CHAPTER VII

ARID FOREST RESEARCH INSTITUTE, JODHPUR

Arid Forest Research Institute, Jodhpur has the responsibility for meeting the forestry research needs of Rajasthan, Gujarat and Dadra Nagar Haveli. The primary objectives of the Institute are (i) to develop technology for desert afforestation with emphasis on evolving species and provenances of high yielding fodder and fuel, (ii) to develop agroforestry and agrisilvipasture models suitable for arid and semiarid regions, (iii) to develop technology for afforestation of sand dunes, saline and alkali lands, etc. (iv) to study the irrigated plantations in Indira Gandhi Canal Project area and (v) evolve package of practices for maximising production on sustainable basis.

In India, 10 per cent of the geographical area is occupied by hot desert, where low and erratic rainfall and high evapotranspirations, result in prevalence of severe moisture deficit conditions. A total of 31.7 m ha area distributed in the states of Rajasthan, Gujarat, Punjab, Haryana, Maharashtra, Karnataka, Andhra Pradesh is arid; of which 78.6 percent is in Rajasthan (61%) and Gujarat (17.6%) only. Extreme desertic conditions are localised in western Rajasthan which forms Thar desert.

The region of Thar desert has extremely dry hot climate with mean annual rainfall varying from 100 mm in north-western sector of Jaisalmer to 450 mm in western districts of Rajasthan. The mean maximum temperature is 40°C in summer, which at times goes upto 50°C. The mean minimum temperature varies from 14°C to 16°C, at times dropping down to 4°C in winters. Potential evapotranspiration is 7 to 9 mm/day in summer, 5.3 to 6.4 mm/day in monsoon and 1.8 to 2.9 mm/day in winter. Strong winds of 20 to 30 km/hr, going upto 130 km/hr during storms, dominate the region.

Soils of the region are shallow, sandy coarse textured, structureless, which besides being infertile are prone to wind erosion. Sand fraction varies from 90 to 95%, clay, 2 to 5% and silt, 1 to 2%. They are very poor in organic matter and nitrogen and medium in phosphorus. Several areas such as Rann of Kutch (Gujarat) and flood plains of the Ghaggar and Luni river system suffer from salinity varying from 4 to 16 dSm^{-1}. Sandy plains of Pachpadra, Pali and Deedwana have both alkalinity and salinity problems.

FORESTRY SITUATION

While the climatic and edaphic conditions in the region are unfavourable, the land use is not as per the principles of sustainable production. The forest cover is sparse, open and inadequate. Land under forests, land not available for cultivation, other uncultivated land excluding fallow land, fallow land and net area sown are 1.88, 23.85, 19.30, 11.72 and 43.25 per cent respectively, of the geographical area.

Forest area in this region of the country is very low. In Rajasthan, it is only 2.45 per cent of the total geographical area amounting to 0.04 ha per capita against the national average of 0.11. Moreover, the forests are in a highly degraded condition with low productivity. Scenario on demand indicates only 10 per cent demand being fulfilled from the recorded production from forests leading to a large gap of 1.65 m tonnes per annum of fuelwood for Rajasthan. There is similar deficit situation in Gujarat. The demand for fuelwood is so alarming that *Calligonum polygonoides* (phog) is fast disappearing from its native habitats due to removal of its root for fuel. This poses serious threat to the stability of sand dunes. The minimum requirement of fodder is 26.50 million tonnes as against anticipated total fodder production of only 10.5 million tonnes from all sources, leaving a chronic deficiency of 16.0 million tonnes annually. The fodder supply has to be increased by improving the productivity of fodder trees and grasses in silvipastoral or silvicultural system. The present productivity of grassland is dismally low.

Important research activities undertaken at the Institute and achievements during the year are as follows:

TREE IMPROVEMENT

To develop plant types with higher production potential and at the same time maintaining the traits of resistance to drought, heat, salinity, insect pests and diseases, research on various aspects of tree improvement such as provenance trials, tissue culture, progeny trials etc. has been done at the Institute.

Provenance Trials

The provenance trials on different tree species of arid region of India have been taken up which forms a very strong base for developing superior plant types suitable for desert afforestation.

Azadirachta indica (neem)

Recently, neem has assumed greater importance world over and has been designated as wonder tree for its enormous uses, exploitable by-products and services to mankind. Indeed, its potential has been foreseen by some scientists, in pest control, inexpensive medicines, as a source of contraceptive, environmental protection, controlling soil erosion besides daily needs of commons as fuel, fodder and timber. Foreseeing the demand of neem based products world over, its production needs to be enhanced by developing superior genotypes of high production potential. The Indian sub-continent provides a very large genetic variability and offers a tremendous scope for genetic gain in the species. Large variations have been reported in azadirachtin content (0.2 g/kg to 3.5 g/kg), growth and biomass production ranging from 10 to 100 tonnes per hectare.

Provenance trial of neem at the Institute, Jodhpur was started in 1992, which includes all the sources in Indian sub-continent and also from other countries like Thailand and Nepal.

Tree height taken after one year of planting indicates that the provenances from Indore and Ujjain performed best of all attaining 146 cm height as against only 45 cm by a provenance from Sawai Madhopur. This trial with very broad range of seed sources will be useful in identifying the provenance having high azadirachtin content besides higher yield of fodder and timber and their quality.

Height (cm) of one year old neem trees of different provenances

Seed lot No.	Source	Height (cm)	Seed lot No.	Source	Height (cm)
1	2	3	4	5	6
1.	Sawai Madhopur	45	20	Nagpur	118
2.	Katni	61	21	Jodhpur	120
3.	Sohagi	82	22	Jaisalmer	122
4.	Ranchi	90	23	Gandhi Nagar	123
5.	Muzaffar Nagar	96	24	North Bilaspur	124
6.	Pali	98	25	Kanpur (T,No.28)	124
7.	Shivpuri	99	26	Kanpur (T.No.48)	124
8.	Bikaner	100	27	Amravati	126
9.	Mulag	103	28	Kanpur (T.No. 46)	126
10.	Kota	104	29	New Delhi	131
11.	Gurgaon	104	30	Rajkot	135
12.	Mathura	105	31	Jhansi	135

Contd.

1	2	3	4	5	6
13.	Solapur	107	32	Pune	136
14.	Kanpur (T.N. 27)	109	33	Palanpur	137
15.	Maihar	112	34	Raipur	137
16.	Sikar	112	35	Ravinagar	139
17.	Satara	113	36	Rewa	141
18.	Hoshangabad	117	37	Ujjain	146
19.	Jabalpur	117	38	Indore	146

Acacia nilotica ssp. *indica* (babul)

Acacia nilotica is an important fast growing species of arid and semi-arid regions yielding fuel, fodder, timber, tannin, gum, etc. Almost every part of *Acacia nilotica* is useful. Besides being a rich source of several useful products, it improves soil fertility by fixing atmospheric nitrogen. In order to identify and develop superior genotypes of fast growth rate, better enhanced volume, better stem form, improved wood properties and resistance to diseases and insect pests, provenance trial on *Acacia nilotica* was started in 1991. Seeds of 28 provenances from different agro-climatic zones of the country were collected. The tree height attained by different provenances after 28 months show that tree height varies from a lowest of 101 cm in Akola provenance to the highest of 293 cm in Shivpur (Madhya Pradesh) provenance. The second best provenance was from Hastinapur (Uttar Pradesh) attaining 267 cm height. Very high variability exhibited by the provenances provides tremendous scope for genetic gain.

Growth of twenty eight month old trees of *Acacia nilotica* provenances

Seed lot No.	Source	Height (cm)	Seed lot No.	Source	Height (cm)
T_1	Hastinapur	267	T_{15}	Bilaspur	246
T_2	Hanikpur	167	T_{16}	Daud	215
T_3	Mathura	206	T_{17}	Gondpipri	228
T_4	Maunath Bhanjan	233	T_{18}	Sangli	227
T_5	Bareley	204	T_{19}	Solapur	223
T_6	Aligarh	256	T_{20}	Akola	101
T_7	Agra	262	T_{21}	Nangal	203
T_8	Makadanpur	191	T_{22}	Sirsa	262
T_9	Haldwani	261	T_{23}	Rajpipla	103
T_{10}	Etawah	248	T_{24}	Parlekhmundi	200
T_{11}	Shivpuri	292	T_{25}	Bolangir	204
T_{12}	Raisen	178	T_{26}	Gurgaon	268
T_{13}	Jhabua	210	T_{27}	Jodhpur	247
T_{14}	Naviakha	211	T_{28}	Jodhpur	187

Tecomella undulata (rohida)

Tecomella undulata is an important timber yielding species valuable for carving work and quality furniture. It is popularly known as "Marwar Teak". It's growth is very slow in nature and production of matured and utilizable wood takes very long time (50-60 years). However, wide variation in its growth exists in the nature, offering opportunities for its genetic improvement. The species is endemic to arid Rajasthan (Jodhpur, Jalore, Barmer, Jaisalmer, Nagour, Churu and Sikar districts).

To evaluate different provenances of *Tecomella undulata* (rohida) for growth, wood production and wood quality, a provenance trial with 13 provenances collected from different zones of its distribution has been initiated at Jodhpur. Variations in height at seedling stage, four and fourteen months after planting so that provenance from Harsawa registered the highest tree height of 142 cm and from Ghoshala the lowest height of 73 cm in fourteen months after planting.

Height (cm) of thirteen provenances of *Tecomella undulata* at Jodhpur

Seed lot No.	Source	At nursery stage	Months after planting	
			4	14
T_1	Mohangarh	13	40	110
T_2	Neemdi	11	43	111
T_3	Khatriyo ki beri	11	40	88
T_4	Jhalamand	13	41	88
T_5	Osian	16	46	115
T_6	Chohtan	14	39	100
T_7	Ratangarh	11	36	101
T_8	Ratannagar	12	37	106
T_9	Bhaislana	13	49	133
T_{10}	Katoti	11	37	138*
T_{11}	Sunderpur Bir	07	39	99
T_{12}	Harsawa	13	41	142*
T_{13}	Ghoshala	08	37	73
C.D. 5%	5%	02	08	

Plus Tree Selection

A survey was carried out to select plus trees of *A. tortilis*. The criteria for this was that the trees should have good stem form, superior height, good

diameter, good bole height, less of taper, narrow crown and resistance to insect pests and diseases. At Jati Bhandu (Jodhpur), about 110 ha of area consisting of *A. tortilis* was surveyed, 26 trees of *A. tortilis* were marked as plus trees having desirable characteristics as narrated above.

Exotic Acacias

The performance of different exotic acacias viz., *Acacia holosericia, A. ampliceps, A. adsurgens, A. coleims, A. bevinosa* and *A. victoriae* was studied. The results of this experiment show that the maximum height was observed in *A. bevinosa* (51.6 cm) followed by *A. ampliceps* (46.6 cm) and *A. victoriae* (43.1 cm) six month after planting in the month of January, 1994.

Mean height (cm) of different exotic Acacias six months after planting

Exotic Acacias	Mean Height (cm)
Acacia adsurgens	29.6
Acacia ampliceps	46.6
Acacia bevinosa	51.6
Acacia coleims	28.4
Acacia holosericea	32.8
Acacia victoriae	43.1

Vegetative Propagation

To develop the techniques of vegetative propagation, studies on different species were carried out with different hormonal treatment under mist chamber conditions. The treatment 100 IAA produced maximum shoots in *A. indica* (63%) and *Tecomella undulata* (81%).

In case of *Pongamia pinnata* and *Tamarix aphylla* the maximum shoot formation was due to 500 ppm IAA resulting in 66 per cent and 100 per cent shoot formation respectively

Response of *Azadirachta indica* and *Tecomella undulata* stem cuttings of different species to IAA and IBA treatments for 24 hours and raised under intermittent misting condition.

Concentration of auxins in ppm	*A.indica*	*T.undulata*	*P. pinnata*	*T.aphylla*
	Cuttings showing shoot formation per cent			
Control	8	16	24	68
100 IAA	63	81	50	88
200 IAA	40	38	56	88
500 IAA	20	31	66	100
100 IBA	18	56	-	-
200 IBA	13	56	-	-
500 IBA	10	52	-	-

Poplars

Vegetative propagation studies on 11 clones of *Populus* hybrids and *Populus euphretica* were conducted. Hybrid L14/82 showed the best performance under field conditions (Table).

Clones of poplars showing shoot formation (%)

Poplar Hybrids	No. of clones showing shoot formation	*Populus euphretica*	No. of clones showing shoot formation
L-27/82	30	L-36/32	22
L-34/82	25	L-14/82	50
S-7/C-8	-	G-3	-
S-48/111	-	L-39/82	30
L-66/82	33		
D-75	40		

Tissue Culture

The techniques of clonal propagation of superior genotypes or plus trees facilitate tree improvement at a faster pace. Cloning of superior genotypes is possible either by macropropagation (Vegetative propagation) or by micropropagation (Tissue culture). Vegetative propagation through stem/root cutting, air layering and grafting under mist conditions are the routine methods in forestry but these methods are having their own limitations and disadvantages. Therefore, there is a great need to adopt advanced techniques to obviate these problems.

In last one year, remarkable success has been achieved in establishing the *in vitro* culture of *Azadirachta indica* and *Anogeissus pendula*. Complete plants have been regenerated and plants of *Anogeissus pendula* and *Azadirachta indica* have been successfully transferred to soil. The protocols for two species, *Anogeissus pendula* and *Azadirachta indica* have been developed.

Anogeissus pendula (dhok)

Seeds were collected from healthy and selected trees of *A. pendula* from Ranthambore (National Park), and Sariska (Tiger Project Area), Rajasthan, India. Seeds are surface sterilized with 0.1-0.2% mercuric chloride for 5 minutes. Surface sterilized seeds are thoroughly washed with distilled sterilized water to remove the traces of mercuric chloride. Surface sterilised

seeds are inoculated on MS medium under aseptic conditions and kept in culture room for germination.

Apical shoot and cotyledonary nodal shoot segments are taken as an explant from the two week old *in vitro* raised seedlings. Cotyledonary nodal segment is better than apical shoot for multiplication. Murashige and Skoog's medium supplemented with 0.1mg/1 IAA and 1.0-2.5 mg/1 BAP induces around 5-10 shoots from the cotyledonary nodal segment within 4-5 weeks at 28+2 C temperature and 2000-2500 lux light for 10 h photoperiod.

In vitro induced shoots from the original explant can be further multiplied by subculturing isolated shoots or shoot segment on MS medium incorporated with 0.1 mg/1 IAA and 1.0-2.0 mg/1 BAP, and induces 3-5 shoots within 4 weeks. Cultures can be maintained in healthy state by subculturing periodically on fresh shoot multiplication medium.

Individual isolated shoots from the shoot initiation or multiplication cultures can be rooted on half strength MS medium incorporated with IBA 0.1 mg/1. About 90-95% of the shoots cultured on this medium induce roots within two weeks period.

Two to four weeks old rooted plants are transferred from test-tube to sterilized glass container (jar) containing autoclaved soil mixture i.e. perlite, vermiculate and sand (1:1:1). This soil mixture is supplemented with $1/5^{th}$ strength of MS basal salts medium. After four weeks of growth, these plantlets were transferred to soil mixture, where they grew normally.

Azadirachta indica **(neem)**

Multiple shoots (3-5 per explant) induced from the nodal region of explant (Nodal shoot segment) on MS medium supplemented with IAA 0.05 mg/1, BAP 2.5 mg/l within 4-5 Weeks under mixed light of 2500 lux for 10 h photoperiod. MS medium incorporated with IAA 0.1 mg/1+ adenine sulphate + activated charcoal induce 5-7 shoots per explant within 4-5 weeks period. Very small callus is induced from the cut base of the explant which hardly interfere in the potentiality of explant for shoot induction and its subsequent growth. Hypocotyl segment induces 10-15 shoots from the apical region (away from the medium) on MS medium fortified with 0.1 mg/1 IAA + 2 mg/1 BAP within five weeks. Length of shoots are reduced if BAP is added more than 2.0 mg/l. Differentiated shoots were transferred to shoot induction medium for further multiplication. Green cotyledon obtained from the *in vitro* raised seedlings induces direct shoots and somatic embryos from the surface of the cotyledon as well as from the cut surface on MS medium

incorporated with 0.1 mg/1 IAA/NAA + 0.5-1.0 mg/1 BAP. Large number of shoots (15-20) are induced from the cotyledon within 4-6 weeks.

Healthy shoots of 3-4 nodes (2.0-3.0 cm in length) are treated with (25-50 mg/l) IBA solution for 24 hrs followed by keeping on half strength MS hormone free medium induce 75-80 per cent rooting. After root initiation cultures are kept under 3500 lux light for 10 h photoperiod. Out of the various auxins like IAA, IBA & NAA, IBA is better for the high frequency (about 95 per cent) root induction from the differentiated shoots. Half strength MS basal salts medium fortified with low IBA induces roots within 2-3 weeks in more than 90 per cent cultured shoots of juvenile in nature.

Miniature plantlets with well developed tap root and lateral roots are taken out from the aseptic conditions and washed carefully to remove medium and adhered agar to avoid chance of infection under pot conditions. Solrite or Perlite, vermiculite and peat mass (1:1:1 v/v) are used as potting mixture. Potting mixture was autoclaved at 15 lbs for 45 minutes. Potting mixture is soaked in nutrient solution (1/4 strength of MS macro and micro element) or Hougland solution. Potted plants were hardened for two weeks in culture room. Nutrient solution was given after an interval of one week. Plantlets were watered daily for the first week and onwards alternate day. Within two-three weeks new shoot growth and leaves developed under artificial light (2000 lux for 10 h photoperiod). Around 80 per cent plantlets grew normal after pot transfer. After two weeks growth, these plants are transferred to soil mixture in poly bags.

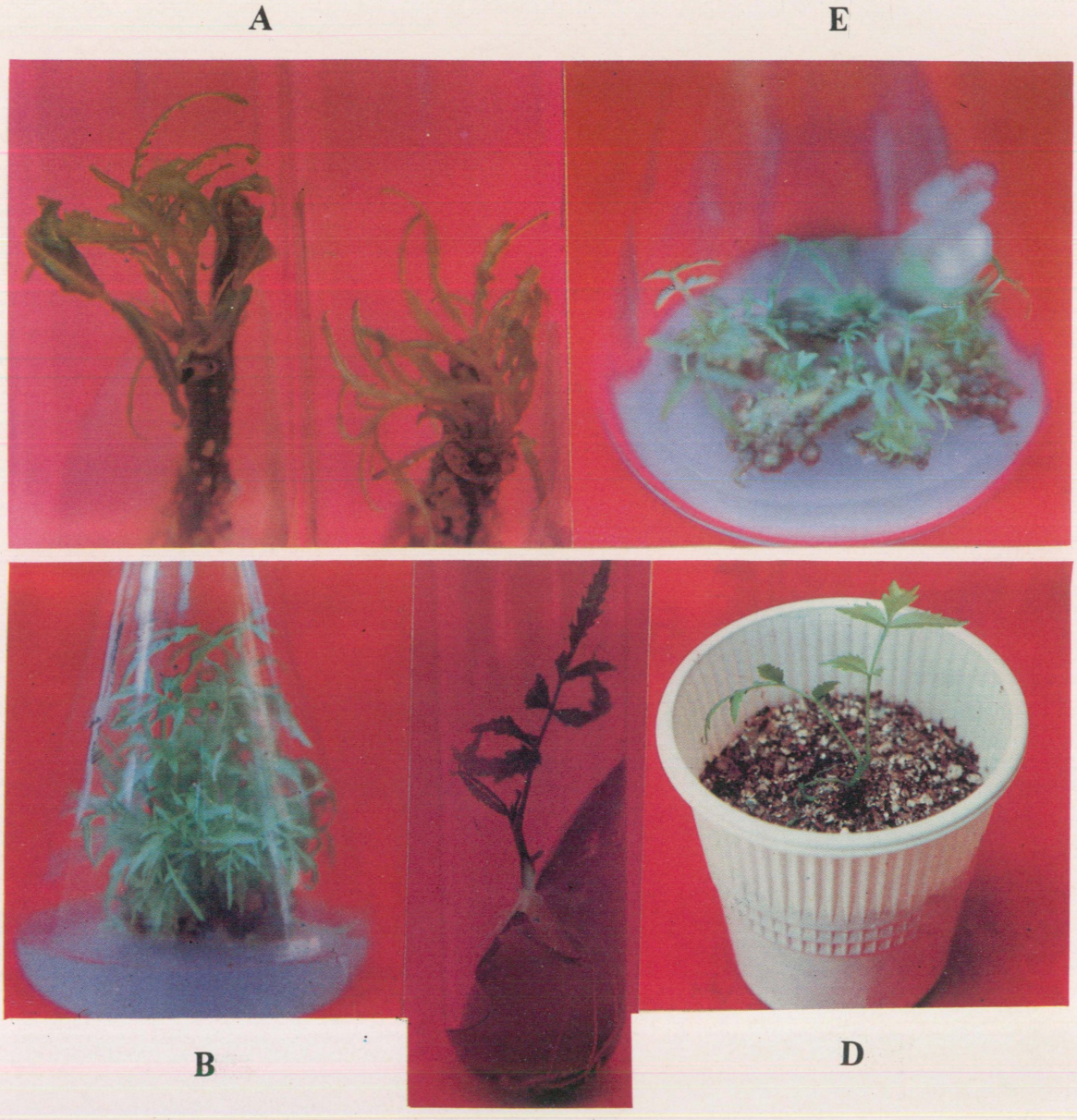
Phenological Studies In Neem

Studies on phenology of neem were taken up at various places in the country lying in different edaphic and climatic conditions. The study was initiated in April' 93 and data upto January' 94 were analysed to generate informations regarding fruiting and flowering time, maximum leafing period, seed availability time etc. at the different locations. Intensity of each observation was recorded visually as 0=nil; 1=slight; 2=moderate and 3=heavy. Following were the twelve different locations in the six agroecological zones where phenological studies were conducted.

1. ER-2: Hot arid western plains and Kucchh peninsula with desert and saline soils [Jodhpur and Jaisalmer in Rajasthan]

Provenance trial of *Acacia nilotica*

Provenance trial of *Tecomella undulata*



A. Shoots induced from nodal shoot segment.
B. Shoot multiplication from subcultured shoot.
C. Rooting of differentiated shoot.
D. *In vitro* hardening.
E. Multiple shoot formation through callus.

In vitro clonal propagation of *Azadirachta indica.*

2. ER-4: Hot semi-arid northern plains and central highlands with alluvium derived soils [New Delhi, Jaipur in Rajasthan, Allahabad in U.P., Ahmedabad in Gujarat]
3. ER-8: Hot semi-arid eastern ghats (TN uplands) and Deccan plateau with red loamy soils [Coimbatore in Tamilnadu and Bangalore in Karnataka]
4. ER-9: Hot subhumid northern plain with alluvium-derived soils [Pinjore in Haryana]
5. ER-10: Hot subhumid central highlands (Malwa and Bundelkhand) with medium and deep black soils [Jabalpur in M.P.]
6. ER-16: Hot subhumid Assam and Bengal plains with alluvium derived soils [Midnapore in W.B. and Jorhat in Assam]

Leafing

In general most of the trees were found to be in heavy leafing during May-October. The notable exception was in the case of northern plains represented by ER-4 and ER-9 where heavy leafing was observed in most of the trees even upto January. Otherwise it can be assumed that leaf shedding in general starts from November and the trees are back in full leafing by May.

Flowering

From the point of view of natural pollination flowering season is very important. At almost all the locations there is an appreciable drop in the percentage of flowering immediately after May. Some restricted flowering is indicated during August in ER-16.

Fruiting

The beginning of fruiting was studied by observing young fruits. It is observed that generally May- June is the season when fruiting starts in neem. Notable exceptions are (1) ER-10 where fruiting seems to have started before May itself and there is a fall in number of trees with young fruits from May onwards (2) ER-9 shows a fruiting peak at June-July. Thus a disparity in fruiting season is indicated for subhumid region. In arid regions the fruiting peak invariably lies in the May-June months. Some fruits appear in the month of Sept. also in ER-16.

Seed collection

This was studied by taking stock of the intensity of ripened fruits. Locations in semi-arid regions gave identical pattern of peak for ripen fruits-peaking in July. But in the arid region the peak is found a month earlier, that is in June. Thus the ideal time for seed collection is June and July for arid and semi-arid regions respectively. In ER-16, some ripened fruits are again available during Oct.-Dec.

In the subhumid regions the analysis show diversity in peak of ripened fruits. In ER-9 the peak is in July August whereas ER-10 and ER-16 show the peak in June. Moreover, in ER-16 many of the trees already have ripened fruits by May itself.

Phenological observations in neem

	Peak months *					
	ER-2	ER-4	ER-8	ER-9	ER-10	ER-16
	ARID		SEMI-ARID		SUBHUMID	
Heavy leafing	Jun-Sep	May-Dec	May-Oct	June-Jan	May-Dec	Jun-Oct
Flowering	Apr-May	Apr-May	May	Apr-May	-Apr	Apr-May
Young fruits	May-Jun	May	Jun	Jun-July	Apr-May	Apr-May
Green fruits	May-Jun	May-June	Jun-July	Jun-July	May	May-Jun
Yellow fruits	Jun	July	July	July-Aug	June	May-June
Fallen fruits	Jun	July	Jun-Aug	July-Aug	Jun-July	Jun

* Months in which atleast 50% of the trees under observation showed flowering, fruiting etc.

Nursery Technology

To produce the healthy seeding stock of arid zone tree species, studies were conducted on different soil mixtures and beds. The best seedling growth of *Acacia nilotica* and *C. mopane* was obtained with pond silt + FYM + coconut husk (5:5:1) on mud bed. *P. cineraria* seedlings attained maximum shoot height with pond silt + coconut husk on raised beds.

Percentage germination and shoot height of *A. nilotica*, *C. mopane* and *P. cineraria* grown in different soil mixtures.

Treatments	*A. nilotica*		*C. mopane*		*P. cineraria*	
	% Germination	Shoot height (cm)	% Germination	Shoot height (cm)	%Germination	Shoot height (cm)
1	2	3	4	5	6	7
T1S1	23.3	72	16.6	61	25.0	22
T1S2	23.3	87	26.6	72	28.3	30
T1S3	13.3	69	27.3	71	28.3	27
T1S4	16.6	70	20.0	69	20.0	21

Contd.

1	2	3	4	5	6	7
T2S1	23.3	57	20.0	53	38.3	31
T2S2	22.3	59	20.0	58	32.3	35
T2S3	20.0	62	16.6	42	38.3	28
T2S4	19.6	69	27.3	61	26.6	34
T3S1	16.6	56	25.0	36	23.3	24
T3S2	16.6	54	33.3	33	65.0	34
T3S3	16.6	53	16.6	40	66.6	41
T3S4	20.0	64	25.0	50	59.3	36

T1 - Mud Bed; T2 - Cemented Bed; T3 - Raised Bed

Potting Mixtures: S1 - Pond Silt + FYM (1:1), S2 - Pond Silt + FYM + Coconut Husk (5:5:1), S3 - Pond Silt, S4 - Pond Silt + Coconut Husk (2:1)

BIOFERTILIZERS

VAM associations play significant role in nutrient supply, particularly phosphorous. Studies were undertaken at the Institute to identify the beneficial strains. Roots and rhizosphere soil samples of 30 different tree species belonging to 16 families were collected from various forest nurseries and plantations in Rajasthan for studying VAM fungal association and extent of root colonization. It was found that, all the rhizosphere soil samples contained VAM fungal spores. Based on the spore characters, following fungi were identified: *Glomus aggregatum, G. fasciculatum, G. fulvus, G. intraradices, G. microcarpum, G. monosporum* and *Gigaspora* sp. Among these fungal species observed, *G. fasciculatum* was found in most of the rhizosphere samples of different tree species (about 22) followed by *G. monosporum* (15 tree species) and *G. aggregatum* (10 tree species). The species of the genus *Gigaspora* was found only in the rhizosphere of three tree species viz., *Prosopis cineraria, P. juliflora* and *Tecomella undulata.*

Occurrence of VAM fungi in the roots and VAM fungal propagules in the rhizosphere soil samples of different tree species collected from various nurseries of Rajasthan

S. No.	Plant species	Family	Presence or Absence of VAM infection in roots	Presence or Absence of VAM fungal spres in soils
1	2	3	4	5
1.	*Acacia leucopholea*	Mimosaceae	***	* (2), (5)
2.	*A. melanoxylon*	"	**	* (1), (3)
3.	*A. nilotica*	"	***	* (2), (5)
4.	*A. senegal*	"	****	* (2), (3), (5)

Contd.

1	2	3	4	5
5.	*A. tortilis*	"	***	* (1), (3)
6.	*Ailanthus excelsa*	Simaroubaceae	**	* (2)
7.	*Albizia lebbeck*	Mimosaceae	***	* (1), (5)
8.	*Azadirachta indica*	Meliaceae	***	* (2), (5)
9.	*Bauhinia variegata*	Caesalpiniaceae	***	* (2), (5)
10.	*Cassia fistula*	"	****	* (2), (3), (4), (5)
11.	*Cassia siamea*	"	**	* (2)
12.	*Citrus aurantifolia*	Rutaceae	**	* (2), (3)
13.	*Cordia myxa*	Ehretiaceae	**	* (5)
14.	*Dalbergia sissoo*	Fabaceae	***	* (1), (2)
15.	*Delonix regia*	Caesalpiniaceae	ND	* (1), (5)
16.	*Dendrocalamus* sp.	Poaceae	**	* (2)
17.	*Eucalyptus camaldulensis*	Myrtaceae	****	* (1), (2), (4), (5)
18.	*E. tereticornis*	"	****	* (2), (4), (5)
19.	*Ficus religiosa*	Moraceae	ND	* (1), (3)
20.	*Leucaena leucocephala*	Moraceae	***	* (2), (3), (4), (5)
21.	*Moringa oleifera*	Mimosaceae	***	* (2), (3)
22.	*Polyalthia longifolia*	Annonaceae	ND	* (1)
23.	*Pongamia pinnata*	Fabaceae	***	* (2), (4)
24.	*Prosopis cineraria*	Mimosaceae	***	* (2), (5), (6)
25.	*P. juliflora*	"	***	* (2), (4)
26.	*Sisymbrium irio*	Brassicaceae	***	* (2)
27.	*Syzygium cumini*	Myrtaceae	**	* (2), (5)
28.	*Tecomella undulata*	Bignoniaceae	**	* (2), (5), (6)
29.	*Ziziphus* sp.	Rhamnaceae	***	* (1), (2)
30.	*Ziziphus mauritiana*	"	***	* (1)

*= 0-25%; **= 26-50%; ***= 51-75%; ****= 76-100%
ND= Not Determined, Infection Positive

1. Glomus aggregatum, 2. G. fasciculatum, 3. G. intraradices, 4. G. microcarpum, 3. G. monosporum and 6. Gigaspora sp.

VAM fungi in plantations

Occurrence of VAM fungi in the rhizosphere soils under the root zone of *A. tortilis, A. indica, P. cineraria, P. juliflora* and *T. undulata* were screened for the isolation of VAM fungal spores. A total of 12 fungal species were identified from the rhizosphere of different tree species studied. *Glomus fasciculatum* was the most dominant fungus and occurred ir the rhizosphere of all the tree species. The other fungi such as *Gigaspora* sp. was isolated from the rhizosphere of *A. tortilis, P. cineraria, P. juliflora* and *T. undulata* and *Sclerocystis* sp was isolated from the rhizosphere under the root zone of *A. tortilis* and *A. indica.*

Distribution of VAM fungi in the rhizosphere soils of different plantations in Rajasthan

VAM fungi	Tree plantations				
	Acacia tortilis	*Azadirachta indica*	*Prosopis cineraria*	*Prosopis juliflora*	*Tecomella undulata*
Glomus aggregatum	-	*	-	-	-
G. fasciculatum	*	*	*	*	*
G. fulvus	*	*	*	*	*
G. intraradices	*	*	-	*	*
G. macrocarpum	*	*	*	*	*
G. microcarpum	*	*	*	-	*
G. monosporum	-	*	*	-	*
G. occultum	*	*	*	-	*
Glomus sp. 1	*	*	*	*	*
Glomus sp. 2	*	-	*	-	*
Gigaspora sp.	-	-	*	*	*
Sclerocystis sp.	*	*	-	-	-

* = Present; - = Absent

Mass Inoculum Production of VAM fungi

Pure culture and mass inoculum production of different VAM fungal isolates/ strains (both indigenous and FRI strains) were made for further experimental studies. This experiment is under progress.

Interaction of VAM fungi with rhizosphere and rhizoplane mycoflora in arid zones.

An experiment was conducted to study the interaction of VAM fungi with rhizosphere and rhizoplane mycoflora of certain important arid zone tree species viz., *Acacia nilotica, A. senegal, A. tortilis* and *Prosopis cineraria* under labortatory conditions. The results of this study revealed the fact that the mycoflora of rhizosphere and rhizoplane was found to be very less in VAM inoculated when compared to uninoculated (control) plants of all the tree species studied. It was seen that most of the pathogenic fungi such as species of *Cylindrocladium, Fusarium, Fusarium oxysporum, Rhizoctonia bataticola* and *R. solani* were suppressed or completely eliminated from VAM inoculated plant roots and the rhizosphere soil samples.

MOISTURE MANAGEMENT

Moisture limits the growth of plantations in arid region. Rain water, which is the main source of water for plantations, needs to be harvested and

conserved to make it available for tree growth throughout the year including water deficit period of 9 to 10 months in a year. The institute is carrying out studies on different techniques of rain water harvesting and conservation.

Various techniques of soil surface alterations are being studied at the Institute. Out of the various techniques, the ridge and furrow structures have been found to be very effective for *A. indica* and caused improvement in tree height from 198 cm to 387 cm and in collar circumference from 20 to 37 cm at three and half years of age. Biomass yield improved from 21.04 to 71.50 per ha. Bigger saucers/ saucers pits were also very effective in run-off collection and improved the height of *A. indica* from 131 to 231 cm in an initial period of 18 months.

P. cineraria (Khejri) on ridge and furrow structures (T_8 treatment) was 206 cm tall and 16 cm thick (collar circumference) producing 17.89 qha^{-1} total biomass as compared to 157 cm 12 cm and 12.58 qha^{-1} respectively, in control. In case of Rohida, trees on ridge and furrow structures were 208 cm tall, 16 cm thick yielding 21.75 q ha^{-1} biomass compared to 161 cm, 14 cm and 7.71 qha^{-1}, respectively, in control (See Table). *Albizia lebbeck* registered highest growth on rig pits, the height increase being 130% (See Table). Thus water harvesting structures played paramount role in maintaining higher soil moisture regime and better tree growth. A mild winter shower in January resulted in storage of double the moisture (9.3%) in top layer of T_8 treatment as compared to control (4.3%).

Very high PET in arid region results in rapid loss of stored moisture in the form of evaporation. Institute has undertaken work on use of mulches in establishing arid zone plantations. Use of *Crotolaria burhia* caused about 50% height increase and 40% girth increase in *A. indica* and 40% height increase in *T. undulata* three and half years after planting. Other tree species *Albizia lebbeck, Acacia nilotica* and *Acacia planifrons* registered 15 to 20% height improvements in 30 months period after planting.

Influence of rainfall harvesting and conservation practices on total biomass yield (qha^{-1}) of 3 year old plantations

Treatments	*A. nilotica*	*P. cineraria*	*T. undulata*
1	2	3	4
T_1-Control	21.04	12.58	7.71
T_2-Weed Removal (W.R.)	57.08	10.50	10.91

Contd.

1	2	3	4
T_3-W.R. + Soil Working (S.W.)	39.96	12.40	10.69
T_4-W.R. + S.W. + Saucers of 1.0m dia	50.06	16.0	12.56
T_5-W.R. + S.W. + Saucers of 1.5m dia	62.96	18.48	19.74
T_6-W.R. + S.W. + Saucers + mulching with dead plant material	48.85	17.85	20.98
T_7-In situ water harvesting structure in checker board	55.65	15.39	15.32
T_8-Ridge and furrow structures	71.50	17.89	21.75

Weeds are another source causing significant loss of stored moisture which, if conserved, could be productively used for improving tree growth. Studies indicate that weed removal (T_2) resulted in height increase from 298 to 392 cm in *A. indica* from 157 to 199 cm in *P. cineraria* and 161 to 250 cm in *T. undulata.*

Growth of three and half yr old trees due to different Water harvesting and Conservation treatments

Treatments	Neem		Khejri		Rohida	
	Height (cm)	Girth (cm)	Height (cm)	Girth (cm)	Height (cm)	Girth (cm)
T_1	298	20	157	12	161	14
T_2	392	27	199	15	200	16
T_3	364	24	142	12	206	16
T_4	372	27	197	15	204	16
T_5	379	25	191	15	196	16
T_6	398	28	177	13	221	16
T_7	376	25	162	12	185	15
T_8	387	37	206	16	208	16

T_1 : Control, T_2 : Weed Removal (W.R.), T_3 : W. R. + Soil Working (S.W.), T_4 : W. R. + S. W. + Saucers of 1.0m dia, T_5 : W. R. + S. W. + Saucers of 1.5m dia, T_6 : W. R. + S. W. + Saucers + mulching with dead plant material, T_7 : In situ water harvesting structure in checker board, T_8 : Ridge and furrow structures.

Influence of various soil working techniques on height (cm) of 18 month old trees

Treatments	Tree species		
	A. lebbeck	*A. indica*	*P. cineraria*
Ordinary pits	98	131	29
Saucer pits	186	231	106
Ring pits	230	191	74
Trench cum mound	99	145	70
Trench and mound	203	230	74
Deep ploughing + pitting	135	204	48

Water Management Under Constrained Water Supply

In arid regions, it is a common practice to apply small quantities of water to the younger plantation for their better establishment and growth. However, no information is available on the optimum number of waterings to be given for efficient utilization of scarce water. Therefore, a field experiment was initiated in July 1991 to study the response of different tree species to varying number of waterings.

With increasing number of waterings, growth of trees enhanced concomitantly. The maximum response to watering was exhibited by *A. nilotica* which was 323 cm tall when number of waterings was ten, as compared to 261 cm in control. (See Table) *A. nilotica* also displayed maximum response to ten number of waterings registering an average height of 255 cm as compared to 217 cm in control. In the case of *A. lebbeck, A.inita* and *P. cineraria* four waterings per annum were optimum, increasing the tree height from 201 to 229 cm, 164 to 184 cm and 77 to 92 cm. Though increasing the number of waterings further increased the tree height, the magnitude was less, therefore, not advisable on economic grounds.

Height (cm) of 30 month old trees as influenced by different levels of watering and mulching

Treatments	*A. indica*	*A. lebbeck*	*A. planifrons*	*A. nilotica*	*P. cineraria*
W_0	261	201	164	217	77
W_2	273	209	178	231	81
W_4	275	229	184	233	92
W_6	284	231	184	239	102
W_{10}	323	234	191	255	114

W_0 : No watering, W_2 : Two watering (September and March), W_4 : Four watering October, January, March and May), W_6 : Six watering (October, December, February, April, May and June) and W_{10} : Ten watering (Monthly September onward).

Sand Dune Stabilization

Indian arid region in western Rajasthan is predominantly covered by sand dunes, occupying about 58 per cent of the geographical area of the region. They are largely moving sand dunes posing serious wind erosion problems, resulting in siltation of canals and wells, blocking road and railway tracks, engulfing agricultural fields and habitations and polluting the environment. Stabilization of these sand dunes is very important not only to protect the establishments and environment but also to improve productivity from

them to supplement fodder, fuel and timber requirement in the region. The Institute has done considerable work on techniques of sand dune fixation. While the micro-wind break technique of fixing mulching material of local shrubs has been successful in checking sand movement and burial of seedlings, the results of an experiment on species suitability further confirmed that *Prosopis juliflora* attained best growth in terms of height and girth (271 cm and 18.1 cm respectively) followed by *A. tortilis* (237 cm and 14.2 cm) and *A. planifrons* (129 cm and 9.1 cm), respectively.

REHABILITATION OF REFRACTORY SITES

Arid Saline Soils with Atriplex (Salt bush)

Problem of salinity and alkalinity is wide spread in arid part of Rajasthan and about 0.44 million hectare of land is affected by primary salinity. Most of it lies in the area where good quality irrigation water is not available, thus traditional solution such as leaching and drainage are ineffective. Considering the pressure on the land for producing fuel, fodder and other biomass these arid saline lands need to be made productive by revegetating them with useful species and by developing site specific reclamation measures. Since growth of locally occurring species is very slow and biomass production is poor, some exotic salt bushes were introduced at one of such sites in Kaparda village (Jodhpur district) in Luni basin. Two species of *Atriplex (A. lentiformis* and *A. amnicola)* were tried. The trial involved study of the growth of Atriplex species vis a vis local species (*Salvadora oleoides, Tamarix aphylla, Prosopis juliflora*) as affected by soil management practices such as mixing of gypsum, farm yard manure, drainage, fertilizer application, replacing with good soil, etc.

Out of the two species of salt bush, *Atriplex lentiformis* performed much better in terms of growth and biomass. It attained considerable size after 6 months of planting. While untreated bushes attained a height of 83 cm and crown diameter of 117 cm, the same for treated bushes varied from 90 to 95 cm (height) and 120 to 137 cm (crown diameter) in various treatments. *A. amnicola* in treated plot was 49 to 62 cm tall and in untreated plots 53 cm tall. There was no crown formation during this period. The treatment effect was tremendous in the subsequent 6 months for *A. lentiformis.* After one year of planting *A. lentiformis* in T_5 treated rows were taller by 24 per cent and had 41 per cent greater crown diameter than the untreated bushes which were 98 cm tall and had 114 cm crown diameter. However, for *A. amnicola* treatment effects were not pronounced in the first year. It attained a maximum average

height of 68 cm due to T_3 treatment (replacement of pit soil with good soil) followed by 66 cm in control. While comparing the two species attained less than half the growth of *A. lentiformis.*

Growth performance of one year old *Atriplex lentiformis* and *Atriplex amnicola* on an arid salt land as affected by different treatments

Treatments	*Atriplex lentiformis*		*Atriplex amnicola*	
	Height (cm)	Crown diameter (cm)	Height (cm)	Crown diameter (cm)
T_1	98	114	66	64
T_2	108	140	61	45
T_3	125	150	68	59
T_4	113	149	61	58
T_5	123	161	60	73

T_1 : Control, T_2 : Gypsum (10 t ha^{-1}), T_3 : Gypsum + Drainage, T_4 : Replacement of pit soil with good soil + FYM (5 kg $plant^{-1}$) and T_5 : Gypsum + Drainge + FYM + Nitrogen (15 g urea $plant^{-1}$) + Zn (7 g $ZnSO_4$ $plant^{-1}$)

Influence of different treatments on biomass production of one year old *Atriplex lentiformis* was dramatic. Total dry biomass production as a result of the T_5 treatment increased 6.4-fold (2690 kg/ha as compared to 419 kg/ha in the control). The magnitude of increase was higher (9-fold) in the foliage mass (641 kg ha^{-1} dry foliage in T_5 as compared to 70 kg/ha in the control). Wood mass (total dry shoots) of one year old bushes showed an increase from 349 kg/ha to 2049 kg/ha as a result of the T_5 treatment.

Response of indigenous species to various treatments was not significant. The maximum average height attained by *S. oleoides* was 60 cm. *T. aphylla* 81 cm and *P. juliflora* 118 cm. There was no crown formation for these species during the first year of their establishment.

AGROFORESTRY MODELS

Practice of agroforestry is an age old practice in arid regions, to provide sustainability to the production system. However, to optimise production from arid lands, information on proper tree density and tree-crop combinations is imperative. With this view, studies on different agroforestry models were taken up. Three different densities of trees were 1600, 800 and 400 per hectare. Tree species were *Prosopis cineraria* and *Tecomella undulata.*

The crop sequence was Guar-Moong-Pearlmillet. In 1993, pearlmillet was the inter crop. Due to prevalence of long dry spell of two months, 10th July to 10th September, the pearlmillet crop failed to reach maturity.

Growth of trees was favourably influenced by inter crop. As compared to 178 cm tall and 13.4 cm thick (collar circumference) trees of *P. cineraria* in uncropped plot, the trees in cropped plot were 195 cm tall and 14.5 cm thick. (See Table). Growth of *Tecomella undulata* is not influenced by inter crop. Trees in cropped plot were 171 tall and 13.1 cm thick as compared to 13.3 cm in uncropped plot.

Tree density, however, had appreciable influence on growth. When tree density was 1600, *Prosopis cineraria* was 161 cm high and 11.6 cm thick as compared to 222 cm high and 16.5 cm thick with the density of 400 trees/ha/ (See Table). In case of *Tecomella undulata*, tree height reduced to 148 cm and girth to 11.1 cm due to higher density of 1600/ha, from 192 cm and 14.9 cm, respectively, due to lower density of 400/ha.

Managing industrial effluent for tree establishment

The experiment was initiated with the aim to find out the suitability of industrial effluent for tree establishment. The plantation of seven different tree species viz. *Acacia nilotica* (T_1), *Acacia tortilis* (T_2), *Albizia lebbeck* (T_3), *Azadirachta indica* (T_6) and *Prosopis juliflora* (T_7), was done in July, 1993. The industrial effluent was analyzed for its composition and characteristics and was applied to trees.

Chemical Composition of Textile Effluent of Jodhpur

Parameters	Range
1	2
pH	8.8-11.8
EC (dSm^{-1})	3.8-10.7
RSC ($meqL^{-1}$)	12-125
SAR	30-850
Phenolphthalein alkalinity ($mgCaCO_3/L$)	49-5200
Total alkalinity ($mgCaCO_3/L$)	560-6200
Chemical Oxygen Demand (mg/L)	160-800
Ionic Compositions (in ppm)	
Sodium	600-5500
Potassium	25-80
Calcium	Traces

Contd.

1	2
Magnesium	Traces
Copper	0.071-0.748
Zinc	0.011-0.537
Iron	Trace-0.67
Manganese	Traces
Lead	Traces-0.134
Cadmium	Traces
Cobalt	Traces
Carbonate	29-3162
Bicarbonate	280-630
Chloride	410-1050
Phosphate	0.5-5.1
Sulphate	100-320

BIOPESTICIDES

Fresh ripened neem fruits were collected from trees in and around Jodhpur during fruiting season and the kernels were shade dried after removing the pulp. The dried kernels were decortified and ground to powder, then used for extraction. The experiments were laid against *Taragama siva*, the babul defoliator.

i. Antifeedant Activity

The antifeedant activity exhibited by extracts of different solvents at the tested concentrations were studied. The amount of leaf consumed after 24hr ranged from 0.16g/larvae in 0.05% concentration of methanolic extract of NSKP to 1.24g/larvae in control. Similarly at 48hr the amount of leaf consumed per larva varies from 0.23g in 0.05 concentration of methanolic extract of NSKP and 1.92g in control. The antifeedant activity at 48hr is lowest being 16.00, 13.30 and 13.30 respectively at 0.05, 0.01 and 0.005 per cent concentrations of chloroform extract of NSKP. Antifeedant activity at 48hr is maximum being 84.00, 80.30 and 75.00 respectively at 0.05, 0.01, and 0.005 per cent concentrations of methanolic extract of NSKP followed by ethanol and water being 77.60 and 62.00 percent respectively at the concentrations of 0.05 per cent. The efficacy of different extracts in terms of antifeedant activity in the ascending order is Chloroform, Petroleum ether, Acetone, Water, Ethanol and Methanol.

ii. Activity on Eggs

Data on inhibition of hatching of eggs dipped in different aqueous concentrations of methanolic extract of NSKP on the eggs of *T. siva* was

investigated. More than 56.3 per cent mortality of eggs was noticed at 0.3 per cent concentrations and resulted in the emergence of only 26.6 percent of adults.

iii. **Activity on Larvae**

The activity of methanolic extract of NSKP against second and third instar larvae of *T. siva* fed for two days on treated leaves dipped for 30 seconds. At 24hr by 0.01 to 0.10% concentration no larval mortality could be achieved in the case of second instar larvae and in the case of third instar larvae no mortality could be achieved at 24hr upto 0.05% concentrations of methanolic extract. At 0.001 and 0.05% concentrations the combined mortality of larval, pupal and adult stages were less being respectively 50 and 60% in the case of second instar while it was only 40% in the case of third instar. But a good level of combined mortality of larval pupal and adult stages was observed at 0.3% concentration being 90% in the case of second instar and 83.3% in the case of third instar.

Further at the 0.3% concentration pupae were formed without cocoon and in some cases the cocoon formed were very small compared to control indicating the growth development and regulation property of NSKP extracts.

Azadirachtin content of neem

Neem seeds were collected from all the nine agro-climatic zones of Rajasthan for study of their azadirachtin content. Preliminary studies on the physical properties viz. seed weight, seed kernel (ratio) of seed revealel that the seed index was maximum in agro climatic zone IV B and minimum in zone II A. A little variation was found in the weight of seed kernel obtained from 100 gms of seed in all the nine agroclimatic zones. It was found almost directly proportional to the seed weight.

Sequential extraction of seed, branches, bark and wood of *Capparis decidua* with petroleum ether, chloroform and methanol was carried out and percentage yield of each extract was found out. Results of preliminary experiments to evaluate the biocidal activity of the pet. ether extract of branches of *Capparis decidua* against *Tetranychus* sp. (Red spidermite, a common pest of neem), using various concentrations of extract was very encouraging, Further work to evaluate the efficacy of other extracts as biocide is continued.

FOREST PROTECTION

Biological Control of Insect Pests

Laboratory and field studies on the nuclear polyhedrosis of lepidopterous insect pests were carried out to understand the insect-virus relationship. The cross infectivity tests against the larvae of *Achaea janata, Atteva fabriciella, Catopsilia crocale, Eligma narcissus* were also conducted.

Insect Pest Problems of Neem

Defoliators

Laspeyresia koenigiana Fabr.: This is one of the important defoliator of Neem. The infestation of *L. koenigiana* was recorded in almost all the neem plantations and nurseries. The moths lay eggs on the tender superimposed shoots and continue this habit through out the process of development. Many immature stages dies due to heavy quantity of gum exudation. The apical growing shoot develops a callus structure due to excessive gum exudation or probably to secondary fungus infection caused by *Candida* species as a result of which plant exhibit a forked appearance.

Control of this pest was achieved by spraying Rogor 30 EC (0.02%) in combination with Blitox (0.05%) and Vipul @ 2ml/ltr.

Sap suckers

Helopeltis antonii Signoret: The apical shoot of young plants were noticed to be heavily attacked by *H. antonii*. This reddish brown active capsid bug has been found to cause severe infestation to Neem plantation. Both the adult and immature stages of this bug suck the sap from the tender shoots and leaves and inject a phytotoxin into the plant system. The injury made by the suctorial mouth parts of the pest caused the tender shoot to exude a resinous gummy substance which on exposure to air gets hardened. Within a short time after sucking , the surrounding tissues became necrotised and brown to black patches are formed, presumably due to the action of phytotoxin present in saliva. In severly infested plants, the flush dries up and the whole plant present a scorched appearance.

The average damage of *H. antonii* in all neem plantations of Gujarat from January to April is estimated to be 10 to 15 percent. Spraying of Rogor

(0.02%) in combination with Bilotox (0.05%) gave a promise of successful control.

Aohidiella orientalis Newstead - Severe infestation of *A. orientalis* is noticed in all the neem plantations of Gandhinagar and Mehsana (Gujarat), Jodhpur, Barmer, Ajmer (Rajasthan). It is a polyphagous armoured scale insect. The insects form large colonies over the stems, branches and sometime spread to foliage. In severe infestations the leaves of the young plants are shed resulting die back of plant. Prunning and removal of infested parts of plant along with the insect colonies may check the further attack. In case of severe attack spray of Monocrotophos (0.02%) is recommended for successful control.

Among the less serious pests are defoliating catepillar, *Eurema* sp., leaf thrip, *Heliothrips haemorrhoidalis* (Bouche) and termite, *Odontotermes obesus* Rambur have been recorded to cause severe damage in certain sections of different districts. Adoption of suitable insecticidal control operations against *L. koenigiana* and *H. antonii* infesting neem at Gandhinagar and Mehsana was thought to be desirable and more economical. Two rounds of spraying were conducted at the time of emergence of new shoots. These sprays were noticed to be very effective against other minor pests which infest tender shoots and leaves.

Non Insect Pests

Besides insect pests one species of mite *Tetranychus* sp. was observed feeding on tender leaves of *Azadirachta indica* at seedling stage. Two species of Mollusc *Laevicaculis alte* and *Machrochlamys indica* were also found damaging neem seedlings (10-25%) in different forest nurseries in and around Jodhpur.

Morphology, bionomics and control of babul defoliator *Taragama siva*: *Taragama siva* is a polyphagous Lasiocampid moth and infests a number of tree species. Field observations revealed that the host- range of the pest comprises : *Acacia nilotica; Acacia senegal; Acacia tortilis; Ailanthus excelsa; Citrus sp. Colospermum mopane; Moringa oleifera; Prosopis cineraria; Prosopis juliflora; Tamarindus indica; Tecomella undulata; Ziziphus mauritiana; Parkinsonia* sp. and *Caligonum polygonoides.*

In August and September infestation was observed very serious. *Prosopis juliflora; Moringa oleiflora* and *Ziziphus mauritiana* have been found completely defoliated due to the heavy attack of voracious feeder larvae of *Taragama siva,* which were in thousands on a single tree. In cage

condition complete defoliation was observed in *A. senegal; A. tortilis; M. oleifera; P. cineraria; P. juliflora; Z. mauritiana.*

Detail morphology and bio-ecology of *T. siva* was studied in the laboratory and field conditions.

Natural enemies of *T. siva*: Random samples of larvae & cocoon have been collected from field. Analysis of the thousands of cocoon and larvae revealed that about 14% mortality of larvae and pupae was caused by the natural enemies including Dipterous larval parasites and viral infection.

Patialus tecomella Pajni: *Tecomella undulata,* commonly known as marwar teak, is the most promising forest tree species of the arid and semi-arid regions of India. *T. undulata* is frequently severely attacked by a curculionid weevil which causes complete skeletonization of leaves leaving veinlets intact of the young saplings. Heavy damage results in the untolerable loss due to growth retardation or on some occasion the mortality of young saplings. *Patialus tecomella* belongs to a new species under a new genus of the subfamily Cioninae of the family Curculionidae (Coleoptera). The pest has been authentically identified as *Patialus tecomella.* Adult weevils are brownish -grey, minute in size ranging from 3 to 4mm. The adults and larvae feed on the leaves. The eggs are laid in the form of ootheca containing 8 to 11 eggs per ootheca. Larvae on emergence start feeding on young leaves. Pupation takes place in soil or in fallen leaves. Complete life cycle lasts in 21 to 27 days. Detail investigations on the morphology, bioecology and management of *P. tecomella* have been conducted.

Seed Borne Microflora and their Management

Research on arid zone tree species viz. *Acacia nilotica, Albizia lebbeck, Azadirachta indica, Prosopis cineraria* and *Tecomella undulata* have been taken up for the study of seed borne mycroflora. The seed samples were collected from various regions of Rajasthan and Gujarat. The seed samples were studied by moist blotter and Agar plate techniques. Surface mycoflora i.e. *Aspergillus niger, Aspergillus flavus* and *Penicillum* sp. were found associated in seeds of all the tree sps. Pods and seeds of *Acacia nilotica* were found severely attacked by *Aspergillus flavus* and *A. niger.* The pods which were damaged by birds were noticed severely infected by the fungus. Seed infection by Botryodiplodia theobromae, Fusarium sp and Alternaria tenuis were also recorded in *Tecomella undulata* pods and seeds from arid areas of Rajasthan.

Seeds of mandate tree sp. were treated with various fungicidal soln. viz., Captaf (0.2%); Foltaf (0.2%); Bavistin (0.1%); Fytolan (0.2%); Blitox (0.2%);

Sultaf (0.2%); Wetsulf (0.2%); and Hot water treatment at 50 c for half an hour The efficacy of Foltaf (0.2%); Captaf (0.2%) were found quite effective to inhibit the surface mycoflora in storage conditions.

Nursery Diseases and their Management

i. Damping off disease due to *Rhizoctonia solani* has been noticed in Eucalyptus from Mehsana, Gandhinagar (Gujarat) causing 50-60% mortality in seed beds.

ii. Wilt disease caused by *Fusarium* sp. was noticed on *Dalbergia sissoo, Eucalyptus, Cassia siamea, Acacia tortilis, Prosopis juliflora* and Neem in high moisture conditions. The loss due to this disease was estimated between 20-25% in various tree sps in polythene bags. The disease could be managed by seed treatment with Emison 6 (0.1%) or Captan (0.2%). Soil drenching with Bavistin (0.1%) or Dithane Z-78 (0.2%) was found effective in reducing the incidence of the disease in polypots.

iii. Charcoal root rot disease was first time noticed on *Prosopis juliflora* from AFRI nursery Jodhpur. The loss due to this disease was noticed about 50-60% in beds and 5-10% in polythene bags.

iv. The seedling blight is the most prevalent disease, was observed in 4-6 months seedlings of neem, amla and *Cassia siamea* from arid areas of Rajasthan. The incidence of disease was recorded about 75% in amla (*Emblica officinalis*). 60% in *Cassia siamea* and 30-40% in neem in various nurseries raised by state forest nurseries and at AFRI nursery, Jodhpur. Three pathogens viz. (I). *Phoma* sp. (II). *Colletotrichum* sp. and (III). *Alternaria* sp. have been noticed in various hosts . For immediate control of the disease in neem , Bavistin 0.1% as soil drenching was applied at monthly interval, other fungicide Foltaf 0.2% was also found effective in reducing the incidence of the disease.

v. *Phoma* leaf blight in *Dalbergia sissoo* was noticed as major problem in Osean, Tinwari and AFRI nursery. The disease was successfully controlled by foliar spray of Blitox 0.2% at monthly interval.

Plantation Diseases and their Management

Ganoderma root rot in neem

Mortality of 3-4 years old plantation of neem was observed in experimental area, AFRI, Jodhpur, (Raj). The disease was cured by soil drenching with Bavistin 0.1%. Most of the affected plants revived

successfully. The same observations were recorded in avenue plantation of neem at Sundarpura (Sikar). However this disease is not common in neem but if susceptible sps like, *Dalbergia sissoo* or *Acacia tortilis* are available in the area, the possibilities of infection becomes more .

Gummosis in *Albizia lebbeck*

During survey of Osean nursery in the month of July and Aug. 1993 a peculiar symptoms of *A. lebbeck* trees , exhibited gum exudation, which covered upto few meters from ground level.

Severe infection of Ganoderma lucidum was recorded causing 15 to 20% mortality in 8 to 10 year old Shisham trees in IGNP area at Chattergarh range.

STUDIES ON IRRIGATED PLANTATIONS IN IGNP AREA

Indira Gandhi Nahar Pariyojana (IGNP) is the biggest canal project covering a command area of 12.0 million ha. To prevent the siltation of 649 km long canal having 7760 km long distributaries, shelterbelt plantations have been raised. Irrigated plantations have also been raised as block plantations for fuel, fodder and timber and for sand dune stabilization, etc. Thus forestry is very important activity in IGNP area. To know the status of plantations, a study was carried out. Important findings are presented here.

About 1,06,000 ha area has been afforested under various schemes in stage-I upto 1991 and about 29,000 ha in stage-II from 1985 to 1992. Achievements have been dramatic in terms of tree cover which increased from 0.61 to 2.75% of the total geographical area, permanent pasture (1.55% increase), employment generation (3.3 million mandays) per year during VII plan period, etc.

The species planted are *Eucalyptus camaldulensis, Dalbergia sissoo* and *Acacia nilotica* as the main species in canal side plantations. A small proportion of *Tecomella undulata, Prosopis cineraria* and *Ziziphus mauritiana* has also been included, recently. In uncommand areas on the canal side, road side and abadi plantations *Acacia tortilis* was the main species in stage I. However, in stage II, it is replaced by *T. undulta, D. sissoo* and *Z. mauritiana*. Under pasture development and sand dune stabilization programme, *A. tortilis* is the only species planted.

Performance of Different Species

A comparative growth performance during three years indicate that in uncommand block plantations in Stage- II with a spacing of 2x3, *Zizyphus*

mauritiana showed better growth compared to *Acacia nilotica*. *Acacia tortilis* grows better compared to *A. nilotica* in both command and uncommand areas. Similarly *Dalbergia sissoo* also is seen to be performing better than *Acacia nilotica* in both command and uncommand areas. In uncommand area 15 year old plantations of *Dalbergia sissoo* and *Acacia tortilis* are seen to be competing as far as growth is concerned. Whereas in command area the diameter of *Dalbergia sissoo* is higher than *Acacia tortilis*. This may be due to the higher water requirement of *Dalbergia sissoo*. In command areas *Eucalyptus camaldulensis* has registered the best growth of all the plantations surveyed. It is to be noted that in two experimental plantations of *Acacia tortilis* and *Prosopis juliflora* raised in 1992 under SDS scheme, the latter has shown a better growth performance. This species should be preferred for sand dune stabilisation for its fast growing habit, its large spread which facilitated faster ground coverage and its unmatched coppicing power in arid environment.

Comparative growth performance of different species

Species	Age (yrs)	Spacing mxm	Command/ Uncommand	Type	DBH (cm)	Height (m)
Acacia nilotica	3	2x3	Uncommand	BP	2.1	1.5
Zizyphus mauritiana	3	2x3	Uncommand	BP	2.5	2.7
Acacia nilotica	15	3x3	Uncommand	BP	13.0	9.9
Dalbergia sissoo	15	3x3	Uncommand	BP	14.7	10.7
Acacia tortilis	15	3x3	Uncommand	CSP	18.4	8.6
Tecomella undulata	7	2x2	Command	CSP	5.8	3.1
Acacia nilotica	7	2x2	Command	CSP	6.5	10.7
Dalbergia sissoo	7	2x2	Command	CSP	10.7	10.6
Eucalyptus camaldulensis	7	2x2	Command	CSP	13.4	12.1
Acacia tortilis	15	3x3	Command	CSP	20.8	12.2
Acacia nilotica	17	3x3	Command	CSP	20.2	12.3
Dalbergia sissoo	17	3x3	Command	CSP	27.3	14.3

BP : Block Plantations, CSP : Canal Side Plantations.

Benefits of Afforestation

Employment generation

Total mandays employment likely to be generated during VIII plan period from IGNP Stage-II is to the tune of 166 lakh which works out to be on an average of nearly 33 lakh mandays per year.

Increase in fuel wood and fodder production

Earlier in these arid areas one family on an average used to clear shrubs and small wood plants from nearly one hectare area for one time cooking. After large scale of afforestation in IGNP area pressure for firewood on marginal lands is reduced because enough fire wood is available from dry and fallen branches. Lot of grasses are also coming up under the plantation areas which forest department allows to be collected by the local people on payment for stall feeding. Other benefits in the form of fruits from ber, khejri trees are also available to the local people.

Impact of vegetation in moderating climate

The plantations have also contributed to reducing the harshness of the environment and this can be felt when one drives along the canal where there are empty stretches adjoining to plantations. The impact of increased vegetation on the rainfall in Ganganagar is encouraging. Figures reveal that there is a significant rise in the decadal values of average annual rainfall in this region during 1951 to 1987.

NON-WOOD FOREST PRODUCTS

Fatty oil contents of some important oil bearing plants of arid regions

Studies on important oil seeds of Rajasthan and some localities of Gujarat were continued to get complete details of variation in oil content of seeds in different areas to select the best provenance for the purpose of oil seed production. Oil content of seeds of *Salvadora persica* and *Salvadora oleoides* collected from different localities of Rajasthan and Gujarat were determined.

Oil content of seeds of *Salvadora persica* and *S. oleoides* from different localities of Rajasthan and Gujarat

S.No.	Localities	% of oil	
		S. persica	*S. oleoides*
1	2	3	4
RAJASTHAN			
1.	Jaisalmer	40.2	41.6
2.	Bikaner	42.3	41.0
3.	Jodhpur	40.8	42.6
4.	Barmer	38.4	40.4

Contd.

1	2	3	4
5.	Sri Ganganagar	44.5	42.5
6.	Jhunjhunun	43.2	41.6
7.	Nagaur	38.6	40.5
8.	Pali	42.5	41.7
9.	Sirohi	40.3	39.5
10.	Jalore	41.2	42.6
11.	Jaipur	43.1	44.2
12.	Ajmer	42.9	43.2
13.	Tonk	43.3	40.7
14.	Alwar	42.6	43.5
15.	Udaipur	45.3	42.8
16.	Banswara	40.74	42.6
17.	Dungarpur	42.5	40.8
18.	Sawai Madhopur	43.2	39.6
	GUJARAT		
19.	Bhuj	39.6	40.1
20.	Bhavanagar	42.4	44.8
21.	Gandhi Nagar	43.5	42.6
22.	Mehasana	44.0	41.8
23.	Disa	42.9	40.6

In Rajasthan, fatty oil content was found maximum in the seed samples of *S. persica* collected from Udaipur (45.3%) and in the seed samples of *S. oleoides* collected from Jaipur (44.2%).

Screening of seed samples collected from five locations of Gujarat suggested that the fatty oil content in *S. persica* seeds was maximum in Mehsana (44.0%) whereas in case of *S. oleoides* it was found maximum in Bhavanagar (44.8%).

GROWTH AND ECONOMIC STUDIES

Agroforestry

Ailanthus excelsa has gained importance as a fodder tree in and around Jaipur area. A survey regarding growth, yield and economics of *A. excelsa* was done by the Institute

Plantation Model

A. excelsa has been planted on farm bunds, farm fields and as homestead plantations. Among these, the widely accepted model is farm forestry. On farm bunds trees are planted at 3 to 6 mts. apart. In agroforestry

and block plantations, the spacing adopted are 6 x 6 and 3 x 3 mt., respectively. Mostly these plantations are under rainfed conditions but the trees in agricultural fields are under irrigated conditions.

Growth Characteristics

The growth of the trees of different ages at different sites planted under various geometries is given below.

Growth of *Ailanthus excelsa* in different models

Location	Age yrs.	Av. height mt.	Av. Gbh cm.	Spacing m.	Pattern of plantation	Irrigated or rainfed
Adarsh Krishi Vaniki Farm, Agra Road	7	7.4	41	3x3	Block	Rainfed
Dahmi Kalan Nursery, Ajmer Road	7	4.3	26	2.5x2.5	Block	Rainfed
Maliyon Ki Dhani, Agra Road	30	22	223	5mt. Apart	Farmbund	Rainfed
Daga Farm, Agra Road	20	12.6	133	6x6	Block	Rainfed
* Jaju Agri Farm, Machwa	8	6.7	69	6x6	Agroforestry	Irrigated
Govindpura Research Farm, Khatipura	3	2.7	33	4x2	- do -	Rainfed
Newaru Village, Jhotwara Road	4	6.7	45	3 mt. Apart	Farm Forestry	Irrigated
Newaru Village, Jhotwara Road	8	10.3	85	- do -	- do -	Irrigated
Newaru Village, Jhotwara Road	13	10.5	124	- do -	- do -	Irrigated

* Trees were completely lopped.

Fodder Yield

Under irrigated conditions leaf fodder yield/tree with respect to age in farm forestry has been found as under:

Age (years)	Av. yield/ tree/ lopping (in kg)
4	20
8	85
12-132	200

Economics

The average rotation of *A. excelsa* is considered as 25 years. The lopping is started fourth year onward. It is estimated that an average tree gives about 5 quintal leaf fodder per year. It is found that in the first 7 years one tree gives leaf fodder of Rs. 50/- per year and in the next 12-15 years it fetches Rs. 100-120/- per year at the site of plantation. Thus a farmer can get around Rs.

2000/- from leaf fodder in its rotation. After felling, *A. excelsa* produces wood of worth about Rs. 2000/-. Thus one A. excelsa tree fetches about Rs. 4000/- in its life to its owner and employment to other persons engaged in its marketing.

Growth of Neem in Arid Region

Neem growth data in arid areas of Western Rajasthan were collected by laying out 22 random plots in different localities.

Growth of neem in arid region.

Age (yrs)	Crop diameter (cm)	Crop height (m)	Crop length (m)	Crop width (m)
5	6.6	5.09	2.74	3.98
10	14.2	6.55	3.68	5.95
15	18.7	7.32	4.42	6.38
20	22.7	7.96	5.11	7.53
25	26.5	8.55	5.80	8.15
30	30.4	9.12	6.52	8.73
35	34.3	9.69	7.26	9.30
40	38.2	10.26	8.02	9.86
45	42.3	10.83	8.81	10.40
50	46.4	11.40	9.63	10.95
55	50.6	11.98	10.47	11.48
60	54.9	12.55	11.33	12.20

Growth in terms of height, dbh and crown width is quite fast upto first 10 years of age attaining a height of 6.55 meter, dbh 14.2 cm, and crown diameter 5.95 meter, after that it slows down gradually while increase in crown length is almost uniform. This trend predicted is only upto 60 years of the age, when tree height is 12.55 meter, dbh 54.9 cm and crown diameter 12.2 m.