CHAPTER-VII

ARID FOREST RESEARCH INSTITUTE JODHPUR

Arid Forest Research Institute (AFRI), Jodhpur was established with the objective of developing technology for desert afforestation and reclamation of arid and semi-arid areas. The main emphasis of research work is on tree improvement programme, agroforestry and agri-silvi-pasture models suitable for arid and semi arid regions, technology for fixation of sand dunes and reclamation of saline and alkaline lands, growth and yield study of irrigated plantations in Indira Gandhi Canal Project area, and evolving package for maximising production on sustainable basis. The institute has a mandate to meet the forestry research needs of States of Rajasthan, Gujarat and Dadra and Nagar Haveli. Achievements during 1996-97 have been as follows :

TREE IMPROVEMENT

International provenance trial on neem

The international provenance trial on neem has been started during July -August 1996. Two experiments were carried out. The first experiment consists of 17 provenances and a control having four replications in a randomized block design. Each replication has 25 seedlings of each provenance. They were planted at a spacing of 3x3 meters at Jodhpur, Jaipur, Palanpur, Jabalpur and Coimbatore. The provenances used in the trial were - Tuang Luang, Ban Nong Rong and Doi Tao (Thailand), Vientiane (Laos), Yezin (Mynamar), Lamahi Dang, Geta and Dhangadhi (Nepal), Chamwion (Tanzania), Ramannaguda, Kulapachra, Kalyani, Balharshah, Sagar, Annur, Mandore, Allahabad and Ghatti Subramaniyam (India) and control (local provenance).

Second experiment was laid out at Jodhpur with the provenances of Myene (Mynmar), Chittagong (Bangladesh), Multan and Tibbi Laran (Pakistan), Sunyani (Ghana) and Control (Local provenance). The trial consists of four replications having 6 seedlings in each replication from a provenance and were planted in a RBD at 3x3 meter spacing.

Provenance trial of *Ailanthus excelsa*

Seeds of *A. excelsa* were collected from thirteen seed sources during 1995-96 and observations were recorded on various seed parameters. In these studies four samples were taken for all the desired characters. The seed sources were Ahmedabad, Balaghat, Bikaner, Bilaspur, Hyderabad, Jabalpur, Jaipur, Kazipet, Mirzapur, Pinjore, Sonbhadra, Varanasi and Jodhpur.

Seedlings from seed sources of Balaghat, Bikaner, Jodhpur, Mirzapur, Pinjore, Sonbhadra, Varanasi and Kajipet were planted at a spacing of 4 x 4 metres for provenance trial at Jodhpur and Jaipur, in a randomized block design with four replications having 16 plants in each replication.

Micropropagation

(1) ***Ailanthus excelsa*:** The work on micropropagation (Tissue Culture) of *Ailanthus excelsa* was started with a view to standardizing the technique for cloning superior genotypes. Amongst the cytokinins tried, BAP proved to be the best for shoot multiplication.

Rooting experiments were also conducted in MS media housing different concentrations of auxins along with lower concentration of cytokinin. Rooting occurred at lower concentrations of Benzyl Amino Purine (BAP) alone as well as on Napthal Acetic Acid (NAA) containing media after 3-4 weeks of culture. It indicates that stress conditions are favourable for rooting. Few young plantlets which were transferred in vermiculite for hardening, survived only for a couple of weeks.

After establishment of culture from *in vitro* raised seedlings as well as mature trees, various experiments were carried out for standardization of media for shoot multiplication. In initial experiments different cytokinin, BAP and kinetins were used to compare the effect. In these experiments BAP showed better response than any other cytokinins.

(2) ***Acacia nilotica:*** For micropropagation of *Acacia nilotica,* nodal shoot segments were collected from a 4 year old tree growing in the field of AFRI. These segments were cut into 1-2 node pieces and were surface washed with Tween-80 for 15 minutes followed by thorough washing with distilled water.

MS medium with different concentrations of auxin and cytokinin was used for bud initiation. Cultures were kept under controlled condition with 12 hours photoperiod and 60-70 per cent relative humidity. 20 per cent bud breaks were observed after 10-12 days of inoculation. 8-12 bud breaks were observed in single node after 2-3 subculturings. Nodal segments exhibited higher contamination. Antioxidant-ascorbic acid, citric acid, different amino acids and adenine sulphate were used to prevent the leachate exudation but these antioxdant did not prevent leaching problem and caused blackening in cultures and reduced survival percentage. Different concentrations of Auxin and Cytokinin are being used for establishment of cultures.

(3) ***Azadirachta indica*:** A field trial of tissue culture raised and macropropagated plants of *A. indica* was initiated and the plants are growing well for one year. Another trial of 14 tissue culture raised plants of neem is also progressing well for almost three years.

Macropropagation

(1) ***Ailanthus excelsa*:** To standardize the macropropagation techniques, different types of stem cuttings were tried, such as coppice shoots and shoots from lower crown of tree. Different concentrations of IBA (500, 1000, 1500, 2000, 2500 ppm) were tried to induce rooting from stem cuttings. Only bud break was observed from these stem cuttings but no rooting occurred in any of the treatment. This experiment was repeated but with the same results. Experiments are in progress to increase the rooting frequency.

(2) ***Acacia nilotica:*** Stem cuttings of *A. nilotica* were raised in the mist chamber. So far only shoot regeneration was observed inspite of giving IBA treatment from 500 to 2500 ppm concentrations.

(3) ***Azadirachta indica*:** Rooting was observed only in *A. indica* coppice cuttings. Different types of vegetative cuttings such as coppice shoots, root suckers and shoot cuttings from lower crown were tried to raise plantlets. Auxins were tried at basal ends in two different ways, one in powder (3%) form and the other in liquid solution (1000 ppm). The upper end was pasted with chobatia paste to prevent the infection. Stem cuttings were raised under intermitted misting for 15 seconds with gap of 3 minutes. Shoot formation was observed within a week. After a period of four weeks almost 95% stem cuttings sprouted. After two months, root initiation was observed in coppice cuttings only. Root sucker plants did not survive beyond two months.

Seed production area (SPA)

Tectona grandis, Acacia nilotica, Dalbergia sissoo and *Eucalyptus camaldulensis* were the species selected for establishment of SPA in the States of Gujarat and Rajasthan. Physical targets for these species were 50, 55, 20 and 10 ha, respectively. The list of potential seed stands were obtained from the SFD's of the States. The areas were surveyed, and seed stands were identified. Following are the details regarding seed stands for conversion into seed production areas.

Species	Rajasthan		Gujrat		Total area (ha)
	Location (place, range/Division)	Area ha	Location (place, range/ Division)	Area ha	
A. nilotica	0-22 RD Gharsana minor, Ganga Nagar	20	Nagina, Chota udaipur Gusar, Panam project Div.	20 15	55
T. grandis	-	-	Chikhli, Dange-south Devmogra, Sagbara, Rajpipla East. Limbadi, Chota udaipur, Kevri	20 20 10	50
E. camaldulensis	0-7 RD, Sangeeta distributory, Ganganagar	10	-	-	10
D. sissoo	40-55 RD, Navrangdeshar, Hanumangarh	20	-	-	20
Grand Total					135

Clonal seed orchard

50 CPTs of *D. sissoo* have been identified in Stage I of IGNP area in Rajasthan. 4000 cuttings of *D. sissoo* from 39 CPTs have been procured and are being multiplied in the mist chamber. Out of these, 2500 cuttings have sprouted roots, and are now being hardened in polybags. Planting is to be taken up during July-August 1997.

Seedling seed orchard

Seedling seed orchard of *E. camaldulensis* and *D. sissoo* have been established over 7 and 1 ha area plots. Further, quality seed from 50 CPTs of *D. sissoo* have been collected and seedlings are being raised in the nursery of AFRI and State Silviculture nursery at Jaipur. Seedlings are being raised from seeds of 46 CPTs of *E. camaldulensis* procured from CSIRO, Australia, in AFRI nursery. Planting of SSO is to be taken up during the coming planting season.

Vegetative multiplication garden

Base population of 17 clones of *D. sissoo* and 25 clones of *E. camaldulensis* has been established in 0.75 ha area in AFRI nursery for the purpose of establishment of multiplication

garden. These plants are being managed for the purpose of multiplication through vegetative cuttings.

Model nursery

70,000 seedlings of various arid zone tree species such as *D. sissoo, E. camaldulensis, A. nilotica, Prosopis cineraria* and *A. indica* etc. have been raised. Experiment on different potting mixtures was laid out and on the basis of preliminary results, changes in the potting mixture have been made. Different types of root trainers are being tried out and nursery techniques for root trainer nursery practices of different arid zone species are being standardised. Experiment has been laid out on the use of chemical, i.e., copper compounds for root pruning.

BIOFERTILIZERS

Studies on VAM association in irrigated plantations and agro-forestry system

Seasonal variation in VAM spore density and root colonization in irrigated plantations of IGNP command area and agro-forestry systems of Rajasthan was studied. Root and rhizosphere soil samples were collected under the root zone of *A. nilotica, A. tortilis, D. sissoo, E. camaldulensis* and *Tecomella undulata* in 3 different age groups of irrigated plantations and under the root zone of *A. nilotica, A. tortilis, E. camaldulensis, P. cineraria* and *T. undulata* in agro-forestry systems.

The results indicate that maximum number of spores are encountered during July to October and the number decreases in the subsequent months. It was observed that higher soil pH and organic carbon (%) directly influences the percent colonization of VAM fungi in the roots of different tree species screened. It was also recorded that number of VAM fungal propagules increases with the age of trees.

From the rhizosphere soil samples, spores of five different VAM fungal genera viz., *Acaulospora, Gigaspora, Glomus, Sclerocystis* and *Scutellospora* were examined. Among these genera, *Glomus* was the most predominant one occurring in all the samples followed by *Sclerocystis* and *Gigaspora*. Pure culture and mass multiplication of the most common *Glomus* spp. were maintained for further studies.

Effect of biofertilizers on the growth of *Albizia lebbeck* seedlings in nursery stage

An experiment was conducted to study the effect of biofertilizers on the growth of *Albizia lebbeck* seedlings in nursery conditions. Inoculation with VAM, *Rhizobium* and *Azospirillum* individually and in combination of *A. lebbeck* seedlings in unsterilized nursery soil mixtures resulted in increased shoot height and biomass production. The study showed efficacy of dual inoculation with biofertilizers in increasing seedling height as opposed to individual inoculation.

WOODY PLANT WATER RELATIONS

Investigation of soil water plant relationship in respect of different tree species

A lysimeter experiment with varying moisture stress and nitrogen levels was initiated in July, 1996 to quantify their influence on tree growth. Tree species were, *A. nilotica, A. lebbeck, A. indica, D. sissoo* and *E. camaldulensis*. Initial observations indicate general decline in tree growth with increasing moisture stress. Data on leaf water potential also indicate the manifestation of soil moisture stress on leaf water content and its consequent influence on tree growth. Maximum growth of 221 cm height was observed in the case of *E. camaldulensis* with no nitrogen.

Screening tree species for drought tolerance on a sandy plain soil

A field experiment was initiated in an existing four year old plantation, in 1995, to study the performance of different tree species on a moisture stressed arid sandy site. Mulching and no mulching treatments were also included. The initial plantation spacing of 3m x 3m was subsequently thinned to 3x6 m^2. *A. indica* continued to be the best performer attaining an average 41 cm girth and 431 cm height at 65 months of age, followed by *A. nilotica* (28 cm girth and 450 cm height), *A. lebbeck* (29 cm girth and 315 cm height), *Acacia planifrons* (32 cm girth and 299 cm height), *P. cineraria* (21 cm girth and 224 cm height) and *T. undulata* (18 cm girth and 208 cm height. Performance of all the species on mulched plots was better than unmulched plots.

Screening of exotic and indigenous plant species on salt land in arid zone

An experiment to rehabilitate salt land at Kaparda village in Jodhpur district was initiated in 1992 with two exotic (*Atriplex lentiformis* and *A. amnicola*) and three naturalised/indigenous (*P. juliflora, Salvadora persica* and *Tamarix aphylla*) plant species using different management practices such as mixing of gypsum, FYM, drainage channels, fertilizer application, and replacing salty pit soil with good soil etc. *A. amnicola* was removed later on due to poor performance.

A. lentiformis responded significantly to the treatments applied and its performance was best among all the species. Among the naturalised/indigenous species, performance of *P. juliflora* was most significant. Control did not register any increase in the height but a slight increase in crown diameter was observed. Soil properties also showed improvement with decrease in pH and EC and increase in percent organic matter contents with extensive weed growth.

Moisture management in arid zone afforestation

A field experiment on different methods of micro-catchment water harvesting was initiated in July 1992. Different treatments were T_1 : Only pitting (control), T_2 : Saucers, T_3 : Ring pits, T_4 : Trench cum mound, T_5 : Trench and mound and T_6 : Deep ploughing. Observations recorded on growth, leaf water potential and soil moisture show significant influence of different treatments. Trees on ring pits continued to exhibit best growth for neem (*Azadirachta indica*) and siras (*Albizia lebbeck*) attaining average heights of 538 cm and 441 cm, respectively and average girths of 43.5 cm and 29.8 cm respectively at 54 months of age. It was followed by Trench and mound, and Saucers of 2.5 m dia in order of growth performance. Growth of khejri (*P. cineraria*) was at par on these three types of structures. Leaf water potential varied only marginally from -3.77 to -4.39 Mega pascal (Mpa) in neem and -3.41 to -4.03 in Siras. Soil moisture storage varied from 17.1 to 26.3 mm in neem, 14.5 to 20.4 mm in Siras and 15.8 to 17.4 mm in khejri in upper 75 cm layer.

IRRIGATION WATER MANAGEMENT

Studies on watering schedule and water requirement of different tree species

The experiment was initiated in July 1995 with six treatment combinations of quantity of water (W_1 & W_2) and watering frequencies (I_1, I_2,I_3). Three species viz., *A. nilotica, D. sissoo* and *E. camaldulensis* were taken for experiment. Irrigation schedule is maintained on the basis of IW/CPE ratio.

Performance of *E. camaldulensis* was better in $I_3 W_1$ treatment where 47.6%, 30.8% and 96.1% increase in height, crown diameter and collar girth was observed respectively compared to the least frequent treatment I_1W_2. *A. nilotica* performed best in I_2W_1 having 187.86 cm, 175.8 cm, and 12.69 cm of height, crown diameter, and girth, respectively. In the case of *D. sissoo*, best growth performance was observed in I_3W_2 treatment.

Species for high yield commercial forestry under irrigated conditions

Experiment was initiated in July 1995 to screen different tree species for their commercial potential with irrigation under arid conditions. Five tree species were taken, viz. *D. sissoo, A. nilotica, E. camaldulensis, A. lebbeck, Tectona grandis and Dendrocalamus strictus* for main treatment alongwith two submain treatments with VAM inoculation and with no VAM inoculation in three replications at a spacing of 3 m x 4 m. The VAM species used for inoculation are *Glomus aggregatum* for *A. nilotica* and *D. sissoo, G. fasiculatum* for *E. camaldulensis*, and mixed *Glomus* culture for *A. lebbeck* and *D. strictus*. Teak was planted without VAM inoculation. Irrigation level was fixed at 45 mm quantity at an interval of 15 days with no watering in monsoon period i.e., from July to mid November. At sixteen months of age *E. camaldulensis, A. nilotica and D. sissoo* showed promising growth attaining average maximum height of 353, 221, and 187 cm respectively and girth of 6, 4.3, and 4 cm respectively.

PESTS AND DISEASE MANAGEMENT

Pests of tree seeds and seedlings

Gall formation upto 40% was observed in *P. cineraria* due to a dipteran fly *Contarina prosopidis*. The gall formation stunted growth. Leaf miner *Lithocoltelis virgulata* damaged seedlings of *P. pinnata* by making circular, whitish blotches. Three to four blotches were observed on a single leaf surface. This resulted in drying and premature fall of leaf and ultimately in seedling mortality (30%). Citrus leaf minor *Phyllocnistis citrella* was found infesting 60% seedlings of citrus at SFD nurseries and AFRI nursery. Spray of monocrotophos (0.036%) was found effective in controlling the leaf minor infestation. The leaf eating caterpillar *Papilio demoleus* was found damaging seedlings of *A. lebbcek* (8%), *Citrus* (10%), and *T. undulata* (60%). Hatchability of *Bruchidius albizziae* in seeds of *P. cineraria* ranged from 80-92.30%. Two seed pests were recorded from *A. tortilis*.

Detailed study on major insect pests

Detailed morphological studies on adult and larval stages of *Patialus tecomella* have been completed. It completes its life cycle within 28 days and has 4-5 overlapping generations in a year. The weevil hibernates in debris and folded leaves under the rohida (*Tecomella undulata*) plant. Relative resistance of different provenance of *T. undulata* and *Patialus tecomella* have been studied. It has been found that the Bhaislana provenance from Jaipur is the best in terms of its resistance to *P. tecomella*.

Observations have been taken, on the infestation by *Taragama siva* of several forest tree species. Check list of insect pest of *Prosopis* species has been made and their natural enemy complex was identified. The population pattern with reference to abiotic and biotic factors for major insect pests has been completed.

Non-insect pests

Phytophagous mites: *Aceria pongamiae; Eriophyes prosopidis; Eotetranychus suginamensis;* and *Oligonychus mangiferus* have been recorded from Rajasthan. *A. pongamiae*

attacks *Pongamia pinnata* and produces leaf galls. Rogor (0.06%) gives satisfactory results for controlling this mite. *E. prosopidis* produces leaf galls on *P. cineraria*. *Eo. suginamensis* feeds on *Morus alba*. *Oligonychus mangiferus* has been recorded from *Syzygium cumini* and Silver oak. *Eo. suginamensis and O. mangiferus* suck the cell sap.

Molluscs: Snail *Macrochlamys indica* was observed on seedlings of *Moringa oleifera*. Life cycle of mollusc *L. alte* revealed that it lays whitish semi-transparent eggs in batches of 10-15. The eggs hatched into young slugs in 20-25 day. A mixture of Tobacco powder, phorate and lime was found effective in controlling the pest. Fungus *Fusarium* was found in the culture of *L. alte*.

Chemical control

Experiments were carried out on the efficacy of five pesticides viz., Chlorpyriphos, Cypermethrin, Methyl parathion, Monocrotophos and Endosulfan against *Taragama siva*. Endosulfan (0.07%) proved superior to others. Methyl parathion (0.05%) ranked second, followed by Cypermethrin and Monocrotophos while. Chlorpyriphos is least effective.

DISEASE SPECTRUM OF ARID ZONE TREE SPECIES.

About 10-15% mortality was observed due to the infection of *Ganoderma lucidum* in *Acacia holoceracea* plantations in experimental field of Silviculture division. The disease was managed by soil drenching with bavistin (0.1%). The same problem was also noticed in *D. sissoo* plantation raised at I.G.N.P. area. For minimising the disease spread in the plantation, making isolation trenches was recommended to the forest officials.

Pod and seed infection due to *Botriodiplodia theobromae*, *Fusarium solani* and *Alternaria tenuis* was observed in *T. undulata* plantation in Rajasthan. The pathogens were isolated in PDA medium and pathogenicity test was established.

Gummosis in Subabul (*Leucaena leucocephala*) was noticed in plants raised at AFRI, Jodhpur. Few plants exhibited symptoms of dying off due to severe infection. The infested area showed growth of white cottony mycelium in PDA medium identified as *Fusarium* sp.

GROWTH STUDIES

Studies on two of the most important species planted in the area viz. *D. sissoo* and *E. camaldulensis* were continued under the World Bank aided FREE project. Sixteen new sample plots of *D. sissoo* and nineteen of *E. camaldulensis* have been laid out at different locations in the area during the year taking the total number of sample plots to twenty four and twenty six respectively. Preliminary volume equations for both the species have been worked out.

Lopping studies on the fodder species of arid zone

Lopping studies on *P. cineraria* and *A. excelsa* are indicative of significant effect of lopping on the dbh growth of *P. cineraria* and height growth of *A. excelsa*. A new experiment to study the effect of pruning on the growth of young plantations of *P. cineraria* has been initiated during the current year.

BIOPESTICIDE

Efficacy of biopesticide against insect pests

A field trial was conducted to study the bioefficacy of neem seed oil alone and in combination with two conventional insecticides viz., monocrotophos and endosulfan against

babul whitefly *Acaudaleyrodes rachipora* on *Acacia senegal* seedlings. The results demonstrated that the neem seed oil alone at 0.5% is good enough to control this pest and its combination with either Neem seed kernel powder 0.1% monocrotophos or endosulfan did not show any improvement. Methanolic extract of NSKP was found to exhibit 100% antifeedant activity at 0.5% concentration against the moringa defoliator *Noorda blitealis*.

Biopesticide from *Capparis decidua* branches was made by two methods, (a) exhaustive extraction with methanol and (b) sequential extraction with methanol after exhausting the plant parts with petroleum ether and chloroform. Extractives obtained by the above methods were tested for their efficacy as biopesticide against the aphid *Aphis gossypii* on rohida by dipping and spraying methods. The result showed that the extractives obtained by total extraction were active in both the methods of application. The order of efficacy of extractives as biopesticide against *A. gossypii* is seed > bark > branch > wood.

Antifungal activity of biopesticides

Neem seed kernel powder (NSKP), karanj seed kernel powder (KSKP), neem leaf powder (NLP) and neem seed oil (NSO) were tested for their bioefficacy against neem seed mycoflora. The results showed that the mean radial growth of mycelium ranged between 11.60-25.56 cms in various treatments. Seeds treated with NSO were found best in inhibiting the spermoplane mycoflora of neem seeds. Among the dry and wet treatments, wet treatment with NLP was found to be more effective.

Antifungal activity of *Pongamia pinnata* extract prepared in various solvents was tested against neem seed mycoflora. The data on radial growth of mycelium showed significant difference between the treatments. It ranged between 28.4-82.21 mm in various treatments. Seeds treated with water extract prepared in 80% methanol showed better results than others.

NON-WOOD FOREST PRODUCTS

Oil Seeds

A survey of literature as well as forest area of arid and semi- arid regions was carried out and plant species containing commercially exploitable amount of oil have been identified. Seeds of *Pongamia pinnata* collected from different localities viz., Jodhpur, Bikaner, Jaipur, Kota, Chittor, Udaipur, Banswara, Bhilwara and Alwar were analyzed for their fatty oil content. Seeds from Dungarpur are found to have highest percentage of fatty oil (41.85 %) whereas oil content in seeds from Alwar (30.7 %) was lowest.

Fungal infestation in Neem seeds collected from three different localities namely Bikaner, Banswara and Tonk of Rajasthan was examined. Six fungal species viz., *Aspergillus niger, Aspergillus flavus, Alternaria alternata, Alternaria tenuis, Xylaria azadirachae* and *Fusarium sp.* were isolated and identified from the infested seed samples of different localities and percentage infestation was recorded.

Active phytochemicals

Azadirachta indica

Seeds of neem were collected from the eight agroclimatic zones of Gujarat State and analyzed for variation in physical constants viz., seed index, seed kernel to seed ratio; and chemical constituents viz., fatty oil content and azadirachtin content. The concentration of

azadirachtin varied from 0.081% (Bhuj, ACZ 5) to 0.632% (Mehsana, ACZ 4) by weight of NSK in different samples of ACZ's of Gujarat State.

NABARD Project

The achievements under this project are as follows :

- Economically preferable species like *Acacia nilotica, Ailanthus* sp., *Azadirachta indica, Zizyphus mauritiana* and *Punica granatum* have been identified and nurseries (22000 bag plants) have been raised for the three selected micro-watersheds.
- VAM inoculation has been done in the silvi-horticulture model of Sangariya micro-watershed. The height measurements of inoculated seedlings have been recorded.
- Fertilizer application and silviculture operations have been carried out in the selected micro-watersheds according to treatments and models.
- Agroforestry plantations with agri-silvi, silvi-horti, silvi-pasture, agri-horti-silvi have been raised in 17 farmers fields. Performance of various models is being studied.

Rural Development Project

Demonstration of rain water harvesting techniques

Data from the trials at Rohat (Pali), Jasol (Barmer) and Jodhpur indicate that trench and mound, and saucers of size 2.5m dia cause dramatic improvement in the growth of tree species. The response of *Acacia nilotica, Z. mauritiana, Albizia lebbeck, Emblica officinalis* and *Dalbergia sissoo* has been particularly significant resulting in 30-70% growth increase in terms of height and collar diameter. These techniques maintain higher soil moisture regime for longer period than control. Trials have also been laid at Nagaur and Palanpur sites.

AGROFORESTRY

Effect of different crop sequences

The field experiment comprised 6 treatments of different intercrops (crop sequences) and two tree species, thus making 12 treatment combinations. This year there was a long dry spell in August-September, resulting in very poor yield in all agricultural crops. Mungbean yielded highest grain (231 kg/ha) followed by cluster bean and mothbean. Grain of pearl millet could not be harvested. Straw yield was highest from mungbean (1962 kg/ha) where mungbean - pearlmillet rotation was followed. Crop yield (grain + dry matter) was significantly higher when planted alongwith *Tecomella undulata* than *Prosopis cineraria*. In general, there is decline in growth of *P. cineraria* (particularly, in height and collar girth) due to growing of agricultural crops. On the contrary, *T. undulata* registered marginal improvement in growth due to growing of agricultural crops with it.

Effect of tree density

A field experiment, comprising three densities (416, 278 and 208 stems per ha) of *T. undulata* and *P. cineraria* was initiated in combination with Mungbean in 1995 to find out the effect of tree density on crop yield and tree growth. The data are being collected.

Emblica officinalis based agroforestry model

Prosopis cineraria based agroforestry model

Zizyphus mauritiana on microcatchments

Local folks preparing microcatchments

Agroforestry for maximising fodder and fruit production

An experiment has been designed to map performance of tree species viz., *Emblica officinalis, Hardwickia binata* and *Colophospermum mopane* and crop and their combined effect on soil productivity. Data collection is going on.

***In situ* runoff agroforestry**

An experiment was started by planting three tree species viz., *Azadirachta indica, Acacia nilotica and Albizia lebbeck* in August 1996 at the spacing of 6 x 4 m with three replications. Bunds were prepared at 6m interval. Data on growth, survival etc. are being collected.

Sand dune stabilization

A study with different tree species and treatments has been initiated during the year at Bikaner. Initial observations indicate highest survival of *A. tortilis* followed by *A. senegal.* The best growth was attained by *Prosospis juliflora* followed by *A. tortilis.*

Trials on Planting technology , Nursery technology, silvipasture models, Silvoherbal Models and Integrated nutrient management studies have been started at different sites.

Spacing trials

A field trial under this project began at Churu to study the effect of spacing on the performance of three arid zone species (*Acacia nilotica, Prosopis cineraria* and *Tecomella undulata*) planted in interdunal plains. Split plot design was followed with three replications covering an area of about 3 ha. The spacing chosen was 3x3, 4x4 and 5x5 m. Soil samples were collected from the planted area and analyzed for their properties. The pH of the soil varied from 8.7 to 9.6 while the electrical conductivity varied between 0.47 to 0.99 dsm^{-1}.

EXTENSION

Achievements under the UNDP Project project are as follows :

- 26 farmers and 2 NGO's were given demonstrative training on various forestry topics.
- About 7,000 seedlings of various species have been distributed among farmers of selected villages.
- A study tour for 17 farmers from selected UNDP villages was taken to Udaipur (Raj.) and Mehsana (Guj.) from 27.3.97 to 31.3.97. The objective being to show and demonstrate various social forestry/farm forestry/agroforestry work being done in Udaipur and Mehsana.
- Biofertilizers like VAM have been multiplied and 3000 seedlings of various species have been inoculated.