanthus emblica*), several species of *Acacia* and *Leucaena leucocephala* are only few examples of multipurpose plants which can be successfully grown in these regions. Neem and Jojoba are known absorber of toxic pollutants.

Separate growth of fuel wood and fodder plants and their limited exploitation upto their regeneration capacity is of vital significance in the protection of the green wood. The cutting cycles of the fuelwood should be periodical and not indiscriminate. Villagers have also to be educated to avoid free grazing and feed their cattles by handcut grasses. The protected pasture yields 7 to 8 times more fodder.

With meagre rainfall in desert, surface water resources can hardly be relied upon for afforestation. Simple measures like construction of "Small Reservoirs" and "Checkdams" can help. The Indira Gandhi canal running to 445 km in the desert with 7875 km of distributaries and the discovery of rich "aquifers" (water bearing rocks) in some parts of Rajasthan desert have added a new hope for greening the desert and checking its expansion.

The most important part of any afforestation programme is its conservation. Ever since the amended Forest Policy Act of 1988 came into force, prohibiting the local inhabitants to draw their daily requirements of livelihood from the forest, they feel alienated. These poor people have no option. History is evidence that the poor illiterate forest-dwellers, consider forest as their means of survival and would never destroy it. The forest is being destroyed due to encroachment of the rich, civilized people to satisfy their greeds. The 1952 Forest Policy Act aimed at ensuring "environmental security and maintenance of ecological balance". The choice is between sustainable management policy with the support of local people or the surreptitious vandalism and death of forest.

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ROLE OF NATURAL VEGETATION COVERS IN IMPROVING THE PHYSICO - CHEMICAL STATUS OF ARID RANGE LANDS OF WESTERN RAJASTHAN

B. D. Sharma, A.K. Bawa and I.C. Gupta

Introduction

Indian arid rangelands have large natural pastures of promising grasses viz. 'Sewan' (*Lasiurus sindicus* Henr), 'Dhaman' (*Cenchrus ciliaris* Linn) and boor (*Cenchrus jwarancusa* Jones, Schult) and number of multipurpose trees i.e. 'Khejri' (*Prosopis cineraria* (Linn Mc Bride), Bordi (*Ziziphus nummularia* Burn F, wt & Arn) and Hingota (*Balanites aegyptiaca*). These plants have variations in their rooting pattern, quantity of litter fall and phenology, consequently their effect on chemical properties of soil under their canopy and rhizosphere are found to be different. The soil under the plant cover is therefore, nutritionally improved than adjacent bare soil (Bjerregard, 1974). Grasses by nature have major roots in surface layer so the changes in the soil fertility are prominent in upper

layer, whereas, in the trees, bulk root biomass penetrates to the deeper layers of the soil, therefore, the changes in soil properties take place in deeper horizons.

Some studies have been conducted in the past, separately either for grasses(Dhir and Gajbhiye, 1970) or for trees (Aggarwal *et al* 1976; Aggarwal and Lahiri, 1977) but no comparative study has been undertaken which could highlight the relative changes in physico-chemical properties of the soil.

Materials and Methods

The soil samples were collected from an area of western Rajasthan between 27° 28' to 29° 36' N latitude and 73° 32' to 75° 06' E longitude with predominantly *Z. nummularia, P. cineraria* and *B. aegyptiaca* tree covers and *L. sindicus, C. ciliaris* and *C. jwarancusa* grasslands. The soil texture was sandy having more than 90% sand content. Five spots were selected randomly at each study site and five plants of *Z. nummularia, P. cineraria* and *B. aegyptiaca* were used as reference points while in grasslands five well dominated patches of grasses under reference were selected. In the case of tree cover, the soil samples were collected within 1 metre radial distance from the stem. Soil samples from bare dunes were also collected for comparing the fertility changes as affected by tree and grass cover.

Soils were sampled at three depths viz. 0 to 15, 15 to 30 and 30 to 60 cm and approximately 0.5 kg of soil was collected from each depth. In all surface samples, superficial organic debris was removed prior to sampling. Soils were sieved to remove root material prior to chemical analysis. The soil samples were analysed for total N, available N, P & K; pH, EC, exchangeable calcium, magnesium and sodium; and important physical properties as per standard laboratory procedures.

Results and Discussions

Effect of tree cover : Soil pH was neutral to slightly alkaline having pH 7.8 under *Z. nummularia*, 8.3 under *P. cineraria* and 8.2 under *B. aegyptiaca* covers, whereas, it was 8.2 in barren dune soil. Organic matter increased several times than bare dune and it was highest under *B. aegyptiaca* (0.48%) followed by *P. cineraria* (0.47%) and *Z. nummularia* (0.25%). Total N increased to 0.05, 0.04 and 0.03% under *Z. nummularia, P. cineraria* and *B. aegyptiaca* respectively, compared to 0.007% in bare dune soil.

Available N was highest under *Z. nummularia* (230 kg ha^{-1}) followed by *P. cineraria* (227 kg per ha^{-1}) and *B. aegyptiaca* (195 kg per ha^{-1}). Available P was same under all trees and it was maximum under *P. cineraria* (18 kg ha^{-1}) and *B. aegyptiaca* (16.0 kg per ha^{-1}) and least in barren dunes (7.5 kg ha^{-1}). Available K was 0.78, 0.75 and 0.65 [c mol (p+) kg^{-1}] under *Z. nummularia, P. cineraria* and *B. aegyptiaca* respectively, and least in barren dune 0.40 [c mol (p+) $100g^{-1}$]. Exchangeable $Ca^{2+} + Mg^{2+}$ constituted about 80% of base exchange capacity which was highest under *B. aegyptiaca* [4.8 c mol (p+) kg^{-1}] followed *P. cineraria* [4.4 c mol (p+) kg^{-1}] and *Z. nummularia* [4.1 c mol (p+) kg^{-1}] and least in barren dunes [1.90 c mol (p+) kg^{-1}]. The sub surface pattern of the organic carbon, total N and available N, P & K was same and decreased at deeper layers (Table 1). The pH of the soil at deeper layers slightly increased under all covers.

Effect of grass cover : Soil pH did not change much, however, pH under *C. ciliaris* reduced slightly in comparison to bare dunes. Organic matter increased under pasture land and was highest under *C. ciliaris* (0.16%) followed by *C. jwarancusa* (0.15%) and *L. sindicus* (0.13%) in comparison to bare dunes (0.03%). Total N was highest under *C. jwarancusa* (0.02%) followed by *L. sindicus* and *C. ciliaris* grasslands (0.01%) and quite low in barren dunes (0.007%). Available N was highest under *L. sindicus* (160 kg ha^{-1}) followed by *C. jwarancusa* (130 kg ha^{-1}) and *C. ciliaris* (120 kg ha^{-1}) and it was also very low in barren dune (87.5 kg ha^{-1}). Available P increased marginally under grass cover in comparison to adjacent barren dune, though it was highest under *C. ciliaris* (10 kg ha^{-1}). Available K also increased marginally and was highest under *L. sindicus* [0.53 c mol (p+) kg^{-1}] followed by *C. ciliaris* [0.49 c mol (p+) kg^{-1}] and *C. jwarancusa* and barren dunes [0.40 c mol (p+) kg^{-1}]. Exchangeable $Ca^{2+}+Mg^{2+}$ were more or less same under all grass covers but about two times higher than barren dunes [1.90 c mol (p+) kg^{-1}].

Effect of tree and grass cover on physical properties of the soil.

The soil texture under trees and grass cover did not change over the time even though percentage of fine particles (silt & clay) increased under tree and grass cover as compared to barren dune soil (Table 2). Water holding capacity increased under tree (26.6%) and grass (24.8%) cover

Table 1 : Soil chemical properties under trees, grasses and bare dunes

Soil properties	Depth (cm)	Tree cover			Grass cover			Bare dunes
		Z. nummularia	*P. cineraria*	*B. aegyptiaca*	*L. sindicus*	*C. ciliaris*	*C. jwarancus*	
pH	0–15	7.8	8.3	8.2	8.3	7.6	8.0	8.2
	15–30	8.0	8.5	8.2	8.0	7.6	8.0	8.2
	30–60	8.2	8.7	8.4	8.0	8.1	8.0	8.2
O. C. (%)	0–15	0.25	0.47	0.43	0.13	0.16	0.15	0.03
	15–30	0.13	0.38	0.35	0.07	0.10	0.15	0.03
	30–60	0.13	020	0.30	0.07	0.08	0.15	0.03
EC dSm^{-1}	0–15	0.34	0.4	0.44	0.31	0.32	0.40	0.30
	15–30	0.34	0.36	0.39	0.32	0.31	0.41	0.30
	30–60	0.35	0.36	0.36	0.32	0.32	0.32	0.29
Total N (%)	0–15	0.05	0.04	0.03	0.01	0.01	0.02	0.007
	15–30	0.03	0.04	0.03	0.009	0.009	0.02	0.006
	30–60	0.01	0.01	0.01	0.008	0.007	0.015	0.007

Table contd...

Soil properties	Depth (cm)	Tree cover			Grass cover			Bare dunes
		Z. nummularia	*P. cineraria*	*B. aegyptiaca*	*L. sindicus*	*C. ciliaris*	*C. jwarancus*	
Available N ($kg\ ha^{-1}$)	0–15	230	227	195	160	120	130	87.5
	15–30	160	200	179	130	100	110	82.0
	30–60	160	120	120	130	100	110	89.0
Available P ($kg\ ha^{-1}$)	0–15	17.0	18.0	16.0	9.0	10.0	8.0	7.5
	15–30	15.0	15.0	15.0	11.0	8.0	7.0	7.3
	30–60	11.0	11.4	11.9	6.0	8.5	6.5	7.5
Available K ($kg\ ha^{-1}$)	0–15	0.78	0.75	0.65	0.55	0.49	0.46	0.40
	15–30	0.70	0.68	0.50	0.45	0.50	0.36	0.39
	30–60	0.67	0.69	0.56	0.39	0.39	0.35	0.39
Exch. Ca+Mg ($me\ 100^{-1}\ g$)	0–15	4.1	4.4	4.8	3.8	3.5	3.0	1.90
	15–30	4.1	4.5	4.0	3.2	3.6	2.60	1.75
	30–60	4.3	5.1	4.9	3.5	3.0	2.90	1.82

over barren dune soil (20.6%). The infiltration rate decreased under tree (6.3 cm hr^{-1}) and grassland (6.5 cm hr^{-1}) in comparison to barren dune soil (8.5 cm hr^{-1}). The field capacity of soil under tree and grass covers increased in comparison to barren dune soil (Table 2).

Table 2 : Effect of tree and grass cover on soil physical properties.

Soil properties	Barren dune soil	Tree cover	Grass cover
Sand (%)	95.6	92.8	93.6
Silt (%)	2.1	3.0	3.1
Clay (%)	2.3	4.2	3.3
WHC (%)	20.6	26.6	24.8
Field capacity (%)	5.4	8.0	7.5
I. R. (cm hr^{-1})	8.5	6.3	6.5

The variation in soil chemical properties due to different covers was narrower in sub-surface layers (15-30 and 30-60 cm depth) in comparison to surface soil (Table 1). The magnitude of the nutrient concentration in sub surface layers is also low as compared to surface soil.

The variation in soil chemical properties in respect of different grass covers is obvious because each grass has different amount of leaf fall and composition of the leaf litter (Dhir *et al.* 1984). This study suggests that sandy desertic soils should be put to silvipastoral use for improving soil environment and productivity, rather than pure pasture.

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33

RECLAMATION OF DEGRADED LANDS THROUGH AERIAL SEEDING

Ram Prasad

Aerial seeding is very effective method of afforesting sites which are inaccessible and difficult for physical movement characterised with rugged terrain or sparse population rendering seeding/planting by conventional methods difficult. However, aerial seeding of forests has yet to catch up because its role has not been adequately appreciated in the restoration of degraded areas. This technique deserves increased testing and research specially in areas where the task of reforestation is stupendous.

Aerial seeding in Chambal ravines commenced in 1980 and has since been continuing in Madhya Pradesh. Afforestation of more and more areas has become essential in view of the existence of extensive wastelands in the country.

Such a programme must be preceded by operation like demarcation of areas to be aerially seeded, soil working, if necessary, advance arran-

gement of quality seeds, sometimes pretreated. Generally, two types of aircrafts are being used for aerial seeding viz., Weaver and Basant, but both have certain limitations.

Much remains to be done after seeding operations are over. There is grazing incidence and other types of biotic pressures. For this it is necessary to have the support of local population.

Experiences

Aerial seeding first began in Gujarat in 1950. However, the details about the area covered, species used and success or failure are not available. Aerial seeding in Chambal ravines were resorted to in 1980 when 503 hectares of Chambal ravines of Madhya Pradesh were covered using seed mixture of *Prosopis chilensis, Acacia nilotica, A. catechu, Holoptelea integrifolia,* etc. Aerial seeding in Chambal ravines has since been continuing with some alterations in number of species in the seed mixture, seed rate, seed pre-treatment, soil working intensity etc. Till the year 1988 about 70,000 hectare area of Chambal ravines has been seeded and reseeded by fixed Wing aircrafts (Basant and Weaver). Aerial seeding was also done in the adjoining areas of Agra district in Uttar Pradesh and Dholpur area of Rajasthan during 1982-83. Species, seed rates and pre sowing treatments were identical. Aerial sowing was also resorted to enrich degraded forests in Chandrapur and Pune districts of Maharashtra where seed mixture of Bamboo (*Dendrocalamus strictus*) and trees were sown during July 1983 and 1984. Except for these four states, aerial seeding, though planned to be taken up in many other parts of the country, could not be executed.

The experience of aerial seeding of degraded areas in India has provided many lessons on which the future programme could be chalked out. Failure to protect the areas from grazing have resulted in browsing and trampling of thousands of seedlings which come up after sowing. Another difficulty which has been experienced is lack of proper seed bed in the area to be seeded. For this purpose the pelletisation of seeds and creation of soil and moisture conservation measures, as have been successfully tried in Chambal ravines of Madhya Pradesh, may be emulated and tried.

The past experiences summarised briefly are

- the results of the aerial seeding programme during 1980-88 indicate that location specific modifications have to be made in the technique of aerial seeding. This applies to pre-seeding operations like soil working and other seed bed preparation measures, seed treatment, selection of plant species, selection of equipment (i.e. types of aircrafts and hoppers to be used) and post seeding operations like fertilizer application, weeding, insecticide application, etc.
- the project estimate must include all the costs of the pre-seeding and post seeding operations.
- the villages in the vicinity, voluntary social service organisations should be involved in a constructive way.
- selection of species should include grasses, minor legumes, shrubs and trees.

Areas for Aerial Seeding

Approximately 10 to 15 million hectares of forest area in the country is either devoid of vegetative cover or has sparse vegetation. Aerial seeding programme appears to have greater scope for application in enriching degraded forests and restoring vegetal cover to the denuded hill slopes. Large areas of degraded forests are available in the Himalayan ecosystem. An estimate shows that 60-70 per cent of forest areas in Karnataka, Orissa, Madhya Pradesh, Assam, Mizoram, Meghalaya, etc have extensive degraded forests. Most of the unclassed forests, revenue wastelands and protected forests are degraded. Sand dunes and ravinous areas which are highly eroded with deep gorges and pose problem in physical movement.

Selection of Areas and Site Preparation

The preliminary selection of potential areas for seeding must be initiated at an early stage. These areas should be selected one year in advance so that the preparatory works could be carried out well in time. Such areas should be appropriately demarcated on the ground. Once the area has been finally selected, surveyed and demarcated, soil and water conservation works are taken up. These preparatory works are absolutely

essential for creating receptive seed beds for the germination of tiny seeds and subsequent survival of the germinants. Many areas where physical movements are not easy as for example in Chambal and Yamuna ravines, manual soil working may not be a feasible proposition. However, construction of soil and water conservation devices and small watersheds may provide receptive seed bed due to silting.

Seed Bed Preparation

Creation of a receptive seed bed is pre-requisite for any seeding programme. Proper seed bed conditions are necessary to hold the seeds for germination and subsequent growth of the germinants. The type of operation for creating receptive seed bed may be by burning of slash, ploughing, hoeing and similar other measures. Site preparation and the seeding operation must be well coordinated to meet the biological requirements for prompt seed germination and seedling survival. Dry sites may have to be specially ridged or disked so as to optimise the rainfall that reaches the seed, excessively wet sites may need to be ridged or drained.

Seed Supply

Seed is the most important input into the aerial seeding programme and as such only seed of the highest possible quality should be used. The good quality seed production areas need to be identified well in advance. Timely harvest of seeds, drying, cleaning, grading, storage and pre-treatment before sowing are to be planned so that the programme can be commenced with the onset of monsoon.

As a pre-requisite to any method of afforestation the species selected must be adapted to factors like temperature, length of the growing season, rainfall, humidity, photoperiod and other environmental characteristics of the area.

A large number of species have been tried in the aerial seeding programme of Chambal ravines (Madhya Pradesh, Rajasthan and Uttar Pradesh). In the pilot seeding programme taken up for stabilising sand dunes in Rajasthan, the seed mixture was comprised of trees, shrubs and grasses. Similarly, aerial seeding programme in Chandrapur and Pune districts in Maharashtra included Bamboo, tree species and *Stylosanthes hamata.*

In denuded areas like Chambal ravines, the most successful species in terms of germination and survival have been *Prosopis juliflora, Acacia nilotica, A. catechu.* Among these three successful species, 80 per cent of the germinants were of *P. juliflora*; 15-18 per cent of *Acacia nilotica* and hardly 2-5 per cent *Acacia catechu.*

Seed Dispensing : Aircrafts and Other Accessories

Today aerial seeding is already regarded as a practical reforestation technique in a few industrialised countries. There it is fully operational. More than a million hectare of well stocked forests in the United States, Canada, Australia and New Zealand demonstrate its success.

Some problems like loss of seeds through predation by a variety of animals is there. However, this problem can be overcome by mixing repellents. Pretreatments are very helpful. Seed pelletisation has been advantageous.

Generally two types of aircrafts are being used for aerial seeding viz., Weaver and Basant. Since both these aircrafts are quite old and require considerable maintenance, they need to be replaced by newer type. Several newer aircraft designed specifically for aerial application work are available with a wide assortment of attachments, making them adaptable to virtually any application need.

There are some other problems like lack of proper flagging, inadequate ground crew, oversized maps, etc.

Aftercare

Much remains to be done after seeding operations are over. Aerial seeding results into several hundred plants per hectare. However, only a small population of 200-300 plants per hectare survive.

There may be several reasons for the low survival of the tiny germinants. Lack of receptive seed-bed and moisture stress conditions prevailing during major period of the year appear to be responsible for large scale mortality in young germinants. Those seedlings which survive on account of their being in sheltered depressions are trampled and grazed by stray animals as unrestricted grazing is rampant in forest areas. The established seedlings and saplings which survive the menace of grazing are illicitly cut to meet the local requirements of fuel and fodder.

Since aerial seeding is done over large areas it may not be possible to protect them by erecting any kind of effective fencing. For the success of the programme, the only alternative therefore, is through enlisting the support of local villagers. In addition to fencing wherever feasible, employment of local people for watch and ward may ensure protection to the areas. Some measures required as after care are :–

— Grazing protection measures should be planned and implemented in such a way that it is effective for 4-5 years and has full support of the local people. This can be done in a number of ways such as keeping watch and ward, where possible CPT, barbed wire, and such measures may be adopted. The concept of social fencing could also be applied. Unless the needs of the people are met, no protection device is complete, so provision has to be made to meet the bonafide needs of the population.

— Grasses often invade aerially seeded areas. Free cutting of grass may be permitted. This would not only minimise the risk of suppression of germinants by tall grasses but would also reduce the chances of fire.

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AFFORESTATION OF RAVINES

M.C. Prajapati and L.S. Bhushan

Introduction

Gullies along a river are termed ravines. In India ravines occupy 39.75 lakh hectares in the states of U.P. (12.30), M.P. (6.83), Rajasthan (4.52), Gujarat (4.00), Bihar (6.00), Punjab and Haryana (1.20), Himalayan foothills (1.93), West Bengal (0.04), Orissa (1.13), Maharashtra (0.02) and Tamilnadu (0.60 lakh ha) (Bali, 1985). Over 90 percent of the ravines are confined to the Indian part of the Great plains which, itself is a trough filled with alluvium. Climatically the Great plains fall in sub-tropical zone with annual precipitation ranging between 500 and 1500 mm. The ravines in India are thus a phenomenon of alluvium in the sub-tropics. Due to massive loss of physical body of soil and impoverishment in nutrients, soil moisture and local climate, the ravines are considered to be the worst form of desertification. For this reason the ravine-vegetation is dominated by xerophytic species of *Capparis, Ziziphus* and *Acacia* making it Tropical Ravine Thorn Forests (Champion

and Seth, 1968). Perpetual breeding of dacoity in ravines further indicates that desertification of land has also deserted the socio-economic and human ethics of the ravine inhabitants. Forests, through their above-the-ground, on-the-ground and under-the-ground actions, not only control soil erosion and restore soil fertility, soil moisture regime but also ameliorate climatic conditions and buildup socio-economic prosperity and consequently the human ethics. The salvation of these problems, thus, lies in afforestation of ravines.

Ecological Status of Ravines

Ecological studies have revealed that in most ravinous tracts e.g. Yamuna (Agra-U.P.), Chambal (Kota-Rajasthan) and Mahi(Vasad-Gujarat) the secondary succession takes 10-15 years to reach a stable tree stage. In ravine bottom it needs 6 to 7 years only (Figure 1). Within one and the same ravine the stable tree species are different on different topographic situations e.g. on the top it is the xeric tree community of *Acacia nilotica, Prosopis juliflora, Balanites aegyptiaca,* etc., on the side it is mesic community of *Dalbergia sissoo, Acacia catechu,* etc and on the bottom it is moist community of *Bombax ceiba, Holoptelea integrifolia, Cordia dichotoma,* etc. The natural establishment of *Bombax ceiba,* in ravine bottom is of notable significance. Champion and Seth (1968b) considered *Bombax ceiba,* basically a characteristic species of "Very-moist- teak-forest (C1a)" in Wyanad (Kerala) and Coimbatore (Tamilnadu)", "Slightly-moist-teak-forest (C1c)" in Bastar (M.P.), "Southern- moist-mixed-deciduous-forest (C2)" in Chanda (Maharashtra), etc. It is thus evident that a ravine-bottom is inherited with the potentiality of sustaining moist type of tree vegetation (Prajapati *et al,* 1989). Thus all desirable associates of above plant communities can be judiciously considered for afforestation of ravines.

Ravine Afforestation Practices

Ghosh (1977) reviewed the ravine-afforestation practices in vogue in the states of Gujarat, Maharashtra, M.P., Punjab, Haryana, Rajasthan, U.P. and Bihar and reported that pits, contour trenches and contour furrows aided by one or more mechanical measures like levelling, stepping, stone-pitching, bunding, diversion channels, masonry checkdams, live checkdams, gully plugging, etc are the common techniques for afforestation of ravines. For salt affected soils he reported mound and pit

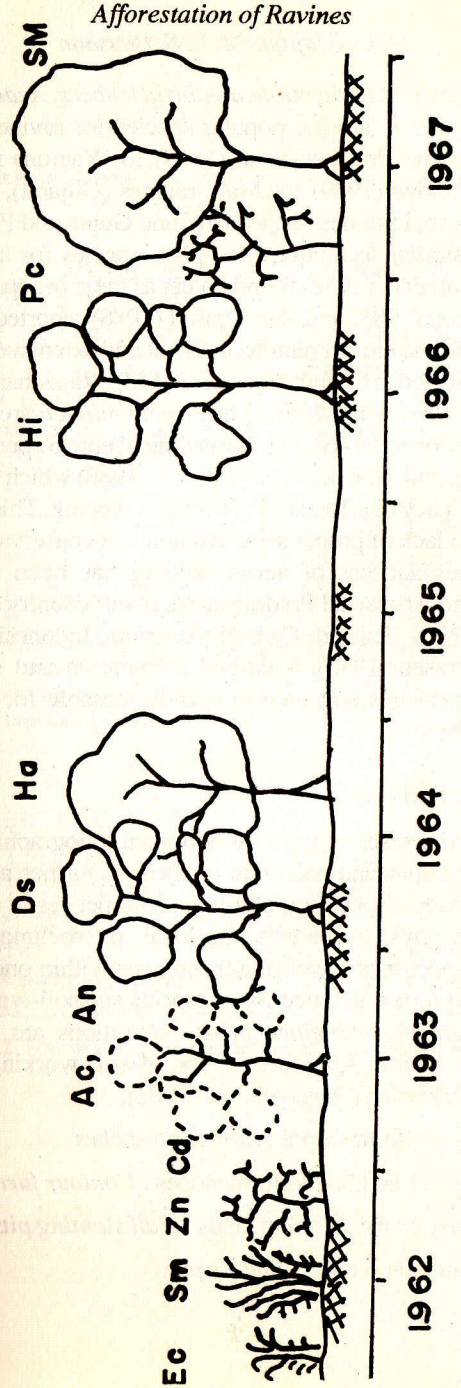

Figure 1. Plant succession in ravines.
Symbols : *Eleusine compressa* (Ec), *Saccharum munja* (Sm), *Prosopis cineraria* (Pc), *Acacia nilotica* (An), *Dalbergia sissoo* (Ds), *Holoptelia integrifolia* (Hi), *Ziziphus nummularia* (Zn), *Capparis decidua* (cd), *Heterophragma adenophylum* (Ha), *Salmalia malabarica* (Sm).

plus trench methods. *Acacia nilotica, Albizia lebbeck, Azadirachta indica* and *Dalbergia sissoo* are the popular species for ravine- afforestation almost everywhere. Prajapati *et al* (1968) for Yamuna ravines (U.P.), Pradhan and Pandya (1969) for Mahi ravines (Gujarat), Prajapati *et al* (1982) for Chambal ravines (Rajasthan), and Gupta and Prajapati (1982) also reported similar techniques and plant species for afforestation of ravines. Prajapati *et al* (1968) found 45 cm as the most appropriate depth of trenches. Joshi (1986) and Ram Prasad (1988) reported that for quick and cheaper afforestation of remote, difficult and extensive ravines, aerial seeding was resorted in Chambal ravines in M.P., Rajasthan and U.P. from 1980 onwards. *Prosopis juliflora* and *Acacia nilotica* are reported to be suitable species for aerial seeding. Reseeding of upto 67 percent area, even more than once, had to be done (Ram Prasad, 1988) which puts a question mark on the efficacy of afforestation by aerial seeding. This partial failure is purely due to lack of proper seed-bed and soil conservation measures. Similar low-key-success of aerial seeding has been reported from Maharashtra and Arunachal Pradesh states of our country and else where from, U.S.A., New Zealand, Canada, Australia, Indonesia, Nigeria and China (Ram Prasad, 1988). Seed-bed preparation and soil and water conservation measures are, therefore, indispensable for successful afforestation of ravines.

Soil Working Technique

A ravine comprises of three predominant topographic features viz. top, side and bottom and each one of them is further associated with variations in slope, aspect and soil-type. The net result is a variety of combination in physical features and local- microclimates warranting scores of site-specific soil working techniques within one and the same ravine. In broad-terms, irrespective of aspects and soil-types, the following four topographic variations in site conditions are invariably encountered in a ravine. Appropriate type of soil working technique is mentioned against each (Prajapati *et al*, 1982).

1. Upto 1:1 uniform slopes : *Contour trenches*
2. Between 1:1 and 3:1 uniform slopes : *Contour furrows*
3. Irregularly broken sloping lands : *Half slanting pits*
4. Ridge and hump apics : *Saucer pit*

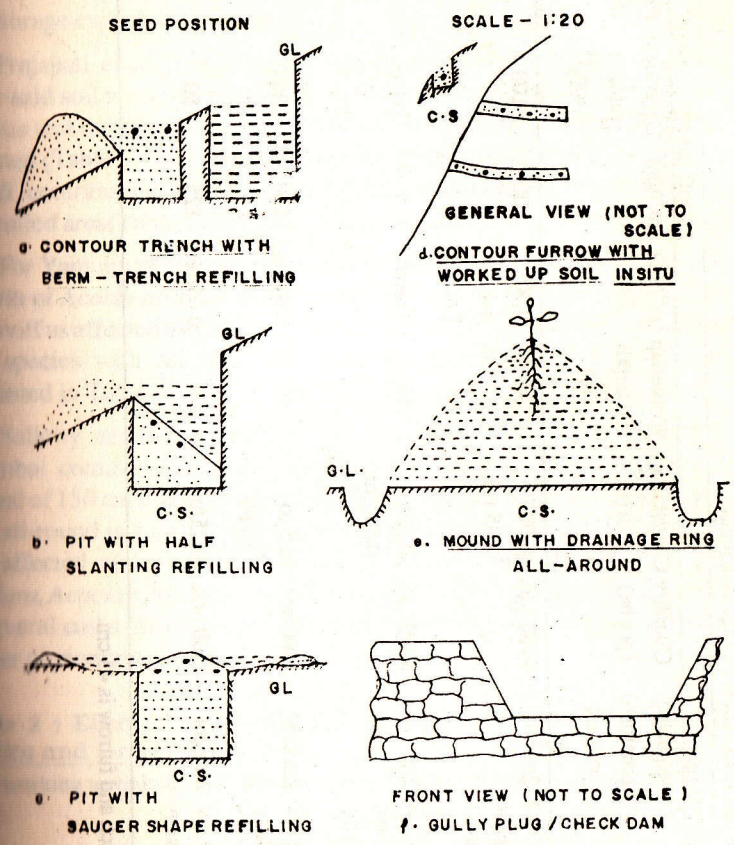

Figure 2. Soil working techniques for afforestation of ravines.

Table 1 : Soil working techniques and their runoff storage efficiency.

Soil working techniques					Runoff storage capacity			
Type	Spacing (centre to centre)	Quantity (per ha)	Contributing area (m^2)	Workedup soil depth (cm)	m^3/unit	m^3/unit	Equivalent rainfall (mm)	Percentage of surface area controlled
Continuous contour trenches (45 cm^2c.s.) with bermtrench type of refilling on gentle to steep, uniformly sloping land upto 1:1 slopes.	2m	5000 r.m.	0.90/ 0.45 r.m.	45	0.90/ 0.45 r.m.	1000	100	100
Continuous contour furrows (10 cm^2c.s) with pulverised soil in situ on precipitous, uniformly sloping ravine side on 1:1 to 3:1 slopes.	2m	5000 r.m.	0.90/ 0.45 r.m.	10	Traces	5	Traces	100
Pit (45cm^3) with half slanting refilling and crescent ridge for runoff on irregularly broken sloping land.	2mx2m	2500 nos.	1.5 to 3.0/pit	40	0.04/pit	100	20	25
Pit (45 cm^3) with saucer shape (100 cm dia) refilling on ridge lines and hump apices	2mx2m	2500 nos.	0.75/pit	50	0.05/pit	125	50	12.5

Note : The unit-length for pit, trench and furrow is 45 cm.

Relevant construction details of soil working techniques are diagramatically presented in Figure 2 and their specifications and runoff and storage capacities in Table 1.

Prajapati *et al* (1982) in a mid-way assessment of the effects of afore-said soil working techniques on the growth of 3-season old *Acacia nilotica* and the interspace forage production in Chambal ravines at Kota reported (Table 2) that the tree growth was most affected by the extent of runoff contributing area and the forage production by the extent of controlled area(Table 1).

For Yamuna ravines at Agra also Prajapati *et al* (1968) found that the growth of *Acacia nilotica* was directly affected by the extent of storage of runoff as affected by the type of refilling of trenches. A list of promising tree species with relevant techniques for afforestation of ravines is presented in Table 3.

Salinity and water logging have developed in ravine bottom in Chambal command area in Rajasthan and Madhya Pradesh. Conical mound of 150 cm diameter and 75 cm height with 20 x 20 cm c.s. drainage ring all-round is a successful soil working technique for afforestation of salt affected and waterlogged ravines. Suitable species are *Prosopis juliflora, Acacia nilotica, Tamarix dioica*, etc (Gupta and Prajapati, 1982). In several cases the exotic provenances exhibited better adaptability and higher phytomass over the indigenous species.

Table 2 : Effect of soil working techniques on growth of *Acacia nilotica* and forage production.

Soil working technique	*Acacia nilotica* (Age 3-growing seasons)		Air dry forage yield (t/ha/yr)
	Height (m)	Collar dia (cm)	
1. Contour trenches	2.8	4.8	2.5
2. Contour furrows	1.4	1.9	2.1
3. Half slanting pits	3.4	5.3	2.1
4. Saucer pits	2.9	4.5	1.9

Soil and Water Conservation Measures

The common mechanical measures constructed across the valley with a view to control erosion, conserve moisture and detain silt include

Table 3 : Promising tree species with relevant techniques for afforestation of ravines

S. No	Botanical name	Seeding time	Nursey technique	Method of planting	Initial spacing (m)	Type of soil working	Tolerable soil depth	Tolerable site condition	Rotation (yrs) for Fuel	Rotation (yrs) for Timber
1.	*Acacia catechu*	Dec-Mar	Pb	Ds,Ep	2x2	TP	M	Sd	25–30	–
2.	*A. nilotica*	Apr-Jun	Pb	Ds,Ep	2x2	TPF	M	To	15–20	25–30
3.	*A. tortilis*	Nov-Feb	Pb	Ds,Ep	2x2	TP	M	To	15–20	–
4.	*Ailanthus excelsa*	May-Jun	Pb	Ds,Ep,Sp	4x4	P	D	B	–	30–40
5.	*Albizia lebbeck*	Jan-Mar	Pb	Ds,Ep	2x2	TP	M	Sd	–	30–40
6.	*Azadirachta indica*	Jun-Aug	Pb	Ds,Ep	2x2	TP	M	To	–	30–40
7.	*Bauhinia racemosa*	Dec-Mar	Pb	Ds,Ep	2x2	TP	M	Sd	–	15–20
8.	*Bombax ceiba*	Mar-May	Pb	Ds,Ep	4x4	P	D	B	–	30–50
9.	*Cassia siamea*	Mar-Apr	Pb	Ds,Ep	2x2	TP	M	Sd	10–15	–
10.	*Dalbergia sissoo*	Nov-Mar	Pb	Ds,Ep,Sp, Bc	2x2	TP	M	Sd	20–30	30–40
11.	*Dendrocalamus strictus*	Nov-Mar	Pb	Ds,Rp	3x3	P	M	B	–	5 Cont.

Table 3 contd...

S No	Botanical name	Seeding time	Nursery technique	Method of planting	Initial spacing (m)	Type of soil working	Tolerable soil depth	Tolerable site condition	Rotation (yrs.-approx) for Fuel	Rotation (yrs.-approx) for Timber
12.	*Emblica officinalis*	Nov-Feb	Pb	Ep	4x4	P	M	B	–	10 onwards
13.	*Eucalyptus tereticornis*	Sep-Oct	Pb	Hp	2x2	P	D	B	5–8	5–8
14.	*Heterophragma adenophyllum*	Mar-May	Pb	Ep	2x2	P	D	B	–	30–40
15.	*Holoptelea integrifolia*	Apr-may	Pb	Ep	2x2	P	M	Sd	–	30–40
16.	*Melia azedarach*	Jan-Feb	Pb	Ep	2x2	P	D	B	15–20	–
17.	*Morus alba*	May-Jun	Pb	Ep,Sp,Bc	4x4	P	D	B	–	10 onwards
18.	*Pongamia pinnata*	Mar-May	Pb	Ds,Ep	2x2	P	D	B	15–20	–
19.	*Prosopis cineraria*	Jun-Aug	Pb	Ds,Ep	4x4	P	S	To	10 onwards	–
20.	*P. juliflora*	May-Jun	Pb	Ds,Ep	2x2	TPF	S	To	10 onwards	–
21.	*Tamarindus indica*	Mar-Apr	Pb	Ds,Ep	4x4	P	M	To	–	40–50
22.	*Tectona grandis*	Nov-Jan	Pb	Ep,SP	2x2	P	D	B	–	40–50

Note : *E. tereticornis* and *T. grandis* need ponded water irrigation or proximity to river bank

Symbols : Pb : polythene bag plant, DS : Direct seeding, Ep : Entire planting, Sp : Stump planting, Rp : Rhizome planting, Bc ; Branch cutting, S : Shallow, M : Medium, D : Deep, Sd : Side, To : Top, B : Bottom, T : Trench, P : Pit, F : Furrow.

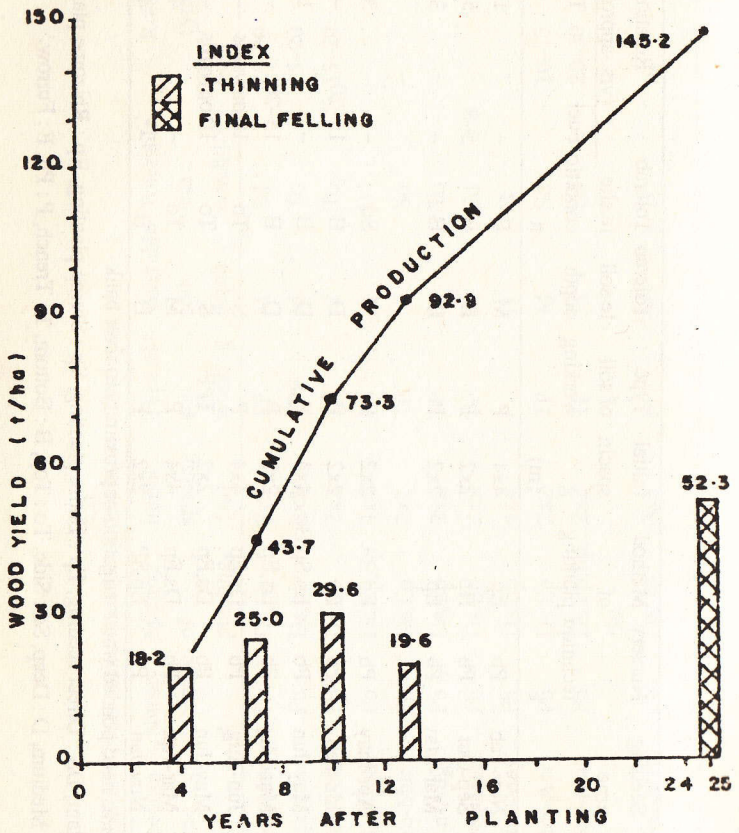

Figure 3. Production potential of *Acacia nilotica* wood in Yamuna ravines, Agra.

checkdams and gully plugs. The masonry or composite checkdams are exhorbitantly costly and are rarely used in forestry areas. Of the earthen, boulders, sand bag, wooden logs and brush wood gully plugs the earthen ones are cheap, simple and common. Likewise the vegetative check dams made of *Agave americana, Vitex negundo, Arundo donax, Jatropha curcas, Ipomoea carnea, Euphorbia royleana,* etc are not only cheap, simple and easy to make but are in conformity with the afforestation programme also. The mechanical measures are an effective aid in successful afforestation of ravines.

Production Potential

A 25 year old *Acacia nilotica* plantation initially raised at 2mx2m spacing necessitated 4 thinnings during 4th, 7th, 10th and 13th years. Air dry wood produced during four mechanical thinnings and at harvest yielded 18.2, 25.0, 29.6, 19.6 and 52.3 tonnes/ha, totalling 145.2 tonnes/ha for the rotation (Figure 3). It worked out 5.8 tonnes/ha/year from Yamuna ravines at Agra.

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DRY ZONES OF NILGIRIS : A CASE STUDY

K.G. Prasad, S.B. Singh, M. George and T. Krishnamurthy

The semi-arid zone of India occupies about 30 percent of the country's geographical area with a human population of about 31 percent, as reported by the Central Arid Zone Research Institute, Jodhpur. The state-wise survey indicates that more than 65% of the total area in Tamilnadu comes under semi-arid zone, supporting more than 60% of the State's population. Naturally, in these areas with such a large population suffer permanent damage through encroachment, excessive grazing, illicit felling, etc. leading to degraded vegetation or even barren lands. It is, thus, essential to identify dry zones, and their soil and vegetation resources, in order to prevent over-exploitation of natural resources before the area becomes fully unproductive.

An attempt therefore, has been made in this article to demarcate reserve forest areas of Nilgiris and its surroundings under dry zones and

describe their soils and floristic composition. The methods to afforest these dry zone areas have also been discussed.

Location and Topography

The study area falls between latitude 10° 45' to 11° 45' north and longitude 76° 22' to 77° 15' east, comprising Gudalur, Nilgiri North, Nilgiri South, Coimbatore, Palghat and Nilambur forest divisions. The area is represented by varying landscapes such as hills, valleys and plains. Vertically, the area ranges from sea level in the west (Nilambur) to as high as 2642 m at Doddabetta (The Nilgiris) and thus is remarkable for its morphological differentiation. 'The Nilgiris' in the western ghats is situated almost in the centre of the study area. The mountain mass, which has raised abruptly to an elevation of about 2000 m from adjoining Nilambur plains in the west and Coimbatore plains in the east, plays an important role as far as climate of this region is concerned and acts as a barrier to intercept south-west monsoon. The area is bounded by Palghat forest division in the south and Bandipur wildlife sanctuary in the north. In the eastern side, The Nilgiris gradually merges with Coimbatore plains having an average elevation of 300-400 m with a small eastward gradient, drained by major rivers namely Bhavani, Noyil and Amaravati. The major west flowing rivers draining this area are Chaliar, Kadalundi, Pulantode and Ponnani to Arabian sea.

Materials and Method

Rainfall data available for 60 stations and temperature data available for 20 stations were collected from the study area. A 30 years (1941-1970) average annual rainfall data were employed to prepare Isohyetal map of the area. Due to limited number of temperature data, the data from neighbouring stations were employed for evapo-transpiration calculation for few stations where temperature values were not available, keeping in mind their elevation and latitudinal positions "Moisture index" was calculated according to Thornthwaite's method (Thornthwaite and Matter, 1957) for 24 stations, and the same was applied to identify humid and arid areas.

Soils of dry zone areas were studied by exposing soil pedons at selected points (Sharma *et al*, 1986) and were examined as per Soil Survey Staff (1969). Soil samples from each genetic horizon were collected for

laboratory analysis. Conductivity and pH were determined in suspension (1:2 soil water) and texture was estimated by hydrometer method(Day, 1965). Cation exchange capacity, exchangeable cations, base saturation, organic carbon and available P_2O_5 were determined as described by Soil Survey Staff (1972) and soils were subsequently classified as per Soil Taxonomy (Soil Survey Staff, 1978).

Vegetation of this area was also studied through quadrate analysis (Sharma *et al*, 1983) at representative sites and various ecological values for different species were derived.

Results and Discussion

It was observed that the 'moisture index' (Im) values for the stations range between -42.4 and +338.7 based on which four climatic zones namely per-humid, humid, dry-subhumid and semi-arid (Table 1) are identified in the study area.

Table 1 : Climatic classification of study area circle on the basis of 'Moisture Index'

Stations		Altitude (m)	Temp. (°C)	Rainfall (mm)	Moisture Index (Im)
	Per-humid (Im-more than 100)				
1.	Silent valley	914	20.2	3968	+338.7
2.	Calicut	5	27.3	3297	+102.7
3.	Marapalam	960	22.3	3039	+185.2
4.	Korakundah	2240	12.4	2281	+264.4
5.	Billithadah	2210	14.4	2196	+223.8
6.	Coonoor	1829	16.3	1560	+111.1
7.	Nanjanad	2134	16.4	1501	+101.4
8.	Avalanchi	1935	14.8	1479	+118.3
	Humid (Im = 100 to 0)				
9.	Burliar	853	25.4	1624	+32.2
10.	Ooty B.G.	2225	14.9	1298	+92.5
11.	Rees corner	2210	14.8	1213	+83.7
12.	Ooty obs.	2249	14.4	1200	+86.2

13.	Kukalthorai	1494	18.1	1075	+32.3
	Dry-subhumid (Im = 0 to -20)				
14.	Walayar	229	26.4	1095	–10.6
15.	Puthur	671	26.4	1982	–16.6
16.	Chikkammangudi	914	23.2	909	–11.0
17.	Sigur	991	23.2	777	–18.1
	Semi-arid (Im = less than -20)				
18.	Moyar camp	884	24.1	793	–20.3
19.	Perianaickanpalayam	427	26.4	785	–25.3
20.	Bhavani sagar	290	28.8	775	–42.4
21.	Tholampalayam	411	26.6	679	–32.2
22.	Arakadupatti	792	24.1	624	–28.8
23.	Coimbatore	409	26.4	617	–32.7

Per-humid zone receives, in general, annual rainfall above 1500 mm whereas humid, dry-subhumid and semi-arid zones receive 1000 to 1500, 800 to 1000 and less than 800 mm annual rainfall, respectively (Table 1).

Eastern dry zone

According to Thornthwaite's moisture index, dry zone is considered as the region where the value of moisture index is negative. Accordingly, both dry-subhumid and semi-arid areas of this region combine together to form dry zone. Dry zone area includes Avakadupatti, Bhavanisagar, Chikkammangudi, Coimbatore, Moyar, Perianaickenpalayam, Puthur, Sigur, Tholampalyam and Walayar. Generally all these stations receive less than 1000 mm annual rainfall. These areas experience only 2 or 3 wet months annually when the mean monthly rainfall exceeds the amount of evapotranspiration (Table 2) and the remaining months are partially or completely dry. Most of the rainfall in these areas arrives during the south-west monsoon. The moisture stored in the soil during this wet period is almost entirely used up soon after the start of dry season, as a result, a long period of pronounced dryness (December to May) invariably precedes every rainy season (Table 2).

Table 2 : Climatic water balance (mm) at representative stations for different climatic zones.

Par	J	F	M	A	M	J	J	A	S	O	N	D	Total
						Per-humid Avalanche							
1.	25	13	26	105	123	172	359	151	121	178	136	70	1479
2.	38	38	57	65	76	66	65	66	63	63	44	38	679
3.	35	34	55	65	76	66	65	66	63	63	44	38	670
4.	290	269	240	267	300	300	300	300	300	300	300	300	3466
5.	3	4	2	0	0	0	0	0	0	0	0	0	9
6.	0	0	0	13	15	106	294	85	58	115	92	32	809
7.	32	16	8	11	13	60	177	131	94	104	98	65	809
						Humid – Ooty							
1.	21	9	22	76	172	113	177	135	108	195	111	60	1200
2.	42	44	63	68	73	58	52	54	53	53	47	41	648
3.	39	33	59	68	73	58	52	54	53	53	47	41	630
4.	282	258	221	229	300	300	300	300	300	300	300	300	3388
5.	3	11	4	0	0	0	0	0	0	0	0	0	18
6.	0	0	0	0	28	55	125	82	55	142	64	19	570
7.	26	16	6	3	16	35	80	81	68	105	85	52	570
						Dry sub-humid – Puthur							
1.	52	8	10	105	87	70	117	52	17	203	201	60	982
2.	80	91	156	165	168	117	106	105	102	102	88	79	1358
3.	80	91	33	105	87	70	106	63	17	102	88	41	982
4.	205	122	0	0	0	0	11	0	0	101	214	233	
5.	0	0	23	60	81	47	0	42	85	0	0	38	376
6.	0	0	0	0	0	0	0	0	0	0	0	0	0
7.	0	0	0	0	0	0	0	0	0	0	0	0	0
						Semi-arid – Perianaickenpalayam							
1.	18	7	16	87	94	27	32	48	69	196	133	58	785
2.	80	91	155	165	168	177	106	105	102	102	88	79	1358
3.	80	63	16	87	94	27	32	48	69	102	88	79	785
4.	56	0	0	0	0	0	0	0	0	0	94	139	118
5.	0	28	139	78	74	90	74	57	33	0	0	0	573
6.	0	0	0	0	0	0	0	0	0	0	0	0	0
7.	0	0	0	0	0	0	0	0	0	0	0	0	0

1 = Rainfall, 2 = Potential evapotranspiration, 3 = Adjusted evapotranspiration, 4 = Soil moisture storage, 5 = Water deficit, 6 = Water surplus, 7 = Runoff.

Vegetation Communities

In the dry zones of the study area eight vegetation communities were identified by George (1984) and George *et al* (1988) which are given below:

Tectona-Anogeissus Community.

Anogeissus-Acacia Community.

Anogeissus-Emblica Community.

Anogeissus-Careya Community.

Anogeissus-Grewia Community.

Albizia-Gyrocarpus Community.

Albizia-Euphorbia Community.

Euphorbia Scrub

Soils taxonomic unit

In the dry zones of study area, five soil sub-groups were described (Gupta *et al* 1984, and Gupta and Mohan, 1988). Those are:

Typic Eutropepts

This series occurs extensively throughout dry zones of study area. Six textural classes at family level have been identified in this sub-group. They are sandy, fine loamy, clayey, sandy skeletal, coarse loamy skeletal and fine loamy skeletal. All these textural classes belong to mixed mineralogical class and isothermic temperature class. The soil is reddish brown, dark brown to yellowish brown, neutral to alkaline (pH 6.2 to 8.5) occurring on 5 to 25% slope at elevations 500 to 1250 m msl. Soils are deep having thick (10 to 30 cm) A - horizon and 50 to 100 cm thick B-horizon. Epipedon is weak fine granular, slightly hard to hard dry consistency and moderate medium subangular blocky structure. Hard to extremely hard dry consistency in the subsurface horizons have been reported. Soils are moderate to poorly drained having very slow to moderate permeability depending on surface texture and presence of skeletal layer.

Typic Haploxeralfs

This series occurs in association with Typic Eutropepts where slope is less than 10 percent. In this sub-group, four textural classes (coarse loamy, fine loamy, coarse loamy skeletal and fine loamy skeletal) belonging to mixed, isothermic family have been mapped. Yellowish red, reddish yellow, dusk red to dark brown surface soil and reddish brown to yellowish red subsurface soil of this subgroup is generally sandy loam in texture throughout the pedon. As the colour becomes darker, texture becomes finer. Skeletal soils are characterised by abundant stones and gravels and non-skeletal soils by the presence of few gravels and stones throughout the pedon. Various horizons of this sub-group have moderate medium subangular blocky to angular blocky structure and dry hard to very hard and moist firm consistency.

Fluventic Eutropepts

This sub-group is generally found on hill slopes and valleys in the proximity of water courses. Sandy skeletal and coarse loamy skeletal soils of fluventic eutropepts belong to mixed, isothermic family and occur above 600 m msl on 10 to 25% slope. Neutral to alkaline (pH 6.8 to 8.2) soils contain plenty of gravels and stones throughout the pedon. On the other hand, sandy and fine loamy soils belonging to mixed isothermic family occur on valley or flat topography below 600 m msl and are neutral (pH 6. 7 to 7.3) in reaction and contain few gravels within pedon. Surface soils are dark brown to weak red loamy sand with weak fine granular structure and moist firm consistency. Dark yellowish brown to weak red sandy loam subsurface soils have moderate medium subangular blocky structure and moist firm consistency.

Lithic Haploxeralfs

This subgroup is generally found overlying lithic or paralithic parent material and occurs on hill slopes varying from 15% (fine loamy skeletal), 25% (coarse loamy skeletal) to 35% (sandy skeletal) belonging to mixed, isothermic family. These neutral to alkaline soils (pH 7.0 to 8.0) are encountered between 550 and 950 m msl. Sandy skeletal soils are characterised by reddish brown with weak fine granular structure and friable consistency on the surface and dark greyish brown with moderate medium subangular blocky structure and firm consistency in the subsurface layer.

Yellowish brown coarse loamy skeletal soils have weak fine granular structure throughout the pedon. Dark brown to reddish brown fine loamy skeletal soils are characterised by moderate medium subangualr blocky structure and moist firm consistency. Abundant gravels and stones are encountered in the subsurface horizons of this sub-group.

Lithic Ustorthents

Only one class (fine loamy skeletal) of this subgroup has been mapped in the study area belonging to mixed, isothermic family. Slightly acidic (pH 6.7), black, sandy clay loam surface soils are characterised by moderate medium subangular blocky structure and moist firm consistency. Plenty of gravels and stones are embedded in the soil.

Problems and Prospects for afforestation:

The following paragraphs deal with the problems and prospects for afforestation of each vegetation communities occurring in the dry zones of Nilgiris.

Tectona-Anogeissus **Community**

In the dry zones, canopy of this community is open and there is tremendous biotic pressure. Natural regeneration is poor. Ground flora and seedlings are affected due to frequent fire and trampling. Typic Haploxeralf and Lithic Ustorthent sub-group of soils are encountered in the locality. Surface layers of Typic Haploxeralfs contain 2.0% organic carbon, 42 ppm available P_2O_5 and 225 ppm exchangeable K_2O, whereas Lithic Ustorthents contain 2.4% organic carbon, 15 ppm available P_2O_5 and 216 ppm exchangeable K_2O.

It is suggested that the area may be protected from fire and biotic interferences in order to encourage natural regeneration. Also in the gaps, saplings of economically important species may be planted after adding phosphaorus which is deficient. Nitrogen may also be applied when seedlings are established to give initial boost to their growth.

Anogeissus-Acacia **Community:**

Overgrazing, constant tramplings, soil erosion and open canopy are some of the limitations of this community. Due to frequent fire, trampling and grazing, regeneration is poor and the forest floor is devoid of herbs.

Typic Eutropept and Typic Haploxeralf sub-groups of soils occur in this community, having 1.3 and 2.0% organic carbon, 48 and 42 ppm available P_2O_5 and 197 and 225 ppm exchangeable K_2O, respectively.

It is suggested that the area may be protected from fire and biotic interferences. In order to check erosion, grasses may be sown at slopes more than 15% and saplings of economically important species of the locality may be transplanted in the gaps. Soil being poor in available phosphorous, chemical fertilizers may be applied.

Anogeissus-Emblica **and** *Anogeissus-Carya* **Communities:**

Open canopy, poor regeneration, underdeveloped second storey and poor quality trees are characteristic of these communities. Highly eroded, shallow Lithic Ustorthent soils have abundant gravels and stones. These soils contain moderate organic carbon(1.5%), low available P_2O_5 (16 ppm) and high exchangeable K_2O (423 ppm).

Erosion control measures like ground covering by grasses may be practised. Plantations of hardy tree and shrub species may be raised. Phosphatic fertilizers may be used for greater survival and better growth. Surface mulch may be used for moisture conservation.

Anogeissus-Grewia **and** *Albizia-Gyrocarpus* **Communities:**

Trees in these communities are of poor quality having stunted growth, unsound stem and crooked branching crowns. Canopy is open. Due to frequent fires natural regeneration is not satisfactory. Saplings of economically important species struggle whereas fire hardy species grow profusely. The area is covered with grasses which attract wild animals and domestic cattle. Surface layer of Typic Haploxeralf soils contain moderate organic carbon (1.4%), low available P_2O_5 (50ppm) and high exchangeable K_2O (225 ppm). Abundant gravels and stones are encountered within the control zone.

It is suggested that the area may be protected from fire and biotic interferences in order to encourage survival and growth of new recruits. The grasses may be cut and removed and or left in the field near trees during January-February to minimise occurrence of fire and at the same time to conserve moisture. Nitrogen and phosphorus fertilizers may be applied to new recruits after soil working for survival and better growth during monsoon (September-October).

Albizia-Euphorbia **and** *Euphorbia Scrub* **Communities**

These communities are highly degraded occurring under hostile climate (very high temperature and low rainfall). Trees lack stem and develop branches from the base. The crowns are branching giving the appearance of shrub. Canopy is open. Lands are bare. Grasses and herbaceous species are restricted to areas where moisture is available for longer period. Regeneration is poor. In the past, this area had experienced high degree of biotic interference (unregulated grazing, unauthorized removal of fuel and small timber) and frequent fire. Massive rocks and boulders are scattered throughout the area. Typic Eutropept and Fluventic Eutropept soils contain abundant gravels and stones within the control zone. Organic carbon content of surface horizon ranges from 1.2 to 1.5%, available P_2O_5 from 50 to 90 ppm and exchangeable K_2O from 250 to 400 ppm, respectively.

Area requires complete protection from nearby villagers. Measures to control fire, grazing and illicit felling should be employed. Seeds of grasses and shrubs may be dibbled before the onset of north-east monsoon so that ground is covered. Encouraging results have been reported (Gupta *et al* 1988 and Singh *et al* 1988) by the use of water harvesting, gravel mulch and fertilization. Using this technology, the area can be revegetated quickly.

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BIOFERTILIZERS AND AFFORESTATION

S.C. Bhandari

Introduction

Thar desert of India covering north and north-west of Rajasthan encompassing Jaisalmer, Barmer, Jodhpur, Nagaur, Bikaner, Sriganganagar districts is characterized by extremes of temperature, frequent droughts, high wind velocity, low relative humidity, evaporation far exceeding the precipitation and scanty vegetation. The soils are sandy having low water holding and nutrient supplying capacity to sustain crop production. Bhandari (1978) carried out a detailed survey of flora of Indian desert and reported that leguminosae is the largest family amongst the dicotyledons with 30 genera and 83 species and was next to poaceae (gramineae). However, dicots had majority on the whole. The bulk of vegetation consisted of stunted thorny shrubs and perennial herbs capable of drought resistance. Owing to adversity of soils and climate, the afforestation activities do not, generally, yield desired results. The ability of some leguminous plants to form symbiotic association with free living bacteria

Rhizobium and fix atmospheric nitrogen for the host plants would help early tree establishment. Vesicular arbuscular mycorrhizae which establish in association with the roots of plants will help better uptake of nutrients like phosphorus, zinc etc. The present review is an attempt to review the possible role of biofertilizers in afforestation of desert.

Rhizobium

Basak and Goyal (1980 a) studied 25 species of tree legumes of desert area belonging to genera *Acacia, Albizia, Bauhinia, Colophospermum, Dichrostachys, Leucaena, Peltophorum, Pithecolobium* and *Prosopis* for their ability to produce nodules from the native rhizobia and reported that only 19 species could produce nodules (Table 1). They further noted that nodulation varied from site to site indicating the variability in the inoculum present in the soil and probability of getting an isolate for those species which were non nodulating. Basak and Goyal (1980 b) further showed that isolates from tree legumes belonged to cowpea group of rhizobia with comparatively high tolerance to salt and ability to grow at higher temperature. All the isolates grew well at 0.8-1.8 per cent sodium chloride and optimum temperature range for the isolates was found to be 35-40° C. These isolates also showed promising effect on other cultivated legumes (Table 2 & 3).

Vesicular Arbuscular Mycorrhizae (VAM)

The necessity for developing strategies for the management of mycorrhizal fungi in arid and semi-arid ecosystems is plagued by the apparent paradox of the role of mycorrhizae. VAM associations are ubiquitous (Trappe, 1981), yet many experiments fail to demonstrate clear responses of native species to VAM. Reeves (1987) based on P/N ratios as a measure of mycorrhizal responsiveness, concluded that VAM fungi confer substantial benefits to semi-arid plants during secondary succession and in natural systems (Table 4). A management strategy for systems should be based around control of the plant community and indirectly the mycorrhizal fungus. The approach to be taken will be dependent upon the degree of perturbation to the site. Miller (1987) had enlisted some of the characteristics for determining the potential of a site for need of management (Table 5). McGee *et al.* (1987) reported that propagules of VAM fungi can survive long periods in soil and some remain viable even when soil reaches high temperature and germinate rapidly after the soil is wetted

Table 1 : Nodulation in tree legumes by the native rhizobia (values average of twenty four plants after 30 days).

Name of host	Number of nodules		Name of host	Number of nodules	
	Tap root	Lateral roots		Tap root	Lateral roots
Acacia catechu	x	12	*A. victoriae*	1	10
A. constricta	x	10	*Albizia lebbeck*	2	21
A. drepanolobium	2	25	*Bauhinia alba*	x	x
A. farnesiana	x	7	*B. purpurea*	x	x
A. gregii	x	x	*B. variegata*	x	x
A. hockii	x	11	*Colophospermum mopane*	x	x
A. nilotica	x	4	*Dichrostachys glomerata*	x	5
A. nubica	1	16	*D. nutans*	x	4
A. salicina	2	20	*Leucaena glauca*	2	15
A. senegal	x	8	*Peltophorum feruginium*	x	x
A. seyal var. seyal	x	10	*Pithecolobium saman*	1	9
A. tortilis	x	8	*Prosopis cineraria*	x	5
			P. juliflora	1	10

Table 2 : Effect of inoculation of *Vigna radiata* var. *mungo* by Rhizobium isolates from tree legumes as compared with the specific strain (E. 9) under sterilized pot culture conditions.

Treatments	Length (cm)		Dry weight (g)		Number of nodules	Dry wt. of nodules (mg)*	Grain yield (mg)**
	Shoot*	Root *	Shoot*	Root*			
Control	8.33	11.00	8.39	0.99	–	–	124.9
Specific *Rhizobium* (E. 9)	16.67	13.33	0.81	2.32	21	21.23	185.6
Acacia farnesiana (R. 13)	11.67	13.33	0.81	1.80	11	18.27	159.3
Acacia nubica (R. 19)	11.33	15.00	1.13	1.28	13	18.07	278.1
Acacia seyal var *seyal* (R. 22)	10.33	15.00	0.91	1.36	16	13.30	162.2
Albizia lebbeck (R. 28)	10.67	14.00	0.78	1.53	19	20.93	295.7
Dichrostachys nutans (R. 32)	11.00	14.67	0.93	2.10	13	14.07	273.9
Prosopis cineraria (R. 41)	9.67	13.67	0.72	2.20	12	18.77	190.6
C. D. at 5%	2.50	1.27	0.21	0.36	–	0.97	13.17

* Average of 4 plants after 30 days ** Average of 20 plants after 84 days

Table 3 : Effect of inoculation of *Vigna radiata* var. *aureus* by *Rhizobium* isolates from tree legumes as compared with the specific strain (D. 10) under sterilized pot culture conditions.

Treatments	Length (cm)		Dry weight (g)		Number of nodules*	Dry wt. of nodules (mg)*	Grain yield (mg)**
	Shoot*	Root*	Shoot*	Root*			
Control	14.67	14.00	0.91	0.88	–	–	132.1
Specific *Rhizobium* (E. 10)	18.67	18.33	1.78	1.51	11	15.63	240.2
Acacia farnesiana (R. 13)	15.33	17.33	1.46	1.30	14	15.93	139.5
Acacia nubica (R. 19)	16.00	15.33	1.06	1.11	10	10.93	248.0
Acacia seyal var *seyal* (R. 22)	17.33	16.00	1.04	1.20	17	61.83	302.1
Albizia lebbeck (R. 28)	19.00	16.33	1.51	0.99	12	22.50	259.7
Dichrostachys nutans (R. 32)	17.33	17.67	1.43	0.99	8	10.63	150.8
Prosopis cineraria (R. 41)	18.33	18.33	1.40	1.00	17	9.53	171.6
C. D. at 5%	1.33	1.20	0.06	0.33	–	8.16	33.03

so that infection is initiated at a very early stage of development of ephemeral plants and has a rapid effect on plant growth in nutrient poor soils (Table 6).

Table 4 : Phosphorus/nitrogen ratios of three species harvested from experimental plots

Treatment	P/N ratio	Significance
P (50 kg P/ ha)	0.1238	
Climax	0.0986	< 0.0025
(Mixture of successional		
species were seeded)		
Fumigated	0.0801	

Table 5 : Conditions where management of mycorrhizae becomes a necessary strategy in semi arid environments

* Low abundance of mycorrhizal propagules and /or propagule form
* The loss of appropriate endophytes
* Extended nonmycorrhizal plant stage
* Aridity of distribution of precipitation events
* Cool temperature
* Degraded or erosive soils
* Low availability of P, Cu, Zn.

Table 6 : Growth phosphate conc. and infection of plant of *Trifolium subterraneum* grown in soil compared with plants grown in autoclaved soil.

	Non sterile soil	Autoclaved soil
Dry weight (mg plant $^{-1}$)	1.58 ± 0.2	0.64 ± 0.1
P Conc.	1.48 ± 0.2	0.51 ± 0.04
Mg mg $^{-1}$ root	2.12 ± 0.1	0.82 ± 0.05
Per cent (root length)	61.0	0
Infected		

Seasonal dynamics of inoculum populations are important considerations in the practical application of biofertilizers, though the incorporation of VAM fungi in the regeneration of sand dunes appears to offer promise (Gemma, 1987 a). The study of Gemma (1987 b) on the biology of these

organisms in natural system had indicated that intensive seasonal sampling is necessary to describe the seasonal dynamics of VAM fungi as spore abundance and its germination vary with time and have practical use in revegetation. Studies carried out by Gomes *et al.* (1987) with eight species of *Eucalyptus* with VAM fungi (*Glomus, Gigaspora* and *Acaulospora*) isolates have shown that majority of them are able to infect the host plant with varying degree of infection indicating the selectivity of strain for species (Table 7). Soil organic matter and micro-organisms (Bhandari, 1988) influence soil aggregation and play important role in improving physical properties of soils. Jastrow *et al.* (1987) observed that VAM parameters were positively correlated with 2 mm diameter but not with 1-2 mm and were negatively correlated with aggregates of 0.2 to 1 mm diameter. Mukerji and Jagpal (1987) observed that *Leucaena leucocephala* infected with *Glomus macrocarpum* and *G. fasciculatum* had better growth and were well established in waste land. The VAM subsidised the adverse effects of salinity, low fertility and drought on plant growth. Similarly, various physiological events in VAM inoculated *Leucaena leucocephala* were compared with that of non-mycorrhizal by Huang and Yost (1987) (Table 8).

Table 7 : Root colonization of 8 Eucalypt sp. by 30 isolates of VAM fungi in two soilless media.

	No. of isolates that colonized root in VAM/ medium plantmax			Av. % root coloniation in VAM in 90 days
	45 days	90 days	45 days	
E. citriodora	28	29	29	57
E. urophylla	18	28	29	37
E. tarelliana	13	29	29	35
E. clocziana	20	20	22	21
E. pilularis	22	29	29	27
E. pyrocarpa	19	28	28	25
E. paniculata	27	30	30	31
E. camaldulensis	14	28	28	29

Table 8 : The sequence of nutrient concentration and growth events following mycorrhizae inoculation of *Leucaena leucocephala* seedlings.

Plants Parameters	Days after inoculation	Comparisons between Mycor. (M) and non mycor. (N) plants
Pinnule P con.	12	M > N
Pinnule P content	12	M > N
Pinnule dry weight	14	M < N
	19	M > N
Root P conc.	10	M > N
Shoot P conc.	15	M > N
Shoot K conc.	15	M > N
Shoot S conc.	15	M > N
Shoot Mg conc.	20	M > N
Shoot Ca conc.	25	M > N
Root/shoot ratio (Dry weight)	10	M > N
	20	M < N
Root dry weight	20	M < N
	30	M > N
Shoot dry weight	25	M > N
Total dry weight	25	M > N
Leaf area	15	M > N
Root area	30	M > N
Daily transpiration	11–14	M > N
Transpiration rate	15	M > N
Leaf moisture content	15	M > N
Specific leaf area	15	M > N
Cumulative transpiration	20	M > N
Water use efficiency	20	M < N
	30	M > N

Table 9. Effect of mycorrhiza, *Rhizobium*, nitrogen and phosphorus on ancillary characters of *Leucaena leucocephala*

	Plant height (cm)			Plant dry wt (g)			Nodule number			Nodule weight (mg)		
	M–	M+	Mean	M–	M+	Mean	M–	M+	Mean	M–	M+	Mean
Phosphorus levels												
P_o	15.31	20.90	18.10	2.193	4.116	3.154	2.77	4.88	3.82	29.46	46.85	38.15
P_1	19.74	25.47	22.60	4.365	6.055	5.120	3.83	4.00	3.91	46.65	56.40	51.52
Mean	17.52	23.18		3.279	5.086		3.30	4.44		38.05	51.62	
Rhizobium												
R_o	14.70	19.29	16.99	2.632	4.310	3.471	0	0	0	0	0	0
R_4	18.70	22.54	20.62	3.650	5.607	4.648	4.49	7.41	5.95	55.85	73.35	64.60
R_5	19.18	27.72	23.45	3.517	5.342	4.429	5.41	5.91	5.66	18.32	81.52	69.92
Mean	17.52	23.18		3.279	5.086		3.30	4.44		38.05	51.62	
Nitrogen levels												
N_o	16.78	22.10	19.44	3.071	4.616	3.843	3.66	4.61	4.13	45.53	58.16	51.84
N_1	18.27	24.27	22.27	3.488	5.556	4.522	2.94	4.27	3.60	30.58	45.08	37.83
Mean	17.52	23.18		3.279	5.086		3.30	4.44		38.05	51.62	
C.D at 5%												
Mycorrhiza (M)			0.51			0.033			1.42			2.83
Rhizobium (R)			0.88			0.016			0.71			1.41
Phosphorus (P)			0.26			0.013			0.58			0.15
Nitrogen (N)			0.88			0.016			0.71			1.40
Interaction (RXM)			0.88			NS			0.71			1.41

M–No Mycorrhiza M+ with mycorrhiza Po No phosphate P1 with phosphate (300 kg super phosphate/ha), No No nitrogen N1 with nitrogen (20 kg CAN ha.)

Dual inoculation with Rhizobium and Vesicular Arbuscular Mycorrhizae (VAM)

Dual inoculation with *Rhizobium* and VAM resulted in improved nodulation, mycorrhizal colonization, dry weight and nitrogen and phosphorus content of *L. leucocephala* (Manjunath *et al.*, 1984; Punj *et al.*, 1987; Punj and Gupta, 1988) (Table 9-11). Hogberg and Kvarhstrom (1982) reported that *L.leucocephala* contributes 110 ± 30 kg/ha of nitrogen annually and concluded that it enriches the soil in less humid areas.

Table 10 : Effect of mycorrhiza, Rhizobium, nitrogen and phosphorus application on nitrogen and nitrate reductase activites of nodules of *Leucaena leucocephala*.

	Nitrogenase activity (nM C_2H_4/h/g nodule wt.)			Nitrate reductase activity (nM NO_2/h/g/ nodule wt.)		
	M–	M+	Mean	M–	M+	Mean
Phosphorus levels						
Po	4505.66	6167.21	5336.43	2.03	3.13	2.58
P1	5800.00	6386.50	6093.25	2.73	4.81	3.77
Mean	5152.83	6276.85		2.38	3.97	
Strain						
Ro	0.00	0.00	0.00	0.0	0.00	0.00
R4	7206.58	9850.00	8528.29	3.63	5.73	4.68
R5	8251.91	8180.50	8216.05	3.52	6.19	4.68
Mean	5152.83	6276.85		2.38	3.97	
Nitrogen levels						
No	5297.66	6208.66	5753.16	2.26	4.01	3.13
N1	5008.00	6345.10	5676.55	2.51	3.94	3.22
Mean	5152.83	6276.85		2.38	3.97	
C.D. at 5%						
Mycorrhiza (M)			53.18			0.06
Phosphorus (P)			75.23			0.08
Rhizobium (R)			92.14			0.10
Nitrogen (N)			75.23			0.08
Interaction (MXR)			N.S.			0.10

Table 11 : Effect of mycorrhiza, *Rhizobium*, nitrogen on phosphorus and nitrogen concentration in stem and leaves of *Leucaena leucocephala*

	Stem						Leaves					
	P (mg/g)			N %			P (mg/g)			N %		
	M–	M+	Mean	M–	M+	Mean	M–	M+	Mean	M–	M+	Mean
Phosphorus levels												
P_o	1.26	2.21	1.74	3.29	5.07	4.18	1.44	3.24	2.32	4.21	7.09	5.65
P_1	2.39	4.34	3.36	4.73	6.46	5.95	2.29	3.66	2.94	5.83	7.77	6.80
Mean	1.82	3.28		4.01	5.75		1.86	3.40		5.02	7.43	
Rhizobium												
R_o	1.35	1.90	1.62	3.08	4.69	3.88	1.25	2.52	1.88	3.82	7.09	5.45
R_4	1.95	3.51	2.73	4.55	6.54	5.55	2.26	3.78	3.02	5.59	7.87	6.73
R_5	2.16	4.46	3.31	4.40	6.04	5.22	2.07	3.91	2.99	5.65	7.34	6.49
Mean	1.82	3.29		4.01	5.75		1.86	3.40		5.02	7.43	
Nitrogen levels												
N_o	1.66	3.33	2.49	3.53	5.27	4.40	1.75	3.20	2.50	5.42	7.01	6.21
N_1	1.00	3.25	2.62	4.49	6.25	5.36	1.98	3.54	2.76	4.62	7.85	6.23
Mean	1.82	3.29		4.01	5.75		1.86	3.40		5.02	7.43	
C.D at 5%												
Mycorrhiza (M)			0.06			0.06			0.03			0.07
Phosphorus (P)			0.09			0.09			0.05			0.10
Rhizobium (R)			0.11			0.11			0.06			0.12
Nitrogen (N)			0.09			0.09			0.05			NS
Interaction (MXR)			0.11			N.S.			0.06			0.12

Phosphorus solubilization

Survey undertaken by Venkateswarlu *et al* (1984) revealed the wide occurrence of P solubilizing micro-organisms like *Bacillus cereus, Pseudomonas fragi, Aspergillus niger, Penicillium pinophyllum.* Rao *et al.* (1982) also isolated an actinomycete *Stretomyces* sp. which can solubilize tricalcium phosphate by producing organic acids. P solubilization can be exploited for increasing the availability of P by isolating strains resistant to high temperature and low moisture and using them for inoculations.

Conclusion

It can be concluded from the foregoing review that use of various biofertilizers may be helpful in maintaining the supply of essential nutrients under arid and semi arid conditions if suitable strains are isolated and used as inoculants in afforestation.

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PROSPECTS OF MYCORRHIZAL RESEARCH IN ARID ZONE FORESTRY

Premlal and G. N. Gupta

Tree planting has been recognised as the most important way of combating desertification. However, tree establishment and growth in arid regions is severely limited by climate and soil related constraints. Soils of arid region suffer from moisture and nutrient stresses and lack of microbial activity. Moisture and mineral supply to the newly planted seedlings in dry zones can be improved by rain water harvesting and conservation and nutrient management through inorganic and organic fertilizers (Gupta, 1990, 1991). However, in the arid region where moisture is the primary limiting factor plant response to fertilizers is uncertain and their use does not appear to provide long term solution on ecological grounds. Some mycorrhizal fungi have been known to increase water and nutrient uptake several folds by extending the absorbing surface of the root system and exploring soil areas beyond the usual depletion zone (Burgess and Malajzcuk, 1989; Miller, 1987; Michelsen and Rosendahl, 1989; Tarafdar

and Rao, 1990). The studies pertaining to the role of mycorrhizae in tree nutrition have been largely for the temperate and tropical tree species. The investigations on plant mycorrhizal interactions with respect to arid zone tree species have been scanty.

Therefore, in view of the scope of mycorrhizal fungi in imparting drought resistance, improving tree nutrition and their establishment on disturbed arid lands, it is of immediate concern to undertake indepth studies on various aspects of mycorrhizal inoculation in arid zone tree species. This is an attempt to review the present status of research on the subject and highlight the future research needs.

Ectomycorrhizae

In ectotrophic mycorrhizal roots, the fungal associates absorb mineral nutrients and water, which have to pass through the fungal sheath where at least in the symplastic compartment storage and/or deposition may occur. The further transfer of the absorbed compounds into the host root is mainly facilitated in the Harting net region. Because of the absence of plasmodesmata between the symbiotic partners exchange has to involve an apoplastic step. Control and selectivity of uptake depends on the functionality of the plasmalemma with the endodermis as a final barrier. Heyser and Donner (1989) found accumulation of Fe, Al and partly P and Zn within the fungal sheath indicating selective exclusion and/or specific accumulation, whereas, highest amounts of Co, Pb and partly of Zn demonstrated a barrier function of the root cortex and the endodermis.

Burgess and Malajczuk (1989) found that the seedling growth of *Eucalyptus globulus* was promoted above that of uninoculated seedlings by an average of 150% when inoculated with *Scleroderma verrucosum*, 170% for *Setchelliogaster* sp and 220% for *Laccaria laccata*. Uniformly high mycorrhizal development due to the three fungi in *Eucalyptus globulus* was also noted. The variation in *E. globulus* was reduced by inoculation with ectomycorrhizal fungi. The coefficient of variation for uninoculated plants was 45%, while for inoculated plants, this was reduced to 17%. Last *et al* (1989) observed that inoculation of *Picea sitchensis* with *L. proxima* and *P. involutus* consistantly and significantly increased mean numbers of mycorrhizae per plant as well as seedlings inoculated with *L. proxima* or isolates of *P. involutus* were related exponentially to total numbers (n) of mycorrhizae.

$$Y = 26.40 + 4.90e + 0.97x, \text{ where } X=\log10 (n + 1)$$

This equation implies that a tenfold increase in number of mycorrhizae from 10 to 10^2 per plant is unlikely to increase heights appreciably, whereas, a comparable tenfold increase from 10^3 to 10^4 mycorrhizae per plant is likely to result in very substantial increase. This relationship is similar to that found by Cline and Reid (1982). However, mycorrhizal Sitka spruce seedlings inoculated with *Paxillus involutus* were not superior over non-mycorrhizal plants in size and N,P and K concentrations and in terms of drought resistance (Lehto, 1989).

Parke *et al* (1983) found a marked difference in the growth of non-inoculated Doughlas fir seedlings and those inoculated with different fungi. Comparing the effects of *Rhizopogon luteolus* and *Pisolithus tinctorius* on growth of *Pinus oocarpa* in Nigeria representing two types of vegetational zones showed that *P. tinctorius* helped significantly in survival and growth of the seedlings in Mokwa and Laiagi (which are real problem areas for establishment of pines). However, there was no substantial improvement at Afaka (moderatly good site for pines) where *R. luteolus* performed equally well (Ghadegesin, 1990). Raman and Elumalai (1991) reported 206 per cent increase in biomass of *Casuarina equisetifolia* due to *Pisolithus tinctorius* inoculation. *Laccaria laccata* mycelium @ 2 g dry weight per square meter was enough for a complete infection of Doughlas-fir seedlings in the first year in a bare root nursery, which was very efficient owing to a late but sustained activity of the entrapped mycelium, compared with an earlier but shorter activity of the mycelium grown on the vermiculite peat mixture and used at approximately the same dose (Mortier *et al* 1989). Mauperin *et al* (1987) also noticed the protective and stabilizing effect of powdered peat added to the gel. The fact that this type of inoculum has already proved to be efficient in another nursery and with another fungus (Le Tacon *et al* 1985) suggests that it could be adapted to a wide range of conditions.

The ectomycorrhizal condition of the seedling at planting significantly affect subsequent growth (Marx *et al* 1985). The growth differences observed between seedlings with different ectomycorrhizal fungi have been caused by either a greater amount of ectomycorrhizal development or more efficient absorption of water and nutrients by the ectomycorrhizae

on the faster growing trees. The most striking differences in soil analysis came from the seedlings with *Pisolithus tinctorius* (Pt) ectomycorrhizae with and without fertilizer at both sampling periods. These samples contained significantly more nitrogen than most others, since N-fixation might have been occurring in the rhizospheres of seedlings inoculated with Pt ectomycorrhizae. Michel *et al* (1989) reported increased growth of inoculated Doughlas - fir accompanied by higher nutrient and protein amounts and higher enzyme activity levels in foliar and stem tissues. Kropacek *et al* (1989) found that under sterile conditions granulated inoculum was effective and almost no mycorrhizae were found in the controls. Marx and Bell (1985) reported that *Pisolithus tinctorius* indices of 82-90 for seedlings with vegetative inoculum were significantly greater than indices for seedlings with *Pisolithus tinctorius* pellets. Finlay *et al* (1989) studied the mycelial uptake, translocation and assimilation of N-lebelled ammonium in *Pinus sylvestris* plants infected with the ectomycorrhizal fungus. They reported that a significant proportion of the total assimilated nitrogen (27%) was incorporated into proteinaceous materials and the proportion of lebel present in this fraction increased from 27% in the mycelium to 32 and 56% in the plant roots and needles, respectively.

Endomycorrhizae (Vesicular - arbuscular mycorrhizae)

Vesicular-arbuscular mycorrhizal (VAM) associations with plants are taxonomically and geographically wide spread. VAM fungi significantly increase the plant growth especially in infertile and marginally productive soils. The plants derive benefits at times when their demand for P is much greater than the capacity of their root system to supply it (Fitter 1989). Kormanick *et al* (1982) reported significant differences in seedling growth due to VAM treatments which may represent host preference for a given symbiont. However, none of the non-mycorrhizal seedlings grew as fast as those with VAM. Thapar and Khan (1985) reported that VAM inoculated seedlings of *Araucaria cunninghamii* showed an increase of 65% in height and 155% in oven dry weight. Srinivas *et al* (1988) reported that inoculation with *Glomus fasciculatum* increased the plant height of *Acacia nilotica* by 135.6% over control followed by *Glomus epigeum*. Under nursery conditions *Glomus fasciculatum* was also found to increase biomass of *Ailanthus excelsa*, *Azadirachta indica* and *Parkinsnia aculeata* seedlings (Kandaswamy *et al* 1987). Studies carried out by Gomes *et al* (1987) with eight species of *Eucalyptus* inoculated with VAM fungi (*Glomus, Gigaspora* and *Acaulospora*) have shown that majority of them are able to infect the host plant with varying degree of infection indicating the selectivity of strain for species. The *Leucaena leucocephala* infected with *Glomus macrocarpum* and *Glomus fasciculatum* had better growth and were well established in wastelands (Mukerji and Jagpal, 1987). The VAM subsidised the adverse effects of salinity, low fertility and drought on plant growth.

Interaction between introduced and indigenous VAM fungal species in Syrian soils were compared by El-Atrash *et al* (1989) who observed that most of the introduced fungi produced good infection and were effective but each fungus showed a differential effectiveness depending on whether sterile or unsterile soil was used as well as on soil characteristics. Their conclusion was that selectively introduced VAM fungi adapted successfully, behaved efficiently and showed good competitive abilities. Hence it may be practical to select and introduce endophytes to improve the nutritional status. The competition between the introduced and indigenous endophytes for colonisation of host root system have been reported by Abbott and Robson (1981) and Sen *et al* (1989). Such results are contrary to the observations made by Wilson (1984) and Lopez-Aguillon and Mosse, (1987).

Mycorrhizae in Arid Zone Forestry

Studies related to the role of mycorrhizae in forest trees in arid and semi arid regions have received little attention (Khan, 1974; Mejstrik and Cudlin, 1983 and Tarafdar and Rao, 1990). Mycorrhizal association particularly of vesicular-arbuscular mycorrhizae may be advantageous to desert plants by improving supply of moisture and nutrients particularly phosphorus which is largely present in the form of insoluble calcium phosphate and its diffusion to plants is decreased by low moisture status prevailing in arid areas. VAM fungi may impart drought resistance to tree seedlings during early establishment phase, which is most crucial part of afforestation in arid and semi-arid areas. Recent scientific results provide data which support the hypothesis that mycorrhizal plants are effective colonisers of disturbed habitats and that the lack of mycorrhizal fungi exerts profound influences on species composition (Tommereup and Abbott, 1981). However, to fully utilize this potential in improving arid zone forestry and plantation management, the understanding of mycor-

rhizal associations assumes greater significance in view of making biofertilizer as practical alternate to moisture and nutrient management by other sources.

Tarafdar and Rao (1990) surveyed nine environmentally hostile sites in arid zone of Rajasthan and found VAM infection in all the species except *Salvadora oleiodes* collected from Chandan. Among the species, irrespective of locations, the maximum infection was observed in *Azadirachta indica* (85.8%) followed by *Parkinsonia aculeata* (76.7%) and *Ziziphus mauritiana* (73.6%). Plant samples of *Punica granatum* collected from Bikaner gave 100% infection. Most of the VAM fungi belonged to *Gigaspora, Glomus, Acaulospora* and *Endogone* genera. Bala *et al* (1989) examined vesicular-arbuscular mycorrhizal (VAM) infection in 17 different Indian desert tree species under glasshouse conditions. The intensity of infection varied from species to species. *Azadirachta indica, Acacia tortilis* and *Acacia aneura* recorded maximum infection while *Acacia catechu* the lowest. *Glomus* and *Gigaspora* were the common VAM genera associated with roots. Also the VAM infections were common in *Opuntia* sp and *Euphorbia* sp and the infection rate (30-100%) in these species was comparatively higher than in trees.

Michelsen and Rosendahl (1989) studied the VAM propagule densities of clay soils from bushland in various stages of degradation and from cultivated areas. *Cucumis sativus* proved to be best host plant giving highest propagule counts than *Acacia nilotica* and *Leucaena leucocephala.* The subsoil showed very low VAM propagule counts in all the samples. Mejstrik and Cudlin (1983) evaluated twenty plant species from different sites in Algeria. Endomycorrhizal associations were found with *Slipa tenacissima, Romsmarinus tournifortii, Helianthenum lippii, Tamarix* sp. *Eryobotria japonica, Casuarina equisetifolia, Eucalyptus globosa* and *Eucalyptus cupressus* were associated with ecto and endomycorrhizae. Presence of mycorrhizae in association with desert plant species has been reported by Khan (1974), Miller (1979) and Rose (1981).

Factors influencing mycorrhizal association

Fertilizer application: The fertilizer application particularly nitrogenous fertilizers can disturb the soil ecosystem of the forest because 1) high levels of available nitrogen do not occur in natural forests, ii) nitrification of ammonium acidifies the soil and iii) the rhizosphere acidifies after the plant absorbed the ammonium ions (Termorshuizen and

Ket, 1989). The nitrogen fertilization of forest also decreases microbial biomass and activity in soils (Baath *et al.*, 1981) and also decreases the number of ectomycorrhizal root tips in coniferous forest soils (Menge *et al.*, 1977; Alexander and Fairley, 1983). Decrease in species number and number of fruit bodies by fertilizer use have been reported by Guillette *et al* (1989) and reduction in infection of root tips by mycorrhizae by Taylor and Alexander (1989).

From pot experiments, Meyer (!985) concluded that excess available nitrogen in soil drastically reduces mycorrhizal development. Jentschke *et al* (1989) found that NH_4^+ ion had a significant negative effect on mycorrhizal development than No_3^- in the seedlings of *Picea abies*. Although this effect has long been known from pot and aseptic inoculation experiments (Slankis, 1967 and Bjorkman, 1942) little conclusive data are available on form and concentrations of nitrogen in the solution phase capable of triggering these effects. However, this effect of nitrogen fertilization was reported to be a short lived (Menge *et al.*, 1977).

pH : There are several reports indicating that the occurrence of several ectomycorrhizal fungi decreases due to the incidence of acid rain which has an acidifying effect on soil (Fellner, 1982; Arnolds and Jansen, 1987 and Jansen and Dobben, 1987). The acid precipitations have been found to adversely affect fruit body formation (Agerer, 1989). Richards (1965) showed that mycorrhizae are formed within a wide range of pH values and in cases when inhibition takes place, the effect can be explained by a high concentration of nitrates, but not by soil alkalinity. According to Mikola (1966), in acidic soils mycorrhizae with a thicker mantle are formed on pine seedling roots. Jongbloed and Borst- Panwels (1989) reported decrease in radial growth of *Laccaria bicolor* in pure culture due to the acidification of medium.

Liming : Liming caused reduction in growth of mycorrhizal flora under beech stands in Germany (Fielder and Hunger, 1963), Guillette *et al* (1989) observed that in limed plots number of mycorrhizal species and yield of fruit bodies was lower than unlimed plots. However, Semjonova (1989) found no correlation between the lime rate applied and intensity of mycorrhizal formation both in pine and spruce stands on sandy soils.

Temperature : Arid zones are characterised by extremes of temperature ranging from sub zero to maximum of 50° C. Therefore, it is important to study the influence of varying temperature on growth of mycorrhizae

and screen the VAM species which can tolerate temperature extremities. During winter, there were few growing mycorrhizae presumably as a result of low temperature (Blasius *et al.*, 1989). When the soil temperature reached the freezing point, the growth of mycorrhizae stopped. However, the number of dormant mycorrhizae increased significantly during the period of reduced growth and were maximum during the lull of the winter period. However, mycorrhizal studies under high temperature conditions are lacking and form a priority area of research.

Other factors which effect the mycorrhizal growth and their association with trees are soil moisture, tree root exudates, formulation of inoculum, clear cutting of forest, specificity among symbionts etc.. Our knowledge about the state and behaviour of mycorrhizae in their natural surroundings is very limited. We know little about the development, seasonal growth or life span of mycorrhizae or about the interplay between mycorrhizae and the diversity of site factors vis-a-vis tree growth. The main reason for this lack of knowledge is that the observation of mycorrhizae in their natural state is methodologically very difficult.

Current problems faced by Mycorrhizal Researchers

A) In pure culture, mass production of ectomycorrhizae inoculum is expensive and production of VAM' has not been successful.

B) Conditions for survival and development of fungal inoculum in the soil are not well known.

C) Even if proven beneficial, is not mycorrhiza-plant-symbiosis already taking place naturally without need for further assistance ?

D) Many people are not convinced that mycorrhizal fungi really play an important role in plant nutrition and growth.

Since the hundreds of ectomycorrhizal fungi differ from each other in regard to ecological requirements and probably in symbiotic efficiency too, suggestions have been made to apply fungal pure cultures for nursery inoculation, instead of indiscriminate soil inocula. Inspite of numerous experiments, progress along this line has been slow. Following have been the main obstacles:

1) Isolation and cultivation of ectomycorrhizal fungi is difficult. Production of vegetative inoculum in large quantities is possible with few species only.

2) Symbiotic efficiency of individual species is not known. Even different strains of the same species may greatly differ from each other.

3) Inoculation of pure cultures into nursery soil has usually failed. The fungus has not been able to compete with indigenous fungi present in the soil (Mikola, 1989).

Future research needs

i) There is a wide gap between the information coming from laboratory and field conditions, therefore, extensive research needs to be carried out to abridge this gap.

ii) There are certain conflicting views on the same subject. No attempt has been made to resolve these differences which represent real areas of uncertainty.

iii) An integrated approach to study the mycorrhizae plant interactions in relation to moisture nutrient dynamics, micro flora and fauna in the soil and other relevant factors in arid and semi arid wastelands, is necessary.

iv) To develop suitable protocols for isolation and identification of indigenous mycorrhizal species from the existing plantations and screening out the best and promising strains for inoculation, studies need to be pursued.

v) Development of proper multiplication technology in the laboratory and field conditions to facilitate promotion of biofertilizers at farmers field and in the Government owned plantations on a field scale.

vi) Standardization of formulation of inoculum and inoculation methods for both endo and ectomycorrhizae.

vii) A formula for establishment of a network for exchange of information of germplasm material and also for joint activities.

viii) To make recommendations for the use of these biofertilizers in the nursery stage so that to make it a usual practice.

Conclusion

Arid zone is characterized by extremes of temperature, low and erratic rainfall, low relative humidity, high wind velocity and infertile soils having poor nutrient and moisture holding capacity. With the result, plant establishment and growth is extremely poor. The top soil layer is particularly affected by these adversities causing heavy mortality of seedling during the initial phase of plantations. The studies pertaining to beneficial effect of mycorrhizal inoculation have been mostly for temperate and sub-temperate species of trees. Such studies have provided ample experimental evidence of dramatic influence of mycorrhizae in improving tree nutrition and growth. The various edaphic and climatic factors are known to influence the mycorrhizal development, yet standard limits for such factors are not well established. There are reports indicating the occurrence of mycorrhizal associations between trees and fungi, but there are no specific limits of various factors above and below which such beneficial effects are drastically reduced. Therefore, mycorrhizal research base needs to be widened to study all the relevant factors and indicate the optimum conditions for the growth of mycorrhizae. This is of utmost importance in arid lands where factors affecting their growth and development are posing severe limitations.

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MULTIPURPOSE NITROGEN FIXING TREES FOR ARID ZONE AFFORESTATION

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Introduction

The total forest cover in the country is recently reported as 64.2 million ha (Anon, 1987) which is only 19.5% of the total geographical area against the National Forest Policy (1988) prescription of 33.3%. The fact that the closed forest is only 10.9% of the total geographical area is indicative of the environmental degradation prevailing in the country. The low proportion of the forest cover and the precarious state of the country's eco-system emphasize the need to enrich the natural forests and to bring as much land as possible particularly the wastelands and marginal lands under tree cover.

The arid and semi-arid regions in India cover 34.74 million ha and 97.05 m ha area, respectively (Mann & Muthana, 1984). The arid zone spreads over the states of Rajasthan, Gujarat, Haryana, Karnataka,

Maharashtra, Andhra Pradesh and Jammu and Kashmir (cold desert). In addition to these states, the semi-arid areas occur in the states of Tamil Nadu, Uttar Pradesh and Madhya Pradesh. Thus the arid and semi-arid regions in the country occupy more than 41% of the total geographical area.

Trees for arid and semi arid lands

The chief limiting factor for raising plantations successfully in arid zone is availability of moisture. So it is essential to identify suitable indigenous and exotic species which are drought resistant, withstand the pressure of biotic interference and well adopted to the climatic and edaphic conditions. Rate of growth, ease in establishment, wind protection value and the economic benefits should also be taken into consideration for selecting the species. The indigenous species are preferred over the exotics because the former are better adopted and specialized to face the inhospitable environment comparing to that of exotics. The introduction of exotics may be done only after trials and thorough study of ecological conditions.

Multipurpose Nitrogen fixing trees: As far as possible it is better to choose multipurpose trees for raising plantations for meeting the day to day needs of the local people. In this context, the tree species in the family leguminosae are of paramount importance. Many of the tree species exhibit a variety of morphological variations and withstand the harsh climatic conditions of the arid and semi arid regions. Several trees are reported to have been grown successfully in different habitats under different soil conditions of the arid lands. Most of the species provide multiple benefits to the local people. The added advantage of these species is the fixation of nitrogen from the air. Other species such as *Casuarina equisetifolia* is also known for fixation of nitrogen and ensure success in the coastal sandy soils.

Silvicultural suitability of the trees

The following are some of the important multipurpose nitrogen fixing trees recommended in different habitats of arid and semi arid portions of the country.

Acacia leucophloea	*Casuarina equisetifolia*
Acacia auriculiformis	*Dalbergia sissoo*

Acacia nilotica	*Derris indica*
Acacia senegal	*Parkinsonia aculeata*
Acacia tortilis	*Pithecollobium dulce*
Albizia lebbeck	*Prosopis cineraria*
Cassia siamea	*Prosopis chilensis*

The fast growing trees in the dry zone have distinct advantage over the slow growing species as they establish quickly and conserve the soil. *Acacia leucophloea* and *Acacia senegal* are the slow growing but all other trees recommended above are relatively fast growing.

Whether the species is evergreen or deciduous is an important parameter for selection of the species in arid zones. The wind velocity can be reduced by the foliage and it is in this context that the evergreen trees are likely to play important role. It is particularly important for the trees raised in wind breaks and shelter belts. Also the trees are efficient sinks for various pollutants. Trees with smaller leaves are the efficient filters of the air borne pollutants, the soil particles, than the trees with larger leaves. *Acacia auriculiformis, Acacia nilotica, Derris indica, Cassia siamea, Pithecollobium dulce* are the evergreen trees. *Prosopis cineraria and Prosopis chilensis* are semi evergreen to evergreen and they may remain leafless for very short periods. *Acacia leucophloea, A. senegal, Albizia lebbeck and Dalbergia sissoo* are the deciduous trees.

The moisture requirement of the species in dry zones is met exclusively from rainfall. *Acacia leucopholea, Acacia senegal, Acacia tortilis, Prosopis chilensis* and *Prosopis cineraria* are adopted to grow in areas where rainfall is less than 400mm.

Acacia auriculiformis, Acacia nilotica, Albizia lebbeck, Dalbergia sissoo, Derris indica, Pithecollobium dulce, Parkinsonia aculeata and *Cassia siamea* grow in areas with rainfall more than 400mm. Further, they thrive under the conditions where the mean maximum temperature in summer varies from 35 to 43°C and the mean minimum temperature ranges from 4°C to 13°C. The ability to withstand drought varies from species to species and depends upon the morphological and physiological modifications of the plant. i.e. small leaf area, thick cuticle, reduction in number of stomata, efficient conducting system and resistance of protoplasm to dehydration, etc. (Khanna, 1984). *Acacia leucophloea, Acacia tortilis, Dalbergia sissoo, Parkinsonia aculeata, Prosopis*

cineraria and *Prosopis chilensis* are highly drought resistant. The drought resistance of *Acacia nilotica* differs from place to place and ranges from moderate to high. Though established plants of *Acacia senegal* are highly drought resistant, the young plants are susceptible and hence require suitable moisture conditions in the nursery and in the early period of planting. As a general rule all the species require better moisture conditions during the seedling stage. *Acacia auriculiformis, Derris indica, Leucaena leucocephala, Pithecollobium dulce* and *Cassia siamea* are moderately drought resistant (Joshi, 1983).

To withstand the pressure of winds, trees are required to develop root system penetrating deep into the soil not only to make the tree windfirm but also to absorb the moisture from lower layers of soil. All the above mentioned trees are windfirm except *Albizia lebbeck, Cassia siamea and Acacia auriculiformis* because they have shallow root system and liable to be blown down by wind.

Coppicing ability is another silvicultural requirement of the species selected for afforestation in arid zone. This is particularly important if the species is raised with objective of fuel wood production. *Acacia leucophloea, Acacia senegal, Albizia lebbeck, Dalbergia sissoo, Derris indica, Pithecollobium dulce, Cassia siamea* are good coppicers. *Prosopis chilensis* and *Prosopis cineraria* are fairly good coppicers. The species can be worked under simple coppice system with rotation of 12-15 years. However, further studies are required to be carried out to understand the management of these species under coppice system specially in arid zone areas.

The soil needs of each species, rainfall range in which the species grow, methods of planting in the field and multiple benefits extended by these trees are given in the Table 1 (Anon, 1981, Anon, 1985 and Joshi, 1983).

Research Needs

Very little work has been carried out on the nitrogen fixing trees growing in the arid and semi-arid tracts, particularly with reference to the supply of fuel, fodder and small timber and their management under coppice systems in different habitats. The efficiency of the nitrogen fixation by these trees in dry region is little known and intensive researches are required to be carried out. Studies are also to be undertaken

Table 1. Soil and planting needs of different tree species in arid region of Karnataka

Species	Soil needs	Rain fall (mm)	Method of planting	Important uses
Acacia laucophloea	Black cotton, alluvial and sandy soils	380 – 1540	DS, EP	Fuel, fodder, poles and agricultureal implements
Acacia Auriculiformis	Red Soils, Lateritic and generally brown soils	700 & above	DS, EP, ST	Fuel, timber, ornamental tree
Acacia nilotica	Alluvial, loamy and black cotton soils	200 – 1270	DS, EP	Fuel, fodder, agricultural implements, gums, tannins
Acacia senegal	Shallow sandy soils with high percentage of salts	250 – 600	DS, EP	Gum, fuel, fodder, timber for agricultural works
Acacia tortilis	Sandy alkaline soils	100 – 1000	EP	Fodder, fuel, fence posts, charcoal
Albizia lebbeck	Loamy soils, lateritic black cotton, calcareous alkaline & saline soils	635 – 2450	DS, EP, ST	Timber for decorative, agricultural and structural works, foder and fuel, avenue tree
Cassia siamea	Variety of soils	500 – 2500	DS, EP, ST	Fuel, timber, avenue tree

Table contd....

Species	Soil needs	Rain fall (mm)	Method of planting	Important uses
Casuarina equisetifolia	Coastal sandy soils	1000 & above	DP	Fuel and timber for post wood
Dalbergia sissoo	Well aerated sandy alluvialsand, gravelly alluvium soils	760 – 4500	DS, EP, ST, BC, RS	Timber for furniture, decorative and construction, fuel and fodder, avenue tree
Derris indica	Deep sandy loam, saline alkaline sandy soils	500 – 2500	DS, EP, ST	Oil seeds, fuel and fodder, medicinal, avenue tree.
Parkinsonia aculeata	Black cotton soils, sandy soils	400 & above	DS, EC	Fuel, timber for agricultural implements, edible fruits
Pithecollobium dulce	Sandy soils, deep alluvilable loamy gravelly soils	500 – 1100	DS, EP, EC	Fuel, timber for agricultural implements, edible fruits
Prosopis cineraria	Black cotton soils, saline and alluvial soils	100 – 850	DS, EP	Fuel, charcoal, timber, fodder
Prosopis juliflora	Black cotton soils, sandy, saline and alkaline soils	250 – 760	DS, EP	Fuel, timber for construction, charcoal, fodder

DS : Direct sowing, EP : Entire planting; St : Stump planting BC : Branch cutting, RC : Rootsuckers

on the utility of leaves as fertilizers, coppicing schedules of different fodder trees and the yield of minor forest produce. It is particularly important to evolve the strains of species with faster growth and greater resistance to drought and other adverse conditions in the arid tracts by application of suitable tree breeding methods. Studies need to be intensified on the application of tissue culture techniques in the production of quality seedlings. Using this technology, possibilities should also be explored to produce the required quantity of seedlings for massive afforestation programmes being undertaken in the country.

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HABITAT SELECTION IN BIRDS ON DRY LAND EUCALYPTUS PLANTATIONS AND MANAGEMENT OF MONOCULTURE IN INDIA

D. N. Pandey and S. K. Dubey

Introduction

Extensive areas of arid lands and deteriorated wastelands have been planted with various species of trees and shrubs. *Eucalyptus* in the recent past made a substantial percentage as a species to be planted in monocultures as well as in poly-arboreal plantations in India. Such man made plantations and choice of species are bound to alter the species diversity and abundance of birds, for different environments support different bird fauna (Orians, 1969).

Our objective of this study was to document the resource utilization and habitat selection in birds on *Eucalyptus* plantations in India. Very few

studies are available on the resident avifauna of *Eucalyptus* plantations in India. Gray (1974) studied the birds of two isolated *Eucalyptus* plantations in Maharashtra. Khan (1980) gave a comprehensive account of the birds of sholas and neighbouring *Eucalyptus* and other plantations in the Nilgiris. Chakravarthy, *et al* (1986) analysed the effect of *Eucalyptus* on birds at Malnad, Karnataka. One of us has provided information elsewhere based on our studies on the nesting of birds on *Eucalyptus* plantations (Pandey, 1989).

Materials and Methods

During our study tours we spent more than 500 days during 1983 to 1990 visiting the forests and plantations of Andhra Pradesh, Kerala, Karnataka, Tamil Nadu, Maharashtra, Madhya Pradesh, Orissa, Rajasthan, Haryana, Punjab, Uttar Pradesh, Himachal Pradesh, Goa and Union Territory of Pondichery and Delhi. During these visits random observations were carried out in paired line transects (Anderson *et al,* 1979) in the plantations including avenues. Each transect covered about 200m straight line and counting of all perched, flashouts, foraging, roosting and nesting birds within approximately 20 m across the transect route. Additional information on various aspects of ornithology was noted. Isolated trees were also included in the study.

Results

Information related to nest site selection on *Eucalyptus* trees is given in Table 1. Information regarding the roost site, forage site and perch site selection is given in Table 3. Table 2 provides the roost site selection on *Eucalyptus* by Indian pea fowl.

During 1983 to 1990, nests of 15 species were recorded on *Eucalyptus* trees in India. This is the most exhaustive and recent information available on nest site selection on introduced *Eucalyptus* in India. Total number of nests for all 15 species were 488 temporarily distributed over the last 7 years of observations.

Number of species selecting roost site on *Eucalyptus* were 18, number of species which selected *Eucalyptus* as forage site were 19 and Perch site selecting species were 67.

Table 1 : Nest site selection on ***Eucalyptus*** trees in india*

No.	Name of the Species	Number of nests recorded
1.	*Acridotheres tristis*	13
2.	*Ardeola grayii*	26
3.	*Chalcophaps indica*	1
4.	*Corvus macrorhynchos*	64
5.	*Corvas splendens*	119
6.	*Dicrurus adsimilis*	3
7.	*Gypus bengalensis*	6
8.	*Nectarinia asiatica*	9
9.	*Nectarinia zeylonica*	7
10.	*Oriolus oriolus*	2
11.	*Psittacula krameri*	5
12.	*Ploceus philippinus*	138
13.	*Sturnus contra*	92
14.	*Tockus birostris*	2
15.	*Terpsiphone paradisi*	1

* Modified after Pandey, (1989 mss) communicated to JBNHS

Table 2 : Roost site selection on ***Eucalyptus*** trees by Pavo cristatus Indian fowl at Jhalana dungari plantation, Jaipur, Rajasthan

No.	Roost tree	Av. height (M)	Roost tree utilization per ha.		
			No. of potential roost tree available	Trees actually used for roosting	% preference
1.	*Albizia lebbeck*	8.5	9	1	
2.	*Azadirachta indica*	7.5	6	1	
3.	*Dalbergia sissoo*	7.5	13	2	
4.	*Ailanthus excelsa*	7.0	21	2	
5.	*Acacia nilotica* & *A. senegal*	6.0	117	6	
6.	*Eucalyptus*	13.0	39	37	

Table 3 : Habitat selection in birds on ***Eucalyptus*** plantation in India

No.	Habitat Attribute	No. of species making resource use
1.	Nest site selection	15
2.	Roost site selection	18
3.	Forage site selection	19
4.	Perch site selection	67

Roost site selection on *Eucalyptus* trees by *Pavo cristatus* is given in Table 2. Common pea fowl preferred *Eucalyptus* to all other species for roosting, occupying 37 trees out of available 39 potential roost trees.

Discussion

NEST SITE SELECTION

As is evident from results, 15 species of birds made nest on *Eucalyptus. Corvus macrorhynchos, Corvus splendens, Ploceus philippinus* and *Sturnus contra* are the regular breeders on *Eucalyptus* in their distribution ranges. This is in contrast to the observations of all the previous workers in India who concluded total absence of nests on *Eucalyptus*. Gray (1974) concluded from his comparative studies that no nests were found in *Eucalyptus* trees or in the *inner area* but 74 nests were found in the *outer area* on babul, cassia, sissoo, and one on toddy palm (*Borassus flabellifer), (Inner area* of Gray meant the area exclusively planted with *Eucalyptus)*. But his findings were at variance with those of Orians (1969) who found that bird species in undisturbed forests in Costa Rica were not measurably affected by the number of species of trees in the forest (Serrao *Pers. Comm.*).

Khan (1980)concludes that so far as food, shelter and breeding places are concerned, *Eucalyptus* and *Acacia* plantations provide poor environment as is evident, from the paucity of breeding birds. He noticed few species nesting in *Eucalyptus* plantations. Chakravarthy *et al*, (1986) pursuing a study on the effect of *Eucalyptus* on birds in Karnataka concluded that after six years in *Eucalyptus* planted areas the number of bird species decreased by two and a half folds. He could not notice any nest on *Eucalyptus* trees.

Australian *Eucalyptus* are also planted in Mediterranean regions, California, Sardinia, Chile and South Africa. As Cody (1985) informs, *Eucalyptus* supports a diverse bird fauna in Australia but their use by birds elsewhere is minimal, perhaps, because of trees often lack their insect fauna and hence have little food resource for birds to offer. Smith (1974) reports use of *Eucalyptus* nectar by hummingbirds in Chilean and Californian plantations.

In our study, selection of *Eucalyptus* as nesting tree by birds is governed by following factors :

1. Non-availability of traditional indigenous nesting trees in any locality may induce the birds to nest on *Eucalyptus* trees present in that locality. In Bilaspur, Madhya Pradesh we found nests of *Ardeola grayii* where in the absence of potential large nesting trees, birds made use of *Eucalyptus* for nesting. Thus birds made optimum use of available resources to pass the genetic material to next generation and they preferred nesting on exotic *Eucalyptus* to non-nesting.

2. Due to pre-occupation of traditional trees by non-colonial breeders, birds which arrived late in the locality preferred to nest on *Eucalyptus* rather than remain floaters. We recorded such examples in case of *Oriolus oriolus, Corvus splendens, Corvus macrorhynchos, Terpsiphone paradisi* and *Sturnus contra.*

3. Pre-occupation of traditional nest trees by colonial nesters compelled the remaining birds of the population to nest in *Eucalyptus* trees growing in close proximity to preoccupied traditional nesting trees. As we recorded in case of *Ploceus philippinus* nest colony where in one small *Acacia nilotica* tree 37 nests were present and 2 nests were constructed in *Eucalyptus* tree growing 2.5m away from *Acacia.*

4. Some times even the traditional nest trees are sacrificed due to presence of secondary factors required for nesting. Normally *Ploceus philippinus* prefers thorny trees growing in shallow water for nesting (Ali and Ripley, 1987). We recorded high density of nests on *Eucalyptus* tree growing in shallow water while an *Acacia* tree growing 50m away had no nests.

ROOST SITE SELECTION

An interesting aspect of habitat selection is roost site selection in birds. We recorded a clear case of preference for roost site selection by *Pavo cristatus* on *Eucalyptus*. Other indigenous trees growing in the Jhalana Dungari, Jaipur were *Albizia lebbeck, Azadirachta indica, Dalbergia sissoo*, etc. Since judicious selection of roost site may enhance survival of *Pavo cristatus,* it roosts on some of the tallest trees available in the area. Since the tallest trees were of *Eucalyptus* they were selected on merit, as they provide better predator protection. There are chances of predation by jungle cat in the area and thus strong selective pressure operates in birds to select nocturnal roost sites that minimize the risk of predation and enhances the chance of survival for the species.

FORAGE SITE SELECTION

Birds feeding directly on the flower-petals and nectar were *Dicrurus hottentottus, Nectarinia asiatica* and *Nectarinia zeylonica* (Pandey, 1989). Here again we disagree with Chakravarthy *et al* (1986) who concluded that *Nectarinia asiatica* neither nests nor collects any food from *Eucalyptus* plantation. Other species foraging in the bark of old *Eucalyptus* trees were *Dinopium benghalense, Picoides mahrattensis* and birds gleaning through the foliage for insects were *Clamator jacobinus, Oriolus oriolus, Dicrurus adsimilis, Dicrurus leucophaeus, Dicrurus caerulescens, Sturnus malabaricus, Sturnus contra, Acridotheres tristis, Pycnonotus cafer* and several species of birds who took perch on *Eucalyptus* and launched aerial sallies to catch the winged insects.

Management Implications

Large scale plantations of *Eucalyptus* are bound to be audited ecologically for their long term effects on faunal communities in India (Shiva and Bandhyopadhyay, 1985). Indigenous floral communities provide traditional nesting, roosting and foraging site and hence are preferred by birds but in such places where arboreal flora are absent and land is barren, *Eucalyptus* does provide a second rate alternative which may be accepted by birds as is evident from our results. However, we make clear that degree of acceptability is very low as during the last 7 years only 15 species could be seen nesting and we could record only 488 nests. Thus, if we want to encourage arboreal nesters on barren wastelands, and at the same time we are unable to grow indigenous species for edaphic and

climatic reasons, *Eucalyptus* may not be a bad choice. But if management objective is to maintain the local bird communities for reasons of their threatened status or rarity, we do not recommend planting *Eucalyptus* in such areas.

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THE EFFECT OF AFFORESTATION ON THE ABUNDANCE AND DIVERSITY OF BIRDS

S. K. Dubey and D. N. Pandey

Introduction

Vast tracts of wastelands in India are being put under afforestation. Man-made plantations are bound to cause changes in the avifauna of wasteland, since differing environments and habitats characteristically support different bird species (Orians, 1969). This alteration in species composition and population density is supposed to be the consequence of altered availability of roosting site, nesting grounds and foraging resorts.

Specific studies correlating the birds and the habitat alterations have been carried out by several workers. Gray (1974) published the information on avifauna of *Eucalyptus* plantation in Maharashtra. Khan (1980)

gives a comparative account of avifauna of sholas and the neighbouring plantations in the Nilgiris. Gole (1987) studied the effect of hill deforestation on birds. Ripley (1978) and Ripley *et al* (1987) while studying the birds of Vishakhapatnam Ghats (Andhra pradesh), gave information on the extent to which large scale habitat alterations through the Ghats region have affected the structure and composition of local bird life. Ripley (1978) studied the changes in the bird fauna of forest areas in Orissa. Gaston (1986) studied the effect of grazing on the abundance and diversity of birds in scrub vegetation at Nathdwara, Rajasthan. Gaston (1984) studied the effect of habitat destruction on birds in India and Pakistan. Bhatt (1990) conducted preliminary observations on avifauna of reclaimed rock phosphate mine in Mussoorie hills. Authors studied the nesting of birds on *Eucalyptus* and Habitat selection in birds on *Eucalyptus* (Pandey, 1989 a & b)

The basic objective of this study was to determine the afforestation induced changes in the diversity and the density of bird life in the original wasteland, nonplanted dryland and altered habitat. Such ecological studies are of special relevance in India where vast tracts of wastelands are being brought under different patterns of vegetational cover through social forestry and wasteland development projects.

Materials and Methods

First study area is situated 8 km from the city of Bilaspur (22°05' N, 82°13'E), Madhya Pradesh. Area locally named as Chakrabhata was originally a wasteland with scanty vegetation. Various species of resident and roosting birds with respective number were recorded by strip census method (Giles, 1981) in the entire study area (10 ha) before plantation. Nests found in the area were also recorded (Table 3). From 1983 onwards Chakrabhata wasteland was put under plantation. Tree species planted are listed in Table 2. Density of plantation is 2500 saplings/ha. Species of birds occurring in the planted area alongwith the total number of birds of each species were recorded on two particular sample days, January 7th, 1988 and June 25th, 1988. Number of nests built between January 1988 and December 1988 were also recorded. To collect the additional information, the study plot was visited on 15 sample days (Table 4).

Table 1 : Vegetation of 'Chakrabhata' wasteland, Bilaspur before the Plantation

No.	Species
1.	*Aristida setacea* Retz.
2.	*Bothriochloa kuntzeena* (hack) Henr.
3.	*Cynodon dactylon* Pers
4.	*Dicanthium annulatum*
5.	*Eremopogon foveolatus* (Hack) Stapf.
6.	*Heteropogon contortus* Beauv.
7.	*Sehima nervosum* stapf.
8.	*Eragrostis* beauv
9.	*Tephrosia purpurea* (L) Pers.
10.	*Ziziphus nummularia* (Burm. f.)

Table 2 : Trees planted in the Chakrabhata, Bilaspur wasteland afforestation

Sl. No.	Species	Average height m	Average crown cover m	
1.	*Acacia arabica* willd.	2.6	1.2	x 1
2.	*Albizia procera* Beth.	3.9	2	x 1.5
3.	*Albizia lebbeck* Benth.	4.2	2.6	x 2
4.	*Azadirachta indica* A. juss.	2.7	1.3	x 1.1
5.	*Cassia siamea* lamk	2.5	2.8	x 1.8
6.	*Dalbergia sissoo* Roxb.	5.2	3.9	x 3.5
7.	*Dendrocalamus strictus* Ness	–		
8.	*Derris indica* (Lamk) Bennet	2.4	1.9	x 1.6
9.	*Eucalyptus* L. Her (hybrid)	7.2	4.2	x 3.1
10.	*Gmelina arborea*	1.9	1.6	x 1.2
11.	*Hardwickia binata* Roxb.	3.2	2.1	x 1.1
12.	*Holoptelea integrifolia*	2.5	1.8	x 1.3
13.	*Leucaena leucocephala*	3.9	1.4	x 1.7
14.	*Peltophorum pterocarpum* (D.C.) Baker Ex Heyna.	3.8	2.1	x 1.3
15.	*Terminalia arjuna* W. et A.	1.8	1.5	x 1.5

Table 3 : Birds of the Chakrabhata, Bilaspur wasteland before plantation

No.	Species	Birds density/ha	Nests density/ha
1.	*Francolinus pondicerianus* (Gmelin)	0.7	0.3
2.	*Coturnix coturnix* (Linn)	1.02	0.2
3.	*Turnix tanki* Blyth	1.1	0.2
4.	*Vanellus malabaricus* (Boddaert)	1.1	0.1
5.	*Eremopterix gorisea* (Scopoli)	2.4	0.9
6.	*Anthus novaeseelandiae* Gemelin	0.9	0
7.	*Ammomanes phoenicurus* (Franklin)	0.3	0
	Species	7.9	1.7

Ali & Ripley (1987)

Table 4 : Birds recored in the plantation area at Chakrabhata Bilaspur wasteland

No.	Species	Birds density/ha	Nests density/ha
1.	*Bubulcus ibis* (Linn)	0.7	0
2.	*Milvus migrans* (Boddaert)	0.1	0
3.	*Streptopelia chinensis* (Scopoli)	0.6	0.3
4.	*Chalcophaps indica* (Linn)	0.2	0
5.	*Psittacula krameri* (Scopoli)	1.1	0
6.	*Cuculus varius* Vahl.	0.3	0
7.	*Eudynamys scolopacea* (Linn)	0.5	0
8.	*Caprimulgus asiaticus* Latham	0.1	0
9.	*Merops orientalis* Latham	1.1	0
10.	*Coracias benghalensis* (Linn)	0.4	0
11.	*Lanius schach* (Linn)	0.5	0
12.	*Dicrurus adsimilis* (Bechstein)	0.7	0
13.	*Sturnus contra* (Linn)	1.3	0
14.	*Acridotheres tristis* (Linn)	1.1	0
15.	*Corvus macrorhynchos* (Wagler)	0.7	0.2
16.	*Pycnonotus cafer* (Linn)	2.0	0.5
17.	*Copsychus cafer* (Linn)	0.3	0
18.	*Nectarinia asiatica* (Latham)	0.9	0.6
19.	*Nectarinia zeylonica* (Linn)	1.0	0
20.	*Ploceus philippinus* (Linn)	0.9	0.7
21.	All birds of Table 3	5.4	1.2

1. Ali & Ripley (1987)

Second study site, Jhalana Dungari, is situated in outskirts of Jaipur, with a semi arid climate and predominantly sandy soil and rocky hillsides. The area forms part of the Aravalli system. All observations were carried out in paired transects one each in planted and non-planted area. Each pair was carried out as close, in spatio-temporal respects, as possible covering the ground with similar slope, aspect and geology to avoid the influence of other factors during each transect. We performed 10 pairs of transects during 9th July to 26th November 1990. Each transect lasted 25 minutes and covered 750 m stretching as a straight line between predetermined points and taking note of all birds within an estimated 20m width of transect route.

Results

In our first study-site at Bilaspur, 79 individuals belonging to 7 ground dwelling bird species and 17 nests were present before plantation in 10 ha study area (Tables 3 and 4). During post plantation observations 199 birds belonging to 27 species were recorded. Number of nests recorded was 35. During post-plantation observations, height of trees ranged from 1.8 m to 7.2 m (Table 2).

In our second study area at Jhalana Dungari, Jaipur, vegetation species richness, number of birds, and species composition recorded are given in Table 5.

Vegetation

Vegetation of non-planted area consisted mainly of *Euphorbia royelei, Ziziphus nummularia, Tephrosia purpurea* and *Aristida setacea.* Vegetation of the plantation area was similar to non-planted area, the only difference being of the tree species planted. More than 80% plantation was of various species of *Acacia* and 20% was occupied by *Eucalyptus* sp., *Dalbergia sissoo* and *Azadirachta indica.* Average height of trees was 5.7 m. Relative completeness of crown was 35 to 40%.

Species richness

Taking into account of all transects, 8 species of birds were recorded in the non-planted area and 22 species in the plantation area. Only 7 species were common to both areas.

Table 5 : Birds of the plantation and barren areas at Jhalana Dungari, Jaipur, Rajasthan

No.	Species	Average number of birds per transect	
		Barren/Non-planted area	Plantation
1.	Grey Partidge *Francolinus pondicerianus*	1	4
2.	Indian Ring Dove *Streptopelia decaocto*	0	2
3.	Little brown dove *S. senegalensis*	6	9
4.	Roseringed Parakeet *Psittacula Krammeri*	0	1
5.	Green Bee eater *Merops orientalis*	0	7
6.	Grey Shrike *Lanius excubitor*	0	2
7.	Baybacked shrike *Lanius vittatus*	0	1
8.	Black Drongo *Dicrurus adsimilis*	0	2
9.	Black headed Myna *Sturnus pagodarum*	0	1
10.	Common Myna *Acridotheres tristis*	0	.5
11.	Marshall's Iora *Aegithina nigrolutea*	0	1
12.	Redevented Bulbul *Pycnonotus cafer*	12	3
13.	Large Grey Babbler *Turdoides malcolmi*	4	0
14.	Indian Tree Pie *Dendrocitta Vogabundra*	0	1
15.	Indian Robin *Saxicoloides fulicata*	3	5
16.	Rufous fronted Wren-ukrbler *Prinia buchanani*	0	2
17.	Plain Wren-Warbler *Prinia subflava*	0	1
18.	Lesser White throat *Sylvia curruca*	1	2
19.	Purple sunbird *Nectarinia asiatica*	0	2
20.	Whitebacked Munia *Lonchura striata*	0	2
21.	Common Pea Fowl *Pavo cristatus*	1	3
22.	Hoopoe *Upupa epops*	1	4
		29	55

Number of birds

The mean number of birds of all species recorded in the non- planted area was 2.9 birds per transect. In plantation the corresponding figure was 5.5 birds per transect. Hence we conclude that bird densities are higher in the plantation area.

Species composition

From Table 1 it is evident that certain species exhibited preference for particular area. Species exclusively recorded in the non-planted area was Large Gray Babbler. Birds recorded exclusively in plantation were Indian Ring Dove, Roseringed Parakeet, Green Bee-eater, Grey Shrike, Baybacked Shrike, Black Drongo, Blackheaded Myna, Common Myna, Common Iora, Indian Tree pie, Rufous fronted Wren-Warbler, plain Wren-Warbler, purple Sunbird and Whitebacked Munia. Most numerous birds of non- planted area were Little-Brown Dove and Redvented Bulbul, and in plantation were Little Brown Dove, Green Bee-Eater, Grey partridge, Hoopoe and Indian Robin. The Little Brown Dove was well represented in both areas.

Discussion

It is evident that after plantation there was a marked increase in density and diversity of birdslife and nests in Bilaspur area. It is noticeable that preplantation avian community comprised mostly of ground dwellers whereas, after the plantation, out of 27 species recorded, 20 species were more or less arboreal. At Jhalana Dungari, also the area showed a marked increase in density and diversity of birdlife in planted area.

The plausible reasons for such changes in avian population can be

1. Increased production of food material for birds in the form of flower nectar, fruits and arthopods associated with vegetation. (Jackson, 1979).
2. Increased availability of roosting sites, protective cover and shade.
3. Qualitative and quantitative intensification of effective nesting site per unit land area on account of crown development of planted trees.

Hopefully, similar studies in future will yield substantial data- base for wildlife managers to go for appropriate choice of species based on the principles of multiple use of forestry on wastelands.

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41

ARAVALLI HILL ECO-RESTORATION– FEW THOUGHTS

N.K. Bohra

Introduction

Aravalli hills are the oldest hill ranges extending from North–East to South west of Rajasthan that is Delhi to Gujarat bisecting Rajasthan into 2 portions, Thar desert and semi-arid region. The western part occupying 2/3 rd of total area of the state of Rajasthan is almost arid, while the eastern part is comparatively well drained and fertile. The Aravalli system stretching over 692 km influences the ecological equilibrium of almost 50% area of the state.

Climate

The climate of Aravalli is characterized by extreme temperature, long period of severe drought, high winds and low humidity. In the South-East part of Aravalli there is a considerable variation in the amount of rainfall

and the maximum temperature touches 48°C mark. The winter is cool and temperature falls below freezing point. The region receives 90% of the annual rainfall in the period starting from 3rd weak of June to September.

Present Environmental Status

At the time of independence, the Aravalli hills had dense forest and provided rich habitat for wild life extending in the vast tracts of higher hills & valleys. During post independence period massive felling of trees to meet the increasing demand for timber, fuel, fodder, etc has resulted in diwindling of forest wealth. Studies by the interpretation of multidate Remote sensing data indicated that (Dhabriya, 1986) Aravalli districts had 10,462 km area under forest cover in 1972-75 which was reduced to 6,116 km in 1980-84 amounting to 41.54% decrease and it might have gone down more than 50% in view of present condition.

The flora and fauna of Aravalli hills vary with altitude due to change in climatic & edaphic factors. On Khetri hills (at 792 msl) the vegetation is scrubby and in degraded stage. The top of the hill is barren while on slopes, *Acacia senegal, A. leucophloea, Balanites aegyptiaca* with *Capparis decidua* and *Euphorbia nivulia* are seen. On Harshnath hills (at 913 msl) the floral composition upto 600 m is same as in Khetri while above that *Anogeissus pendula, A. latifolia, Prosopis cineraria, Wrightia arborea* are more prominent. Further south- westwards at Kho (920 m), Raghunath garh (1055 m) and Todgarh in Ajmer district besides *Anogeissus sp,* and *Prosopis cineraria* other plants viz. *Boswellia serrata, Bauhinia racemosa* etc are present. At Mt. Abu (1727 m) *Carvia callosa, Mangifera indica, Jasminum humile, Cradinea belylanica, Catava nurvala* etc are more prominent. However, the ground cover comprising of *Acanthospermum hispidum, Blainvillea acmella, Selerocarpous africanus* and species of *Cassia, Alysicarpus,* etc were also seen.

In the north-eastern direction from Bijapur right upto Khetri hills not only the density of the above mentioned flora decreases but species like *Boerrhavia diffusa, Dactyloctenium aegypticum, Evolvulus alsinoides, Glossocardia aegypticum,* etc become more common.

Suggestion for Restoration

For the regeneration of degraded Aravalli hills, following development programmes may be formulated

(1) The natural regeneration of the native species of Aravallies, particularly *Anogeissus pendula* and *Anogeissus latifolia* need to be improved for which indepth studies on seed technology, soil management practices and tree improvement are required.

(2) Protection of the fragile areas (hill slopes) particularly Seeta mata forest in Chittorgarh and forest areas of Alwar and Dholpur, etc is required.

(3) The fuel and fodder productivity from fringe areas (foot hills) will help in meeting the day to day needs of the local population and diffuse pressure from the highly degraded sites. This will also include involvement of people in plantation programme.

(4) Water and soil conservation programmes on wasteland basis by planning, conservation and management of resources.

(5) Providing alternate energy sources, such as regular supply of L.P.G. gas cylinder, gober gas, solar cooker, etc on easy terms in the hilly areas.

(6) Educational and mass media programmes need to be developed to educate the tribals in the vicinity of these hills not only in improving productivity but also about the role of environmental improvement in that area.

(7) Development of wasteland.

As the hill area of Rajasthan suffers the most because of the existence of large chunk of land under the category of wasteland, this area is increasing day by day. Such areas should be developed by undertaking different programmes under :-

(i) Tree plantation (ii) Water conservation

(iii) Pasture development (iv) Dense afforestation (v) Regeneration of rocky hill areas

(vi) Preservation of left over top soil, etc

Conclusion

The rapidly decreasing forest area of Aravalli could be checked and to re-established by soil and water conservation programmes, protection

of existing forest area, increasing productivity of fuel, fodder & other minor products & also by educating local inhabitants to improve the environment.

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FORESTRY IN SUPPORT OF LIVESTOCK ECONOMY OF ARID REGION

A.L. Chaudhry, R.K. Beniwal and J.S. Mann

Introduction

About 12 per cent of the total area of India is covered under arid zone and 90 per cent of it lies in the north western part. Livestock farming plays an important role in the economy of arid regions as there are risks involved in the crop farming because of uncertainty of rainfall. In addition to direct economic contributions through meat, milk, wool, skins and hides the livestock population provides employment to about two-third proportion of human population in this region. The important livestock species contributing to the economy of arid region are cattle, sheep, goats and camel.

Over exploitation of natural resources by increased human and livestock pressure resulting in scarcity of feed and fodder resources is the major constraint in animal productivity. Agro- forestry or forage forestry

(silvipasture) is one of those several types of integrated systems for balanced use of natural resources of arid regions capable of giving high productivity on sustained basis. Thus, carrying capacity of existing rangelands can be increased manifold through the adoption of forage forestry system which in turn may help in bridging the gap between the demand and supply of feed resources.

Extent and Distribution of Arid Zone in India

The arid regions of India (including the cold desert of Ladakh) comprise about 12 per cent of the total area of the country. The statewise area of the arid zone in India and the percentage of the total arid zone area in the country are presented in Table 1.

Table 1 : Statewise areas of the arid zone in india

State	Area under the arid zone (km^2)	Percentage of the total arid zone in India
Rajasthan	196150	62
Jammu & Kashmir	70300	–
Gujarat	62180	20
Andhra Pradesh	21550	7
Punjab	14510	5
Haryana	12840	4
Karnataka	8570	3
Maharashtra	1290	0.4
Total	387390	–

* The total excludes the area of cold arid zone in J&K

The arid area in north-western India constitutes about 90 per cent of the total arid zone in the country (excluding the cold desert area of Ladakh in J&K). Further, about 62 per cent arid area of the country falls in the western Rajasthan. The boundary between the arid and semi arid zones in Rajasthan cuts across Jalore and Pali districts which are lying along the boundaries of Ajmer and Nagaur districts. The arid districts of the Rajasthan State are Barmer, Bikaner, Churu, Ganganagar, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagaur, Pali and Sikar which are also the home tracts of the prized breeds of sheep, milch and dual purpose cattle, dual purpose goats and camels.

Vegetative covers of arid region

Hot Arid Region: Due to harsh climatic conditions, the physiognomic aspect of the hot arid zone is poor, scanty xerophytic vegetation widely dispersed leaving large area barren. Champion (1936) has recognised the following principle types of vegetation in arid regions of Rajasthan: (1) the northern desert thorn forest (2) the northern *Acacia* scrub forest (3) the northern *Euphorbia* scrub (4) the inland dune scrub. However, according to Meher-Homji (1977) following vegetation types of India may be listed under the category 'arid' in its broadest sense in the decreasing order of aridity:

(1) *Calligonum polygonoides* type

(2) *Prosopis cineraria - Capparis decidua - Ziziphus-Salvadora* type

(3) *Acacia - Capparis* type

(4) *Acacia senegal - Anogeissus pendula* and *Acacia catechu - Anogeissus pendula* type

(5) The marginal sub-dry types

Out of the above vegetation types, only the first three types are most commonly found in the hot arid region of north-western India.

Cold Arid Region: In the cold desert of J&K, the dominant vegetation type is alpine and sub alpine pastures. According to the estimates made by Butt *et al* (1980) a total area of 0.3 m hectare is under alpine and sub alpine pastures in Kashmir. Locally known as Margs, Bhaks or Dhokes these are dominated by grass covers. The most common grasses found are *Agropyron caninum, Agrostis canina, A.gigantea, A.nervosa, Bromus mollis, Chrysopogon echinulatus, Dactylis glomerata* , etc. The common legumes are *Austragalus candolleanus, A.bucocephalus, A. macropterus, A. subulatus, Lespedeza sericea, Medicago lupulina, M.sativa, Trifolium repens, T.pratense*. Besides grasses and legumes, a large number of weeds are found in these pastures which are responsible for the degradation of these pastures. These pastures in the cold arid region of Kashmir produce about 0.75 m tonnes of dry forage annually.

Table 2 : Livestock population expressed in million adult cattle units (ACU) in north western Indian arid zone.

State/Districts	1961	1966	1972	1977	1981
Rajasthan					
Barmer	8.58	10.68	8.04	7.98	12.98
Bikaner	5.23	6.48	5.21	5.28	11.93
Churu	3.39	3.99	4.98	6.32	7.14
Ganganagar	6.32	6.87	8.34	9.48	11.94
Jaisalmer	3.00	3.64	1.87	2.22	4.91
Jalore	4.78	5.63	4.98	5.44	5.95
Jhunjhunu	3.23	3.15	3.92	4.45	4.77
Jodhpur	4.78	5.74	6.20	8.47	8.73
Nagaur	4.78	5.74	6.20	8.47	8.73
Pali	6.52	7.42	7.44	8.29	7.89
Sikar	4.16	4.61	5.79	5.78	6.66
Total	54.72	64.38	64.61	76.33	86.56
Gujarat					
Kutch	5.33	4.89	4.25	3.90	
Jamnagar	4.18	4.18	4.45	3.69	
Rajkot	5.11	5.32	5.76	4.79	
Surendranagar	3.21	3.29	3.14	2.86	
Junagadh	5.72	6.05	6.59	6.28	
Banaskantha	7.95	8.25	6.99	7.21	
Mehasana	7.08	7.22	7.32	7.25	
Ahmedabad	4.28	4.22	4.60	4.26	
Total	47.99	43.44	43.10	40.24	
Haryana					
Hissar	8.01	–	10.98	5.93	
Jind	2.84	–	3.16	4.75	
Mahendranagar	2.52	–	3.42	3.35	
Ambala	3.59	–	4.42	4.78	
Rohtak	6.49	–	7.83	4.91	
Total	23.45		29.81	23.72	

Source : Shankarnarayan and Kalla, 1985.

Role of livestock in the arid region economy

Livestock farming has built-in superiority over crop farming in the arid regions of India with respect to growth, stability and resource conservation. The uncertainty and uneven distribution of rains in this region severely affect the productivity of crop farming and thus leads to instability of agricultural production. On the contrary, the impact of disturbed natural forces is much less on livestock farming. The economic analysis of the farming systems of arid zone (Shankar and Kumar, 1987 and Kalla and Bhati, 1988) also revealed that amongst the elements of agrarian production systems, mixed livestock farming has traditionally demonstrated an economic edge over other enterprises on account of relatively greater capacity to withstand rigours of arid environment.

Table 3 : Livestock population of the arid districts of Rajasthan (1981)

(Livestock Population in million numbers)

Districts	Cattle	Buffalo	Goat	Sheep	Camel
Barmer	0.39	0.03	1.11	0.85	0.12
Bikaner	0.28	0.04	0.34	0.80	0.06
Churu	0.27	0.14	0.60	0.46	0.10
Ganganagar	0.48	0.31	0.41	0.33	0.11
Jaisalmer	0.12	–	0.43	0.68	0.05
Jalore	0.35	0.11	0.36	0.48	0.02
Jhunjhunu	0.17	0.17	0.40	0.18	0.04
Jodhpur	0.53	0.015	0.75	1.01	0.06
Nagaur	0.58	0.17	0.72	0.85	0.04
Pali	0.57	0.15	0.48	0.75	0.01
Sikar	0.28	0.18	0.56	0.29	0.04
Total of arid districts	4.02	1.315	6.16	6.68	0.65
Total of Rajasthan	12.90	5.07	12.31	9.94	0.75
% of total population of State arid zone	31.2	25.9	50.0	67.2	86.7

The livestock population expressed in million adult cattle unit (ACU) of the arid zone districts of north-western India, given in Table 2, indicate that the livestock population in the arid districts of both Gujarat and Haryana, decreased between 1972 and 1977, whereas in the arid districts of Rajasthan livestock population increased by 18.4 per cent between the same period and it further increased by 13.4 per cent in 1981.

According to 1981 census, the arid districts of Rajasthan account for 31.2 per cent cattle, 25.9 per cent buffaloes, 50.0 per cent goats, 67.2 per cent sheep and 86.7 per cent of camel population of the whole State (Table 3). Thus, livestock species are contributing substantially to the economy of the region. Well established milch breeds namely Tharparkar and Rathi, dual purpose Kankrej and Nagauri cattle have their home tract in this region. Carpet wool sheep and dual purpose goats are also important livestock of this region.

The specieswise animal population in the arid regions of Rajasthan indicates increase in the population of all the species during 1972-82 decade. The highest increase of 69.19 per cent is in sheep followed by 58.02 per cent in buffaloes, 30.54 per cent in cattle and 27.18 per cent in goats.

Distribution of livestock species and per cent increase in the arid regions of Rajasthan.

(in lakhs)

Year	Livestock Species			
	Cattle	Buffaloes	Sheep	Goats
1972	34.79	11.10	51.66	58.14
1982	45.44	17.54	87.30	73.94
Percent increase	30.54	58.02	69.19	27.18

On moderate estimates based on the livestock population of Rajasthan (1982), the economic gains through animal products in the arid districts of Rajasthan excluding Ganganagar and Pali are given in Table 4.

Table 4 : Estimated economic gains through animal products in the arid districts of Rajasthan

S. No.	Name of the product	Estimated value in mill. rupees
1.	Milk (cattle and buffaloes)	3878.00
2.	Milk (goats)	870.00
3.	Wool	185.82
4.	Meat (sheep and goats)	425.00
5.	Eggs	5.97
6.	Skins and hides	27.41
7.	Farm yard manure	558.00

It is evident from the above that livestock rearing is the main economic stay of the region. In addition, livestock provides employment to a sizeable proportion of population. According to the socio-economic surveys conducted by CAZRI, Jodhpur about two- third of the earning members in the household surveyed in this region followed animal husbandry as their main occupation. The livestock sector in Rajasthan is estimated to account for more than 20 per cent of the total income of the State and considering the employment provided by this sector, the contribution of livestock to the economy of this region would be even higher. In addition to managing livestock a sizeable population in the region is engaged in the handicraft industry utilising animal products such as wool, skins, hides, hair and in marketing milk and milk products and livestock. The arid region contributes almost 40 per cent of the total wool produced in the country. Similarly, the contribution of this region to the production of meat, milk and other animal products in the country is also substantial.

Demand and supply of feed resources in arid zones

In spite of the quality breeds of various livestock species having their home tract in the arid regions of the country contributing substantially to the rural economy, the major constraint in their optimum and efficient productivity is the availability of not only inadequate quantity of forages, but even the quality of the range forages and crop residues with respect to their energy protein and mineral contents. On account of this major constraint and recurring failure of rainfalls the animal husbandry now falls in the category of trans-human and migratory type. Any effort made towards increasing grazing resource availability as an inbuilt component

of the development approach of arid regions will definitely be reflected in increased animal productivity, thereby improving the socio-economic condition of the arid region population.

Table 5: Demand-supply of grazing resources in north-western arid zone (Lakh tonnes) in 1981

State/Districts	Demand	Supply	
		Without crop residue	With crop residue
Gujarat			
Kutch	9.75	12.23	26.83
Jamnagar	9.23	0.94	11.52
Rajkot	11.99	2.86	19.78
Surendranagar	7.15	1.68	15.60
Junagadh	15.69	2.29	15.10
Banaskantha	18.03	1.91	18.87
Mehasana	10.65	1.55	15.14
Ahmedabad	18.14	1.54	17.06
Total	100.63	25.00	139.90
Haryana			
Hissar	14.83	0.40	6.17
Jind	11.88	0.16	4.25
Mahendranagar	8.39	0.20	4.14
Ambala	11.96	0.94	4.07
Rohtak	12.27	0.20	4.95
Total	59.33	1.30	23.58
Rajasthan			
Barmer	32.46	2.49	24.87
Bikaner	29.83	3.40	16.34
Churu	17.86	0.60	19.97
Ganganagar	29.86	0.87	23.19
Jaisalmer	12.28	6.09	10.96
Jalore	12.87	0.88	9.65
Jhunjhunu	11.82	0.28	6.74
Jodhpur	21.84	2.05	20.57
Nagaur	25.80	2.06	19.81
Pali	19.75	3.80	11.81
Sikar	16.66	0.50	8.04
Total	233.03	23.83	172.00

Source : Shankarnarayan and Kalla, 1985.

Hot Arid Region: In an exercise on demand-supply situation of grazing resources of different districts (Shankarnarayan and Kalla, 1985), it was revealed that from 1961 to 1981, demand for grazing resources has registered a continuous increase in the western arid Rajasthan; a decline in Gujarat; and an increase in 1971 with decline in 1981 in Haryana to attain almost an equal level of 1961 demand. It was further stated that even if estimates for crop residues were added to the supply of herbage from grazing lands, all five districts of Haryana, 10 districts of Rajasthan (except Churu) and three districts of Gujarat were deficient in forage supply in 1981 (Table 5). The deficit was larger for Rajasthan (1.266 to 13.48 lakh tonnes) and Haryana (4.25 to 9.666 lakh tonnes) and much less for Gujarat (0.58 to 1.07 lakh tonnes). It was also concluded that if crop residue is excluded from these estimates almost all arid districts in all years experienced continuous deficit. Although top feed component has not been added to this exercise, it is likely to change the situation only slightly.

Cold Arid Region: The fodder resource availability situation in the cold arid region is also not much different. During the last more than three decades, the livestock population has increased by more than 90 per cent (Shah, 1987) which has further aggravated the problem of animal nutrition. The gross fodder requirement is estimated around 7 m tonnes on dry matter basis and the gap between demand and availability is much wider which is progressively increasing due to increase in animal population. Permanent pastures and grazing lands comprising about 0.41 m ha are largely depleted and deteriorated.

In view of the above, it is apparent that not only to increase the animal productivity, but even to sustain it at the present level, concerted efforts are required to improve the grazing resources availability in the arid regions. Adoption of large scale silvi-pastoral systems and agro-forestry through coordinated efforts of the development agencies engaged in the task of desert development is the only answer. Moreover, in order to develop location specific technologies for enhancing the productivity as well as post harvest technology, concerted research efforts are needed to be taken up.

Role of forestry in increasing fodder resource availability in arid regions

The fodder trees and shrubs present in the existing rangelands as well as cultivated fields as a component of traditional agroforestry system in the hot arid and semi-arid region of north-western India contribute substantially to the fodder needs of the region specially during the scarcity periods. In this region rangelands and pastures occupy on an average 45 per cent of the total land and in extreme arid tracts like Jaisalmer district of Rajasthan, 90 percent of the area is used as grazing lands (Shankar and Kumar, 1987). In these rangelands there are few scattered thorny trees and bushes some of which have high forage value. Shankar and Kumar (1987) estimated that in Jaisalmer existing forage shrubs and tree cover was much less (1.5 to 9.5 per cent) than the desired level. The leaf fodder yielding shrubs and trees and their production potential in Jaisalmer district are given in Table 6.

It is difficult to estimate the quantity of dry matter available through the top feeds in the arid region, however, it is roughly estimated that 60 per cent of the feed available to sheep, goats and camels come from top feeds only (Singh, 1981). Studies have shown that a density of 14 per cent *Ziziphus nummularia* is optimum for increased forage production (Kaul and Ganguli, 1963a). *Prosopis cineraria* is an important forage tree species which grows in rangelands and cultivated fields (sometimes more than 80 to 100 trees per ha) without any detriment to the associated ground cover. The tree is lopped for its protein rich (17.49%) leaves. Studies have shown that complete lopping of Khejri tree gives a significantly higher yield (58.72 kg per tree) than the lopping of the lower two-thirds (28.48 kg per tree) and the lower one-third (19.73 kg per tree) of the crown. Similar results were reported by Mann *et al* (1989) from the lopping management studies carried out in the semi-arid region of Rajasthan. The results of dry leaf fodder yield obtained from representative trees are given in Table 7.

Table 6. Density of top feeds and their leaf fodder yield on different land forms in Jaisalmer district

Habitats	Bordi		Lana		Khejri		Total
	(*Ziziphus nummularia*)		(*Haloxylon salicornicum*)		(*Prosopis cineraria*)		browse
	Density (Plant/ha)	Leaf fodder yield (kg/ha)	Density (Plant/ha)	Leaf fodder yield (kg/ha)	Density (Plant/ha)	Leaf fodder yield (kg/ha)	yield (t/ha)
Piedmonts and inter-montane colluvial plains	66	3	160	40	45	675	0.7
Rumels and streams	68	5	54	14	20	300	0.3
Buried pediments	81	7	250	63	10	150	0.2
Alluvial plains	96	10	20	5	75	1125	1.1
Ranns	40	3	0	0	7	105	0.1
Dunes & interdunes	10	1	66	17	10	150	0.2
Interdunal plains	39	4	390	98	36	540	0.6
Sandy undulating hummocky plains	28	3	354	89	10	150	0.2

Table 7 : Effect of age and lopping intensity on dry fodder yield (kg/tree)

Treatments	Ardu	Khejri	Neem
A_1I_1	9.4	10.7	6.3
A_1I_2	14.3	17.8	7.0
A_2I_1	14.8	38.8	28.3
A_2I_2	31.2	47.5	32.7

A_1 = Young trees I_1 = Lopping of lower 2/3 part
A_2 = Full grown trees I_2 = complete lopping

The cost of lopping of some tree leaves of semi arid zone was worked out by Singh *et al* (1980) and the results are presented in Table 8. The cost of collection varies from Rs. 27.72 to Rs. 143.00 per quintal of dry fodder. In general the increased production of dry fodder per tree decreases the cost of collection. Stall feeding of these tree leaves is generally not economical, therefore, it is desirable to feed the animals by direct lopping to get the benefits both nutritionally and economically.

Table 8 : Dry fodder yield and economics of fodder collection of tree leaves

S. No.	Name of tree	No. of trees lopped	Dry leave prodn (kg/tree)	Mandays reqd. per qtl dry leaves.	Average cost of lopping (Rs/q)
1.	*Prosopis cineraria*	45	12.04	2.21	30.94
2.	*Acacia senegal*	182	2.98	10.28	143.90
3.	*Matenus emarginata*	44	4.55	4.73	66.22
4.	*Bauhinia racemosa*	18	6.67	4.17	58.38
5.	*Ailanthus excelsa*	68	8.65	3.06	42.84
6.	*Azadirachta indica*	20	16.50	1.98	27.72

A large number of tree and shrub leaves and pods serve as an important feed resource for the livestock, specially sheep and goats. These leaves and pods are fed during summer months and other scarcity periods as freshly lopped or as dry leaves conserved after collection. During the last four decades numerous experiments have been conducted to determine the nutritive value of these leaves. The nutritive value of the top feed leaves commonly found in arid zone are given in Table 9.

The economic aspects of feeding top feed leaves have been reviewed by Patnayak (1983) and the benefit cost analysis of the top feeds of western Rajasthan was reported by Mrithyunjaya (1983).

A particular tree leaf may not be suitable for all kinds of livestock. Cattle and buffaloes have the least preference for tree leaves, whereas, camel and goats have the highest preference. When sheep and goats are compared, goats generally have performed better than sheep when maintained on tree leaves (Bohra, 1980; Mali *et al* 1983).

The utility of the top feeds has been limited by the presence of toxic substances. The toxic factors which are much talked about are tannins, mimosine, etc. Most of the tree fodders of the arid region are rich in tannins (Kumar and Singh, 1983). The adverse effects of tannin rich top feeds can easily be avoided when such feeds are fed mixed with other roughages in right proportion as it is a common age old practice in arid regions of western Rajasthan.

In addition to the leaf fodder available from the arid region trees and shrubs, the production of grasses in the protected forest areas also serves as an important source for grazing animals. The grass production from these protected forest areas is being utilised through cut and carry system in the initial stage of forest establishment and in later stages when the trees have attained safe height, controlled grazing can be allowed. Thus it is amply evident that forestry plays a vital role in meeting the fodder demand of arid region livestock specially during the scarcity period.

The contribution of forestry in bridging the gap between demand and supply of fodder situation in arid regions can be further enhanced manifold through the large scale adoption of location specific tested technologies of agroforestry and silvipastoral systems. In the hot arid regions of north-western India vast area is available under various categories of land use such as, forests, rangelands, wastelands and fallow lands (Table 10) which can be utilised for large scale adoption of agroforestry and silvipastoral multitier systems under the social forestry development programme.

The traditional production forestry has limited scope in the arid regions due to limited water supply and harsh environment. Therefore, both the forest research and development programme in the region should

Table 9. Nutritive values of top feeds of arid zone

Name	C.P.	Ether extract	Crude protein	NFE	Ash	Ca	P
Acacia senegal (Kumat)	70.30	–	9.7	65.7	16.40	6.90	0.05
Ailanthus excelsa (Ardu)	19.87	3.53	12.72	51.81	11.97	2.11	0.24
Albizia lebbeck (Siras)	16.80	4.00	31.50	36.20	11.50	2.57	0.15
Anogeissus pendula (Dhokara)	7.60	–	19.00	65.30	8.10	3.50	0.10
Azadirachta indica (Neem)	14.50	2.31	23.08	51.59	8.52	2.39	0.14
Bauhinia racemosa (Jinja)	15.36	3.38	18.50	54.60	8.21	4.13	0.14
Calligonum polygonoides (Phog)	7.40	–	12.50	67.30	9.10	3.70	0.10
Maytenus emerginata (Kankera)	9.60	2.46	11.46	55.19	21.25	5.39	0.13
Prosopis cineraria (Khejri)	13.98	1.88	17.80	43.44	22.90	2.73	0.15
P. Juliflora (Vilayati babool)	21.40	–	20.80	50.00	7.70	1.50	0.20
Salvadora oleoides (pilyal)	9.60	–	9.30	40.20	40.80	11.90	0.10
Tecomella undulata (Rohida)	12.70	–	15.80	63.00	8.90	3.40	0.20
Ziziphus nummularia (Pala)	14.25	4.34	15.73	57.12	8.56	2.43	0.14
Acacia nilotica (Babool)	11.23	–	10.72	64.8	15.43	5.45	0.14

Table 10 : Grazing resources of arid regions in different states in India

(, 000 ha)

States/Districts	Total geographical area	Forests	Pastures	Misc. tree crops & groves	Wastelands	Fallow lands	Total grazing resources
HARYANA							
Bhiwani	460	10	2	–	–	6	18
Hissar	660	10	–	–	–	36	46
Sirsa	427	6	2	–	–	6	14
Total	1547	26	4	–	–	48	78
PUNJAB							
Bhatinda	537	11	–	–	–	–	11
Faridkot	554	10	–	–	–	1	11
Ferozpur	586	7	–	21	–	36	64
Total	1677	28	–	21	–	37	86
GUJARAT							
Jamnagar	1017	86	74	–	27	53	240
Mahesana	4565	321	70	–	1600	671	2662
Banaskantha	901	16	56	–	19	678	769

Table contd...

(, 000 ha)

States/Districts	Total geographical area	Forests	Pastures	Misc. tree crops & groves	Wastelands	Fallow lands	Total grazing resources
Kutchh	1232	146	70	–	31	56	297
Total	7715	569	270	–	1677	1458	3968
Rajasthan							
Jaisalmer	3840	182	101	198	2822	168	3471
Barmer	2817	16	208	–	290	543	1057
Jodhpur	2256	5	122	5	55	544	726
Nagaur	1764	14	76	2	11	322	425
Jhunjhunu	593	33	44	–	8	36	121
Churu	1686	5	46	–	30	216	297
Ganganagar	2063	391	23	60	82	28	584
Total	15019	646	620	205	3298	1857	6681

give top priority to the social forestry programme. Agroforestry and multitier silvipastoral and hortipastoral systems should be made as an integral part of social forestry development programme. Adoption of such large scale silvipastoral systems will not only increase the fodder availability per unit area per unit time but also increase the annual return per unit land area (Gupta, 1980) as well as the soil productivity to sustain further production (Singh and Lal, 1969, Aggrawal *et al* 1976).

To give major thrust to the large scale pasture development programme through improved silvipastoral techniques under the social forestry programme in the region, adequate administrative organisation should be built up. A regional level standing committee should be constituted and should include the members from the Department of Agriculture, Forest, Soil Conservation, Sheep Development, Dairy Development and Animal Husbandry Departments of the State. The committee should formulate the programme of social forestry with a view to increase forage availability in the region. There must also be an effective coordination among desert development, wasteland development, pasture and rangeland development, forest development and other developmental agencies engaged in the task of arid region development.

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TREE-CROP INTERACTIONS : IMPERATIVES FOR ARID ZONE AGROFORESTRY

N. C. Jain

Introduction

Low productivity of arid lands and spreading deserts are cause of concern for everyone. Hostile environmental conditions, heavy wind erosion, poor fertility and low moisture retention make these areas highly unfavourable for crop cultivation. Growing of trees, nevertheless, can improve these lands to a great extent, besides providing possibility for intercultivation of crops/grasses and meeting the needs of fuel, fodder and food simultaneously. Livestock production being main occupation in the region, extra importance is attached to increasing forage production, which is also possible through inclusion of trees in the system. Discussing various facets of afforestation of arid zones, Kaul (1970) stated that shrubs and trees create conditions conducive for grass species. Ahuja and Mann

(1975) recommended that for better productivity trees should form essential component of good grasslands. Trees play vital role in improving the soil productivity (Nair, 1984) and therefore, agroforestry occupies special significance for arid areas.

Various land use systems involving trees and agroforestry practices prevalent in the arid regions of India have been extensively reviewed by Mann and Daulay (1981), Shankarnarayan *et al* (1987) and Srinivasan and Caulfield (1989). However, our understanding of interactive relations of the components is inadequate and therefore, a comprehensive analysis, for better understanding of these aspects, has been attempted here.

Tree - Crop Interactions

When perennial woody and herbaceous annual components are grown together, their performance would largely depend on their ability to share various growth resources in a given environmental situation. Due to difference in growth pattern and resource requirement of components in agroforestry situation, interactive relation is obvious, which could be of various kinds.

In an ideal relationship, production of tree as well as crop/grasses in combination could be comparable to their sole performance. Muthana and Shankarnarayan, (1978) reported that grass production did not differ under different trees, nor intercropping of grasses affected tree growth. The four tree species involved were *Acacia tortilis, Azadirachta indica, Albizia lebbeck* and *Holoptelia integrifolia* and the grasses intercropped were *Cenchrus ciliaris, Cenchrus setigerus, Dicanthium annulatum* and *Panicum antidotale*. Similarly, Sheikh *et al* (1983) observed that poplar trees did not affect the yield of wheat grown in the interrow spaces.

Agroforestry could be even more advantageous if the production of associated components is increased due to influence of trees. This is possible because trees are capable of improving productivity of soil in many ways (Nair, 1984). Large number of trees are known to fix nitrogen symbiotically (Pokhriyal and Maithani, 1989). The nutrients extracted from deeper zones are added to surface soil through litter fall and other mechanisms. Substantial improvement in organic matter and nutrient contents was noted under *Prosopis cineraria* in arid areas (Singh and Lal, 1969; Ahuja *et al*, 1978). Enhanced organic matter content also improve soil physical environment and moisture retention (Aggarwal *et al*, 1976; Gupta and Saxena, 1978; Misra *et al*, 1982). Relative humidity is higher below trees and soil and air temperature is favourably modified (Ramakrishna and Shastri, 1977; Gill and Abrol, 1987) making the microclimate more congenial to crop growth. Thus, positive role played by tree component could be beneficial to the productivity of crop component grown together as is evidenced by numerous studies.

Rao (1980) observed that growing of pigeonpea, pearlmillet and groundnut under sheltered conditions improved their poductivity by 48, 63 and 75 per cent, respectively. In a pot culture study, dry matter production of pearlmillet was higher on soils collected from *Leucaena leucocephala* plots with or without intercropping compared to plots with natural grasses (Misra *et al*, 1982). Pathak and Gupta (1987) recorded 40 per cent increase in fodder oat yield by intercropping with *Leucaena leucocephala*. Singh (1987) noted that fodder yield of pearlmillet was enhanced by 31.3 per cent due to presence of 100 trees of *Prosopis cineraria* per hectare. On infertile soils of peanut basin in Senegal, growing of peanuts and millet under *Acacia albida* increased their production by nearly 50 to 100 per cent (Felker, 1978). Similarly, yield of rainfed maize improved by 76 per cent and that of sorghum by 36 per cent by raising under *Acacia albida* canopy in Eastern Ethiopia (Peter Poschen, 1986).

Nevertheless, instances of crop inhibition in association of trees are not uncommon. Sheikh and Haq (1978) noted deleterious effect of *Acacia nilotica* and *Dalbergia sissoo* trees on crop yield, the maximum loss being within 2 m radius of the tree. In some shelterbelt studies, Sheikh (1984) and Sheikh and Haq (1986)observed that trees depressed yield on either side of the belt, and the effect lasted upto 5-15 m. Shekhawat *et al*, (1988) recorded 44, 49 and 43 per cent reduction in pearlmillet, cowpea and cluster bean yield, respectively, by growing in association of 15 year old *Acacia tortilis* trees compared to sole crop plots. Considerable reduction in cluster bean yield has been reported below unlopped *Holoptelia integrifolia* (Muthana and Arora, 1977). Such inhibitions are primarily caused by shade effect as well as competition for below ground resources such as nutrients and water. In some cases inhibitory effect may also result from allelochems secreted by some of the tree species. For instance, the leaf extracts of *Eucalyptus globulus* (Saxena and Singh, 1978; Kohli *et al*, 1987), *Eucalyptus tereticornis* (Rao and Reddy, 1984), *Eucalyptus camaldulensis* (de Moral and Muller, 1970), *Prosopis juliflora* and *Sal-*

vadora oleoides (Sankhala *et al*, 1985) have been found to cause allelopathic influences on many agro-crops.

The interactive relations of components are affected by many factors such as choice of species, density of tree stand, age of trees, various management practices, site factors, etc. Many of these are manipulable in favour of better production and some of these aspects are discussed here with salient examples.

Effect of Species

Growth pattern varies in different species and accordingly affects the relationship with the associated components. Grass yield was higher under *Prosopis cineraria* compared to *Tecomella undulata, Albizia lebbeck* and *Acacia senegal* (Shankar *et al*, 1976; Ahuja *et al*, 1978). Sajwan *et al*, (1980) noticed that herbage yield under *Acacia nilotica* (12.35 t ha^{-1}) was almost equal to that of open (12.04 t ha^{-1}) but under *Eucalyptus hybrid* herbage production was considerably lower (7.37 t ha^{-1}). Kermaoi (1980), on the contrary, reported better yield of agricultural crops under *Eucalyptus (E. camaldulensis)* compared to *Acacia nilotica*. Khattak *et al* (1980) observed that yield of wheat under *Dalbergia sissoo* was comparable to control plot where as under *Populus deltoides, Eucalyptus citriodora* and *Bombax ceiba* it was considerably lower.

Not only the effect of tree species differ but different crop/grass species are also affected differently by same tree species. Deb Roy *et al* (1978a) recorded higher forage production of mixture of *Sehima nervosum* and *Chrysopogon fulvus* compared to *Cenchrus ciliaris* only under *Hardwickia binata*. Similarly, forage production of *Cenchrus ciliaris, Sehima nervosum* and *Chrysopogon fulvus* was 7.9, 7.4 and 5.7 t ha-1 in association with *Albizia lebbeck* (Deb Roy *et al*, 1978b).

Effect of Density

Canopy cover of trees intercepts light depending upon density of trees and consequently affect the performance of the undergrown crops. Ahuja (1980) observed decrease in forage yield with increasing density of *Prosopis cineraria* trees. The characteristics of undergrown crop species will also determine the impact of canopy cover. Cluster bean yield improved considerably by coppicing *Holoptelia integrifolia* but the yield of mungbean did not change appreciably (Paroda and Muthana, 1979).

Light is not the only factor altered by presence of trees. Trees also modify microclimate of crops grown below and improve physical conditions and fertility of the soil. Thus, increase in tree density should accrue some benefits while increasing the competition for other resources at the same time. Therefore, optimum density in agroforestry would vary with variation in components. In a silvipastoral study in which *Acacia tortilis* and *Leucaena leucocephala* were grown at two densities (4x4 m and 4x6 m), forage production of *Cenchrus ciliaris* was higher at wider spacing than the closer one in *Acacia tortilis* while with *Leucaena leucocephala* the reverse was true (Deb Roy and Pathak, 1972). Similarly, Muthana *et al* (1977) recorded higher grass yield under widely spaced *Hadwickia binata* and *Colophospermum mopane* but not in case of *Acacia tortilis*. When density of *Ziziphus* spp. (*Z. nummularia* and *Z. rotundifolia*) was varied from 70 to 280 plants ha^{-1}, the dry forage yield of *Cenchrus ciliaris* was highest at 210 plants ha^{-1} of *Z. nummularia* (Sharma *et al*, 1980). The grass yield did not vary under *Z. rotundifolia*.

Effect of Age

The demand for various growth resources and therefore, competition offered by the components would be affected by age and growth of the components. Trees take long time to attain full size and stature and thus, no competition might be offered to crops grown in interrow space initially. Nevertheless, as the trees grow, their effect on crop growth becomes apparent. Shankarnarayan *et al* (1987) reported that cluster bean yield was suppressed by *Acacia albida* in the third year of growth though *Prosopis cineraria* did not affect the crop yield even in the third year. Through root studies they explained the cause to be horizontal spread of roots in *Acacia albida* and fast shoot growth.

Due to slow growth of trees initially, even associated component may dominate and affect the tree growth. For instance, when *Acacia tortilis* seedlings were grown with *Cenchrus* spp., the growth of tree seedlings was depressed for first three years but later they acquired better growth rate (Muthana *et al*, 1985). Similarly, Sharma and Vashistha (1985) noted that jujube species (*Z. nummularia* and *Z. rotundifolia*) in initial years cannot withstand competition from established pasture of buffel (*Cenchrus ciliaris*) grass, however, once the jujube bushes attain good growth in two years, buffel pasture does affect its growth.

Site Factors

Climatic, edaphic and physiographic features of any area affect the plant growth which varies in different species and consequently the interactive relationship of component species in agroforestry situation also vary. In a Silvipastoral Operational Research Project, a study was conducted at three sites (Anon., 1985). The first site was located at the Central Research Farm of IGFRI, Jhansi, the second one represented heavily grazed eroded plains while the third represented ravine tract with saline-sodic soil. The results of pasture production studies revealed that pasture species could not establish at all at the third site. At the first site highest mean forage yield was recorded in association with *Leucaena leucocephala* while at the second site, it was lowest in this combination. Reverse was true for the association of *Albizia amara* at the two sites.

Variation in rainfall also affects the interactive relation of components. Ahuja *et al* (1985) reported a study in which grass production was recorded below four tree species for 5 years with considerable rainfall variation. In a year of high rainfall (641.8 mm) grass production was highest below *Tecomella undulata*, while in a low rainfall year (244.8 mm) grass was maximum under *Albizia lebbeck*. Similar variation in forage production of two *Cenchrus* spp. was reported by Deb Roy *et al* (1980).

Management Practices

Various management practices may be adopted to favourably alter the interactive relationship in agroforestry situation. For fodder tree species lopping done for harvesting forage periodically can at the same time increase light availability to the undergrown crops and improve their performance. Muthana and Arora (1977) noted considerable reduction in yield of greengram and cluster bean below unlopped *Holoptelia integrifolia* trees, but lopping resulted in their production to be comparable to open grown crops. In alley cropping removal of leaf prunings and using them as green manure or animal fodder is common practice (Kang and Duguma, 1985; Duguma *et al*, 1988). Pathak (1988) reported that in long term studies alley cropping with *Leucaena leucocephala* spaced at 2 m distance improved the crop yields besides adding 6 t ha^{-1} of forage annually.

Lopping helps in removing competition for light. However, spreading of tree roots depress the yield of adjoining crop. Singh and Dayal (1975) recommended trenching around shelterbelts to avoid this competition. They observed that separating 15 year old tree rows of *Dalbergia sissoo* and *Acacia nilotica* by long trenches resulted in 21 and 68 per cent improvement in yield of cotton and tobacco in respective combinations. Trenching also lowered the moisture use by crops.

In poorly fertile soils, addition of fertilizer enhance productivity of components. In a trial conducted at CAZRI, Jodhpur, application of N and P fertilizers positively influenced production of grasses below trees (Shankarnarayan *et al*, 1987). The effect was more pronounced for *Chrysopogon fulvus* compared to other grasses *viz. Cenchrus ciliaris, Cenchrus setigerus* and *Sehima nervosum*. The tree species were *Prosopis cineraria, Acacia tortilis* and *Albizia lebbeck*.

Conclusions

From the foregoing discussion on tree crop interactions it is evident that compatibility of the components is of prime importance for productivity. Tree being a dominant component, its architecture decides its impact on associated component. Appropriate canopy form would ensure light penetration apart from facilitating a fast rate of nutrient cycling within the system through rapid turn over of leaves (Ramakrishanan, 1987). Besides, architectural characteristics of roots of trees are important for ascertaining reduced competition for nutrient resources between the crop and tree species. The search for ideal plant types from available genotypic variability and the development of new ones, should therefore, become an obvious priority.

To a great extent, compatibility can be ensured through selection of appropriate species and suitably choosing their temporal and spatial arrangements. Competition for various growth resources can also be avoided through some of the management practices as has been discussed earlier. Harvesting of the produce should be so regulated that nutrient balance in soil is not disturbed drastically. Modern trend of raising fast growing species with short rotation may deplete nutrients heavily and may be deleterious in long run (Harwood, 1983). Compensating this loss through artificial supply would be inevitable choice in such a situation.

Moisture is one of the most limiting factors in establishing trees in arid lands and often conservation techniques are essential (Gupta and Muthana, 1985). However, once established, moisture holding capacity below trees improves (Aggarwal *et al*, 1976; Gupta and Saxena, 1978; Misra *et al*, 1982) and favourable microclimate lowers the transpirational needs of the undergrown crops. Moreover, exploitation of water from different zones by the two components would be advantageous for per unit area production compared to either of the components grown in isolation. Nevertheless, information on moisture use efficiency under agroforestry is highly wanting to understand and favourably modify the moisture relations of the components.

It becomes, therefore, imperative to place greater research emphasis on deeper incite of various aspects of tree-crop interactions. Inhibitory relations in agroforestry need to be given priority and mechanisms such as allelopathy need to be understood better, not only for avoiding harmful influences but also for utilizing it beneficially in agroforestry.

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DESIRABLE CHARACTERISTICS FOR CROPS AND TREES ASSOCIATION UNDER ARID ENVIRONMENT

N.D. Yadava and I.C. Gupta

Introduction

The adverse climatic conditions, such as high solar incidence (450-500 calories / cm^2/day), high temperature (upto 48° C), high wind velocity (Av. 10-12 km/hr) resulting in high potential evapotranspiration (PET) of 6 mm/day, low and erratic rainfall, scarce and poor quality ground water, and infertile soils increase the instability of crop production in arid zone. Therefore, combination of field crops and trees on the same piece of land in agroforestry system may be a valuable system to help in the development of optimal land uses in drought prone areas of western Rajasthan besides reducing the risk of uncertainity of production.

Characteristics of Crops and Trees Desirable for Agroforestry System

The success of crop in a given region does not indicate its success in any particular system. The crop in agroforestry system under rainfed condition has three major constraints viz. (i) availability of rain water for better crop growth beneath the tree canopy, (2) solar radiation available for crop, (3) germination and crop growth behaviour (Ereise, 1936). On the basis of the above three criteria the crop should meet out the following requirements for fitting well in agroforestry system.

(a) Crops and trees should not have any constraint for their growth and development in association viz. adverse residual effect, secretion of toxic elements by roots in soil, etc.

(b) Under rainfed condition crop water requirement should match with the amount of the rainfall received or soil moisture available beneath the tree during rainy season.

(c) Radiation should be optimum for fulfilling the photosynthetic requirement of crop.

(d) Growth of crop plants should not be adversely affected by trees.

(e) Crops grown under the system should not be of exhaustive nature but they should have the characteristics to improve the soil fertility.

The crops with the better yield potential in arid region which can be well fitted under agroforestry system are mentioned below (Saxena, 1984):

Crops	Varieties
Kharif	
Pearlmillet (*Pennisetum typhoides*)	BJ-104, BK-560,
Greengram (*Phaseolus radiatus*)	S-8, S-9, T-44,
Mothbean (*Vigna aconitifolius*)	Jadia, T-18

Clusterbean (*Cymopsis tetragonaloba*)	Durg. safed, Fs-277, Durgajay.
Sesame (*Seasamum indicum*)	T-13, Tc-25, Pratap.
Sewan (*Cenchrus ciliaris*)	-Local.
Rabi	
Raya (*Brassica compestris*)	T-59, Durgamani,
Chickpea (*Cicer arietinum*)	G-24, C-235, Rs-510.

In Rajasthan *Kharif* crops are grown as rainfed which give the full benefits of the integrated system with better utilisation of rain water with stabilised and increased production from the land. But during *rabi* without irrigation facility the crops could not be grown successfully on the conserved soil moisture, whereas the additional yield of trees can be obtained with very little management. The use of leguminous crops should be preferred more than the cereals because of their many advantages viz. (1) Addition of atmospheric nitrogen to the soil through their root nodules, (2) deep root system which can tolerate drought for longer period, (3) better soil binding ability which helps in checking soil erosion, and (4) high value of the crops. The amount of nitrogen added to soil through growing of different leguminous crops was highest e.g. 156 and 19 kg/ha at P_2O_5 level of 40 kg ha^{-1}, in mothbean and clusterbean, respectively whereas in greengram it was highest (86 kg ha^{-1}) at 60 kg P_2O_5 ha^{-1} (Table 1).

Table 1. Nitrogen addition through legumes under different P_2O_5 levels

Crop/Variety	P_2O_5 dose (kg/ha)				
	0	20	40	60	80
Greengram (S–8)	20	37	332	86	76
Mothbean (local)	68	122	156	106	105
Clusterbean (Fs–277)	55	187	192	168	156

Source : Agarwal et al. (1976)

Among different crops, pearlmillet and sesame showed the maximum resistance potential when rainfall was above average and ill distributed,

mothbean and clusterbean performed well in below average rainfall years, but if monsoon is concentrated in later half of the growing season only clusterbean yields were better, whereas during prolonged drought condition, cultivated crops failed and only natural vegetation gave some subsistence (Singh *et al* 1984).

Trees

In agroforestry system, tree is the main component having the wider adaptability with its very distinct plant induced soil chemical patterns in different vegetation covers. Accumulation of litter above and below ground increases nutrient status of soil, causes change in microclimate of the site, and tend to reduce soil pH. The effect of different tree covers on soil fertility manifests in different ways by influencing their rooting depth, litter quality and plant phenology differences from species to species within the community. Therefore, selection of tree species is very important and preference should only be given to such type of trees which do not affect the crop growth adversely and are able to improve the soil fertility. The main characteristics of trees for agroforestry system are as follows:

(a) Trees should be of multiple uses viz. foliage for fodder, wood for domestic purposes, etc.

(b) Low water requirement and ability to be established with little care.

(c) Wide range of adaptability viz. resistant to high temperature and frost with the special characteristics of nitrogen fixing ability, rapid growth and ability to coppice.

The suitable tree and shrub species for agroforestry in western Rajasthan are as follows:

Khejri	*Prosopis cineraria*
Bordi	*Ziziphus nummularia*
Mopane	*Colophospermum mopane*
Israily Babool	*Acacia tortilis*
Kair	*Capparis decidua*
Phog	*Calligonum polygonoides*

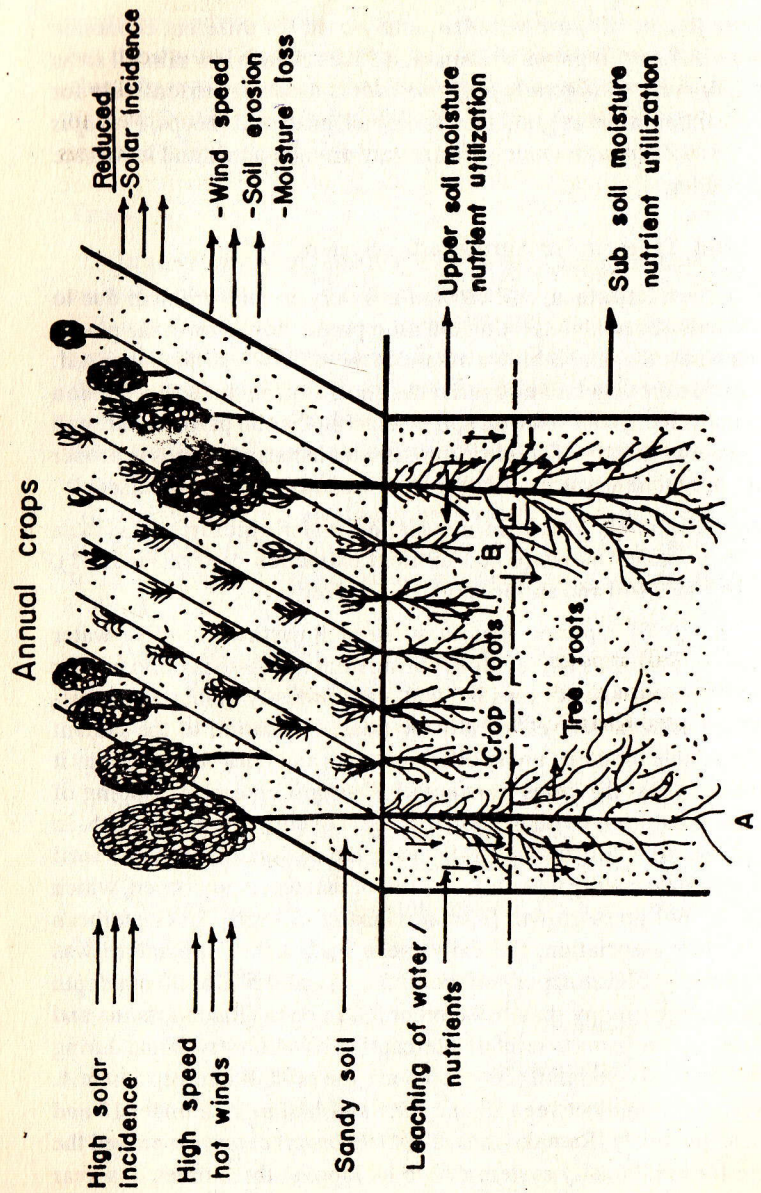
These tree species are very frequently used for different economic purposes viz.*A.tortilis* grows well on sand dunes even in low rainfall areas (below 250 mm), *Calligonum polygonoides* is used very extensively for sand dune fixation and as good feed for camel, goats and sheeps, *Prosopis cineraria* and *Ziziphus nummularia* are very drought hardy and leaves are used as fodder.

Crops and Trees under Agroforestry System

In western Rajasthan, soil erosion is a very serious problem due to speedy winds adversely affecting the crop production in both the places viz. from where the sand is blown off and at the place where it is deposited. Trees provide the vegetative cover, reduce soil erosion through reduction of the wind velocity and stabilise soil by binding the soil particles through their vast network roots. Therefore, by the establishment of trees in proper way into production system, wind erosion hazards can be minimised.

Trees and crops grown in association under agroforestry system enforce two storied moisture and nutrient extraction pattern(Figure 1), from subsurface soil and surface soil, respectively.

Singh (1980) reported that in western Rajasthan 25-40% water penetrates into murram sub-stratum during rainfall which is of no use for moderately rooted Kharif crops but under agroforestry system this moisture can be utilised very efficiently by trees. In relation to the radiant energy available for crops under different crops and trees combinations it has been seen that the crops grown with *Prosopis cineraria*, lopping of trees is essential for providing enough radiant energy for crop growth. In case of *Cenchrus ciliaris* grown beneath the *A. tortilis* trees the total incoming radiant energy was only 14-30% of that received in open, which resulted in poor grass growth (Ramakrishna *et al* 1980). In clusterbean and *A. tortilis* association, the daily mean maximum temperature was lowered by 10-16°C at upper surface (0-5 cm) and 4.5°C at 30 cm depth beneath the tree canopy than those recorded in open (Rama krishna and Sastri, 1977). In relation to rainfall interception it was observed that during moderate and heavy rainfall (200-350 mm), the rainfall interception in *A. tortilis* plants, varied between 23 and 33% and 14 and 19% under 13 and 7 years, respectively (Ramakrishna, 1984). *Prosopis cineraria* proved the best tree for agroforestry system due to its lopping three times in a year before the crop sowing viz. 1st during the month of December before the sowing of rabi crops, 2nd at 10 to 30% cutting during May for Kharif



sowing and 3rd in the month of September when crops get matured. Sekhawat *et al* (1988) have reported that growing of pearlmillet, clusterbean and cowpea for fodder purposes with *A. tortilis* gave additional returns of Rs. 2000, 2106 and 1756 per ha over sole forestry. Thus, to conclude that the crops and trees in the agroforestry land use management in arid western Rajasthan may be a boon for stabilising the production alongwith fulfilling the requirement of wood, grain and fodder in one time from same piece of land and also improving the environment.

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HORTI-SILVI-PASTORAL SYSTEM FOR INCREASED PRODUCTIVITY OF MARGINAL AND DEGRADED LANDS UNDER RAINFED CONDITIONS

G.B. Raturi and S.S. Hiwale

Introduction

Land degradation is a phenomenon known all over the world. So far India is concerned, it is generally said that almost half of the total land area of the country is degraded in one form or the other. The National Commission on Agriculture had estimated that of the total geographical area of about 329 million hectares for the country, approximately 175 m ha is affected by problems of soil erosion and soil degradation. This includes 104 m ha of cultivable land (including 87 m ha of eroded lands and permanent pastures), 19 m ha of forest lands, 8 m ha of uncultivable

nonforest lands, 43 m ha of lands with special problems (saline, alkaline, deserts, ravines, etc) (Singh, 1989).

Per capita consumption of fruits and vegetables in daily diet of the people in India is very low. For proper dietary supplementation, it is estimated that the country needs at least 250 million tonnes of fruits and vegetables against the present production of 60 million tonnes (24 m tonnes of fruits and 36 m tonnes of vegetables). Due to increasing population pressure, the country has to put more area under cereals, pulses and oil seeds. Therefore, the fertile land may not be available for fruit cultivation in the near future. Under these circumstances, the only possibility is to utilize the marginal and degraded lands and other available waste lands for fruit cultivation.

In present agricultural production systems, both fodder and fuel wood are also becoming progressively deficient. Fuel wood shortage is estimated to the tune of 100 million m^3 by 1990. According to King (1980) it is estimated that 73 percent of the wood harvested in Asia is utilised as firewood. The firewood situation is predicted to worsen so alarmingly that by the year 2000 A.D. even if we produce enough food, there would not be enough firewood to cook it. Similar is the case of fodder. It is estimated that currently there is a shortage of 822 million tonnes of forages (Pathak and Debroy, 1987). Therefore, there is immediate need to alleviate this deficiency of food, fodder and fuel simultaneously maintaining a balance in the ecosystem based on long term consideration of land use.

Horti-Silvi-Pastoral farming has a considerable potential to increase the productivity, sustainability and economic diversity of the marginal and degraded lands. This potential can be fully realised through a systematic optimization and integration of biological and structural measures. Experiments were carried out at Central Horticultural Experiment Station, Godhra to study the efficacy of a Horti-Silvi-Pastoral system. The studies were initiated to evolve cropping systems for optimum utilization of production potential of marginal/degraded lands under semi-arid dryland conditions by adopting a composite farming system with components of horticulture, silviculture and pasture grasses alongwith soil and water management techniques.

Material and Methods

The present studies on Horti-Silvi-Pastoral project at Central Horticultural Experiment Station, Godhra commenced in 1985. The soil of the project area had been subjected to severe erosion. Uninterrupted grazing over the years had robbed the soils of organic matter content and trampling by cattles had caused compaction of soil. The project area was heavily eroded by a network of 2 deep and 3 medium gullies (Fig.1). Nearly one third area consisted of pebbles and boulders. The soil depth is 1.25 m having an impervious calcareous hard pan underneath. The soil is sandy clay loam to clay in texture with an average pH of 7.61 to 8.50. The annual precipitation of the area is about 700mm. The region experiences constraints in available moisture in major part of the year resulting in continuous water deficit for optimum growth of the crops.

Before starting the experiment, contour survey of the project area was undertaken. The area was divided into 12 different plots according to the contours and depth of soil. The plots where the soil depth ranged between 1 to 1.25 m were selected for planting hardy fruit crops like mango, guava, ber, pomegranate, annona and kagzi-lime. Staggered contour trench planting system was adopted as a measure for water harvesting. In case of mango and ber, *in- situ* grafting/budding was done while for other fruit crops, transplanting of saplings was resorted. The area within a distance of 6 metre from the gully rims was highly degraded and prone to soil erosion. This was planted with *Eucalyptus and Leucaena leucocephala* on either sides. All along the gullies, Bamboo saplings were planted. Grass *Cenchrus ciliaris* was planted along the gully collars to check soil erosion and *Stylosanthes hamata*, a tropical pasture legume was planted in the inter-spaces available between the fruit crops. Live check-dams of *Agave americana and Ipomea carnea* and gully plugging with earthen dams was resorted to control soil erosion. The surface run-off from the project area was collected in a R.C.C. check-dam to give life saving irrigation at critical crop growth stages.

Results and Discussions

(1) ESTABLISHMENT OF CROPS

The three successive years from 1985 to 1987 were the years of drought in the area. Still the establishment of all the fruit crops, silvicultural species and pasture grasses was quite successful. The fruit trees

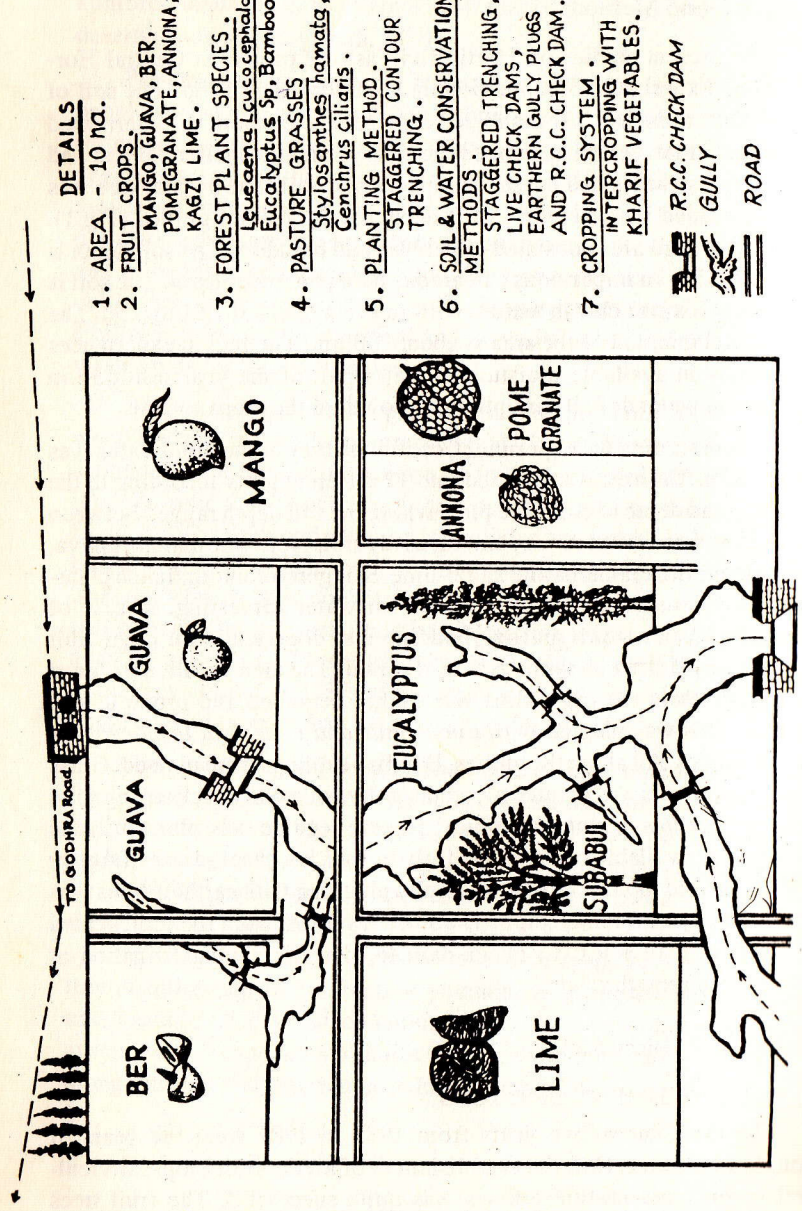

Figure 1. Layout plan of a Horti–Silvi–Pastoral System.

continued their normal growth and the plants in the project area remained healthy. In three years period, the *Stylosanthes hamata* had formed a thick cover over the entire planted area. The *Cenchrus ciliaris* had also formed a dense bund all along the gully collars.

(2) PRODUCTION OF FRUITS, FODDER AND FUEL

The *in-situ* budded ber plants had come into bearing just after one year while the other fruit crops remained in vegetative stage until third year. The two year old ber plantation yielded 16.10 q ha^{-1} fruits giving a net return of Rs. 1705. Despite drought conditions, the trees kept on growing normally and in the third year yielded 49.0 q fruits per hectare giving a net return of Rs. 11,599. In addition, the two year old ber trees produced 2.20 q ha^{-1} pruned wood (on fresh weight basis) which could be used as fuel. The fuel wood production increased to 13.00 q ha^{-1} in the third year.

Crop production on drylands depends primarily on the quantum and distribution of rainfall. The pattern of growth and production observed in ber trees showed that the crop can withstand the monsoonal aberrations better than the annual crops. A total rainfall of 525 mm was received during 1986 and 475 mm in 1987. However, the distribution of rainfall was entirely different during both the years (Fig. 2). While during 1986 the total rainfall was received in 24 rainy days, during 1987 it was received in 16 rainy days out of which 350 mm fell in just 8 days. Thus, during 1987 there was a long period of drought as compared to the previous year. Still the ber trees kept on putting up normal growth and registered steady increase in the yield. The results of the studies thus confirm the drought hardy nature of the ber trees.

Both the pasture grass species grew successfully and in the third year (1987) the *Cenchrus ciliaris* and *Stylosanthes hamata* produced 55.00 and 38.88 q ha^{-1} green fodder, respectively (Table 1).

Table 1 : Fodder and fuel wood production (fresh weight basis q/ha)

	Crop	Second year (1986)		Third year (1987)	
		Fodder	Fuel	Fodder	Fuel
1.	*Cenchrus ciliaris*	38.87	–	55.00	–
2.	*Stylosanthes hamata*	31.91	–	38.88	–
3.	*Leucaena leucocephala*	55.00	105.00	80.00	132.00
4.	Ber (Pruned wood)	–	2.20	–	13.00

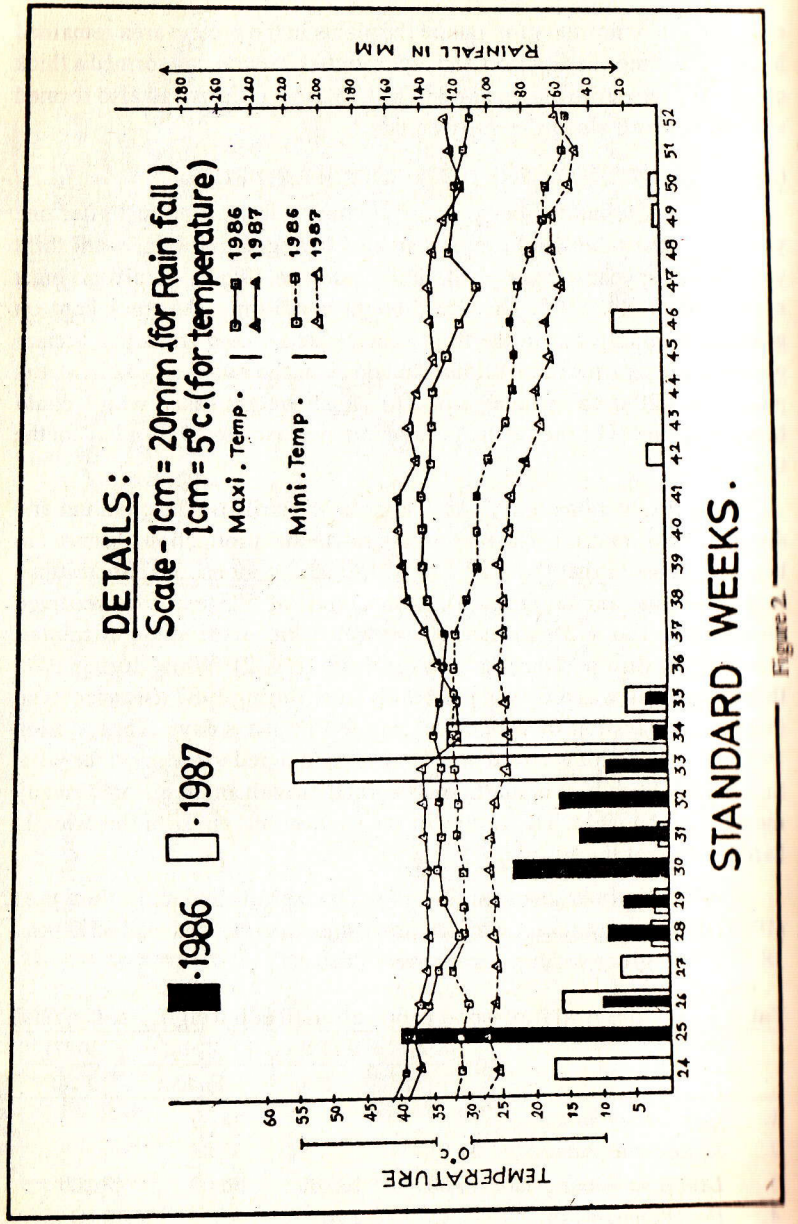

Figure 2

The silvicultural species *Leucaena leucocephala, Eucalyptus* and bomboo kept on putting up normal growth despite the recurrent droughts. The green fodder production from 3 years old subabul (*Leucaena leucocephala*) plantation was about 80 q ha^{-1} and fuel wood production on fresh weight basis 132 q ha^{-1}. *Eucalyptus* was grown primarily for the log purpose and in three years period the plants had attained an average height and girth of about 7.46 m and 11.8 cm (DBH), respectively.

Under rainfed conditions, raising ber plantation on marginal and degraded lands was found highly remunerative giving a net return of Rs. 11,599 in the third year. The traditional farming system of growing maize plus pigeon pea was in contrast severely affected by the prevailing drought conditions and gave a poor return of Rs. 616 per hectare. Growing of pasture grasses and silvicultural species further provided fodder for cattles and fuel for home consumption. It is therefore felt that adoption of such horti-silvi-pastoral farming systems would be most appropriate to increase the productivity of marginal and degraded lands and meet the requirements of food, fodder and fuel of the farming families.

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SOME CASE STUDIES OF ALTERNATE LAND USE SYSTEMS AGROFORESTRY IN SEMI ARID FARMING SITUATIONS

G. P. Khurana, P. P. Sharma and G. D.Singh

With the lack of rainfall and frequent droughts prevailing in the semi-arid areas of Rajasthan, the farmers have realised that tree based system of farming can only provide sustained livelihood to them. Certain tree species which showed promise in agroforestry system of alternate land use as recommended by CAZRI are *Hardwickia binata, Prosopis cineraria, Holoptelia integrifolia* and *Albizia lebbeck.* From last several decades farmers of semi-arid districts of Rajasthan are practising agro-forestry systems of Pearl millet, Cluster bean, Mung bean, Moth bean, etc with *Prosopis cineraria, Acacia nilotica, Ailanthus excelsa* and some other trees growing at their field. To visualize the comparative suitability of such agro-forestry systems based on combination of different trees with various rainy season crops, a case study was undertaken for three years. The details of sites with agro-forestry system are indicated in Table 1.

Table 1 : Details of Agro-forestry systems taken for study

S. No.	Village	District	Agro-forestry type
1.	Piprali	Sikar	*Ailanthus excelsa* – pearl millet
2.	Piprali	Sikar	*Ailanthus excelsa* – cluster bean
3.	Jorpura	Jaipur	*Prosopis cineraria* – Pearl millet
4.	Jorpura	Jaipur	*Prosopis cineraria* – Cluster bean
5.	Asalpur	Jaipur	*Acacia nilotica* – Pearl millet
6.	Asalpur	Jaipur	*Acacia nilotica* – Cluster bean

The study sites so selected were exclusively rainfed during the period of study. The studies were made from fields that possessed a minimum number of trees, i.e. *Prosopis cineraria-12, Ailanthus excelsa-7* and *Acacia nilotica*-6. Yield data of grain and straw of crops, fodder and fuel data of trees were recorded from three sets of farm families continuously for three years. The average yield data of three years with total monetary returns are given in Table 2.

The data in Table 2 clearly indicate that growing of crops with *Prosopis cineraria* system is more profitable when compared with other types of systems as it led to maximum yield of pearl millet and cluster bean. Irrespective of the agro-forestry system, taking cluster bean was found to be more remunerative than pearl millet, probably due to high market price of cluster bean grain. More yield of crops from *Prosopis cineraria* fields also reflect the enrichment of soil by added nitrogen from leaves fallen from trees. Lowest yield of pearl millet and cluster bean was recorded with *Acacia nilotica* and maximum with *Prosopis cineraria.* Forage yield was maximum in case of *Prosopis cineraria* and minimum in case of *Acacia nilotica.* In terms of fuel wood production *Ailanthus excelsa* proved to be the best followed by *Prosopis cineraria* and *Acacia nilotica.* Total monetary returns were maximum, when the agro-forestry system of *Prosopis cineraria* and cluster bean was followed by the farmers. From the foregoing discussion it can be opined that plantation of *Acacia nilotica* in general decreased the yield of crops grown in its association/vicinity. Also, taking cluster bean instead of pearl millet with *Ailanthus excelsa or Prosopis cineraria* proved more remunerative.

In the eastern plains of Rajasthan, particularly around Ramgarh Tehsil of Alwar district, social forestry has been in vogue for quite some

Table 2 : Grain and straw yield of crops and fodder and fuel yield of trees in agro-forestry systems with monetary returns[1] (mean of trees).

S. No.	Agro-forestry system	Yield (q/ha)					Total monetary return (Rs/ha)
		Grain	Straw	Tree	Fodder	Fuel	
1.	*Ailanthus excelsa* – Pearl millet	14.5	32.0	4.0		8.5	4260
2.	*Ailanthus excelsa* – Cluster bean	7.8	10.5	4.5		7.6	4636
3.	*Prosopis cineraria* – Pearl millet	15.0	35.5	12.5*		6.5	4340
4.	*Prosopis cineraria* – Cluster bean	8.4	11.8	12.0*		6.0	4736
5.	*Acacia nilotica* – Pearl millet	13.0	28.5	1.2		4.6	3469
6.	*Acacia nilotica* – Cluster bean	6.4	7.5	1.4		5.0	3456

* Green leaf fodder

1 Monetary returns calculated on the basis of the following market prices per quintal of products, say –

(a) Grain – P. millet Rs. 150/- (b) Straw– P. millet Rs. 50/- (c) Tree fodder – *P. cineraria* Rs. 100 /- (d) Fuel wood Rs. 10/-

C. bean Rs. 500/- C. bean Rs. 20/- *A. excelsa* Rs. 20/-

A. nilotica Rs. 40/-

years. The trees are planted around the cultivable fields to substantiate the fuel and fodder requirement which are becoming extremely scarce with the passage of time. This system of forestry is also resorted to augment the farmers income. The kind of trees chosen are usually the ones that grow rapidly to provide for the needs listed above in the shortest possible timespan. The trees, most commonly adopted here, are the species of *Eucalyptus, Leucaena* (Subabul) and *Acacia* (Babul). These are generally seen planted on the field boundaries. The relative returns obtained by way of substantiating farm income from the three kinds of trees have been given in Table 3. It is obvious from the Table that older the tree, the more are the returns obtainable. In this study, *Eucalyptus* spp. and *Acacia* spp. were found to give quite desirable income in about 9-10 years after plantation, whereas, *Leucaena* spp. became ready to give returns after three years of its plantation. Again, the selling price of these three types of trees is not the same and would depend upon the size of their girth or the length of log. Result of a comparative study about the returns from the different trees based on 0.2 hectare piece of land are presented herein where 20 trees each of *Eucalyptus* and *Acacia* and 40 trees of *Leucaena* were planted around the periphery of 0.2 ha land. It was observed that *Eucalyptus* gave a timber yield of about 44 quintals (the log being one metre in girth and 12 metres in length) giving returns of about Rs. 2400/- when sold at the prevailing market rate of Rs.55/- per quintal. Besides timber, the same trees provided additional income of about Rs. 2500/- from the same area from non-timber wood. Thus the total income from *Eucalyptus* was about Rs. 4900/- per 0.2 ha in ten years. Similarly trees of *Acacia* of ten years age having an average girth of about 1-1.25 metres gave an income of Rs. 14000/- from 0.2 ha piece of land when sold in the local market at the rate of Rs. 700/- per tree. On the other hand, *Leucaena* trees in the similar area gave 30 quintals of fuel wood in three years resulting in income of Rs. 600/- when sold at the rate of Rs. 20/- per quintal. In addition, these trees afforded two loppings of 900 kg green fodder each in a year yielding Rs. 400 only with selling rate of Rs. 20 per quintal. When sold as tree wood @Rs. 35 per tree, the returns would be Rs. 1400 from the same area. Thus the total income from *Leucaena* trees would come to Rs. 2400/- per 0.2 ha piece of land but this income would multiply three folds by the time other trees i.e., *Eucalyptus* and *Acacia* became saleable. *Leucaena* also provides soil nutrition symbiotically because of its leguminous character. The economics of these trees attains a higher proportion when grown in block planting system in 0.2 ha land

Table 3 : Production economics of peripheral trees in 0.2 ha

S. No.	Name of tree	Number of trees	Distance between trees	Age of trees	Tree girth (metres)	Wood weight (g)	Income (Rs.)			Remarks
							Wood	Fuel	Fodder	Total	
1.	*Eucalyptus* sp.	20	8–9 meters	10 years	1–1.25	44	2400	2500	–	4900	Wood used as packings
2.	*Leucaena* sp.	40	4.5–5.5 meters	3 years	0.6–0.75	–	1400	400	600	2400	
3.	*Acacia* sp.	20	8–9 meters	10 years	1–1–25	–	14000	–	–	14000	Sold as tree

Table 4 : Production economics of block tree planting in 0.2 ha

S. No.	Name of tree	Distance between trees (metres)	Number of trees	Age at selling (Years)	Return (Rs.)	Remarks
1.	*Eucalyptus* sp.	1.5	900	5	13500=00	Rs. 15/– per tree
2.	*Leucaena* sp.	1.5	900	3	13500=00	Rs. 15/– per tree
3.	*Acacia* sp.	6.0	64	10	19200=00	Rs 300/– per tree
4.	*Ziziphus* sp.	4.5–5.0	80	–	6000=00	Per year contract rate on fruit basis.

instead of growing on periphery. The simple reason for higher income is the increased tree population in block planting system. The earliest to start yielding income is *Leucaena* followed by *Eucalyptus* and *Acacia* which become saleable after 3, 5 and 10 years, respectively. As detailed in Table 4, *Acacia* gives the highest return of Rs. 19200/- per 0.2 ha land with tree density of 64, whereas Eucalyptus and *Leucaena* provide income of Rs. 13500/- each from the equal piece of land. It is, however, important to mention that *Leucaena* can be replanted after 3 years that would end up resulting in the highest returns followed by *Eucalyptus* and *Acacia*.

In another instance, Dhaincha (*Sesbania aculeata*) that had been used earlier as green manure by turning it in the soil while succulent, is no longer being used in this manner by farmers. It is being grown for wood and fuel purpose which gives about 60 q of wood per hectare which is of 5-10 cm diameter and used for thatched roof construction in place of costly bamboo giving a return of Rs. 1500/- @ Rs. 25/- per quintal per hectare alongwith 8-10 quintals of firewood per hectare worth Rs. 160-200 per hectare and another Rs.60/ha for 10 kg seed produced in about 100 days. The leaves fall into the ground that act as organic manure providing also nutrition after leaf decomposition to the extent of 3.5, 0.6 and 1.20 percent respectively of N, P_2O_5 and K_2O. Moreover, because of its dicot character, it assimilates calcium from the soil from greater depth that is released into the upper soil after its burial, a practice essentially suited to reclaiming salt affected soils. In this context, the results of an experiment conducted at A.R.S. Navgaon show that average yield of barley increased by at least 11.6 per cent (Table 5) by turning and mixing the *Dhaincha* into the soil when succulent as compared to that obtained without this treatment in salt-affected soils. Moreover, there was reduction in soil pH and salt concentration after two years of this treatment.

In yet another situation in the area, the ber (*Ziziphus sp.*) cultivation could be adopted for obtaining fruits as an alternative to sole cultivation of fuel and fodder providing trees. This yields an income of Rs. 6000/- per 0.2 ha when sold through contractors in the area, thereby providing a source of maximum returns with the minimum of maintenance expenditure per year. The efforts are on to motivate the local farmers to resort to more and more ber cultivation.

In a survey of cultivators, adopting the above mentioned social forestry system, it was opined that they planted the trees on the periphery of their cultivated fields in right or good earnest but realised that the crops

Table 5 : Grain and straw yield of barley (var. RD–2052) as affected by different soil ameliorants

S. No.	Treatments	Yield (q/ha)					
		Grain			Straw		
		1988–89	89–90	Average	1988–89	89–90	Average
1.	Absolute control	37.50	31.89	33.70	76.6	67.2	71.9
2.	Dhaincha (*Sesbania aculeata*)	40.50	34.71	37.61	84.9	86.9	85.9
3.	Gypsum @ 2 t/ha (0.5 G.R.)	41.25	39.30	40.28	80.2	84.7	82.5
4.	Gypsum @ 4 t/ha (1.0 G.R.)	42.87	39.38	41.13	82.1	78.3	80.2
5.	Soil chiselling (30 cm depth)	44.37	38.98	41.38	84.9	91.9	88.4
6.	F.Y.M. @ 10 t/ha	42.50	34.57	38.54	83.3	74.8	79.1
7.	Soil chiselling + Dhaincha + Gypsum @ 2 t/ha	51.25	42.29	46.77	93.4	86.6	90.0
8.	Dhaincha + Gypsum @ 2 t/ha	45.62	39.93	42.78	83.7	96.1	89.9
9.	Soil chiselling + Gypsum @ 2 t/ha	48.75	40.48	44.62	92.1	79.4	85.8
	S. Em ±	0.44	1.99		2.9	5.5	
	CD (5%)	1.28	5.81		8.5	16.1	

* Gypsum requirement.

grown in field get adversely affected upto a distance of at least 5 metres on each side of plantation resulting in about 10-15 per cent reduction in cultivable/ crop growing area. The reasons advocated for the damage to the crop are rapid depletion of moisture and nutrients and the shading effect. This was found to be maximum in case of *Eucalyptus*. A study indicated a decrease of 66 to 99 per cent of grain yield of field crops in Kharif season grown in association with *Leucaena* and 24 to 86 per cent in association with *Eucalyptus* (Ramshe, 1988). Besides, the crops become highly susceptible to damage by birds, poor germination and growth and development, due to presence of trees around cultivated land. On account of this drawback rural folks are trying to completely eliminate the trees from cultivable lands. It is therefore, necessary to introduce and encourage the rural folks to resort to tree planting around the residential areas to meet the fuel and fodder needs as well as the timber needed for making their agricultural tools like plough, handles for spades, khurpi, etc. and the household items. This will help in easy maintenance of trees during early period of growth and development when their survival rate in the existing semi-arid conditions is extremely low. Above all the rural folks are to be made conscious about the necessity of their involvement in maintaining the eco-system not only for themselves but also for the sake of posterity.

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EFFECT OF INTERCROP AND ROOT TRENCHING IN AGROFORESTRY SYSTEM

N.K. Chopra, N. Chopra and L.N. Harsh

Introduction

Growing of agricultural crops with perennial woody crops is an age old practice in India. Traditionally, Khejri(*Prosopis cineraria*), Babool (*Acacia nilotica* var. *cupressiformis*) and Bordi (*Ziziphus nummularia*) are being grown as natural tree species in farmlands of arid and semi-arid parts of Rajasthan and Haryana. In Madhya Pradesh, Babool, Siris (*Albizia* spp.), Arjun (*Terminalia arjuna*) and Palas (*Butea monosperma*) grow naturally on berms of agricultural fields. In the recent years more emphasis has been given for growing trees in agricultural fields to meet the increasing demand of fuel and timber and to increase the total productivity per unit of land; but no systematic studies have been carried out. During the last decade some efforts have been made to generate

scientific information on effect of trees on agricultural crops and vice versa. (Shankarnarayan *et al* 1987, Harsh and Tiwari, 1987, Harsh and Tiwari, 1988, Tiwari *et al* 1989, Agbede, 1985 and Prasad, 1987).

The present paper deals with the results of two studies carried out at CAZRI, Regional Research Station, Pali in 1988 viz; (i) Effect of crops on *Acacia nilotica* var. *cupressiformis* and (ii) Effect of (deep) trenching near the root zone of established plantation of *Acacia tortilis* on agricultural crops. The average rainfall of the station is 400 mm and soil is sandy clay loam. The depth of soil is 15-30 cm followed by a calcareous layer.

Materials and Methods

Experiment-1 : Six month old seedlings of *A. nilotica* var. *cupressiformis* were planted at the spacing of 5x3 sq metre and 10x3 sq metre with different crops viz. moongbean, clusterbean, and sorghum and without crop to see the effect of different crops on the tree growth.

Experiment-2 : Three treatments of trenching were given to 22 year old plantation of *A. tortilis* planted in 1966 at the spacing of 4x4 sq. m. In 1987 the trenches were dug out near the main stem on single side, both sides and without trench to study the effect of root pruning on agricultural crops. Three crops viz; moongbean, clusterbean and forage sorghum were sown in between the tree rows in July, 1988. The trench depth was kept only upto 45 cm as the active root zone of *A. tortilis* is in the upper soil depth 45-100 cm (Muthana & Arora, 1979 & Muthana *et al* 1984).

The growth parameters of tree seedlings (height and collar diameter) were recorded both before sowing of the crop and after the harvest of crop. Under different treatments data on crop yield were taken at the time of harvesting.

Results and Discussion

In the first experiment, data on percent increase in height and collar diameter revealed that crop growth had negative effect on the growth parameters of tree seedlings. Compared to no crop treatment, sorghum showed more negative effect on tree height than clusterbean and moongbean, whereas effect on collar diameter of tree remained more or less similar in all the crops (Table 1). In the initial years of establishment of trees, the crops gave enough competition to trees for moisture and nutrients, consequently, affecting the growth of woody component of the

system. Different spacings for trees did not exhibit any effect on the growth of tree seedlings.

Table 1 : Effect of crops on growth of ***Acacia nilotica*** and vice-versa in agroforestry systems

Treatment	Percent increment in tree growth over initial height	Collar diameter	Crop production (q ha^{-1}) Grain	Fodder
TC0	219.0	156.0	–	–
TC1	161.0	103.0	5.2	–
TC2	161.0	102.0	9.9	–
TC3	147.0	103.0	1.3	47.4
SEM ±	19.5	12.1		
CD at 5%	41.0	40.1		

Where T = *Acacia nilotica* var. *cupressiformis*

C0 =Trees without crop C1= Trees with moongbean
C2 = Trees with clusterbean C3 = Trees with sorghum

Among the crops, clusterbean produced the maximum seed yield followed by moongbean and minimum with sorghum (Table 1). Shankarnarayan *et al* (1987) and Muthana *et al* (1985) also reported that in the initial years of establishment of trees, their growth is slowed down as grasses gave enough competition to trees for moisture and nutrients.

On the other hand, trees do not have any negative effect on the grain production of different crops in the initial years of their establishment. For the initial 2-3 years leguminous crops (clusterbean or moongbean) should be grown to reduce the competition. Harsh and Tiwari (1987) have identified three phases of tree- crop interaction in agroforestry systems and they have also reported that in first phase (initial establishment of trees) the crop suppresses the growth of tree seedlings.

In another study the effect of trenching on crop yields was quite pronounced. The grain yield of moongbean and clusterbean and forage yield of sorghum was 5.0 and 5.4 q ha^{-1} and 119.0 q ha^{-1} respectively in case of trench on both sides compared to 3.62 and 1.10 q ha^{-1} and 60.12 q ha^{-1} in case of without trench. The vigour of the crops was also higher under both side trenching treatment followed by single side trenching and

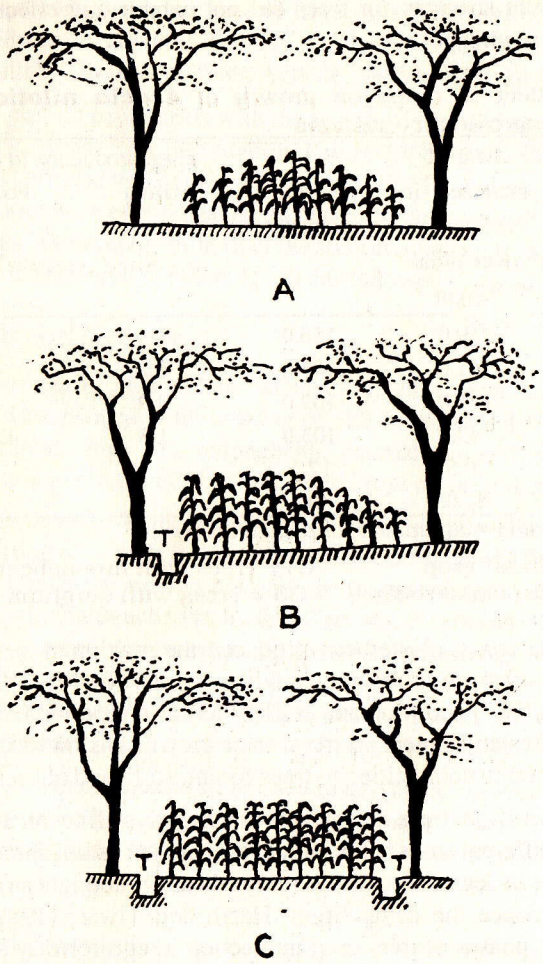

Figure 1. Effect of trenching on crop growth.

A–Without Trench B–One-sinded Trench (T) C–Two-sided Trench (T)

poor growth was under no trenching (Table 2) (Figure-1). Hence the study revealed that if surface feeder roots of trees are cut to avoid moisture and nutrient competition then crop production can be increased. Muthana and Arora (1979) and Muthana *et al* (1984) also reported that *A. tortilis* had more of horizontal roots which spread upto 20 m in horizontal direction. Therefore, trenching upto the depth of 45 cm near the trees gave higher grain and fodder yield.

Table 2 : Effect of trenching near the established ***Acacia tortilis*** on the crop growth and production.

Crops	Crop yield parameters	No trenching	Single side trenching	Both side trenching
Moongbean	Height (cm)	70	76.0	78.0
	Grain production (q ha^{-1})	3.6	4.0	5.0
	Fodder production (q ha^{-1})	–	–	–
Clusterbean	Height (cm)	76.0	119.0	130.0
	Grain production (q ha^{-1})	1.1	4.1	5.4
	Fodder production (q ha^{-1})	–	–	–
Sorghum	Height (cm)	67.0	107.0	117.0
(fodder)	Grain production (q ha^{-1})	–	–	–
	Fodder production (q ha^{-1})	60.0	96.3	119.3

Dadhwal *et al* (1986) also reported that the yields of rabi crops were higher in the trenched plot. Harsh and Tiwari (1987) reported that in the third phase of interaction, the trees suppress the growth and production of crops and suggested the management practices for the trees viz. lopping, polarding, coppicing and root pruning. Muthana and Arora (1977) reported that lopping of *Holoptelia integrifolia* trees gave the higher grain production of cluster and moongbeans over the unlopped tree plots.

The effect of trenching on moisture status revealed that average soil moisture percentage was maximum in plots trenched from both sides followed by one side and without trench. Under the moong crop the percentage moisture was low in 0-15 cm soil depth as compared to 15-30 cm soil depth in the trenched plots, whereas the trend was reverse in case of plots without trench. This indicates that under the low availability of water moong crop having tap root system penetrated to deeper layers of

soil profile and utilized the available moisture. In all the trenching treatments for sorghum crop, percentage moisture was of lower order in the upper layers than in deeper layers, because of its fibrous root system which extracted maximum moisture from 0-15 cm depth.

Hence the present two studies revealed that (i) initially crops have negative effect on the establishment of tree seedlings, but it can be avoided by growing of leguminous crops.

(ii) The negative effect of established trees on crops can be reduced by trenching near the trees facing towards the crop fields. *Acacia tortilis* has sparse canopy therefore shade effect does not have any major impact on the crops.

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EVALUATION OF TREE SPECIES FOR USE IN DRY ZONE SILVI-PASTURE SYSTEMS

M. H. Swaminath and D.S. Ravindran

Introduction

India is predominantly an agricultural country with a very large cattle population, which cannot be maintained on the fodder produced on arable land alone. Production of green fodder on cultivated land is handicapped by the difficulty in setting apart sufficient area for fodder production, lack of inputs such as irrigation, manure, low economic returns from fodder crops, etc (Singh, 1982). Trees, which can be grown either in combination with agricultural crops or on separate land usually not fit for agriculture offer an opportunity of producing green nutritious fodder for the livestock. In Karnataka, the Social Forestry Project has taken up the task of growing and making available fodder to the rural people. About six lakh hectares of 'Gomal' lands (village common land) are available for development of

silvi-pasture. Under the project several species are being raised for fodder purpose. However, there has been no systematic study to test the suitability of various fodder species to different agroclimatic zones, nor have there been studies estimating the forage productivity of different species. Hence, the present study was taken up with the following objectives:

i) To study the suitability of four fodder species for Gomal afforestation and

ii) To assess the forage productivity of the four species and to compare their relative performance.

Location

The trial was taken up in BG Kere Gomal, Challakere Research Range, Chitradurga district located at a distance of 240 km from Bangalore. This region comes under the rain-shadow zone of the maidan tract, receiving an annual rainfall of 300-400 mm. The soil type is red sandy with a high proportion of gravel and stones. The terrain is undulating with moderate slope.

Methodology

i) Species tried : *Hardwickia binata*
Dalbergia sissoo
Albizia lebbeck
Leucaena leucocephala (Soobabul)

of these four species *H. binata* is native to the locality and *A. lebbeck* and *D. sissoo* are the local species of the state. Soobabul is exotic.

ii) Technique adopted: Trenches of size 4 m X 0.45 m X 0.45 m were excavated 4 m apart. The plant population was maintained at 2000 plants/hectare @ 4 plants/trench (500 trenches/ha). A combination of all the four species was tried in each trench. The planting was done during third week of August 1986. The inter row space between the trenches was ploughed and *Stylosanthes hamata* seeds were sown.

iii) Design: Completely Randomised Design.

iv) Data recorded : Growth data relating to height and girth was collected bi-annually. Destructive sampling was carried out during January 1989 to account for the biomass production.

Results and Discussion

The data relating to the growth parameters are presented in Table 1 and Figures 1 & 2. Among the four species tried soobabul was found to perform better than any other species, attaining a mean height of 4.08 m and a girth of 14.68 cm (2 1/2 years age), highly significant growth comparing with the others. There was no significant difference in the growth among *Dalbergia sissoo*, *Hardwickia* and *Albizia*. Thus the data reveal that while there was no significant difference in growth among the local species, soobabul was found to perform significantly better than the others, indicating a better growth rate and suitability to the site.

The destructive sampling data revealed that in the pool of the four species, total biomass production, (both green and dry weight) was highest in case of soobabul and showing no critical difference among the others, producing 24.20 tonnes/hectare. On the whole the average biomass produced was found to be 8.49 tonnes/hectare. The findings are furnished in Table 2 and Figures 3 to 6.

Table 1 : Growth parameters of the four species (March 1989)

Species	Height Data			Girth Data		
	Height (cm)	S.D.	CV%	Girth (cm)	S.D.	CV%
Albizia lebbeck	205.15	16.65	8.11	6.08	0.78	12.82
Hardwickia binata	164.68	8.53	5.18	5.88	1.66	28.31
Dalbergia sissoo	218.50	36.29	16.60	5.88	1.21	20.60
Leucaena leucocephala	408.03	33.13	8.11	14.68	1.58	10.76
C.D. (0.05)	51.57			1.702		
C.D. (0.01)	71.31			2.354		

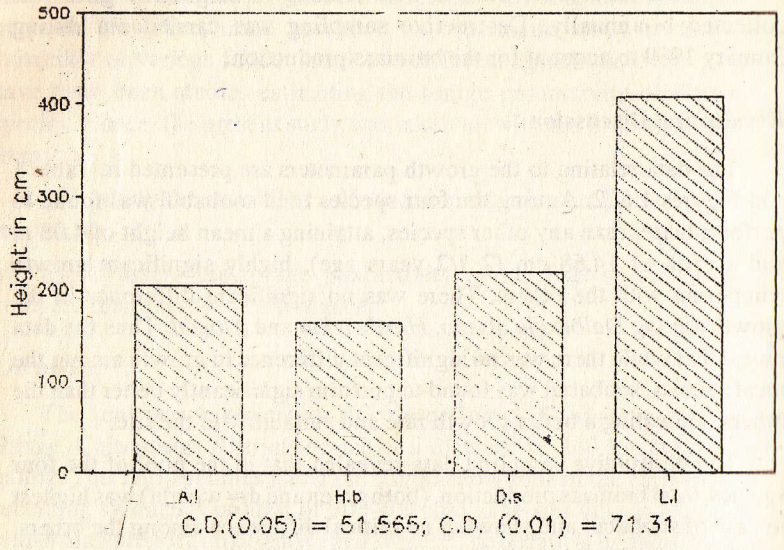

Fig. 1. Height growth of different species (March 1989)

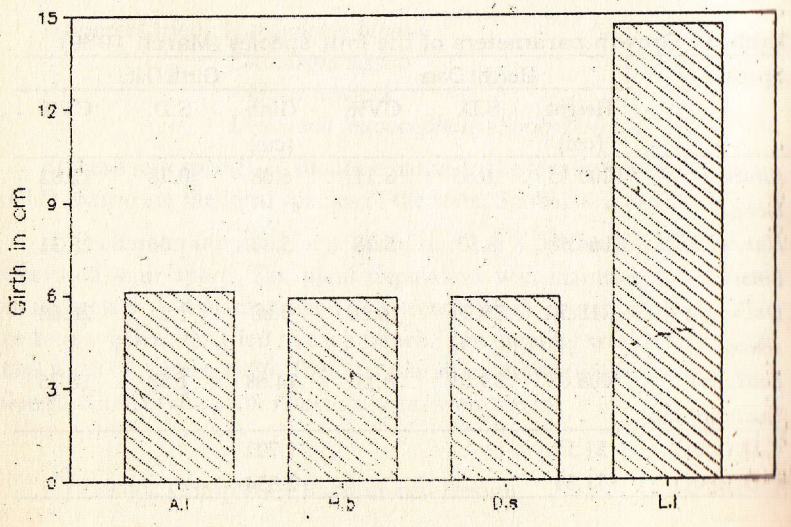

Fig. 2. Girth data of different species (March 1989)

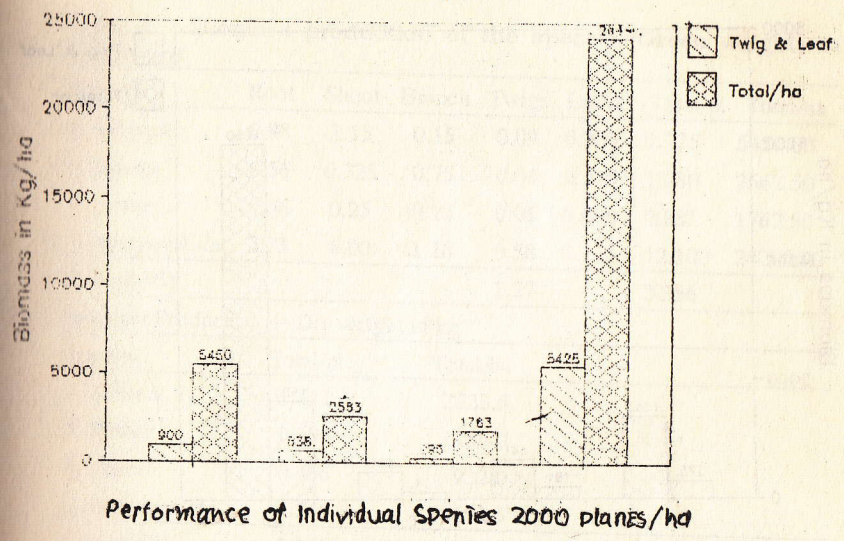

Fig. 3. Biomass production (Green weight) of different species

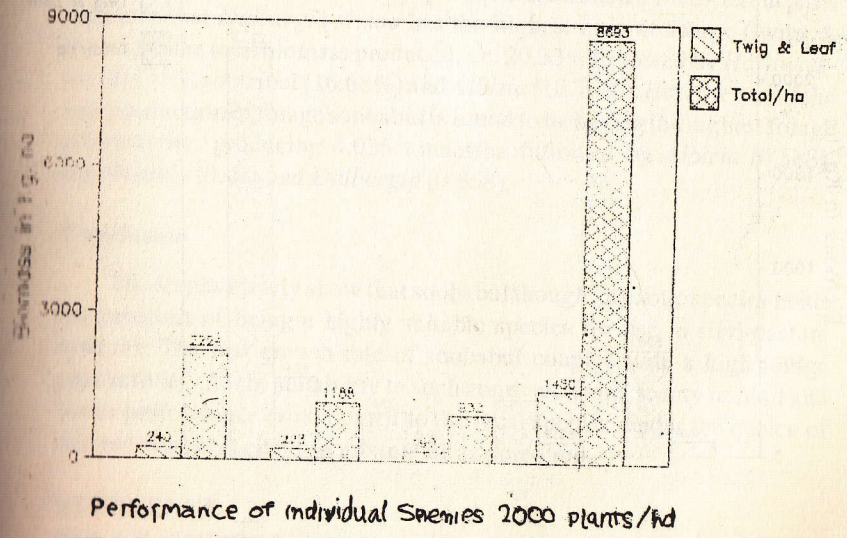

Fig. 4. Biomass production (Dry weight) of different species

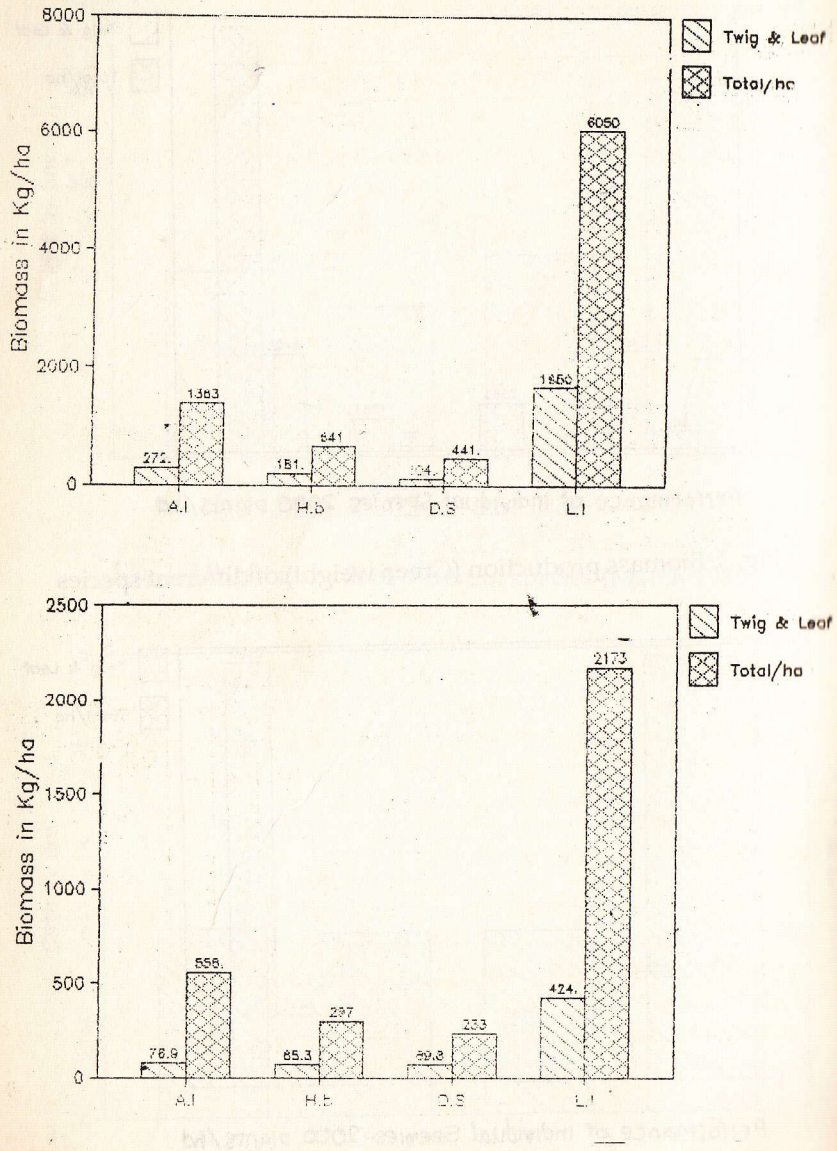

Fig. 5. Biomass production (Green weight) of different species

Table 2 : Biomass production of the species (Green weight) in Kilograms.

Species	Root	Shoot	Branch	Twigs	Leaves	Total/pl	Total/ha
A. lebbeck	0.98	1.15	0.15	0.09	0.356	2.725	5450.00
H. binata	0.56	0.325	0.75	0.04	0.275	1.280	2562.50
D. sissoo	0.36	0.25	0.12	0.06	0.088	0.881	1762.50
L. leucocephala	2.23	6.00	1.16	0.58	2.125	12.100	24200.00
C.D. (0.05)				1.27		3.356	

Biomass Production — Dry weight in kg

Species	Total/pl	Total/ha
A. lebbeck	1.111	2223.5
H. binata	0.594	1188.0
D. sissoo	0.466	932.0
L. leucocephala	4.346	8692.5
C.D. (0.05)	0.269	

A comparison of the biomass production estimated for different parts indicates that *Dalbergia sissoo* has the highest ratio of forage (twigs & leaves) to the total biomass produced, i.e. 20.33% followed by *Hardwickia* (18.77%), soobabul (16.68%) and *Albizia* (10.79%). But in terms of the unit production of forage soobabul is found to be having the highest forage productivity, producing 4.036 tonnes/ha followed by *Albizia* (0.588), *Hardwickia* (0.48) and *Dalbergia* (0.358).

Conclusion

The results clearly show that soobabul though an exotic species holds the prospect of being a highly suitable species for use in silvi-pasture systems. The fast growth rate of soobabul coupled with a high forage productivity and the suitability to such zones receiving scanty rainfall and better performance as compared to the local species render the choice of this species ideal either in mixture or as pure crop.

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MORTALITY IN IRRIGATED PLANTATIONS OF DALBERGIA SISSOO ROXB.

K. K. Srivastava

Introduction

Dalbergia sissoo Roxb. belongs to family fabaceae and occurs throughout the plains of North India, from Punjab to Assam and tarai regions of Himalayas. The timber is strong and durable. The species in high soil moisture with good drainage conditions. It cannot withstand water logging conditions even for a short period (Streets, 1962) but can sustain in drought. In I.G.N.P. area particularly in abadi plantations of *A. nilotica, Eucalyptus camaldulensis* and *Dalbergia sissoo* a large scale mortality was reported due to faulty irrigation practices (Gupta, 1990). Such a situation has caused heavy mortality of *D. sissoo* plantations in Stage I of I.G.N.P. area. These plantations were found to suffer from die

back. The paper presents causes and symptoms of the disease and control measures.

Symptomology

A field visit was undertaken in July 1990 to Chattargarh area of Bikaner circle. 8-10 years old plantations of *D. sissoo* raised by state forest department exhibited symptoms in the form of yellowing of leaves from top to downwards of crown. Such leaves showed pre-mature defoliation. Adjoining trees were found mostly affected and formed patches. Dieback symptoms developed on the trees finally killing them. The incidence of disease ranged between 15-20%.

Etiology : Ganoderma lucidum (Leyss) Karstt.

Infection and damage

Ganoderma-lucidum (Leyss.) Karst. causes a serious root rot in broad leaved tree species. The pathogen survives in dead stumps and residual roots from previous forest cover (Bakshi *et al* 1976). The disease spreads through root to root contact and infects neighbouring healthy plants. The disease is also transmitted through basidiospores released by fruiting bodies by water or air. The pathogen enters through cracked surface of the bark and make mycelial mat between the bark and sapwood which was observed during investigations. It spreads very rapidly in light textured soil as compared to heavy textured soil. Free mycelial spreads do not occur in the soil. Therefore, in line planting disease becomes serious due to similar host due to direct root contact.

Sporophore characteristics

Sporophores are dark brown to chocklate coloured perennial fruit bodies collected from base of the stem. Hymenial layer was white, with minute pores generally having stalk, confirming the attack of *Ganoderma lucidum* root rot disease in *D.sissoo* (Bakshi, 1971).

Control Measures

Mortality in *D. sissoo* due to *Ganoderma* root rot may be minimised by adopting one or more of the following precautionary control measures:

(1) *Site Preparation* - Planting area should be cleared by removing the old stumps, roots and rootlets, debris should be burnt. Sporophores should be collected manually and buried & destroyed completely.

(2) *Isolation trenches* - To prevent the lateral spread of the disease, it can be isolated by digging the isolation trench about 0.3 m wide, 0.7m deep and 1.5 m long across the line (Bakshi, 1976), it is advisable to make an additional trench to separate the diseased plants from adjacent healthy plants.

(3) *Raising resistant species or mixed plantation technique.*

Ardu (*Ailanthus excelsa*) and semul (*Bombax ceiba*) may be raised as a guard line to break the continuity of same host. In severely infested soil with *G. lucidum* crop rotation of these species should be adopted.

(4) *Chemical Treatment* :- Though chemical treatment is not advisable in forestry crops in the routine manner, in case of severe attack chemicals like Blitox 0.2% or Bavistin 0.1% may be used after removing the soil and making the trench around tree @ 5 lt per tree. In coppice plantations open surface should be pasted with copper based paste i.e. chaubattia paste (one part $CuCO_3$ + 1 part red lead + 2 part white petroleum jelly) as a prophylactic treatment.

Discussion and Conclusions

Ganoderma root rot is an important and serious disease amongst forest tree species. The disease has been reported to be a serious problem on *A. lebbeck, Cassia fistula, Acacia nilotica*, and *Prosopis palida* in arid zone areas (Ahmed & Srivastava 1991). Faulty irrigation practice was also one of the causes of mortality (Gupta, 1990).

Due to flood irrigation the tape root was observed to be poor as compared to lateral roots which may come in contact of infested roots infecting adjoining healthy plants of Dalbergia Sissoo. Therefore, monoculture or planting of susceptible host is not advisable particularly severely infested area of Ganoderma root rot disease.

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USEFUL TREES FOR ARID CLIMATE – SILVICULTURAL CHARACTERS AND PROTECTION MEASURES AGAINST POSSIBLE DISEASES

R.K. Namdeo, V. Nath and Neelum Verma

Introduction

Arid climates may be defined as those in which commercial crops cannot be regularly raised without adequate irrigation (Mc Ginnies *et al* 1968; Fuchs, 1973; Jones *et al* 1981). They are generally characterized by two sporadic rainfall of great variability over time and space, averaging 200 mm or less annually, which when it arrives, can be of high intensity, resulting in devastating floods. Semi-arid climates have characteristics that are even more variable than those of arid regions although, as implied, conditions do not preclude plant growth to the same degree (Armitage, 1988).

Climate has important influences on soil formation and characteristics. In arid regions, wind and occasional water erosion are severe so that gravelly desert plains, sand dunes and sand sheets are prevalent. The interrelationship between climate and soil formation in arid and semi-arid zones are described by Dan, 1973 and Kaul, 1970.

The selection of appropriate tree species for plantation in these areas depends on the purpose, physical and climate characteristics of the site. Trees with moisture conservation mechanism can survive in arid regions and grow better. The survival of plantations in these areas is likely to become more difficult than those being raised under normal conditions. Therefore, the planting stock and young plantations for this purpose need an extra vigour or health to withstand the adverse conditions of soil and environment. The silvicultural characters of some tree species for arid climate alongwith important diseases recorded on them and possible control measures are suggested in this paper for raising healthy plantations.

Trees suitable for planting in arid region

1. *Acacia Catechu* WILLD. (KHAIR)

It is a medium size tree of warm and dry regions used for fodder, timber, fuel, gum, katha and soil conservation purposes. It grows on wide variety of soils such as sandy, gravelly, alluvial, loam with varying proportions of sand and clay and black cotton soils (Singh, 1985). Leaf shedding and flowering normally occur in February - March and new leaves appear in April - May. Seed collection time is January - March. The seeds do not have dormancy and germinate readily when provided with favourable conditions. Germination is epigeous. It is a strong light demander and does not tolerate heavy shade. *A. catechu* reproduces naturally through coppice as well as from seed. It can be raised by direct sowing, planting out nursery raised seedlings and stump planting.

Pathogens : Root rot caused by *Ganoderma lucidum*, seedlings mortality due to attack by *G. lucidum* which persists in residual stumps, decay of heart wood which reduces katha yield by *Fomes badius* - a wound parasite and leaf rust by *Ravenelia tandonii* are common pathogens of *A. catechu* (Bakshi, 1976). Other pathogens recorded on *A. catechu* are *Ganoderma applanatum, Polyporus* spp; *Phyllactinea acaciae* and *Erysiphe acaciae* (Bilgrami *et al* 1979 & 1981).

2. *Acacia Nilotica* (LINN) Willd. Ex Del (Babul)

It is a medium size tree widely used for timber, fuel, fodder, fencing material, tannin and gum. Village artisans extensively use this wood in preparing tool handles used in village industries, cart and farm implements and it holds promise for small scale industries in rural sector for manufacture of tool handles and agricultural and farm implements (Tiwari, 1983). It is capable of growing on a wide variety of soils, provided sufficient moisture is available for its growth. However, it prefers heavy soils. Flowering generally takes place during June - September. Seed collection time is April - June.

The seeds have no dormancy and germinate when provided with favourable conditions. Germination is epigeous. The new leaves appear from March - May. It is a strong light demander and gets suppressed under heavy shade. The development of seedlings is always better in full sunlight than under shade. Natural reproduction is mainly through seed and seedling coppice. Direct sowing is the most common and successful method of raising this species (Howard, 1926).

Pathogens - Butt and root rot caused by *Ganoderma lucidum,* heart rot by *Fomes badius* causing the wood to become brittle and foliar infection by *Ravenelia acaciae - arabicae* and *Cladosporium acaciae* are recorded on *A. nilotica.*

3. *Acacia Leucophloea* Willd. (reunza)

A. leucophloea is a tree of tropical and subtropical climate. It is a medium size tree used for fuel and medium to good quality fodder for goats and sheep (Singh, 1985). It can grow on a variety of soil, ranging from shallow and gravelly on hill slopes to deep alluvial. The old leaves fall during winter season and new leaves appear in April. Flowers appear from August-November. The pods ripen from April to June. The seeds have hard testa, but exhibit no dormancy. Germination is epigeous. It is a light demander, drought resistant and frost hardy (Troup, 1921).

Direct sowing is reported to be more successful than planting out of nursery raised seedlings (Troup, 1921). The tree coppices well and produces root suckers (Rao, 1953).

Pathogens - Root rot caused by *Ganoderma lucidum* and foliar infection by *Haplophragmium* sp. and *Catacauma acaciae* are reported on *A. leucophloea.*

4. *Ailanthus Excelsa* Roxb (Maharukh).

It is a large tree used for timber, packing cases, fishing boats and boards. Fodder and bark is of medicinal value. *A. excelsa* is most suitable species for planting in dry areas of Rajasthan (Bhimaya *et al* 1963). It grows on a wide variety of soils, but thrives best on porous sandy loams (Chaturvedi, 1956). Leaf fall takes place in February and new ones appear in March - April. Flowers appear in February - March. Seed collection time is in May - June. The seeds are short lived and viability period is 1-6 months only. The germination is epigeous.

It is a strong light demander. The seedlings get suppressed by weeds as a result of shading. They are succeptible to frost also. Natural reproduction takes place through seed and coppice. However, seedling regeneration is generally scanty. It can be grown by direct sowing, entire transplant, stump planting or branch cutting.

Pathogens -Leaf spots causing mortality when appear in severe form caused by *Cercospora ailanthicola* and infection to dead parts by *Didymosphaeria ailanthi, Nodulosphaeria indicum* and *Ovulariospsis* sp. are reported on *A. excelsa.*

5. *Albizia Lebbeck* (Linn) Benth. (Siris)

It is a large tree grown widely in Central India used for timber, fuel, fodder and medicinal purposes. *A. lebbeck* is a tree of tropical and subtropical climate and found to be suitable for planting in dry areas of Rajasthan (Bhimaya *et al* 1963). It grows on a variety of soils, but does well when planted in black cotton soil (Troup, 1921). Leaf shedding takes place in October-November and new leaves appear in March - April. Flowering takes place in April - May. Seed collection time is January - March. The seed germinates readily when favourable conditions are provided. Germination is epigeous (Brandis, 1906). Natural reproduction is through seeds. It can be artificially propagated by direct sowing or planting of nursery raised seedlings (Muthana *et al* 1976).

Pathogens - *Ganoderma lucidum* causes root rot while *G. applanatum* and *Fomes* sp. cause heart rot. *Fusarium solani* causes greyish black cankers. Leaf spots by *Cercospora albizziae, Phyllosticta albizziae, Colletotrichum dematium, Alternaria* sp., *Phoma* sp., *Ascochyta* sp., *Helminthosporium* sp., *Camptomeris* sp., leaf rust by *Ravenelia sessilis.*, pod blight by *Colletotrichum compactum* and seedling wilt by *Curvularia lunata* are reported on *A. lebbeck.*

6. *Azadirachta Indica* A. Juss. (Neem)

It is a common and important tree of dry zone. It is a large tree used as timber and fuel. The bark and seeds are of medicinal, insecticidal, fertilizer and fodder value. The seeds of this plant contain oil which is in great demand for pharmaceutical, soap and disinfectant industry. *A. indica* is a tree with wide climatic adaptability and more especially in the drier parts. It grows well on wide variety of soils ranging from sandy to clayey. The new leaves appear in March - April soon after old ones have fallen. It flowers generally in March-April. The seed collection time is June to August. The seeds have no dormancy and germinate quickly. Germination is epigeous. It is a hardy and light demanding tree. It can be raised successfully through direct sowing, planting out of entire plants or stump planting.

Pathogens - Root rot caused by *Ganoderma lucidum*, stem/twig blight by *Corticium salmonicolor*, foliar infection by *Cercospora meliae*, *Fusarium* sp., *Oidium* sp., *Candida* sp, *Cladosporium* sp, seedling wilt by *Fusarium* sp, and decay to wood by *Xylaria azadirachta* are reported on *A. indica.*

7. *Dalbergia Sissoo* Roxb. (Sissoo)

It is a large tree used for timber, plywood, fuel and fodder. The wood is extensively used in furniture industry, musical instruments, farm implements, cart, carriage and wheel works industry and also for carving works. It is a tree of subtropical climate. It prefers well drained sandy loam soil with good moisture supply. The leaf fall begins in November - December and new leaves appear in February. Flowers appear in February - March. Seed collection time is November - March. The seeds germinate when favourable conditions are provided. Germination is epigeous.

It is a strong light demander. Natural reproduction takes place through root suckers, coppice and seedling regeneration. It can be raised by either direct sowing, planting out entire plants raised in the nursery, stump planting or planting out root suckers.

Pathogens -*Ganoderma lucidum* causes root-rot both in plantations and natural crops. White rot in sapwood is caused by *Polyporus gilvus. Fusarium oxysporum* causes seedling wilt in nurseries. Leaf spots by

Cercospora sissoo, Diplodia dalbergiae, Phyllosticta sissoo, Phyllachora spp., leaf rust by *Maravalia achroa*; Powdery mildew by *Phyllactinia dalbergiae*; and leaf blight by *Colletotrichum gloeosporioides* are reported on *D. sissoo.*

8. *Dendrocalamus Strictus* Nees (Narbans)

Pathogens - *Fomes caryophylli* causes heart rot; *Cercospora haticola, Pestalotia dichaeta, Pestalotiopsis dichaeta* cause leaf spots/ blights; *Scopella echinulata* causes leaf rust and decay in felled timber are caused by *Chondrostereum purpureum, Daedalea flavida, Fomes durissimus* and *Polystictus steinheilianus* are recorded on *M. latifolia.*

9. *PArkinsonia Aculeata* Linn. (Vilayati Babul)

It is a small evergreen tree used for fuel, fodder and ornamental hedge purposes. It can grow easily in drier localities. It bears numerous bright yellow flowers chiefly in March - April and also at other times of the year. It is a light demander and fairly drought resistant. Seeds germinate readily. It can be raised by direct seedling. The trees can also be propagated easily from cuttings.

Pathogens - *Botryosphaeria parkinsonii* and *Oidium* sp. causing infection are recorded on *P. aculeata.*

10. *Pithecellobium Dulce* (Roxb) Benth. (Jangli Jalebi)

It is a large tree used for packing cases, agricultural implements, fruits, fodder and also for making effective hedge, if cut repeatedly. It is a tree of tropical region. Flowers appear in January - February and the pods ripen from April - June. The seed collection time is April. Sowing season is July to August. It can be grown easily by direct sowing of seeds. For hedges it is usual to sow the seeds at site and to trim the plants. The growth is fast.

Pathogens - Heart rot caused by *Fomes robiniae*; and leaf spots/ blights by *Phyllosticta pithecellobii; Cercospora mimosae* and *Colletotrichum* spp are recorded on *P. dulce.*

11. *Prosopis Cineraria* (L.) Druce (Jand)

It is a medium size tree used for house construction, agricultural implements, turnery articles, fuel, charcoal, fodder and soil conservation purposes. It is a tree of dry and arid region and grows on coarse and sandy an soils. It is an evergreen tree or nearly so. New leaves appear before or

simultaneously with the fall of the old leaves in summer. Flowers appear from March to May. Seed collection time is June to August. The seeds have hard testa and germinate when provided with favourable conditions. Germination is epigeous. It is a strong light demander. *P. cineraria* reproduces through seed, root suckers and coppice.

Pathogens - *Ravenelia spicigera* causes leaf rust disease on *P. cineraria.* Other fungus recorded on this host are *Botryosphaeria prosopidisa, Patellaris atrata, Rosellinia bunodes* and *Guignardia tilaki.*

12. *Prosopis Juliflora* Stuntz. (Vilayati Kikker)

It is a small to medium tree used for fuel, fodder, small timber and soil conservation purposes. It is an exotic species which has become naturalized in India. It is capable of growing under dry conditions on poor soils and also on saline and water logged sites. This species can tolerate alkaline soil much more than any other species (Tiwari, 1983). This species withstands almost annual coppicing and therefore, becomes a good source of fire wood right from the first or second year of planting. The fruits ripen in May - June. Seeds are long lived and viability remains upto two years. It is a strong light demander, drought resistant and good coppicer. The species can easily be raised by direct sowing or through root suckers.

Pathogens - *Colletorichum capsici, Diplodia* sp., *Septoria* sp. *Sydowia prosopidis, Xylochora arxii, Massaria* sp and *Robergea indica* are recorded on *P. juliflora* causing more or less damage.

13. *Acacia Tortilis* Forsk (Israeli babool).

It is a small tree with a flat, parasol type of crown, multiple boles and red to brown coloured young shoots of current years. It generally attains a height of about 4m, which may go up to 8-10 m in favourable localities. It was introduced in India at Jodhpur in 1958 (Kaul, 1970). It's wood is widely used as fence posts & small timber for agricultural implements & foliage for fodder, besides its value as sand stabilizer as it grows well on sand dunes. It has naturalized in arid zones of India and forms an important component of the arid zone vegetation.

It flowers in the month of May. Pods begin to form by the middle of July which ripen in November to February. It would appear to be a strong light demander in all stages of its growth. It comes up on saline soils very well and is extremely drought resistant. It has a long tap root & a number

of side roots to enable it to utilize the limited soil moisture of arid soil effectively. It can tolerate extremes of temperature. It is a fast growing species and an effective nitrogen fixer.

Germination is epigeous. The seeds have a hard testa and require pretreatment before sowing. Sowing in containers is generally done in the month of August and outplanting is done in July.

14. *Tamarix Linn*

It is either a shrub or a small tree known as Tamarisks distributed in Europe, Asia and Africa. The Tamarisks exhibit xerophytic adaptations in the scale like form of their leaves and in some cases in the shedding of the smaller twigs as in *Tamarix aphylla.* Several species of *Tamarix* are planted for the fixation of sand dunes, afforestation on sea shores as wind breaks and shelterbelts on field boundaries in arid regions and also for ornamental purposes.

The galls found on species of Tamarix are used in dyeing and are reported to have medicinal properties. Sometimes tannin is extracted from the galls and the bark. Flower is stiff, compact spikes forming terminal panicles. Flowering of *Tamarix dioica,* Roxb is from July to October. Fruit ripens in February.

15. *Salvodora. Linn*

1. *Salvadora oleoides :* A shrub or small tree with drooping branches used for building, agriculture implements, and as fuel. Fruit is eaten, often dried. This is a common species in arid region tract of the Punjab and Sind and occurs to some extent in Rajputana. In the trans Indus hills it ascends to 3000 feet and in the salt range to 2000 feet. It seems to thrive where the rainfall is below 25 inches. It thrives well on saline soil. The new leaves appear in April, flowers appear from March to April and fruit ripening completed in June. Fruit is yellow berry 0.2 cm in diameter. *S. oleoides* regenerates freely by root suckers and to some extent by natural layers.

2. *Salvadora persica*: A small evergreen tree with drooping branches, sometimes attaining 30 to 40 ft height with a short often fluted stem. The leaves and fruits are pungent and wood soft. A tree of the dry and arid regions of India, with a wider distribution, in the regions of Baluchistan, Sind, Trans Indus, Punjab, Rajputana, Ganges valley round Delhi and Agra. It is often found on saline soils and in the peninsula on black cotton soils. In North Kanara it grows on the sea coast above high water mark in

thickets with *Clerodendron irmerme, Ziziphus oenoplia, Ziziphus jujuba* and other species.

It grows readily from seed and coppices well. In Punjab the seed ripens in June.

16. Tecomella Undulata (Rohida)

It is a shrub or small, medium sized tree of Indian arid zone used for fine carving work on furniture, etc. *Tecomella undulata* is slow growing in nature. It is a native of Thar desert having low rainfall and high temperature during summers. This tree is growing under rainfed/irrigated conditions. The tree inhabitates the plain deep coarse sandy soils. This is a tree of drier regions of India, namely the Suliman and salt Ranges, Sind Baluchistan, Trans Indus, Punjab, Rajputana, Gujarat, Khandesh.

It is an evergreen, with simple grey leaves and large yellow to orange flowers, which appear from January to April. The fruit, a curved capsule 6-8 inches long, ripens from May to July. It coppices fairly well and is easily grown from seed or cuttings. It is drought hardy and very resistant to fire.

Management of Diseases

The important disease problems likely to occur in above tree plantations and management of these problems for raising disease free plantations are suggested here under. The diseases recorded on these plantations from Madhya Pradesh are listed in Table 1.

1. SEED DISEASES

The health of seed is perhaps, the most important factor in determining the fate of a plant in the stand. The seeds get infested on the tree during the process of maturing as well as in storage by many fungi. For this dry, wet or slurry treatment of seeds prior to storage and sowing are recommended to control the diseases of seed and/or soil borne nature such as pre-emergence blights, wilts and damping off in the nurseries. Bavistin, Benlate, Methyl Thiophanate, Thiram and Fytolan at the rate of 0.2% (W/W) can be used for this purpose.

2. SOIL BORNE DISEASES

In nurseries where pre-emergence blight, wilt or damping off diseases have occurred in serious form year after year, the sick should be avoided. If not possible, the soil may be fumigated with commercial grade formalin

(38% formaldehyde), 250 ml diluted in 4 lit of water can be applied as soil drench per sq.m. of bed. To prolong the volatile effect of the formalin, the beds should be covered with polythene sheets for 2-3 days after application.

II. The diseased seedlings showing wilting symptoms should be removed as soon as the symptoms are noticed. Early diagnosis through surveillance and removal of infected seedlings are found useful in preventing rapid spread of the diseases in nursery stock.

III. Sanitation of weeds should be done regularly as the weeds are known to be collateral hosts of the fungus and act as the source of infection.

IV. Little or over watering should be avoided in nurseries and proper drainage around plants should be provided. Care should also be taken during transplanting to avoid injury to the root system of seedlings.

V. During transplanting of seedlings from nursery beds to polypots, the rootlets and delicate roots are usually damaged thus opening wounds to be attacked by soil pathogens. Root dips in a solution of fungicide for 3-5 minutes secure the root system against such invasions. Bavistin or Fytolan @ 0.2% in water (4g/lit water) can be used as root dips.

Plantation diseases

Healthy and vigorous seed and disease free seedlings would yield healthy plantations. Proper choice of site and species also play an important role in raising healthy plantations. Adequate compacting of soil at the time of planting, proper spacing, proper pruning, fire protection, regular thinning, treating injuries and maintaining sanitation as and when required also help in raising disease free plantations.

II. Root rots due to *Ganoderma lucidum* mostly takes place from infected root mass of previous crops present in the site. Removal of residual stumps and old roots from trenches and pits prior to planting is the best measure to minimize incidence of root rots.

III. Isolation of infected trees with root rot fungi adjoining healthy trees in lines by digging trenches is found effective and economical method for checking the spread of root rots in plantations.

IV. Prevention of injury resulting from the lopping of trees, collection and destruction of fungal bodies, removal of infected trees and mixing of resistant tree species with those susceptible to root rots also helps in checking lateral spread of root rots.

Wood-decay problem

Wood-decay in storage and use can be controlled by proper management practices starting from the stand and right after felling like removal of infected parts, wound dressing, prevention of fire, winter felling, immediate removal after felling, proper storage, preventive sprays such as pentachlorophenol in oil, sodium salt of penta in water, water soluble $ZnCl_2$, $HgCl_2$ or $CuSO_4$, Creosote oil, etc.

Foliage diseases

Foliage fungi causing leaf spots/blights, powdery mildew and rusts may attack newly emerging leaves and cause serious damage. Use of chemicals in controlling tree diseases is uneconomical and troublesome. However, in nurseries and young plantations, the foliar diseases above economic threshold level can be controlled by application of suitable fungicides. Some of the chemicals effective in controlling foliage diseases are listed in table 1.

Table 1 : Diseases recorded on tree species from Madhya Pradesh

Host/Disease	Causal organism	Control(Chemical)
Acacia catechu		
Root-rot	*Ganoderma lucidum*	–
Acacia nilotica		
Butt and root rot	*Ganoderma lucidum*	–
Ailanthus excelsa		
Leaf spots	*Cercospora ailanthicola*	

		Spraying of 0.2% Bavistin or Dithane M45
Albizia lebbeck		
Seedling wilt	*Curvularia lunata*	Seed treatment, soil fumigation
Leaf spots	*Phyllosticta albizziae*	Spraying of 0.2% Bavistin or Dithane M45
	Cercospora albizziae	–
	Colletotrichum dematium	spraying of 0.2% Captafol
Pod blight	*Colletotrichum compactum*	–
Leaf rust	*Ravenelia sessilis*	spraying of 0.2% Sulfex
Azadirachta indica		
Seedling wilt	*Fusarium* sp.	Soil drench with 0.2% Bavistin or seed dressing with 0.2% Topsin -M.
Leaf spots	*Cercospora meliae*	Spraying of 0.2% Bavistin or Dithane M45
	Fusarium sp.	
Dalbergia sissoo		
Seedling wilt	*Fusarium oxysporum*	as above
Leaf spots	*Cercospora sissoo*	spraying of 0.2% Bavistin
	Diplodia dalbergiae	or Dithane M45
	Phyllosticta sissoo	0.2% Fytolan
Leaf blight	*Colletotrichum gloeosporioides*	spraying of 0.2% captafol
Leaf rust	*Maravalia achroa*	spraying of 0.2% sulfex
Powdery mildew	*Phyllactinia corylea*	–
Dendrocalamus strictus		
Seedling wilt	*Fusarium* sp.	as above
Leaf spots	*Drechslera rostrata*	spraying of 0.3% captafol or Fytolan
Leaf rust	*Dasturella divina*	spraying of 0.2% sulfex

Eucalyptus hybrid		
Seedling mortality	*Macrophomina phaseoli*	as above
Leaf spots	*Alternaria alternata*	spraying of 0.2% Fytolan or Dithane M45
	Biospora sp.	–
	Phyllosticta eucalypti	–
	Phaeoseptoria eucalypti	Dithane M45
Leaf blight	*Pestalotiopsis* sp.	spraying of 0.2% Bavistin
Powdery mildew	*Oidium* sp.	spraying of 0.2% sulfex
Madhuca latifolia		
Leaf spots/blights	*Pestalotiopsis dichaeta*	spraying of 0.2% Bavistin
Leaf rust	*Scopella echinulata*	spraying of 0.2% sulfex
Heart rot	*Fomes caryophylli*	–
Wood-decay	*Chondrostereum purpureum*	–
	Daedalea flavida	–
	Fomes durissimus	–
Melia azedarach		
Leaf spots	*Cercospora subsessilis*	Spraying of 0.2% Bavistin or Dithane M45
	Alternaria alternata	–
Pithecellobium dulce		
Leaf spots	*Phyllosticta pithecellobii*	Spraying of 0.2% Fytolan
Heart rot	*Fomes robiniae*	–

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SCOPE OF BIOLOGICAL AGENTS IN FOREST PEST MANAGEMENT IN ARID ZONE

S. I. Ahmed

INTRODUCTION

Replacement of risky insecticides with more safe control methods are not only desirable from the safety point of view but necessary if we grow large plantations. It appears that creation of integrated pest control system combining microbial, biological, chemical, silvicultural and mechanical control methods may present the best solution, for the insect pest management in arid zones and Aravallies.

In forest ecosystem entomopathogenic micro organisms may replace some of the least specific and most dangerous chemical insecticides, thus enabling the naturally occurring parasites and predators to play a greater role in regulating the insect pest situations. The microbes causing disease

in insects are *bacteria, fungi, viruses, nematodes, protozoa* and *rickettsiae.* Among these pathogens insect viruses, belonging to the nuclear polyhedrosis (NPV) and granulosis (GV) groups have shown to be more specific and to have a more lasting effect than other pathogens presently known. The two groups are almost exclusively found in *Lepidoptera* and *Hymenoptera.*

The general objectives of this paper are to make comparison between entomopathogenic micro organisms and chemical insecticides, to discuss and assess the possibilities of developing the use of insect pathogens to the extent that they may be used in a practical way in forest pest management and to suggest environmentally acceptable measures to prevent and minimise hazards.

GENERAL

There are atleast six major points to be considered in arriving at an assessment of the suitability of any agent for insect control. These are :

(i) Specificity for the particular insect to be controlled with minimum effects on the other species and especially on those that are beneficial.

(ii) Safety to man, higher vertebrates and forest trees so that there is no accumulation of toxic products.

(iii) Persistence of the effect so that the necessity for repeated application is minimal.

(iv) Resistance of the insect population.

(v) Ease of application.

(vi) Cost, including all factors such as formulation, propagation and utilisation.

Despite the increasing use of chemical pesticides, all of them are deficient in one or more of the foregoing criteria. Practically none of them is selective, and parasites and predators are frequently killed indiscriminately with the target species. Many insecticides leave persistent residues on the treated plants, necessitating treatment to make them acceptable as food. Others may be concentrated in the biological chain of

life, and become a hazard in foods. Detailed discussions on this aspect are made by Carson (1962) and, Rudd (1964).

On the other hand, the forest ecosystem is an ideal environment for biological pest control for several reasons such as :

(i) The natural enemy complex for forest insects has a high degree of predictability upon which sophisticated pest management strategies can be based.

(ii) Along with their rich complex of natural enemies like, parasites, predators and pathogens, forest communities often extend uniformly over large areas and these complexes exhibit only minor regional differences.

(iii) Forests are usually long lasting ecosystem with a high degree of stability and a long evolutionary and great diversity of plants and animal life.

ENTOMOPATHOGENIC MICRO ORGANISMS AS CONTROLLING AGENTS

Micro-organisms pathogenic for insects belong chiefly to four main groups : viruses, bacteria, fungi and protozoa. In addition several rickettsiae have also been reported from insect pests.

Viruses

Insect viruses contain some of the most important naturally occurring insect pathogens as well as promising candidates for microbial insecticides. There are many records of control of forest insect outbreaks by viruses from Canada (Morris et al, 1977; Cunningham et al, 1978), U.S.A. (Stelzer et al, 1975), West Germany (Schonherr, 1969), Japan (Koyama and Katagiri, 1967). Denmark (Zethner, 1976), France (Grison, 1960), and S.Africa (Ossowski, 1960). But from India a few reports have been recorded (Ahmed and Sen-Sarma, 1983; Ahmed and Joshi, 1988; Ahmed et al 1989a, 1989b).

In India, examples of forest insects that can be controlled by artificial dissemination of viruses, are the poplar defoliator, *Pygaera fulgurita,* Amaltas defoliator, *Catopsilia crocale,* teak defoliator, *Hyblaea puera,* and a polyphagous defoliator, *Achaea janata.* The control programmes of the above pests could not be under taken on large scale because of lack of adequate supply of virus material.

The lasiocampid defoliator of *Khejri* and Rohida, Taragama silva is found to be infected with a polyhedral viral disease at Jodhpur during July 1990. The larval morality due to polyhedrosis ranged from 40 to 50 per cent. The deaths in naturally infected population occurred during the fifth instar and this may be due to lower inoculum of polyhedral inclusion bodies in the early larval instars. The larvae stop feeding a few hours before death. They then become sluggish and the pigmentation of the integument becomes slightly discoloured. Detailed study on the nature of disease and insect - viral interaction is in progress. Apart from this microbial controlling agent, a dipterous endoparasite is also encountered to control the larval population in the experimental area of AFRI, Jodhpur.

Bacteria

Although a number of earlier attempts to utilize bacteria in controlling forest insect pests have been recorded in many countries lik Canada, Japan and U.S.A. (Morris, 1984) but in India a very little work has been carried out to control forest insect pests by the application of bacterial preparations. The first case of utilization of bacterial preparation, that can be termed really successful, was that of milky disease of Japaneses beetle, *Popillia Joponica* Newn., caused by *Bacillus, Popilliae* Dutky. Recently, in India, efforts to utilize bacteria have been concentrated on various strains of *Bacillus thuringiensis* (Berliner), which have now been developed to the point that we can say this is the only industrial production of a microbe for general use in controlling any lepidopterous forest insect pest. *B. thuringiensis* is now being produced at the rate of hundreds of tons per year in several countries, and has been certified by the appropriate licencing authorities, for its use on a number of forest insect pests (ESC, 1986)

Fungi

Entomopathogenic fungi in general are much less host specific than viruses or even bacteria. One strain of *Beauveria bassiana* has been reported as occurring on more than 30 different insect species and another strain (*B.globulifera*) on nearly 100 (Cameron, 1974). In Canada, a large scale screening programme has been established for entomogenous fungi which can be massproduced and this will serve as a basis for well planned field trials in future (CESC, 1986).

It has been generally believed that fungus' spores germinate only under condition of very high relative humidity and high temperature (Cameron, 1974) and this has often been given as the reason for the sporadic and unpredictable occurrence of epizootics. Tests carried out at the Institute of Forest Genetics and Tree Breeding, Coimbatore during 1989 revealed that the spores of certain entomogenous fungi like *Beuveria bassiana (Balas), Metarrhizium anisopliae (Mets); M. flavoviridae, Verticillium lecanii (Zimm).; Paecilomyces farinosus* (Holm); *P.fumosoroseus* (Wize); *P.lillacinus* can germinate very well on artificial media under laboratory conditions of temperature and relative humidity being 27 to 35^0C and 45 to 70%, respectively.

Recently a curculionid weevil, *Patialus tecomella* which causes heavy defoliation problem in Rohida plantation at Jodhpur and adjacent areas is found to be infected by Metarrizium species. The tests on the pathogenicity of the fungus are being conducted in the laboratory. The life history of the pest has been studied in detail.

Protozoa

There are many records of control of forest insect outbreaks by protozoa (Wilson, 1986). Microsporadia of the genera, *Nosema* (Ishihara and Sohi, 1966), *Pleistophora* and *Vairimorpha* (Wilson, 1986) cause disease in many forest insect pests. There is ample evidence that the presence of microsporadia in insects has a depressing effect on fecundity (Thomson, 1958). Though in India no study on insect pathogenic protozoa has so far been done, the informations now available in other countries indicate that extensive studies in this group are warranted.

Nematodes

Several nematode families contain species that are parasites of insects during at least part of the nematode's development. *Steinernematid* nematodes can be easily and economically mass produced (Bedding, 1981) and are now available commercially in Canada. Laboratory tests have shown that a wide range of forest insect pests are susceptible to them (Finney and Bennet, 1984). Feasibility studies on entomopathogenic nematodes are presently underway in British Columbia and New Foundland (ESC, 1986).

Nematodes, particularly those belonging to the family Mermithidae have been reported to have a potential against many forest insects (Ahmed 1982., Chatterjee and Singh, 1965). Further research and development on

entomopathogenic nematodes is necessary and hence it should be encouraged.

CONCLUSIONS

Judging from the results which have been published, it is now possible to make an assessment of the scope and potentiality of entomopathogenic microorganisms for the biological control of forest insect pests. The following major points may be referred on which such an assessment should be based.

Selectivity

Insect viruses are generally highly selective because they show greatest potential for their utilization as being restricted to one or a few closely related host species.

Among the entomopathogenic bacteria, *Bacillus thuringiensis*, which is a broad spectrum microbial agent, has a little effect on members of other insect orders. Thus it can be effective against several lepidopterous pest and at the same time it does not affect hymenopterous and dipterous parasites and predators.

Entomogenous fungi usually have a broad host range but there are a very few cases reported where parasites have been affected by the same species that infect pest species.

Safety

There is no known case where a microbial pathogen of an insect has caused infection in the higher animals. (ESC, 1986).

Resistance

There is no evidence to indicate that natural populations of insects develop resistance to entomopathogenic microorganisms (Cameran, 1974).

Persistence

Insect viruses, when once introduced, cause an epizootic in an outbreak that will generally persist as long as the outbreak lasts. In case of *Achaea janata* the virus epizootics has been noticed to exert control throughout the season (Ahmed et al 1989).

It has been reported that the spores of bacteria (B. popillae) persist for long periods in the soil and exert continuing control of Japanese bettle (Cameran, 1974). *B. thuringiensis* usually does not persist and repeated applications are necessary.

Insect pathogenic protozoa persist and spread by transovarial transmission, so once introduced they can be expected to exert a continuing effect.

Application

All the micro-organisms can be applied by conventional equipments.

Cost

Only bacteria (Bacillus thuringiensis and *B. popilliae*) have yet been produced industrially. It is known that NPVs of many forest insects can be propagated successfully under laboratory conditions. The required propagation work is labour intensive and does not need much capital investment.

Thus it is apparent that the entomopathogenic micro-organisms are at par with chemical insecticides for controlling some forest insects. In view of the hazards involved in the uses of chemical pesticides - the acute toxicity, persistence in the environment, creation of new pest problems by upsetting the biological balance and the development of residues in the food chain - it is now evident that pathogens may become more important in the regulation of forest insect pests.

There is a need for research in order to make potential contribution in the field of biological control of forest insects. This will require the training of more insect pathologists and the provision of more research facilities. The situation regarding use of chemicals is becoming critical and the general public is becoming concerned. Applied insect pathology has a promising future.

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RODENT PESTS OF SILVI-PASTORAL SYSTEM AND THEIR MANAGEMENT IN AN ARID ENVIRONMENT

R. S. Tripathi, A.P. Jain and B.D. Rana

Introduction

Desert afforestation and pasture development programmes include silvi-pastoral practices as the most important component aimed at improving arid environment and to suppiy fuelwood, fodder, timber, etc. (Mathur, 1980). Introduction of silvi-pastoral systems however, have provided better shelter and continuous nourishment to free living rodents in arid areas, as a result, increasing their population which adversely affect the successful implementation of such desert development programmes (Jain and Tripathi, 1988,b). Such programmes are taken up either on wastelands/fallow lands/bunds/common property resources which experience little human interference. Such areas thus become an ideal place

for rodent breeding and shelter. Present communication embodies the integrated management practices to minimise the losses to various plant species of silvi-pastoral system in the arid lands.

Distribution of Rodent Pest Species

Fifteen species of rodents have been identified to cause serious damages in different silvipastoral plantations in Rajasthan viz., *Hystrix indica, Funambulus pennanti, Meriones hurrianae, Tatera indica, Gerbillus gleadowi, G.nanus, Rattus meltada, R. gleadowi, R.cutchicus, Golunda ellioti, Mus platythrix, M. cervicolour, Nesokia indica* and *Bandicota bengalensis* (Rana, 1983). The rodent pests and their association with major silvipastoral plantations are detailed in Table 1.

Table 1 Predominant rodent pests associated with major afforestation trees, shrubs and grasses in arid areas

Plantation species	Rodent species
a) Trees :	
Albizia lebbeck	*M. hurrianae* and *T. indica*
Anogeissus pendula	*H. indica, F. pennanti, R. cutchicus, M. platythrix* and *M. cervicolor.*
Prosopis cineraria	*G. gleadowi* and *M. hurrianae.*
Prosopis juliflora	*M. hurrianae, T. indica* and *N. indica.*
Parkinsonia aculeata	*M. hurrianae* and *T. indica.*
Acacia senegal	*R. cutchicus, M. cervicolor* and *H. indica.*
Azadirachta indica	*H. indica, T. indica* and *R. rattus.*
b) Shrubs :	
Ziziphus nummularia	*M. hurrianae, T. indica* and *Golunda ellioti*
Calligonum polygonoides	*G. gleadowi, M. hurrianae* and *R. gleadowi.*
c) Grasses :	
Cenchrus ciliaris	*F. pennanti, M. hurrianae, T. indica* and *M. platythrix.*
Lasiurus sindicus	*G. gleadowi, G. nanus* and *M. hurrianae.*
Panicum turgidum	*G. gleadowi* and *T. indica*
Dichanthium annulatum	*R. meltada, G. ellioti, T. indica,* and *M. platythrix.*

Some species of rodents show a clear distributional patterns in terms of various rainfall zones in arid ecosystem.

(A) *100-250 mm RAINFALL ZONE*

The important rodent species inhabiting this zone are: *G.gleadowi* and *M.hurrianae.* Tree plantations in this zone are *Prosopis juliflora, Acacia tortilis, A.senegal* and *Dichrostachys glomerata.* Likewise, chief shrubs are represented by *Calligonum polygonoides* and *Ziziphus nummularia. Lasiurus sindicus* is the important forage grass species of this zone.

(B) *250-400 mm RAINFALL ZONE*

Among trees this zone is represented by *A.tortilis, A.senegal, P.juliflora, P.cineraria, Tecomella undulata* and *Colophospermum mopane.* Important grasses are *Cenchrus ciliaris and C. setigerus.* Predominant rodent species are *M.hurrianae, Tatera indica, Nesokia indica* (Nagaur, Bharatpur and Jhunjhunu districts).

(C) 400 mm AND ABOVE RAINFALL ZONE

Main tree plantations of the zone are *Albizia lebbeck, A. nilotica, Parkinsonia aculeata, Ailanthus excelsa, Dalbergia sissoo, Cassia auriculata* and *Azadirachta indica.* Major rodent species are *M. hurrianae, T.indica, R.meltada, N.indica* and *B.bengalensis.*

Major Characteristics of Rodent Damage

(A) SANDY HABITAT

(a) Trees : There are two main kinds of damages to trees viz., (1) debarking and (2) slicining of stem and roots. Plantations of *A. lebbeck, P.cineraria, Parkinsonia aculeata* and *A.tortilis* are much susceptible to the former type of damage when rodent gnaw about half a meter above the ground resulting into significant reduction in tree growth (Jain and Tripathi, 1988a). In the process of debarking, rodents destroy the lateral branches too.

Trunks of *P.juliflora, A.tortilis, A.indica* and *D. sissoo* have been observed to be completely sliced by rodents. *N.indica* has been reported to inflict losses to a tune of 4.5 and 10.0 per cent in plantations of *A.tortilis and P. juliflora,* respectively in two months period in Nagaur district. Slicing activity results in complete death of the plant.

A.tortilis plantation in Bikaner district established for the purpose of sand dune fixation by Central Arid Zone Research Institute was devastated by rodents (Prakash, 1976). The slicing activity of rodent was also found beneath the soil surface. Similar damages have also been observed in *A.tortilis* and *P.juliflora* plantations at Gadra Road (Barmer) in western Rajasthan and in Great Run of Kuchch, respectively.

(b) Shrubs : Z.nummularia, C.polygonoides and C.auriculata are devoured by gnawing activity of rodents, which also find the fruits of these plants as an attractive source of food. Besides this, underground burrowing activities of rodents also cause severe destruction of these shrubs.

(c) Grasses: The desert rodents usually prefer grasses which are also liked by sheep and other livestock in the desert. The rodent attack starts with the sowing of the grass seeds by digging up and feeding on the sown seeds. At later stage of grass growth too the losses due to rodents are immense. Rana(1983) reported severe rodent damage in *Saccharum munja* on dunes in Shekhawati region of western Rajasthan. At the onset of monsoon, the desert rodents, mainly *M.hurrianae, G.gleadowi and T. indica* feed on germinating clumps of *C.ciliaris, C. setigerus, L.sindicus, Panicum turgidum* and *Dichanthium annulatum* pasture grasses. At one of experimental pasture lands, the gerbil population was recorded to be as high as 477/ha. Annual food requirement of this size of rodent population is about 1,040 kg/ha, whereas the total biomass production of the area was only 1210 kg/ha/year. Thus rodents left practically nothing for the livestock. The rodents are very versatile in their feeding habits i.e. they feed on grass seeds in winter, rhizomes in summer and leaves, stems and flowers, etc in monsoon season.

(B) ROCKY HABITAT

Hystrix indica, Rattus cutchicus and Mus cervicolor are the predominant rodents of the rocky habitats. Later two species have been observed to destroy the inflorescence of *Euphorbia caducifolia and Capparis decidua.* Saplings of *A.senegal, Anogeissus pendula, Commiphora wightii and Salvadora oleoides* are also damaged by these rock dwelling rodents. Some of the grass species viz. *Eleusine compressa, Aristida funiculata, Barleria acanthoides and Lepidagathis trinervis,* which are unpalatable to the livestock have also been observed to be partially damaged by rodents (Rana, 1983).

(C) FOREST NURSERIES

The squirrels, *Funambulus pennanti* is one of the most destructive rodent pests in nurseries. Besides these, *H. indica, T.indica and M.hurrianae* are also serious pests in these sites. These rodents eat away the sown seeds and young seedlings of almost all the forestry species.

The Management Practices

Rodent management, as a rule should be a pre-requisite for the successful development of silvi-pastoral system in high risk areas such as Rajasthan. The active as well as freshly opened rodent burrows should be checked and prebaiting (one kg bajra grain and 30 g groundnut/sesame oil) is suggested for two days only. On the fifth day, 2.0 per cent zinc phosphide should be added to the bait (i.e. 1 kg bajra + 20 g vegetable oil + 20 g zinc phosphide) and rolled deep into the active burrows at the rate of 6.0 g per burrow. After 8-10 days of operation, Bromadiolone (0.005 per cent) ready to use loose bait or wax cakes should be rolled deep in the freshly opened burrows for managing the residual population of rodents. In certain desert afforested rocky terrains, where it is difficult to approach the burrow openings, the scattering bait technique with utmost care may be adopted. The management operations are suggested to be carried out twice a year i.e. (a)in May-June and (b) in November- December.

In the forest nurseries the zinc phosphide baiting followed by Bromadiolone baiting or aluminium phosphide fumigation should be resorted to as a pre-requisite for establishment of nurseries and afterwards on a regular basis i.e. twice a year.

The reduction in their damage after management operation was estimated to be 92.5 per cent, after achieving 90 per cent control success. The cost benefit ratio was worked out to be 1 : 1250 which includes fuel, fodder, small timber, grass, etc. The cost of control operation was worked out as Rs. 1.90/ha (Rana and Jain, 1984).

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INNOVATION FOR THE PROMOTION OF TREE PLANTING WITH ACTIVE PARTICIPATION OF PEOPLE IN URBAN AREAS OF ARID ZONE

A.R. Bapat

Social Forestry was introduced in our country in 1979 which has now assumed focal position in the Forestry. The message of raising silvan stands for the amelioration of climatic conditions, and for the produces of daily utility has been reached to masses through various audio-visual media. In general there is growing awareness about forests and forestry amongst the masses. However, there is wide gap between the message and implementation.

The tree planting activity proper seems to have remained limited amongst social workers, tree lovers, NGO's and forest administration. Active participation of masses in general in tree planting programme has

been wanting. It is necessary, therefore, to device certain mechanism to encourage and enhance the active participation of people in tree planting.

In the recent past, new concept of social forestry, viz. urban social forestry is being talked about. Active participation of urban masses in tree planting is anticipated under the banner. However, there are certain limitations faced by urban population to promote tree planting.

Tree planting in urban areas would require some open space, seedlings of choicest species, knowhow of planting; nurturing and tending techniques, profuse water, manures, fertilizers and may be some insecticides and pesticides. The availability of space to plant and water to irrigate, are the two major constraints amongst the urban dwellers. In urban areas space for tree planting along the fencing and on the strip of public land stretching between road and fencing etc. are readily available.

The availability of water for irrigation is a slightly difficult problem. This problem is further aggravated in arid zone. In arid zone, rainfall is between 100 to 350 mm annually. Not only that the rainfall is uncertain, but the distribution pattern is also uncertain. The entire precipitation may occur in few days with long intermintant dry spells. Therefore, sparing of scarce water to irrigate tree species except during rainy season is difficult proposition.

In arid zone, hot and dry climate considerably increase evapo transpiration rate. Thereby water demand of tree species to ensure survival and effective growth is quite high. The soils in arid zones of India are mostly sandy. The under ground seepage is at a rapid speed. In view of scare water resources and low rainfall, water conservation is of paramount importance. Every agricultural, pastoral, horticultural or silvicultural activity should, therefore, aim at the most efficient use of the scare input, water. To over come the situation, innovative water harvesting and recycling has been suggested for irrigating tree species in urban areas of arid zone.

There is large scale migration of rural masses to city due to natural attraction for glamourous city life. Some migrants are added to city population in search of job, business and persuite of education etc. As a result city limits are sprawling in all possible directions for housing colonies. The dwellings are consist of small, medium and high income group tenements, which are designed to accommodate small families generally of 5-6 members. They are self contained with modern amenities

such as electrification, tap water and storage and necessary sanitary fittings. The water supply scheme and disposal of sewerage are the the added problems for the civic administration. However, those have been successfully tackled by the modern building technology. Overhead tanks to store enough water are generally provided in every dwelling. Septic tanks and soak pits are designed to collect and dispose off sewerage. Every average family of five members consumes on an average 150 liters. of water every day for washing utensils, clothes bathing and to flush the latrines. The severage and waste water is finally collected into underground septic tanks and disposed off gradually through soak pits. The sludge settles at the bottom of septic tank and water is allowed to drain off through natural deep seepage or by way of evaporation. Thus nearly 150 litres per day of valuable water is the cost of modern style of living. This water can be harvested to irrigate the tree species with advantages.

The cross sectional view of standard septic tank and soak pit is enclosed herewith for ready reference.

A pipe akin to casing pipe of a tube well is fitted suitably in a corner as shown in sketch. The pipe bears small holes and tightly stretched over by the fine nylon wire mesh. The dipping end of pipe thus acts as separator and permits water into the humen of the pipe while solid impurities, sludge, remain behind. One end or simple hand pump is inserted through the top opening or separator pipe to draw out water as shown in diagram. The drawn water is collected into suitable size of bottles. The bottles have arrangement to fit stopper with a transfusion set, similar ones used for blood transfusion to patients, as shown in diagram. Bottles are then kept hanging over a suitable stand near the growing seedling in inverted position. Spilling of unhygienic, conaminated water is thus avoided. The use of bottles will also permit easy and safe handling. Through dripping nozzle, water is gradually allowed to percolate near the root zone of planted seedling.

The innovative harvesting of water will obviate the construction of soak pit in sewerage system. Thereby the construction of septic tank and sewerage system in general will also be economic.

If water is daily drawn out then it is expected that atleast 50% of consumed water can be recovered and recycled for irrigation purposes. As already stated, daily consumption of water of an average family is about 150 litres per day. Therefore, water harvest to the tune of about 75

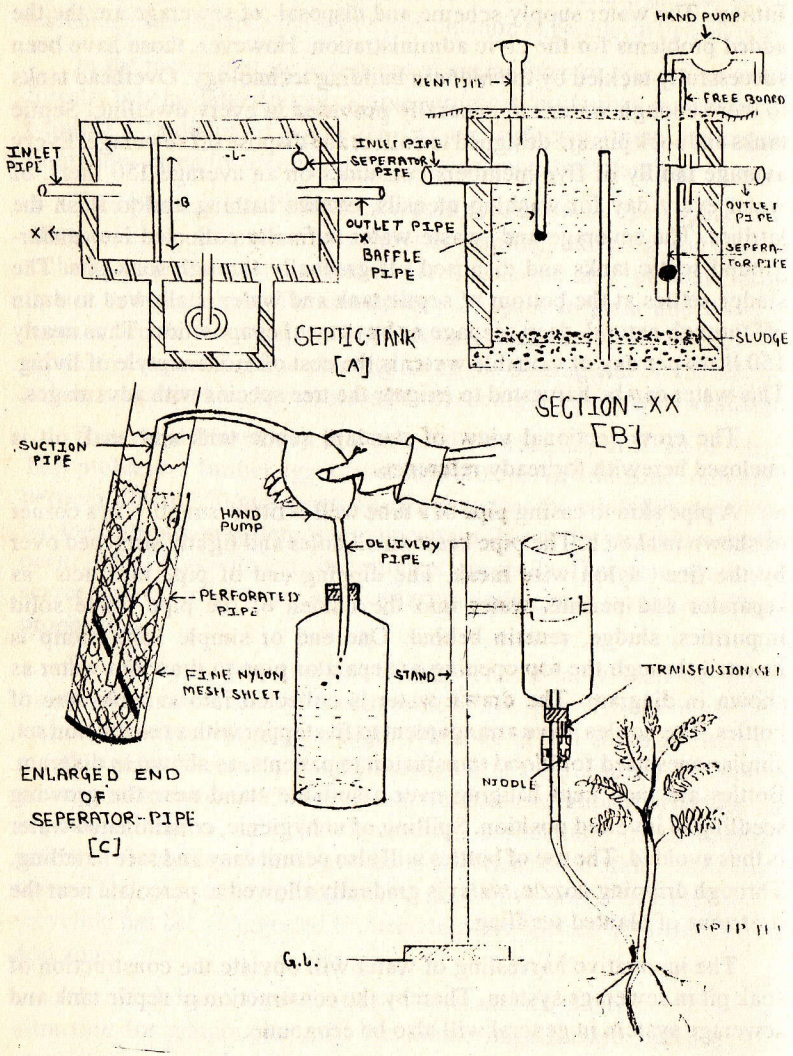

Diagram showing septic tank, soak pit and assembly of pipes & water bottle.

litres. per day can safely be considered as available. The recovered water coupled with drip system of irrigation will be enough to rear at least 20 seedlings of tree. Thus every seedling will regularly receive assured supply of 15 litres. of water after every 4 days. The water availability of the order, to nurture and tend trees in arid zone would be considered as luxury by all the standards. Therefore every urban dweller in arid zone can easily raise about 20 tree species of choice in his premises.

In arid urban zone choice of species will normally depend on three objects in view viz. amelioration of the climatic conditions, aesthetic purposes,or as a source of edible fruits or minor produce. Therefore, the choice of species would lie on species fulfilling the said objectives. The species should be local which normally can flourish well in the arid zone. The species recommended for the innovative planting are Gulmohar (*Delonix regia*), Gultura (*Poniciana elata*) Vaishakhi (*Peltoforum ferruquinium*), Siris (*Albizia lebbeck*), Sissoo (*Dalbergia sissoo*), Neem (*Azadirachta indica*), sitafal (*Anona squamosa*), Nimbu (*Citrus medica var. lemona*), Anar (*Punica granatum*), Amrud (*Psidium guava*), Sahijan (*Moringa pterygosperma*). champa (*Plameria acutifolia.*)

Every seedling would get regular supply of water, ensuring successful attempt of planting. Recycling of water coupled with drip system of irrigation would ensure conservation and most efficient utilization of scarce water resource, thereby, arid urban habitations and surroundings would be achieved with success.

Daily activity of drawing water, weeding and mulching around planted seedling, and tending operations in general, performed by dwellers will muster the active support and involvement of urban population in tree planting.

It will be thus a forward step in bridging the gap between theory & practice of water conservation, tree planting for the amelioration of climatic conditions through active participation of the real beneficiary masses

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PEOPLES PARTICIPATION IN AFFORESTATION OF ARID LAND

J. P. Chandra

The forests and the forest produce have traditionally been managed by the government. Till few years back, almost all the timber/wood required for consumption by the society came through the forest department. With the increase in population and as a result, the increasing need for more and more timber is pressing the forests to meet the timber needs of the society. It is also well known that, the forest cover in our country is decreasing at an alarming rate due to over exploitation of our forest resources. This has forced many state governments to drastically reduce or completely stop exploitation of forests. Many industries are dependent on forests and they cannot be shut-down as these are fulfilling the needs of the society by producing goods and services and are important economic links of the society.

Natural forests are no more available for harvesting. It has now become imperative that, trees be grown by people at their own initiatives

to meet the requirement of timber. Today emphasis is being given on social forestry/farm forestry activities, still, the desired results are not coming-forth. Many reasons are being attributed to this. One important factor which has surfaced is the lack of people's participation in these schemes.

Most of the people who want to practice farm forestry are doing so purely for better or improved economic returns. The farm forestry produce must fetch the producers a fair return to keep them interested in this activity. Unfortunately, due to poor infrastructural facilities available to people for the disposal of farm-forestry produce, the producers get un-economic return, which, not only desists them from practicing farm forestry but acts as a deterrent for others who want to practice farm forestry.

It has now become critical that, proper focus be given for creating a conducive marketing infrastructure to facilitate the producers in the disposal of their produce. An efficient marketing support of the produces would go a long way in making the farm forestry a self-sustaining system and would act as a great motivational factor for the people to practice farm forestry. The major spin-off benefit would be afforestation and increase in tree density in our land besides stepping-up of other economic activities indirectly.

Social forestry projects are concerned with the proper use of land, so that, the best is obtained from it. This does not necessarily mean that the land yields the highest financial return from every part of it, but, taking all interests into consideration, the greatest benefits are obtained from the land from the national point of view. The object of management of a Social forestry project should be to provide forest produce on a sustained yield basis to meet requirements of the local population. To achieve this, local people will have to be educated to organised forestry means and how minor restrictions that it will impose on them will affect them by its direct and indirect benefits.

Social forestry projects may be in scattered blocks. Some of these may be fairly near each other and for administrative purposes they can be grouped. Constitution of working units normally provides the guarantees, that is needs for the continuity of the work. The over all task of social forestry projects is generally creation of plantations for protective and aesthetic purposes and also as a source of forest produce. Hence, a good

number of tree species are included in each project, with a view to satisfy all possible forest produce needs of the locality and this makes social forestry projects much more complicated than production forestry projects. The problem starts right from nursery, where, plantable stock of many species is to be produced. While planning for nurseries, care must be taken not to disperse them to the extent that, administrative costs are increased unduly. Medium sized or large permanent nurseries may answer the purpose better than many small ones.

Social Forestry Projects are a must for our country, as, regular forest area under tree cover is already under heavy pressure. Large area in the recent past has been excised out for agriculture, irrigation, hydroelectric projects, settlement of repatriates, etc. Therefore, it is necessary to depend on planting trees outside the forest areas. On the other hand acute shortage of wood for pulp and increased demand of it has pushed up fire wood prices. This has made the tree farming a profitable business on land unsuitable for agriculture. Such degraded lands occupy vast tracts of our country and can be put under tree farming through social forestry projects. This, in turn will increase productivity and will simultaneously improve land. Success of social forestry projects depends on choosing suitable species with correct planting technique, depending on climatic and edaphic disadvantages. Assessment of productivity of these projects should be in terms of the weight of wood produced. This is because, most of the species planted on such sites do not develop a clean stem. The initial expenditure on tree cultivation on degraded land is higher than on fertile land. The economic returns are low, but, considering the fact that lands available are of low value and the social benefits of afforesting these lands are considerable, the internal rate of return of 10% to 15% can be considered to be good.

In case of social forestry projects in arid localities, the first and foremost thing is protection. This is because, for want of enough wood and fodder, local people as well as animals both understand value of tree leaf fodder and wood. People love to plant and protect tree seedlings on their private lands and if possible, will always like to collect wood or graze animals in community or government forest. Erection of barbed wire fence is a costly operation in such localities and no fence is effective for protection of vegetation. To sum up, it can be said that, apart from adverse site conditions, excessive usage of the sites have made them free from tree

growth. This brings out quite clearly that, sense of belonging is the only feeling which may help in protection of vegetation in arid zone.

Trial conducted in this respect by Rastriya Vriksha Mitra Sahyog Limited (RVMSL) have positive indications. In this trial, revenue waste land of village is allotted to Tree Growers Cooperative Society (TGCS) of the village for planting trees and to avail benefit out of them. RVMSL provides initial financial assistance and technical know-how to TGCS. All the members of TGCS, decide about tree species to be planted and arrange planting of the site. Area of such plantations ranges 10 to 40 ha, depending upon availability of land. To protect land, 1 m wide trench is prepared all around plantation. Seeds or seedlings of *Prosopis juliflora* or other drought hardy species are grown on both the sides of trench and a Watchman is engaged in each plantation. The species planted are Babul, Jungal Jalebi, Adusa, Ber, Neem, Israeli Babul, Khejri and Vilayati babul. In depressions, Shisham and Bamboo have been added.

For these plantations, villagers/society members are clearly told that, plantation belongs to them and any benefit out of the plantation can be enjoyed by them jointly, for which, they have to develop distribution system. The net outcome is, that, area of Sarwar Village of Ajmer district, which was planted only in 1989 monsoon has covered the ground almost cent per cent. The seedlings planted have not provided this coverage but on account of rigid protection, most of the stumps in the ground have sprouted and developed healthy stems with nice crown. The society plans to harvest grass from 1991 onwards with a nominal royalty for each head load removed. This area has become an excellent demonstration area and few villagers are so much impressed with growth of seedlings in this plantation that, they have started planting tree seedlings on their private land. Protection of private plantations is not effective on account of fragmented holdings, which is being reflected on growth of seedlings. Like Sarwar, community land plantations are growing well in Khatoli, Pichaulia, Bhatyani, Saradhna, Mawasia, Sergarh, Bhagwanpura and Mandhor villages of Ajmer district. Similar examples are available in Jaipur district of Rajasthan and Panchmahal district of Gujarat and only factor helping these plantations is sense of belonging. Once villagers are assured and feel that plantation being raised is only for them, they consider it as their property in future and look forward for maximum benefit they can have from it. When plantation starts yielding some revenue, it becomes more dearer and is attended more closely.

In case of farm forestry projects, farmers of arid locations understand value of a tree very well. Since in such locations they are dependent on animals more than agriculture, the first choice is to grow fodder trees. It was interesting to know that, in a village where there were good number of middle aged and old Neem trees, no one had ever seen a Neem seed. This is because, all the neem trees are regularly lopped every year hundred per cent for fodder, there by, no chance is left for flower bud formation. In case, some branch remains unlopped and bears flowers next year, birds do not permit the seed of it to mature and fall on the ground. Similarly, in Papad village of Jaipur district, a farmer was allowing his goats to browse his one year old Adusa seedlings. On inquiry, he explained that, browsing at an early age will help in future development of many branches and there by larger fodder producing surface per tree.

Grant of subsidy under farm forestry projects is not working well as almost every farmer plants seedlings for availing subsidy. Their main interest is keeping seedling alive for 3 years. Under the crown of a large tree, many seedlings are planted at a close spacing. Even if they are told that container/poly bag is to be removed before planting, to save some time they do not bother to follow advice. Even if extension worker supervises pit digging at proper spacing, farmers plant one to two seedlings in between two pits. Seedlings planted on bunds are never attended or provided any input and domestic animals are allowed to graze them. Some farmers carry out weedings/soil working but, only to impress visitors/teams involved in evaluation. In such cases farmers have no interest in tree species and they will plant any thing given to them. To avail subsidy a minimum number of seedlings are to be planted, irrespective of land available and resources/interest of the farmer. Such planting is not expected to produce any raw material.

On account of intensive extension education work carried out in the field of agriculture, by now, farmers understand role of quality seed/planting material and inputs in crop production. Advantage of this feeling can be availed in extension education work of forestry. To do so, quality planting material will be needed. To start with, production of such material may be limited to grow on demonstration area. Once proper demonstrations are established, seeing them farmers will ask for planting material capable to produce trees similar to the demonstration. This will generate object of planting seedlings and there by proper look after of seedlings planted in farm forestry.

Any material distributed free of cost does not so much attract the farmers, and even if there is large scale mortality, it is not taken seriously, as, again seedlings can be had free of cost. The material which is to be distributed free is not looked for quality by nursery workers as well as farmers. The another thinking is to have maximum and then to find out space for them. One example of such feeling is a farmer of Nilgiri who planted 18,500 blue gum seedlings during 3 years time in 3.5 acres land, because, seedlings were being distributed free of cost by a pulp mill in the locality. The net out come of that planting was that, even after 6 years age, aerial biomass produced was not marketable for pulp wood or fuel wood. Thus, farmer lost his normal income from agriculture for 6 years and no one in that village and near by villages was willing to take up blue gum plantation on his agricultural fields.

To make farmers conscious of quality seedlings/planting material and to create their interest in look after of trees, assured market and forecasting of price per tree/per unit weight of wood is necessary. Once price of end product is known, farmer can always do back calculations and will not mind even to pay premium price of planting material/seedling. Planting of poplars by M/S WIMCO LTD. and M/S Green Gold Tree Farmers (P) Ltd in Uttar Pradesh, Haryana and Punjab is living example of such working.

Last but, not the least is the man power involved in forestry extension education work. Let us compare it with man power in agricultural extension education activity. Regarding man power, another important item is calibre of man power involved. Before, farmer accepts an extension educator/worker as his friend, philosopher and guide, he tests him time and again to find out his capability. Hence, leaving farmers in the hand of few and very junior workers will not be able to motivate them to join us in tree planting activity. For a sound footing, work should be on pilot project basis which can be expanded when adequate persons have experience to deal with farmers, climatic, edaphic and social factors of locality.

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RATIONAL USE OF TIMBER AND ITS ROLE FOR CONSERVING THE FORESTS

M.S. Rajawat

Introduction

The timber resources are quite meagre in the country and the situation is still worse in the arid and semi arid areas of Rajasthan, Gujarat, Haryana and Punjab and therefore, whatever timber is available, needs proper attention and care so as to avoid its wastage. The wastage could be as high as 50% beginning from the logging stage itself till it is processed for end use (Anon, 1977). If proper care is taken, the available volume of timber could be stretched to meet the demand of about twice the population to which it is serving at present. Since there is an acute shortage of timber, it is no exaggeration to say that a tree saved is equal to a tree grown (Marra, 1984). It implies that if proper care is taken to avoid wastage of timber, it will help a lot to conserve our forest cover.

The main points at which care has to be exercised are :

1. Adoption of improved logging technology.
2. Proper storage of logs.
3. Supply of seasoned and preservative treated timber to the end users as per their product requirements.
4. Utilisation of non conventional species of timber.
5. Use of composite wood and modified wood.
6. Creation of training facilities.
7. Publicity and co-ordination on timber saving devices.
8. Research and development.

1. ADOPTION OF IMPROVED LOGGING TECHNOLOGY

The logging operation should be carried out in the presence of trained personnel only. Supervision by officers of forest department is necessary. Use of cross cut saws and bow saws should be implemented in place of axe to avoid wastage of wood. Since community forestry programmes are being popularised, it is all the more important that training is also given on logging to persons connected with agro-forestry, forestry personnels of village panchayats, tribal people and other forest owners (Anon, 1987).

2. PROPER STORAGE OF LOGS

After conversion, the logs should be protected against end splitting, decay, fungi, borers and termites at the sites and in depot (Findlay 1984). These could be treated by compositions like creosote, bitumen, fuel-oil, pentachlorophenol, dieldrin, copper resinate or Ascu: IS: 9104-1973 and IS: 1141-1973 gives guidelines in this respect. It must be seen that the logs are supplied to the end users at the earliest to avoid wastage of timber due to decay, etc (Padmanabhan et al, 1986).

3. SUPPLY OF SEASONED AND PRESERVATIVE TREATED TIMBER TO THE END USERS AS PER THEIR PRODUCT REQUIREMENTS

Forest Departments and Forest Corporations should supply timber to the user agencies after seasoning and preservative treatments (Anon, 1982). This would check lot of wastage and increase the durability of product for the end users. The distribution and marketing system should be modified so as to have effective check to ensure that each species of wood is utilised for which it is most suited. The user agencies could be supplied the appropriate sizes of the timbers only according to the product which they manufacture.

4. UTILISATION OF NON-CONVENTIONAL SPECIES OF TIMBERS

Since properties of several indigenous species of timber have been determined and quite a large number have been found to posses equivalent properties to that of the conventional species, the use of such species should be encouraged in place of commonly used ones like teak, shisham, deodar and sal. The durability of such secondary species could further be enhanced by seasoning and preservative techniques. Since these days timber is also being imported, properties of such timber should be determined in collaboration with Bureau of Indian Standards etc. and used rationally (Chaturvedi, 1990).

5. USE OF COMPOSITE WOOD AND MODIFIED WOOD

Wood based panel products like plywood, particle board and hardboard may be used in place of solid wood as per requirements (Rajawat et al, 1990). Similarly, use of compressed wood, compreg, laminated wood and woodmetal composites, etc. would increase the life span of articles prepared by them. Bamboo-veneer mat prepared from PF resin has got high durability. It may be used for making furniture items and huts. Small dimensioned and short length timber pieces too should be utilised for construction purposes. These may also be utilized for making black boards and sandwich constructions (Jain et al, 1990). Finger jointing technique may be used for such species which generally suffer from warping during sawing and seasoning (Pruthi et al, 1990). wooden packing cases may be substituted by corrugated fiberboard boxes (Nayer, 1990).

6. CREATION OF TRAINING FACILITIES

Training facilities should be created for efficient utilisation of timbers for architects, engineers and builders. Standard design codes should be developed and made to be adopted by builder agencies through Bureau of Indian Standard. Training facilities should also be created for artisans, craftsman and carpenters, so that they may learn use of modern tools and adopt modern techniques to avoid wastage of timber.

7. PUBLICITY AND CO-ORDINATION.

Publicity should be given to avoid wastage of timber and for its rational utilisation. Rural people may be encouraged to use solar cooker, improved chulhas and gobar gas plants to save fuel wood. Furniture items made from plastics, metals and wood-metal composites, etc should be used in place of wooden furniture. Village and tribal people may be demonstrated that huts made from preservative treated bamboo and wooden-poles have 3 to 4 times more durability than the untreated ones (Kumar et al, 1989). Co-ordination amongst Industries, Bureau of Indian Standards, Research Institutes and Forest Departments should be established to avoid timber wastage. Consultancy services would also help a lot in this respect.

8. RESEARCH AND DEVELOPMENT/TRANSFER OF TECHNOLOGY

Research and development should be carried out on wood quality evaluation and upgrading of agroforestry and plantation grown wood species of arid and semi arid areas. Data on testing should be made available on *A. nilotica, P. cineraria, P. juliflora, A. tortilis, T. undulata, A. indica, L. coromandelica, B. serrata, A. lebbeck*, etc of these regions through scientific processing for structural use. Results of such studies would be much useful in rational utilisation of timber for rural housing, farm needs and wood based industries. Testing facilities should be enhanced for P.W.D., Housing Boards, Railways, Defence needs and Public in general for testing the wood based materials as per the standard specifications.

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REQUIREMENT OF SMALL FARMERS FOR PLANTING MULTIPURPOSE TREE SPECIES IN ARAVALLI REGION

U.M. Lodha and B. Mc Gean

Introduction

The terrain of Aravalli region in Udaipur district is mountainous and submountainous. The soils are gravelly and loam with very meagre soil depth. The region has been inhabited mostly by Bhil tribals for centuries, and their holdings are small and fragmented, on average 1-2 ha. The mean annual rainfall is 624 mm and drought conditions are frequent. The total land under cultivation is about 18 per cent, and irrigation sources are mostly wells with small water columns and some tanks. The total irrigated area is about 28 per cent of the area under cultivation. About 50 per cent of the area was under good forest about 50 years ago. However, now it is hardly 2.8 per cent according to satellite data. This forest cover must be restored. It is, therefore, necessary to identify multipurpose tree species

which can also meet the requirements of the small farmers inhabiting this region and will also contribute to ecological rehabilitation.

Farmers' requirements from forests

The tribal agriculturists, once fulfilled most of their own subsistence needs from these mixed deciduous forests. They also sold fuel and timber wood in exchange for cloth. Due to indiscriminate deforestation over the recent past decades, they are now deprived of these natural resource assets. Their plight is very much visible. Even to satisfy their own fuel requirements, they are burning the cowdung so vital otherwise for the fertility of agricultural fields. Nor there is enough fodder for their cattle, goats, etc and their own requirements for building and repairing huts with timber are not met. Due to forest degradation, the soil is badly eroded and bedrock and stones are exposed.

The farmers' basic needs include fuel, fodder and timber. Soil fertility status must also be improved and maintained. While drawing up a plan and choosing species for replanting this area, it is necessary to carefully study their suitability to the agroclimatic conditions, as well as their multi-purpose utility, soil fertility status and response to drastic or wild pruning/lopping.

Policy know-how

It is necessary to motivate the farmer in tree planting while giving priority to multipurpose tree species. Also, the leguminous species, both trees and shrubs, should be encouraged to improve soil fertility.

It is desired that village communities enter into cooperative partnerships in the process of afforestation on degraded forest lands. In the department-owned areas where village communities undertake protection and planting, the flow of benefits should acrue to villagers and a percentage of timber harvest should be given to the villagers when the trees mature. These joint forest management partnerships are currently underway in 6 states and are proving quite promising. The N.G. O's functioning in rural areas with a programme for afforestation should play a strong role as motivators. Village communities should be involved both in protection of existing forests and in regenerating forests.

All mining operations in the forest areas should be restricted. Mining agencies should be required to rehabilitate the destruction caused during

mining, and should give adequate compensation and ensure prompt payments.

In primary and middle schools, knowledge about environmental utility of forests, ecology, afforestation and negative effects of forest destruction will also be helpful.

Because the tribal farmers are very poor, and the opportunity costs of developing their wastelands are high, we have built in a monetary incentive to motivate their involvement i.e. payment of labour in pit digging and maintenance, as well as annual survival subsidies. Also, the village communities should be conscientized about destruction from free grazing of their cattle and goats.

Inputs

Seva Mandir and other N.G.Os have been working on large scale in wasteland development for the last 5 years. On the basis of our experiences, the following inputs are needed :

(i) Saplings of trees with multi-purpose character and of villager's choice to be made available to the planters.

(ii) Training to the farmers in land preparing, planting techniques, after care such as weeding, soil and moisture conservation measures, nursery raising, etc.

(iii) A hedge of vegetation or stone wall, whichever is feasible for strict protection and enclosure.

On the basis of experience, it was revealed that the following species are acceptable to the farmers in Aravalli region :

(i) Runjia (*Acacia leucophloea*)
   (a) Leguminous - nitrogen fixation
   (b) Quick growing and good growth quality in areas with negligible soil depth.
   (c) Drought resistant.

(ii) Ber (*Ziziphus jujuba*)
   (a) Response to drastic pruning, yields sufficient fuel and plant comes up again to its same height within a year.
   (b) Leaves are nutritious fodder for cattle.

(c) It yields edible fruits.

(d) Deep tap root system; once established, it does not vanish.

(e) Drought resistant.

(iii) Dhak (*Butea monosperma*)

(a) Leguminous species, nitrogen fixation.

(b) Leaves used for making leaf plate and leaf cup as income generation.

(c) Remains green during hot pre-summer, providing shade and tempering climate.

(iv) Mahuwa (*Madhuca indica*)

(a) Seeds used for cooking oil.

(b) Provides shade during summer.

(c) Flowers are used for local alcohol and for food.

(d) Species long-lived, about 100 years.

(v) Mesquite (*Prosopis juliflora*)

(a) Response to drastic pruning, yields enough fuel wood and plant comes up again within a year.

(b) Leguminous - nitrogen fixation.

(c) Can be a good hedge in the forest.

(d) Can grow where no other species thrives.

(vi) Bans (*Dendrocalamus strictus*)

(a) Used in hutments to provide roof.

(b) Raw-material for paper industry.

(c) Basket making.

(vii) Subabool (*Leucaena leucocephala*)

(a) It is leguminous - nitrogen fixation.

(b) Quick growing.

(c) Leaves very rich in protein, used as fodder by mixing with other fodders.

(d) Response to pruning.

(viii) Babool (*Acacia nilotica*)

(a) Good timber wood in Aravalli. Suitable for furniture and agricultural implements.

(b) Leguminous.

(c) Pruned material during winter yields some fire wood and leaves are edible by sheep and goat.

(ix) Kala siris (*Albizia lebbeck*)

(a) Leguminous

(b) Fodder

(c) Quick growing

(d) Timber wood

The saplings of aforesaid species are needed by farmers for planting. Some of them will naturally regenerate if left protected from grazing pressure (i.e. ; *Acacia* sp., Dhak, Ber, Khejri). Technical know-how regarding planting needs to be imparted to the farmer. Names of some of species which provide fruits and other useful products are given in Table 1.

Table 1 The species of plantation importance in aravalli region.

Name	
Diospyros melanoxylon	(Tendu)
Melia azedarach	(Bakayan Limbdi)
Boswellia serrata	(Salar)
Holoptelia integrifolia	(Churel)
Terminalia chebula	(Harra)
Terminalia belerica	(Bahera)
Tamarindus indica	(Imli)
Annona squasmosa	(Sita phal)
Madhuca indica	(mahua)
Syzygium cumini	(jamun)
Mangifera indica	(Mango)
Azadirachta indica	(Neem)
Wrightia tomentosa	(Khirni)
Acacia nilotica	(kikar)

Pongamia pinnata (Karanj)

Field Problems

(i) Protection from stray cattle and other livestock is necessary. In order to provide protection to the newly planted saplings enclosures preventing stray cattle and other livestock are critical.

(ii) Some elements may still destroy the regenerating forests for their own benefit. Hence, it is imperative to obtain full community cooperation, and often useful to enlist a night patrol for protection in early years.

(iii) For some of the improved techniques like soil/moisture conservation measures the farmers are somewhat reluctant. This is due to the labour required initially while benefits are only visible over time.

(iv) Forest policy of users' rights on classified protected and reserved forest is still not clear to the farmers. This has to be further elucidated by the government so that NGOs can help and motivate the communities to assist in protection and regeneration on these lands in cooperation with Forest Department.

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FUEL WOOD CRISIS IN ARID AND SEMI ARID AREAS

Vinod Kumar

Energy plays a vital role in human development and welfare, as all important economic activities of the present civilisation are dependent on the availability and level of consumption of energy. Energy is an important parameter in the over all economic activity of any country. It has become synonymous with progress in all fields of activities. The more important, it is an essential input to all production activity. The process of economic development demands increasingly higher level of energy consumption. The per capita commercial energy consumption in India is only a tenth of the global average. The per capita power consumption in India was only 178 kwh in 1987-88 compared to 9857 kwh in the United Kingdom. The per capita power consumption in 1987-88 ranged from just 13 kwh in Manipur to 484 kwh in Delhi.

The bulk of commercial energy consumption is in the industry and transport sectors, while the domestic and the agricultural sectors continue to rely mostly on the so called non-commercial fuels. Coal, oil, and electricity constitute commercial or non- renewable sources of energy, while fuelwood, agricultural waste & animal dung constitute non-commercial or renewable sources of energy and continue to contribute a substantial proportion of the total energy consumed in the country. Out of a total energy consumption of 492.3 million tonnes of coal replacement (MTCR) in the country, 60 percent comes from commercial sources while 40% from non commercial sources. The share of non-commercial energy was just 13.9% in 1953-54. The position of commercial and non- commercial fuels in rural and urban areas given in Table 1.

India has 75 million ha recorded forest area. The rapid depletion of forests as also the loss of forest areas has led to serious problems of erosion, flood, siltation and desertification etc. Out of a total of about 3.3 million km^2 land area in the country, around 1.4 million km^2 are subject to soil erosion while an additional area of about 0.27 million km^2 is being degraded by floods salinity and alkalinity.

In many parts of the country, particularly in the arid and semi arid regions, large tracts of land mainly of low or marginal productivity exists without clearly defined ownership and organised management. The management of these lands is based on customs but their primary use is grazing. Vegetation on these lands is either in the form of scattered trees, xerophytic bushes or shrubs. Apart from forage, these lands, also provide considerable quantities of fuel wood to the people in rural areas and adjoining urban centres in view of the high pressure exerted on these lands, the management of fuel wood resources of these lands is both difficult and complex. If however, managed scientifically, these lands possess a tremendous potential for fuel wood production provided such lands are made available for raising fuel wood plantation.

Demand For Fuel Wood

The important factors that effect the calculations for demand are :-

(1) A large quantity of fuel wood is collected from the forest by the local population as a matter of right and does not find any record any where.

Table 1. Source-wise energy consumption in household sector

	Energy	Rural per capita energy consumption				Urban per capita energy consumption			
		% share of energy forms.	% share of source of supply of each form			% share of energy forms	% share of source of supply of each form		
				Home grown			Purchased	Home collected	grown
1.	Electricity	0.6	100.0	0.0	0.0	5.9	97.0	3.0	0.0
2.	Oil products	16.9	100.0	0.0	0.0	30.2	100.0	0.0	0.0
3.	Coal products	2.3	65.1	34.9	0.0	13.7	95.6	4.4	0.0
4.	Fire wood	68.5	12.7	64.2	23.1	45.5	73.7	14.8	11.5
5.	Animal dung	8.3	5.1	26.2	68.7	3.2	49.1	12.3	38.6
6.	Other	3.4	8.9	61.0	30.1	1.5	71.2	28.8	0.0
7.	Share of commercial fuels	20%				49%			
8.	Share of non commercial fuels.	80%				51%			

(2) Most of the fuelwood is used in the rural sector near the centre of production and is collected mainly from the forest nearest to the villages. The people go to distant forests only when no fuel wood is available nearby and

(3) The pilferage from nearby forests meet a large part of their fuelwood requirement.

There is no likelihood of change in the pattern of consumption of fuelwood in rural areas. The demand for fuelwood for Gujarat and Rajasthan is given in Table 2.

Table 2 Fuel damand in Rajasthan and Gujarat

State	Population in millions	Forest area million ha	Annual production million m^3	Fuel wood requirement m^3	Deficit million m^3
Gujarat	32.6	1.70	0.18	8.0	7.82
Rajasthan	3.3	3.59	0.23	1.0	0.77

The fuelwood for cooking and heating are in a deficit situation and local people could meet their needs by depleting wood reserves. The situation is worsening rapidly.

Creation of new fuelwood resources

Except for financial constraints establishment of fuelwood plantations does not present any serious technological problems. Since the objective would be to produce energy rather than industrial wood species, selection assumes greater significance. Tree species yielding greater biomass of high calorific values, fast growing and able to coppice are considered best suited for fuelwood production. The problem of man-made fuelwood resources are largely economic and also involve questions of competition for land use for fuelwood vis-a-vis food and fibre crops. Distance and accessibility of fuelwood resources are critical factors when considering the choice of suitable sites for fuelwood plantations since the produce is bulky in relation to its energy out put. The costs of transformation of the product must be kept at the minimum possible level.

Economic considerations and land scarcity suggest that optimum benefits could result from cultural practices when fuelwood is not the

primary but a secondary byproduct from the point of view of investment. For example, there are economic advantages in combining fuelwood with industrial wood or agricultural crop production so that some investment on input costs are absorbed by the primary product. In view of the above, all possible community wastelands, Panchayat lands, roadsides, canal sides, railway sides etc., need be appropriately used for growing fuelwood trees.

A strategy for action

Forests have an important role to play in human development. For the moment however, the issue of energy for subsistence has priority because the current fuelwood problem is acute. The problem of fuelwood must be solved within the context of rural development. FAO'S forestry department has identified five major tactics in the battle against fuelwood deficits. In most field programmes, these tactics should be combined to produce an action plan operating on several different forests simultaneously. The tactics are :

1. Increasing the productivity of existing resources :- Putting the existing woods and forests under management, particularly by local population can increase productivity by as much as 50 percent. Resting over worked areas can also be very beneficial and bring all existing biomass including non-forest areas, shrubs, bushes and what is normally regarded as 'waste' can increase fuelwood supply substantially.

2. Creating new fuel wood resources :- Planting stands of fast growing trees present no serious technological problem. In many areas new plantation can start to yield fuelwood within a few years. The cost may appear high. If 2-5% of available land with the farmers is planted with trees there need be no net loss of agricultural production, indeed, in same areas, tree planting actually increases food production. The species suitable for arid zone and their average rate of growth are given in Table 3.

3. Improving fuelwood distribution:- A key factor in the price of fuelwood and charcoal is the distance over which it must be transported to the user. FAO studies indicate that fuel wood can not be transported economically over distances of more than 100 km.

4. Improving conversion technologies :- There are three possible ways of improving the efficiency with which fuelwood or charcoal are

Table 3. Fuel wood species suitable for arid zone

Spicees name	Adapted to rainfall range (mm/year)	Altitude range	Yield of wood (m^3/ha/yr)	Average wood weight (kg/m^3)	Average calorific value (k cal/kg)
Acacia nilotica	400–1500	0–500	3–8	760	4950
Acacia tortilis	100–1000	0–900	4–7	700	4400
Azadirachta indica	300–1150	0–1830	n/a	650	4800
Prosopis cineraria	75–850	50–800	1–4	770	5000
Prosopis juliflora	150–750	0–1500	2.5–5.0	1200	n/a
Salvadora oleoides	180–1000	0–900	n/a	730	n/a
Ziziphus mauritiana	125–2250	0–1500	n/a	650	4878

used & made; pre-processing the fuel, by pressing it into bundles, for example, increasing the efficiency of charcoal production (traditional methods waste upto 60 percent of the energy value of the wood), & large scale dissemination of efficient wood stores, combined with efforts to improve cooking efficiency. An efficient wood stove can produce fuel saving of 30% or more at a small cost. In some cases, changes in cooking habits can also produce similar savings.

5. *Finding substitutes for fuel wood :-* The impact of substitution over the next two decades is likely to be limited but biogas and solar energy can usually make some contribution. Fossil fuels may have to be used, regardless of the cost in areas where appropriate forestry solutions can not be implemented in time to avert a disastrous fuelwood shortage.

Over the next few years, the supply of rural fuelwood will become increasingly commercialised and the concept of firewood as a free good will disappear.

Sale of fuelwood offers an important source of income for the rural poor and in India studies have shown that it is usually the poorest, the landless and the jobless who depends on selling firewood. Many of those who have to travel long distances to collect fuelwood do, not only to provide fuel for the home but also to provide a modest cash income as well. The danger is that the urban centres with their huge appetites for fuel and their ability to offer cash for payment, will ultimately deprive the rural dweller of the trees on which he depends for his own energy.

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TECHNO-ECONOMICS OF MECHANISED POST HOLE DIGGER FOR ENERGY PLANTATION

V. K. Vijay, N.S. Rathore and A.N. Mathur

Introduction

Increasing population and deforestation trend throughout the world is disturbing the ecological balance on earth. In most of the developing countries, population growth is creating the food and shelter problem. Forest are being cut for livelihood. Manyfold expansion of cities & villages caused loss of trees and forests. In this regard, it becomes essential to develop more forest and trees on wastelands to check the environmental degradation. The scientists suggest that the environmental degradation can be checked by vigorous plantation on all the available wasteland and developing thick forests. Successful plantation at any site requires hard practices and measures. Most of the practices are done manually and are

time consuming. To reduce time in soil preparation, nursery practices, harvesting, storage and processing mechanisation is essential.

Conventional mechanisation practices for soil preparation and cultivation, used in agriculture are different from the practices used in energy plantation. In crop production practices, whole field is worked for cropping, instead in energy plantation only holes are dug for putting up plants.

A mechanised post hole digger may play an important role in digging the pit for plantation. It can expedite the work many times. It can easily dig a pit of any dimension required for plantation in hard soil, hillock and other wasteland sites. The Renewable Energy Centre, College of Technology and Agricultural Engineering, Udaipur, has designed and developed a tractor operated post hole digger for digging the pit for energy plantation. The digger was tested in different agroclimatic regions and on different soils to adjudge its suitability. The salient features of post hole digger and its testing alongwith economics in comparison with manual operation are included here.

Post Hole Digger

The Renewable Energy Centre, Udaipur, has developed a tractor PTO shaft operated three point linked post hole digger for digging pits for plantation. The working part of digger is centre punch, which in fact initiates the dig, is formed by weld fill in the shape of drill bit. The cutter blades adjacent to centre punch, extend the activities of digging. These blades are connected with auger body with the help of nuts and bolts. The cutter blade and centre punch get motion from tractor PTO through a gear box mechanism.

Working Performance of Digger :

The post hole digger was operated to dig holes in various soil profiles. More than two hundred holes have been made in class-IV, V and VI lands. The results of the trial runs are presented in Table 1.

Table 1 Adaptive trial runs on post hole digger

Class of land	Av. duration of each (min)	No. of holes dug (Av.)	Av. dimension of dug (mm)		Variation in dug hole dimensions (in height)	Diesel consumption in lit per m^3 of earth work
Class–IV having watering facilities	60	65	390	x470 ht	+ 10 %	0.699
Class–IV with no watering facilities	60	62	390	x470 ht	+ 10 %	0.7032
Class V land	30	17	390	x670 ht	+ 10 %	0.954
Class V with watering facilities	30	10	390	x670 ht	+ 5%	0.966
Class VI land without watering	30	28	390	x480 ht	+ 10 %	1.008

It was observed that diesel consumption per unit of earth work done works out to be ranging from 0.699 to 1.866 lit/m^3 depending upon the soil conditions of the plantation site. The maximum diesel requirement was in class-VI land where no water facilities were available.

Economics of Post Hole Digger

Mechanical digging through post hole digger and manual digging have been evaluated for their economics and presented in Table 2. The processes are compared on identical base in similar soil conditions, with average sixty holes of 390 x 460 mm ht. It was observed that one unskilled labour can dig 20 holes per day, where as tractor driven post hole digger with one operator can dug about 480 holes per day considering eight hours

of operations. Therefore, it was calculated that cost of mechanised digging is about two third of the cost of manual digging.

Table 2 Economics of post hole digger

S. No.	Particulars	
i)	Cost of digger	Rs. 10,000
ii)	Cost of diesel	Rs. 4.20 per lit
iii)	The hourly cost of tractor operation excluding fuel consumption.	Rs. 30/ hour
iv)	Requirement of earth work per 100 holes for average hole size as 300 mm x 450 mm ht	31.5 m^3
v)	Diesel consumption per m^3	0.7 lit per m^3
vi)	Diesel consumption per 1000 holes	22.05 lit
vii)	Total cost for digging 480 holes/day	53.69 rupees
viii)	Cost of digging by mechanised systems	53 paise per hole
ix)	Cost of manual digging considering 20 holes per day	75 paise per hole

Conclusions

Energy plantation is a universal source for fuel and wood. However, conventional practices involved in this field may be inadequate. The post hole digger used for preparation of dig can play an important role in energy plantation programme. This mechanical system operated through tractor is economical as compared to manual digging. But still existing design has number of limitations in construction and operation. Thus there is an urgent need to overcome all limitation in existing design and standardize a perfect design of post hole digger.

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REGENERATION OF DEGRADED COMMON PROPERTY LAND RESOURCES IN RAJASTHAN

G. S. Nathawat and Laxmi Thakur

Introduction

The common property resources (CPR) are overused or abused all over the globe. It is more pronounced in developing countries with high population growth rates such as India. The 2/3 of Rajasthan state has desertic conditions with fragile ecosystem. The ever increasing human and livestock populations are putting higher demands on the CPR in this region. The 'commons' with free access are fast degrading in their biotic potential. The traditional balance between the resources and the populations is lost. In the past, each and every desert settlement had well guarded water storage and catchment area the 'Paithan', good pasture land the 'Gochar', and natural wood land 'Oran'. The 'Orans' or 'Dev vans' were

designated to honour village diety or saint and are preserved meticulously on socio-religious grounds. It is like a bioreserve for the village.

Sporadic attempts are made to regenerate some of the CPR through social forestry programmes. Social forestry on 150 ha of 'Gochar' land at Dahmi Kalan is discussed in this paper. Management of CPR at micro-level with people's participation is a necessary element of ecologically sustainable development. The Common Property Resources (CPR) are the resources used by the whole village community without any exclusive property or access right to any individual member. Thus, they belong to every body for usage but to none for their protection and maintenance. On the contrary people over-use and abuse CPR in order to maximise private gains. This over-exploitation is responsible for their shrinkage and quality degradation.

Abel and Blaikie (1988) feel that common property may be regarded as private property under the ownership of a group of people and can be distinguished on the basis of following three characteristics :–

1. That it is subjected to individual use but not in individuals' possession.
2. That it has a number of users with independent rights of use which implies that a common ceases to be common if any user or an institution gains control of the use made by others.
3. That users constitute a collectivity and together home rights to exclude others who are not members of that collectivity.

If we look at the past settlement patterns in the arid regions of Rajasthan; we find that every village had agglomeration of houses for mutual protection in compact units. Each village had earmarked low lying water catchment areas as 'Paithan' (Figure 1). Good grassland areas were earmarked as 'Gochar' or village 'Pasture land' (Figure 2). Small wood lands were left to honour village diety or saint prophet, these were called 'Orans' or 'Devvans' (Figure 3). All the above named three areas come under the common property resources of the village. The remaining land was allotted for agriculture and other purposes.

PAITHAN

Since the local population largely depends on rain water, the surface run-off water is stored in 'Paithan' and is meticulously guarded for

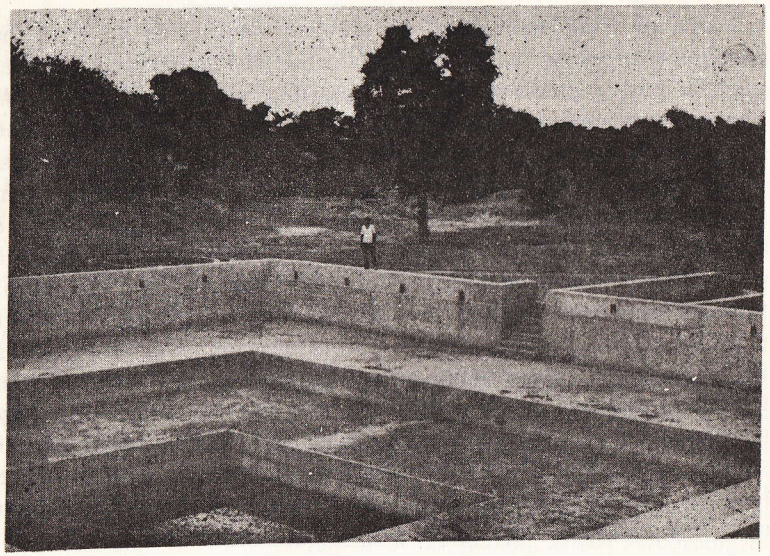

Figure 1. Water reservoir with catchment area at Norang

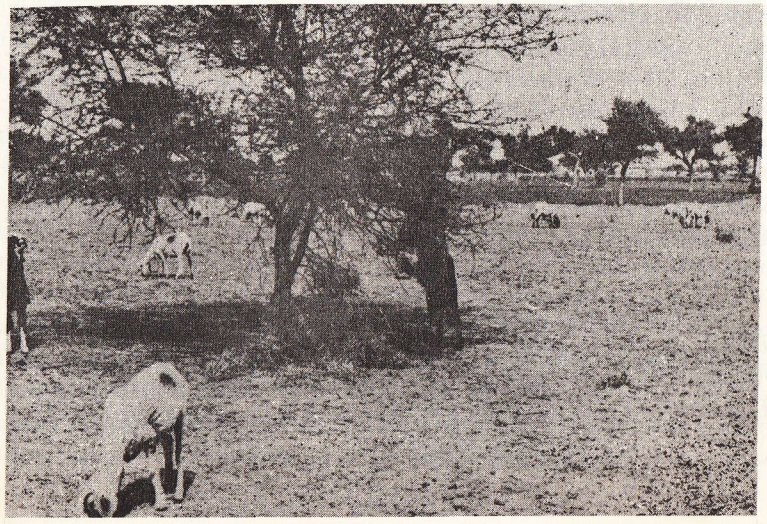

Figure 2. Overgrazed Gochar land at Didwana.

subsequent use. It was the onerous duty of individuals and the community to keep the catchment area and the storage free from contamination and to follow conservation ethos.

Our ancestors knew that the problem was not so much of the availability of water but that of its collection and conservation. Consequently, they adopted a system of maximising collection of rainwater at household and community levels and its proper use and supply. Each and every individual had a participatory role in water conservation practices. However, with the changing social system, the water management system also got disturbed. The Governmental agencies not only took over the water resources but started overexploiting them beyond the recharge potential. Mismanagement of catchment areas and neglect of traditional water storage system led to water shortage and lowering down of water table. Despite the growing shortage of drinking water the government has not adopted water conservation policy. In the garb of development the traditional methods of rainwater harvesting and storage are not only abandoned but are abused. Whereas, in the past the 'Paithan' the water storage and catchment areas were guarded and worshipped. Today these lands are allotted for house construction purposes or are reduced to filth collection centres.

ORAN

The best portion of the wood land in each and every village was earmarked as 'Oran'. There are no formal arrangements for guarding these orans. The socio-religious constraints do not allow the people to cut or defoliate the trees from these orans. They are small biospheres of the village and the propagules released from these orans help regenerate vegetation in other areas. As compared to 'Paithan' and 'Gochar' Orans are less degraded, they still maintain the original vegetation of the area. Even the dry wood or a dry plant is not removed at many places due to the fear that the diety or the saint will be displeased and may bring wrath to the village.

Due to illiteracy and backwardness superstitions still prevail in the villages. In the scientific age the persistence of superstitions is not welcomed. However, they have proved useful so far as the conservation of these 'green patches' in the arid regions of Rajasthan is concerned.

GOCHAR

Common property resources specially grazing lands have declined in area as well as in productive capacity (Figure 4). The decline of CPR is largely associated with institutional changes in the villages. The introduction of land reforms in the early 1950s led to large scale privatisation of CPR, reduced the private cost of use of CPR and slackened their upkeep by disrupting their traditional management systems. Increased commercialisation of livestock farming and certain demographic factors have played important role in the decline of CPR. Farmers seem to have adjusted to shrinking CPR by reducing their *herd* size, changing the composition of their livestocks and by relying more on private resources to rear animals. The shrinking of CPRs is largely a result of the transfer of sub-marginal lands from grazing to cropping consequently resource degradation is accelerated.

'Gochar' lands are village pasture lands and are important components of common lands. With the increase in the population of livestock in Rajasthan, there is a growing pressure on grazing lands. Although permanent pasture lands are only 5.4 per cent of the total land area of the state, the village forests, waste lands, fallow-lands and the crop lands in the post-crop season also supplement the grazing lands. According to Jodha (1982) there had been a decline in the CPR preceeding 1963-64 due to a large scale distribution of public lands to landless individuals persuing the land-reform policies of 1950s. In addition, people with political influence also took possession of some of the common lands. The shrinking CPR and increasing livestock per unit area resulted in overexploitation of vegetal cover. Not only the biomass production per unit area has declined, even the composition of the plant species has changed. The palatable plant species have disappeared and the non-palatable plant species have increased both in number as well as in density. As the rainfall is scanty and variable there is unequitable distribution of the vegetation. Some areas are rich in vegetal cover in comparison to others causing mass migration of livestock population from one end of the state to the other. Very often they even migrate to neighbouring states like Uttar Pradesh and Madhya Pradesh. During this period the pasture lands are relieved from the grazing stress. The migratory livestock returns to original pasture lands only in the months of August-September after rains and again they are subjected to heavy grazing. This is going on year after year and is more pronounced during the drought years. Although the grazing in the forest

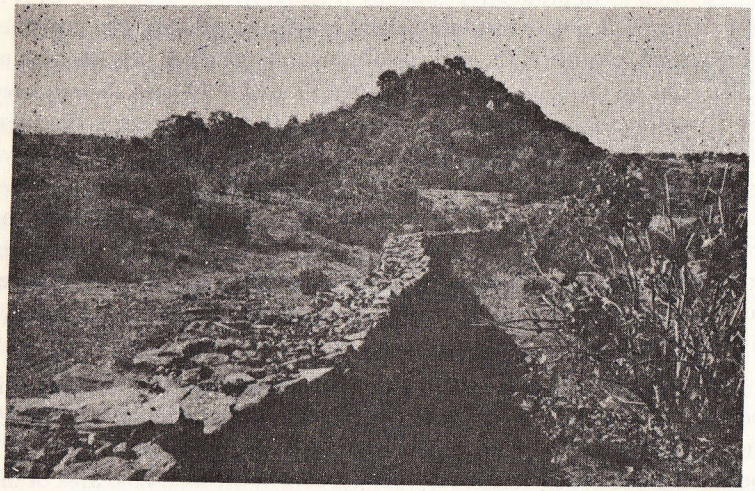

Figure 3. Oran at Syera.

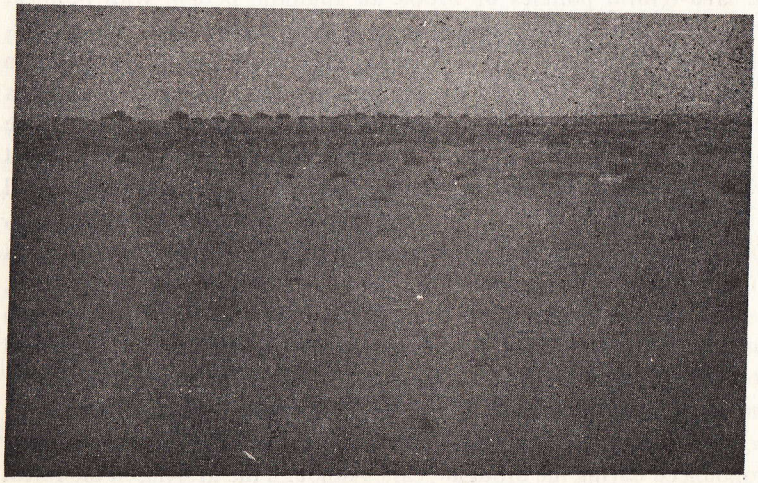

Figure 4. Denuded land-scape near Hanumangarh.

lands and fallow lands is being discouraged under the apprehension that the livestock damage the saplings coming out from the forest floor.

On the contrary, the livestock through grazing clears the weed- flora from the forest floor and the droppings further add manure to the forest land.

Some attempts have been made to restore biological potential of the Gochar lands through social forestry. A successful attempt of plantation has been made at Dahmi Kalan.

Social Forestry in 'Gochar' at Dahmi kalan Village

Dahmikalan with population 2,385 and 337 households (Census, 1981) is situated at 30 km west of Jaipur city about one km from National highway and is connected by a metalled road.

The total area of the village is 905 ha out of which 374 ha are lift irrigated (200 wells), 272 ha unirrigated fallow, 218 ha cultivable waste and 41 ha is not available for cultivation. The common pastureland (Gochar) is covering 150 ha. The livestock population of Dahmikalan in 1977 was recorded as cattle 604, buffaloes 530, sheeps 55, goats 342, camels 2, and donkeys 7.

The average ground water table is 8-10 m. About forty years ago wildlife was abundant consisting of spotted dear, blue-bulls, jackals, rabbits, etc but now only odd rabbits are seen sometimes.

The pressure of population, livestock growth and extension of agriculture in marginal lands is responsible for over- exploitation of vegetal cover, degradation of pasturelands and loss and disturbance in the breeding habitats of wildlife. The CPR have easy and unrestricted access and are prone to fast degradation and denudation. The barren pastureland was subjected to heavy soil erosion and got covered with shifting sand dunes. The entire 150 ha of Gochar land became barren with little or no vegetation.

In order to improve the natural environment, to prevent further degradation, to meet the requirement of fuel, fodder and timber of the villagers and to uplift the economic status of the Panchayat, the village panchayat had an agreement (Sept. 1985) with Forest Department, Government of Rajasthan under which the entire Gochar land was handed over to the Forest Department on lease for five years. The Forest Depart-

ment under phase- plantation programme planted 0.27 million plants belonging to 13 species (Table 1). The percentage of survival is 90% (Oliver, 1990a).

Table 1 Common/panchayat land plantation, Dahmi Kalan

Species/Common Name		Plantion year/hectares planted/ Funding Agency/quantity				Total 130 ha	% of total no. of trees planted
		1985 45ha RFWP	1988 30 ha RFWP	1987 12ha/ 23ha NPEP /RFEP	1988 20 ha NSFP		
A. Timber (T)/Fuel (Fu)/Fodder (Fo)							
Acacia tortilis (Israeli babul)	FU	58,850	19,500	32,500	–	110,850	64.64
Ailanthus excelsa (Ardu)	Fo/T	300	5,150	575	1,325	7,350	4.29
Azadirachta indica (Neem)	T/Fu	100	800	456	475	1,831	1.07
Bomboosa sp. (Bans)		–	–	–	655	665	0.39
Cassia siamia	Fu	500	–	–	–	500	0.29
Dalbergia sissoo (Shisham)	T	200	6,500	16270	18,415	41,385	24.13
Prosopis cineraria (Khejri)	Fo/Fu	2,000	–	2,000	–	4,000	2.33
Tecomella undulata (Rohida)	T	–	200	–	205	405	0.24
B. Fruit :							
Carrisa carandus (Karunja)		–	–	700	–	700	0.41
Cordia myxa (lasoda; gonda)		550	100	–	–	650	0.38
Emblica officinalis (aunla)		–	650	–	1,270	1,920	1.12
Grewia sapida (falsa)		–	–	–	575	575	0.32
Ziziphus sp. (Ber)		–	100	–	570	670	0.39
Total		62,500					

The plantation had been successful in sand stabilization, providing fuel and fodder, generating employment and providing income source to the Panchayat. However, the villagers feel that during this 5 years period they have lost about 75% of their cattle wealth for want of free access to 'Gochar'. The forest authorities agree that they did not allow the livestock to enter the plantation as the saplings were within the reach of cattle but they did allow the villagers to cut grass and carry free of charge. Secondly, they are not satisfied with some tree species which are exotic and do not provide good fodder. The handing over of the plantation back to Panchayat may not help in equitable benefits. The major share may go to the influential persons. The Dahmikalan plantation is a successful experiment. The plantation has already started giving moentary benefits to panchayat and has generated employment for the villagers. The soil erosion is also checked.

From the Dahmikalan experiment it is possible to regenerate biological potential of 'Gochars' in other villages. However, care has to be taken that the villagers should have a participatory role and only indigenous plant species from utilisation point of view should be planted.

DISCUSSION

Nearly 75 per cent of India's population live in 0.6 million villages. The population will continue to swell and the country's natural resources will continue to be depleted and degraded. Even now the majority of India's rural population depends on biomass for their survival. It includes wood for fuel and agricultural implements, fodder for livestock, fibre with

which to build houses, green mulch as fertilizer, fruits and nuts for food and a host of plants for medicinal uses. The marginal land holders, landless labourers, tribals and nomads depend so much on natural resources, that without them their very survival is threatened. Low productivity of land, degraded grazing lands and unemployment compell them to over use natural resources for survival . Consequently, the environment is further depleted and make them all the more poor. Indira Gandhi and the UN called this cycle the 'Pollution of Poverty'. Some people become 'ecological refugees' and finally migrate to the city in search of work and further increase the urban poor in the industrial and growing cities (Oliver, 1990b).

Having lived among villagers, Mahatama Gandhi foresaw that India needed to develop its villages into self sustaining communities, independent of the international and national market economics which tend to exploit villagers and deprive them of their natural resources. He said that the needs and not the greed of all could be met with a simple lifestyle.

The development has to focus on the basic needs of the low income people. It will emphasis the decision making at the grass root level using local traditional knowledge. Villagers should plan and implement development as they best see fit according to their needs.

In the past the over use or abuse of common property resources were prevented through the enforcement of number of exploitative regulations. The prevalent methods of revenue generation from CPRs were grazing tax on per unit livestock, auctioning of CPRs products, a number of levies or cesses on CPR users and penalties charged for violation of any of the regulations (Jodha 1987).

The increased human and livestock population and lack of concern for the conservation and systematic use of CPRs has resulted in their degradation. Pressure on CPRs gets aggravated once the area of CPR is deliberately reduced. A massive public intervention programme in the form of land reforms during the early 1950s proved a single biggest factor which adversely affected the quantitative and qualitative status of CPRs in Rajasthan (Jodha 1982).

In 1952 land-reforms were introduced with the aim of lessening the inequalities in Indian society. The right over rented land were transferred from landlords to tenants. A good proportion of CPR lands was allotted to landless peasants, for farming. Although the remaining CPRs were

open to common access but lost the previous management systems. The village ''Panchayats'' became the custodians of CPRs and Panchayats being elected bodies are more concerned about the electoral response of the CPR users. They could neither impose grazing taxes nor regulate the use of CPRs (Jodha, 1987).

Nature, when used directly by individuals, according to their needs, imparts a sense of respect for it. Harvesting rain water and its collection in 'Paithan' and using it at a rate that conserves it till the next rain, makes the people familiar with nature's cycles.

Government departments have to learn to work with people and for them in a spirit of cooperation, mutual confidence and camaraderie. Involving local communities in decision making and execution will lead to active participation of the people in achieving their perceived goals. Environmental degradation cannot be checked by prescription, technology or management alone, but by the people who through education, improved living conditions and employment, can conserve non- renewable resources and promote renewable resources.

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MANAGEMENT OF NATURAL VEGETATION — AN IMPERATIVE FOR THE ECOSTABILITY OF THE ARID ZONES

Rajendra Sharma

The dominant flora of this region consists of the legendary tree *Prosopis cineraria* (Khezri) which has been worshipped as a religious tree akin to *Ficus religiosa* in many other parts of the country. Besides, this tree being historically linked with the first Chipko-movement in the country, it has a very significant role to play in the life of the desert people. This tree is associated with species like *Capparis decidua*, the fruits of which are pickled as well as cooked as vegetable. The shrub is of ethno-botanical importance as the fruits act as medicine for stomach ailments. It also helps in purifying the blood. Other shrubs include *Aerva pseudotomentosa* the flowers of which are cotton like and are used for stuffing pillows and mattresses, *Calligonum polygonoides* (Phog) which

provides the necessary fuelwood to the people in addition to its ecological role of binding the desert soils, *Crotolaria juncea* which also helps in providing the necessary mulch to the desert soils, etc. *Lasiurus sindicus* (Sewan) is one of the grass species, which is highly palatable and nutritive and provides the fodder for the animals of this region. Extensive areas in the Jaisalmer district are covered with *Lasiurus sindicus,* a natural adaptation to the low rainfall conditions in this locality. No significant steps have been taken so far to manage these grasslands. This is a rich resource having a great potential. It is therefore, proposed that grass lands of the desert be managed in such a way that their production is increased. It will have an impact on the fodder available from trees, large scale lopping of trees like *Prosopis cineraria,* results in not only disfiguring the trees but also results in a large scale mortality of these trees, and consequently the number of trees per hectare in this region is decreasing at a faster rate, disturbing its symbiotic relationship with marginal agriculture practised in this region. It is clear that natural resources are inextricably linked with each other and destruction or mismanagement of any ecosystem is bound to effect the other. It is, therefore, imperative to develop these natural grassland ecosystems through a sound range management practice which may consists of hay making, ensilaging, inter alia developing a sustainable grazing system through effective closures and rotation. This will help in improving the productivity of these grasslands, so as to sustain the increasing number of cattle which is the only economically and ecologically viable model of economy for this region. Even in the agricultural fields, as per the law in this state, the removal of *Lasiurus sindicus* is prohibited, because it has a supplementary role to play in sustaining the animals, even during the time of crop failures due to repeated droughts.

Calligonum polygonoides which is locally known as "phog" is another species which is of vital economic and ecological importance. No other shrub species has so deep roots and spreading mat behaviour of roots as this species. The root biomass is ten times more than the stem biomass and it yields fuelwood of high calorific value which is presently being converted into charcoal in the cities like Bikaner & Jodhpur and is being sold at very high prices.

The mat like nature of the roots helps in binding the loose soil very firmly and prevents the shifting of sand dunes. With the development of Indira Gandhi Nahar Pariyojana (Rajasthan Canal) this shrub is being uprooted and is being replaced by fast growing exotics like *Eucalyptus*

hybrid, Acacia tortilis etc. with intensive irrigation. The people who have been allotted lands in the command area for agriculture are also in the process of uprooting this shrub so as to raise agricultural crops in their lands with irrigation support. The net impact of such change in the land-use practices had been heavy siltation of the canal and a substantial stretch of the canal between Falaudi and Mohangarh (in Jaisalmer district, the terminal end of the canal) is half silted and lakhs of rupees are being spent every year, even before the canal could be completed on desilting operations. The agricultural fields from where these shrubs have been uprooted have also been subjected to shifting sand dunes, and in the process are being just converted into wastelands. It is a glaring example, as how manmade ecosystems are unsustainable both economically as well as ecologically.

From times immemorial, the people of this region have been accustomed with low rainfall and as a result adapted a land-use system which was ecologically and economically sustainable, viz. the animal based economy reinforced by adequate vegetal cover on the land. The society was ecosensitive and knew the importance of water conservation, and accordingly went in for water harvesting measures like 'Nadis' which were nothing but small ponds in each village where rain water could be impounded, in addition to collecting water on the roof tops, and letting it being channelised in storage tanks, which were to meet their needs adequately.

The animals and the tree cover provided adequate food, fodder and fuelwood for the people who by and large led a happy contended life, even though they were subjected to adverse climatic conditions and caprices of nature. The economy was self-sustaining and also qualified for ecological sustainability. But unfortunately, such a *milieu* was considered to be under development, and it was conceived that the real development can be brought about through changes in the traditional land use practices by the development of water resources in the region.

The calcules of such a development strategy in this region went wrong, as the ecological dimension was totally neglected and it was presumed that economics would take care of ecology. But the recent developments in this region, through the development of water resource, like salinization, increased desertification and deforestation (of natural vegetation) has made us to believe that the matrix of development is not as simple as one usually thinks of, but it is a complex exercise of making

it sustainable. The removal of natural vegetal cover, not only from the lands which were sought to be put under agriculture in the command area, but also from other areas by the marginalised lot, owing to lucrative economics, has resulted in the intensification of desert conditions in the region. It is estimated that nearly 200 camel carts loaded with the reddish roots of *Calligonum* reach everyday to the city of Bikaner in Rajasthan, where it is converted into charcoal and is being sold at Rs. 2 to Rs. 2.50 per kilogram. Each camel cart in one trip brings wood, worth Rs. 400/- which means a business of about Rs. 1 lakh per day is transacted, by way of its selling in the market, which represents indirectly the ecological cost of bringing about land-use transformations in this region.

The camel carts are exempted from transit passes for forest produce as per the provisions of the law in the State. In such a milieu any amount of afforestation under the prevailing constraints of locality factors, would not help in restoring the ecosystem balance in this region.

The afforestation programmes which are being taken along the canal, primarily with the ecological objective of arresting the sand dunes and thereby prevent the siltation of the canal, have also turned into an economic exercise of optimising the net returns from such plantations. With this objective, fast growing exotics have been raised, but their performance by and large have been dismal. This region is known for Marwar Teak which has been lavishly used in the old houses and "Havelis" (big houses) in the form of carved windows and doors, which bears ample testimony to the potentiality of this area with respect to tree growth. This tree species is known as *Tecomella undulata*, which is drought resistant and one of the most demanded species by the local people. Its strength compares favourably with Teak (*Tectona grandis*) and is now an endangered species of this region. It is imperative, that all the above mentioned species of this region, be listed in the data book of endangered species so as to focus international attention, (as what the FAO has did through its Forestry paper -11) and take remedial measures on a war footing basis to prevent the loss of this genetic material from this eco-sensitive region. Off late, some plantations have been taken up in this area consisting of local indigenous species near Jaisalmer, but again the predominant consideration is economics.

It is therefore, imperative to go in for natural vegetation management in this region, which can promote the desired eco- stability in the region and at the same time carry out afforestation with priority to indigenous

species, which would meet the day to day needs of the people both by providing them much needed employment and through such plantations meeting their biomass requirements for firewood and fodder. The need for strengthening the animal-based economy need not be over emphasised, as it is the only economically viable and ecologically sound strategy for the development of such regions. The water resources of the region have to be judiciously managed in line with the traditional conservation of culture of the people so as not to alter their life styles and create unsustainable man-made ecosystems. In the ultimate analysis, what is required is economic growth with ecological sustainability, through rational resource management policy which can reinforce the traditional life style of the people, improving their physical quality of life, the ultimate objective of development.

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ROLE OF FRUIT PLANTS IN AFFORESTATION OF ARID LANDS

B. Prasanna Kumar and P.Sampath Kumar

The survival of man on earth is very much dependent upon plants for they provide him with food, fuel, shelter, fibre, medicine and fodder for livestock plus innumerable other domestic requirements as well as providing the protective blanket of environment. Ever increasing population and life span of human as well as bovine has resulted in increased demand for food, fuel and fodder. This trend is more aggressive in developing countries. As a result forests are being felled indiscriminately to meet these needs (Grenville LI 1985). Consequently, there is alarming increase in area under arid and semi-arid regions. On the planet, a large area covering 10 degree to 30 degree latitude in both the hemispheres constitutes the arid lands(Virmani, 1980). This covers about 49 countries inhabited by 600 millions of people. These are characterised by low and uncertain rainfall (200-400 mm), high evapotranspiration rate and low soil fertility (Le Houerou, 1981). These factors make the plant growth difficult under afforestation in these regions.

In the never ending struggle for existence, some plants adapted themselves to the arid regions. Among them, there are some important fruit crops suitable for afforestation/reforestation in arid regions such as;

Ber (*Ziziphus mauritiana*), Annona(*Annona squamosa; A. cherimoya; A.atemoya;A.reticulata*), Pomegranate (*Punica granatum*), Aonla (*Emblica officinalis*), Jamun (*Syzygium cumini*), Karonda(*Carissa carandes*), Fig(*Ficus carica*),Phalsa(*Grewia asiatica*),Guava (*Psidium guajava*), Tamarind (*Tamarindus indica*), Wood apple (*Feronia limonia*), Bael (*Aegle marmelos*).

These fruit crops qualify for planting in arid conditions owing to their deep tap root system which in a short time grows vertically down. The cell sap is very thick which makes them less prone to desiccation during hot weather. Leaf surface of some plants has thick coating of epicuticular waxes making reduction in transpiration rate. Stomatal density is less. Vegetative phase of the plants which generally demands more moisture content pass through the monsoon season.

In case of severe drought conditions shoot tip abscission sets in arresting vegetative growth to over come stress. This phenomenon is prominent in Annona, Ber, Phalsa, Pomegranate, Jamun and Guava. On the other hand, during the favourable season vegetative growth will be maximised by sylleptic branching behaviour. Ber, Pomegranate and Annona are the best examples of this character. Some adaptive characters of arid zone fruit crops to resist drought are given in table 1.

Table 1. Some adaptive characters of arid zone fruit crops to resist drought

Character	Function	Crops
Deep root system	To explore larger volume of soil in search of water	All arid zone fruit crops
Shoot tip abscission	To arrest the vegetative growth under moisture stress conditions	Annona, Ber, Pomegranate, Phalsa
Sylleptic branching	To maximise growth under favourable conditions	Ber, Annona, Pomegranate, Jamun
Fruit set & maturity during monsoon	To avoid stress to the fruit growth	Ber, Annona, Phalsa, Karonda, Jamun
Deciduous nature	To avoid transpiration losses	Annona, Ber, Phalsa, Fig, Jamun.

These fruit crops also undergo some dormancy period unlike evergreen fruit crops. For instance, deciduous nature of annona, ber, repeated, jamun, fig and phalsa. Some varieties of pomegranate also exhibit this tendency. The second major consideration for these fruit crops make them fit for afforestation or reforestation is in the fuel wood yield. Crops like Ber, Phalsa and Fig require regular pruning to obtain better yields. Experiments conducted at IIHR in a pruning trial of Ber and Phalsa revealed that 4-8 tonnes of wood/ha can be obtained from these crops. (Table 2) Besides this wood average fruit yield of 100 kg and 1.2 kg per plant can be reaped in case of Ber and Phalsa, respectively.

Table 2. Fruit and wood yields of ber and phalsa in a pruning Trial

S. No.	Crop	Level of pruning	Wood yield (kg/tree) (air dry weight)	Fruit yield (kg/tree)
1.	Ber (Cv. umran)	Pruning to 6 secondaries	32.75	97.0
		Pruning to 4 secondaries	20.32	27.13
		Pruning half branches to 6 secondaries & rest to previous season's growth	24.0	128.87
		Pruning half branches to 4 secondaries & rest to previous season's growth	21.45	40.0
2.	Phalsa	0 cm from ground level	0.960	1.12
		50 cm from ground level	1.000	1.25
		100 cm from ground level	1.080	1.47

The third qualifying character of these arid zone fruits is the fodder value of leaves. Some of the crops like Ber, Jamun and Tamarind produce nutrient rich foliage and seeds fit for bovine consumption.

Among these fruit crops Ber is having one more advantage. It is an excellent host plant for lac insect (*Kerria lacca*) and Tassar silk worm (*Antheraea pappia*). Tassar silk moths do not mate under captivity and hence caterpillars cannot be domesticated. But cocoons can be collected from wild ber plantation which yield reelable silk provided harvesting is done before emergence of moth (Davis, B.V. 1984). Ber is an important host plant for lac insect. Crops like Phalsa and Fig also act as secondary

hosts. As the insect needs lot of fresh foliage as food to produce more raw lac, practice of pruning not only fulfils the demand of insect but also helps in getting higher fruit yield. The lac yield varies from 1.20 kg to 15.0 kg/tree depending on inoculum.

Table 3. Fodder value of some arid zone fruit crops (nutritive value %)

Crop		Crude protein	Crude fibre	Ether extract	Calcium	Phosph-orus
Jamun	a	7.9	20.7	2.6	1.38	0.12
	b	1.6	70.0	40.0	–	–
	c	8.5	16.9	–	0.41	0.17
Tamarind	a	15.8	23.7	9.6	2.86	0.26
	b	18.3	26.4	7.4	0.14	0.30
Ber (Z. mauritiana)	a	0.9	30.1	1.7	2.16	0.23
	b	36.0	27.0	34.0	–	–
Ber (Z. nummularia)	a	11.5	33.8	1.6	1.9	0.31
	b	47.0	54.0	69.0	–	–

a Fresh leaves; b Digestability; c Seeds
Source : Y. N. Reddy, 1988

In view of all these advantages of food, fodder and fuel generation which is the main aim of afforestation programme, arid zone fruit crops assume important place in arid land afforestation. One more caution we have to observe is the after care. These plants if protected from biotic interferences, perform still better. This can be done by wire fencing, guarding with empty coal tar drums, or by thorn fencing and digging circular trenches around trees. Once in 6 or 8 months after planting gap filling should be carried out with grafts/seedlings. With this little care we can expect a boon in afforestation programme under arid lands.

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AFFORESTATION THROUGH AGROFORESTRY RESEARCH AND DEVELOPMENT

R.L. Joshi and Dr. K. Janakiraman

In Gujarat, forest area is 1.88 million hectares which constitutes about 9 per cent of the geographical area of the state. According to the National Remote Sensing Agency (1980-82) about 68 per cent of the notified forest area has forest cover. Again the forest cover is relatively good only in South Gujarat and South Saurashtra sub-regions. It is widely recognised that there has been a general trend towards forest degradation due to well known biotic pressures. This clearly indicated that there is an urgent need for research and development on agroforestry systems to satisfy demand of fuel wood and fodder for the growing population of human beings and animals in the state.

Agro-forestry is a collective term for a land use system in which woody perennials like trees and/or shrubs are deliberately combined on

the same land management unit as crops/and/or animals, either in some form of spatial arrangement or in time sequence. In short, it is the deliberate use of special productive and protective features of woody plants to increase, sustain and diversify the total output from the land.

Advantages of agro-forestry systems are as under:-

1. It yields extended range of products, viz., food, fodder, fuel, fibre, fertilizer, fruits, etc.
2. It helps in utilization of off-season precipitation. Most of the drylands are cropped for a single season, so the precipitation occurring during off-season will go unutilized, but if a perennial tree component is there in the system, it would make use of the same efficiently.
3. It helps in soil and water conservation. The perennial component of the agro-forestry system, either on contours or in some other geometry, helps in reducing soil and water losses.
4. It imparts stability and results in risk reduction of the two or more components of the system, even if one fails, the other would give a harvest.
5. Presence of trees in agro-forestry system gives extended management options for the farmers i.e., the trees can be harvested either for fodder or fuel or pole or small timber or for nitrogen as per farmer's requirements and market demands.
6. Agro-forestry system checks the increase in soil temperature, especially during summer months. Thus, it protects the soil microflora and fauna, which would be of great benefit in crop production. Trees serve as shade for cattle.
7. It helps in recycling of nutrients from lower soil horizons. The deep rooted nature of most trees results in tapping of nutrients from deeper soil layers and returning them to plough layer through leaf drop and litter.
8. Off-season family labour utilization. During off-season, there would be no field work for family labour in dryland areas. This time can, thus, be effectively used for harvesting/pruning/marketing of the tree components in agro-forestry systems.

9. Tree component of agro-forestry system results in improvement in the micro-climate of the whole system.
10. Agro-forestry results in improved and stable income.
11. It improves economic conditions of the farmers in the region.

Agro-forestry systems relevant to arid lands

(A) FOR FODDER PRODUCTION

Fodder is a major constraint in drylands, especially during off-seasons. The fodder trees (top feed species) can be incorporated in alley-cropping system as hedge-rows, or as hedgerows along the contour lines. The hedge height can vary from 30 to 60 cm as per requirement. The trees can also be introduced as full grown plants at very low intensity in the arable crop areas and the canopy can be managed either by lopping or pollarding. *Leucaena leucocephala, Sesbania* sp. and *Calliandra* sp. are suitable fodder trees as hedge rows. *Hardwickia binata, Prosopis cineraria, Grewia optiva* etc are suitable for lopping purpose. *Leucaena* yields 3-4 tonnes per ha of green leaf fodder on dry weight basis in alley cropping system. A full grown *Prosopis cineraria* tree yields 45 kg leaf on dry weight basis per year.

(B) FOR FUEL WOOD PRODUCTION

Fuel wood shortage is felt everywhere, more so in dryland areas. *Prosopis cineraria, Acacia nilotica* var. cupressiformis, *Acacia tortilis* and *Eucalyptus camaldulensis* can be grown alongwith the arable crops, and the trees can be harvested for fuelwood purpose. The yield potential of each of the above tree species is given as under:

Fuel wood yield of promising tree species

Tree species	Yield potential (t/ha/year)	Calorific value (k calories/kg)
Prosopis cineraria	12.6	5000
A. nilotica Var. cupressiformis	6.5	4950
A. tortilis	4.5	4400
Eucalyptus camaldulensis	6.6	4800

(C) FOR TIMBER PRODUCTION

Producing timber in the dryland improves the economy of the dryland farmers. Tree species like *Leucaena leucocephala, Grevillea robusta, Dalbergia sissoo, Azadirachta indica, Populus* sp. can be grown alongwith arable crops for timber purpose.

(D) FOR FRUIT PRODUCTION

The fruit trees and crops or forage grasses/legumes are taken together. Examples of such system are ber and cowpeas, custard apple and grasses, orange and wheat, etc. In the initial years when the trees are smaller, regular cropping with arable crops can be done. In the later years when the fruit trees develop bigger canopy, they can be permanently under-cropped with some grasses and legumes.

(E) FOR FERTILITY BUILD-UP

Growing trees like *Acacia albida, Prosopis cineraria, Acacia ferruginea* at low density in the arable field, contribute to the improvement of fertility of soil through leaf shedding and with loppings of the trees used as mulch for such purposes. Alternatively, *Leucaena* can be planted in hedge-rows and the loppings from the hedge-rows can be added back to soil to improve its fertility. *Stylosanthes hamata* grown as undercrop with trees can fix 30-40 kg N/ha in 2 years period.

In Gujarat, the Operational Research Project on Silvipastoral system in Kutch was put in to operation from 1983. The significant achievements are summarised below :-

1. Bench-mark survey of Banni-Pasture land : In all, 45 villages of Banni region were surveyed at the start of the project. In addition to villagers and livestock population, the survey was also made on the vegetation component. During the surveillance 24 grass/legume species and 5 tree species were found to be growing in this region.

2. Soils of Banni-Pasture lands : The soils are alluvium, mixed at places with aeolin deposits. The surface soil is clay in texture and the sub-surface, silty clay loam. Very high concentration of sodium chloride is recorded. The under groundwater table is encountered within 2 m depth even in the summer season.

3. Silva-nursery at Agril Research Station, Bhachau : A large number of saplings of the tree species are raised in the polythene bags as per

standard nursery raising technique and supplied to the ORP farmers. From 1984 to 1990, over 12,000 samplings per year were supplied in the ORP area. Very good response of farmers has been received and they readily take away the saplings for plantation.

4. Demonstrations in the ORP areas : During last 5 years, 66 demonstrations were organized on the farmers fields in Bhuj(Banni-Khawda), Anjar, Bhachau and Rapar Talukas of Kutch district. This included silvipastoral, farm forestry and demonstrations on arid fruit tree species in Kutch district.

Amongst the tree species with top-feed (forage) value, the relative growth rate and total above ground biomass production was high in *Brussilatia mollish. Dichrostachys nutants* and *Leucaena leucocephala* even under the stress climatic conditions which prevailed during three consecutive years of drought (1985-1986-1987). Among tree species with multi-purpose value the growth of *Acacia nilotica, Inga dulcis* and *Prosopis cineraria* was better. Such trees can be propagated in drought prone areas.

The arid fruit tree species hold greater promise under the agro-climatic conditions of Kutch region. Under the ORP, Pomegranate, Ber, Phalsa, Gunda and Aonla have been introduced. The acceptance of arid fruit tree species by the ORP farmers was excellent. If the crops fail due to severe drought which is of common occurrence, the farmer can get some income from fruits and the livestock. Thus agri-horti-silvi-pastoral system of farming should be popularised among the farmers to stabilize their income make their and living comfortable in drought prone areas.

In Gujarat, Agro-forestry research has been carried out at Targhadia (Rajkot), and Sardar Krushinagar. The results given in Appendix-I clearly indicate that agro-forestry systems gave higher economic returns as compared to arable crops of the respective agro-climatic regions.

In conclusion, it can be stated that agro-forestry, the practice of growing trees and arable crops together has many advantages, viz. it yields extended range of products, utilizes off-season precipitation, conserves soil and water, helps in recycling of nutrients from lower soil layers, imparts stability and results in risk reduction, thus it is very important in dryland agriculture. Many agro-forestry systems, viz. for fodder production, fuel wood production, timber production, fruit production and fertility build-up are relevant to drylands. Various agro-forestry options for

different agro-climatic regions are now available, choice from them should be made depending upon the production objectives of the farmer.

Some strategies for agro-forestry research and development for afforestation in arid land

1. Research project on agro-forestry should be started on priority basis especially in dryfarming areas.
2. An ideal agro-forestry system should be developed to sustain increase in overall production using management practices compatible with ecological, social, cultural and economic conditions of the area.
3. Agro-forestry systems which give higher economic returns over arable crops according to the agro-climatic conditions should be developed.
4. Agro-forestry is equally important in wasteland and hence suitable agro-forestry system should be developed according to the nature of wasteland.
5. Fast growing trees which provide fodder, fuelwood, timber, fruit production and build-up soil fertility should be identified.
6. Arid zone fruits should be given due weightage in the agro-forestry system.
7. Agro-forestry system which is economically viable must be immediately propagated among the cultivators.
8. Some pasture land available in villages can be brought under social forestry and income of village Panchayat can be increased.
9. Some land available on both the sides of canals, roads and railways can be used for agro-forestry and employment potential can be generated.

The region specific strategies for afforestation can be worked out and appropriate technology for rapid afforestation can be evolved through agro-forestry research and development in the country.

APPENDIX–I

A. Leucaena alley cropping system – Targhadia (Rajkot)

	Yield (q/ha)			Total returns (Rs/ha)
	Green fodder (Main crop) Subabul	Grain (Intercrop)	By-product (Intercrop)	
Subabul uniform row	230.43	–	–	4609
Subabul paired row	219.41	–	–	4388
Groundnut sole	–	5.28	20.01	4169
Greengram sole	–	6.64	8.12	2818
Blackgram sole	–	3.22	5.97	1407
Subabul (Paired row) + groundnut	180.48	3.18	13.22	6179
Subabul (Paired row) + greengram	206.30	2.84	5.45	5371
Subabul (Paired row) + blackgram	177.88	1.22	3.74	4120
C.D. at 5%	9.12			

B. Leucaena Silvipastoral system-Sardar Krushinagar.

	Fodder yield (Q/ha)		Gross income (Rs./ha)
	Green	Dry	
Leucaena leucocephala	101.55	26.29	2031
Cenchrus ciliaris	148.68	36.68	1487
+ *Stylosanthes hamata*	57.19	15.40	1144
Leucaena leucocephala	15.20	3.87	304
+ *Cenchrus ciliaris*	175.43	44.72	1754
			2058
Leucaena leucocephala	67.75	16.85	1355
+ *Stylosanthes hamata*	57.16	14.59	1143
			2498

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TREE SPECIES AND FIELD CROP COMBINATIONS FOR AGROFORESTRY IN RAJASTHAN STATE

O. P. Mathur

Balanced ecosystem consisting of soil, water, plant, environment, human and animal population is essential for the welfare and survival of mankind as well as to check environmental deterioration. Destruction of vegetative cover exposes soil to erosion hazards by both water and wind leading to ecological imbalance. A myriad of factors viz. ecological, economic, social, cultural and governmental are involved in functioning of a system to meet economic needs while simultaneously taking care of proper maintenance of continued biological productivity. The core strategy, therefore, always needs to be a combination of the principles of protection, regeneration and production. Since the economic problems are essentially the social problems, the active participation of local masses in the activities is of paramount importance. The rural population today is generally interested and involved only in utilization of the natural resour-

ces but not in their conservation and production. It is, therefore, necessary that farmers are educated and made to realise the necessity to adopt agroforestry system of farming. This will not only help in meeting food, fodder and fuel needs but would enable them to utilize the total land and water resources more judiciously and scientifically with substantially added income.

Present Status of Food and Fuel Supply

Rajasthan is a forest deficit state with only 3% wooded area against 33% as recommended by National Commission on Agriculture (1978). In arid and semi-arid tracts, it is still thiner (2%) due to adverse climatic conditions and over exploitation. The general pattern of fuel sources and utilization observed is (1) charcoal, soft coke and coal-2%, (2) fuel wood and kerosene-3% and (3) vegetation and cattle dung-95%. Thus huge quantities of vegetation and cowdung are wastefully burnt which otherwise could have been utilized as organic manure and other purposes for attaining higher level of production.

Except the command areas, most of the districts are deficient in fodder and fuel supply, and the requirements are met by importing huge quantities of non nutritive fodder like wheat & barleystraw from the neighbouring states.

Basic Principles of Combining Crops and Tree Species

Rajasthan has been divided into 9 different agroclimatic zones based on varying soil and climatic conditions (Annexure-I). Like field crops the suitability and choice of tree species vary according to agroclimatic conditions. To promote agroforestry in different set of agroclimatic conditions, determination of suitable combinations of crops and tree species for maximising production without impairing environment is very important. Knowledge of soil water plant relationship under each situation of agroclimatic condition in relation to crop/tree *behavior* pattern/requirement is a prerequisite for planning their combinations.

Agroforestry although in vogue in varying forms, its adoption on scientific lines and on large scale is greatly lacking. Systematic studies have recently been taken up by Rajasthan Agriculture University at their Fatehpur research station. Based on the observations in the field and studies conducted in other states, the possible combinations of various

Annexure 1. Suitable tree species and crops for possibile combination for three broad climatic conditions of Rajasthan state.

S. No.	Tree Species	Crops	Remarks
I. Poor annual rainfall (below 450 mm)			
1.	*Prosopis cineraria*	All suitable rainfed crops	Crops grow successfuly beneath the tree.
2.	*Ailanthus excelsa, Moringa oleifera, Ricinus cuminus*	All suitable rainfed/irrigated crops including fodder, vegetables, chillies, onion, garlic, cucurbits.	Proper tree pruning & spacing necessary.
3.	Fruits : citrus, guava, pomegranate, ber, phalsa, custard apple etc. (Irrigated/unirrigated)	All suitable rainfed/irrigated crops including fodder, vegetables, chillies, onion, garlic, cucurbits.	Proper tree pruning & spacing necessary.
4.	*A. tortilis, Parkinsonia, Prosopis juliflora, P. cineraria.*	All suitable rainfed crops	Proper tree pruning & spacing necessary.
II. Moderate annual rainfall areas (451–650 mm)			
1.	*Prosopis cineraria*	All suitable rainfed crops	Crops can grow beneath the tree.
2.	Fruits : citrus, guava, pomegranate, ber, custard apple, phalsa, papaya, karonda, mehndi (Irrigated/rainfed)	All suitable irrigated/rainfed crops including vegetables, fodder viz. sweetpotato, cucurbits, onion, garlic, chillies.	Proper tree pruning & spacing necessary.

contd....

S. No.	Trees Species	Crops	Remarks
3.	Subabool, sulia desibabool, safeda, shesham, ardu, senjna, dadon, gular, castor, jangal jalibi.	All suitable rainfed crops.	Proper tree pruning & spacing necessary.
III. Good annual rainfall areas (above 650 mm)			
1.	Sagwan, shesham, safeda, sewan, subabool, bans, churain, vilayati babool, khejdi, kher, shehtut, bakin, rainjh. Fruits : mango, papaya, citrus, guava, mahuwa, sitafal.	All suitable field crops including fodder, vegetables etc. viz. sweetpotato, potato, cucurbit, onion, garlic, chillies, pan, turmaric, ginger, zamikandi, knchalu, arvi etc.	Proper tree pruning & spacing necessary.

crops and tree species suitable under varying agroclimatic conditions are discussed in this paper. Following are the basic principles which need to be considered while deciding the desired combinations :-

(1) Crops and Vegetables : Dwarf and less shady/canopy trees are comparatively more suitable for the combination with field crops.

(2) Shade loving crops including fodder & vegetables should be preferred.

(3) Field crops and/or tree species, if leguminous, have the added advantage of fixing atmospheric nitrogen.

(4) Root crops, radish, turnip, sweet potato, carrot, tuber crops, ginger, arvi, turmaric, potato, leafy vegetables-spinach, corriander, methi, bettel, gute and fodder crops are the ones which can tolerate shade to varying extent.

(5) Crops which bear seeds/fruits like cereals, pulses, oilseeds, cucurbits, etc generally require sunlight particularly at the time of seed/fruit setting and development. Such crops also generally need high temperature at the fruiting/seed setting and maturity stages.

(6) Shallow root crops are likely to suit more than deep rooted crops.

(7) The water requirement of crops and tree species combined should not vary too much.

(8) Similarly, the nutritional requirements should not be too much divergent and application of fertilizers, particularly nitrogenous, to field crops should not adversely affect the production of tree species.

(9) Care may be taken that tree species selected do not host insects causing damage to agricultural crops.

Tree Species

Tree species greatly vary in their requirement for soil, water and nutrients. It is a common observation that rainfed crops like pearlmillet and kharif pulses do better in association with *Prosopis cineraria*. This is

due to the fact that *P.cineraria* is a leguminous and drought resistant tree. It's roots extract nutrients and water from lower soil zones and the biomass which falls on the ground not only enriches the soil but also helps in conserving soil moisture. Thus it promotes better plant growth in its vicinity. On the contrary, eucalypts is a an extensive and exhaustive user of soil nutrients and moisture. It has smothering effect on the vegetation grown in its vicinity. Its root spread is also observed on top surface soil. The shade effect is also there when planted close and when it has attained good growth. Crops are generally not planted in association with it except a few selected crops in those areas where soil is rich, rainfall is higher and the crops selected require shade.

Other Points For Consideration:

(1) Only dwarf and less bushy trees suitable for the area may be selected.

(2) Periodical pruning may be practised so that shade effect may be reduced.

(3) Fodder trees may be preferred so that cut material is utilized for feeding to animals.

(4) It is a well known and common practice that crops are raised in between trees till full height of the trees is attained under agroforestry/agro horticulture programmes.

(5) Photo insensitive fodder, tubers, bulb, cole, leafy vegetables, maize for green cobs, peas for vegetable, etc can be grown successfully under shade.

(6) Spacing of trees needs to be so adjusted that enough light is available to field crops for seed formation.

(7) Selection of tree species and crops will have to be based on agroclimatic suitability, economics, farmer's choice, social and other similar factors.

Summary

Importance of agro-forestry through people's participation has been highlighted for more scientific and optimum use of land and water resources as well as boosting farmer's income. It will also help in meeting fodder and fuel needs, scarcity of which is acute. In the absence of any research finding, basic principles of combining crops and suitable tree species under varying agro- climatic conditions have been discussed. The main idea is to combine the two according to their compatibility without adversely affecting any one and gaining maximum return. For obtaining best results important measures suggested are proper spacing of trees, pruning them adequately and regularly, selection of fodder trees, selection of tree species and crops according to their suitability in a situation.

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TECHNOLOGY FOR AFFORESTATION OF DRYLANDS IN U.P.

Chandra Gupta, A.K. Dwivedi and R.J. Srivastava

The national forest policy of 1952 envisaged that 33% of the land area in our country should be under forest cover, whereas according to the available records and a more recent survey done by the Centre for Remote Sensing Applications indicates that the area under forest cover is only 17% in our country. Hence, the figures are quite alarming and an immediate action is required to increase the forest cover for maintaining the ecological balance. Vast tracts of our country are devoid of vegetation. These lands lie fallow throughout the year. Some grasses and shrubs come up during the rainy season. These are however, destroyed by herds of cows, goats, sheeps, etc. The land continues to be over used and thus keeps on deteriorating physically and chemically.

Vast tracts of user land can be seen around districts of south-west and central part of U.P. The banks of the river Yamuna contain the most deteriorated ravinous tracts. The banks of the holy river Ganges consist

of vast stretches of Khadar lands which are devoid of any vegetation. Waterlogged areas can be seen along major canal systems and along road sides. According to Bhumbla and Khare(1984), an estimated area of the waste lands in this state is about 66.36 lakh hectares. All such lands are at present unfit for agriculture and animal husbandry. If the present abuse continues, they will go on degrading. The more serious effect of their misuse is their impact on neighbouring areas which also lose their productivity due to ecological degradation. Tree farming offers a viable method of making these lands productive, checking their further degradation and restoring the ecological balance.

Based on rainfall, terrain and soil characteristics, ten different agroclimatic zones have been recognised in the state of U.P. Out of these climatic zones, the following four zones extending from south western to lower southern region fall in the dry tracts of the state.

(1) South-western semi-arid zone.

(2) Bundelkhand zone.

(3) Vindhyan zone.

(4) Lower southern parts of central plain zone

The South-Western Semi-Arid Zone

Some districts like Mathura, Aligarh, Etah, Mainpuri and Agra fall within this ecological zone. The mean annual rainfall varies from a low of 600 mm to about 1100 mm. The temperature varies from a minimum of 5-8°C in winter to a maximum of 46°C in summer. Frosts are rare but the winters are harsh because of cold winds. There are pronounced hot winds (Loo) in the summer. The western parts of the zone has lower rainfall as compared to the eastern part.

A very sizeable portion of land is affected by heavy to medium usar conditions. Some parts of districts of Agra and Mainpuri are infested by ravines. These areas are also facing serious problem of brackish water. Large scale deforestation in arid tracts is one of the most important causes of formation of brackish water.

The Bundelkhand Zone

The districts e.g. Banda, Jhansi, Lalitpur, Hamirpur and Jalaun fall within this ecological zone. The annual rainfall varies from 650 to 800

mm. Most of the rainfall is received in the months of the June to August with a little winter rains. The rainy days vary from 20 to 30 annually. The summer temperature even goes upto 48°C in May and June. Mornings are generally cool and the small water resources, dams, reservoirs which impound the rain water for drinking and irrigation dry up.

The soil varies considerably but most of the areas have red lateritic soil with often pronounced nodules locally called 'murram'. Such murram soils are very poor and are associated with sheetrock underneath. Some areas of districts like Banda, Hamirpur and Jalaun in this zone are also infested by ravines.

The Vindhyan Zone:

This zone consists of the Vindhyan plateau and the hills in the southern part of the state. The climatic conditions in this zone are, by and large similar to that of Bundelkhand zone. The annual rainfall varies from 750 mm to about 1,100 mm. The number of rainy days vary from 30 to 60. The Mirzapur district has rich forests as far as timber is concerned, besides rich bamboo and fuelwood resources and Tendu. But the tragedy is that the open-cast mining of coal has ruined vast forest areas for the supply of coal to the super thermal power stations. There is the problem of finding dumping sites for the enormous quantities of flyash discharged by the power stations.

In most of the tract, the soil is red lateritic, rocky and dry having iron nodules. The depth of the soil also varies a great deal. Much of the area has a soil depth of just a few cm. Deep and fertile soils are often found in the valleys between folds of hills where the soil washed from hill slopes has accumulated. Since the edaphic and climatic conditions in both the above mentioned ecological zones are mostly similar, the afforestation technique generally applied in these areas is also common.

The Lower Southern Parts of Central Plain Zone

The lower southern parts of districts of Etawah, Kanpur and Fatehpur lie in the dry tract of this zone. These areas are mostly infested by the ravines. The semi arid nature of this tract is characterised by a wide range of temperature and an irregularly distributed rainfall. The mean annual rainfall varies from 750 to 950 mm. Whereas, total number of rainy days vary from 30 to 60.

Afforestation of different drylands in U.P.

In view of the different edaphic, climatic and biotic factors prevailing in the different dry tracts, afforestation with appropriate technology and choice of suitable species could be done successfully. A brief description of these techniques adopted in different land categories is as under:-

(1) AFFORESTATION OF SALINE-ALKALINE LANDS:

Saline and alkaline soils (usar soils) have been formed due to the combined effect of climate, topography, hydrology and economic activities of men. Destruction of vegetative cover, water logging due to seepage and lack of proper drainage are the main causes for formation of usar lands in this state. Sometime water pollution by industrial effluents also contribute in the formation of usar soils. Such soils are generally deficient in organic matter and micro-organisms with high pH and increased salt concentrations. Several attempts were made to reclaim usar soils with different types of soil workings and choice of species.

The following soil working treatments and species have yielded best results :-

(a) Soil working techniques and application of soil amendments

(1) Pit digging (size 120 cm deep x 20 cm diameter) by mechanical augers.

(2) Pit digging (size 45 cm x 45 cm x 45 cm) manually followed by cylindrical pits of size 75 cm deep x 20 cm diameter by augers.

The optimum proportion of different soil amendments is given in following table:

pH value of usar soil	Quantity of gypsum per pit (in kg)		Quantity of F.Y.M. per pit (in kg)		Sand
	pit (i)	pit (ii)	pit (i)	pit (ii)	
8 to 8.5	1.0	5.0	5.0	15.0	50% of the soil
8.5 to 9.5	2.0	6.0	5.0	15.0	– do –
9.5 to 10.5	3.0	9.0	5.0	15.0	– do –
above 10.5	4.0	12.0	5.0	15.0	– do –

(i) – Pit size (120 cm x 20 cm)
(ii) – Pit size (45 cm. x 45 cm. x 45cm. + 75cm. x20cm

(b) Suitable species:

The following species are suitable for planting according to the pH value of usar soil.

(1) pH 7 to 8.5 :

Prosopis juliflora, Acacia nilotica, Leucaena leucocephala, Pongamia pinnata, Terminalia arjuna, Acacia leucophloea, Butea monosperma, Dalbergia sissoo, Cassia siamea, Eucalyptus hybrid, Pithecollobium dulce, Ziziphus jujuba, Acacia auriculaeformis, Azadirachta indica, Cordia dichotoma, Madhuca indica, Parkinsonia articulata, Albizia lebbeck, Albizia procera and Emblica officinalis.

(2) pH 8.5 to 9.5 :

Prosopis juliflora, Acacia nilotica, Acacia leucophloea, Butea monosperma, Albizia procera, Terminalia arjuna, Cassia siamea, Ziziphus jujuba, Pithecollobium dulce, Parkinsonia articulata.

(3) above 9.5 :

Prosopis juliflora, Albizia lebbeck, Albizia procera, Terminalia arjuna, Butea monosperma.

(c) Irrigation:

After plantation frequent irrigation should be provided. During winter season, atleast one irrigation should be given per month whereas during summer season 2 to 3 irrigations should be provided every month.

In the water logged areas of saline-alkaline soils, planting should be done on mounds of 45cm height during winter months.

The results of root development studies in the saline-alkaline soils, carried out at Makdoompur Usar Research Centre (Unnao), revealed that the species which develops good lateral root system should be preferred for planting in usar soils.

As mentioned earlier, there are some areas facing serious problem of brackish water which is toxic to many agricultural crops and trees. On these sites, there is a layer of coarse sand probably deposited by dust storms from the near by desert areas. Below this sandy layer, the formation is clayey with different stages and depth of Kankar nodules. The site is deficient in organic matter and nitrogen contents. Due to nitrogen deficiency of soil, nitrogen fixing species have a better chance of success.

The results of trials conducted at Brindavan Forest Block, Mathura revealed that *Acacia nilotica, Prosopis juliflora, Cassia siamea, Albizia lebbeck, Leucaena leucocephala, Pongamia pinnata, Cassia fistula, Mitragyna parviflora*, and *Haplophraoma adenophyllum* grow well with brackish water. Some shrubs like *Cassia auriculata* and *Adhatoda vasica* also grow successfully on these sites.

With an objective to test the survival and growth of hard wood species of Central America in semi-arid conditions at Brindavan Forest Block, Mathura an international trial of dry zone hard wood species was laid down in 1985. Out of 26 different tested species from Central America, the following species have shown better survival and growth *Guazuma ulmifolia, Crescentia alata, Caesalpinia coriaria, Parkinsonia aculeata, Mimosa tenuifolia, Prosopis juliflora, Senna atomaria, Glyricidia sepium, Enterolobium cyclocarpum and Pithecolobium dulce.*

(2) AFFORESTATION OF RAVINOUS AREAS:

In U.P. about 1.25 million ha of land is ravinous occurring predominantly in Agra, Banda, Etawah, Hamirpur, Firozabad, Jalaun & Jhansi districts. The main problems of ravinous areas are; the soil is prone to erosion, high temperature, erratic rainfall, severe frost on bottom lands, uncontrolled grazing and lack of irrigation facilities.

Table land soil is loam to clayeyloam in texture and neutral to mildly alkaline in reaction (pH 7.5 to 8). Soil is moderately well drained and Kankar is observed throughout the profile. The ravine beds generally contain well drained sandy loam which remains comparatively moist.

Planting technique:

Box trenches: About 200 to 250 staggered trenches at the distance of 3 to 4.5 m (size 3 m x 60 cm x 45 cm) per hectare are dug up and after 4 to 5 rows of such trenches, a continuous trench (C.C.T.) is dug out with 30 cm septum. The soil is piled up on downward side and dressing is done for making ridges. Seed sowing is done in 2 to 3 rows on the ridges. In order to reduce the speed of run off water (to facilitate soil and moisture conservation)bunding (3x1x $1m^3$) and gulley plugging is must, normally at the rate of 350 to 400 m^3 per ha. The size of bunding may vary depending upon slope and depth of gullies. On gentle slopes and flat tops of ravines, pits (45 cm x 45 cm x 45 cm) are dug normally at the rate of

200 pits per ha. The seed sowing and planting work is carried out during the rainy season.

Suitable species:

(a) On gentle slopes and flat tops:

Acacia nilotica, Prosopis juliflora, Acacia leucophloea, Holoptelia integrifolia, Acacia catechu etc.

(b) On bottom of ravines:

Ailanthus excelsa, Holoptelia integrifolia, Albizia lebbeck, Ziziphus jujuba, Pithecolobium dulce, Dalbergia sissoo, Bombax ceiba and *Pongamia pinnata.*

(3) AFFORESTATION OF DRY LANDS IN BUNDELKHAND AND VINDHYAN ZONE:

Most of the soils in this tract is murram associated with rocks and red clay. The soil depth is also very low and soil moisture is scarce. There is a heavy biotic pressure on forest area causing enormous damage to the ecological balance of the forest ecosystems, reducing their capacity to regenerate naturally. Thus, uncontrolled grazing is one of the major constraints in success of plantations in this region.

The most of the tract is rainfed, it is always advisable to adopt effective technique of insitu soil and moisture conservation so as to reduce runoff of water and consequent soil erosion.

Planting technique

Box Trenches: About 300 to 350 staggered trenches per ha are dug at a distance of 2.5 to 3.0 metres (size 3.0 x 0.45 x 0.30 m^3). These staggered trenches are dugup in different pattern of soil workings. After every 4 to 5 alternate rows of staggered trenches and pits (size 45cm * 45cm x 45cm) at a distance of 2 metres, a continuous contour trench is dugout with 30 cm septum. In another pattern of soil workings, after one C.C.T., 4 to 5 rows of pits (at a spacing of 2 m) are dug. The soil is piled on downward side and dressing is done for making the ridges. Seed sowing is done in 2 to 3 rows on the ridges.

The advance soil working is completed before onset of monsoon followed by filling of pits after weathering in the month of May and June.

The seed sowing is done on ridges of trenches in the month of June before rains. Since these areas are under heavy pressure of grazing, browsing and lopping, the choice of species should be the main consideration for planting vis-a-vis the entire area should be protected by stone wall (normally of size 1.20 x 1.0 x 0.90 m^3) before planting work is carried out. The species which are good fodder should not be planted in the first two years.

Suitable species

Acacia nilotica, Prosopis juliflora, Acacia catechu, Holoptelia integrifolia, Madhuca indica, Albizia amara, Haplophraoma adenophyllum, Pongamia pinnata, Cassia siamea, Dendrocalamus strictus, Dalbergia sissoo, Buchanania lanzan, Diospyros tomentosa(Tendu), Acacia auriculaeformis, Anogeissus pendula, Bauhinia variegata, Albizia lebbeck, Emblica officinalis, Leucaena leucocephala, etc.

The planting techniques and suitable species for afforestation of different ecological zones of semi-arid tracts of U.P. as described in this paper are being practiced successfully.

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FOREST PROTECTION IN ARID ZONES: PROBLEMS AND RESEARCH PRIORITIES.

M.L. Thakur and R.K. Thakur

Introduction

The Indian desert with extreme climatic conditions and scanty vegetation is the most thickly populated desert region in the world, supporting roughly 10 persons/km^2 as against 3 person/km^2 in most of the other desert zones (Muthana, 1988). This figure rises rather alarmingly to 62 persons/km^2 for Rajasthan. The total forest cover in the Indian desert is only 0.3% of the total land area and the hills of Aravallies are fast getting denuded. Therefore, the challenge ahead is to create forests and increase area under forest cover and pasture lands as well as adopt appropriate technologies to protect it. Thus the task of forest protection comes into force immediately and the proverbial statement that "Forestry is 90% protection", perhaps is more apt for arid zones.

This paper highlights the major problems of forest protection, particularly the biotic agencies, with emphasis on the need to prioritize the thrust areas in forest protection in the Indian desert.

Some Major Problems in Forest Protection In Arid Zones

In the wake of bringing the arid lands under green cover, and the growing demand for fodder, fuelwood and industrial wood, the coming decades are likely to witness large scale planting (with monoculture indigenous and exotic species) of wastelands, vacant village lands as well as stabilizing sand dunes under long term forestry. This has to be dealt with in combination with various other problems of increasing agricultural productivity for the inhabitants, developing pastures for livestock and forestry for over-all development and eco-restoration of the region, all at one time, through scientifically well planned agri-silvi-pastoral programmes. All these activities are no doubt fraught with serious consequences from damages of biotic agencies, involving insect pests, diseases, rodents and the most important, hardy and reproductively highly potential livestock. Keeping this in view, some of the problems are outlined below:

(A) FELLING FOR FUELWOOD AND FODDER

Fuelwood and the fodder are the two essential requirements of the inhabitants and their livestock in the Indian desert. This increased demand has resulted in dwindling tree cover as well as commercialization of firewood, thus adversely affecting the economy of the rural poor. This has further led to poaching and deforestation of the once rich vegetation cover of the region, creating in the process desertification, environmental degradation and scarcity of the natural renewable resources. Afforestation on massive scale with plantations of suitable fuelwood and fodder tree species have to be carried out to their logical goals. Some of promising tree species for arid regions are *Acacia nilotica, Albizia amara, Albizia lebbeck, Ailanthus excelsa, Prosopis cineraria, Ziziphus rotundifolia, Ziziphus nummularia* (indigenous species), *Acacia tortilis, Acacia albida, Prosopis alba, P. juliflora*, some species of *Eucalyptus*, etc. (Exotic species) (Muthana, 1988).

(B) GRAZING

Apart from the little agriculture, animal husbandary is the main livelihood of the desert people, predominantly a rural inhabited region. It is indeed paradoxical that areas with too few trees are also the areas with

far too many cattle (Kapashi & Misra, 1988). While the livestock population has been increasing rapidly, the grazing lands and pastures have been declining gradually and as of today, grazing lands are practically non-existent in the desert region and that whatever is available, are in a highly degraded state. The resultant biotic pressure has made large areas of the arid zone ecologically most fragile zones far in excess of the forest's carrying capacity.

As per the available figures, the cattle population in 1951 was 10.2 million. Which swelled up to 23.2million by 1983. Grazing by the livestock, particularly goats and sheep, in forest areas is considered as an ecological liability. While grazing by goats, described as "desert makers-par-excellence" endangers forests by destroying seedlings and preventing natural regeneration, sheep are more dangerous because of their preference for woody plants to herbaceous ones (Anon, 1990). The stall feeding is little practiced and free grazing renders many a plantations as failures. Small trees and shrubs are badly damaged, resulting in stunted and mutilated tree cover by the continuous browsing of the leaves and tender apical portion. Developing technology for afforestation of arid zones, particularly wasteland and salt affected soils through agro-silvi-pastoral system for different agro-climatic zones and for regeneration of degraded hills shall provide solution to this problem.

(C) INSECT PESTS, DISEASES AND RODENTS

No afforestation programme can be successful until both the planting and growing stocks are fully protected. Among the various destructive agencies, insect pests and diseases are the two principal biological determinants of forest productivity. Besides grazing and browsing by bovine stock and other vertebrates, insects, diseases and rodents cause significant damage to forest cover. The problem is more pronounced in forest nurseries and young plantations, where the ecosystem is still unstable and the biological determinants cited above constitute the major constraints for higher productivity of healthy growing stock. Indigenous species in monocultures are often subjected to pest build up. Exotics, though initially free from insect attack, succumb subsequently to indigenous fauna which develop historically with the crop (Singh, 1988). For example, babul shoot and root borer of indigenous *Acacia* has developed fancy for *Eucalyptus* in some part of the country.

Most of the species, occurring or being grown in the Indian desert, as elsewhere, suffer defoliation, at times, in epidemic form, by various species of lepidopterous larvae, sap suckers, stem borers and root feeders. Most of them are polyphagous and the damage caused, though occasionally, can be serious. Larvae of bagworm *Cryptothelia crameri* (Psychidae) have been reported to defoliate *Acacia nilotica, Acacia catechu.* The larvae sometimes completely strip off the leaves or even the growing tip of the Acacias. *Ailanthus excelsa* is attacked by webworm, *Atteva fabriciella, Dalbergia sissoo by Plecoptera reflexa, Albizia lebbeck* by *Laodamia strigivenata, Morus alba* by *Glyphodes pyloalis* and *Diacrisia abliqua.* A few species of cock-chafer beetles damage foliage of babul, ber, Jandh and neem trees and the species associated with damage are *Holotrichia insularis, Adoretus nitida* and *A. pellens, (Beeson, 1941; Singh, 1988). Ber (Ziziphus mauritiana*), an important fruit and fodder tree being planted in most of the arid zone areas, is subjected to defoliation by many species of insects (Butani, 1979). The ber butterfly *Tarucus theophrastus,* hairy caterpillars, *Thiacidas postica, Euproctis fraterna, E.lunata, E. flava,* and ber mealy bug, *Perissopheuman tamrindus.* Among these, the ber butterfly and ber mealy bug are the major pests of *Ziziphus* species.

The Oriental scale insect, *Aspidiotus orientalis* attacks a number of forest trees, including *Azadirachta indica, Dalbergia sissoo, Ziziphus mauritiana.* The scale thickly covers the shoots, stems and drains the plants of their sap and in severe infestations, the growth is retarded.

Seed and soil borne fungi are the main pathogens in forest nurseries causing serious losses both in seed beds and polypot seedlings. Important diseases in forest nurseries generally are pre-and post-emergence damping off, root rots, web blight, leaf rusts, mildew and leaf spots.

Among these pre-and post-emergence damping off disease, caused by unspecialized soil inhabiting fungi of genera *Pythium, Phytopthora, Rhizoctonia* and *Fusarium* (Singh, 1988; Sen-Sarma et al., 1989), is the most serious disease in forest nurseries. This disease causes loss in viability of the seed and the resultant failure of seed germination.

The polypot seedlings also suffer from heat injury as well as mortality by *Fusarium* and *Rhizoctonia* root rot fungi. Nursery seedlings also suffer from attack of pathogens on the aerial parts of the seedlings e.g. stem-canker disease by *Cylindrocladium quinqueseptatum.*

Study of diseases of trees raised on wasteland and lands not fit for agriculture, supporting scrubby vegetation in arid and semi arid regions, by and large, still remains an untouched area of pathological research. Root rot fungus *Ganoderma lucidum* is the major disease in leguminous tree species. Infections spreads through haustorial connections of infected roots. The disease spreads rapidly in sandy and sandy-loam soils where the infected plants may be killed within a year after the appearance of die-back symptoms in the crown (Singh, 1988). Whereas species of *Acacia, Leucaena leucocephala* and *Eucalyptus* are highly susceptible to *Ganoderma lucidum* root rot in all age classes, *Dalbergia sissoo* becomes susceptible after 10-12 years of age and *Ailanthus excelsa* has been found resistant to the disease.

Priority areas of research in forest protection

A. ENTOMOLOGY:

Surveillance: No organised survey has ever been carried out of forest areas to study the problems of insect pests, diseases and other biodeteriorating *agencies* in the arid areas and which perhaps could have been of value in programming the research priorities. Thus organised surveys are essential in the whole of the arid region to prepare a pest inventory of both major and minor pest species, pest incidence and outbreak of epidemics, if any, problems of rodents and pathogens and mapped them for follow up action. This will also help building up rich reference collection.

Insect pests of forest nurseries in arid zones

Production of healthy seedlings is important, where the planting stock raised from seeds or cuttings, is maintained for about six months to almost one year before being transplanted in the field. During this period, white grubs, termites, cutworms and plant parasitic nematodes and even rodents can cause significant mortality in the planting stock and can be a limiting factor in the supply of healthy nursery seedlings in desirable quantities. Root feeding termites in particular along with cockchafer grubs have emerged as a major hazard in forest nurseries and young newly established plantations in arid zones. Hence the need to initiate an organised research with an independent research project on "Insect pests of forest nurseries and their control". Similarly, many phytophagous insect species do cause damage for protecting growing stock in forest nurseries but the damage

thus caused, by and large, is insignificant. However, some of them are potential pests, therefore, it would be worthwhile to prepare a pest inventory of all nursery pests in arid zones and evolve suitable control measures.

Insect pests of fuelwood and fodder tree plantations and their control: (*Acacias, Albizias, Eucalyptus, Prosopis* **etc.)**

As already stated (*vide supra*), fuelwood and fodder are the essential requirements of the desert inhabitants and raising of large scale fuelwood and fodder plantations are likely to be fraught with serious constraints from problems of insect pests and pathogens. While the fuelwood may not take up much inputs, the fodder species will require special attention, because the use of chemicals for the protection of foliage has its limitation, for obvious reasons of animal health. Cheaper and safer control measures will have to be evolved.

Insect pests of agri-silvi-pastoral systems

Development of pastures and forestry has to be carried out as complement to agriculture and with whole hearted involvement of the local inhabitants because that is going to be the only way to bring greenery in the desert. With growing of such crop combinations, there is bound to be new typey of insect problems. It would be pertinent to conduct indepth study of such ecosystems and the protection problems on many of the minor pests which are capable of emerging as major pests. Some pests recorded on one crop may become pests on forestry, agriculture or pasture, not observed so far and vice-versa. Thus, it will be an interesting study to survey these crops for insect pest problems and establish their pest status along with evolving of suitable control measures.

Problems of white-grubs in arid zone forestry and their integrated control

Apart from other forest pests, whitegrubs are likely to be a serious problem in arid zone forestry. It would be necessary to include the indepth study of whitegrub problem under a separate research project on "The Biosystematics and integrated control of whitegrubs in arid zone forestry" under priority areas, laying special emphasis on:

(1) To conduct regular surveys in forest nurseries and forest areas for collecting basic data on occurrence, distribution and seasonal fluctuations in whitegrub under varied agro-climatic zones. Prepare maps and project the grub problem.

(2) To conduct surveys and prepare pest inventory (white grubs) of different cropping systems under agro-forestry programmes.

(3) To conduct white grubs pest surveillance and monitor their populations regularly.

(4) To evolve IPM strategy for effective management of adult beetle or grub populations.

Insect pests of forest tree seed, fruit and their control

Natural regeneration is very poor in arid zones, perhaps almost negligible. Health of the tree seed, is very vital and essential requirement for forest tree propagation. This is the most important aspect in production forestry and unfortunately the most neglected area of entomological research in forestry as well. No organised research study has been conducted on tree-seed entomology. It would therefore, be worthwhile to initiate research on this aspect and evolve suitable control measures without affecting the seed viability.

Systematics of forest insects of arid zones

Taxonomical studies of insects associated with forestry is the most important and essential aspect of fundamental research. To diagnose the cause of mortality of seedlings or a tree, correct identity and bio-ecology of the pest species are essential requirements for adopting most effective control measures. However, unfortunately, this is an area of research which is most neglected, and infact, it is a field to which even most of the professional entomologists are allergic too. Besides, the identity of parasites and predators, is also important for biological control of forest insects. Systematics of insects should form an essential component of forest protection. Though Forest Research Institute,Dehra Dun, with its rich and well maintained reference collection can provide the service, but unfortunately, we do not have experts of different groups. It would therefore, be advisable to have a full fledged section on systematics of

insects and engage experts for such an important aspect of forest protection.

Priority areas of research in forest pathology

The diseases are known to cause several types of disorders in forest nurseries and plantations. Among the incidence of diseases, the fungi are the most destructive pathological agents which incur severe losses and adversely affect the productivity. In forestry, pathogen management may be achieved through forest sanitation, cultural or silvicultural practices. The question of protection arises only when pathogenic problems become aggressive and affect growth and the productivity of forest tree species. The areas of research priorities in forest pathology identified are as under:

DISEASE SURVEILLANCE OF FOREST TREE SPECIES IN ARID ZONES:

Relevance and importance of such research projects has already been outlined under Entomology and therefore, hardly needs any further emphasis for an organised research in disease surveillance of forest tree species in arid zones.

Not much is available on record in so far as forest pathology in arid zones is concerned. Many diseases of most of the plantations species occurring or being exploited for plantation forestry in arid zones have been recorded from other regions (Singh, 1988) which perhaps may also be occurring here as well. Therefore, the areas of research priorities in forest pathology identified as under are in line with and identified for Forest Research Institute, Dehra Dun.

FOREST SEED PATHOLOGY OF IMPORTANT TREE SPECIES OF ARID ZONES:

Quality of seed is the prime requirement for obtaining healthy planting stock in larger quantities for afforestation programmes. However, seeds of majority tree species are attacked by the seed borne fungi, which cause considerable losses during collection and under storage conditions, affecting their germinability seriously, necessary studies are therefore, warranted to safeguard the seeds of important tree species of arid zones against fungal deterioration, more particularly of seeds collected from seed orchards or seeds imported from abroad.

DISEASES OF FOREST NURSERIES IN ARID ZONES:

Diseases of serious nature in nurseries may upset the tree propagation programmes, affecting materially the production aspects. Therefore, study of nursery diseases will be necessary for growing healthy planting stock. Soil amendments should also be incorporated for effective control of diseases.

VAM AND RHIZOBIUM AND THEIR ROLE IN AFFORESTATIONS IN ARID ZONES:

Leguminous tree species are likely to be exploited for most of the afforestation programmes in arid zones, use of chemical fertilizers for increased biomass productivity is perhaps not a feasible preposition. However, VAM and *Rhizobium* can play an important role as biofertilizers in afforestation programmes for meeting the fuelwood and fodder requirements of the rural population. This Institute should undertake research programmes to standardise technologies for successful bulk culturing of VAM and *Rhizobium* and their application as biofertilizers under varied conditions in the Indian desert.

DISEASES OF FUELWOOD AND FODDER TREE SPECIES IN ARID ZONES:

Fuelwood and fodder tree planting, outside the forest areas, on all available land around agricultural fields, village wasteland, along railway tracks and all other lands unsuitable for agriculture or industrial plantations, is likely to be subjected to diverse types of diseases. Necessary research projects should be chalked out to study the diseases of forestry species likely to be exploited for afforestation.

Rodents:studies on ecology and control of rodents in arid zones

Apart from insect pests and diseases, the rodents are important pests in arid zones, particularly in agricultural fields and to a great extent in forest nurseries. Besides, ravaging sown seeds, they attack all stages of the growing stock. In areas, likely to be developed for forestry or pastures, along or near the agricultural crops, rodents can be a serious threat. In the Indian desert, about 17 species of rodents (Jain, 1980) have fully adopted to agri-silvi-pastoral-ecosystems, and have the capability of fast multiplication, building-up large populations in very short period. Among these, the desert gerbill, *Meriones hurrianae* is known to sustain water

stress for well over a year and have emerged as the most serious pest in arid zones.

The rodent damage in forestry occurs by way of debarking or completely slicing stem. Usually the corticle cells of the stem are debarked, hindering in the process, the growth of the plant. Sometimes, even the xylem portion is injured, resulting in death of the affected plant. Debarking activity is invariably confined to trees of 3-4 years age. No doubt, CAZRI has carried out pioneering work in studying the ecology of desert rodents and evolving effective control measures, but there is a need to complement efforts and monitor the activity of rodents in forestry crops.

The research projects prioritized above are only cited to focus attention on the importance and relevance of the thrust areas, requiring immediate action plans. However, there are still more areas uncovered but quite important and some of them are indicated below :

1. Taxonomy of organisms causing forest disease, maintenance of cultures, museum and harbaria collections.
2. Biological control of forest diseases and insect pests.
3. Microbial control and insect behaviour and insect growth regulators.
4. Timber entomology and timber pathology.
5. Biological control of weeds.
6. Post-entry quarantine measures/regulations for planting material imported from foreign countries and biological control agents.

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