CONTENTS Page No.

AFRI Annual Report 2016-17

Executive Summary

Arid Forest Research Institute (AFRI), Jodhpur has been undertaking forestry research with the aim of addressing the needs of its mandated areas of Rajasthan, Gujarat, Dadra & Nagar Haveli and Daman and Diu (Union Territory), which are characterized by harsh climatic extremes typical of arid and semi arid conditions. AFRI has been undertaking multi-disciplinary research projects under different thrust areas and themes identified by ICFRE. Out of the 39 projects executed in the financial year 2016-17, nine projects were concluded, 15 new ICFRE & 3 Externally Aided Projects (EAP) were initiated and 5 ICFRE & 15 EAP projects are ongoing. Research findings were disseminated to the end users/stakeholders through three Van Vigyan Kendras (VVKs) established in Rajasthan, Gujarat & Dadra Nagar Haveli and a Demo-village at Salawas, Jodhpur and through organization of ten trainings and one workshop. A 'Tree Growers Mela' was also organized to bring together people involved in tree growing and tree product marketing, processing and value addition together.

Integrating tree is an age old practice in dry areas. Study conducted on different traditional and improved models of agroforestry on farmer's land covering 21 districts in eight agroclimatic zones of Rajasthan showed dominance of 12 tree species in agroforestry systems. Among these *P. cineraria* and *A. nilotica* observed dominating in arid and semi-arid regions, respectively. Intensive survey was also conducted in *Acacia senegal* trees based agroforestry areas in Barmer, Jodhpur and Nagaur districts and interaction was made with a number of farmers to obtain their views and suggestions on *Acacia senegal* based agroforestry. In another experiments conducted to enhance fodder productivity through silvi-pastoral systems on degraded land through resource management indicated establishment of *Cenchrus ciliaris* (CAZRI-75) grass on soil slope in the inter row spaces of *Colophospermum mopane* (mopane) plantation on a salt affected soil. Mopane based silvipastoral systems with other studied grasses viz. *Bracharia ramosa* (Murat), *Dactyloctenium scindicum* (Ganthia), *D. aegyptium* (Makda), *Sporobolus diander* and *Chloris virgata* improve pastoralism in the arid salt affected soils and provided greater buffer capacity ensuring sustainable production even in critical years of droughts.

Various combinations of manure and VAM were tested to enhance productivity of Kair (*Capparis decidua*), and application of Leaf Compost Manure (LCM) in combination with various inorganic fertilizers enhanced the number of fruiting plants and fruit yield significantly followed by VAM application. Leaf compost treatment with SSP, K and Zn was the best combination with 3.662 kg total annual fruit yield as compared to control (0.1456 kg) in LCM treated shrubs. In LCM block 55% plants fruited 3 times, 17.5% plants fruited 2 times and 20% plants fruited only 1 time. No flowering was observed in two plants under control and one under LCM. To enhance durability and to maintain nutritional value of fruits of *Prosopis cineraria* (Khejri) and *Capparis decidua* (Kair), plastic jar has been observed the best. Dried fruits can also

be packed under vacuum (Shrink packaging) and nitrogen atmosphere (Pillow packaging) for a longer period of preservation and safe and easy transportation without any infestation.

Non-destructive harvesting practice of *Commiphora wightii* oleogum resin has been standardized, where horizontal cut of 4 cm yielded maximum gum. Although the average gum yield per plant (three cuts per plant) in the experiment without any enhancer was 6 g/plant, which is almost 13 times less than the best gum yield (80 g/ plant) using enhancer. In the present study no casualty was observed even after three years. Seasonal variation indicated November to February as the best period for gum tapping.

As an alternative timber species for handicraft industries sawn woods of *Azadirachta indica* and *Acacia senegal* were treated with industrial method using Biflex Tc. and complex mixture of Copper sulphate, Potassium dichromate and *Prosopis juliflora* bark extract at 2.5% dilution with water. Coffee table (with chip carving) from *A. indica* wood and photo frames with carving from *A. senegal* wood were prepared. Work on quantification, value addition and improved agricultural productivity to enhance livelihood in tribal belt of Sirohi District of Rajasthan has also been carried out. The data analysis on market price spread in Abu road block revealed that on average 3.65 family members are involved in collection of identified key NTFPs and normal employment generated per year per family was 13.37 days. Maximum employment generated per year per family was by *Tamarindus indica* (Imli). Detailed socio-economic survey of 103 villages in Pali district (Rajasthan) and 59 villages in Mehsana district (Gujarat) was done to assess the role of neem products in rural livelihood. Gap between demand and supply of neem leaves was estimated as 100 tons/year in Pali district. On an average, 150 tons dry green neem leaf powder was traded in India and abroad in the form of 80-100 kg packets at the prevailing rate of Rs. 800/- per kg. Baling of neem leaves is done at a rate of Rs.1/- per kg and 80 kg or 100 kg bales are prepared on job basis by M/s. Kamal Plastics, Sojat, Pali. Neem fruit collection and processing is a labour intensive and time consuming process, therefore, in Pali district villagers prefers to work in MNREGA.

Performance of different species for their soil phytoremediation ability and productivity enhancement during land disposal of effluent is under evaluation. Experiment in lysimeter consisting of four levels of irrigation levels and 7 tree species revealed that mean annual increment in height, collar diameter and crown diameter were highest in *E. camaldulensis, Salvadora persica* and *A. indica* respectively. Soil sample collected and analysed revealed that there is a decrease in NH_4-N, available PO_4-P, K, EC and increase in NO_3-N while moving down in soil layers. Lowest amount of NH_4-N was in *A. indica,* NO_3-N in *E. camaldulensis,* PO_4-P in *P. juliflora,* K in *Salvadora persica,* soil pH in *A. indica, P. juliflora* and *S.oleodies* and EC in *T. aphylla*. In field trial involving 480 plants of ten forestry tree species and four irrigation levels, highest height increment was observed in *A. indica* and collar diameter in *P. juliflora*. Least growth increment in height and collar diameter was observed in *P. cineraria* and *T. undulata,* respectively. Treated effluent observed beneficial in growth of most of the species. In another experiment, species

evaluation for landscaping and restoration of degraded Aravalli hills through contour trenches as soil and water conservation has also been carried out. Seedlings of 20 species planted in blocks as per soil and land characteristics. Survival and growth was high in *Dendrocalamus strictus, Terminalia arjuna, Emblica officinalis* and *Thespesia populnea.*

Efficacy of different bio-agents, botanicals and chemical fungicides has also been tested against *Ganoderma lucidum*. *T. harzianum* has been identified as the most effective biocontrol agent against ganoderma in *P. cineraria.* Out of 20 different extracts of plant origin (*A. excelsa* roots, *P. juliflora* leaf and fruit extract of *B. aegyptiaca* and *D. stramonium* showed maximum inhibition of test pathogen. Among chemicals, Bavistin, Mancozeb and Propiconazole were found the most effective fungicides in inhibiting growth (100%) of test fungus. Among the combinations, Propiconazole and leaf extract of *P. juliflora* and *T. harzianum* were able to manage the pathogen. Neem, Hingota and Calotropis showed antifeedant activity against *Acanthophorous serraticornis.* In order to find out possible resistant or escape trees of *P. cineraria*, ninety two Candidate plus Trees (CPTs) were selected from Nagaur, Churu, Jhunjhunu, Sikar and Jaisalmer districts in Rajasthan. Progeny trials have been established at Jodhpur (with 30 families) and at Samaspur, Jhunjhunu (with 52 families). Analysis of variance of data collected from 52 individual CPTs revealed differences at 1 % level for pod length and weight of 10 pods amongst all the selected trees. Significant variation was observed in seed germination percent and germination velocity index. Best shoot multiplication method was finalized. DNA was extracted, purified and quantified for molecular marker based diversity. Multiplication of microshoots was obtainable only from fresh coppice material obtained from partially lopped mature trees lopped last year and establishes coppice shoots as best material for multiplication in Khejri. Maximum rooting percentage achieved was 30%. Analysis was carried out between khejri mortality and collected ecological data, but no significant correlation could be established between khejri mortality and selected ecological parameters. Different biochemical parameters were studied to determine their variation in healthy and infected trees. Proline and phenol content were higher in infected trees as compared to healthy trees and can be used as biochemical marker for identifying infection in Khejri trees. Data on socio-economic survey carried out in Nagaur, Churu, Sikar, Jhunjhunu and Jodhpur to assess the effect of khejri mortality on rural livelihood indicated reduction in lopped fuel wood ranging from Rs.132 per tree in Nagaur to Rs.151 per tree in Churu and Sikar at a prevailing rate of Rs.5/- kg. The reduction in fodder ranged from Rs.111 pertree in Jhunjhunu to Rs.178 per tree in Jodhpur at a prevailing rate of Rs.7/kg. Pamphlets on Problem of Khejri mortality in North-western Rajasthan were distributed among farmers and other stakeholders for raising awareness about Khejri mortality problem. Posters on Khejri mortality problem and its management were prepared for Extension and Interpretation Centre and Van Vigyan Kendras.

In another experiment, three bio-agents viz., *Trichoderma harzianum, T. viride* and *T. pseudokoningii* were tested for their antagonistic effect against the isolated pathogens. *T. viride* showed maximum inhibition (70%) on the tested pathogens. Botanical extract (Neem, Dhatura

and Hingota) and entomopathogenic fungi (*Metarrhizium anisopleae, beauvaria bassiana and Trichoderma harzianum*) were used for management of 'Slug' and 'Snail'. Thirty two combinations of 5 growth promoting rhizobacteria as well as fungi were tested to study their efficacy in promoting growth and vigour of neem seedlings. Maximum growth was observed in combination of *Azotobacter+Azospirillum+Trichoderma.*

With a view to use biofertilizer in rehabilitation of salt affected soil rhizosphere soil samples of *Salvadora persica* (Khara jal) were collected from Jodhpur, Bikaner, Jaisalmer, Nagaur and Pali, where two most important AM fungal genera isolated were *Glomus* and *Scutellospora*. Rhizosphere soil and root samples of *Dendrocalamus strictus* and *Bambusa bambos* were also collected from various forest nurseries of Rajasthan for mass multiplication of associated AM fungi. Soil samples were analyzed for various physic-chemical properties and AM fungi have been isolated. The important genera were identified as *Glomus, Acaulospora, Gigaspora* and *Sclerocystis.* Among these four genera, *Glomus* occurred most frequently.

Insect and non-insect pests were collected from 35 nurseries covering 7 district of State Forest Department, Rajasthan and Arid Forest Research Institute, Jodhpur. *Laevicaulis alte* (slug) was recorded from all the forest nurseries. *Macrochlamys indica* was recorded from nurseries at Jodhpur. *Alstonia scholaris, Terminalia arjuna* and *Bougainvillea* spp. recorded as new host for defoliator *Hasora chromus* Cramer. *Pongamia pinnata* (Karanj) was found infested with leaf miner *Lithocolletis virgulata. Dalbergia sissoo* was infested by leaf miner *Leucoptera sphenographta*. Sap sucker *Aphis gossypii* was found infesting cuttings of *Cascabela thevetia* (kaner), whereas *Citrus limon* (lemon) was found infested by leaf miner *Phyllocnistis citrella.*

A preliminary survey of Khejardhali, Guda Bishnoiyan, Phalodi, Lohawat, Osian, Nagaur, Pali and Luni was conducted to get status of severity of flower gall and to develop integrated management strategy against flower gall inducers of *Prosopis cineraria* (L.) Druce (khejri). Study was also carried out on diversity of pollinators and their role in fruit/ pod production of *Acacia senegal, Capparis decidua* and *Prosopis cineraria* in Rajasthan. Data on diversity and population of pollinator insects on *A. senegal, P. cineraria* and *Capparis decidua* and foraging behaviour of insect pollinators on the inflorescence was collected during their blooming stage.

Work on multilocational clonal trials of *Casuarina* species for multiple end uses in Gujarat State has been initiated with the aim to identifying the most-adapted and fast-growing clones of *Casuarina equisetifolia, Casuarina junghuhniana* and their hybrids for increasing productivity of plantations in Gujarat State. Sixteen outstanding clones including five winds tolerant, 4 salts tolerant and seven fast growing, high yielding hybrids were selected and collected from Clonal Bank of IFGTB, Coimbatore. They were transplanted in root trainers and kept in AFRI, Nursery for hardening and attaining plantable size. Seeds of *Anogeissus pendula* from seventeen locations of Rajasthan were also collected and maximum percent germination (3.5%) was observed in seeds collected from Kailana area of Jodhpur. Works on development of seed

production areas and haploid plants of *Commiphora wightii* was also carried out, where mature seeds from individual plant (genotype) were collected from four field trials at Deesa, Gujarat. Sixty stem cuttings of nine male plants were raised in mist chamber. Sprouting was observed in almost 30% stem cuttings.

Tree improvement programme included all India co-ordinated project for genetic improvement of *Melia composita*, where genetic variation and inheritance pattern of species were investigated by establishing multi-location progeny trials at Jodhpur, Deesa and Gandhinagar. This consisted of 24 families with five replications and Ghodiwara (Jhunjhunu) and Bassi (Jaipur) with 21 families and 4 replications. Progeny trials of *Tecomella undulata* were also established at Jodhpur and Jhunjhunu districts of Rajasthan. In this progeny of CPT No-36 from Pali district and progeny of CPT No-25 from Churu district out performed others at Jodhpur and Jhunjhunu, respectively. Clustering pattern of dendrogram generated by pooled ISSR data showed two major clusters based on genetic diversity. These two major clusters were made up of one and seven minor sub clusters. The preliminary analysis indicates the element of geographical distinction which ISSR markers were able to resolve.

Under the multilocation programme on induction, evaluation and development of polyploides in *Azadirachta indica*, sixty six new CPTs were identified and marked. Fruits were collected, de-pulped and seeds were extracted. 1650 seedling of 20 CPTs and more than 2000 seedling of local provenance were raised and provided to FRI, Dehradun for establishing genetic test trials. Seeds from individual trees of 33 families of 20 Clones were also supplied to FRI, Dehradun.

Biotechnological tools were utilized for clonal propagation and supply of genetically superior trees of Neem, Adusa and Bamboo. Best *in vitro* shoot multiplication was achieved in MS medium supplemented with Benzyl amino purine (BAP) 1.0 mg/l, Kinetine (Kn) 1.0 mg/l and additives in Neem. In case of *Dendrocalamus asper*, and *D. hamiltonii* best *in-vitro* shoot multiplication was achieved in MS medium supplemented with BAP. In case of Neem, *in-vitro* rooting was obtained on MS medium supplemented with IBA. In case of Bamboos, *in-vitro* rooting was obtained on MS medium supplemented NAA or IBA. Mature, semi mature and mini cuttings of neem treated with 500 ppm IBA gave forty percent rooting. The technology was explained and demonstrated to SFD Staff of Ghandhinagar.

Under tissue culture protocol for economically important bamboo- *Schizostachym dullooa* offset cutting were collected from Bambusetum at Rajpipla, SFD- Gujarat. The collected offsets were established at AFRI nursery. Micropropagation studies initiated using nodal segments as an explant from newly sprouted material and collected from Ukaii Bambusetum. Axillary bud break is achieved in some of the nodal segments. For another study, nodal segments of *Leptadenia reticulata* collected from Barmer and Jodhpur were used as an explant and bud break was achieved after one week of inoculation in MS medium in the dark for initial 2-3 days and later

kept in 16 h photoperiod. In vitro shoot proliferation was obtained on MS medium supplemented with 5.0 mg/l BAP.

Screening of DNA markers to distinguish male and female trees of *Ailanthus excelsa* for higher biomass production indicates that male tree bark is comparatively light in colour than females, whereas leaves of male trees are thicker, smoother and softer than females. Initiation of branching is found earlier in females than in male trees. Likewise work on identification of juvenility markers to improve rooting potential of some important tree species carried out. Significant changes were recorded in number of leaflets per leaf in case of *Azadirachta indica* (Neem) and *Ailanthus excelsa* (Ardu). The coppicing initiation was faster in case of Ardu, followed by Neem. It was slowest in *Tecomella undulata*.

Work on *in -silico* identification of abiotic stress-tolerance candidate genes using co-expression network analysis and comparative genomics was carried out. A preliminary list containing 123 genes was prepared that was later truncated to 100 gene list called henceforth the "Curated Gene List" (CGL), forming a list of "bait genes" of *Arabidopsis thaliana* to be used for gene co-expression network analysis.

Studies on the effects of MPOWER programme on mitigation and adaptation towards climate change in western Rajasthan was initiated for identification of activities that enhanced livelihood and adaptations to climate change among the villagers of the selected villages in western Rajasthan; selecting best practice supporting mitigation of climate change in these villages; and documentation on level of sensitization and adoption of best practices of MPOWER for replication at large scale.

Socio-economic and vegetation survey in forest fringe village of Rajasthan revealed that majority of the population in fringe districts is tribal and have small and marginal land holdings. Data indicated that the area was either teak dominating or mixed type of communities. Common tree species associated with teak are *Anogeissus pendula* (Dhok) scrub, *Tectona grandis* (Teak), *Anacardium occidentale* (Kaju), *Carrisa carandus* (Karonda), *Terminalia tomentosa* (Sadar) *Diospyros melanoxylon* (Tendu), *Butea monosperma* (Palash), *Eucalyptus camaldulensis* (Safeda), *Acacia catechu* (Khair), *Syzygium cumini* (Jamun), *Lagerstroemia parviflora* (Kankedia). The natural regeneration of teak was low, whereas regenerations of *Diospyros melanoxylon* and *Butea monosperma* were relatively better. Frequencies of occurrence of *Prosopis juliflora*, *Lantana camara, Cassia auriculata (*Anwal) and *Cassia tora* (Puad) were 35.32%, 31.2%, 20.3% and 18.30%, respectively.

Important research findings and technologies for applications to forestry in Rajasthan were compiled and published in the form of books 'A manual for Dry land Afforestation and Management' and शुष्क क्षेत्र वनीकरण एवं वन प्रबंधन: तकनीकी एवं कार्यविधियाँ. Documentation work of

sacred groves of Rajasthan has also been done and published in the form of book 'Sacred Groves of Rajasthan: Threats and Management Strategies'. Another book entitled "राजस्थान के पवित्र उपवन: संभावित खतरे तथा प्रबंधन नीतियाँ." was also published in 2017.

Summary of the projects

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2016-17
Plan	4	2	15
Externally Aided	5	10	3
Total	9	12	18

1. Introduction

Arid Forest Research Institute, Jodhpur (Rajasthan), is one of the nine institutes of the Indian Council of Forestry Research & Education (ICFRE), an autonomous organization of the Ministry of Environment, Forests & Climate Change, Government of India. The goals of the institute are to carry out scientific research in forestry & allied fields to enhance the productivity and vegetative cover, to conserve the biodiversity and to develop the technologies for the stakeholders working in forestry sector in Rajasthan, Gujarat, Dadra & Nagar Havelli and Daman & Diu (Fig. 1).

Fig.1. Jurisdiction map of AFRI, Jodhpur

The major emphasis of research at the institute are on soil, water & nutrient management; technologies for afforestation of stress sites; management of plantations; growth and yield modeling; planting stock improvement and biotechnology; bio-fertilizers and bio-pesticides; Agroforestry & extension; phytochemistry & non-timber forest products; integrated pest and disease management; biodiversity and climate change; and forestry education and extension.

2. Research Highlights

2.1 Ecosystem Conservation and Management

2.1.1 Overview

2.1.1.1 Summary of the achievement under the Theme

This theme includes finding of five projects highlighting the importance of climate change adaptation and mitigation, carbon stock and soil mapping, utilization of effluent in growing woodlots for phytoremediation, socioeconomic and ecological studies for identifying root causes of the destabilization and shrinkage of the forests lands in forest fringe villages in Rajasthan and Gujarat, and evaluation of species performance during restoration of degraded hills of Aravalli region. These includes identification of activities that enhanced livelihood and adaptations to climate change among the villagers of the selected villages in western Rajasthan; selecting best practice supporting mitigation of climate change and documentation on level of sensitization and adoption of best practices for replication at large scale. District wise maps have been prepared showing data points which are linked to date base on carbon stock and soil characterization of different forest blocks of Rajasthan. In other project users friendly map prepared and one can visualize different parameters on forest soils, site, vegetation, regeneration status of different species, erosion, drainage characteristics and carbon stock of studied forest blocks of Rajasthan by clicking on the maps. This map is available in soft copy and can be viewed in any PC using 'Google Earth' and 'TNTmips' software. Under phytoremediation experiments are maintained, growth parameters recorded and soil analysed. Treated effluent observed beneficial in growth of most of the species. Socio-economic and vegetation survey in forest fringe village revealed majority of tribal population with small and marginal land holdings in these area, where teak mixed type of communities are dominating. Under species performance, survival and growth was high in *Dendrocalamus strictus*, *Terminalia arjuna*, *Emblica officinalis* and *Thespesia populnea.*

2.1.1.2 Project under the theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2016-17
Plan	1	-	1
Externally Aided	3	1	1
Total	4	1	2

2.1.2 Climate Change

Project 1: Studies on the effects of MPOWER programme on mitigation and adaptation towards Climate Change in western Rajasthan (Phase II) (AFRI-17/FED/Ext./SFD/2017).

Principal Investigator: Dr. G. Singh, Scientist G

This project is funded under Mitigating Poverty in Western Rajasthan (MPOWER), which has been implemented in six blocks, one each in Jaisalmer, Barmer, Jodhpur, Pali, Jalore and Sirohi district of western Rajasthan. The basic objectives of this project are (i) Identification of activities that enhanced livelihood and adaptations to climate change among the villagers of the selected villages in western Rajasthan; (ii) Selecting best practice supporting mitigation (i.e., carbon sequestration in soil) of climate change in these villages; and (iii) Documentation on level of sensitization and adoption of best practices of MPOWER for better adaptation and mitigation to climate change and improvement in people's livelihood for its further replication at large scale. Data from Baitu block in Barmer have been collected through different questionares and soil sampling in 0-30 cm soil layer from different land uses were done for soil organic carbon, bulk density and gravel content estimation. In Baitu block, 407 numbers of households were surveyed, where number of family members has been worked out at 5.27. Number of days employed in agriculture and animal husbandry in this block were 113 and 355 days, respectively. Number of animals per household is 8.48 in which 7.22 numbers is for goat/sheep. Cow dung, fuelwood, crop residue, LPG and kerosene are used for cooking/energy generation. Consumption of respective energy source during summers and winters are 1.55 and 1.74 kg, 9.53 and 12.6 kg, 2.43 and 4.11 kg per day, and 3.86 and 7.01 kg per month and 0.17 and 0.25 liter per month, respectively.

Benefits of the research project: Knowledge about adaptation and mitigation measures adopted by local people to climate change for improved livelihood and environmental quality.

Project 2: Carbon stock and soil classification mapping for Rajasthan forests (AFRI-115/FED/ICFRE/2011-16).

Prinicipal Investigator: N. Bala, Scientist F

The data base generated on forest soil and vegetation of Rajasthan under two projects in Forest Ecology Division, AFRI have been utilized in GIS platform to present them in the form of digitized maps (Fig. 2).

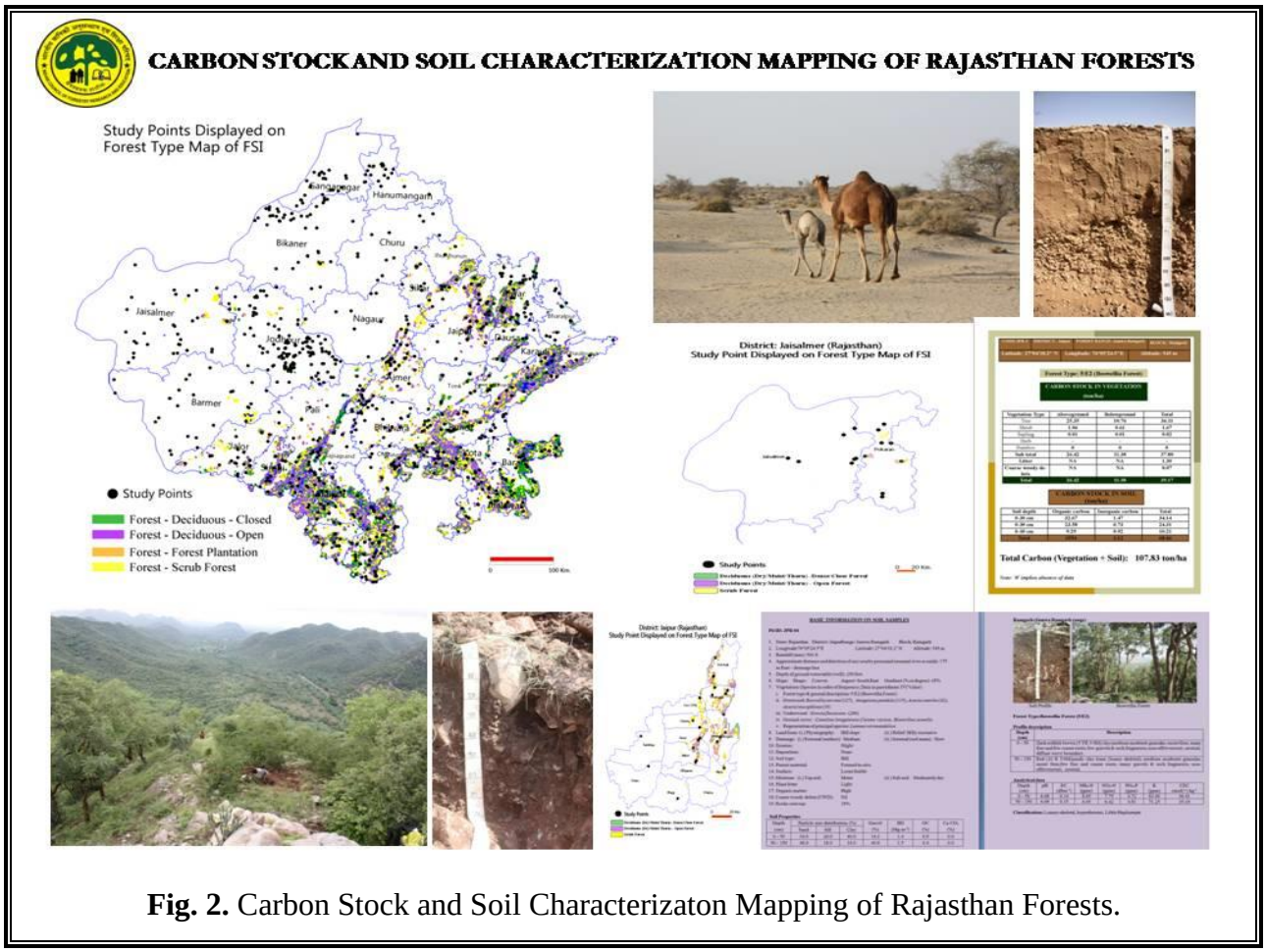


Fig. 2. Carbon Stock and Soil Characterizaton Mapping of Rajasthan Forests.

The National Forest Type map of Forest Survey of India (FSI) was utilized as the base map in a raster based Geographical information System (GIS). On GIS 'Tntmips' software was used to create the maps. District wise maps on forest soils, site characteristics, vegetation, regeneration status of different species, erosion, drainage characteristics and carbon stock of studied forest blocks of Rajasthan have been developed. Users can visualize different parameters by clicking the data points on the map (Fig. 2).

The maps generated on the basis of primary data on forest soils and carbon stock will serve as source for baseline information in the present climate change scenario. Digitized maps on forest carbon stock, Forest soil types as per USDA classification and Forest soil nutrient status of Rajasthan is a pioneering work in the state. The maps developed will be useful to the researchers, forest managers and policy makers and also help to formulate appropriate management strategy for forests of Rajasthan. The maps are available in soft copy and can be viewed in any PC using 'Google Earth' and 'TNTmips' software.

2.1.3 Ecology and Environment

Project 1: Phytoremediation of soil for productivity enhancement during land disposal of effluent (AFRI-113/FED/SFD-Raj/2011-18).

Principal Investigator: Dr. G. Singh, Scientist G

This project was initiated with objectives (i) To assess the most efficient species for soil improvement and phytoremediation; (ii) To monitor changes in soil health and phytoremediation ability of different species; and (iii) To utilize industrial treated effluent as source of irrigation in afforestation with overall improvement in soil and environmental quality and productivity from wastewater. It involves an experiment in lysimeter tanks (non-weighing type) started in September 2012 with 7 tree species and for irrigation levels and a field experiment started in September 2013 with 10 forestry tree species irrigated with treated effluent (1/2 and 3/4 ET) and canal water (1/2 and 3/4 ET) at different levels.

Experiment 1: Experiment in lysimeter was established in completely randomized design consisting of four levels of irrigation and 7 tree species in three replications utilizing 84 numbers of lysimeter tanks accommodating one plant in each tank (Fig. 3). Irrigation levels are: (I_1) normal water at ½ ET (evapo-transpiration) as control, (I_2) effluent water at ½ ET; (I_3) effluent water at ¾ ET; and (I_4) effluent water at 1.00 ET. Tree species planted are *Azadirachta indica (*Neem), *Eucalyptus camaldulensis* (Safeda), *Prosopis cineraria* (Khejri), *P. juliflora* (Vilayati Babul), *Tamarix aphylla* (Farash), *Salvadora persica* (Khara Jaal) and *S. oleoides* (Meetha Jaal). Data on height, collar diameter and crown diameter are being recorded since September 2013 at three months interval, i.e. March, June, September and December. Mean annual increment in height (49.5 cm per year), collar diameter (12.0 mm per year) and crown diameter (31.5 cm per year) were highest in *E. camaldulensis*, *Salvadora persica* and *A. indica*, respectively during September 2013 to March 2017(Fig.4). Respective MAI was least in *T. aphylla*, *E. camaldulensis* and *T. aphylla*. Among irrigation, highest MAIs in height (36.0 cm per year), collar diameter (11.0 mm per year) and crown diameter (29.6 cm per year) were in I_3, I_4 and I_2 levels. Least MAIs for all growth variables were in control (I_1 level).

Soil sample collected from 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm soil layers in December 2015 indicated a decrease in NH_4-N (13.09 to 10.47 mg kg^{-1}), available PO_4-P (8.16 to 6.6.75 mg kg^{-1}), K (128.92 to 88.14 mg kg^{-1}), EC (0.90 to 0.72 (Sm^{-1}) and increase in NO_3-N (3.53 to 4.00 mg kg^{-1}) while moving down in soil layers. Lowest amount of NH_4-N (11.60 mg kg^{-1}) was in *A. indica*, NO_3-N (3.31 mg kg^{-1}) was in *E. camaldulensis*, PO_4-P (6.22 mg kg^{-1}) was in *P. juliflora*, K (99.62 mg kg^{-1}) was in *S. persica*, soil pH (8.34) in *A. indica, P. juliflora* and *S. oleoides* and EC (0.69 mSm^{-1}) was in *T. aphylla*. Among the irrigation levels, concentrations of most of the soil variables were higher under effluent irrigation though soil pH, K and EC did not differ significantly ($P>0.05$).

Experiment 2: This field experiment was started in September 2013 involving 480 plants of ten forestry tree species like *Acacia nilotica* (Desi Babul), *Ailanthus excelsa* (Ardu), *Azadirachta indica* (Neem), *Eucalyptus camaldulensis* (Safeda), *Prosopis cineraria* (Khejri), *Prosopis juliflora* (Vilayati Babul), *Tamarix aphylla* (Farash), *Tecomella undulata* (Rohida), *Salvadora oleoides* (Meetha Jaal) and *S. persica* (Khara Jaal) planted at 3 m x 4 m spacing and in Split Plot Design with three replications. Four irrigation levels are: (i) effluent water at 1/2 ET, (2) effluent water at 3/4 ET, (3) normal water at 1/2 ET, and (4) normal water at 3/4 ET. The irrigation is based on cumulative pan evaporation at one month interval. Height and collar diameter of the plants recorded since June 2013 after start of treatment (effluent and control) on annual basis indicated highest height increment of 72.1 cm per year in *A. indica* and collar diameter of 18.6 mm per year in *P. juliflora*. Least growth increment in height (16.8 cm per year) and collar diameter (6.5 mm per year) were observed in *P. cineraria* and *T. undulata*, respectively up to November 2016 (Fig. 3-4). Among the irrigation levels, height and collar diameter increments were highest in tree irrigated with effluent at 3/4 ET and 1/2 ET, respectively.

Fig. 3. Lysimeter experiment.

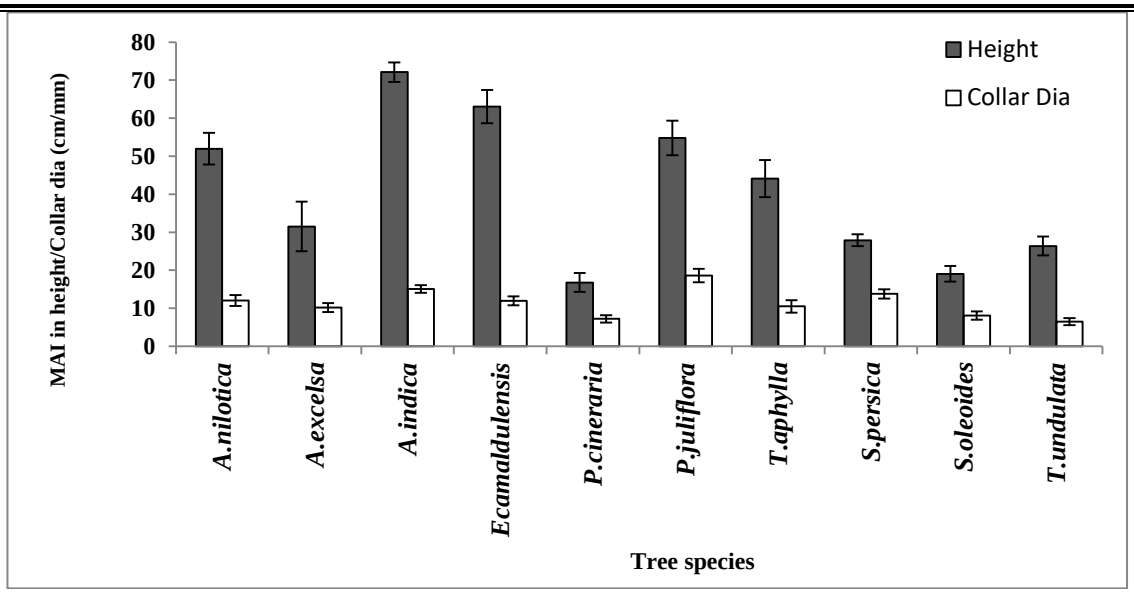


Fig. 4. Mean Annual Increments (MAI) in height and collar diameter of different species irrigated with treated effluents.

Benefits of the research project: Treated effluent can be utilized in raising tree plantation with some amendments to enhance environmental quality and green cover in suburban areas.

Project 2: Identification of extent of forest land in forest fringe village (AFRI/FED/NRAA/2011-2016).

Principal Investigator: S. R. Baloch, Scientist C

The project 'Identification of extent of forest land in forest fringe villages' was started to gather information on forest dependency and socio-economic conditions of the forest surrounding inhabitants and the root causes of the destabilization and shrinkage of the forest land in the selected forest fringe villages of Rajasthan and Gujarat. Ecological survey and vegetation studies were done in Jamnagar, Panchmahal, Jamnagar, Junagarch, Surat, Vadodra, Valsad, Dahod, Kauchh, Narmada, Sabarkantha Banaskantha and the Dangs districts in Gujarat; and Pali, Sirohi, Baran, Kota Bundi, Jhalawar, Banswara, Chitorgarch, Udaipur, Jaipur, Sawai Madhopur and Dhaulpur districts in Rajasthan. The information so collected were entered simultaneously through online web portal and further reports on floristic and socioeconomic status of forest fringe areas were prepared and sent to FRI, Dehradun. The forest fringe villages of Rajasthan and Gujarat districts indicate that the area was either teak dominating or mixed type of communities (Fig. 4). Common tree species associated with teak were *Anogeissus pendula* scrub, *Tectona grandis, Anacardium occidentale, Carrisa carandus, Terminalia tomentosa, Diospyros melanoxylon, Butea monosperma, Eucalyptus camaldulensis, Acacia catechu, Syzygium cumini, Lagerstroemia parviflora* etc. Due to continuous hacking or clearing of tree for cultivation and uncontrolled grazing, the natural regeneration of teak was low, whereas regenerations of Timru

(*Diospyros melanoxylon*) and Palas (*Butea monosperma)* were relatively better. Frequency of occurrence of *Prosopis juliflora*, *Lantana camara, Cassia auriculata* and *Cassia tora* was 35.32% 31.2% 20.3% and 18.30, respectively. Majority of the population in fringe districts of Rajasthan are tribal and have small and marginal land holdings. The irrigation facilities are poor, therefore, the farmers depend on kharif crops. Bheel, Meena and Garasia are dominant tribal castes in these areas.

Fig. 5. Mixed vegetation in fringe forests of Surat district (left) and forest of *Butea monosperma* (right) in Banaskantha district in Gujarat.

Project 3: Species evaluation for landscaping and restoration of degraded Aravalli hills at IIM campus, Udiapur (AFRI-13/FED/EXT (IIM, UDAIPUR)/2014-17).

Principal Investigator: N.Bala, Scientist F

The project was initiated with the aim to evaluate different tree and shrub species for their suitability in restoration of degraded hills. Suitable species selected depending on the site parameters. Arrangement was made for the planting stock in collaboration with the forest department. Advance soil working was initiated involving village forest protection and management committee (VFPMC). Contour trenches of 2200 running meter were made in the experimental area as soil and water conservation measure. Seedlings of *Terminalia arjuna* (Arjun*), Ficus bengalensis* (Bad), *Dendrocalamus strictus, Tamarindus indica, Wrightia tinctoria* (Aritha), *Acacia catechu, Sterculia urens* (Kadaya), *Emblica officinalis, Ficus religiosa* (Pipal), *Thespesia populnea, Anogeissus pendula, Azadirachta indica, Holoptelia integrifolia* (Ronj), *Erythrina variegata, Delonix regia* (Gulmohar), *Pongamia pinnata, Commiphora wightii*, *Thevetia nerifolia* (Pili Kaner), *Zizyphus mauritiana* and *Pithecellobium dulce* (Jungle jalebi)) were planted in blocks as per soil and land characteristics (Fig. 6). Planting of branch cutting of *Boswellia serrata* (Salar) was done at 150 places. To protect the plants from browsing by Blue bull brushwood fencing made for individual plants. Seeds of different species were also sown on the mounds of contour trench. Available trees, tree saplings and shrubs in the plantation

area were pruned to give better shape. Mortality replacement and replanting was done in the plantation area. Life saving irrigation provided at regular interval. Survival and growth was high in *Dendrocalamus strictus, Terminalia arjuna, Emblica officinalis* and *Thespesia populnea.*

Benefits of the research project: Information generated will help in landscape planning of the IIM, Udaipur campus.

(a) Plantation area with contour trench filled with rain water.

(b) Sapling and stump planting.

(c) *Dendrocalamus strictus.*

(d) *Anogeissus pendula.*

(e) *Boswellia serrata* branch cutting **(f)** *Emblica officinalis*

Fig. 6: (a-f). Establishment of different species for landscaping and restoration of degraded Aravalli hills at IIM campus, Udiapur.

2.1.4 Biodiversity

Project 1: Diversity of insect pollinators and their role in fruit/ pod production of *Acacia senegal, Capparis decidua* and *Prosopis cineraria* in Rajasthan. (AFRI-26/FP/ICFRE/2016-19).

Principal Investigator: Dr. Shiwani Bhatnagar, Scientist C

Experimental site for *Acacia senegal (*Kaylana Kumathiya enclosure, Jodhpur*), Capparis decidua* (GTB & FPD field, Jodhpur*)* and *Prosopis cineraria* (Ecology field, Jodhpur) were selected. In *Acacia senegal*, flowering was observed in the end of July and flowers were creamy-white in colour. Top of the canopy came to bloom first followed by lower branches. The bagging experiment was laid to check the chances of autogamy, where bagged flowers set no fruit, ruling out the chances of autogamy. The insect pollinators were recorded during morning to evening hours of a day. The number of visits made by insect pollinator and the time spent by insect pollinator were also recorded during flowering period. Hymenopterans (*A. dorsata, A. florea, Vespa* spp, *Xylocopa* spp., ants, *Polites* spp, *Megachile* spp.), Coleopterans (*Mylabris pustulata, Oxycetonia* spp.), Hemipteran (*Bagrada* spp.), Lepidopteran (*Colotis fausta, Colotis etrida, Catopsilia* spp., *Eurema* spp., *Papilio* spp.) and Diptera (Syrphids) were observed. Insect pollinators visiting the blossoms of *A. senegal* were collected, properly pinned and placed in the display showcase. Foraging behaviour of insect pollinators visiting the flowers of *C. decidua* in Februray - March and April- May were also observed. Flowering was observed in second fortnight of February and April and flowers were red in colour. Flowering was asynchronous. No fruit set was recorded in the bagged flowers of *C. decidua* also. The insect pollinators recorded

were Hymenopterans (*A. dorsata, A. florea, Vespa* spp, ants, *Xylocopa* spp.), Lepidopteran (*Pieris* spp., *Colotis* spp., *Danus* spp. *Eurema* spp. Cephora spp., Ixias spp.,) and Diptera (Syrphids). Flowering was observed in second fortnight of February in *Prosopis cineraria.* The flowers are in form of axillary spikes and yellow in colour. No autogamy was observed in *P. cineraria*. Insect pollinators recorded during blooming period were Hymenopterans (*A.dorsata, A. florea, Vespa* spp., Halictids, megachilids, *Trigona* sp. ants *Xylocopa* spp., *Vespa* spp.), Diptera (Syrphids), Lepidopteran (*Pieris* spp., *Colotis* spp., *Eurema* spp.).

The foraging insects were found maximum between 10.00h to 12.00h. There was a sudden decline in the number of insect visiting the flowers from 12.00h to 14.00h. However foraging activity increased again around 16.00h.

Benefits of the research projects: Project will be beneficial in finding out role of insect pollinators in fruit/pod production of Khejri, Kair and Kumat.

2.1.5 **Forest Botany: NIL**

2.1.6 **Tribals and Traditional Knowledge System**:

Project 2: Documentation of sacred groves of Rajasthan and assessment of biological diversity in some of them for improved management and people livelihood. (AFRI/FE/SFD-Raj./2016-2017). (PHASE-II).

Principal Investigator: Dr. G. Singh, Scientist G

This project was sanctioned by State Forest Department, Rajasthan to document status of sacred groves in Rajasthan and development of management strategies of these groves during 2013-14. Based on the project work, existing literatures and field observations a book **'Sacred Groves of Rajasthan: Threats and Management Strategies'** containing 7 chapters was published by AFRI, Jodhpur in 2016 (Fig. 7). SFD, Rajasthan sanctioned Rs 1.50 lakhs in 2016 for (i) Translating 'Sacred Groves of Rajasthan: Threats & management Strategies' book in Hindi and (ii) Publication of Hindi Book and supply to SFD, Rajasthan for its distribution. Book 'राजस्थान के पवित्र उपवनः संभावित खतरे तथा प्रबन्धन नीतियाँ" published in 2017 and is focusing on sacred groves-traditionally protected forest fragments and the past and present researches on this important community resource supporting livelihoods in the region. An attempt was made to provide historical background of the sacredness of historical forests of India, biological, social and economic status of the groves, threats arising out of various anthropogenic activities like overexploitation, developmental and mining activities and encroachments of various types, and the strategies for their effective management considering their importance in people livelihood.

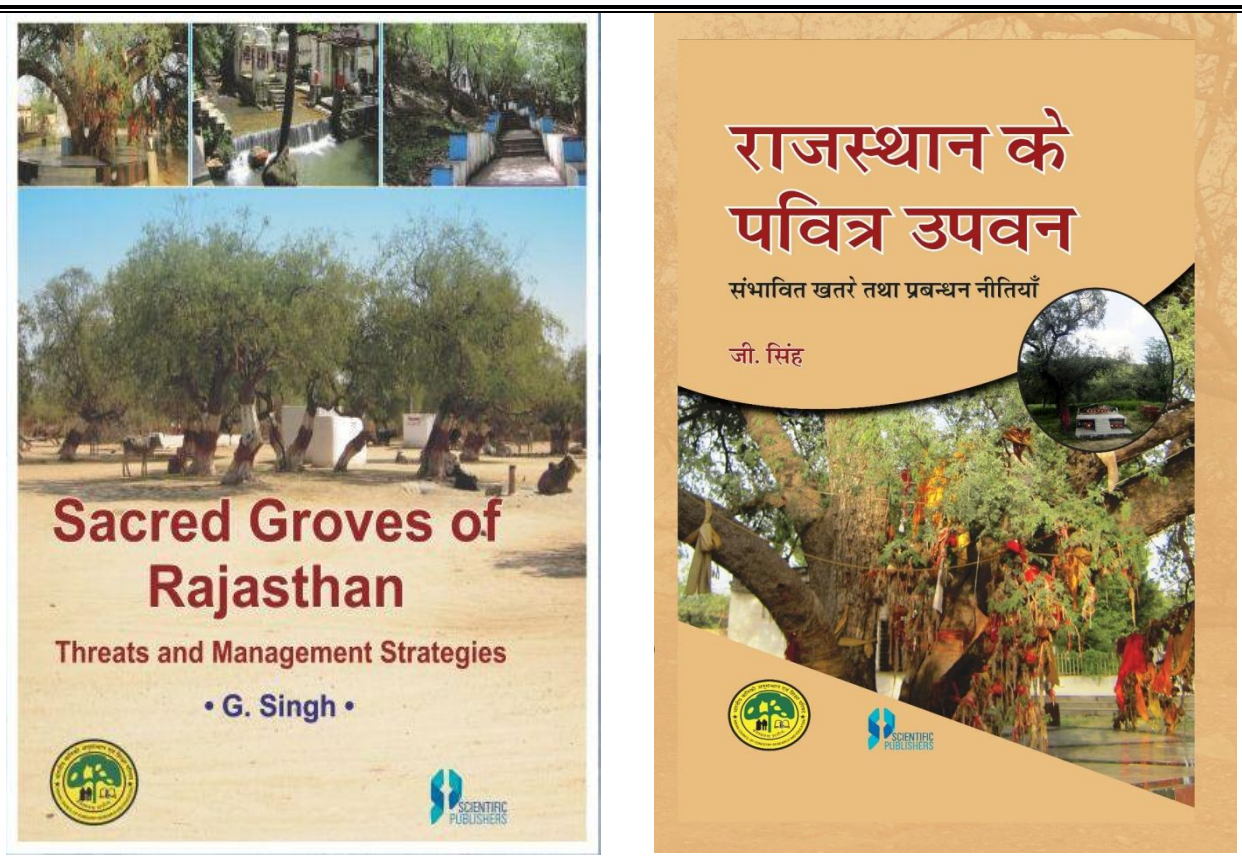


Fig. 7. Book published in English (Left) and in Hindi (Right).

There are 8 chapters in Hindi book, which initiates with sacredness of historical Indian forests, an overview of the sacred places, trees and the groves and background context and methods of field observation recording. The remaining chapters describe status of 123 sacred groves distributed throughout Rajasthan, biological diversity and invasion status; soil characteristics and soil nutrients and carbon status; types of livelihood supports and the threats on these sacred groves; and people's perception and management strategies by accommodating the desire of grove dependent communities and level of participation of the local villager in protecting and conserving these sacred groves. This publication provides the readers a wide ranging knowledge about the sacredness of our historical forests, importance of sacred groves, to enhancing tree cover, resilience and livelihoods of the local population and to improve the environmental conditions of this degrading ecosystem for local, regional and global benefits.

Benefits of the research project: It could be useful to the policy makers, forest managers, non-government organizations, extension agents, environmentalists as well as researchers and academician, who are involved in developing, conserving and managing community resources for the benefit of local people. Giving permission for selling of books for revenue is in the process.

2.2 Forest Productivity

2.2.1 Overview

2.2.1.1 Summary of the achievement under the Theme

Studies on seed germination and nursery technology of *Anogeissus pendula* was taken up. Seed germination is very poor which is a great problem to raise nursery in Rajasthan state. Seeds of *Anogeissus pendula* from seventeen locations of Rajasthan were collected and Seed germination was maximum (3.5%) in seeds collected from Kailana area of Jodhpur. Besides, *Casuarina* species is most adoptive and fast growing in salt affected, coastal and insland sites. Therefore, multilocational clonal trials of *Casuarina* species has been initiated with the objective to identifying the most-suitable and fast-growing clones of *Casuarina equisetifolia, Casuarina junghuhniana* and their hybrids for higher productivity in Gujarat State. Sixteen outstanding clones were collected from IFGTB, Coimbatore and transplanted at Nursery AFRI Jodhpur.

A project was also initiated on Sandalwood (*Santalum album*) cultivatation in Gujarat and Rajasthan. The objectives of the project was to evaluate the exiting plantation of ***Santalum album*** in Gujarat and Rajasthan and demonstrate best agroforestry model for farmers. ***Santalum album*** growing four farmers were selected and surveyed as they were growing ***Santalum album*** plants with different silvi and horti hosts and data was recorded.

A. senegal an important desert tree which grows on scatter, bund, hilly and sandy tract or plantation on farm in arid region of Rajasthan where tree density is one dominant factor in agroforestry system for optimum benefit and reduces competition for natural resources like water, nutrient and light. Presently, Ethephon induces high-yield of gum from *A. senegal* tree which create interest among farmers for *A. senegal* based agroforestry and its benefits. Thus, intensive survey was also conducted in *Acacia senegal* trees based agroforestry areas in Barmer, Jodhpur and Nagaur districts and interaction was made with a number of farmers to obtain their views and suggestions on *Acacia senegal* based agroforestry.

Study on the effects of tree on soil fertility and crop production in Rajasthan in under process.
Food insecurity increases by adverse climatic conditions and droughts in dry areas. Study conducted on different traditional and improved models of agroforestry on farmer's land covering 21 districts in eight agroclimatic zones of Rajasthan showed dominance of 12 tree species in agroforestry systems. Among these *P. cineraria* observed dominating in arid region and *A. nilotica* observed dominating in semi-arid regions of Rajasthan. Preliminary results indicate that different models have different potential depending upon the availability of natural resources, tree management and cultivars of crops.

In Rajasthan large area (0.38 mha) suffers from problems of salinity and alkalinity; and its rehabilitation through bio-corrective measures is required to make effective use for providing agricultural sustainability and resilience against frequent droughts . In experiments conducted to enhance fodder productivity through silvi-pastoral systems on degraded salty land through

resource management indicated establishment of highly palatable non salt tolerant *Cenchrus ciliaris* (CAZRI-75) grass on soil slope in the inter row spaces of *Colophospermum mopane* (mopane) plantation on a salt affected soil. Mopane based silvipastoral systems with other studied grasses viz. *Bracharia ramosa* (Murat), *Dactyloctenium scindicum* (Ganthia), *D. aegyptium* (Makda), *Sporobolus diander* and *Chloris virgata* improve pastoralism in the arid salt affected soils and provided greater buffer capacity ensuring sustainable production even in critical years of droughts.

2.2.1.2 Project under the theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2016-17
Plan	-	1	4
Externally Aided	-	1	-
Total	-	2	4

2.2.2 Silviculture

Project 1: Studies on seed germination and nursery Technology *of Anogeissus pendula*. (AFRI-22/Silvi/ICFRE/2016-19).

Principal Investigator: Dr. N. K. Bohra, Scientist B

Seeds collected from different locations in Bundi, Sawai Madhopur, Kota (Durra), Karauli and Jodhpur areas during 2016 were processed and number of seeds per gram and percent germination were calculated. Seeds were also collected from individual seed trees from 25 seed sources during 2017. Seeds were cleaned and seed testing parameters were estimated. Seeds collected from Jodhpur sources showed higher mean percent germination (3.80%), whereas seeds collected from Bundi source indicated minimum mean percent germination (1.09%). Seed germination was very low in *A. pendula* (Table 2).

Table 2. Seed quality parameters of *Anogeissus pendula* collected from various sources.

S. No.	Seed Sources	GPS Locations	Trees	No. of seeds /g	% germination	Mean % source germination
1	Bundi	$25^0$28.075 N :$75^0$38.269E	1	132	0.83	1.09
2	Bundi	$25^0$28.107 N:$75^0$37.864	2	154	0.7	
3	Bundi	$25^0$28.93N:$75^0$37.070	3	143	1.76	
4	Sawai Madhopur	$25^0$55.451 N:$76^0$19.650	1	132	2.31	2.31
5	Kota-Durra	$25^0$5.435N:$75^0$51.920E	1	154	2.62	2.53
6	Kota-Durra	$25^0$3.755N:$75^0$51.954E	2	155	1.09	
7	Kota-Durra	$25^0$03.737N:$75^0$91.928E	3	144	1.86	

8	Kota-Durra	$25^0$03.700N:$75^0$51.887E	4	150	4.55	
9	Karauli	$26^0$19.878N:$76^0$53.454E	1	162	2.46	1.51
10	Karauli	$26^0$19.572N:$76^0$53.378E	2	165	0.2	
11	Karauli	$26^0$19.179N:$76^0$53.541E	3	180	2.66	
12	Karauli	$26^0$18.940N:$76^0$53.846E	4	172	0.72	
13	Jodhpur	26°17′N 72°58′E	1	199	1.10	3.80
14	Jodhpur	26°17′N 72°58′E	2	140	3.29	
15	Jodhpur	26°17′N 72°58′E	3	179	8.17	
16	Jodhpur	26°17′N 72°58′E	4	162	3.32	
17	Jodhpur	26°17′N 72°58′E	5	173	3.11	

Project 2: Multilocational clonal trials of *Casuarina* species for multiple end uses in Gujarat State. (AFRI-41/Silvi/ICFRE/2017-22).

Principal Investigator: A. Durai, Scientist B

This project aims to identifying the most-adapted and fast-growing clones of *Casuarina equisetifolia* and *Casuarina junghuhniana* and their hybrids for increasing productivity of plantations in Gujarat State. The top-ranking clone(s) in salt affected, coastal and inland areas like environment will be recommended for large scale cultivation in similar areas. It is expected that these clones will be yielding a minimum of 20% more wood production benefiting farmers, Forest Department and wood-based industries. This project was implemented in January 2017 wherein sixteen outstanding clones including five winds tolerant, 4 salts tolerant and seven fast growth and high yielding hybrids were selected and collected from Clonal Bank of IFGTB, Coimbatore. They were transplanted in root trainers and kept in AFRI, Nursery for hardening and attaining plantable size.

Benefits of the research Projects: These clones are expected to yield a minimum of 20% more wood benefiting farmers, Forest Department and wood-based industries.

Fig. 8. Casuarina clones collected from IFGTB, clonal bank, Coimbatore.

Fig. 9. Labeling and shortlising of Casuarina clones.

2.2.3 Social Forestry, Agro –forestry/Farm Forestry

Project 1: Evaluation of existing plantations, establishment of agro forestry trials and capacity building to promote Sandal wood (*Santalum album*) cultivation in Gujarat and Rajasthan. (AFRI-40/Silvi/ICFRE/2017-20)

Principal Investigator: Dr. N. K. Bohra, Scientist B

This project was started in January 2017 under 15-points programme of ICFRE. The objective of the project was to evaluate the existing plantation of *Santalum album* established in Gujarat to identify best cultural practices and to develop and demonstrate best plantation model for the farmers. Survey was conducted in different agro climatic zones of Gujarat to get information about various *Santalum album* (Sandal) plantations established by farmers. In Central Gujarat, climate is semi-arid to dry sub humid with an average rainfall of 1000-1500 mm annually. Shri Nitin Bhai Patel of Kheda village Anand used *Casurina equisetifolia* plants as host with spacing of 4 m x 4 m host with host at 0.45 cm distance. 1250 plants of Sandal were plated in 2014 with drip irrigation. Height and girth of the plants were 4-4.5 meter and 25-30 cm, respectively. At Nanu bhai's Farm in Anand district, 550 Sandal seedlings were planted in year 2011 with *Moringa oleifera* as the host. The height ranged from 2-4 m and collar girth from 15-30 cm.

In North Gujarat, climate is arid to semi arid with an annual rainfall of 635-875 mm. In Kherva village, Mehsana at Tulsibhai Patel field, Citrus species were planted as host and spacing was 5 m x 3 m and 8 m x 3 m. Replacement of causality of host was done with *Alstonia seholaris* and Guava. Height of sandal wood plants was 3-4.5 m and collar diameter was 36-43 cm. In Satlasna taluka, 15 km from Kheralu in Mehsana district at Narendra Chavda's Farm, Sandal with different hosts were planted in 2013 at 6 m x 6 m spacing. In this farm, Sandal with pomegranate host attained height of 3-4 m and collar diameter of 15-24 cm. In another plot with *Citrus limettas* host sandal plant attained height of 2-3 m and collar diameter of 15 cm to 24 cm. In association with mango (variety kesar) sandal plants attained average height of 2 to 3 m and collar diameter of 18-25 cm (Fig. 10).

(a) Sandal with *Mangifera indica.* **(b)** Sandal with *Casuarina equisetifolia.* **(c)** Sandal with *Citrus limettas.*

Fig. 10 (a-c). Sandal with different host tree species.

Benefit: Scientific cultivation of sandal will be encouraged for profitable cultivation.

Project 2: Study on crop yield, soil fertility and gum production in *Acacia senegal* based traditional agroforestry system in arid region of Rajasthan. (AFRI-42/AF&E/ICFRE/2017-22).

Principal Investigator: Dr. Bilas Singh, Scientist B

Project was initiated in February 2017. An intensive survey was conducted in *Acacia senegal* trees based agroforestry areas in Barmer, Jodhpur and Nagaur districts. Farmers were interacted and their views and suggestions on *Acacia senegal* based agroforestry obtained. Tree stands of *A. senegal* having different spacing have been selected for cultivation of crop and application of gum producing hormone.

Benefits of the research projects: The project will help to enhace land productivity and livelihood of farmers.

Project 3: Study on the effects of tree on soil fertility and crop production in Rajasthan (AFRI-33/AFNED/SFD-Raj/2016-19).

Principal Investigator: Dr. Bilas Singh, Scientist B

Survey was conducted to study exiting agrofoforestry models in 21 districts of Rajasthan. Different agroforestry models on farmer's land were studied in Nagaur, Sikar, Churu, Ganganagar, Bikaner, Barmer, Karauli and Dausa covering eight agroclimatic zones in kharif season. Improved as well as traditional agri-horti and agri-silvi models like grafted *Zizyphus mauritiana,* Kinnow mandarin, *Punica granatum, Mangifera indica,* and *Prosopis cineraria, Acacia tortilis, A. nilotica, Ailanthus excelsa, Azadirachta indica* and *Dalbergia sissoo* were

found integrated with agricultural crops. Crop yield recorded and soil samples were collected from exiting irrigated agroforestry systems in Ganganagar, Bikaner, Karauli and Dausa in Rabi season. Collected information on tree growth, crop production and cost of cultivation were tabulated and their analysis is under process. Collected soil samples were analysed for their physico-chemical characteristics. Most dominant agroforestry systems were *P. cineraria* based in arid region and *A. nilotica* based in semi-arid region.

Literatures on different aspect of agroforestry were collected from various organizations viz. Central Arid Zone Research Institute (CAZRI) and AFRI, Jodhpur, CAZRI-Research Station at Bikaner, Research Station at Kota of Soil and Water Conservation and Training Institute, Dehradun, SKAU at Kushinagar, Banaskatha and their synthesis is in progress.

2.2.4 Forest Soils & Land Reclamation:

Project 1: Enhancing fodder productivity through silvipastoral system on degraded land of India. (AFRI-02/NWFP/Int (ICFRE) AICP/2012-2018).

Principal Investigator: Dr. Ranjana Arya, Scientist G

***Colophospermum mopane* (Mopane): *Cenchrus ciliaris* (Dhaman) trial**: A systematic study was conducted on loamy sand saline alkali soils in Jodhpur district of hot arid part of Rajasthan. The field trial was laid out to evaluate the growth and yield of *Cenchrus ciliaris* and other grasses with *C. mopane* established in 2003. Tree plantation was done at a spacing of 3 m X 4 m. There were six blocks of 9 plants in three replications. Soil was raised as mound of 90 cm x 120 cm x 25 cm size- referred as soil structure. Planting of non salt tolerant but highly palatable grass species, *C. ciliaris* (CAZRI – 75) was done on mound slope in inter-row spaces of *C. mopane* in 2013. Seed sowing was done at 30 cm distance in the lines and 40 cm apart from each other on the mound soil structures**.** Green grass yield for *C. ciliaris* was measured by laying quadrate of 1m x1 m randomly on soil structures; while for other grasses quadrates were laid out in vicinity of trees in the experimental area. Growth and yield data of various grasses with *C. mopane* (Table 1) reveald maximum green fodder yield in *Sporobolus diander* (drop seed gram), while the minimum in *Brachiaria ramosa.*

Table 1: Growth and yield of various grasses with *C. mopane* in the year 2016-17.

Grass species	Height range (cm)	No of clumps/m^2	Tillers (no)/clump		Green yield g/m^2	% ash
			Mean	range		
Sporobolus diander	65.0-130.0	17.3-30.0	38.5	65.0-95.0	471-720	18.0
Chloris virgata	35.0-80.0	17.0-22.0	27.0	110.0-191.0	244-270	20.3
Dactyloterium sindicum (Ganthia)	40.4-80.1	17.3-20.3	15.0	65.0-80.0	185-450	17.8
Dactylocternium aegyptium (Makada)	22.0-50.0	15.0-17.0		45.0-60.0	170- 210	18.5
Brachiaria ramosa	43.4-98.4	7.3-10.3	20.8	4.7-55.3	130-205	7.5

(Murat)						
Cenchrus ciliaris-75 (Dhaman)	52.1-109.6	6.7-10.3	21.0	3.0-70.6	130– 208	8.0
Cyperus arenarium (Motha)	20.0-70.0	5.7-13.0	15.5	4.7-34.7	200-250	6.5

The most significant finding is the fact that *C. ciliaris* CAZRI- 75 could be established on soil slope in the inter row spaces of *C. mopane* plantation to convert it in to a silvipastoral system. Generally, *C. ciliaris* does not grow and establish on salt affected soils. The growth of C. *ciliaris* was in the medium range as compared to performance of other grasses (less palatable). *Cyperus* spp. is a sedge (cyperaceae) and very highly palatable. The palatability range is:
C. ciliaris > Brachiaria ramosa > Dactyloctenium scindicum > D. aegyptium > S. diander > C. virgata.
The annual tree growth data was recorded for the year 2016 and the incremental growth was 8.35 percent for height, 7.41% for crown diameter and 18.3% for collar diameter under grass treatment, which is higher as compared to growth in control trees (7.3% in height, 8.64% in crown diameter & 8.0% in collar diameter). Same trend was observed in the year 2015-16 indicating better moisture availability due to soil structures under grass trees combination.
***Sueada nudiflora*: *Pennisetum typhoides* (Bajara) trial:** *S. nudiflora* seedlings planted in August 2013 at a spacing of 4 m x5 m on double ridge mounds established well (Fig. 11). Mean percent survival was 64.5% as compared to 70.3% in 2016. Increments over respective average values were 30.5% in height, 16.9% in crown diameter and 70.52% in collar diameter. Bajra variety HHB-67 (IMP) was sown on 14 July 2016 in the inter row slopes. Germination was observed after 5-7 days (Fig. 12). Rain for two weeks, 43.3 mm on 30.7.16 and very heavily on 8-9 August 2016 (206 mm) resulted in water logging in many lanes. Bajra survived the water logging in few lanes showing its potential to grow on improved salty soil (Fig. 13). Vegetation status of the area was also evaluated and a total of 17 plant species were recorded. Out of which, 10 were grasses.

Fig. 11. *S. nudiflora* under waterlogged conditions.

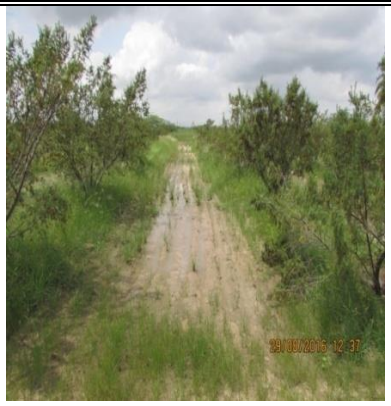


Fig. 12. Bajara emergence in the inter row slopes.

Fig. 13. Bajara crop in the inter row slopes.

Benefits of the research project: Will be useful for rehabilitation and increasing productivity of arid salt affected soils.

2.2.5 Watershed Management : NIL

2.3 Genetic Improvement:

2.3.1 Overview

2.3.1.1 Summary of the achievement under the Theme

Forest Genetics and Tree Breeding Division of Arid Forest Research Institute, Jodhpur is actively engaged in conducting basic and applied research to improve and mass propagate the planting stock of important tree, medicinal plants and Bamboos like *Azadirachta indica* (Neem), *Ailanthus excelsa* (Ardu), *Tecomella unduata* (Rohida), *Commiphora wightii* (Guggal), *Schizostachym dullooa* (Dulua Bamboo) and *Leptadenia reticulata* (Jivanti) using conventional and biotechnological tools. Besides applied research, laboratory experiments have been conducted using molecular and bioinformatics tools to generate more knowledge of gene functions on stress tolerance.

Tree improvement programme included all India co-ordinated project for genetic improvement of *Melia composita*, where genetic variation and inheritance pattern of species were investigated by establishing multi-location progeny trials at Jodhpur, Deesa and Gandhinagar. This consisted of 24 families with five replications and Ghodiwara (Jhunjhunu) and Bassi (Jaipur) with 21 families and 4 replications. Progeny trials of *Tecomella undulata* were also established at Jodhpur and Jhunjhunu districts of Rajasthan. In this progeny of CPT No-36 from Pali district and progeny of CPT No-25 from Churu district out performed others at Jodhpur and Jhunjhunu, respectively. Under the multilocation programme of FRI Dehradun on induction, evaluation and development of polyploides in *Azadirachta indica*, AFRI has selected sixty six new CPTs. Fruits were collected, de-pulped and 1650 seedling of 20 CPTs and more than 2000 seedling of local provenance were raised and provided to FRI, Dehradun for establishing genetic trials.

Work on multilocational clonal trials of *Casuarina* species for multiple end uses in Gujarat State has been initiated with the aim to identifying the most-adapted and fast-growing clones of *Casuarina equisetifolia*, *Casuarina junghuhniana* and their hybrids for increasing productivity of plantations in Gujarat State. Sixteen outstanding clones including five winds tolerant, 4 salts tolerant and seven fast growing, high yielding hybrids were selected and collected from Clonal Bank of IFGTB, Coimbatore. Seeds of *Anogeissus pendu*la from seventeen locations of Rajasthan were also collected and maximum percent germination (3.5%) was observed in seeds collected from Kailana area of Jodhpur. Works on development of seed production areas and haploid plants of *Commiphora wightii* was also carried out, where mature seeds from individual plant (genotype) were collected from four field trials at Deesa, Gujarat. Juvenility markers were studied to improve rooting potential of some important tree species. Significant changes were recorded in number of leaflets per leaf in case of *A. indica* and *A. excelsa* during seedling growth upto six months. The no of leaflet in new coppice shoot were same as in case *A. indica* and *A. excelsa* seedlings. The coppicing initiation was faster in case of *A. excelsa,* followed by *A. indica*. It was slowest in *Tecomella undulata*.

Biotechnological tools were utilized for clonal propagation and supply of genetically superior trees of Neem, Adusa and Bamboo. Best in vitro shoot multiplication was achieved in MS medium supplemented with Benzyl amino purine (BAP) 1.0 mg/l, Kinetine (Kn) 1.0 mg/l and additives in Neem. Best in-vitro shoot multiplication was achieved in MS medium supplemented with BAP (3.0-5.0 mg/l) in case of *Dendrocalamus asper*, whereas in case of *D. hamiltonii* it was MS + BAP (3.0 mg/l). In case of Neem,

in-vitro rooting was obtained on MS medium supplemented with 1.0 mg/l IBA. In case of Bamboos, in-vitro rooting was obtained on MS medium supplemented 3.0 mg/l NAA or 10.0mg/l IBA. Mature, semi mature and mini cuttings of neem treated with 500 ppm IBA gave forty percent rooting. *Schizostachym dullooa* offset cutting from Bambusetum at Rajpipla, SFD- Gujarat were established at AFRI nursery. Axillary bud break is achieved in the nodal segments collected from Ukaii Bambusetum. In another study, nodal segments of *Leptadenia reticulata* collected from Barmer and Jodhpur were used as an explant and bud break was achieved after one week of inoculation in MS medium in the dark for initial 2-3 days and later kept in 16 h photoperiod. In vitro shoot proliferation was obtained on MS medium supplemented with 5.0 mg/l BAP.

Studies on morphological and DNA markers were carried out to distinguish male and female trees of *Ailanthus excelsa* even at seedling stage. Morphological studies indicate that male tree bark is comparatively light in colour than females, whereas leaves of male trees are thicker, smoother and softer than females. Initiation of branching is found earlier in females than in male trees.

Work on in -silico identification of abiotic stress-tolerance candidate genes using co-expression network analysis and comparative genomics was carried out. A preliminary list containing 123 genes was prepared that was later truncated to 100 gene list called henceforth the "Curated Gene List" (CGL), forming a list of "bait genes" of Arabidopsis thaliana to be used for gene co-expression network analysis.

2.3.1.2 Project under the theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2016-17
Plan	2	-	5
Externally Aided	1	1	2
Total	3	1	7

2.3.2 Conservation of Forest Genetic Resources: NIL

2.3.3 Tree Improvement

Project 1: Genetic improvement of *Azadirachta indica* (Neem) through transgene pyramiding for enhancement of cold endurance. (AFRI-39/FGTB/ICFRE/2017-22).

Principal Investigator: Dr. Tarun Kant, Scientist F

This is a newly initiated project started in February 2017. The mother trees were locally identified to serve as source of explants and seeds for use during the course of the project. Surface sterilization experiments were performed using NaOCl and will continue with NaDCC, both are are non-hazardous surfactants. This exercise will replace the use of environmentally hazardous $HgCL_2$ which has been reported in literature all through, and should be replaced. The surface sterilized leaf segments were cultured on MS Medium containing auxins for induction of callus.

Project 2: Identification of juvenility markers to improve rooting potential of some important tree species. (AFRI-31/FGTB/ICFRE/2016-20).

Principal Investigator: Dr. Shivesh Rajput, Scientist B

This project aims to identify juvenility characteristics (markers) of *Azadirachta indica*, *Ailanthus excelsa* and *Tecomella undulata* in order to improve the rooting potential of these economically important tree species. Growth pattern of seedlings and coppice shoot were studied. Morphological data were recorded on number of leaflets/leaf, shape of leaf, length of leaves, chlorophyll content of leaves etc. at different time intervals of seedlings and coppiced shoots growth. Significant changes were recorded in number of leaflets per leaf in case of *Azadirachta indica* (Neem) and *Ailanthus excelsa* (Ardu).

Three leaflets were recorded at the initial stage of seedlings as well as in coppice shoots. The number of leaflets gradually increased up to nine in case of Ardu and seven in case of Neem after three to four months of their growth, whereas the maximum number of leaflets per leaf was 21 in Neem and 29 in Ardu (more than twenty years old). The shape of leaves was highly variable in juvenile stage whereas in mature trees they were more or less similar in shape. With passage of time the rate of increase in the number of leaves was slow in seedlings, whereas it was higher in case of coppiced trees (Fig. 14). The coppicing initiation was faster in case of Ardu, followed by Neem (Fig. 15). It was slowest in *Tecomella undulata* (Rohida). Quantitative and qualitative data on morphological parameters are being recorded on seedlings and coppiced shoots at fixed time intervals for close monitoring and analysis on morphological changes during transition period, i.e. from juvenile to mature phase.

(a) 9 days

(b) 135 days

16 days **(c) 35** days

Fig. 14 (a-b). Junvenile seedlings of *Ailanthus excelsa.*
(c-d). Coppiced shoots of *Ailanthus excelsa*.

(a) 18 days **(b)** 45 days

(a) 21 days (b) 32 days

Fig. 15 (a-b). Junvenile seedlings of *Azadirachta indica.*
(c-d). Coppiced shoots of *Azadirachta indica.*

Project 3: Induction, evaluation and development of polyploides in *Azadirachta indica* (AFRI-20/Sil./Ext.(IFFCO)/2015-2018).

Principal Investigator: Dr. U.K.Tomar, Scientist F

Surveys were conducted in Palanpur, Deesa and Gandhinagar areas of Gujarat. Sixty six new CPTs were identified and marked. Data from unreplicated progeny trial at Deesa were collected and tabulated. Seeds of 51 individual CPTs were collected and depulped. Seeds from individual clone from CSO at Deesa were also collected. Similarly, seed from individual tree of good families were also collected from progeny trial. Seeds form these collections were germinated in the nursery and seedlings were raised. 1650 seedlings from 20 CPTs and more than 2000 seedling of local provenance were provided to FRI, Dehradun for establishing genetic test trials. Seeds from individual trees of 33 families and 20 clones were also provided to FRI, Dehradun.

Project 4: Development of seed production areas and haploid plants of C*ommiphora wightii* (Arnott) a rare and threatened medicinal plant. (AFRI-35/FGTB/Ext(NMPB)/2016-19).

Principal Investigator: Dr.U.K.Tomar, Scientist F

This project focuses on the establishment of seed production area of guggal plant to get better germplasm for viable and quality seeds. Male plants are extremely rare in this species, therefore, attempts are being made to develop protocols and to produce haploid or male plants through tissue culture as it is difficult at present to produce male plants even using conventional macropropagation techniques due to non-availability of large number of plants. Four sites have been visited to get suitable areas for seed production. These are: 1) Bituja range in Barmer district, 2) Kayalana field in Jodhpur, 3) AFRI Arboretum, Jodhpur, and 4) Ranpur Forest Nursery, Deesa Gujarat. AFRI Arboretum and Deesa sites were selected for developing seed production areas, beacuase of well protection and having large germplasm collection. Mature seeds from individual plant (genotype) were collected from four field trials at Deesa, Gujarat. Data have been tabulated in the following table to understand the best families or clones producing highest seed yield:

Field Trials	Family or Clone x plant/ family or clone	Percent of plants bearing mature seeds and Best CPT Number
Field A (SSO)	10 x 12 = 120	Ave. 32%; A9 (50%)
Field B (SSO)	10 x 15 = 150	Ave. 21%; B2 (73%)
Field C (CSO)	10 x 20 = 200	Ave. 40%; C1, C3&C4 (60%)
Field D (CSO)	20 x 10 = 200	Ave. 16%; D6, D10, D17 (50%)

Work on development of protocol to produce male plants through tissue culture is in progress. The nodal segment of the male plants selected from Deesa Forest nursery and AFRI Arboretum are being used for this purpose (Fig. 16a). Sixty stem cuttings of nine male plants were raised in

mist chamber in February 2017. Sprouting was observed in 30% stem cuttings, where 10 male plants from these cuttings are expected (Fig. 16b). Pollen studies have also been initiated to observe variation in size, shape and viability within and between the nine genotypes (Fig. 16c).

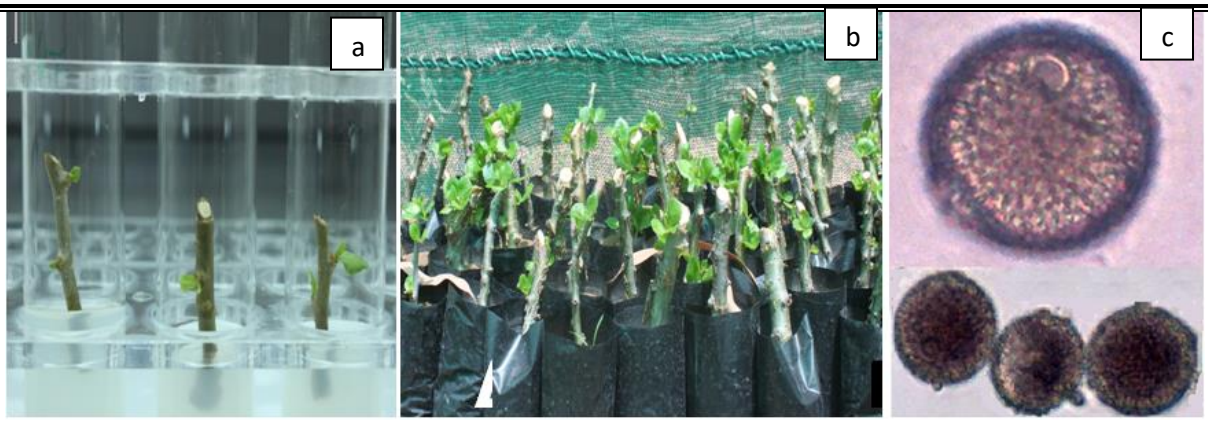


Fig. 16 (a-b). (a) Establishment of cultures of nodal explant from male plant, (b) Sprouting in stem cuttings of male plant, and (c) Pollen studies in *C. wightii*.

Project 5: All India co-ordinated project for genetic improvement of *Melia composita*. (AFRI-10/Silvi/(ICFRE)AICP/2012-17).

Principal Investigator: Dr.U.K.Tomar, Scientist F

Genetic variation and inheritance pattern of *Melia composita* were investigated by establishing progeny trials at Jodhpur, Jhunjhunu, Gandhinagar and Deesa sites in 2013 and at Ghodiwara (Jhunjhunu) and Bassi (Jaipur) in 2014 (Fig. 18a-d). Multi-location progeny trials at Jodhpur, Deesa and Gandhinagar consisted of 24 families with five replications and Ghodiwara (Jhunjhunu) and Bassi (Jaipur) with 21 families and 4 replications.

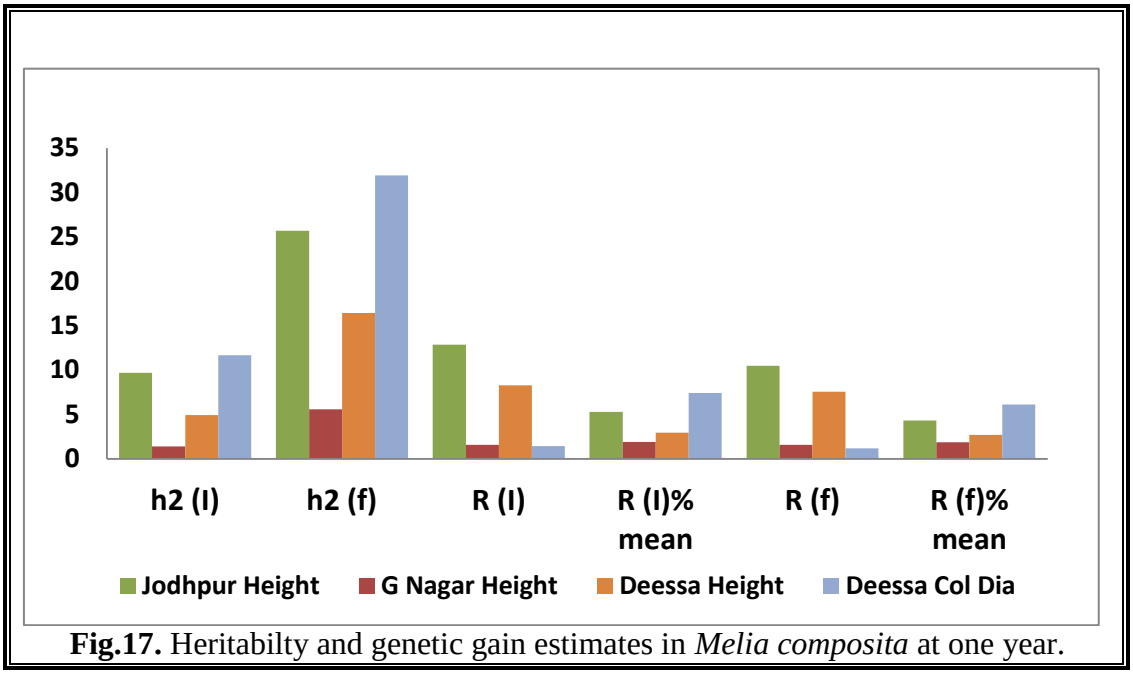


Fig.17. Heritabilty and genetic gain estimates in *Melia composita* at one year.

Growth data were collected from these trials and subjected to analysis of variance followed by computation of genetic parameters. Analysis of variance performed at six month age revealed significant variation in height and collar girth amongst the tree tested except in the case of collar girth at Jodhpur and Gandhinagar. In narrow sense, individual and family heritability for height were 25 and 54 in Jodhpur, and 31 and 57 in Deesa, whereas for collar girth these estimates were 30 and 59 in Deesa trial, respectivey (Fig. 17). As the family x replication variance were greater in case of other two trials, genetic estimates were not computed. Analysis of data collected on girth and height in March 2017 indicated better performance of family number 114 amongst the five families at all five sites. Other three families performing better at two or more than two sites are 237, 64 and 25 as given in following table. Further selection of superior individual genotypes can also be carried out within families from different sites. Top five families on the basis of survival, girth and height at five locations are listed below:

Site	Family	Survival %	Family	Girth (cm)	Family	H (cm)
Jhunjhunu	64	50.0	263	20.7	236	475.0
Jhunjhunu	**114**	43.8	235	19.1	260	400.0
Jhunjhunu	268	43.8	**114**	15.6	25	392.0
Jhunjhunu	265	37.5	28	15.5	235	390.0
Jhunjhunu	128	31.3	64	15.1	64	336.0
Jodhpur	260	84.0	28	28.9	237	439.4
Jodhpur	76	64.0	75	27.4	**114**	414.0
Jodhpur	265	60.0	**114**	27.3	25	411.4
Jodhpur	25	57.0	159	27.1	235	399.3
Jodhpur	233	56.0	20	27.0	267	395.9
Jaipur	75	100	114	27.7	237	436.4

Jaipur	25	93.72	237	26.9	**114**	414.0
Jaipur	28	93.71	267	26.4	25	411.4
Jaipur	64	93.7	25	25.3	235	399.3
Jaipur	20	81.2	64	23.4	267	395.9
Deesa	271	72	**144**	44.4	263	467.0
Deesa	237	60	**114**	42.0	24	461.0
Deesa	32	56	260	41.8	265	458.0
Deesa	64	52	271	39.3	**114**	436.0
Deesa	20	49	104	38.0	104	433.0
Gandhinagar	20	80	75	12.3	75	173.1
Gandhinagar	32	72	263	9.2	263	151.2
Gandhinagar	237	68	259	9.0	195	126.0
Gandhinagar	144	64	24	8.7	24	120.4
Gandhinagar	76	56	237	7.9	268	113.2

(a) Jodhpur progeny trial

(b) Gandhinagar progeny trial

(c) Dessa progeny trial Kanota

(d) Bassi progeny trial

Fig. 18(a-d). View of different progey trials.

Project 6: Assessment of variability, improvement and refinement of cloning techniques of *Tecomella undulata* (Sm.) Seem. (AFRI-4/FGTB/ICFRE/2012-17).

Principal Investigator: Desha Meena, Scientist C

Progeny trials of *Tecomella undulata* have been established at Jodhpur and Jhunjhunu districts of Rajasthan. Plantation maintained and growth data were collected. Preliminary data showed an average height of 1.08 m and collar diameter of 1.21 cm for progeny established at Jodhpur. The progeny of CPT No.36 from Pali district gave the best growth attaining the height of 1.59 m and collar diameter of 2.4 cm. At Jhunjhunu, average height was 42.5 cm and collar diameter was 0.48 cm. The progeny of CPT No.25 from Churu district gave the best growth where height was 75.5 cm and collar diameter was 0.78 cm. Leaf DNA samples collected from 40 CPTs and 120 individuals representing 12 populations of *Tecomella undulata* collected from Churu, Sikar, Nagaur, Bikaner, Pali, Jalore districts in Rajasthan for carrying out genetic diversity analysis. Total 50 ISSR primers were screened, out of which 25 primers resulted in distinct and reproducible bands. ISSR data were scored as presece (1) and absence (0) of bands. The data thus obtained in the form of binary matrix was analysed by UPGMA method of hierarchical clustering among different populations. Clustering pattern of CPTs showed two major clusters based on genetic diversity. These two major clusters were made up of five and four minor sub clusters. Clustering pattern of the population's showed one and seven minor sub clusters. Thus elements of geographical distinction were resolved through ISSR markers.

2.3.4 Vegetative Propagation:

Project 1: Screening of DNA markers to distinguish male and female *Ailanthus excelsa* trees for higher biomass production / Forest genetic resource management & tree improvement. (AFRI-28/FGTB/ICFRE/2016-19).

Principal Investigator: Dr. U.K. Tomar (Scientist F)

This project aims to screen DNA markers and identify morphological characteristics of *Ailanthus excelsa* (Ardu) in view to identify male and female trees at seedling stage, and to improve the fodder production and timber yield potential of this economically important tree species. A total of 52 (26 male and 26 female) trees at CAZRI, Jodhpur (Rajasthan) and 75 (33 male and 42 female) trees at Deesa, Gujarat were marked on the basis of flowering. Morphological data (including DBH) and GPS coordinates have been recorded. Initial analysis indicates that male tree bark is comparatively light in colour compared to females, whereas leaves of male trees were thicker, smoother and softer than that of females. Initiation of branching was found to occur earlier in females than in male trees. Leaf samples of marked male and female trees at both sites (Jodhpur and Deesa) were collected for screening gender specific DNA markers.

2.3.5 Biotechnology

Project 1: Development of tissue culture protocol for economically important bamboo-*Schizostachym dullooa*. (AFRI-29/FGTB/ICFRE/2016-21).

Principal Investigator: Dr. Sarita Arya, Scientist F

Schizostachyum dullooa, commonly known as dolu bamboo, is a thin walled sympodial, moderate to large sized tufted bamboo of North East India. This bamboo is used in kite- making in Gujarat due to its long internodes. Gujarat state wants to promote this bamboo for its commercial use. The present project is being carried out for development of tissue culture protocol and field evaluation in Gujarat. Offset cutting were collected from Bambusetum, at Rajpipla, SFD- Gujarat. The collected offsets were established at AFRI nursery. Shoots proliferated from nodal region of some of the offsets. Rooted cuttings of *S. dullooa* were procured from RFRI, Jorhat and its centre at Agartala as a source material for micropropagation. Micropropagation studies were initiated using nodal segments as an explant from newly sprouted material collected from Ukaii Bambusetum. Sterilized nodal segments were inoculated on MS medium with various growth hormones. Axillary bud break has been achieved from some of the nodal segments. Experiments are underway for axillary shoot proliferation.

Benefits: As this Bamboo is used in kite making, development of Tissue Culture Protocol and its mass production will help Gujarat State in revenue generation and overcome its dependence on North-East State for procurement of this Bamboo.

Project 2: In silico identification of abiotic stress-tolerance candidate genes using co-expression network analysis and comparative genomics. (AFRI-30/FGTB/ICFRE/2016-18)

Principal Investigator: Dr. Tarun Kant, Scientist F

The aim of the project is to utilize high-quality gene expression microarray data for *Arabidopsis*, available in public domain, for genome-wide exploration and discovery of genes associated with response of a plant under abiotic stresses and also to use this information to generate secondary information for trees for large-scale identification of orthologs in *Populus* that have a role in plant's response to abiotic stress, using an *in silico* (bioinformatics) pipeline. In this, a thorough and structured literature database mining was carried out using NCBI PubMed database. The queried terms used reflected plant's ability to cope-up with salinity. Based on the research results, the abstracts of the shortlisted peer reviewed papers were screened and, the genes implicated in plants response to salt stress were selected. A preliminary list containing 123 genes, was prepared that was later truncated to 100 gene list called henceforth the "Curated Gene List" (CGL). This forms a list of "bait genes" of *Arabidopsis thaliana* to be used for gene co-expression network analysis with the aim of gene-mining. Coexpression networks were constructed gene by gene initially using ATTED-II and with multiple genes using Cress Express

bioinformatics tools (Fig. 19). Correlation threshold was kept at 0.8. Based on the constructed gene expression networks, larger bait gene list (pooled using network neighbors) is being prepared, which will be used further for orthologs identification in *Populus*.

Benefits: The identification of orthologous genes in trees that are equivalent to this abiotic stress tolerance counterpart in *Arabidopsis* will lead to new gene discovery that will help the improvement work of trees.

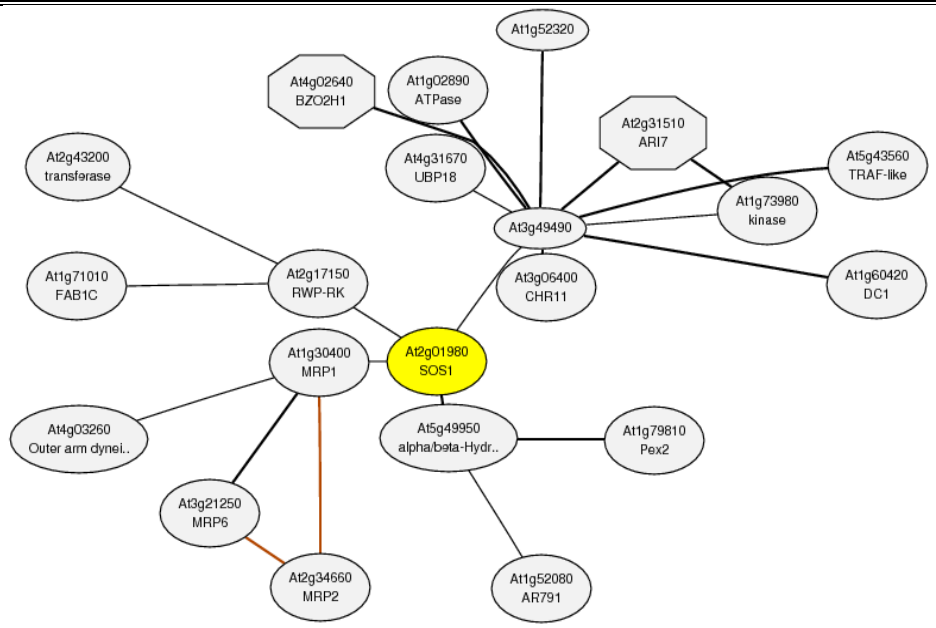


Fig. 19. Gene co-expression network around At2g01980 Gene.

Also known as *AtSOS1*, a sodium ion antiporter at plasma membrane, this gene prevents sodium ion toxicity in plant under salt stress. The gene in the network is directly connected to 4 other genes, indicating their associated roles during response of plant under salt stress. Analyzed using ATTED-II with Network rendering through Cytoscape.

Project 3: Clonal propagation, characterization and biochemical analysis of *Leptadenia reticulata* – A threatened medicinal plant. (AFRI-36/FGTB/Ext(NMPB)/2016-19).

Principal Investigator: Dr. Sarita Arya, Scientist F

Leptadenia reticulata is commonly known as Jivanti/Dodi/Dudi is a valuable threatened medicinal plant belonging to family Asclepiadaceae. This plant propagates naturally through seeds. However, very low seed setting and low germination rate of seeds has resulted in low natural regeneration potential. Hence, this plant has a threatened status. Development of technologies is being in progress in terms of selecting high yielding/superior genotypes, their mass multiplication and conservation. Plants of *Leptadenia reticulata* were selected from 3 sites

at Manaii, Jodhpur & Barmer. Nodal segment were used as an explant and surface sterilized with 0.1% Mercuric chloride and inoculated on MS medium supplemented with different concentration of BAP. Bud break was achieved after one week of inoculation in the dark for initial 2-3 days followed by 16 h photoperiod. Best shoot proliferation was obtained on MS medium supplemented with 5.0 mg/l BAP. For *in vitro* shoot multiplication, cultures were transferred on Murashige and Skoog medium supplemented with Benzyleaminopurin and Kinetin. Experiments are ongoing for *in vitro* shoot multiplication.

Benefits of the research projects: There is high scope of identifying superior genotypes having high contents of bioactive componds which can be clonally multiplied and field tested.

Project 4: Utilization of biotechnological tools for clonal propagation and supply of genetically superior trees of neem, ardusa and bamboo. (AFRI-06/FGTB/Ext (SFD-Guj)/2013-17).

Principal Investigator: Dr. I. D. Arya, Scientist G

This investigation was undertaken to develop appropriate macropropagation and micropropagation technologies for mass multiplication of Neem, bamboo and Adusa. In bamboo, existing tissue culture protocols were used and cultures were initiated which involved axillary bud break, *in vitro* shoot multiplication and *in vitro* rooting of shoots. The technique so developed was demonstrated and transferred to State Forest Research Laboratory, Gandhinagar. In Ardu, attempts were made to develop tissue culture protocol through axillary bud induction and *in vitro* shoot proliferation. Nodal segments of neem, ardu and bamboo were collected (each segment contained one axillary bud) and were inoculated on MS medium supplemented with different concentration of cytokinin (BAP and Kn) alone and in combination with auxin (NAA). Best *in vitro* shoot multiplication was achieved in MS medium supplemented with BAP (1.0 mg/l), Kn (1.0 mg/l) and additives in neem. Best *in vitro* shoot multiplication was achieved in MS medium supplemented with BAP (3.0-5.0 mg/l) in case of *Dendrocalamus asper*, whereas in case of *D. hamiltonii* it was MS +BAP (3.0 mg/l).

In case of neem, *in vitro* rooting was obtained on MS medium supplemented with 1.0 mg/l IBA plus additives (ascorbic acid, citric acid, adenine sulphate and amino acids). In case of bamboo, *in vitro* rooting was obtained on MS medium supplemented 3.0 mg/l NAA or 10.0 mg/l IBA. Forty per cent rooting was achieved in neem cuttings when treated with 500 ppm IBA in all three types of cuttings used, i.e. mature, semi mature and mini cuttings. The technology was explained and demonstrated to SFD Staff of Ghandhinagar.

2.4 Forest Management

2.4.1 Overview

2.4.1.1 Summary of the achievement under the Theme

This aspect has been covered by one project involving documentation of research finding related to rehabilitation and restoration of dry forests/lands and their management. In this important research findings and technologies for applications to forestry in Rajasthan were compiled and published in the form of books 'A manual for Dry land Afforestation and Management' and शुष्क क्षेत्र वनीकरण एवं वन प्रबंधन: तकनीकी एवं कार्यविधियाँ. Documentation work of sacred groves of Rajasthan has also been done and published in the form of book 'Sacred Groves of Rajasthan: Threats and Management Strategies'. Another book entitled "राजस्थान के पवित्र उपवन: संभावित खतरे तथा प्रबंधन नीतियाँ." was also published in 2017.

2.4.1.2 Project under the theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2016-17
Plan	-	-	-
Externally Aided	1	-	-
Total	1	-	-

2.4.2 Sustainable Forest Management (SFM) : NIL

2.4.3 Forest Economics: NIL

2.4.4 Forest Biometrics: NIL

2.4.5 Participatory Forest Management: NIL

2.4.6 Policy and Legal Issues: NIL

2.4.7 Information and Communication Technology (ICT)

Project 1: Documentation of important research findings and technologies for application to forestry in Rajasthan.

Principal Investigator: Dr.G.Singh, Scientist G

This project was sanctioned by State Forest Department, Government of Rajasthan with total outlay of Rs. 11.66 Lakhs to develop a book in the form of manual based on existing knowledge in the region and abroad. The books entitled **'A manual for Dry land Afforestation and Management' and** शुष्क क्षेत्र वनीकरण एवं वन प्रबंधन: तकनीकी एवं कार्यविधियाँ have been published in 2017(Fig.20). These books provide enough knowledge on climatic, ecological, social and economic condition of dry areas and lay out approaches and strategies to restore degraded drylands in general and dry forests in particular for increasing green cover with emphasis on people's participation. These books are divided into 15 chapters, among which first three deals with physiography and environmental conditions of Rajasthan, drylands ecology and problems of

land degradation and desertification. Next two chapters cover economic evaluation of land degradation and the approaches and strategies of drylands restoration and rehabilitation. These are followed by problems of sand drift, salinity, water logging and effluent inflicted areas and technologies to rehabilitate such lands in sixth and seventh chapters. Ninth and tenth chapters deal with productivity enhancement by various methods like genetic improvement, seed production areas, quality planting materials including vegetative propagation and planting of superior clones and genotypes. Various kinds of *ex-situ* and *in-situ* rain water harvesting and conservation measures, and promotion of natural regeneration through resource conservation and direct seed sowing for restoration of degraded and succession forests are covered in subsequent two chapters. Chapter 13 describes effective management of pests and diseases in nurseries and plantation, whereas chapter 14 highlights growth and yield prediction equations and models. Last chapter covers people's perception, participation and management of forest resources with a view to improve overall forest cover and ecological services for future climatic changes. Direct contribution of these this work are to strengthen the forest functionaries and readers with wide ranging knowledge about the land degradation, desertification and eco-biology of drylands with sufficient references and method applied in restoring and rehabilitating the degraded lands for increasing tree and forest cover, enhancing resilience and people livelihoods and improving the environmental conditions of dryland ecosystem. Academician, researchers, forest managers, non-government organizations, extension agents and environmentalists will be equally benefited while working in development, conservation and management of forest ecosystems of dry areas.

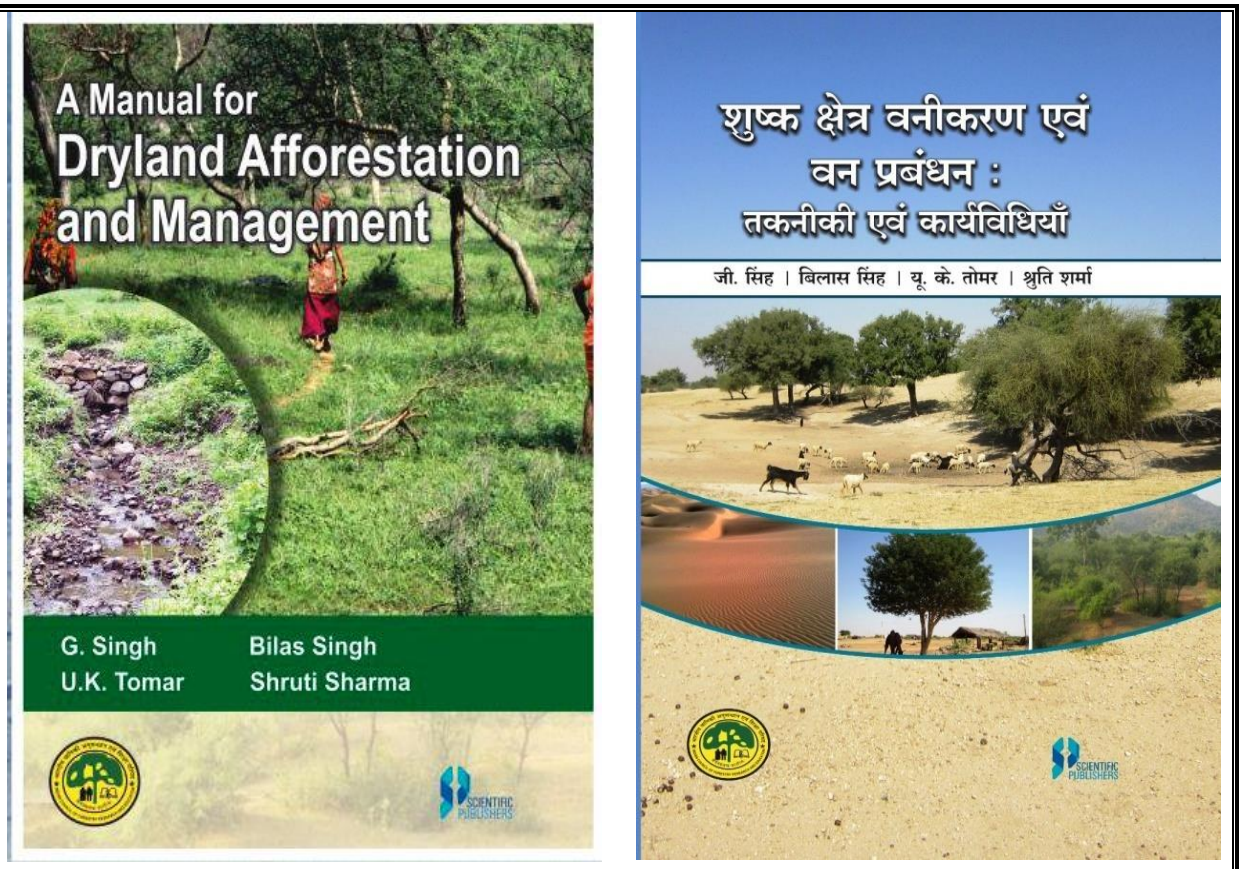


Fig. 20. Book published in English (Left) and Hindi (Right).

Benefits of the research project: These books have practical applicability in rehabilitation of degraded drylands and enhancing vegetation cover and sequestering carbon alongwith with social benefits. Financial achievement is Rs. 11.66 lakhs (4.206 lakhs in 2016-17). For c**ommercialization of technology**, it is in the process of giving permission for selling of books for revenue.

2.5 Wood Products

2.5.1 Overview

2.5.1.1 Summary of the achievement under the Theme

Jodhpur handicraft industry in Rajasthan, well known for its wood-work. Presently the industry is using woods of *Acacia nilotica* (Babool), *Dalbergia sissoo* (Shisham), *Tectnoa grandis* (Teak), *Mangefera indica* (Mango), *Azadirachta indica* (Neem) and other miscellaneous species. There is need to search lesser known, under exploited, locally available timber species.

As an alternative timber species for handicraft industries sawn woods of *Azadirachta indica* and *Acacia senegal* were treated with industrial method using Biflex Tc. and complex mixture of Copper sulphate, Potassium dichromate and *Prosopis juliflora* bark extract at 2.5% dilution with water. Coffee table (with chip carving) from *A. indica* wood and photo frames with carving from *A. senegal* wood were prepared.

2.5.1.2 Project under the theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2016-17
Plan	-	-	-
Externally Aided	-	1	-
Total	-	1	-

2.5.2 Wood and other Lignocellulosic Composites: NIL

2.5.3 Wood Processing: NIL

2.5.4 Value Addition and Utilization

Project 1: Studies on post harvest technologies of *Azadirachta indica* and *Acacia senegal* as alternative timber species for handicraft industries (AFRI-14/NWFP/Ext. (DST)/2014-17).

Principal Investigator: Dr. Ranjana Arya, Scientist G

Sawn Wood of *Azdirachta indica*, (neem) and *A. senegal* (Kumat) was treated with Biflex Tc (industrial method) and a complex mixture of Copper sulphate, Potassium dichromate and *Prosopis juliflora* bark extract which was prepared at the laboratory by using method prescribed by IWST Bangalore and was used at 2.5% dilution with water. After treatment, seasoning with standard method of wood was done at Sun Art Export, Jodhpur and value added products with carving were prepared. Coffee table (with chip carving) from *A. indica* wood and photo frames with carving from *A. senegal* wood were prepared (Fig. 21-22).

Benefits of the research projects: Once completed, the finding will be useful for wood and handicraft industry.

Fig. 21. Coffee table (with chip carving) from *A.indica* wood.

Fig. 22. Photo frames with carving from *A. senegal* wood.

2.5.5 Wood Chemistry: NIL

2.5.6 Pulp and paper: NIL

2.6 Non-wood and Forest Products (NWFPs):

2.6.1 Overview

2.6.1.1 Summary of the achievement under the Theme

The forests are home to variety of NTFPs used traditionally by the local communities for various purposes. Forests and forest products generate income and employment in the rural community. Many experiments are being carried out in AFRI under this theme detailed as below.

C. decidua is most important indigenous NTFP yielding plant species of Western Rajasthan, rank high in local people's preferences to support their economy and also have importance for its domestication. Fruit of *C. decidua* yield supplementary income to the rural people as it is converted to pickles as value added product with very high demand. However, they are mainly collected from the wild. In a trial in collaboration with SFD Rajasthan various combinations of manure and VAM were tested to enhance productivity of Kair (*Capparis decidua*), and application of Leaf Compost Manure (LCM) in combination with various inorganic fertilizers enhanced the number of fruiting plants and fruit yield per plant significantly followed by VAM application. Leaf compost treatment with SSP, K and Zn was the best combination with 3.662 kg total annual fruit yield as compared to control (0.1456 kg) in treated shrubs. In LCM block 55% plants fruited 3 times, 17.5% plants fruited 2 times and 20% plants fruited only 1 time. No flowering was observed in 7.5% plants only.

To enhance durability and to maintain nutritional value of fruits of *Prosopis cineraria* (Khejri) and *Capparis decidua* (Kair), plastic jar has been observed the best. Dried fruits can also be packed under vacuum (Shrink packaging) and nitrogen atmosphere (Pillow packaging) for a longer period of preservation and safe and easy transportation without any infestation.

Work on quantification, value addition and improved agricultural productivity to enhance livelihood in tribal belt of Sirohi District of Rajasthan has also been carried out. The data analysis on market price spread in Abu road block revealed that on average 3.65 family members are involved in collection of identified key NTFPs and normal employment generated per year per family was 13.37 days. Maximum employment generated per year per family was by *Tamarindus indica* (Imli).

Detailed socio-economic survey of 103 villages in Pali district (Rajasthan) and 59 villages in Mehsana district (Gujarat) was done to assess the role of neem products in rural livelihood. Gap between demand and supply of neem leaves was estimated as 100 tons/year in Pali district. On an average, 150 tons dry green neem leaf powder was traded in Sojat city of Pali in Rajasthan and abroad in the form of 80-100 kg packets at the prevailing rate of Rs. 800/- per kg. Baling of neem leaves is done at a rate of Rs.1/- per kg and 80 kg or 100 kg bales are prepared on job basis by M/s. Kamal Plastics, Sojat, Pali. Neem fruit collection and processing is a labour intensive and time consuming process, therefore, in Pali district villagers prefers to work in MNREGA.

Non-destructive harvesting practice of *Commiphora wightii* oleogum resin has been standardized, where horizontal cut of 4 cm yielded maximum gum. Although the average gum yield per plant (three cuts per

plant) in the experiment without any enhancer was 6 g/plant, which is almost 13 times less than the best gum yield (80 g/ plant) using enhancer. In the present study no casualty was observed even after three years. Seasonal variation indicated November to February as the best period for gum tapping.

2.1.1.2 Project under the theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2016-17
Plan	-	1	-
Externally Aided	-	4	-
Total	-	5	-

2.6.2 Resource Development of NWFPs

Project 2: Productivity enhancement of Kair (*Capparis decidua*) to generate livelihood in rural area of 'Thar Desert. (AFRI-07/NWFP/Ext(SFD:Raj)2013-18).

Principal Investigator: Dr. Ranjana Arya, Scientist G

Experiment-1 (Gogelao Beed, Nagaur): A research project was taken in collaboration with SFD Rajasthan to study yield of *Capparis decidua* (kair) fruit. Field was selected in July 2013. All the plants were divided into three blocks. Leaf compost (LCM), goat FYM (GM) and VAM with different combination of SSP, K, Zn and NPK fertilizers were applied with irrigation in October 2013.

Flowering and fruiting shrubs: Fruiting in April 2016 was 80% (ranging from 40% to 100% in different treatments) in LCM block followed by VAM block with 68.6% (ranging from 43% to 100%). Fruiting was lowest in Goat Mannure (62.5%) plot. In April 2016, there was an increase in fruiting plant percent in VAM (2.3 times) and GM blocks (1.3 times) as compared to mean fruit yield in 2015**.** There was 100% fruiting in T_1 (LCM + SSP + K), T_4 (LCM + SSP + K + Zn) and T_5 (LCM + NPK) treatments in LCM block, while shrubs of only T_4 (GM + SSP + K) treatment in GM block (SSP + K) and VAM block (VAM only) recorded 100% fruiting. In June – July 2016, fruiting was 65.0% (ranging from 20% to 100% in different treatments) in LCM block, 60.0% (ranging from 40% to 100% in different treatments) in GM Block and 65.8 % (ranging from 43% to 100% in different treatments) in VAM Block, which is significantly high in all the three blocks as compared to June 2015.

Phenological observations recorded in October, 2016 indicated 80.2% fruiting plants in VAM treated plants (ranging from 43% to 100% in different treatments) closely followed by LCM block 75.0% (ranging from 20% to 100% in different treatments). Fruiting was minimum 62.5 % (ranging from 40% to 100% in different treatments) in GM treated plants. In October,

2016 there was increase in fruiting plant present in VAM block as compared to April 2016 while LCM and GM recorded a slight decrease (Fig. 23).

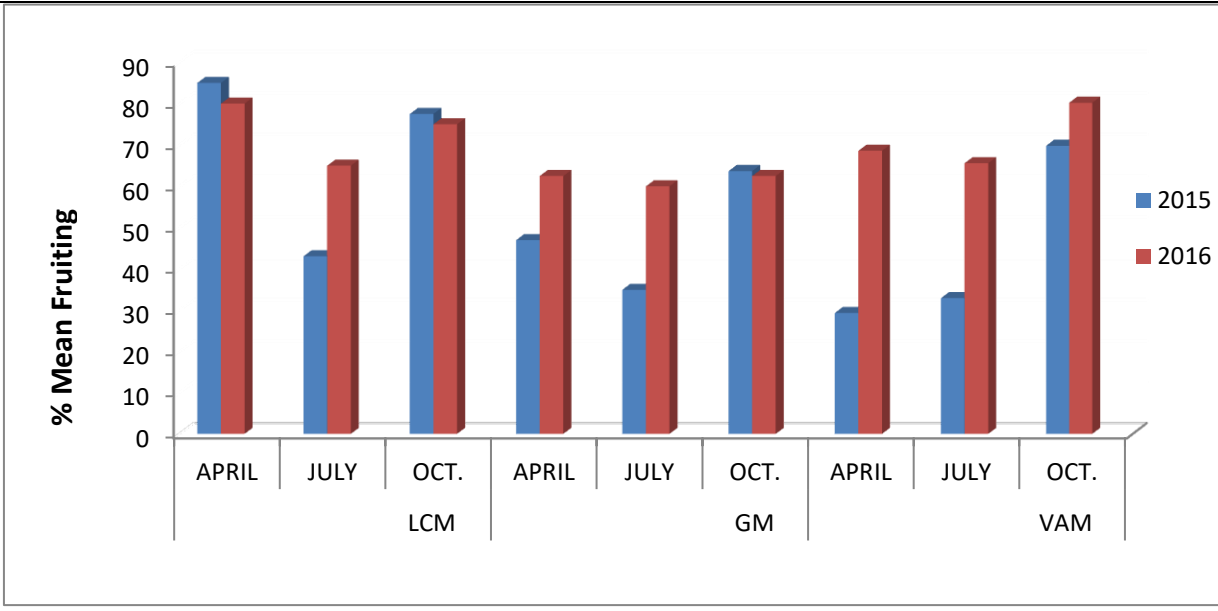


Fig. 23. Effect of various treatments (LCM, GM & VAM) on mean fruiting during 2015-16 in *C. decidua.*

Fruit yield: LCM alongwith SSP and K, Zn is the best treatment with 3622.0 g yield as compared to control (145.6 g) only in LCM block (Fig. 24). GM alongwith SSP and K produced 2564.0 g as compared to control 305.0 g in GM block. VAM with SSP is the best treatment with 1925.0 g yield as compared to 762.2 g in control in VAM block. Data analysis for the year 2016 (Fig. 24) indicate that 55% plants fruited 3 times, 17.5% plants fruited 2 times and 20% plants fruited only 1 time in LCM block. There were 3 plants (7.5%) two in control and one in LCM only treatments, which did not fruit. These unfruited plants though belong to T_7 & T_8 treatments but different from 2015. In GM block, 47.5% plants fruited 3 times, 10% plants fruited 2 times and 22.5% plants fruited only 1 time. There were 20% plants which did not fruit as compared to 35% last year. Plants without fruiting distributed in all the treatments except T_4. In VAM block, 54.3 % fruited 3 times, 20% plants fruited 2 times and 11.4% plants fruited only 1 time. There were 14.3 plants which did not fruit. Most number of fruting plants were in T_1 (NPK+ VAM) treatment.

Experiment 2. Khari Khurd, Jodhpur: Area was finalised in Luni forest range in July 2014. All plants were divided into two blocks, i.e. organic fertilizer and inorganic fertilizer, which were applied in different combination like LCM (1 Kg) + SSP 625g/ stem + K_2SO_4 (115 g/ stem) + $ZnSO_4$ (40 g /stem in Block –A, and GM (1.5 kg/stem) +SSP SSP 625g/ stem + K_2SO_4 (115 g/ stem) + $ZnSO_4$ (40 g /stem) in Block- B in August 2014.

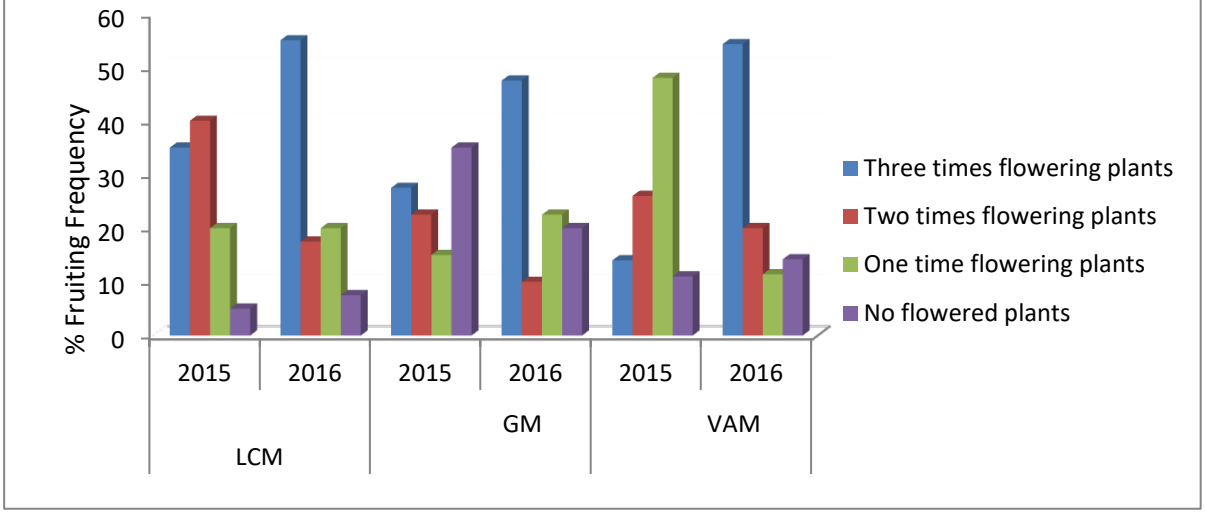


Fig. 24. Fruiting Frequency in *C. decidua* during 2015-16.

(a) Flowering in T_4R_3 in LCM block **(b)** Fruiting in T_4R_1 in LCM block

Fig. 25(a-b). Gogelao Beed, Nagaur.

Appreciable fruiting in experimental plants was recorded in March-April 2016. Overall mean fruiting was 74.3% in LCM block ranging from 40% in control to 100 % in T_1 (LCM + SSP + K + Zn). In GM block, it was 60.0% ranging from 20 % in T_2 (LCM + SSP + K) to 100% in T_5 (LCM + SSP) treatment (Fig. 26). The treatment wise total maximum fruit yield was 869 g in T_6 (LCM only) to minimum 505 g in control (420 g) treatment. In July, mean fruiting shrubs were 57.2%, but in October it was 62.9%. In GM block, the maximum fruit yield 665 g was in T_4 treatment (GM + Zn) and minimum in control 7 g only. Here also fruiting is recorded in July (42.9%) and October (54.3%).

(c) Flowering in T1R4 (LCM block) (d) Fruiting in T1R4 (LCM block)

Fig. 26 (a-b). Khari Khurd,Luni Forest Range, Jodhpur.

Benefits of the research project: Once completed project will be useful for rehabilitation of arid salt affected soils, project will be completed in March 2018.

Project 3: Documentation of Neem products and their role in socio-economic upliftment of rural livelihood in Rajasthan and Gujarat (AFRI-15/NWFP/Ext(DST)/ 2014-17).

Principal Investigator: Sangeeta Tripathi, Scientist B

Quantification of neem leaves in Pali district: For quantification of *Azadirachta indica* (neem) leaves a meeting of farmers was organized in Sehwaj village in November 2016. Ten farmers were selected and existing *Neem* trees in their fields were classified in different girth classes and lopped for collection of green leaves and fuel wood (Fig. 27-30). The lopped portion of each tree was heaped on the ground near the tree and weighed to obtain fresh biomass. The heaps were then left for sun drying for 15 days and then beaten by sticks to remove leaves from branches and small twigs, which are used as fuel wood and sold in market @ Rs.5/ kg. Except small trees (less than 45 cm diameter at breast height or DBH), 100 % trees are lopped in the farmers field. Green fodder yields per tree (for each DBH class interval) per year were 22.5 kg (45-60 cm), 110.5 kg (60-75 cm), 121.05 kg (75-90 cm), 145.78 kg (90-120 cm), 239.84 kg (120-150 cm), 258.75 kg (150-200 cm) and 331.25 kg (201cm and above). Baling of neem leaves is done @ Rs.1/kg and 80 or 100 kg bales are prepared on job basis (Fig. 30).

Improving livelihood- Initiation of Group Marketing: To promote group marketing in order to avoid middle man concept, meeting at Panchayat level in Sehwaj village was organized on 17 November 2016 for community mobilization. Ten farmers agreed for group marketing and were linked directly with M/s. Laxmi Herbals, Sojat city in Pali district. The income of individual

farmers varied from Rs. 13,241/- to 35,053/- by selling of neem leaves. Before initiation of Group marketing, average commission of middleman was Rs.6330/- per ton.

Fig. 27. Lopping of Neem trees in Pali.

Fig. 28. Purchase of fuelwood in Mahesana.

Fig. 29. Oil extraction unit in Sumerpur.

Fig. 30. Baling of neem leaves.

Benefits of the research projects: Initiation of group marketing for sale of dry green neem leaves directly to the industries will improve income of farmers by removing the commission of midlleman.

2.6.3 Sustainable Harvesting and Management:

Project 1: Standardization of non-destructive harvesting practice of *Commiphora wightii* gum oleogum resin. (AFRI-01/NWFP/Ext(NMPB)/2014-17).

Principal Investigator: Dr.U.K.Tomar, Scientist F

Present traditional methods of tapping are destructive for the *Commiphora wightii* (Guggul). Information on sustainable tapping methods of *C. wightii* is very scarce and there is an urgent need to develop non-destructive harvesting technique of the species as it has been listed in red

data book of IUCN. Systematic studies on tapping methods are also not standardized. The production of guggul gum also varies with climatic conditions. The objectives framed were: (i) to standardize non-destructive harvesting technique for obtaining oleogum resin (Guggul), (ii) to standardize optimum harvesting age of plant for tapping of Guggul and (iii) to find out the influence of harvesting season, age and technique on quantity and quality of Guggul.

Four different cut sizes and three different cut patterns were applied as treatments on selected Guggul plants growing naturally at Kailana area of Jodhpur and Ler area in Bhuj (12 treatments). The results revealed that horizontal cut of 4 cm resulted maximum gum yield (2 g per cut). Although the average gum yield per plant (three cuts per plant) without any enhancer, was 6 g/plant. The study on seasonal variation showed that best period for tapping is November to February (Fig. 31). An inverse correlation appears in rainfall and average gum yield per plant (Fig. 31). After rain plant starts producing new leaves, which in turns provide carbohydrates as raw material for synthesis of secondary metabolites and storage in specialized cells (resin canals) as guggul gum. But this process takes almost 3 months.

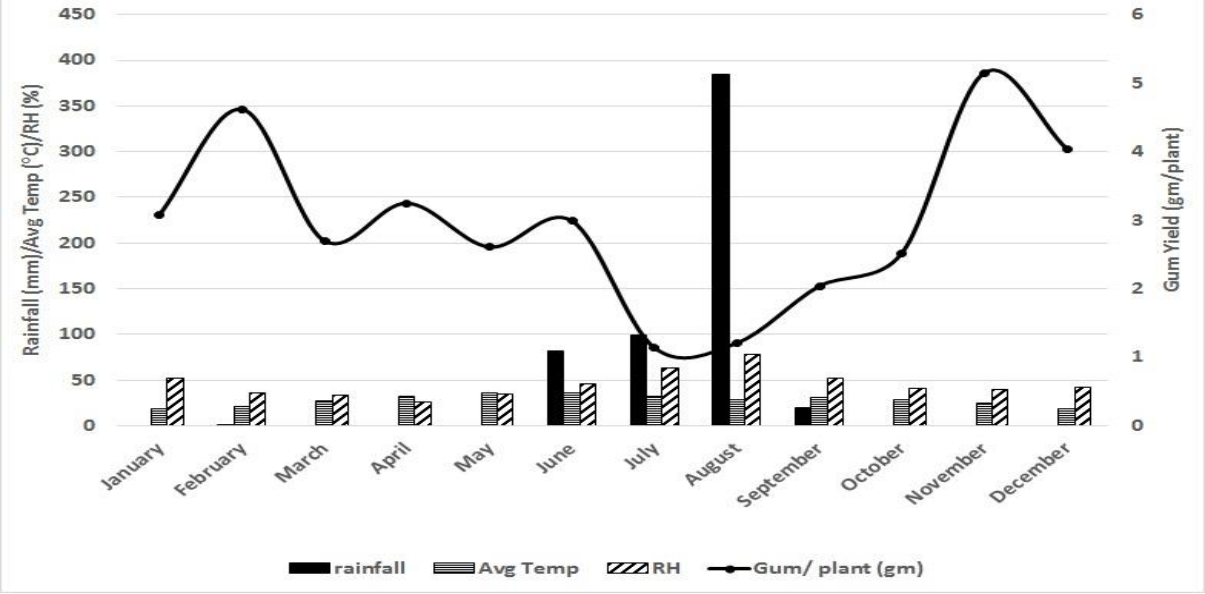


Fig. 31. Changes in average gum yield in each month of a year under varying rainfall, average temperature and relative humidity.

Standardization of non-destructive benefit: Establishment of harvesting method *C. wightii* oleogum resin will help conserving this value like endangered species.

2.6.4 Chemistry and NWFPs, Value Additional and Utilization:

Project 1: Optimization of processing methods for *Prosopis cineraria* and *Capparis decidua* fruits for their improved utilization in western Rajasthan (AFRI-15/NWFP/Ext.(DST)/2014-2017).

Principal Investigator: Dr. Mala Rathore, Scientist D

In continuation to the work on development of processing and drying methodology for two important arid zone fruits, *Capparis decidua* (ker) and *Prosopis cineraria* (sangri), cleaning methodology for the collected fruits was standardized. Dried flowers, dust, small twigs and very small ker buds present in ker fruits were removed by sieving, washing, drying followed by grading using custom fabricated sieves (Fig. 32). Sangri was separated from galls and leaves by manual picking, washing and then drying either directly or after boiling. Samples dried in lyophilizer showed protein and sugar content comparable to those dried in shade. Out of the four storage containers viz. Glass, Plastic, Steel and Earthen pots used for preservation of dry fruits (ker fruits of category- 4 and sangri of immature stage), plastic jar was found most suitable for storage of fruits upto 2 years followed by Glass containers. The sugar and protein content was 8.34 % and 14.51% in plastic containers, whereas it was 7.06 % & 11.25% respectively in glass containers. In sangri, sugar & protein content was 12.5 % & 13.1% in plastic containers whereas it was 11.2 % and 10.5%, respectively in glass containers. Dried (lyophilized) ker and sangri were packed under vacuum (Shrink packaging) and nitrogen atmosphere (Pillow packaging) for longer preservation and safe & easy transportation (Fig. 33). No infestation was observed in any of the samples and they were in good condition till 15 months. Preserved fresh ker fruits and sangri pods in freezer (-4^{o}C), deep freezer (-22° C), brine and vinegar were found to be in good condition till 2 years.

Benefits of the research project: Project will lead to optimization of traditional processing and packaging methods for improved utilization of the selected fruits.

Fig. 32. Removal of impurities in fruits of Ker (left) and Sangri (right).

Fig. 33. Shrinked and pillow packing of fruits of Ker (left) and Sangri (right).

Project 2: Quantification, value addition of NTFP and improved agricultural productivity to enhance livelihood opportunities in Tribal belt of Sirohi district of Rajasthan. (AFRI-03/ NWFP /Int(ICFRE)AICP/2012-2018).

Principal Investigator: Dr. Sangeeta Tripathi, Scientist B

The data analysis on market price in Abu road areas of Sirohi district in Rajasthan at collectors level revealed that average family members involved in collection of identified key NTFPs was 3.65 and normal employment generated per family per year was 13.37 days. In respect of employment generated by an individual NTFP, maximum employment generated per family per year was by *Tamarindus indica* (5.28) followed by *Annona squamosa* (Sitaphal - 4.57), *Momordica dioica* (Kankeda - 4.42), *Pithocellobium dulce* (Jungle Jalebi - 4.25), *Madhuca indica* (Mahua seeds (3.95), *Pongamia pinnata* seeds (Karanj-3.86), *Diospyros melanoxylon* fruits (Tendu - 2.98), *Syzygium cumini* (Jamun - 2.88), *Phoenix* fruits (Khajoor - 2.82), *Jatropha curcas* (Ratanjot) and *Manilkara hexandra* (Rayan) 2.58 each. In studied villages, NTFP provided 20.21 mandays/annum employments to the tribals.

Value addition of *M. dioica* (Kankeda) fruits by SHG members in Jamboori village: To introduce activity of value addition for identified key NTFPs through VFPC/SHG members and linking them with District Industries Centre for income generation, three days training cum demonstration programme was organized (Fig. 34) on value addition of *Momordica dioica* (Kankeda) during 4-9-16 to 6-9-16 for members of Bhurki Devi Mahila SHG, Jamboori (constituted with the help of SFD, Rajasthan and Prabhu Foundation, Sirohi) in tribal dominated area of Abu Road (Sirohi district, Rajasthan).

Benefits of the research projects –The project will be beneficial for increasing livelihood opportunities to the tribals through value addition of key NTFPs.

Fig. 34 (a-d). Demonstration and preparation of *M. dioica* pickle by SHG members in Abu Road.

2.6.5 Biofuels and Bioenergy: NIL

2.7 Forest Protection

2.7.1 Overview

2.7.1.1 Summary of the achievement under the Theme

Thirty-five nurseries in and around were surveyed in seven districts of Rajasthan for collection of pests and diseases. *Laevicaulis alte* (slug) was recorded from all the forest nurseries. *Macrochlamys indica* was recorded from nurseries at Jodhpur. *Alstonia scholaris, Terminalia arjuna* and *Bougainvillea* spp. recorded as new host for lepidopteran defoliator *Hasora chromus*. Leaf miners *viz*. *Lithocolletis virgulata* was recorded on *Pongamia pinnata* (Karanj), *Leucoptera sphenographta* on *Dalbergia sissoo* (shisham) and *Phyllocnistis citrella* on *Citrus limon* (lemon). Sap sucker *Aphis gossypii* was found infesting cuttings of *Cascabela thevetia* (kaner).

Studies on diversity of pollinators and their role in fruit/ pod production of *Acacia senegal, Capparis decidua* and *Prosopis cineraria* in Rajasthan was carried out. Data on diversity and population of pollinator insects on *A. Senegal, P. cineraria* and *Capparis deciduas*, foraging behavior of insect pollinators on the inflorescence was collected during their blooming stage.

Preliminary survey was conducted to get status of severity of flower gall problem of Khejri in Rajasthan and sites selection for recording annual incidence of flower galls.

For an integrated management of Khejri survival efficacy of different bio-agents, botanicals and chemical fungicides were tested against *Ganoderma lucidum* an.d *T. harzianum* was identified as the most effective biocontrol agent.

Out of 20 different extracts of plant origin *A. excelsa* roots, *P. juliflora* leaf and fruit extract of *B. aegyptiaca* and *D. stramonium* showed maximum inhibition of test pathogen. Among chemicals, Bavistin, Mancozeb and Propiconazole were found the most effective fungicides in inhibiting growth (100%) of test fungus. The combinations of Propiconazole and leaf extract of *P. juliflora* and *T. harzianum* were able to control the pathogen. The extracts of Neem, Hingota and Calotropis showed antifeedant activity against *Acanthophorous serraticornis.*

Ninety two Candidate plus Trees (CPTs) of *P. cineraria* were selected from five desert districts of Rajasthan in order to find out the possible resistant or escape tree.

Progeny trials have been established at Jodhpur (with 30 families) and at Samaspur, Jhunjhunu (with 52 families). Analysis of variance of data collected from 52 individual CPTs revealed differences at 1 % level for pod length and weight of 10 pods amongst all the selected trees. Significant variation was observed in seed germination percent and germination velocity index. Best shoot multiplication method was finalized. DNA was extracted, purified and quantified for molecular marker based diversity. Multiplication of microshoots was obtainable only from fresh coppice material obtained from partially lopped mature trees lopped last year and establishes coppice shoots as best material for multiplication in Khejri. Maximum rooting percentage achieved was 30%. Analysis was carried out between khejri mortality and collected ecological data, but no significant correlation could be established between khejri mortality and selected ecological parameters. Different biochemical parameters were studied to determine their variation in healthy and infected trees. Proline and phenol content were higher in infected trees as compared to healthy trees and can be used as biochemical marker for identifying infection in Khejri trees. Data on socio-economic survey carried out in the five desert districts to assess the effect of khejri mortality on rural livelihood indicated reduction in lopped fuel wood. Pamphlets on Problem of Khejri mortality in North-western Rajasthan were distributed among farmers and other stakeholders for raising awareness about Khejri mortality problem. For dissemination of Information and create awareness to the end users posters on Khejri mortality problem and its management were prepared for Extension and Interpretation Centre and Van Vigyan Kendras.

Biofertilizers are essential component of organic farming and is responsible for maintaining soil fertility and sustainability by fixing atmospheric nitrogen, mobilizing micro and macro nutrients or to convert them from their insoluble form into forms available to plants, thereby increasing their efficiency and availability. It was observed during the experiment that the consortia of the biofertilizers which included *Azotobacter, Azospirillum* and *Trichoderma* were more effective as compared to individual microorganisms in case of production of quality planting stock of neem. It was also observed that *P. indica* is the most effective biofertilizers for increasing the plant productivity, early flowering and maturation.

Survey was done in Jodhpur, Bikaner, Jaisalmer, Nagur and Pali district for *Salvadora persica L.* (Khara jal, pilu) tree population and collection of rhizosphere soil samples. The important genera were identified as *Glomus and Scutellospora.*

Rhizosphere soil and root samples of *Dendrocalamus strictus* and *Bambusa bambos* were collected from eight different forest nurseries of Rajasthan for mass multiplication of associated AM fungi. Soil samples were analyzed for various physico-chemical properties and AM fungi have been isolated. The important genera were identified as *Glomus, Acaulospora, Gigaspora* and *Sclerocystis. Glomus* occurred most frequently and was dominant in rhizospheric soil samples collected from nurseries as well as in plantations.

2.7.1.2 Project under the theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2016-17
Plan	1	-	5
Externally Aided	-	2	-
Total	1	2	5

2.7.2 Insects pests, diseases and control

Project 1: Integrated pest and disease management (IPDM) of important tree species in nurseries of Rajasthan. (AFRI-24/FP/ICFRE/2016-21)

Principal Investigator: Seema Kumar, Scientist E

Thirty nurseries (34 nurseries of State Forest Department, Rajasthan and 1 nursery of AFRI) were surveyed in seven districts during different months and seasons. Forest areas around the nurseries were also surveyed to work out the pest distribution and its status. Ten species of leaf feeders (defoliators), 3 species of gall producers, one species of shoot borer, 3 species of leaf miners, 4 species of sap suckers were the main arthropod pests recorded. Eight species of spiders, five species of ants, 2 species of coleoptera were collected as biological predators. Two species of mollusc *viz*. 1 species of slug and 1species of snail were recorded from different forest nurseries of Udaipur, Banswara, Jodhpur, Ajmer, Bharatpur, Jaisalmer and Jaipur mainly from temporary nursery beds of neem seedlings. Though no damage was recorded due to the mollusc species, but hand picking and killing of mollusc was suggested to keep the population in check. One species of coleopteran predator was identified as seven-spotted ladybug beetle (*Coccinella septempunctata*). Fungus infestation was recorded on leaves of *Gmelina arborea* (Hawan), *Manilkara hexendra* (Khirni) and *Madhuca indica* (Mahua) from Udaipur areas. Three species of tree were recorded as new host for Common Banded Awl Butterfly with new distributional record from 3 districts. One tree species was recorded as new host for Castor semi-looper with new distributional record from Banswara. Two leaf miners were recorded for the first time from four districts of Rajasthan.

Details of New Records			
Name of pest/ Disease	Name of host tree species	New tree host record	New distributional record
Hasora chromus Common Banded Awl Butterfly	*Pongamia pinnata* (Karanj)		Ajmer, Bharatpur and Jodhpur
		Alstonia scholaris (Saptparni)	Jodhpur

		Bougainvillea sp.	Jodhpur
		Terminalia arjuna (Arjun)	Jodhpur, Banswara and Udaipur
Achaea janata Castor semi-looper		*Terminalia arjuna* (Arjun)	Banswara and Jodhpur
Lithocolletis virgulata Karanj Leaf miner	*Pongamia pinnata* (Karanj)	-	Jaisalmer, Ajmer, Jaipur and Bharatpur
Leucoptera sphenographta Shisham leaf miner	*Dalbergia sissoo* (Shisham)	-	Jaisalmer, Ajmer, Jaipur and Bharatpur

Benefits: The research project will help in reducing the pest population in nurseries by adopting an integrated approach for pest and disease management thereby helping in raising healthy seedling stock.

Project 2: Development of Integrated management strategy against flower gall inducers of *Prosopis cineraria* (L.) Druce. (AFRI-37/FP/ICFRE/2017-2022).

Principal Investigator: Dr. Shiwani Bhatnagar, Scientist C

Khejdhali, Gudha Bishnoiyan, Phalodi, Lohawat, Osian, Nagaur, Pali and Luni area were surveyed to get status of severity of flower gall problem of *Prosopis cineraria (*Khejri) and sites selection for recording annual incidence of flower galls. It was found that problem of flower gall formation is more severe in the khejri trees which were not lopped at all in comparison to the trees lopped in alternate years.

Benefits of the research projects: Project will be beneficial in managing the problem of flower galls of Khejri adopting integrated management approach.

Project 3: Development of package for integrated management of insect pests & diseases (IPDM) and improvement of planting stock material of neem (*Azadirachta indica*) through biofertlizers (AFRI-12/FP/Ext. (DST)/2014-17).

Principal Investigator: Dr. Sangeeta Singh, Scientist E

Experiments on management of diseases were layed out using bioagents, botanicals and chemical fungicides. Three bioagnets were tested for their antagonistic effect against the isolated pathogens viz. *Trichoderma harzianum*, *T.viride* and *T. pseudokoningii.* Out of these three bioagents, *T.viride* showed maximum inhibition (70%) on the tested pathogens. Various botanical extract (*Azadirachta indica, Calotrpis procera* and *Balanites aegyptiaca*) and entomopathogenic fungi (*Metarrhizium anisopleae, Beauvaria bassiana* and *Trichoderma harzianum*) were used for management of slug and snail causing maximum loss to the neem

seedlings. Although the entomopathogenic fungi used were ineffective against the slug and snail but Dhatura and Hingota extracts were effective against snail.

About 32 combinations of 5 growth promoting rhizobacteria as well as fungi were tested to study their efficacy in promoting growth and vigour of Neem seedlings in greenhouse condition. Data recorded on shoot length, root length, collar diameter, fresh weight and dry weight after 90 days of treatment with these biofertilizers. The results showed that the consortia of biofertilizers were more effective as compared to individual microorganisms. Overall, maximum growth in Neem seedlings was observed with in of *Azotobacter+Azospirillum+Trichoderma* followed by PSB+*Azotobacter*, *Azospirillum*+AMF and PSB+*Azotobacter+Azospirillum* combination.

Benefits of the research projects: The technology will be benefitial to the users in the form of package for development of large scale quality planting material for plantation purpose.

Project 4: Integrated management of khejri mortality for socio-economic upliftment in Rajasthan (AFRI-99/FPD/ICFRE/2010-2017)

Principal Investigator: Dr. Tarun Kant, Scientist F

Protection component

In vitro studies of different bioagents, botanicals and chemical fungicides were observed using *Ganoderma lucidum* as test pathogen. Among the three biocontrol agents studied, most effective was *T. harzianum.* Out of 20 different extracts of plant origin, extracts from *A. excelsa* roots, *P. juliflora* leaf and fruits of *B. aegyptiaca* and *D. stramonium* showed maximum inhibition of test pathogen. Among chemicals, Bavistin, Mancozeb and Propiconazole were found the most effective fungicides in inhibiting growth (100%) of the test fungus. *In vivo* studies were conducted using these selected biogents, botanicals and chemicals in different combinations. The results revealed that propiconazole and leaf extract of *P. juliflora* and *T. harzianum*are managed the pathogen, and propiconazole was the best. Thus, the repeated application of chemical can be avoidable by use of botanicals and bioagents as its substitute. Significant achievementsare:

- Field surveys conducted in Jodhpur, Nagaur, Sikar, Churu and Jhunjhunu revealed 20.93% khejri mortality in all six districts.
- Natural regeneration was higher in Oran and Gochar lands and undulated terrains as compared to mechanically ploughed farmers' field.
- Tractorization had no direct role in mortality of mature/old Khejri trees but reduced the population of Khejri by damaging the new sprouts and lateral roots of the tree which play significant role in invasion of pathogen. According to Koch's Postulate *Ganoderma lucidium* was reconfirmed as a pathogen associated with mortality.

- Aritificial diet of *Acanthophorous serraticornis* was standarized for Bio-ecological studies. Till March 2017, 18th instar has been completed on aritifical diet in laboratory conditions and larvae have pupated.
- Out of 20 tested, 11 extracts found inhibiting the growth of fungus to different extent but four of them had shown significant result in labortaory as well as on three years old infected seedlings in nursery.
- No entomopathogen so far tested showed positive effect against root borer. Neem, Hingota and Calotropis leaves showed antifeedant effect against root borer.
- The management trials laid at six different sites in five districts revealed increase in average loong production in the treated trees.
- Maximum average increase in loong (Khejri leaf) production of severely infested Khejri trees of all sites was 1.64 kg per tree in T_1 (root treatment containing 20gm Bavistine (0.1%) + 20 ml Chloropyriphos (0.1%) + 40 ml Agromin (2ml/lit) @ 20 lit aqueous suspension per tree at three months interval) as compared to control 0.296 kg.

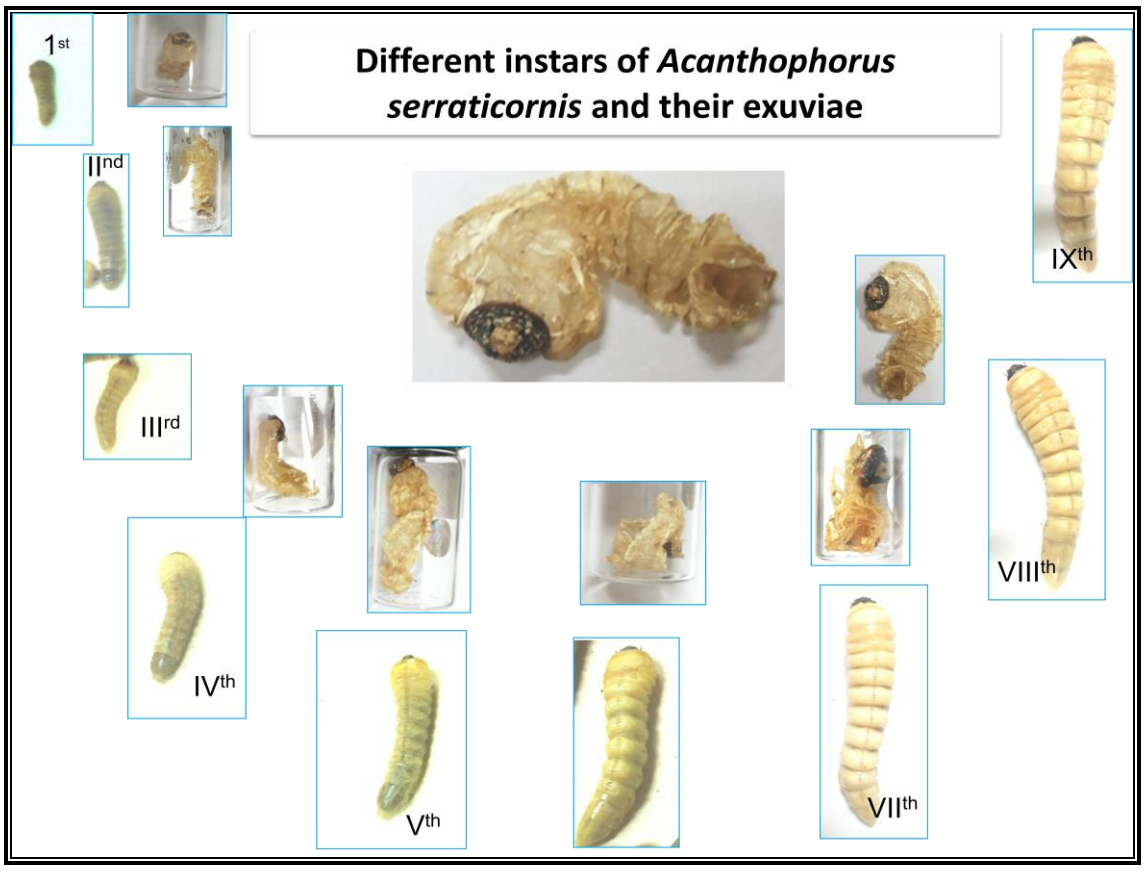


Fig. 35. Different instars of *Acanthophorus serraticornis* and their exuviae.

Genetics component

Ninety two Candidate Plus Trees (CPTs) were selected from Nagaur, Churu, Jhunjhunu, Sikar and Jaisalmer districts in Rajasthan (Fig. 36). Progeny trials have been established at Jodhpur (30 families) and Samaspur, Jhunjhunu (52 families, 6 individuals, 4 replication). Significant achievements are:

- The selected trees exhibited wide variation as indicated by the range and variance for different selection criteria (growth parameters), which is beneficial for maintaining breeding population with wide genetic base.
- Analysis of variance of data collected from 52 individual CPTs revealed significant differences at 1 % level for pod length and weight of 10 pods amongst all selected trees, which can be used for improvement programme.
- Significant variation was observed in seed germination percent and germination velocity index. The results also revealed moderate heritability and exhibited high genetic gain estimates.
- In Jodhpur trial, significant variation was observed for both collar diameter and height amongst the families.
- Twelve trees namely RT-11, RT-3, RT-7,K-1, L-2,LM-1, JRM4, S-9,T-1, B1, LJ2 and JP2 out performed others as indicated by their general combining ability values.

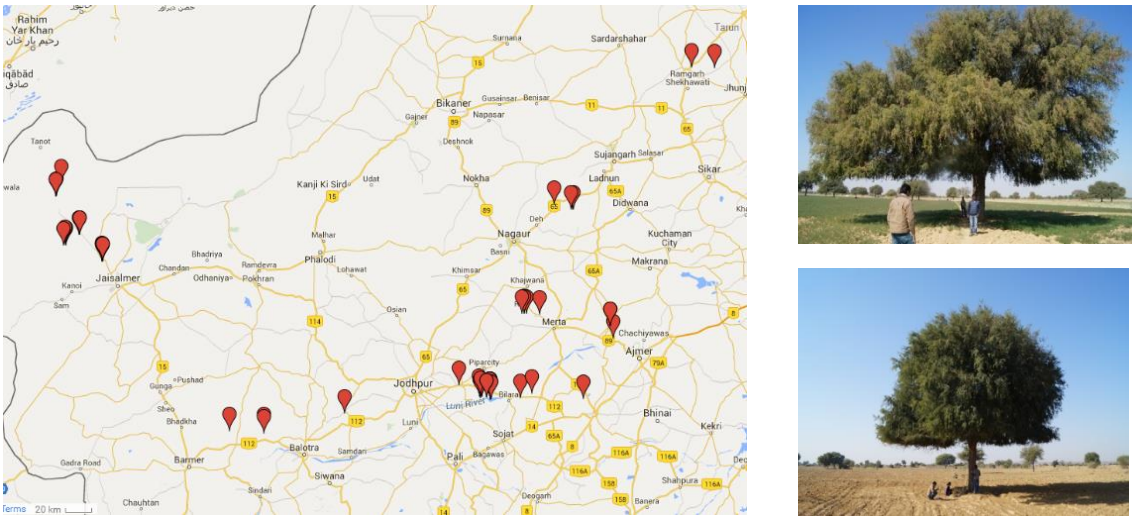


Fig. 36 (a-c). (a) *Prosopis cineraria* (Khejri) selected CPT Locations in Rajasthan; (b) CPT at Merta; (c) CPT at Lanela.

Biotechnology component

Best shoot multiplication method was finalized. Rooting experiments were repeated using auxin application (IBA and NAA used alone and in combination of 1.0 to 15 µM supplemented in Whites medium for extended periods (4 + 4 weeks) and auxin application (dipping in 5 and 10 mM IBA and NAA for 20 sec -Pulsing) was carried out. Emphasis was given on pulsing

treatment to get better rooting. All the selected CPTs (selected under genetics components) in different locations in Rajasthan were revisited. Leaf material was collected from the surviving CPTs as well as diseased trees. DNA was extracted, purified and quantified for molecular marker based diversity analysis (Fig. 37). After complete screening of 25 RAPD and 50 ISSR markers, final analysis of genetic diversity and preparation of phylogenetic trees is underway for selected CPTs of Khejri trees. Detailes achievements are:

- Multiplication of microshoots was obtainable from fresh coppice material obtained from partially lopped old trees, lopped last year, and establishes coppice shoots as best material for multiplication in Khejri.
- For rooting, Pulsing treatment consistently gave better results, but the rooted plantlets did not survive after removal from media. Maximum rooting percentage achieved was 30%. Plantlets when transferred to potting mixture survived only upto 2 weeks.
- Top 5 markers from each category –RAPD and ISSR, based on Polymorphic Information Content and Resolving Power values, were selected for further Genetic Diversity Analysis. Genetic Diversity values have been calculated.

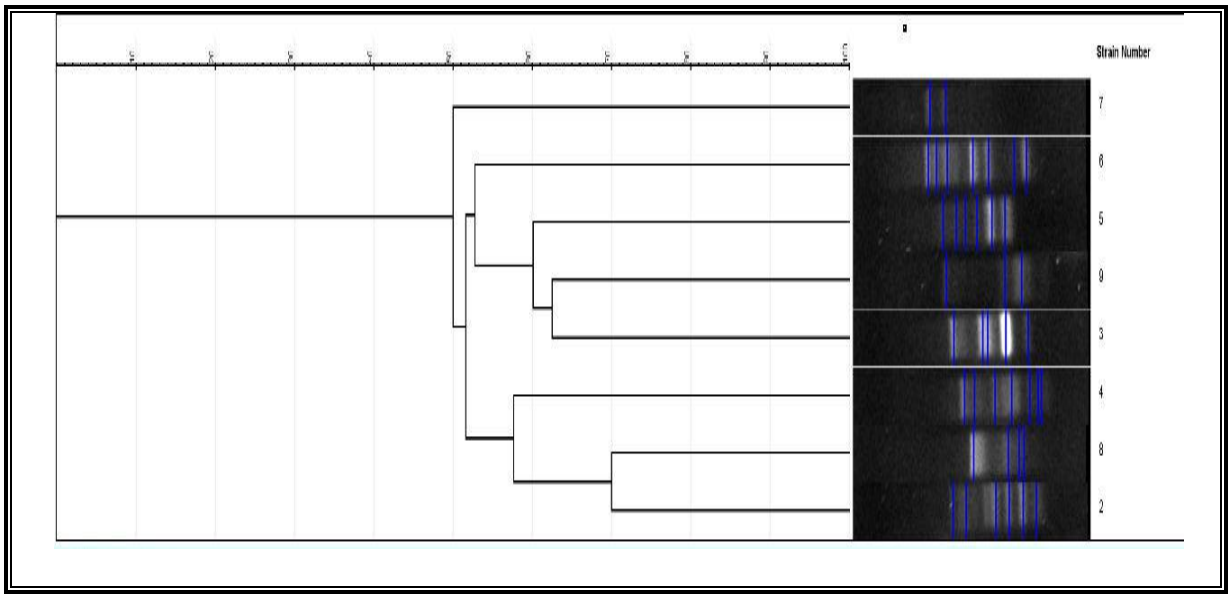


Fig. 37. Dendrogram showing extent of genetic diversity amongst random Khejri CPT from different locations (districts) using ISSR Markers.

Ecology Component

Information on various abiotic factors like rainfall, ground water level, temperature, evaporation etc. were collected from khejri growing districts of Rajasthan and analysed in depth. Metrological data of Churu, Pilani (in place of Jhunjhunu) and Jodhpur district were collected. Analysis was carried out to find out any correlation between khejri mortality and collected ecological data, but no significant correlation could be established between khejri mortality and the selected ecological parameters.

Biochemical component

Different biochemical parameters viz. sugar, protein, phenols, ash and proline contents were studied in leaves, bark, roots and pods of khejri to determine their variation in healthy and infected trees. Proline and phenol content were higher in infected trees as compared to healthy trees and can be used as biochemical marker compounds for identifying infection in Khejri trees. Significant achievements in this component are:

- Sugar content in pods varied from 12.83% in healthy trees to 7.32% in infected trees.
- Proline content in leaves varied from 6.48% in healthy to 8.86% in infected trees and in bark from 1.08 % in healthy to 5.15% in infected ones.
- Mineral ash content varied from 8.89% (healthy) to 3.28% (infected).
- Phenol content in leaves varied from 1.9% in healthy to 2.6% in infected and in bark from 3.76% in healthy to 6.1% in infected trees.

Socio-economic component

Data from socio-economic survey carried out in 382 villages of Nagaur, Churu, Sikar, Jhunjhunu and Jodhpur districts to assess the effect of khejri mortality on rural livelihood in the previous year was analyzed. Number of respondents in each village was 10. The highlights are summarized in following table:

S.No.	District	No. of villages surveyed	Av. Family size	Average Land Holdings (Beegha)	Average Annual Income (Rs.)
1	Jodhpur	60	7.04	9.48	79,444
2	Churu	75	7.58	4.98	73,800
3	Nagaur	86	10	19.8	71,877
4	Sikar	85	7.8	19.0	72,262
5	Jhunjhunu	76	7.2	23.8	1,08,657

- The reduction in lopped fuel wood ranged from Rs. 132/ tree in Nagaur to Rs.151/tree in Churu and Sikar at a prevailing rate of Rs. 5/ kg.
- The reduction in fodder ranged from Rs. 111/tree in Jhunjhunu to Rs. 178/ tree in Jodhpur at a prevailing rate of Rs. 7/ kg.

Extension component

Under the extension component of the project, emphasis has been on educating the masses about the problem of Khejri mortality and how to manage it. In this

- Pamphlets on Problem of Khejri mortality in North-western Rajasthan were distributed among farmers and other stakeholders for awareness generartion about Khejri mortality

problem. In this pamphlet problem of khejri mortality and recommendation for control and various factors affecting khejri tree were explained in simple Hindi language.

- Posters on Khejri mortality problem and its management were prepared for Extension and Interpretation Centre and Van Vigyan Kendras.
- Pamphlets addressing Khejri mortality problem were also distributed to farmers/Forest staff/NGO during 'Tree Growers Mela' organized on 21.03.17 at AFRI.

2.7.3 Mycorrhizae, rhizobia and other useful microbes

Project 1: Rehabilitation of salt affected soil with amendments of biofertilizer (AM Fungi). (AFRI-23/AF&E/ICFRE/2016-19).

Principal Investigator: Bhawana Sharma, Scientist D

Survey was conducted to collect rhizosphere soil samples from *Salvadora persica* L. (Khara jal, pilu) growing areas in Jodhpur (Bilara, Jhak, Kala Una, Bhavi, Dhava, Kalyanpura and Gangani), Bikaner (Kotri, Jordbeed, Lunkaransar, Rajera and Binjwani), Jaisalmer (Pokaran, lathi and Jaisalmer range), Nagaur (Kuchaman & Sambhar) and Pali (Rohat, Lalki, Sindari, Neemli, Mukanpura and Jalore road) districts. *Glomus* and *Scutellospora* were identified as important genera of AM fungi. *Glomus* occurred most frequently and was dominant in rhizosphere soil samples collected from nurseries as well as in plantations (Fig. 38-49).

Benefits of the Research Project: The study under this project will provide first hand information of AM technology to end users and will encourage use of biofertilizer to enhance the productivity of *Salvadora persica* in salt affected soil.

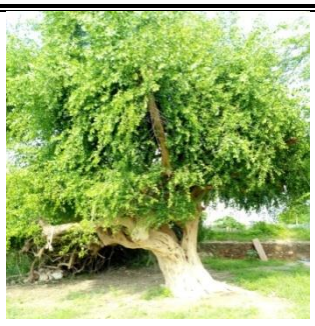


Fig. 38. *Salvadora persica* Tree.

Fig. 39. Flowering in *Salvadora persica*.

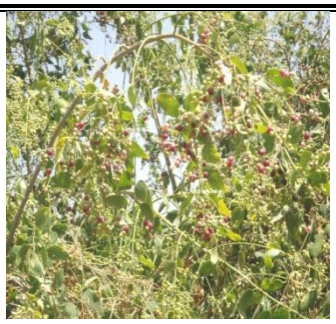
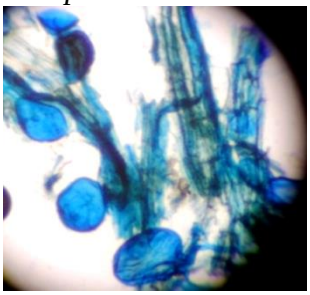
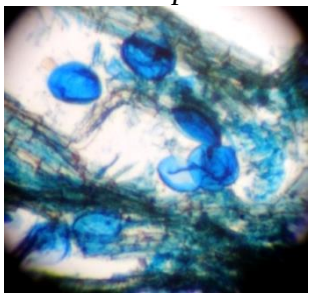


Fig. 40. Fruting in *Salvadora persica.*





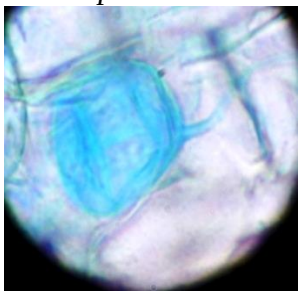


Fig. 41. Globose type of vesicles (Rohat, Pali).

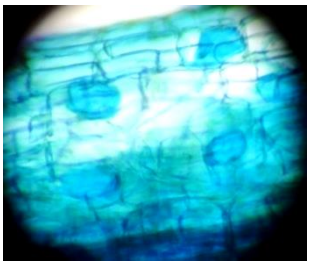


Fig. 42. Globose & subglobose type of vesicles (Rohat, Pali).

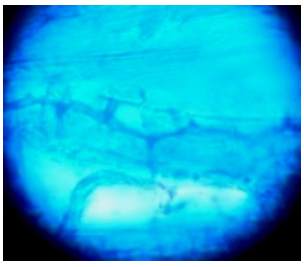


Fig. 43. Young chlamydospore (Sambhar).

Fig. 44. Globose vesicles (Sambhar).

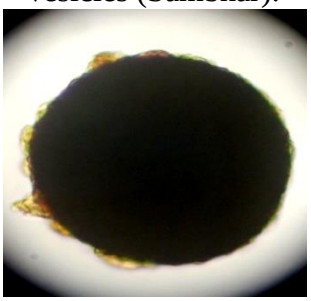


Fig. 45. Intercellular hyphae (Sambhar).

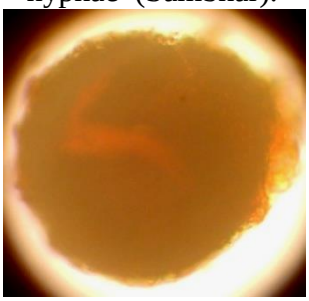


Fig. 46. Extramatrical hyphae (Sambhar).

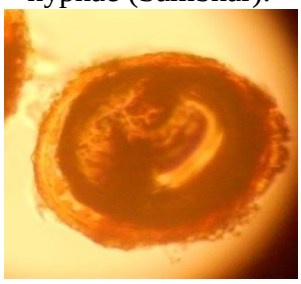


Fig. 47. Scutellospora species at AFRI nursery.

Fig. 48. *Glomus* species at AFRI nursery.

Fig. 49. *Glomus* species at Rohat.

Project 2: Selection of efficient AM fungi, PSBs and Azospirillum for productivity enhancement of *Dendrocalamus strictus* & *Bambusa bambos.* (AFRI-25/FP/ICFRE/2016-20)

Principal Investigator: Dr. Neelam Verma, Scientist B

Rhizosphere soil and root samples of *Dendrocalamus strictus* (Solid Bamboo) and *Bambusa bambos* **(**Thorny Bamboo**)** were collected from various forest nurseries *viz.*, Sandri nursery, Range-Ogna and Ghata Nadi Nursery, Range-Devla; Bijaypur Nursery; Pratapgarh Nursery**;** Pungatalab in Jataran block, and Kumbalgarh nursery. Rhizosphere soil and root samples of *Dendrocalamus strictus* were also collected from various plantation of Udaipur (5), Chittorgarh (4), Pratapgarh (6), Mount Abu (4), Pindwara Range in Sirohi (4), Kumbalgarh in Rajsamand (4), Banswara (6), Dungarpur (2) and Sariska in Alwar (6) areas of Rajasthan. For *Bambusa bambos* samples were collected from Udaipur (2), Chittorgarh (2), Pratapgarh (2) and Banswara (7) of Rajasthan. Soil samples were analyzed for soil moisture, pH, EC, per cent organic carbon, phosphorous (P) and AM fungi were isolated (Fig. 50-61). *Glomus, Acaulospora, Gigaspora and Sclerocystis* were identified as important genera associated with *D. strictus* and *B. bambos.* Among these, *Glomus* occurred most frequently. Different species of *Glomus* were *G. aggregatum, G. fasciculatum* and *G. mosseae*. *Glomus* species dominated in both nurseries as well as in plantations.

Fig. 50. *D. strictus* at Shakbor Van Khand (Chittorgarh).

Fig. 51. *D. strictus* with seeds in Ghatol Range (Banswara).

Fig. 52. *B. bambos* curved spines in Ghatol Range (Banswara).

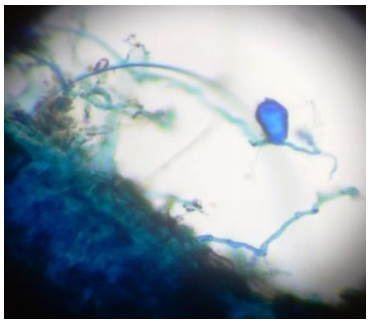


Fig. 53. Extramatrical hyphae emerging from root of *D. strictus.*

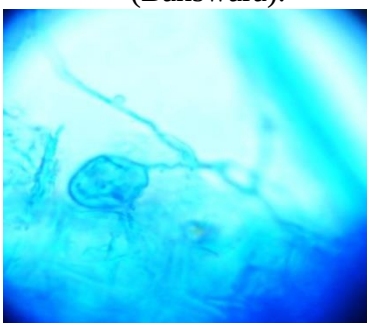


Fig. 54. Root of *D. strictus* with young chlamydospore and extramatrical hyphae.

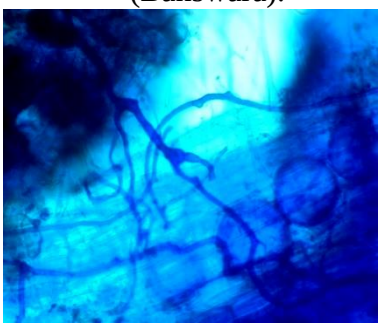


Fig. 55. Root of *B. bambos* with hyphae and globose type vesicles.

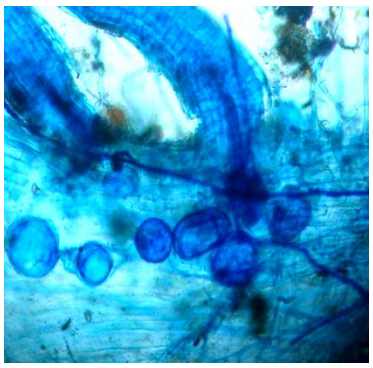


Fig. 56. Root of *B. bambos* with hyphae and subglobose, globose type of vesicles.

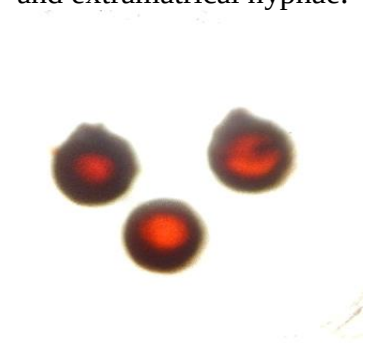


Fig.57. *Glomus* species from *D. strictus* in Ghatol Range (Banswara).

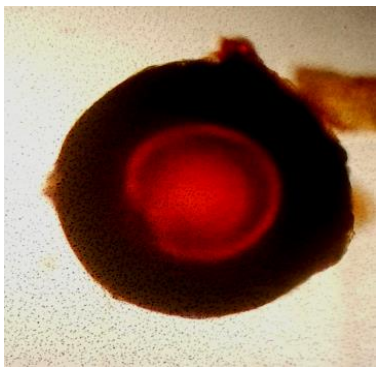


Fig. 58. *Glomus* species collected from *D. strictus* at (Banswara).

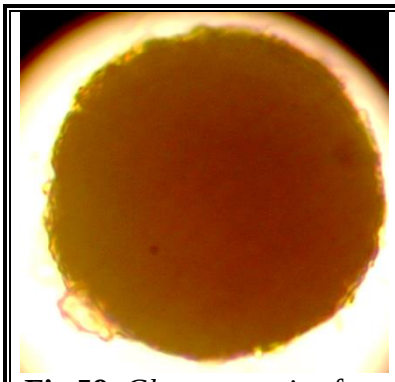


Fig.59. *Glomus* species from *D. strictus* in Ghatol Range (Banswara).

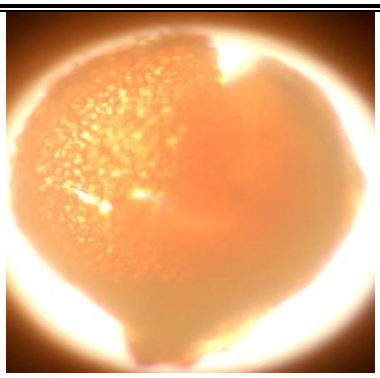


Fig.60. *Glomus* species from *D. strictus* in Banswara.

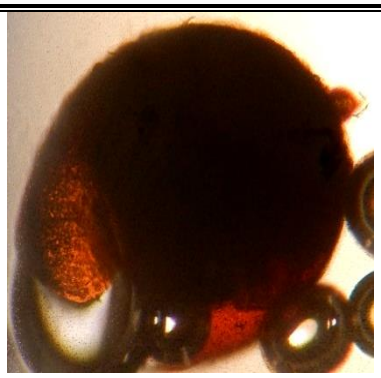


Fig. 61. *Gigaspora* species from *D. strictus* in Banswara.

Benefits of the research projects: The study under this project will provide first hand information of AM technology to end users and encourage them to adopt eco-friendly teconology of biofertilizer to enhance productivity of *Dendrocalamus strictus* and *Bambusa bambos*.

Project 3: Value addition to plants of agricultural and horticultural importance by application of consortium of root fungal endophyte and nitrogen fixing prokaryote – Azotobacter spp. (AFRI- 19/FP/EXT. (DST)/2015-17).

Principal Investigator: Dr. Sangeeta Singh, Scientist E

Seeds of neem (*Azadirachta indica*), Khejri (*Prosopis cineraria*), Senna (*Cassia angustifolia*) and Isabgol (*Plantago ovata*) were treated with formulation of the AM fungi *Piriformospora indica*, *Azotobacter* spp. and consortia of both these microbes to study their individual as well as combined effect on the growth and development of these plant species. Growth parameters like collar diameter, shoot length, root length, biomass, sturdiness quotient, quality index and vigour index were calculated for the neem and Khejri, while yield was calculated for Isabgol and Senna. In case of Khejri, the consortia showed better results in case of shoot length (28.7 cm), root length (48.2 cm), number of leaves (18.4), sturdiness quotient (9.4) and vigour (28.7) followed by *P. indica (*shoot length (20.6 cm), root length (34.7 cm) number of leaves (18) sturdiness quotient (10.4) and vigour (15.6) as compared to control (shoot length, 17.8 cm; root length 29.8 cm; number of leaves 15.2; sturdiness quotient 14.7 and vigour, 13.5. In neem seedlings, *P. indica* showed better results (shoot length 13.12 cm; root length, 27.1 cm, number of leaves- 7.8 sturdiness quotient - 3.2 and vigour - 12.5 as compared to control (shoot length - 11.54 cm; root length-19.92 cm, number of leaves -4.6, sturdiness quotient -11.376, and vigour - 10.41. In annual plants senna and isabgol, *P.indica* has performed better than all other treatments. Mean yield in Isabgol seed and husk, respectively, increased to 57% and 33% in *P.indica* treated seeds

followed by 36% and 14% in consortia of the fungus and bacterium, and 23% and 4% in *Azotobacter* treated seeds as compared to control. Similarly, mean yield of senna seeds was maximum in *P. indica* treated seeds (39.7 g), followed by consortia (20.0 g) and *Azotobacter* (19.2 g) than in control (16.3 g).

Project 4: Evaluation of plant growth promoting (PGP) activity of rhizobium from native legumes and development of consortia with other PGP rhizobacteria. (AFRI-38/FP/ICFRE/2017-22).

Principal Investigator: Dr. Sangeeta Singh, Scientist E

This project is started in February 2017. From ten districts of Rajasthan, soil samples were collected for isolation of bacteria and work on physical and chemical properties of soil is in progress.

2.7.4 Weeds and Invasive species: NIL

2.7.5 Forest Fire and Grazing: NIL

3. Education Vistas/Activities

3.1. FRI University (Applicable for FRI, Dehradun only) :N.A.

3.2 Training organized

S.No.	Tranings	Duration (in days)	No. of Participants
1.	Training on "Combating Desertification"	1 Day (17^{th} June, 16)	184
2.	Training on "Nursery Management"	2 Days (27^{th} to 28^{th} September, 2016)	31
3.	Training on "New techniques in forestry and agroforestry" VVK, Bikaner	3 Days (8^{th} to 10^{th} November, 2016)	79
4.	One week training for supporting staff of ICFRE on "Integrated approach for sustainable development of fragile desert eco-system'	5 Days (7-11^{th} November, 2016)	10
5.	One-Week Refresher Course on "Integrated Approach for Sustainable Development of Fragile Desert Ecosystem" for IFS Officers	5 Days 19^{th} to 23^{rd} November, 2016)	33
6.	Training on Nursery Management	2 Days (22^{nd} to 23^{rd} November, 2016)	29
7.	Traning at VVK, Rajkot	3 Days (28^{th} to 30^{th} November, 2016)	76

8.	Training on Nursery Management	2 Days (08th to 09th December, 2016)	30
9.	VVK training at Bikaner	2 Days (15th to 16th February, 2017)	40
10.	Training on "Production of female Ardu plants through grafting technique for higher biomass production" under Direct to consumer Scheme of ICFRE.	2 Days (1st - 2nd March, 2017)	29
11.	Training cum workshop on "Wild Animal Rescue and Rahabilitation" organized jointly by AFRI, Jodhpur and SFD, Rajasthan	2 Days 24th to 26th March 2017	120

3.3 Visit Abroad: NIL

3.4 Participation in Seminar/Symposia/Workshop/Trainings

- Sh. A. Durai, Scientist-B, Participated in HRD training on "Forest Genetic Resource Management and Conservation" for Scientists and Research Officers of ICFRE at Institute of Forest Genetics and Tree Breeding, Coimbatore, held from 13.02.2017 to 17.02.2017.
- Dr. I. D. Arya, Scientist-G and Dr. Sarita Arya, Scientist-F attended 38th Annual meeting of Plant Tissue Culture Association (India) & National Symposium on "Current Perspectives on Medicinal and Crop Plants" at CSIR-Institute of Chemical Biology from 3-5 March 2017.
- Dr. Mala Rathore, Scientist-D and Smt Sangeeta Tripathi, Scientist-B participated in two days Rajbhasha "Vagyanik Sangosthi" on 6th -7th February, 2017 organized at Defence Laboratory, Jodhpur.
- Dr. Ranjana Arya, Scientist-G, Dr. Mala Rathore, Scientist-D and Smt Sangeeta Tripathi-Scientist-B, attended "Group Monitoring Workshop of DST (SEED Division)" on 21-22 Jan. 2017 at Udaipur, and presented work progress of three DST funded projects.
- Smt Sangeeta Tripathi, Scientist-B attended five days training programme on "Economics and Marketing of Forest Produce" at Indian Institute of Forest Management, Bhopal, 13-17 Feb, 2017.
- Smt. Seema Kumar, Scientist-E delivered an invited talk on "Insect pests of forestry importance and pest management" as a resource person in a two days Workshop on "Faunal Identification and Conservation", organized by Department of Zoology, Govt. Dungar College, Bikaner from 06-07 January 2017.
- Shri S.R. Baloch, Scientist C participated in three days training cum workshop on "Wild animal Rescue and Rehabilitation" organized by AFRI and State Forest Department, Jodhpur from 24th to 26th March, 2017 at AFRI, Jodhpur (Rajasthan).

- Shri S.R. Baloch, Scientist C participated in two days national Seminar on "Sustainable models of Agriculture and tree based livelihood for western Rajasthan" organized by AFRI and MPOWER from 22nd to 23rd February 2017, at AFRI, Jodhpur (Rajasthan)
- Dr. Tarun Kant, Scientist F participated as a resource person in ICAR sponsored Summer School (Workshop/Orientation Course) on "Livelihood and Climate Change Mitigation and Adaptation through Agroforestry" from 03rd to 23rd August, 2016 at CAZRI, Jodhpur.
- Dr. U.K. Tomar, Scientist F participated in National Conference on "Tree Improvement Research in India: Current Trends and Future Prospects", 2-3 February 2017 at IWST, Bangalore for an oral and poster presentation.
- Smt Sangeeta Tripathi, Scientist-B attended three days National Seminar on "Forest and Tree based Land Use Systems for Livelihood, Nutritional and Environmental Security", organized at Navsari Agriculture University, Navsari from 21-23 December, 2016.

Participation in Extension meetings and Mela etc.

- Uma Ram Choudhary, IFS & Head, Agroforestry and Extension, participated in "Pradhanmantri Fasal Beema Yojna Jagrukta Abhiyan Evam Kisan Mela" held at Lunawas Khara village, Jodhpur, which was organized by K.V.K. CAZRI, Jodhpur on 03/04/16. AFRI arranged a stall in the programme and disseminated developed technologies on agroforestry and forestry.
- Uma Ram Choudhary, IFS delivered a lecture on plantation and seed sowing techniques in the training imparted by forest department Pali for different executive agencies of the district under "Mukhyamantri Jal Swablamban Abhiyan" at Pali on 10-06-16.
- Uma Ram Choudhary, IFS participated in programme organized on the subject, "Gramin Stariya Jalbhrat Prabandhan" under Jal Kranti Abhiyan of Govt. of India on 14-15 July at Jal Gram Lavera Kala, Panchayat samiti, Babdi, district – Jodhpur and delivered a lecture on "Vrikshon Ka Mahatva Evam Krishi Vaniki."
- Uma Ram Chaudhary, IFS participated in district level plantation Programme under "Mukhyamantri Jal Swablamban Abhiyan" organized on 21st July 2016 by the district administration, Jodhpur at Gram Sar, Gram Panchayat Sanrecha, Panchayat Samiti, Luni, district- Jodhpur.
- Uma Ram Chaudhary, IFS and Dr. Bilas Singh, Scientist B participated in Intensive Plantation Programme of Rajasthan Patrika under its Hariyalo Rajasthan Abhiyan at Goshala Parisar, Sinvachi gate on 25th July 2016. About 251 Plants were planted.
- Dr. Bilas Singh, Scientist B attended "Agricultural Technology Management Agency (ATMA)" meeting on 23/8/2016 at Collectrate, Jodhpur
- AFRI participated in Kisan Mela at Central Arid Zone Research Institute Jodhpur on 21st September 2016. Recognized technologies and research activities of AFRI were showcased through posters along with forest products through the stall. Seedlings raised at AFRI nursery, specially desert & medicinal plant species were demonstrated. Folders & leaflets related to medicinal plants were also distributed.

- Participation was done by means of stall and demonstration at "District Level Farmers Fair" organized at Agricultural Research Center, Mandore, Jodhpur under ATMA on 9th Feb. 2016. Shri Uma Ram Choudhary, Dr. Bilas Singh and Shri Mahipal Bishnoi participated in the Mela. Research activities and recognized technologies developed by AFRI were displayed by posters. Plants raised in AFRI experimental nursery, different forest produces, seeds of various forest sp. were also demonstrated. Pamphlets published by AFRI on various subjects were distributed.
- AFRI participated in "Jan Suchna Abhiyan" organized by Press Information Bureau at Saansad Adarsh Gram Kalyan Singh Ki Sid, from 18/2/16 to 20/2/16 through a stall, where in, developed technologies of AFRI were showcased by posters. Sh. Ratna Ram Lohra R.A- I & Mahipal Bishnoi R.A- II represented AFRI from 18/2/16 to 20/2/16 informed about AFRI research activities & developed technologies at the stall. To impart knowledge to the visitors at stall, plants including medicinal plants, forest products, seeds etc were also demonstrated. Shri Uma Ram Chaudhary delivered a lecture on 19/2/16 emphasizing importance of trees and needs of Agroforestry.
- AFRI participated in "Krishak Prashikshan" at Krishi Vigyan Kendra, Maulasar, Nagaur, organized by Assistant Director Agriculture (Extension), Kuchaman City, Nagaur. Shri Uma Ram Chaudhary delivered a lecture narrating direct and indirect benefits of trees. Research activities & developed technologies were also demonstrated by posters & plants raised in AFRI nursery, including medicinal plants, and forestry products were demonstrated. Pamplets and leaflets were also distributed.
- Uma Ram Chaudhary, IFS participated in "Scientific Advisory Committee" meeting of K.V.K Gudamalani & SURE, Danta, Barmer on 18/02/16. In the meeting Shri Chaudhary emphasized the importance of trees and the need of Agroforestry by delebrating upon the research activities of AFRI.
- Uma Ram Chaudhary, IFS participated in base level orientation training programme organized by NABARD, Jaipur for Farmer's Club of Bilara, Pipad city, Bhopalgarh & Bawri region under Jodhpur district on 3.3.2017. A lecture was delivered on importance of tress, environment conservation and agroforestry etc.. Pamplets and brochures about AFRI and its research activities were also distributed.
- One day division level programme on "Mission Water Conservation" was held at Jodhpur on 26.03.17 by Zila Parishad, Jodhpur. A lecture on Natural Resource Management & technicalities of NRM was delivered.
- Uma Ram Choudhary, IFS participated in one day "Jan Chetna Samaroh" organized by Central Ground Water Board, Jaipur at village Oriya Panchayat Samiti, Abu Road, district Sirohi on 27.03.17. A lecture was delivered on the importance of trees, water conservation, environment conservation etc. Various research activities of the institute were also informed about. Plants grown at AFRI nursery, forest products such as gums, oils etc. & various seeds were also showcased and pamphlets were distributed.

4. Extension Panorama/Activities:

4.1 Van Vigyan Kendra (VVKs) and Demo Village (DVs)

State wise locations of established and proposed VVKs

- Bichhwal in Bikaner district of Rajasthan.
- Chhipardi Beedi in Rajkot in Gujarat.
- Rudana Nursery, Khanwel (Silvasa), Dadra & Nagar Haveli and Daman.

VVK established at Bichhawal Nursery, Bikaner (Rajasthan)

Uma Ram Choudhary, IFS and Head Agroforestry and Extention Division and Smt Bhawana Sharma, Scientist B visited VVK Bikaner. VVK activities were discussed with CCF Bikaner, and DCF, IGNP Stage II of Bikaner. Hitech nursery at Bichwal, Bikaner was also visited.

Maintenance of Hi-Tech Nursery: At Hi –Tech VVK nursery maintenance work was done by SFD. Rajasthan.

Raising of Seedlings: 3000 quality seedlings were raised in Hi-Tech nursery at Bichhwal, Bikaner for distribution to farmers and to promote agroforestry under VVK.

Training: Two trainings were organized under VVK in Rajasthan.

i. Three days training programme on "New Techniques in Forestry and Agroforestry" was organized at Swami Keshwanand Agriculture University, Bikaner under VVK, Bikaner from 8th to 10th November 2016. Frontline staff of State Forest Department, Rajasthan, VFPMC members and Farmers from Bikaner circle attended this training programme. Classroom sessions and field visit were organized to explain various aspects of forestry (including agroforestry) during this training programme.
ii. Two days training programme was organized at Bhimsen Choudhary Kisan Ghar, Swami Keshwanand Agriculture University, Bikaner under VVK from 15th to 16 th February 2017. A total of 40 frontline staff of State Forest Department, Rajasthan, specialy from Bikaner circle attended this training programme. Clasroom sesssions and field visit were organized to explain various aspects of forestry during this training programme.

VVK established at Chhipardi Beedi, Rajkot (Gujarat)

Shri Uma Ram Choudhary and Dr. Bilas Singh met Dr. D.K. Sharma, Addl. PCCF (Training & Research), Gujarat Forest Research Institute, Gandhinagar and Shri Mukesh Kumar, DCF (Research) and Nodal Officer, Gujarat Forest Research Institute, Gandhinagar on 3rd August 2016 and discussed about requirement for nursery maintenance, seedling raising, training and other VVK works in Gujarat. Addl. PCCF (Training & Research) suggested that VVK training may be organized in Kuchch region, which will be more useful. Also visited Hi-Tech

nursery at Research and Development Centre, Rajkot and nursery requirement was assessed through discussion with Shri Godiya Bhai, RFO.

Maintenance of Hi-Tech Nursery: Nipple, fogger garden pipe and accessories, fertilizer & insecticide were procured for the maintenance of Hi-Tech nursery at Research and Development Centre, Rajkot under VVK.

Raising of seedlings: Grafted seedlings of *Emblica officinalis* and *Cordia myxa* and high quality seedlings of *Casuarina equisetifolia*, *Morus nigra, Vitex negundo* species were raised. A total of 5000 seedlings were raised for their promote agroforestry among the farmers.

Training: Three days training programme on "New Techniques in Forestry and Agroforestry" was organized at Bhuj Gujarat under VVK, Rajkot from 28th to 30th November 2016. Front line staff of State Forest Department, Gujarat and Farmers (total 76) attended this training programme. Classroom sessions and field visit were organized to explain various aspects of forestry including nursery, production of quality planting stock, nursery management, plantation techniques, soil and water conservation, afforestation on saline land and agroforestry during this training programme.

4.2 Technologies transferred

Macropropagation and micropropagation technologies developed for multiplication of Neem trees was transferred to State Forest Research Laboratory, Gandhinagar. In bamboo, tissue culture technique so developed, were used and cultures were initiated which involves axillary bud break, *in vitro* shoot multiplication and *in vitro* rooting of shoots. This Tissue- Culture technique as well as cultures were transferred and demonstrated to State Forest Research Laboratory, Gandhinagar.

4.3 Research publication

Sl. No	National Journals
1	Singh G. (2017). Carbon sequestration during restoration of degraded hills by rainwater harvesting and afforestation in Rajasthan, India. *Indian Forester*. 143(3): 213-222.
2	Sharma M. and Sharma N. (2017). Suitability of Butterflies as Indicators of Ecosystem Condition: A Comparison of Butterfly Diversity across four habitats in Gir Wildlife Sanctuary. *International Journal of Advanced research in Biolological Sciences.* 4(3):43-53.
3	Srivastava K.K., Verma N. and Singh S. (2016). Role of biofertilizer in plant establishment and growth of *T. undulata*. *International Journal of Engineering Research and Management*, 3 (10):5-8.
4	Meena D., Singh A. and Sharma A. (2016). Studies on seeds germination and seedling growth of *Tecomella undulata* at nursery stage. *International Journal of Agriculture and Environmental Research*, 2(03):314-321.

5	Meena D., Bhatnagar S. and Singh A. (2016). Infestation of termite in progeny trial of *Tecomella undulata*. *Indian Forester*, 142(11): 1130-1134.
6	Sharma Meeta, Sharma Noopur, Srivastava K. K. and Parmar Ashok (2016). Population dynamics of major insect pests on *Ailanthus excelsa* Roxb. and their management in arid and semi-arid areas of Rajasthan and Gujarat. *Indian Forester.* 142(9): 900-912.
7	Sharma Meeta (2016). Insect pests of Forestry plants and their management. *International Journal of Advanced research* (IJAR). 4(8): 2099-2116.
8	Sharma M. and Tripathi S. (2016). *Miliusa tomentosa* (Roxb.) J. Sinclair: Wild food plant for larval host of butterflies in tribal dominated area of Abu Road in Sirohi district of Rajasthan, India. *International Journal of Advanced Research,* 4(8): 2094-2098.
9	Verma N. Tarafdar J.C., Srivastava K.K and Sharma B. (2016). Correlation of soil Physico-chemical factors with AM fungal diversity in *Ailanthus excelsa* Roxb. under different Agroecological zones of Western Rajasthan. *International Journal of Life-Sciences Scientific Research,* 2 (4):316-323.
10	Tripathi S. (2016). Customs, Traditions, NTFP Collection, Marketing and Key issues of Garasia Tribes of Abu road block in Rajasthan, India. *International Journal of Innovative Research* & *Advanced Studies*, 3(8):113-119.
11	Tripathi S. (2016). Livelihood Dependency of Garasia tribes utilizing Non Timber Forest Products in Abu Road area of Sirohi district in Rajasthan, India. *International Journal of Advanced Research,* 4 (7): 498-504.
12	Tripathi S. (2016). Reviving SHGs for income generating activities through Value Addition of *Momordica Dioica*; An underutilized NTFP in tribal dominated area in Sirohi District of Rajasthan (India). *International Journal of Innovative Research* & *Advanced Studies*, 3(11):196-202.
13	Tripathi S. and Sharma M. (2017). Selected underutilized edible wild food plants; their association with lepidopteron fauna and role in tribal livelihood of Jamboori Panchayat Samiti , Abu Road block in Sirohi district of Rajasthan. *International Journal of Advanced Research,* 5(3):1468-1475.
14	Bhatnagar S., Singh S**.,** Khan A.U., Kumar B., Goran P., Ahmed S.I., Srivastav K.K. and Rathore T.S. (2016). Effect of tractorization on reduction in natural population of *Prosopis cineraria* (l.) In agro ecosystem of Thar desert. *International Journal of Advanced Research*, 4(8):603-606.
15	Bohra N.K., Mishra D.K., Meena S.L. and Deora S.R. (2016). *Ex-situ* conservation of medicinal plant of arid and semi arid regions for education, research and utilization, *International Journal of Usufruct Management*, 17(1):2-7.
16	Mishra, D. K. and N. K. Bohra (2016). Effect of seed pre-treatment and time of sowing on germination and biomass of *Cassia angustifolia* Vahl.in arid regions. *Annals of Arid Zone*, 55 (1 and 2):29-34.
17	Saini H. and Arya I.D. (2016). Bioremediation of oil polluted soil: Effect on hill bamboo (*Drepanostachyum falcatum*) plant emergence and height. *Journal of Agricultural Biotechnology and Sustainable Development*, 8(6):46-52

18	Saini H., Arya I.D., Arya S. and Sharma R. (2016). *In-vitro* micropropagation of Himalayan Weeping Bamboo, *Drepanostachyum falcatum*. *American Journal of Plant Sciences,* 7(9):1317-1324.
19	Kamal B., Arya I.D, Sharma V. and Jadon V.S. (2016). *In-vitro* Enhanced multiplication and molecular validation of Eucalyptus F 1 hybrids. *Plant Cell Biotechnology and Molecular Biology,* 17(3&4): 167-175.
20	Mishra Aditi, Mishra D.K. and Bohra N.K. (2015). Synthesis and characterization of Silver nanoparticles by *Azadirachta indica* leaves. *Annals of Arid Zone,* 54 (1 and 2):43-49.
21	Bala N., Kumar P., Bohra N.K., Singh B. and Singh G. (2014). Production and decomposition of litter in *Prosopis cineraria* plantation along canal banks in Indian Desert. *Annals of Arid Zone,* 53: 173-176.

Sl. No	Foreign Journals
1.	Tripathi A., Shukla J.K., Gehlot A. and Mishra D.K. (2016). Condensed node proliferation technique (CNPT): a better low cost macro propagation approach through mini-cuttings of *Commiphora wightii* (Arn.) Bhandari an endangered plant of Indian Desert. *Advances in Forestry Science*, 3(4): 65-69.
2.	Nirwan Bindu, Choudhary S., Sharma K. and Singh S. (2016). *In vitro* studies on management of root rot disease caused by *Ganoderma lucidum* in *Prosopis cineraria*. *Current Life Science*, 2(4):118-126.

Sl. No	Chapter in Books/proceedings
1.	Rathore M. and Meena R.K. (2016). Nutritional evaluation of pods of *Leptadenia reticulata*- an important plant of arid zone. In: Proceedings of Silviculture Conference, 24-28 November, 2014, FRI, ICFRE, Dehradun, (Vol II) 13, pp. 441-445.
2.	Arya Ranjana (2016). Performance *Acacia ampliceps* (Exotic) on Lithic, Calcid, Coarse sandy to loamy sand arid salt affected soil in Rajasthan. In: Proceedings of Silviculture Conference, 24-28 November, 2014, FRI, ICFRE, Dehradun, (Vol II) 13, pp. 206-214.
3.	Arya R., Kumar H. and Purohit N. (2017). Wood products from lesser known timber species for Jodhpur Handicraft Industries. In: Proceeding on National Seminar on Important Timber trees of India, 9-10 February, 2017, IFGTB, Coimbatore, pp. 214-225.
4.	Tripathi Sangeeta and Arya Ranjana (2016). *Momordica dioica*-a potential NTFP for enhanced tribal livelihood in tribal belt of Sirohi district of Rajasthan. In: Proceedings of Silviculture Conference, 24-28 November, 2014, FRI, ICFRE, Dehradun, (Vol II) 13, pp. 490-494.

Research article presented in seminar/conferences/workshops and abstract and popular articles published

Sl. No	Article presented
1.	Arya Ranjana (2016). Medicinal plants: status, cultivation and nondestructive harvesting practices for Rajasthan in national conference on "Forestry in India: Current Challenges and Future Prospects" at HFRI, Shimla, 15-18 November, 2016.
2.	Arya R., Lohara R.R., Kumar H. and Aboti Jyoti (2016).Soil amelioration due to growth and biomass production from the species on degraded highly saline, silty black soil in the little runn of kachchh, paper presented in the symposium on "Electrochemistry energy and environment", organized by Chemistry department, JNVU, Jodhpur, 16-18 December, 2016.
3.	Rathore M. and Sharma H. (2016). *Calligonum polygonoides* – an important but dwindling shrub of Thar Desert. In the symposium on "Electrochemistry energy and environment", organized by Chemistry department, JNVU, Jodhpur, 16-18 December, 2016.
4.	Rathore M., Kumar H. and Tripathi S. (2016). *Cassia tora*- a nutritious leafy vegetable of Rajasthan and its role in income generation; presented in national seminar on "Forest and tree based land use systems for livelihood, nutritional and environmental security organized at Navsari Agriculture University, Navsari, 21-23 December, 2016.
5.	राठौड़ माला एवं त्रिपाठी संगीता (2017) तेंदू पत्ता–आदिवासियों की आजीविका का एक प्रमुख एवं उपयोगी स्त्रोत, पृष्ठ सं. 99, राजभाषा वैज्ञानिक संगोष्ठी, 6–7 फरवरी, 2017, रक्षा प्रयोगशाला, जोधपुर।
6.	त्रिपाठी संगीता एवं राठौड़ माला (2017) आदिवासी अर्थव्यवस्था में महुआ का योगदान, पृष्ठ सं. 93, राजभाषा वैज्ञानिक संगोष्ठी, 6–7 फरवरी, 2017, रक्षा प्रयोगशाला, जोधपुर।
7.	वर्मा नीलम एवं श्रीवास्तव के. के. (2017) पौधों की वृद्धि के लिए उर्वरकों की आवश्यकता क्यों?, सशक्त भारत के निर्माण मे' अनुसंधान एव् विकास, राजभाषा वैज्ञानिक संगोष्ठी, रक्षा प्रयोगशाला, जोधपुर 06–07 फरवरी, 2017 पृष्ठ 86–87।

Sl. No	Abstract published
1.	Gaur Arti, Singhal H., Saini L.S. and Tomar U.K. (2016). *Commiphora wightii* (Arnott) Bhandari: an important medicinal plant heading toward genetic erosion? studies, results and future strategies. In proceedings of national conference "Forestry in India: Current challenges and future prospects. 15-18 November, HFRI (Indian Council of Forestry Research and Education), Shimla, pp. 144.
2.	Singh B. and Singh G. (2016). Effect of lopping and root barrier on crop production in *Hardwickia binata* based agroforestry system in western Rajasthan. In proceeding of National Symposium on "Agroforestry for environmental challenges, sustainable land use, biodiversity conservation and rural livelihood options". 3-5, December 2016, ICAR-CAFRI, Jhansi (U.P.), pp.115.
3.	Meena D., Sharma A., Singh D. and Singh A. (2016). Molecular diversity analysis of flower color variants of *Tecomella Undulata* using inter simple sequence repeat. In proceedings of National conference Forestry in India: Current challenges and future

	prospects. 15-18 November 2016, HFRI (Indian Council of Forestry Research and Education), Shimla, pp.136.
4.	Meena D. and Singh Anil (2017). Growth performance of seven year old half sib progenies of *Tecomella undulata*. In proceedings of national conference on "Tree improvement research in India: Current trends and future prospects". Organised on 2-3 February 2017 at IWST (Indian Council of Forestry Research and Education), Bengaluru, pp.144.
5.	Kant Tarun (2017). GM Technologyas a tool for achieving sustainable development goals through synergies between agriculture and forestry. In: Proceedings of National Conference on "Tree Improvement Research in India: Current Trends and Future Prospects". 2-3 February 2017, IWST, Bengaluru, pp.120.
6.	Arora K., Arya, I.D. and Arya S. (2016). Tissue culture studies of medicinal plant: *Moringa concanensis*. In proceedings of national conference on Forestry in India: Current challenges and future prospects. November 15-18, Himalayan Forest Research Institute Shimla (HP), pp.141.
7.	Ranjana Arya (2016). Medicinal plants: Status, cultivation and nondestructive harvesting practices for Rajasthan. In proceedings of national Conference on "Forestry In India: Current Challenges and Future Prospects". 15-18/ Nov, HFRI, Shimla. pp.70.
8.	Ranjana A., Lohara R.R. and Jayant B.V. (2016). Performance *of Colophospermum mopane* based silvi-pastoral system on arid salt affected soil in western Rajasthan. In: proceedings of National symposium on "Agro-forestry for environmental challenges, sustainable land use, biodiversity conservation and rural livelihood options". 3-5 December 2016, ICAR-CAFRI, Jhansi (U.P.), pp.28.
9.	Ranjana A., Kumar, H., Garg S. and Purohit N. (2017). Harvest wood products from lesser known timber species for Jodhpur Handicraft Industries and their role in Climate change. In: Proceedings on national seminar on "Role of wood in climate change mitigation". 15-16 February, IWST, Bengaluru, pp.11
10.	Rani B., Rathore T.S. and Kant T. (2017). Suitablitiy of *Lepidium sativum* L. (Brassicaceae) for functional genomics analyses of salt tolerance mechanism in halophytes and development of its hydroponic culture system. In: Proceedings of National Conference on "Tree Improvement Research in India: Current Trends and Future Prospects". 2-3 February, IWST, Bengaluru, pp. 125
11.	Saini L.S., Rajput, S. K. Rathore T. R., Tomar U.K. (2016). Non-destructive harvesting practices for oleo-gum resin in *Commiphora wightii* (Arnott) – an important data deficient medicinal plant. In: Proceedings of national conference on "Forestry in India: Current challenges and future prospects". 15-18 November, HFRI (Indian Council of Forestry Research and Education), Shimla, pp. 29.
12.	Sangeeta T. (2016). Constraints in Marketing and trade of identified key NTFPs of study area and their future interventions for enhanced livelihood opportunities in tribal belt of Sirohi District in Rajasthan. In: Proceedings of national seminar on "Forest and tree based land use system for livelihood, nutritional and environmental security". 21-23, December, Navsari Agriculture University, Navsari, Gujarat, pp. 36.

13.	Bhatnagar S., Singh S.**,** Khan A.U., Kumar B., Goran P., Srivastav K.K. Ahmed S.I. and Rathore T.S. (2016). *Prosopis cineraria* (L.) Druce mortality associated with infestation of *Acanthophorous serraticornis* (Oliver) and *Ganoderma lucidum* (Curtis) P. Karst. In: proceedings of conference on "Forestry in India: Current challenges and future prospects". November 15-18, Himalayan Forest Research Institute, Shimla, pp.35
14.	Tomar U.K., Gaur Arti, Singhal H., Saini L.S. (2017). Studies on genetic problems associated with *Commiphora wightii* (Arnott): an important medicinal plant of Thar Desert. In: Proceedings of national conference "Tree improvement research in India: Current trends and future prospects". 2-3 February, IWST (Indian Council of Forestry Research and Education), Bengaluru, pp. 132.
15.	Tomar U.K., Rathore T.R. and Bano S. (2017). Evaluation of growth performance of grafted male and female *Ailanthus excelsa* trees and their economics. In: Proceedings of national conference on "Tree improvement research in India: Current trends and future prospects". 2-3 February, IWST (Indian Council of Forestry Research and Education), Bengaluru, pp. 99.
16.	Bohra, N.K., Mishra, D.K. and Rathore, T.S. (2017). Standardization of nursery technology for Raising quality seedlings of *Tecomella undulate.* In: Proceeding of national conference on "Tree improvement research in India: Current trends and future prospects" at IWST, Bangalore from 2nd to 3rd February, Bangalore, pp.45.
17.	Bohra N.K. and Mishra D.K. (2016). Changing climatic scenario of western Rajasthan-a case study. In: Proceeding of national conference on "Forestry in India: Current challenges and future prospects". 15-18 November, 2016, held at HFRI, Shimla, pp.112.
18.	Bohra N.K. and Mishra D.K. (2016). Conservation of Medicinal wealth of Thar Desert-Need of present era. In: Proceeding of the national conference on "Forestry in India: Current challenges and future prospects". 15-18 November 2016, held at HFRI, Shimla. pp.71.

Sl. No	**Popular articles**
1	मीता शर्मा एवं नुपूर शर्मा (2015) **तितली प्रजाति के रोमांचकारी तथ्य;** आफरी दर्पण, शुष्क वन अनुसंधान संस्थान, जोधपुर **वर्ष–13 अंक–01व 02 पृष्ठ** 9-11.
2	के.के. श्रीवास्तव, नीलम वर्मा, संगीता सिंह एंव मीता शर्मा (2016) औषधीय फसल ""ईसबगोल" को बीमारियों एवं कीटों से कैसे बचाएं" आफरी दर्पण, शुष्क वन अनुसंधान संस्थान, जोधपुर **वर्ष–13 अंक–01व 02पृष्ठ 2–4**
3	के.के. श्रीवास्तव, नीलम वर्मा, संगीता सिंह एवं् मीता शर्मा (2016) "व्यवसायिक फसलः मेहंदी को बीमारियों एवं कीटों से कैसे बचाएं" आफरी दर्पण, शुष्क वन अनुसंधान संस्थान, जोधपुर **वर्ष–13 अंक–01व 02 पृष्ठ 5–8**
4	माला राठौड़ हेमंत कुमार एवं रंजना आर्या, (2017) मरु क्षेत्र की फलदार झाड़ी-गंगेती, पृष्ठ सं. 1-4, आफरी दर्पण, वर्ष-12 अंक-04
5	संगीता त्रिपाठी (2017) सिरोही जिले के अकाष्ठ वनोपजों का आदिवासी अर्थव्यवस्था में योगदान, पृष्ठ सं. 5.7, आफरी दर्पण, वर्ष-12 अंक-04
6	नीलम वर्मा एवं के. के. श्रीवास्तव (2017) पौधों की वृद्वि के लिए उर्वरकों की आवश्यकता क्यों?, सशक्त भारत के निर्माण मे' अनुसंधान एव् विकास**,** राजभाषा वैज्ञानिक संगोष्ठी, रक्षा प्रयोगशाला, जोधपुर 06–07 फरवरी, 2017 पृष्ठ 86–87**।**

Books and booklets, brouchers/pamphlets published by the institute

Sl. No	Books
1	Singh G., Singh B., Tomar U.K. and Sharma S. (2016). A Mannual for Dryland Afforestation and Management, Scientific Publisher, Jodhpur Rajasthan India. 605p.
2	सिंह, जी., सिंह, बी., तोमर, यू. के. और शर्मा, एस. (2016)। शुष्क क्षेत्र वनीकरण एवं प्रबंधन: तकनीकी एवं कार्य विधियाँ, साईंटिफ़िक पब्लिशर, जोधपुर, राजस्थान, इंडिया, 642p
3	Singh G. (2017). Sacred Groves of Rajasthan: Threats and Management Strategies. Scientific Publisher, Jodhpur Rajasthan India. 294p
4	सिंह, जी. (2017). राजस्थान के पवित्र उपवन: संभावित खतरे तथा प्रबन्धन नीतियाँए। साईंटिफ़िक पब्लिशर, जोधपुर, राजस्थान, इंडिया। 349p.

Eight types of published Pamphlets in 2016-17 under VVK

1. मॉडल नर्सरी की स्थापना और प्रबन्धन
2. जैविक खेती उपयोगिता तथा तैयार करने की विधियॉ
3. अच्छे बीजों का महत्व, चयन की विधि व एकत्रीकरण
4. नर्सरी में पौध प्रंवर्धन
5. कृषि वानिकी के विविध लाभ
6. अवक्रमित पहाड़ियों का पुनर्वासन एवं उस क्षेत्र में रहने वाले लोगों की आजीविका में वर्षा जल संग्रहण की भूमिका
7. अवक्रमित पहाड़ियों के पुनर्वासन के दौरान कार्बन संचयन
8. नर्सरी में होने वाले प्रमुख रोग एवं उनके उपचार

Sixteen types of published leaflets in 2016-17 under Extension

1. आयुर्वेदिक औषधि के लिए वरदान: अश्वगंधा '' विदानिया सोम्नीफेरा डुनाल ''
2. अरेबिक गोंद का एक मात्र स्त्रोत कुमट ''*अकेशिया सेनेगल* विल्ड''
3. कई बीमारियों की एक दवा: ग्वारपाठा (घृतकुमारी) ''*एलोय वेरा* लिन''
4. मारवाड का सागवान: रोहिड़ा ''*टिकोमेला अन्डूलेटा*''
5. शक्तिवर्धक औषधीय गुणवाला: शतावरी ''ए*स्पेरेगस रेसीमोसस* विल्ड''
6. मुलैठी ''*ग्लाइसीराइजा ग्लैबरा* लिन''
7. आर्थिक उन्नति का आधार: सोनामुखी ''*केसिया एंगस्टीफोलिया* बहल''
8. सफेद मूसली ''क्लोरोफाइटम बोरिविलिएनम सांतापउ व फरनानडिस''
9. कैर ''कैपेरिस डेसिडुआ इडज्यु''
10. नीम एक: लाभ अनेक
11. कई मर्ज़ की एक दवा: गुग्गुल '' कोम्मीफोरा विगटाई अर्न.''
12. प्रोसोपिस सिनेरेरिया लिन
13. गिलोय ''*टीनोस्पोरा कार्डीफोलिया* (विल्ड) मियर्स''
14. कालमेघ ''*एन्ड्रोग्रेफिस पेनिकुलेटा* वाल नीस .''
15. कंकेड़ा (*मोमोर्डिका डायोइका*)
16. आयुर्वेदिक औषधि के लिए वरदान: अश्वगंधा ''*विदानिया सोम्नीफेरा* डुनाल

4.4 Seminar/Symposia/Workshop organized:

S.No.	No. of Seminars/Symposia Workshops meeting organized	Days
1	Training cum workshop on **"Wild Animal Rescue and Rahabilitation'** organized jointly by AFRI, Jodhpur and SFD, Rajasthan	2 Days 24-26th March 2017

4.5 Consultancies: NIL

4.6 Technical Services:

4.7 Activities of Rajbhasha

2016-2017 के दौरान संस्थान का हिन्दी पत्राचार 80.62 प्रतिशत रहा। संस्थान में प्रति तिमाही हिन्दी के प्रयोग को बढ़ाने तथा राजभाषा नियमों के अनुपालन की समीक्षा हेतु विभागीय राजभाषा कार्यान्वयन समिति की तिमाही बैठकों का आयोजन किया गया। दिनांक 14 से 28 सितम्बर 2016 के दौरान 'हिन्दी पखवाड़ा' आयोजित किया गया। जिसका आरंभ 'हिन्दी दिवस' के दिन हिन्दी स्वरचित 'कविता पाठ' से हुआ। हिन्दी पखवाड़ा में हिन्दी टंकण, हिन्दी निबंध, सामान्य प्रशासनिक ज्ञान प्रतियोगिता, व हिन्दी अनुवाद प्रतियोगिता का आयोजन भी किया गया। हिन्दी पखवाड़ा के दौरान दिनांक 26/09/2016 को हिन्दी में वैज्ञानिक व्याख्यान सह कार्यशाला का आयोजन भी किया गया। (चित्र 62).

संस्थान में दिनांक 10 मार्च, 2017 को शुष्क वन अनुसंधान संस्थान, जोधपुर एवं विज्ञान परिषद प्रयाग जोधपुर शाखा के संयुक्त तत्वावधान में *'मरुस्थल में विज्ञान के बढ़ते आयाम'* विषय पर हिन्दी में विज्ञान संगोष्ठी का आयोजन किया गया, जिसमें आफरी, काजरी, भारतीय प्राणि सर्वेक्षण, जोधपुर आदि के वैज्ञानिकों की सहभागिता रही। (चित्र 63).

Fig. 62. समापन समारोह में अपने विचार व्यक्त करती मुख्य अतिथि डॉ. (श्रीमती) कैलाश कौशल।

Fig. 63. विज्ञान संगोष्ठी में संस्थान निदेशक श्री एन.के. वासु संबोधित करते हुए।

4.8 Awards and Honours: Nil

4.9 Special Actities (such as Van Mahotsava, Forestry Day and Other occasion)

(i) INTERNATIONAL BIODIVERSITY DAY was celebrated on 22nd May, 2016 along with the officials and employees of Forest Department, Jodhpur and environment group representatives. On this occasion, Director AFRI, Shri N.K.Vasu I.F.S. emphasized the need of mainstreaming the Biodiversity. Shri Vasu addressed the importance of interspecies dependence and urged the need for the conservation of Biodiversity. Shri V.S Bohra, Chief Conservator of Forest, Jodhpur graced the occasion as Chief Guest. Shri Uma Ram Chaudhary informed about the scope, importance and the outline of the celebration. Shri Guru Prasad Vyas, retired IFS officer and Dr. A.K. Mishra, Head, Livestock and Management division, CAZRI, Jodhpur were also present (Fig. 64).

Fig. 64. Celebration of International Biodiversity Day.

Dr. G. Singh, Scientist - G delivered a multimedia presentation on the amazing biodiversity flourishing in the harsh environment of the Thar Desert. Dr. Tarun Kant, Scientist-F showed a video on biodiversity and the regeneration of the forest. Dr. N. K Bohra, Scientist-B gave a multimedia presentation on the history and themes of International Biodiversity Days celebrated till date covering huge biodiversity of the desert. Ms. Meeta Singh Tomar, Technical Assistant gave a multimedia presentation on biodiversity and impending threats in the hotspots all around the world. Mr. Pooran Singh retired driver of State Forest Department, Rajasthan narrated a poem in context of present and past status of the environment in Rajasthani language.

(ii) World Environment Day was celebrated at Arid Forest Research Institute (AFRI), Jodhpur on 5th June, 2016. Dr. Ashwani Kumar (IFS) the then D.G. ICFRE graced the occasion as Chief Guest. He talked about historical background and various international meetings and policy issues. Shri N.K. Vasu, Director, AFRI addressed the issue of the increasing environment degradation and the role and responsibility of every citizen toward sustainable use of existing

resources. Head, AF & E division, Shri U. R. Chuadhary presented the outline of the programme. Sh.G. S. Bharadwaj, CCF Jodhpur was special guest at the programme. He gave a presentation on Illegal Wild Life Trade. Ceremonial plantation was also done by the Chief Guest the then D.G. Dr.Ashwani Kumar for increasing the awareness about clean environment (Fig. 65).

Fig. 65. World Environment Day Programme 5th June 2016.

(iii) World Day to Combat Desertification (WDCD) 2016 –Under the guidance of the Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India a series of events, involving school children, members of village forest protection and management committees, practitioners, various research organizations, political leaders and private sector were organized at Arid Forest Research Institute (AFRI), Jodhpur, on the occasion of WDCD on 17th June 2016. Honorable Member of Parliament, Jodhpur, Shri Gajendra Singh Shekhawat presided as the chief guest of the function. Ceremonial plantation of saplings was done at the AFRI campus by the Chief Guest and other dignitaries. Other distinguished guests were Dr. Y. V.N. Krishnamurthy, Scientific Secretary, Department of Space, Additional Secretary, MoEF&CC, Sh. Rajani Ranjan Rashmi, Joint Secretary, Ministry Environment, Forest and Climate Change, Sh. Ravi Shankar Prasad and Director, Green India Mission, MoEF&CC, Ms. Bharati. There was a prize distribution ceremony for the winners of drawing and painting competition. Chief Guest of the function distributed certificates and trophies to the winners (Fig.

66). A large number of paintings made by the winners and other participants were displayed at the programme venue.

Fig. 66. Prize distribution to winners.

One day training was also organized on the occasion of Combating Desertification Day with association of SFD Rajasthan on 17 June 2016. A total of 184 members of different VFPMCs and 75 foresters attended this training programme. Classroom lecturers and field visits were also included in this programme. Various aspects of seedling raising at Hi-Tech nursery were explained to the participants. Participants also visited Extension & Interpretation Centre & gained knowledge on various interventions of AFRI. Several stalls were displayed by various Self Help Groups at training venue to showcase their products. In addition, a workshop on **Desertification and Land Degradation: Assessment and Rehabilitation Measures** was also organized as the technical part of the daylong celebrations of the World Day to Combat Desertification. The workshop was attended by scientists from Space Applications Center (SAC) Ahmedabad; RRSC-W, Jodhpur, CAZRI and AFRI as well as Director, Green India Mission, Mrs. Bharati. The workshop was chaired by Dr. L.N. Harsh, Former VC, Agricultural University, Jodhpur and Co-Chaired by Dr. D. K. Das, Associate Director, SAC, Ahmedabad.

Two books were also released by the honorable guests on dais on this occasion. One atlas titled **Desertification and Land Degradation Atlas of India** by Space Application Center, Ahmedabad; and **Cacti in Desert botanical Garden** by Central Arid Zone Research Institute (CAZRI), Jodhpur (Fig. 67 & 68).

Fig. 67. Inauguration of the book *Cacti* in Desert botanical garden.

Fig. 68. Inauguration of Desertification and Land Degradation Atlas of India.

(iv) Van Mahotsava was celebrated at Sivanchi Gate Goshala Parisar, Jodhpur under "Hariyalo Rajasthan Abhiyan" on 24th July 2016. Shri Gajendra Singh Shekhawat, Honourable Member of Parliament, on this occasion said that, "Plantation is an auspicious work and it should be undertaken in the form of a movement". In this plantation programme, MLA Smt. Suryakanta Vyas and Mahapaur (Mayor) Shri Ghanshyam Ojha were also present. Divisional Commisioner Shri Ratan Lahoti, Director AFRI, Shri N.K Vasu (IFS), Chief Conservator of Forest Shri G.S Bharadwaj, Group Cordinator Research, Dr. T. S Rathore, D.C.F, Shri Mahendra Singh Rathore, Director, Mehrangarh Trust, Shri Karni Singh Jasol, and Environmentalist Shri Prasannpuri Goswami were also present on this occasion. Senior scientist, Dr. G.Singh and Dr. K.K. Shrivastava, Dr. Mala Rathore, Shri Uma Ram Chaudhary, Shri Bega Ram Jaat, Scientist B- Dr. Bilas Singh and Smt. Sangeeta Tripathi, PS to Director Shri K.S Parmar, RO Shri Saraj lal Meena, RA –I Shri Gangaram Chaudhary and other staff members represented AFRI in this celebration.

Office bearers of Gaushala Sanchalan Samiti, President, Shri Surendra Singhvi, Secretary, Shri Mohanlal Shah, Dr. Prabha Bhandari and Shri Sanpatraj Bhandari also took part in the plantation programme. On this occasion plants of Neem, Jamun etc were planted by the guests and Samiti members (Fig. 69).

Fig. 69. Van Mahotsava Celebration. Plantion by Shri Gajendra Singh Shekhawat, Honourable Member of Parliament (left) and by Sh. N.K. Vasu, Director, AFRI (right).

(vi) Tree Growers Mela was organized on 21.03.17 to bring together the people involved in tree growing and tree product marketing, processing and value addition. A total of 208 people participated in the mela. On this ocassion stalls were set up by various SHGs, Botanical Survey of India, CAZRI and Ayurveda University, KVK (Danta, Barmer), NGO's etc. A workshop was also organized on this ocassion for interaction of tree growers with the scientist of the institute to facilate mutual knowledge sharing. Director CAZRI, Dr. O.P Yadav was chief guest on this occasion (Fig. 70).

Fig. 70. Tree Growers Mela.

(v) World Water Day-2017 was celebrated on 22nd March 2017. The theme for the year was "WHY WASTE WATER". On this occasion, Director AFRI, Shri N.K. Vasu stressed on the need for proper management of the existing water sources and proper use of water and its conservation. Group Coordiantor Research Dr. T.S Rathore stressed upon the judicious and scientific use of the water. Dr. G. Singh, Scientist – G gave a multimedia presentation related to waste water. Shri Uma Ram Choudhary, Head, AF & E told about the importance of the day. Shri N. Bala, Scientist –F, Dr. N. K. Bohra, Scientist-B, and Shri Anil Sharma, RA- II also expressed their views on this occasion. Dr. Bilas Singh, Scientist – B presented vote of thanks and pogramme was conducted by Ms Bhawana Sharma, Scientist- D, AF & E division.

Vigilance Awareness Week

As per the Government of India mandate, 'Vigilance Awareness Week' was celebrated at AFRI from 31-10-2016 to 5-11-2016. The programme started with the oath-taking ceremony for Vigilance awareness by the Director AFRI, Sh N.K. Vasu. During this week, essay & slogan writing and poster making competition on the different aspects of the theme "Public participation in promoting Integrity and Eradicating Corruption' were also organized. In the closing ceremony a lecture on "भ्रष्टाचार उनमूलन में ईमानदारी एवं जनसहभागिता की भूमिका" was held. The chief guest of the closing ceremony was Dr. S.R. Vadera, Director, DRDO, Jodhpur, who shared his experience of preventive vigilance enlightened the audience about the legal matters in vigilance. Director AFRI, Sh N.K. Vasu also addressed the staff and officers of AFRI and suggested the AFRI staff to work with whole heartedness and diligence. Memento and certificates were also distributed to the winners of different competitions organized in the week by the Chief Guest. Vote of thanks was given by Dr G. Singh, Vigilance Officer, AFRI, who also provided informations about different activities, transparency in working and good governance (Fig. 71).

Fig 71 (a-d). Celebration of Vigilance Awareness Week.

Other activities

- Four issues (one six monthly and three quarterly issue) of Hindi magzine AFRI DARPAN were published (400 copies of each issue).
- Leaflets on sixteen important species of arid region were prepared and published.
- Eight types of pamphlet were printed for distribution among the stakeholders.
- Display board and banners were also prepared for extension activities of AFRI.

5. Administration and Information Technology

5.1. Information Technology

The existing IT infrastructure was maintained properly with the help of annual maintenance contract of network. The leased line provided by the National Knowledge Network (NKN) was maintained and 24 x 7 internet connectivity was provided to the users. Saveral video conferencing sessions were organized during the year. The Hindi and English website of the institute was updated regularly throughout the year. The reports of the important events held at the institute were uploaded on the institutes as well as on the ICFRE websites. The PIMS and Payroll modules of IFRIS were run successfully throughout the year. The annual report, RPC presentations and other important documents of the institute were prepared. The E-Procurrement was implemented successfully at the institute and twleve tenders including six labourer contracts, two equipments including a foreign one, annual rate contract of chemicals and glasswares and two tenders related to publishing of books were finalized through it. Four new computers with UPS and Tally accounting software were procured for computerizing the accounting system. Other routine tasks related to the Information Technology were performed during the year.

5.2 Sevottam: Activities relating to the Citizens/Clients Charter:

5.2.1 Action taken to formulate the Charter for the Department and its subordinate formation

The charter has been prepared based on the seven steps mentioned in Sevottam. Considering the ICFRE's mandated mission "To generate, preserve, disseminate advance knowledge, technologies and solutions for addressing issues related to forests and promote linkages arising out of interactions between people, forests and environment on a sustained basis through research, education and extension", AFRI is enduring its forestry research for conservation of biodiversity and enhancement of bio-productivity in Rajasthan, Gujarat and Dadra & Nagar Haveli with special emphasis on arid and semi-arid regions. Keeping the National Forestry Research Plan (NFRP) in view, AFRI has identified its thrust areas based on the inputs and active participation of different stake holders. The institute is implementing its research endeavors after duly recognizing the users need. Main research focus of the institute includes:

1. Soil, water and nutrient management,
2. Development of technologies for afforestation of stress sites,
3. Seed handling, nursery, plantation techniques and management,
4. Planting stock improvement and biotechnology,
5. Biofertilizers and biopesticides,
6. Phytochemistry; non-wood forest products,
7. Biodiversity conservation and climate change,
8. Agroforestry and JFM,
9. Forestry education & extension.

Procedures have been formulated for identifying the research problems of the arid region; developing the projects based on the problems and dissemination of the research results and technologies to the users. In order to identify the research problem, stakeholders meeting are organized in the two states viz. Rajasthan and Gujarat falling under the jurisdiction area of the institute. Officials from SFD's, progressive farmers, scientists and NGO's participate in the stakeholders meeting and express the problems on which the research is required.

Based on the research problems given by the stakeholders, in house discussions are made amongst the scientists of the institute and the research projects are formulated by the scientists after the thorough review of scientific literature.

The projects are sent to the external experts for evaluation and their suggestions. After incorporating the suggestions/modifications, the projects are presented before the Research Advisory Group (RAG) meeting. After including suggestion of RAG members, if any, revised projects are prepared and progress of the ongoing projects are presented in the Research Policy Committee (RPC) meeting for approval. After the approval of projects, the funds are allotted for the projects and the projects are executed by the scientists.

The technologies developed through the projects are extended/ demonstrated to the end users with the help of demonstration trails, extension trainings, Van Vigyan Kendras, Demovillege, printed material, radio talk, workshops, conferences and the publications uploaded to the website of the institute.

5.2.2 Action taken to implement the Charter

To fulfill the charter, research projects have been prepared addressing the research mandate of the institute and submitted for funding to various donor agencies for implementing the Charter. Eleven new projects were approved for initiation in the next financial year by RPC held in January 2017. Several extension trainings were held during the year for dissemination of research results of the various projects executed in the institute. The research results of the projects, the technologies developed by the institute and the events held at the institute were continuously updated on the website of the institute.

In addition to these, environmental awareness programs were organized by the institute in the form of World Environment Day, Biodiversity Day, World Day for Combating Desertification and Van Mohotsava. The details of these have been mentioned in this report.

5.2.3 Details of Training Programmes, Workshops, etc. held for proper implementation of Charter: Mentioned above under point No. 3.2 & 4.9.

5.2.4 Details of publicity efforts made and awareness campaigns organized on Charter for the Citizen/Clients: Various events were organized, manuscript published and talks delivered by AFRI officials during different events, conferences, farmer fairs etc helped in publicity efforts made and awareness campaigns organized on Charter for the Citizen/Clients. The details are given under point No. 6.4 & 7.3.2.

5.2.5 Details if internal and external evaluation of implementation of Charter in the Organization and assessment of the level of satisfaction among Citizen/Clients:

All the new projects and progress of the ongoing research projects were presented to the internal and external experts of the RPC, who gave their comments on the quality of the new projects and the progress made in the ongoing projects. The experts prioritized the new projects and expressed their satisfaction on the progress of the ongoing projects.

5.3 Welfare measures for the SC/ST/Backward /Minority communities

To promote the general interest of SC/ST/OBC employees and to work for their collective betterment, development and upliftment, AFRI SC/ST/OBC Employees Welfare Association was formed. As per the DOPT's guidelines for various social groups, Liaison Officers had been nominated as below:

1. Shri N. Bala, Scientist-F — Chief Liasson Offce (SC/ST/OBC)
2. Shri Shiv Lal Chouhan, RO-I — Liaison Officer, SC
3. Smt. Desha Meena, Scientist-B — Liaison Officer ST
4. Shri Anil Singh Chouhan, RA-II — Liaison Officer, OBC
5. Under Secretary — Member

For promotion/recruitment process, roaster has been maintained in AFRI, Jodhpur as per guidelines of the GOI. The roaster usually checked by the liaison officer at the time of considering promotion/recruitment for SC/ST/OBC. The roaster has been signed by the concerned liaison officers.

To spread the message of equality and harmony among the various sections of the society the SC/ST/OBC Employees Welfare Association of A.F.R.I made their efforts to celebrate Dr. Bhim Rao Ambedkar Jayanti on 14th April 2017 to commemorate the birthday of Babasaheb Ambedkar. Shri N.K. Vasu, IFS, Director, A.F.R.I presided over the program to pay homage to Baba Saheb Ambedkar on his 126th Birth anniversary (Fig. 72). Scientists/officers/staff of A.F.R.I assembled on this occasion.

Fig. 72.(a to f) Celebration of 125th birth anniversary of Baba Saheb Ambedkar at AFRI, Jodhpur.

6.Annexure

1. RTI

Names and addresses of public information officers and appellate authorities under the right to information act 2005 in ICFRE and its institutes

Headquarters / Institutes	Appellate Authorities	Public Information Officers	Subject matter(s) allocated
Arid Forest Research Institute	N.K. Vasu, Director, AFRI 0291-2722764 Email: dir_afri@icfre.org Phone : 0291-2742549 FAX : 0291-2722764	Shri Ramesh Kumar Malpani, Dy.CF Email: rameshkumarmalpani@icfre.org Phone : 0291-2729163 FAX : 0291-2722764	All matters related to AFRI, Jodhpur

RTI Annual Return Information System
Quarterly Return Form

Public authority : Ministry of Environment & Forests

Quarter – IV (April, 2016 to June, 2016)

Year: 2016-17

Mode Insert : Status : New Return

		Progress during the month				
	Opening Balance as on beginning of qtr.-III	No. of applications received as transfer from other PA's U/S 6 (3)	Received during the Quarter (including cases transferred to other Public Authority)	No. of cases transferred to other PA's U/S 6 (3)	Decision where requests/ appeals rejected.	Decision where requests/ appeals accepted
Requests	Nil	01	02	Nil	Nil	03
First Appeals	Nil	Nil	Nil	Nil	Nil	Nil

No. of CAPIO's designated	No. of CPIOs designated	No. of AA's designated
01	01	01

Block II (Details about fees collected, Penalty imposed and disciplinary action taken)			
Registration Fee collected (in Rs.) U/s 7(1)	Additional fees collected (in Rs.) U/s 7(3)	Penalties Amount recovered (in Rs.) as directed by CIC U/s 20(1)	No. of cases where disciplinary action taken against any officer U/s 20(2)
Nil	Nil	Nil	Nil

Block III (Details of various provisions & while rejecting the requested information) - NA													
No. of times various provisions were invoked while rejecting requests													
Relevant Section of RTI Act 2005													
Section 8(1) -										Sections			
a	b	c	d	e	f	g	h	i	j	9	11	24	other

Block IV (Details regarding compliance of direction/recommendation of the commission)- NA			
S. No.	Reference no. of cases wherein commission made specific recommendation as per sec.25(5)	Where action is initiated to comply with recommendation of Commission .	Details thereof (Max. 250 chars.)
		-Select-	
		-Select-	
		-Select-	
		-Select-	
If the public authority made any changes in regard to its rules/regulations/procedure as a result of requested information by the citizens, please provide the summarized details of the changes (Max. 500 chars.)			

Block V (Details regarding compliance of direction/recommendation of the commission) - NA		
Last Date of Uploading the Pro-active Disclosures on the website of PA	Name of the person who is entering/updating data	Designation of the person who is entering/updating data
General information uploaded	Smt. Kusum Parihar	Research Assistant –II C/o IT-Cell of the Institute

04/7/16

(Tarun Kant)

Public Information Officer,

AFRI, Jodhpur.

RTI Annual Return Information System
Quarterly Return Form

ublic authority : Ministry of Environment & Forests

Quarter – II (July, 2016 to Sept., 2016)

Year: 2016-17

Mode Insert : Status : New Return

		Progress during the month				
	Opening Balance as on beginning of qtr.-III	No. of applications received as transfer from other PA's U/S 6 (3)	Received during the Quarter (including cases transferred to other Public Authority)	No. of cases transferred to other PA's U/S 6 (3)	Decision where requests/ appeals rejected.	Decision where requests/ appeals accepted
Requests	Nil	Nil	Nil	Nil	Nil	Nil
First Appeals	Nil	Nil	Nil	Nil	Nil	Nil

No. of CAPIO's designated	No. of CPIOs designated	No. of AA's designated
01	01	01

Block II (Details about fees collected, Penalty imposed and disciplinary action taken)

Registration Fee collected (in Rs.) U/s 7(1)	Additional fees collected (in Rs.) U/s 7(3)	Penalties Amount recovered (in Rs.) as directed by CIC U/s 20(1)	No. of cases where disciplinary action taken against any officer U/s 20(2)
Nil	Nil	Nil	Nil

Block III (Details of various provisions & while rejecting the requested information) - NA

No. of times various provisions were invoked while rejecting requests

Relevant Section of RTI Act 2005

Section 8(1) -										Sections			
a	b	c	d	e	f	g	h	i	j	9	11	24	other

Block IV (Details regarding compliance of direction/recommendation of the commission)- NA

S. No.	Reference no. of cases wherein commission made specific recommendation as per sec.25(5)	Where action is initiated to comply with recommendation of Commission .	Details thereof (Max. 250 chars.)
		-Select-	
		-Select-	
		-Select-	
		-Select-	

If the public authority made any changes in regard to its rules/regulations/procedure as a result of requested information by the citizens, please provide the summarized details of the changes (Max. 500 chars.)

Block V (Details regarding compliance of direction/recommendation of the commission) - NA

Last Date of Uploading the Pro-active Disclosures on the website of PA	Name of the person who is entering/updating data	Designation of the person who is entering/updating data
General information uploaded	Smt. Kusum Parihar	Research Assistant –II C/o IT-Cell of the Institute

(Desha Deena)
Public Information Officer,
AFRI, Jodhpur.

RTI Annual Return Information System
Quarterly Return Form

Public authority : Ministry of Environment & Forests

Quarter – IV (Oct., 2016 to Dec., 2016)

Year: 2016-17

Mode Insert : Status : New Return

		Progress during the month				
	Opening Balance as on beginning of qtr.-III	No. of applications received as transfer from other PA's U/S 6 (3)	Received during the Quarter (including cases transferred to other Public Authority)	No. of cases transferred to other PA's U/S 6 (3)	Decision where requests/ appeals rejected.	Decision where requests/ appeals accepted
Requests	Nil	08	08	Nil	Nil	08
First Appeals	Nil	Nil	Nil	Nil	Nil	Nil

No. of CAPIO's designated	No. of CPIOs designated	No. of AA's designated
01	01	01

Block II (Details about fees collected, Penalty imposed and disciplinary action taken)			
Registration Fee collected (in Rs.) U/s 7(1)	Additional fees collected (in Rs.) U/s 7(3)	Penalties Amount recovered (in Rs.) as directed by CIC U/s 20(1)	No. of cases where disciplinary action taken against any officer U/s 20(2)
Nil	Nil	Nil	Nil

Block III (Details of various provisions & while rejecting the requested information) - NA													
No. of times various provisions were invoked while rejecting requests													
Relevant Section of RTI Act 2005													
Section 8(1) -										Sections			
a	b	c	d	e	f	g	h	i	j	9	11	24	other

Block IV (Details regarding compliance of direction/recommendation of the commission)- NA			
S. No.	Reference no. of cases wherein commission made specific recommendation as per sec.25(5)	Where action is initiated to comply with recommendation of Commission .	Details thereof (Max. 250 chars.)
		-Select-	
		-Select-	
		-Select-	
		-Select-	
If the public authority made any changes in regard to its rules/regulations/procedure as a result of requested information by the citizens, please provide the summarized details of the changes (Max. 500 chars.)			

Block V (Details regarding compliance of direction/recommendation of the commission) - NA		
Last Date of Uploading the Pro-active Disclosures on the website of PA	Name of the person who is entering/updating data	Designation of the person who is entering/updating data
General information uploaded	Smt. Kusum Parihar	Research Assistant –II C/o IT-Cell of the Institute

11/01/17

(Tarun Kant)
Public Information Officer,
AFRI, Jodhpur.

RTI Annual Return Information System
Quarterly Return Form

Public authority : Ministry of Environment & Forests
Quarter – I (January, 2017 to March, 2017)
Year: 2016-17

Mode Insert : Status : New Return

		Progress during the month				
	Opening Balance as on beginning of qtr.-I	No. of applications received as transfer from other PA's U/S 6 (3)	Received during the Quarter (including cases transferred to other Public Authority)	No. of cases transferred to other PA's U/S 6 (3)	Decision where requests/ appeals rejected .	Decision where requests/ appeals accepted
Requests	01	04	06 (01 + 05)	Nil	Nil	06
First Appeals	Nil	Nil	Nil	Nil	Nil	Nil

No. of CAPIO's designated	No. of CPIOs designated	No. of AA's designated
01	01	01

Block II (Details about fees collected, Penalty imposed and disciplinary action taken)			
Registration Fee collected (in Rs.) U/s 7(1)	Additional fees collected (in Rs.) U/s 7(3)	Penalties Amount recovered (in Rs.) as directed by CIC U/s 20(1)	No. of cases where disciplinary action taken against any officer U/s 20(2)
10/-	6/-	Nil	Nil

Block III (Details of various provisions & while rejecting the requested information) - NA													
No. of times various provisions were invoked while rejecting requests													
Relevant Section of RTI Act 2005													
Section 8(1) -										Sections			
a	b	c	d	e	f	g	h	i	j	9	11	24	other

Block IV (Details regarding compliance of direction/recommendation of the commission)- NA			
S. No.	Reference no. of cases wherein commission made specific recommendation as per sec.25(5)	Where action is initiated to comply with recommendation of Commission .	Details thereof (Max. 250 chars.)
		-Select-	
		-Select-	
		-Select-	
		-Select-	
If the public authority made any changes in regard to its rules/regulations/procedure as a result of requested information by the citizens, please provide the summarized details of the changes (Max. 500 chars.)			

Block V (Details regarding compliance of direction/recommendation of the commission) - NA		
Last Date of Uploading the Pro-active Disclosures on the website of PA	Name of the person who is entering/updating data	Designation of the person who is entering/updating data
General information uploaded	Smt. Kusum Parihar	Research Assistant –I C/o IT-Cell of the Institute

(Tarun Kant)
Public Information Officer,
AFRI. Jodhpur.

2. Email and Postal Address

Arid Forest Research Institute,
P.O. Krishi Upaz Mandi,
New Pali Road, Jodhpur, 342005
Email: dir_afri@icfre.org
Phone: 0291-2742549
FAX: 0291-2722764

3. Intellectual Property

3.1 Patent Property - NIL

3.2 Others – NIL

List of Abbreviations

AF&ED	Agroforestry and Extension Division
AFRI	Arid Forest Research Institute
AM	Arbascular Mycorrhiza
ARS	Agriculture Research Station
AICP	All India Co-ordinated Project
CAZRI	Central Arid Zone Research Institute
CETP	Common Effluent Treatment Plant
CIT	Chartered Institute of Technology
CSOs	Clonal Seed Orchards
CTAB	Cetyl Tri-methyl Ammonium Bromide
DEMO	Demonstration
DFO(WL)	Divisional Forest Officer (Wild Life)
DRDO	Defence Research Development Organization
DST	Department of Science & Technology
DNH	Dadra & Nagar Haveli
DNA	Deoxy Ribo Nucliec acid
DVs	Demo Village
EC	Electrical Conductivity
ENVIS	Environmental Information System
ET	Evapo- Transpiration
FED	Forest Ecology Division
FGTB	Forest Genetics and Tree Breeding
FPD	Forest Protection Division
FSI	Forest Survey of India
FRI	Forest Research Institute
FYM	Farmyard Manure
GM	Genetically Modified
GEF	Global Environmental Facilities
GIS	Geographic Information System
GoI	Govt. of India
GPS	Global positioning system
HoD	Head of Division
HFRI	Himalayan Forest Research Institute
ICFRE	Indian Council of Forestry Research & Education

ICBN	International Conference on Bio-technology & Nano-technology
IBA	Indole butyric Acid
ICAR	Indian Council of Agriculture Research
ICRAF	International Council for Resrach on Agroforestry
IES	Indian Engineers Service
IFFCO	Indian Farmers Fertiliser Cooperative Limited
IFRIS	Indian Forestry Research Information System
IFS	Indian Forest Service
IT	Information Technology
ISSR-PCR	Inter Simple Sequence Repeat-Polymerase Chain Reaction
KVK	Krishi Vigyan Kendra
LCM	Leaf Compost Manure
Mg	Mega Gram (10^6g)
mM	Milli mole
MoU	Memorandum of Understanding
MoEF&CC	Ministry of Environment, Forest & Climate Change
NAA	Naphthalene Acetic Acid
NFRP	National Forestry Research Plan
NKN	National Knowledge Network
NSFDDE	National Scheduled Castes Finance and Development Corporation
NTFP	Non-Timber Forest Product
NWFP	Non-Wood Forest Product
OBC	Other Backward Class
PIMS	Personnel Information Management System
PSB	Phophorus Solubilizing Bacteria
PAR	Photosynthetic Active Radiation
RAG	Research Advisory Group
RFD	Rajasthan Forest Department
RIMS	Research Management Information System
RPC	Research Priority Committee
RSFD	Rajasthan State Forest Department
RSR	Root to Shoot Ratio
RTI	Right To Information
SAAER	The Society for Agriculture and Arid Ecology Research
SC	Scheduled Caste
SFD	State Forest Department

SFS	State Forest Service
SLEM	Sustainable Land And Ecosystem Management
SPAs	Seed Production Areas
SPSS	Statistical Package for Social Science
SSP	Single Super Phosphate
SSOs	Seedling Seed Orchards
ST	Scheduled Tribe
SWC	Soil Water Content
TREE	Training, Research, Extension & Education
TDS	Total Dissolved Solids
TERI	The Energy and Resources Institute
UT	Union Territory
UNCCD	United Nations Convention to Combat Desertification
UV	Ultra Violet
VAM	Vesicular Arbuscular Mycorrhiza
VMG	Vegetative Multiplication Garden
VVK	Van Vigyan Kendra
VFPMC	Village Forest Protection & Management Committee
ZSI	Zoological Survey of India

ARID FOREST RESEARCH INSTITUTE

ANNUAL REPORT

2016-17

(Indian Council of Forestry Research & Education)

P.O. Krishi Upaj Mandi, Basni, New Pali Road, Jodhpur

WEB:afri.icfre.org MAIL: dir_afri@icfre.org & groupco_afri@icfre.org