ICFRE

Annual Report

2017 — 2018

Arid Forest Research Institute

Jodhpur, Rajasthan

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AFRI Annual Report 2017-18

Overview

A total thirty five projects were executed at AFRI, Jodhpur during 2017-18 including five new projects initiated in the year 2017-18. Out of this 13 projects were completed. Significant finding of the projects includes: documentation of various innovative strategies of climate change mitigation and adaptation the people of western Rajasthan followed; *Acacia nilotica*, *Prosopis juliflora* and *Azadrachta indica* as best performing species against treated effluent irrigation and assessment of biological diversity and sociological association of wildlife and role of insect pollinators in pollination and fruit setting in *P.cineraria*, *Capparis decidua* and *A.senegal.* Enhancing kair fruit productivity through fertilization to increase rural livlihood. Nursery technology included quality seedlings of *Anogeissus pendula*, use *Azotobacter* and *Piriformospora* species as biofertilizer and superior clones of *Casuarina equisetifolia*, *C.junghuhniana* and their hybrids. Survey and assessment of Sandalwood and traditional/improved agroforestry system in Rajasthan, reclamation of saline-alkaline land by planting suitable species and soil amendments, and impact assessment of VAM and consortium of *Azotobacter, Rhizobium* and *Piriformospora* species have been observed enhancing seedling quality and forest (land) productivity. Severity of gall formation in Khejri, 61 pests and predators and diseases like leaf blight, root rots etc., caused by species of *Fusarium*, *Rhizoctonia*, *Alternaria* and *Colletotrichum* have been assessed in Rajasthan. Use of botanical extract, chemicals observed successful in controlling snails and slugs affecting Neem seedling. Genetic transformation on *A. indica,* germplasm enrichment for Neem and Guggul, *in vitro* shoots multiplication of *Schizostachyum dullooa* and *Leptadenia reticulata,* identification of morphological juvenility markers in Neem and Ardu are covered in ten different projects. Role of Neem products in socio-economic upliftments, promotion of value added wood products of *A.indica* and *A.senegal* and fruit products of *Manilkara hexandra* and *Momordica dioica* and preservation of *P. cineraria* and *C.decidua* fruit through improved practices are other important are other studies. In additions, research findings are esxtended by celebrating days related to Biodiversity, Environment, Desertification, Ozone, Forests, water etc, and Van Mahotsava Hindi Saptah and Vigilance Awareness Week along with trainings and workshop.

Summary of the projects

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2017-18
Plan	03	14	03
Externally Aided	10	03	02
Total	13	17	05

1. Introduction

1.1 New Initaitives

AFRI has developed three concept notes on All India Cordinated Research Projects (AICRP), which are approved by Project Advisory Group (PAG), ICFRE and one concept note on developing detailed projet report on Luni river basin.

1.2 MoU Signed

One MoU was signed between National Medicinal Plant Board (NMPB) and AFRI.

1.3 Vistit of Dignitaries

- Smt. Somita Biswas, CEO, NMPB New Delhi visited AFRI Jodhpur in April 2017 and reviewed the ongoing and completed projects funded by NMPB. A field demonstration on guggul gum tapping with ethephone injection method in the AFRI campus was shown to her.
- Shri Narendra Singh Mehra, Joint Director (Implementation), Ministry of Home Affairs Govt. of India , New Delhi visited Extension and Interpretation center and Farmer's gallery on 27 November 2017.
- Dr.Shruti Sharma, APCCF, Rajasthan Forest Department visited AFRI nursery on 24 November 2017.
- DG, ICFRE Dr. S.C.Gairola, IFS visited AFRI Jodhpur during 23-24 November 2017 for inaugration ceremony of Regional Research Conference and Directors Meet.
- DG, ICFRE Dr. S.C.Gairola, IFS visited AFRI, Jodhpur on 16 February 2018 for inaugration ceremony of National Symposium on Plant Biotechnology-Recent Trends in Plant Propagation, Genetic Improvement & Industrial Applications (PTCA-2018).

1.4 Recruitment and Promotions during the year:

स्थानान्तरण/कार्य–मुक्त

1. श्री हरीश कुमार अवर श्रेणी लिपिक का सामाजिक वानिकी एवं पारि–पुनस्थापन केन्द्र, इलाहाबाद में स्थानान्तरण होने पर दिनांक 21 जुलाई 2017 (अपराह्न) से कार्यमुक्त किया गया।
2. प्रतिनियुक्ति पर कार्यरत श्री एन.के. वासु, भा.व.से. को समय पूर्व प्रत्यावर्तन पर दिनांक 01 सितम्बर 2017 को निदेशक पद से कार्यमुक्त हुए।
3. श्री सी.पी. राहंगड़ाले, अवर सचिव अधिवर्षिता आयु पर दिनांक 30 सितम्बर 2017 को सेवा निवृत्त हुए।
4. डॉ0 ड़ी.के. मिश्रा, वैज्ञानिक–जी अधिवर्षिता आयु पर दिनांक 31 जनवरी 2018 को सेवानिवृत्त हुए।

नवनियुक्त/कार्यभार ग्रहण

1. श्री रमेश कुमार मालपानी को प्रतिनियुक्ति पर दिनांक 11 अप्रेल 2017 को उप वन संरक्षक पद पर कार्यभार ग्रहण किया।
2. श्री आकाश कंडारा ने दिनांक 05 दिसम्बर 2017 को एम.टी.एस. के पद पर कार्यभार ग्रहण किया।

पदोन्नति

1. डॉ0 ड़ी.के. मिश्रा, वैज्ञानिक–एफ ने पदोन्नति पर दिनांक 01 जनवरी 2018 को वैज्ञानकि–जी पद पर कार्यभार ग्रहण किया।

1.5 New Infrastructure Developed During the Year: NIL

1.6 All India Coordinated Research Projects: NIL

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). 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.

Figure 1. Jurisdiction map of AFRI, Jodhpur

2. Research Highlights

2.1 Ecosystem Conservation and Management

2.1.1 Overview

Dry areas are outcome of the long term water scarcity and all living organism evolve themselves for survival under the harsh conditions of drylands. Human population also coexists as the part of this ecosystem. However, challenges are increasing in these areas under climate change as compared with other parts of world. AFRI has undertaken four research projects under this thrust area. Climate change mitigation and adaptation strategies assessed in six blocks one each in a district of western Rajasthan under Mitigating Poverty in Western Rajasthan Programme. Constructions of goat/cowshed, promotion of stall feeding, use of cream extractor,

sewing machine, heat and drought tolerant crops, rainwater harvesting and tube-well are adaptation strategies, whereas organic manuring, plantation of horticultural plants and use of solar light, solar pumps etc are mitigation options. Phytoremediation research carried out to recycle industrial treated effluents as the source of irrigation on selected tree species revealed that *A. nilotica, P. juliflora* and *A. indica* are tolerant to wastewater as compared with other species. Soil parameters and biomass also enhanced when plantations are irrigated with treated effluents. Wildlife is mostly concentrated in the areas supported by availability of fodder in pasture, Oran or forest lands and the areas dominated by Bisnoi community. Role of insect pollinators visiting the blossoms of *Prosopis cineraria*, *Capparis decidua* and *Acacia senegal* and help in pollination and fruit setting has been scientifically established.

2.1.1.1 Project under the theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2017-18
Plan	0	1	-
Externally Aided	2	-	1
Total	2	1	1

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

Mitigating Poverty in Western Rajasthan (MPOWER) programme was implemented in Aburoad, Bali, Sanchor, Sankara, Baap and Baitu blocks situated in Sirohi, Pali, Jalore, Jaisalmer, Jodhpur and Barmer district, respectively. Various activities carried out were related to decrease the climatic risks of most vulnerable group of society in the region by increasing productivity and livelihood and build capacity to adapt to and mitigate the effects of climate change. Funded under MPOWER this project had the objectives: (i) identification 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 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

livelihood. In this 1792 households represented by 56.6% male and 43.4% female of different age group were surveyed and soil samples collected from different land uses viz. agriculture, forests/plantation, pasture/grassland, Oran, roadside and fallow lands were analyzed for soil organic carbon (SOC). Agriculture and animal husbandry are the main source of livelihood. About 69.1% households fallow rainfed agriculture. Average human and livestock per HHs were 5.6 and 7.1 respectively. Contribution of cow and goat/sheep in total population was 19.7% and 72.8% respectively. However, relative cash flow from agriculture and animal husbandry were significantly low. Use of dung cake, fuel wood, crop residue, LPG and kerosene was 2.5 kg, 11.5 kg, 2.6 kg, 0.11 kg and 0.16 liter per day per HH, respectively. Use of fuel is relatively greater during winter than in the summer months. Main sites of fuel wood and fodder collection are forest and agriculture lands. People are experiencing increase in air temperature ('Tawada') and wide variation in rainfall pattern in these days. Reduction in green house gas emissions (i.e., carbon dioxide) by reduction in burning of dung cake, crop residue and fuelwood due to use of kerosene stoves, LPG, solar light, solar Chulha, pressure cooker, improved Chulha etc., were observed as the climate change mitigation strategies. Use of organic manure and vermin-compost and plantation of horticultural species enhanced soil carbon storage in agriculture land as shown by 11.4% increase in soil carbon storage during 2013-14 to 2016-17 (Fig 2). Soil carbon stock in the order of Baitu<Sankara<Baap<Sanchor<Bali<Aburoad indicates positive impact of increased soil water, vegetation status and soil conditions on soil carbon development and storage. Increased land holding, livestock number per HHs and use of dung-cake and crop residue showed negative impact on SOC stock.

Figure 2. People interaction (left) and plantation of *Punica granatum* (pomegranate) as climate change adaptation (right)

Soil organic carbon stock (after gravel correction) was lowest (5.09 tons ha^{-1}) in Baitu and highest (16.63 tons ha^{-1}) in Aburoad block, whereas in land uses carbon stock ranged from 5.72 tons ha^{-1} in fallow lands to 9.72 tons ha^{-1} in forest land. Formation of SHGs, monthly savings, revolving funds, developing bank linkages, seed capital, field visits etc., were various steps of reducing vulnerability. Crops and vegetable demonstrations, fertilizer and seed distribution, promotion of vermin-composting, polyhouse, trellis for climbing vegetables, use of drips and sprinkler and distribution of sprayer pumps altogether helped in improving productivity under efficient use of available resources. The increase in the availability of irrigation water through tube-well, dug wells, Saran and canal water supply and supply of quality seeds of crops more resilient to drought and heat stresses were motivating factors in adaptive agriculture. However, most of the HHs appeared more adamant to such changes because of the associated risks involved in it. Constructions of goat/cowshed for livestock and distribution of 'Manger' for stall feeding of domestic animals, bilona machine for cream extraction, and sewing machine for enhanced income are the activities for improved livelihoods and are making people more resilient to climate change. Rainwater harvesting and development of 'Saran' to increase water supply for drinking and irrigation, and distribution of plastic and steel tanks for water storage further added to climate change adaptation.

For further improvement, traditionally developed adaption strategies and coping mechanism against climatic adversities in the form of soil and water conservation and rainwater harvesting to enhance crop production and augment drinking water supply, promoting and protecting tree on farmlands, and conservation of community forests, i.e. 'Oran' need to be revived and renovated on scientific basis. An integrated natural resource management is essential to utilizes the benefits of best use of available resources and enhance the yields for improved livelihood and better climate change adaptation.

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

Scientific names of species with vernaculars in parenthesis: *Punica granatum* (pomegranate)

2.1.3 Ecology and Environment

Project 2: Phytoremediation of soil for productivity enhancement during land disposal of effluent. (AFRI/FED/SFD-Raj/2011-18).

Land application of wastewater including tree irrigation has become a viable solution when the cost of a typical tertiary treatment process is considered. Soil and vegetation act as filters that encourage the entrapment of particulate contaminants from wastewater, and then the treated effluent is allowed to drain through the soil profile. 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. To fulfil the objectives survey were conducted to screen plants growing on and tolerant to effluent inflicted area along Luni, Bandi and Jojri rivers considering three microhabitats like river bed, river bank and uninfluenced area as control. Two afforestation experiments, one in lysimeter tanks (non-weighing type) started in September 2012 and other one in field condition started in September 2013.

A completely randomized design was adopted and plantation established consisting of four levels of irrigation and 7 tree species. *Azadirachta indica* (Neem), *Eucalyptus camaldulensis* (Safeda), *Prosopis cineraria* (Khezri), *P. juliflora* (Vilayati babool), *Tamarix aphylla* (Farash), *Salvadora persica* (Khara Jaal) and *S. oleoides* (Meetha Jaal) were planted at 2.1 m x 3.2 m spacing in three replications utilizing 84 numbers of lysimeter tanks accommodating one plant in each tank (Fig 3). Irrigation levels were: (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.

Figure 3. Experimental plantation in lysimeter (left) and field condition (right) utilizing treated wastewater

In field condition, ten tree species like *Acacia nilotica* (Deshi Babool), *Ailanthus excelsa* (Ardu), *Azadirachta indica*, *Eucalyptus camaldulensis*, *Prosopis cineraria*, *Prosopis juliflora*, *Tamarix aphylla*, *Tecomella undulata* (Rohida), *Salvadora oleoides* and *S. persica* were planted at 3 m x 4 m spacing and in Split Plot Design with three replications. Four irrigation levels were: (i) treated wastewater at 1/2 ET, (2) treated wastewater at 3/4 ET, (3) Tube-well water at 1/2 ET and (4) Tube-well water at 3/4 ET. The irrigation was based on cumulative pan evaporation (Figure 2). Data on height, collar diameter and crown diameter were since September 2013 at three months interval, i.e. March, June, September and December in Lysimeter experiment and at 6 month intervals in field experiment. Soil, wastewater and plant samples were collected and analyzed for different physico-chemical properties and mineral contents.

Experiment 1: Field survey and soil and water sampling along Jojri, Bandi and Luni rivers showed wide variations in water and soil characteristics and vegetation status (Figure 3). Waters flowing through these rivers were alkaline and highly saline in nature, low in nutritional quality and high concentrations of Na and Ca and low concentration of K and metal ions like Mn, Cu, Co, Zn, Cd and Pb. Though varied with places of soil sampling, soil pH was alkaline, electrical conductivity was high at most of the places and availabilities of NH_4-N, NO_3-N and PO_4-P were low. Vegetation study showed availability of a total number of 50 species along Luni, Bandi and Jojri rivers. There were 6 tree species, 9 shrubs, 8 herbs, 2 sedges and 9 grass species along Luni River, 8 tree species, three shrub species, 8 herb species and 5 grass species along Bandi and 6 tree species, 2 shrubs, 6 herb species, 1sedge and 5 grass species along Jojri River (Fig 4).

Figure 4. *Prosopis juliflora*, *Tamarix ericoides* and *Paspalum virgatum* grass growing along effluent inflicted soils along Bandi (left) and Jojri (right) rivers.

Tree diversity was highest along Bandi, whereas diversities of shrubs and herbaceous species were highest along Luni River. Lowest diversity of all plant habits was along Jojri River. *Prosopis juliflora, P. cineraria, Tamarix ericoides* and *Phragmities karka* grew in the wastewater inflicted area, whereas *P. juliflora, P. cineraria, Acacia nilotica, Salvadora persica, Calotropis procera* and *Aerva persica* were flourishing along the edge of river courses. Common herbaceous species growing in the flooded area of all three rivers were *Aeluropus lagopoides, Blumea* spp., *Cynodon dactylon, Paspalum virgatum, Glinus lotoides, Heliotropium curassavicum, Schoenoplectus articulates, Solanum surattense, Sueda fruticosa,* and *Typha angustifolia* indicating their tolerance towards the wastewater flowing through these rivers and adapted to survive on effluent inflicted soils.

Experiment 2 (Lysimeter): Species characteristics and its phenological behaviour coupled with environmental effects was shown by significant ($P<0.01$) variations in height, collar diameter and crown diameter recorded in July-September, October-December, December to March and March-June. Highest growth of most of the species was during monsoon period of July – September, but *P. cineraria* and *P. juliflora* showed better growth during October to December and *E. camaldulensis* during January-March. Mean annual increment (MAI) in height varied from 25.5 cm per year in *T. aphylla* to 47.4 cm per year in *E. camaldulensis* and in collar diameter from 8.5 mm per year for *P. cineraria* to 14.7 mm per year for *S. oleoides.* The order of

different tree species was: *T. aphylla< P. cineraria <S. oleoides <S. persica<P. juliflora <A. indica<E. camaldulensis* for height; *P. cineraria<S. oleoides<E. camaldulensis<T. aphylla<S. persica<P. juliflora <A. indica* for collar diameter; *E. camaldulensis< T. aphylla< S. oleoides<P. cineraria< S.persica<A. indica<P. juliflora* for crown diameter and *T. aphylla<P. cineraria<E. camaldulensis<S. oleoides<S.persica<P.juliflora <A.indica* for dry biomass. MAI in biomass ranged from 0.66 kg per plant per year in *T. aphylla* to 2.20 kg per plant per year in *P. juliflora*. *S. persica*, *P. juliflora* and *A. indica* appeared better tolerant to wastewater irrigation with highest MAI in biomass. Different components like stem, branches, twigs, leaves and roots contributed to 20.6%, 26.3%, 17.5%, 0.11% and 24.5% respectively in total dry biomass. Contribution of stem and branches were highest in *A. indica*, and those of twigs, leaves and roots were in *juliflora*. Total dry biomass production was almost similar in *P. juliflora, S. persica,* and *A. indica*, whereas *T. aphylla, P. cineraria* and *S. oleoides* were least dry biomass producer with almost 3.1-fold variation in biomass.

Lowest growth variables and biomass production was for the plants irrigated with bore-well water at ½ PE. The irrigation levels fell in the order: $I_1<I_2<I_3<I_4$ for most of the growth variables. Variations in MAI in height was from 32.3 cm per year in I_1 to 34.6 cm per year for the plants irrigated at I_4 level, and in collar diameter from 11.0 mm per year in I_1 to 12.7 mm per year in I_4 level indicating the beneficial effects of wastewater irrigation on plant growth and biomass production of these species (Fig 5). Application of wastewater increased soil pH, EC, NH_4-N, NO_3-N and PO_4-P values in September 2017 as compared to the initial values in September 2013. The increase was in the order of $I_2<I_3<I_4$ irrigation levels. Higher growth and biomass production in soil under *A. indica*, *P. julflora*, *S. persica* etc., led to relatively lesser increase in soil nutrients. Uptake and accumulation of most of the minerals elements in leaves and twigs of different species depended upon the species characteristics and their bioremediation ability. Concentration of Mg was high in *P. juliflora*, Cr, Ni, Cu, Se, Cd and Pb in *A. indica*, Mn in *E. camaldulensis*, Fe in *S. persica* and Co and Zn in *S. oleoides.* Increased concentration of these mineral elements was related to the level of wastewater application being highest n the plants irrigated at I_3 and I_4 levels.

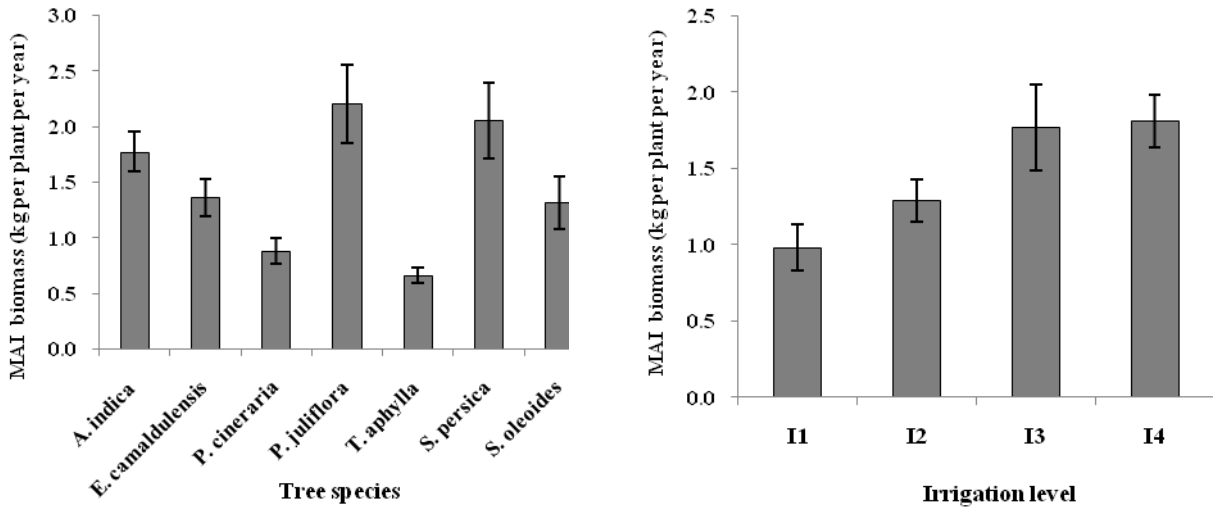

Figure 5. Mean annual increments in dry biomass for different species (left) and at different levels of wastewater application. Error bars are ±1SE of three replications.

Thus increased level of soil nutrient observed beneficial in plant growth and biomass production, which increased with increase in quantity of wastewater application. However, responses of different species were different depending upon their hytoremediation ability through mineral uptake in different parts and turnover of litters and fine roots. *A. indica*, *P. julflora*, *S. persica* observed better species both in terms of growth and biomass production and lead to relatively lesser increase in soil nutrients and hence can be utilized to solve problems of increasing urban green patches and utilization of treated wastewater of the city under afforestation and environmental amelioration.

Experiment 3: Survival per cent of tree species after 51 months of plantation varied ($P<0.05$) both between species as well as types and levels of irrigation. Survival ranged from 10.4% in *Ainlanthus excelsa* to 100% in *P. juliflora*. Survival in *Eucalyptus camaldulensis*, *Tamarix aphylla* and *Tecomella undulata* was 64.5% to 81.3%. It was 72.9% to 89.6% in *T. aphylla, T. undulata, Salvadora oleoides* and *Prosopis cineraria* and 90.0 to 100% in *Acacia nilotica, Azadirachta indica, Salvadora persica* and *P. julifora*. Tree species fell in the order: *S. oleoides<T. undulata<P. cineraria<S. persica<T. aphylla<A. nilotica<P. juliflora<E. camaldulensis<A. indica* for height; *T. undulata<P. cineraria<S. oleoides<T. aphylla<S. persica<E. camaldulensis<A. nilotica<P. juliflora<A. indica* for collar diameter; and *S. oleoides <T. undulata<P. cineraria<S.persica< T. aphylla<E. camaldulrnsis<A. indica<A.*

nilotica<*P. juliflora* for crown diameter. Irrigation levels fell in the order: TW1/2<TW3/4<WW1/2<WW3/4 for height, which ranged between 195.6 cm in TW1/2 and 247.8 cm in WW3/4 level. The order was TW1/2<TW3/4<WW1/2<WW3/4 for collar diameter ranging between 35.0 mm and 42.9 mm. Average crown diameter ranged from 139.1 cm at TW1/2 to highest crown spread for the plants irrigated with treated wastewater at WW3/4. MAI ranged from 17.8 cm to 89.8 cm per year in height and from 5.1 mm per year to 15.2 mm per year. MAI varied from 20.7 cm per year in *S. oleoides* to 80.3 cm per year for *A. indica* for height and from 4.7 mm per year in *T. undulata* to 13.8 mm per year in *A. indica* for collar diameter. MAI in height was highest in wastewater irrigated plants at ¾ PE closely followed by wastewater application at ½ PE (Fig 6).

Height, collar diameter and crown diameter growth were 24.1%, 14.4% and 21.4% respectively, greater for the plant irrigated with treated wastewater than the plants irrigated with bore-well water. Likewise, the plants irrigated at ¾ PE were 2.3%, 6.8% and 2.3% greater when irrigated at ¾ PE as compared to the plants irrigated at 1/2PE. MAI in height and collar diameter was 31.4% and 17.8% greater in the plants irrigated with wastewater as compared to the plants irrigated with bore-well water. However, MAI in height and collar diameter of the plants irrigated at ¾ PE was 1.3% and 6.1% greater as compared to the plants irrigated at ½ PE. This indicates the positive influence of both wastewater application as well as its quantity on height and collar diameter growth of different tree species.

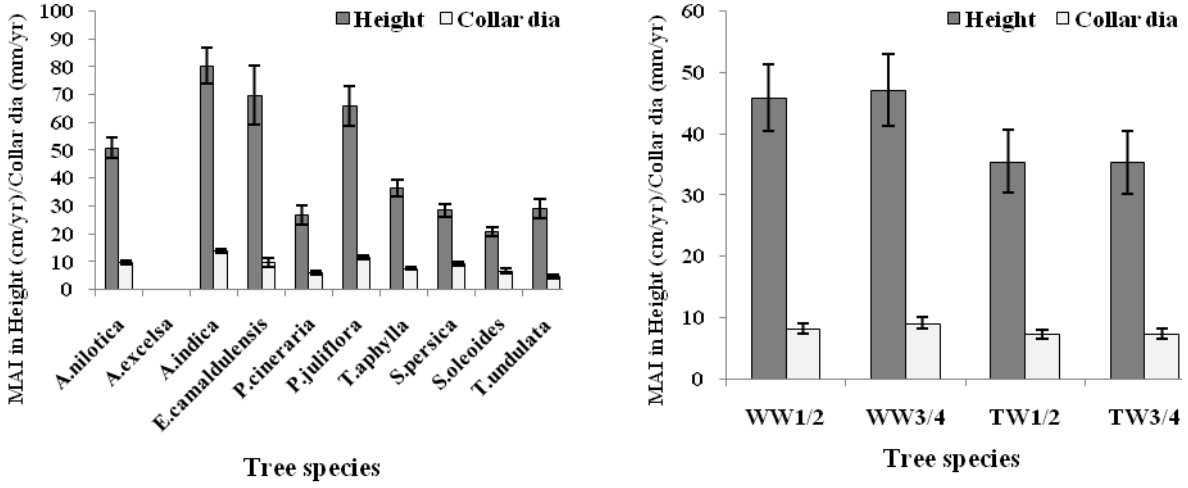

Figure 6. Mean annual increment in height and collar diameter of tree species across irrigation level (left) and irrigation level across species (right). Error bars are ±1SE of three replications.

Average biomasses of leaves, twigs, branches, stem and roots contributed to 8.6%, 17.1%, 17.2%, 25.0% and 32.5% respectively in total dry biomass produced. Highest leaves biomass was in *E. camaldulensis*, branches and twigs biomasses were in *P. juliflora*, and stem and roots biomasses were in *A. indica*. Total dry biomass was highest in *P. juliflora*, closely followed by *A. indica*. Least dry biomass production was in *S. oleoides* followed by *T. undulata*. There was 6.5-fold variation in dry biomass in these species. Leaves, twigs, branches and roots biomasses were highest in the plants irrigated with wastewater at ¾ PE, stem biomass in the plants irrigated with bore well water at ¾ PE. Total dry biomass production was high ($P<0.05$) for the plants irrigated at WW3/4, closely followed by biomass produced under TW3/4 level of irrigation. Least dry biomass production was for the plants irrigated with bore-well water at ½ PE. There was 1.4-fold higher dry biomass in the plants irrigated with wastewater as compared to the plants irrigated with bore-well water, but the increase was 1.5 fold in the plants irrigated at ¾ PE as compared to the plants irrigated at ½ PE.

All soil parameters like soil pH, EC, SOC, NH_4-N, NO_3-N and PO_4-P increased during irrigation. The increase was greater when irrigated at ¾ PE as compared to that at ½ PE. *E. camaldulensis, A. nilotica, P. juliflora* and *A. indica* appeared better tolerant to treated wastewater application as compared to the other species. The main negative effects of effluent use are related to increased salt concentrations, besides the accumulation of metals on soil surface to some extent but water and nutrients are added benefits enhancing growth and biomass production of all species under study.

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.

Scientific names of species with vernaculars in parenthesis: *T. undulata* (Rohida), *P. cineraria* (Khejri), *S. oleoides* (Pilu), *T. aphylla* (Lal Jhar), *S. persica* (meswak), *E. camaldulensis* (river red gum tree), *A. nilotica* (Babool), *P. juliflora* (Junglee kikar), *A. indica* (Neem)

2.1.4 Biodiversity

Project 3. Assessment of biological diversity and people perception for developmental plan and awareness generation in different community reserve areas in Jodhpur district (AFRI-47/FED/2017-18).

Because of non-availability of protected areas and limited forests in Jodhpur district in western Rajasthan, most of the wild life and vegetation concentrations are found in outside the protected area, i.e. community lands like Oran, Gauchar and even the agricultural lands. Furthermore, a considerable change has been taken place in the extent of social status, biological diversity, vegetation structure, peoples' perception towards environmental problems and biological diversity and the religious beliefs with the passage of time. This project was conceived to assess biodiversity in wildlife intensive areas outside protected areas; prepare wildlife conservation plan at village/panchayat/cluster level for areas outside protected areas; and help forest department in motivating people and gram panchayat in declaration of these areas as community reserves; build capacity of the local community in conservation, protection and improving livelihoods and conducting awareness activities for conservation and protection of wildlife. Through an interactive workshop organized on 16 October 2017 fifty seven villages were identified for survey and data collection based on probability of findings maximum numbers of wild life. Two types of questionnaires for village profile and household survey developed and were filled up after interacting with 1014 respondents covering 26 villages in the district. Name of the people involved in wild life protection and conservation were also recorded. In these villages, gauchars are dominated by *Salvadora oleoides* (Meetha Jal) *Capparis decidua* (Ker), *Acacia tortilis* (Israli Baool) and *P. juliflora* (Vilayati Babool). Availability of *P. cineraria* (Khezri) is relatively less. Orans are dominated by *Ziziphus nummularia* (Jaad Ber) and *P. cineraria*. Agriculture lands are totally dominated by *P. cineraria*, whereas forest lands are dominated by *A. tortilis*. Among the grasses, most of the areas are dominated by *Dactyloctenium sindicum* (Ganthiya), some patches of *Lasiurus sindicus* (Shrwan) were also noticed.

Benefits of the research project: Help in declaring community reserves and managing wildlife in these reserve areas of Jodhpur district.

Scientific names of species with vernaculars in parenthesis: *Salvadora oleoides* ((Meetha Jaal), *Capparis decidua* (Kair), *Acacia tortilis* (Israeli babool), *P. cineraria* (Khejri), *Ziziphus nummularia* (Jharber) and *P. juliflora* (Junglee kikar).

Project 4: Diversity of insect pollinators and their role in fruit/ pod production of *Acacia senegal, Capparis decidua* and *Prosopis cineraria* (Tricuta) in Rajasthan (AFRI-26/FPD/ ICFRE/2016-19)

Foraging behaviour of insect pollinators on the inflorescence of *A. senegal*, *P. cineraria* and *Capparis decidua* was studied. Insect pollinators visiting the blossoms of these species were collected, properly pinned and placed in the display showcase. On the blosoom of *A. senegal* seven species of Hymenoptera (*A.dorsata, A. florea*, *Vespa* spp., *Xylocopa* spp., ants, *Polites* spp. and *Megachile* spp.), 2 species of Coleoptera (*Mylabris pustulata* and *Oxycetonia* spp.), 1 species of Hemiptera (*Bagrada* spp.) 5 species of Lepidoptera (*Colotis fausta, Colotis etrida, Catopsilia* spp., *Eurema* spp. and *Papilio* spp.) and Diptera (Syrphids) were observed. In *C. decidua* 5 species of Hymenoptera (*A. dorsata, A. florea, Vespa* spp, ants, *Xylocopa* spp.), 5 species of Lepidoptera (*Pieris* spp., *Colotis* spp., *Danus* spp., *Eurema* spp. and *Ixias* spp.,) and Diptera (Syrphids) were recorded. In *P.cineraria* blosoom, 7 species of Hymenoptera (*A.dorsata, A.florea, Vespa* spp., megachilid, Halictid, black ants and *Xylocopa* spp.), 3 species of Lepidopteran (*Pieris* spp., *Colotis* spp. and *Eurema* spp.) and Diptera (Syrphids) were recorded. Among these, the most abundant pollinator in *C.decidua, A. senegal* and *P.cineraria* were *A. florea* among Hymenopteran insect.The foraging insects were found maximum between 10:00 h to 12:00 h. No fruit set was observed in the bagged inflorescence (pollinator exclusion). However where specific insect pollinator was released in the bag, fruit setting was observed in case of *A. senegal* and *C.decidua.* Bagging experiment has been laid to study the effect of insect pollinators on fruit production of *P. cineraria* also.

Benefits of the research projects: Enhancing fruit/pod production of Khejri, Kair and Kumat through controlled pollination.

Scientific names of species with vernaculars in parenthesis: *A. senegal* (Kumat), *P.cineraria* (Khejri) & *Capparis decidua* (Kair).

2.1.5 **Forest Botany: NIL**

2.1.6 **Tribals and Traditional Knowledge System: Nil**

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2.2 Forest Productivity

2.2.1 Overview

Six different research projects were executed covering nursery technology, superior clones selection, agroforestry system and forest soil and land reclamation to enhance the forest (land) productivity. In this superior seedlings of *Anogeissus pendula* raised in nursery from identified superior trees (CPTs) and seeds technology was improved. Integrated approach was also adopted for raising quality planting material by using different microbes.Thirty outperforming clones of *Casuarina equisetifolia*, *Casuarina junghuhniana* and *Casuarina* hybrids based on growth, stem form, salt tolerance, wind tolerance and high yielding were collected and their Vegetative multiplication Garden established for large scale multiplication and production of superior clones. An extensive survey was also conducted in different agro climatic zones of Gujarat and information on different host, spacing, soil type and growth performance of Sandalwood were collected and compiled. Traditional and improved agroforestry system in Rajasthan assessed, where highest economic return (Rs 1.33 lakhs/ha) was in paddy/wheat with *Acacia nilotica* under irrigated conditions of Kota districts. It was followed by (Rs 1.21 lakhs/ha) cotton/wheat with *Dalbergia sissoo* in Shriganganagar. Rehabilitation of salne-alkaline area through afforestation applying corrective measures indicates that *Cenchrus ciliaris* (CAZRI-75) could established on soil slope with *C. mopane* plantation. *S. nudiflora* was established in saline soils in Bharuch area of north Gujarat coupled with sowing of Bajra variety HHB-67 (IMP) in 2017. Integrated use of organic and inorganic fertilizers has been observed helpful in enhancing the number of fruiting in *Capparis decidua* shrubs and per shrub yield. A combination of leaf compost manure and P, K and Zn enhanced fruiting three times closely followed by leaf compost manure and N, P and K as compared to control.

2.2.1.2 Project under the theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During the Year 2017-18
Plan	**1**	**4**	**1**
Externally Aided	**-**	**1**	**-**
Total	**1**	**5**	**1**

2.2.2 Silviculture

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

Seeds from 28 seed trees of *Anogeissus pendula* (Dhok) were sown in mother bed at AFRI nursery (Fig 7). Germination initiated within 6-7 days and completed in 30 days period. Various germination enhancers (growth enhancers, i.e. IBA, GA_3, IAA) were also used. In laboratory condition, seeds were sown in sterilized coarse sand medium after treatment with growth enhancers along with a control. In laboratory condition, highest germination (10.79%) was recorded in seeds collected from Desuri of Pali district without any treatment of growth enhancers (control). Growth enhancers did not enhance germination percentage. Highest germination (2.11% percent) was in seeds collected from Sirohi after treatment with IBA. In field condition, best germination (5.73%) was observed in seed lot collected from Parasram Mahadev with GA_3 treatment and 4.49% for seeds collected from Desuri without any treatment.

Figure 7. *Anogeissus pendula* seed germination in Nursery beds.

Root trainers (150 and 300cc) and poly bags (12x25cm, 15x25cm and 16x20cm) were used for filling potting mixture of 1:1:1 and 1:1:2 (Sand: Soil: FYM). The best seed sources were sown in mother bed and seedlings were transferred to polybags and root trainers having different potting mixtures at 3-leaf stage. Seeds collected from all sources were tested for their germination percentage, rate of emergence and germination index. Data are being processed for further analysis.

Benefits of the research Project: Development of technology for enhancement of germination and producing quality seedlings.

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

This project was initiated during January 2017 under 15 Research points initiative suggested by MOEF&CC. Thirty outstanding clones of *Casuarina equisetifolia*, *Casuarina junghuhniana* and *Casuarina* hybrids were collected from clonal bank of IFGTB, Coimbatore and Tamil Nadu News Print Ltd, Karur. Selection was based up on growth, stem form, salt tolerance, wind tolerance and high pulp yield. They were transplanted in root trainers and kept in AFRI, Nursery for growth hardening. Vegetative multiplication Garden established at AFRI, Nursery. Growth data recorded for six month. Initial data revealed that three hybrid clones and one second generation clone performed better in the arid zone (Fig 8).

Figure 8. Vegetative multiplication Garden at AFRI, Nursery and Best performing hybrid clone.

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

Scientific names of species with vernaculars in parenthesis: *Casuarina equisetifolia* (Junglisaru), *Casuarina junghuhniana* (Savukku maram)

2.2.3 Theme: Social Forestry, Agro-forestry/ Farm Forestry

Project 3: Study on crop yield, soil fertility and gum production in *Acacia senegal* based traditional agroforestry system in arid region of Rajasthan. AFRI-42/AFED/ICFRE PLAN/2017-22.

Survey was conducted for *Acacia senegal* (Kumath) based agroforestry areas. Both scattered trees in the field and farm boundary were considered in the study. Sample plots of tree densities viz. 10-20, 20-30 and 30-40 trees/ ha were laid out at nine sites on farm land in Sheregarh in Jodhpur, Jakhara (Bayatu) and Lilsar (Chouhatan) in Barmer district and three sites on farm boundary in Didwana, Nagaur District. Tree growth of *A. senegal* trees measured and crop yield recorded.

Height and diameter at best height (DBH) of the trees ranged from 3.5 to 11.1 m and 7.0 to 45.6 cm, respectively. Crop yield reduction differed significantly ($p<0.05$) between tree densities. Reduction of crop yield was greatest (44.9 %) at 30-40 trees/ha and reduction was less (30.5%) at 10-20 trees/ha. Crop yield reduction was higher (60.9%) at high tree density (30-40 trees/ha) and less (42.9%) at low tree density (10-20 trees/ha) near tree trunk (1 m distance from tree trunk) than respective sole crop. Ethophon was injected in *A. senegal* trees to enhance gum arabic production where gum arabic yield ranged between 25 and 1270 gm per tree. Cost of cultivation recorded and its economic return was calculated. Economic return was highest in Gaur (crop Rs. 4360/ha) followed by bajra (Rs. 1357-3290/ha) crop and economic return of Moth based agroforestry was negative (Rs. 634 /ha) in Kharif season. Soil pH, Ec, organic carbon and available phosphorus were estimated. Soil organic carbon (SOC) did not differ between tree densities and SOC ranged between 0.06 and 0.24%.

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

Project4: Study on the effects of tree on soil fertility and crop production in Rajasthan.
(AFRI-33/AF&ED/SFD- Raj/2016-19)

Study of different traditional and improved agroforestry models on farmers fields were conducted in Pali, Jodhpur, Nagaur, Sikar, Churu, Shreeganganagar, Bikaner, Dausa, Karouli, Swaimadhopur , Kota, Jhalawar, Banswara and Barmer in each ten agroclimatic zones during Kharif and Rabi seasons. There were 116 tree-crop combinations covering 12 crops in Kharif and 7 crops in Rabi season found associated with trees. Dominant crop was Bajra followed by

Gaur and Moong in Kharif and Wheat followed by Mustard in Rabi season. There were 7 horticultural species and 12 silvicultural species in agroforestry system.

Crop reduction was observed in all agroforestry systems. Crop yield reduction was the lowest in *Prosopis cineraria* (Khezri) based agroforestry where it was 17.3% (across the crops) as compared to the sole crops. About 50% observation showed highest crop yield at canopy edge of *P. cineraria.* Reduction of crop yield was greater (75.6%) at 1 m distance from the tree trunk of *Salvadora oleoides* (Meetha Jaal) as compared to sole crop followed by *Prosopis juliflora* (Vilayati Babul, 74.9%), *Acacia tortilis* (Israili Babul, 71.8%), *Mangifera indica* (Mango, 59.0%) *Azadirachta indica* (Neem, 58.5%) and *A. nilotica* (Deshi Babul, 56.7%). Crop yield reduction was less in *P. cineraria* (28.5%) at 1 m distance from tree trunk as compared to sole crop followed by *A. nilotica* var. *cupressiformis* (41.5%). Reduction of crop yield at canopy edge was 46.6% with *S. oleoides*, 37.6% with *P. juliflora*, 31.5% with *A. tortilis*, 23.6% with *D. sissoo*, (23.4% with *A. Senegal*, 22.7% with *T. undulata*, 21.8% with *A. indica* and 21.5% with *Z. mauritiana* than under sole crop. Soil organic carbon (SOC) was 17.26% higher in agroforestry system than sole agriculture field. SOC was 0.045% greater in *A. nilotica*, 0.030% in *D. sissoo*, 0.016% in *T. undulata* and 0.012% greater in *P cineraria* based agroforestry system as compared to sole agriculture field. It was 0.014% higher at 1 m distance from tree trunk as compared to sole agriculture soil whereas it was 0.031% higher at canopy edge.

Economic return of traditional and improved agroforestry systems have been assessed. Economic return was highest (Rs. 132500/ha) in paddy/wheat with *Acacia nilotica* in Kota district, followed by cotton/wheat with *Dalbergia sissoo* based agri-silvi system (Rs. 121070/ha) in Shriganganagar under irrigated condition. It was lowest (Rs. 565-12922) in hyper-arid regions of Churu and Barmer districts. Crop failure in some sites due to very low rainfall in hyper-arid region resulted in low or negative economic returns. Economic return of *Psidium guajava* (Guava) based agri-horti system was highest (Rs. 126653/ha/annum) in Sawaimadhopur district followed by grafted *Zizyphus mauritiana* (Ber) (Rs. 106750/ha/annum) and *Punica granatum* (Pomegranate) (Rs. 89503/ha/annum) in Barmer district under irrigated condition. Literatures on agroforestry were collected from CAZRI and AFRI, Jodhpur, of Arid Horticulture Research Institute, Bikaner, Research Station, Bikaner of CAZRI, Agriculture Research Station, Fatehpur, Sikar and Research Station at Kota of Soil and Water Conservation and Training Institute, Dehradun and their synthesis is in progress.

Benefits of the research Project: It will be beneficial in screening best agroforestry models for their replication and improved people livelihood in different agroclimatic zones of Rajasthan.

Project 5: Evaluation of existing Sandal wood (*Santalum album*) plantations and development of agro forestry trials and capacity building to promote cultivation in Gujarat and Rajasthan (AFRI-40/Silvi/ICFRE).

A survey was undertaken in different agro climatic zones of Gujarat to get information about various *Santalum album* (Sandal, Chandan) plantations established by farmers with respect to different host, distance and other parameters (Fig 9). Growth data were collected along with soil samples. Soil samples were analyzed for pH, EC and soil organic carbon. Two one-day trainings on 'Scientific cultivation of Sandal' have been organized for farmers and officials of state forest department and other departments for promoting sandalwood cultivation.

Figure 9. Sandal plantation at Kheda (left), Sandal plantation, Nanubhai's farmland, Anand (middle) and Sandal plantation at Bhavnagar (right)

Benefit of Research project: Scientific cultivation of sandal will be encouraged for profitable cultivation in dry areas.

2.2.4 Theme of Research: Forest Soils and Land Reclamation

Project 6: Impact of harvesting on soil nutrients and carbon stock in canal side plantations of Indira Gandhi Nahar Pariyojana (IGNP) AFRI-43/FE/ICFRE/2017-2022.

Objective of the project is to study the impact of harvesting on soil nutrients and carbon stock in canal side plantations of IGNP, quantify harvested wood biomass and develop allometric equations based on tree growth parameters and monitor temporal changes in soil parameters brought about by new plantations. Information collected on harvesting schedule from the concerned forest officials. Visit to the IGNP has been made to mark plots, measure tree growth parameters and collect soil samples for analysis (Fig 10). Ten plots have been enumerated comprising four species (*Acacia tortilis*, *Acacia nilotica*, *Eucalyptus camaldulensis* and *Dalbergia sissoo*) and soil samples collected. Five trees have been marked in each plot for recording biomass during harvesting. Soil samples have been analysed for pH, EC, organic carbon, bulk density, NH_4-N, NO_3-N and available Phosphorous. All the samples are slightly basic in nature with pH ranging from 7.65 to 8.55. Organic carbon varies between 0.23% and 0.41% being high in *A. tortilis* plantation. Compared to the soils outside plantation area, SOC, NH_4-N, NO_3-N and P were higher in all plantations. Significant increase in electrical conductivity was observed in *E. camaldulensis* and *D. sissoo* plantations.

Figure 10. Canal side stand of *Dalbergia sissoo* (left) and data recording in the study plot (right).

Benefits of the research project: Data generated will help in silvicultural operations in managing plantation and controlling land degradation.

Scientific names of species with vernaculars in parenthesis: *Acacia tortilis* (Israeli babool), *Acacia nilotica* (Babool), *Eucalyptus camaldulensis* (Safeda) and *Dalbergia sissoo* (Shisham).

Project 7: Enhancing fodder productivity through silvipastoral system on degraded land of India (AFRI-02/NWFP/Int-ICFRE)/2012-2018

***Colophospermum mopane : Cenchrus ciliaris* Silvipastoral trial**

About 0.38 mha suffers from problems of salinity and alkalinity in Rajasthan. Its rehabilitation through afforestation and soil corrective measures was done for effective use and providing fodder for animals in the region. Our research conducted during 2003-08 revealed that exotic glycophytic tree species *Colophospermum mopane* (Mopane) proved ideal species maintaining high survival (89 %) and growth after five years of establishment and it was the only species the roots of which penetrated the $CaCO_3$ kanker pan further enhancing its utility**.** Reduction in soil pH and electrical conductivity and improvement in organic carbon content was also observed during the study period. Despite of exotic, it did not suppress the growth of indigenous salt tolerant low palatable grasses like *Sporobolous* diander, *Chloris virgata* and *Dactyloctenium sindicum, D. aegyptium*. Hence, the investigation was undertaken to introduce non salt tolerant but highly palatable grass *Cenchrus ciliaris* and to evaluate its growth and yield with other grasses in the inter row spaces of *C. mopane* available at a spacing of 3 X 4 m . There were 18 blocks of 9 trees between which soil was raised mound of 90 cm x 120 cm x 25 cm size. Seed sowing of *C. ciliaris* CAZRI 75 was done on the bund slope in inter-row spaces of *C. mopane* in 2013**.** Green grass yield was recorded by laying quadrate of 1x1 m on bunds; whereas other grasses were measured from the quadrates laid out in the vicinity of trees in the experimental area (Fig 11).

C. ciliaris CAZRI 75 established in 3 years and now converted into a silvipastoral system. There were 12 grass species in the area. Height and green yield recorded for 7 species were: *Sporobolus diander* (106.6 -60.4 cm, 578 g), *Dactyloctenium aegytium* (46.0-22.5 cm, 300.0 g), *Chloris virgata* (52.0-31.0 cm, 282 .3 g), *Digitaria didactyla* (50.5-29 cm, 256.5 g), *Brachiaria ramose* (53.0-28.0 cm, 256.6 g), *Dactyloctenium sindicum* (51-27 cm, 152.2 g), and *Cyperus* spp. (33.4-19.5 cm, 147.6 g). Annual tree growth data for *C. mopane* recorded in 2017 showed incremental growth height 7.06%, crown diameter 10.5% and collar diameter 4.04% under grass treatment which is comparable to growth in the control trees with increment of 11.3% in height, 5.70% in crown diameter and 4.69% in collar diameter.

Figure 11. *C. ciliaris* 75 with *C. mopane* (left) and Other grasses with *C. mopane* (right)

Soil analysis of summer 2017 indicated slightly higher soil pH ranging from 8.45 (0-20 cm soil layer) to 8.60 (20-40 cm soil layer) on soil slop, plant pit with grass, control and inter row slop (IRS) with almost no variation. Soil EC was slightly high for the upper soil layer compared to the lower layer, but was in normal range. EC values varied between 0.66 and 0.41 dSm^{-1} for soil slope, 0.78 and 0.65 dSm^{-1} for plant pit with grass treatment, 0.56 and 0.61 dSm^{-1} for plant pit in control trees, and 0.80 and 0.77 dSm^{-1} in IRS. Per cent soil organic carbon was maximum inside plant pit, 0.42% and 0.40 % for the upper and lower soil layers for trees with grass and 0.38% for both layers in control trees, followed by 0.36 % & 0.41 % SOC on soil structure and minimum in IRS (inter row slope) 0.25 % & 0.38% for both the soil layers respectively.

***Suaeda nudiflora*: *Pennesetum typhoides* trial**

S. nudiflora, a member of family Chenopodiaceae, is an evergreen, highly salt tolerant shrub with numerous slender, erect branches, endemic to coastal regions throughout the world. It is found on mud flats along sea coast/saline soils in Bharuch, Cambay, North Gujarat (Kharaghoda), Saurashtra and Kutchh region of Gujarat state. *S. nudiflora* seedlings planted in August 2013 at a spacing of 4 m x5 m on double ridge mounds were established well (Fig 12). There was no decrease in survival which was 64.5% in September 2017 as in last year. After monsoon rains, plants attained significant growth. Mean increment was 5.76 % in height, 15.9% in crown diameter and 5.21% in collar diameter.

Figure 12. *S. nudiflora* on DRM after rain in June (left), Bajara with *S. nudiflora* in August I week 2017 (middle) and Bajara with *S. nudiflora* in II week August 2017 (right)

Bajra variety HHB-67 (IMP) was sown on 1 July 2017 in the inter row spaces of *S. nudiflora*. There was 80% germination after 10 days with 4-5 cm height. Crops height ranged from 60 cm to 30 cm from lesser to more saline soil at one month. The crop attained height of about 60-90 cm, and flowering initiated but dried in absence of by September. Stalk harvested straw mass ranged from 561.2 g m^{-2} to 256.7 g m^{-2}. Vegetation status on plant bunds evaluated in September 2017 showed the presence of 18 plant species, one more than last year. Out of 18 species, 10 were grasses. The soil pH was 8.30 and 8.24, soil EC was 0.817 and 0.797 dSm^{-1} and % SOC was 0.39 and 0.23% in 0-20 and 20-40cm soil layer respectively inside plant pit in winter 2018 indicating soil improvement. Findings suggest that these saline silvipastoral systems could provide an alternative capacity of fodder buffer and allowing sustainable production of grass even in low rainfall years.

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

Scientific names of species with vernaculars in parenthesis: *Suaeda nudiflora* (seepweeds) *Colophospermum mopane* (mopane) *Cenchrus ciliaris* (Dhaman) and *Pennesetum typhoides* (Bajra).

2.2.5 Watershed Management: NIL

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2.3 Genetic Improvement

2.3.1 Overview

Ten different projects executed under this thrust area covering *Azadiracta indica*, *Ailanthus excelsa*, *Commiphora wightii*, *Leptadenia reticulata*, *Schizostachyum dullooa* and *Tecomella undulata* for conservation of genetic resource, tree improvement, development of clonal techniques and genetic engineering. Genetic transformation work on *A. indica* has been initiated to enhance cold tolerance using transgene pyramiding technique. Two strains of agrobactriumand plasmid vector pCAMBIA containing reporter (GUS and GFP gene) and interested genes (gly III and cod A) have been procured and genetic transformation with desired genes is in progress. Germplasm is enriched with selection of new CPTs of Neem and Guggul on species specific criteria. Superior families of these were screened on early growth characteristics of seedlings to raise progeny trials cum seedlings seed orchard. Twenty two genotypes of C. wightii have been screened as superior genetic resource from 660 genotypes. Ten putative high gum yielders of *C. wightii* have also been identified for initiating guggulsterones extraction using bioreactor technique and cell suspension cultures. Success has also been achieved in establishing and multiplying *in vitro* shoots of *Schizostachyum dullooa* from adult clumps. Similarly micropropagation protocol of *Leptadenia reticulata* (Jivanti) was evaluated for selected high yielding/ superior genotypes of this plant. Morphological juvenility markers in Neem and Ardu have been identified to develop reliable macropropagation method. Significant differences in morpho-physiological characters of male and female trees were also recorded which can help in enhancing productivity by planting selective female Ardu trees.

2.3.1.1 Project under the theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2017-18
Plan	1	4	1
Externally Aided	1	2	1
Total	2	6	2

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).

Surface sterlized explants (leave segments, stem nodes, immature fruits/embryos) were cultured on MS medium containing 2, 4-D, IAA and NAA auxins at 2.5 mg/L concentration. Callus induction was successful. Experiments on regeneration from callus cultures were initiated. The callus obtained from immature fruits resulted in formation of somatic embryo after moving the callus to hormone free medium (Fig 13). Callus cultures from leaf segments were further transferred to medium containing IAA and NAA. Callus turned green and compact with signs of shoot primordial formation. Two *Agrobacterium*-strains (GV-3101 and LBA-4404) were procured cultured at AFRI and the stocks are being maintained. These bacteria will be used for transferring the desired genes to neem cell lines in future. The plasmid vector pCAMBIA containing one reporter gene and scorable marker (GFP and GUS) has been procured and experiments on transferring the plasmid pCAMBIA to the competent cells of *Agrobacterium* strains is underway. Approval of Institute Biosafety Committee (IBSC) has been obtained from the Review Committee on Genetic Manipulation (RCGM), Government of India, New Delhi.

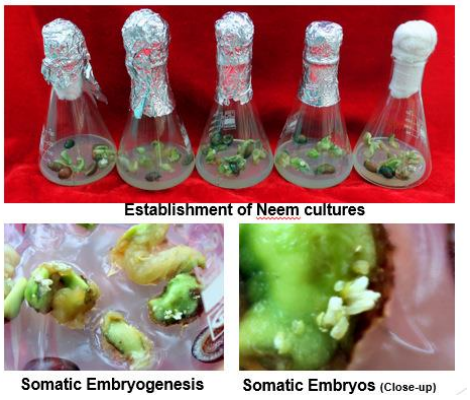


Figure 13. Establishment of Neem cultures from immature fruits (top); Initiation of Somatic embryos of Neem (bottom left); Close-up of somatic embryos (bottom right).

Benefits of the research project: This research programme addresses the problem of frost-susceptibility of Neem trees. It will lead to the introduction of two types of genes, one that stabilizes the protein structures through synthesis of a cellular protectant compound glycenebetaine and the other that enables removal of metabolic toxic compound, methylglyoxal (MG) from the cells produced during cold-shock.

Scientific names of species with vernaculars in parenthesis: *Azadirachta indica* (Neem)

Project 2: Development of Seed Production Area and Haploid plants in *Commiphora wightii* (Arnott) - A rare and threatened medicinal plant (AFRI-35/FGTB/NMPB/2016-19)

Twenty-two genotypes (A0104, A0201, A0303, A0404, A0601 & A0701, B0115, B0202 & B0211, C0118, C0305, C0309, C0312, C0317, C0406, C0412, C0419, C0511, C0516, C0609, C0617, D0409) were selected having equal or above 80% black seeds as well as high total seed yield out of 660 genotypes screened. Two hundred stem cuttings of ten male plants were raised in mist chamber in July 2017. A total 96 male plants have been developed through cuttings and are growing well in FGTB nursery (Fig 14).

Figure 14. Sprouting in stem cuttings of male plants.

Pollen studies revealed significant variation in size though the number of pollen grains per anther were very poor (25-50). Pollen radius ranged from 18 to 54 µm. Seven male genotypes were separated into two homogeneous groups after DMRT (Fig:15).

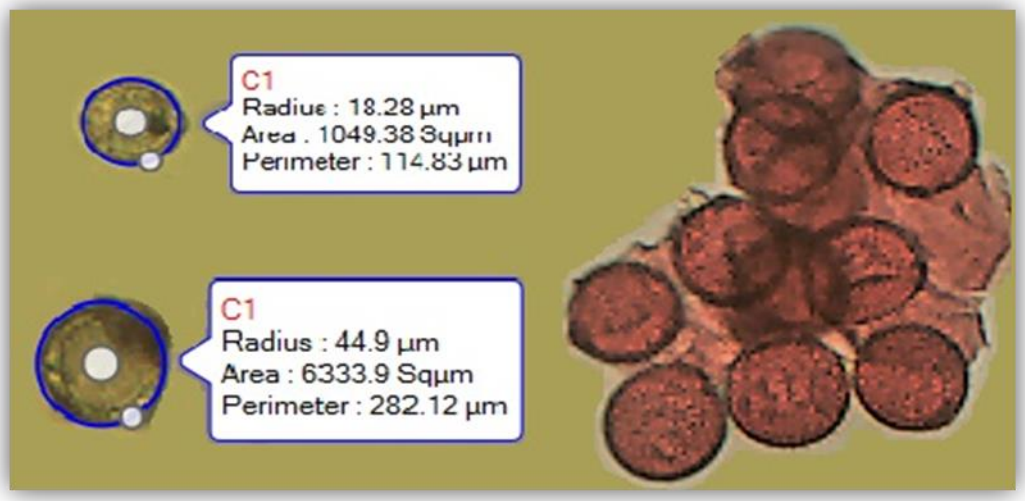


Figure 15. Microscopic view of pollen grains and their measurements.

Benefits of the research project: The inforamtion of superior gerplasm is beneficial to SFDs for *ex situ* conservation of Guggul a critically endegered medicinal plant. As well as it will be useful in developing agrotechnique and domestication of Guggul.

Scientific names of species with vernaculars in parenthesis: *Commiphora wightii* (Guggul)

Project 3: Studies on phenology, molecular analysis and wood properties of *Tecomella undulata* with respect to three flower color morphotypes (AFRI-45/FGTB/ICFRE/2017-2020)

To study the phenology of *Tecomella undulata,* a site in Jalore district (Bhadrajune) was identified and total of 68 trees were marked. Leaf size, flower size, pod size, flowering pattern and percentage for each of the marked trees were recorded accordingly (Fig 16). To study the density pattern of the species quadrates of 30 m X 30 m were laid at two sites in Nagaur, two sites in Sikar and one site each in Barmer and Jodhpur district of Rajasthan. For molecular analysis of three flower color morphotypes of *Tecomella undulate*, 25 Scot markers were shortlisted.

Figure 16. Flowering observed in an identified population of *Tecomella undulata.*

Benefits of the research project: The project has logterm benefits for improving wood production and quality for arid and semi arid areas and main beficiries are timber industry, SFDs and even farmers.

Scientific names of species with vernaculars in parenthesis: *Tecomella undulata* (Rohida)

Project 4: Identification of juvenility markers to improve rooting potential of some important tree species. (AFRI-31/FGTB/ICFRE/2016-20).

The coppicing potential of Ardu, Neem and Rohida were studied and the results showed that after 11 weeks of coppicing, average shoot numbers in Ardu and Neem were 3.80±0.31 and 3.69±0.74 respectively, while it was lesser in Rohida (1.40±0.24) (Fig 17). The average shoot length after 11 weeks was greatest in Ardu (10.36±1.03 cm) and it was almost equal in Rohida (7.40±1.75 cm) and Neem (7.20±1.77 cm). The markers for the juvenility were identified on the basis of leaflet numbers in Ardu and Neem. The appearance of three leaflet number in initial stage indicates juvenile nature. The coppiced shoots showed juvenile nature as at first stage three leaflets were observed in Ardu as well as in Neem. Seedlings of Ardu and Neem start with three leaflets and go upto nine leaflets in 30-32 weeks. Coppiced shoots grew faster and reached at nine leaflet stage after 12-14 weeks. The leaflet number in mature tree of Ardu and Neem reached to 29 leaflet and 21 leaflet respectively.

Figure 17. Coppicing potential in Ardu, Rohida and Neem.

The rooting potential of juvenile shoots in neem was investigated by dividing the coppiced shoots on leaflet number and results revealed gnificant difference ($P<0.01$) in rooting potential between these cuttings. Maximum rooting (41.25%) was observed in cuttings of stage 13 leaflet number followed by 11 leaflet number (24.7%). Mature cuttings showed 1% rooting

only. In rohida, the rooting in coppiced shoots was very poor and cuttings were dried after callusing.

Benefits of the research project: It is highly important for tree species to identify juvenile markers for developing a consistent macro propagation protocol of selected species Neem, Ardu and Rohida. By Identifying juvenility markers propagation technique will be robust and reproducible as desirable for commercial purpose. A guideline to field forester will also be prepared to develop viable vegetative propagation technique to raise cutting in field conditions.

Scientific names of species with vernaculars in parenthesis: *Ailanthus excelsa* (Ardu), *Azadirachta indica* (Neem) and *Tecomella undulata* (Rohida)

Project 5: Induction, evaluation and development of polyploides in *Azadirachta indica* (AFRI-20/Sil./Ext.(IFFCO)/2015-2018).

This is a coordinated project and major contributor is FRI Dehtradun. The insititute part of this project was completed in 2017-18. Seed collected from selected trees was supplied to FRI, Dehradun with all basic information for further linked activities. Progeny established from superior trees at AFRI nursery for establishing field trail by FRI Dehradun.

Benefits of the research project: IFFCO, New Delhi is the sponsorer of this project and also the main beneficiary of the research output. Being a national research problem, the longterm benefits will be providing neem oil for coating urea.

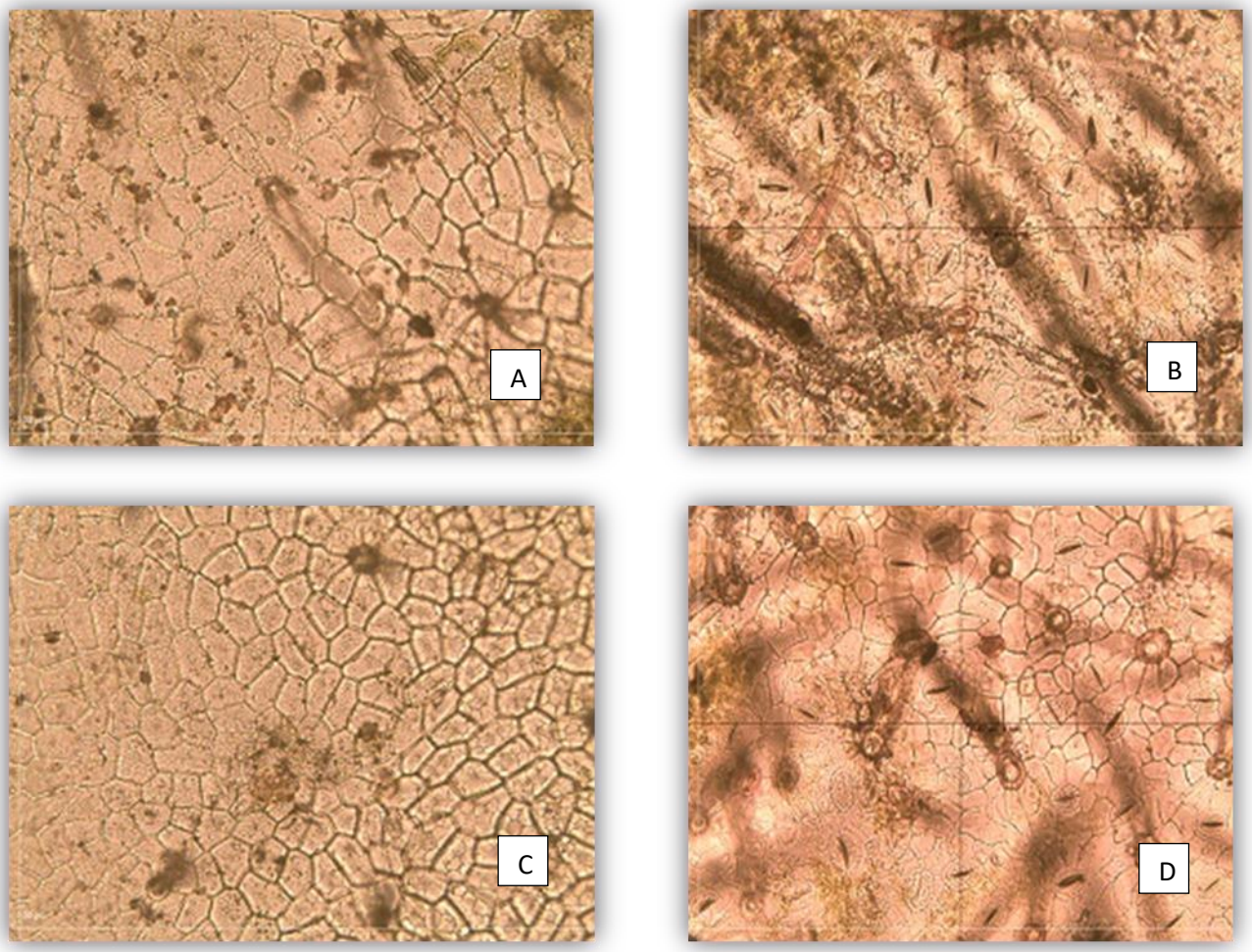
Scientific names of species with vernaculars in parenthesis: *Azadirachta indica* (Neem)

2.3.4 Vegetative Propagation:

Project 6: 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).

Studies carried out on the morphological and biochemical characters viz. bark colour, chlorophyll content, leaf length, leaflet surface area, leaf hair density and stomatal index of male and female adult trees of *Ailanthus excelsa*. Analysis of these studies revealed that female have higher stomatal index (11.01±0.23), chl-a (50.70±3.64 µg/ml) and chl-b (1.73±0.13 µg/ml)

contents as compared to male, where the stomatal index was 9.86±0.89, chl-a was 46.95± 5.05 µg/ml and chl-b was 1.58 ± 0.16 µg/ml. Leaf thickness and leaf hair density was higher in male as compared to the female trees (Fig 18). Male trees also have higher leaflet surface area (65.15±1.92 cm^2) and leaflet length (17.52±0.27 cm) as compared to female trees (39.43±1.97 cm^2 and 14.69 ±0.31 cm, respectively). Leaf samples were collected from 33 Male and 39 female Ardu trees from the plantation at Deesa, Gujarat and DNA was extracted and purified. Total 31 RAPD primers were screened for identification of DNA markers for male and female trees. Out of 31 primers, only 8 polymorphic primers were selected for further amplification. The DNA bands produced by these polymorphic primers were analysed to distinguish the gender. Unfortunately, all these 8 primers could not separate sample population of trees into two clear gender groups.



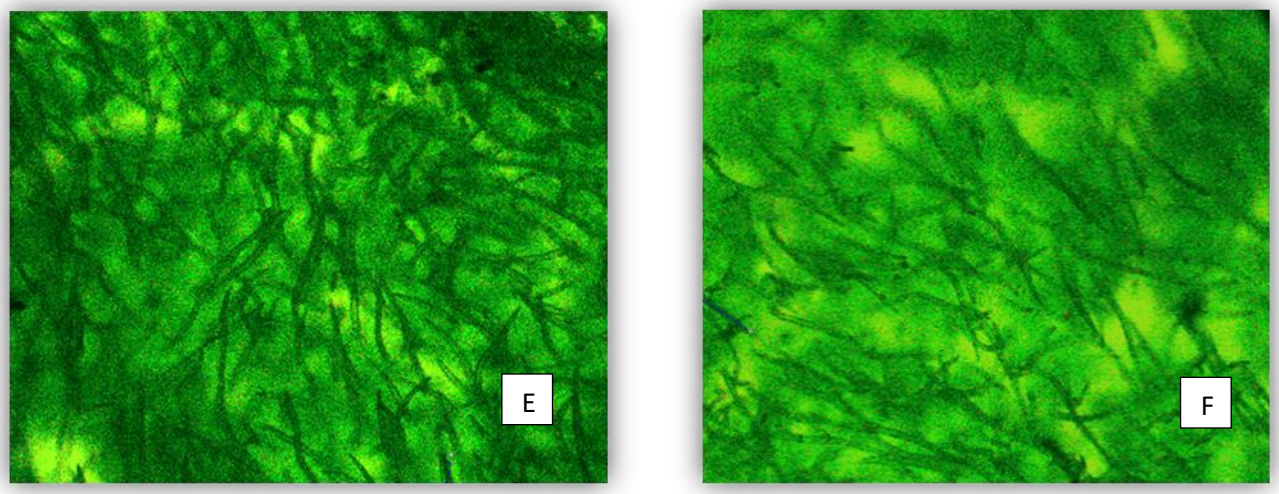


Figure 18. Stomatal density on adaxial (A) and abaxial (B) leaf surfaces of female and adaxial (C) and abaxial (D) leaf surfaces of male ardu trees and leaf hair density of male (E) and female (F) ardu trees.

Benefits of the research project: Enhancement of biomass production by screening female plants at nursery stage using morphological, biochemical or molecular markers.

Scientific names of species with vernaculars in parenthesis: *Ailanthus excelsa* (Ardu)

2.3.5 Biotechnology

Project 7: Development of tissue culture protocol for economically important bamboo-*Schizostachyum dullooa*. (AFRI-29/FGTB/ICFRE/2016-19).

Survey was conducted in Rajpipla (Gujarat) area and plant material and nodal segment were collected. Shoots proliferated from offsets established at AFRI nursery were collected and surface sterilized with 0.1% Mercuric chloride for 4-8 mins. The sterilized nodal segments were finally washed 3-4 times with autoclaved distilled water and inoculated on medium. Murashige and Skoog's medium supplemented with different concentration of BAP (1.0-7.0 mg/l) were tested for axillary bud proliferation. 0.7% agar was used to solidify the medium. 3% sucrose was added to the medium as a carbon source. The pH of the medium was kept between 5.8- 6.0. Best axillary bud break was achieved on MS medium supplemented with 5.0 mg/l BAP. 2-3 shoots proliferated from single axillary bud. Proliferated shoots were sub cultured on fresh MS medium supplemented with cytokinin after 4 weeks of inoculation. The proliferated shoots were excised and transferred in fresh MS medium supplemented with BAP for *in vitro* shoot multiplication. Large scale *in vitro* shoot multiplication is in process.

Benefits of the research project: Being used in kite making, development of Tissue Culture Protocol and mass production of this species will help Gujarat State in revenue generation and overcome its dependence on North-East State for this resource.

Scientific names of species with vernaculars in parenthesis: *Schizostachyum dullooa* (Dolu bamboo)

Project 8: *In-silico* identification of abiotic stress-tolerance candidate genes using co-expression network analysis and comparative genomics. (AFRI-30/FGTB/ICFRE/2016-18)

Bioinformatics (*in-silico*) tools are being used under the current programme to carry out new gene exploration and identification for abiotic-stress tolerance. Huge amount of experimentally validated data is being queried and processed through different bioinformatics and statistical tools and analyzed for identification of genes associated with abiotic stresses tolerance. The genes so identified are then being used to identify related genes in tree species like *Populus. Arabidopsis* has been chosen as the primary species because maximum research has been done on it and thus maximum data is available in public domain. In trees, *Populus* is the tree selected because its genome sequence data is available to enable orthologous-gene identification and new associated gene-mining.The project aims to look for such genes, for which functional assignment is not yet there. Through correlational bioinformatics analysis, such putative genes are searched under this study, that have similar expression pattern, as the well-known genes involved in a plant's abiotic stress tolerance mechanism. Co-expression network analysis has been conducted gene by gene for shortlisted 100 genes, using bioinformatics platform-ATTED-II. Based on this analysis, gene co-expression networks have been constructed. Work on identification of orthologous genes in Poplar was completed. The Secondary Clusters were finalized. Linked genes were tabulated and were further used for functional analysis. BlastP searches against the *Populus* genomic datasets for identification of orthologous genes associated with abiotic stresses in the tree species (i.e., Populus) was completed. Reciprocal Best Hit (RBH) one-to-one analysis through two-way BlastP was initiated and completed successfully. Final data analysis is underway and findings would be brought out in due course.

Benefits of the research project: 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.

Project 9: Non-destructive *in vitro* production of pharmacologically-active natural extract containing guggulsterones – a potent cardio-protective and anti-cancer drug from *Commiphora wightii* (Guggul) using bioreactor. (AFRI-46/FGTB/NMPB/2017-20)

Immature fruits were collected from plants of *Commiphora wightii* growing growing at AFRI nursery and also from tissue culture raised plants growing at AFRI campus, Jodhpur. Embryos were scooped out from immature fruits and inoculated on Gamborg's B5 medium supplemented with 0.5 mg/l 2, 4-D. Callus obtained were further inoculated on hormone free B5 medium for induction of somatic embryogenesis. Non-embryogenic callii upon further media manipulations were converted to embryogenic state. Immature fruits were also collected from the above-mentioned sources and were used as an explant for somatic embryogenesis protocol. Fruits were soaked in water. The floating fruits were discarded. Only the settled fruits were used as explant source. These were washed with tween 20 followed by bavestein and streptomycin treatment. Finally fruits were surface sterilized with 5% NaOCl. Embryos were scooped out from immature fruits and inoculated on Gamborg's B5 medium supplemented with 0.5mg/l 2, 4-D. Callus obtained was further inoculated on hormone free B5 medium for induction of somatic embryogenesis. Embryogenic callus were transferred to modified MS medium supplemented with 0.1 mg/l IBA, 0.25 mg/l BAP and 0.5% activated charcoal.

Tissue culture raised plants showed 66.66% callusing while callusing from seed raised plant source was only 57.24% on Gamborg's B5 medium (Fig 19). Percentage of conversion of primary callus to embryogenic state was 78.94% in explants derived from tissue culture raised mature plants compared to only 60% in case of explants from seed derived plants. Explants from tissue culture raised plants were more responsive with fast somatic embryogenesis in just 15 days of inoculation. Our protocol for somatic embryogenesis in *C. wightii* is reproducible and showing good results. This embryogenic calli would be further tested for guggulsterone content and used for production of natural extract containing guggulsterones.

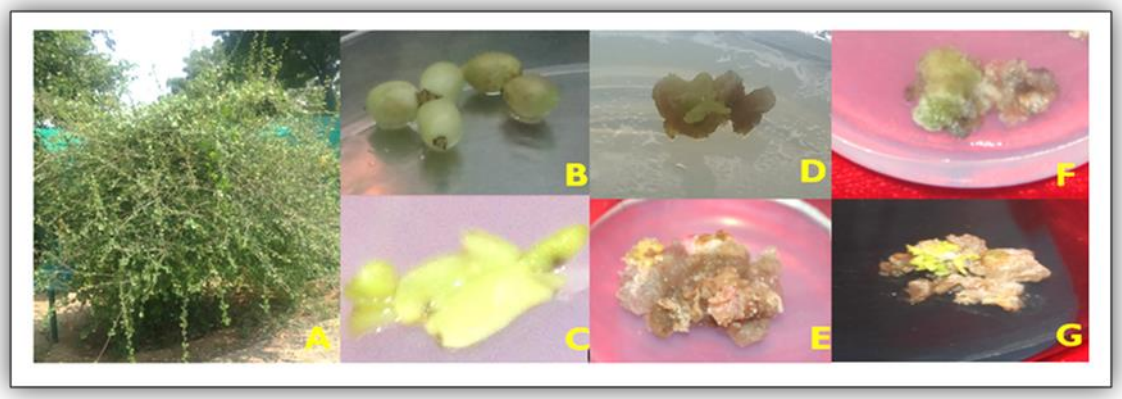


Figure 19. A- Guggal plant growing at AFRI nursery, B- Immature fruit, C- Scooped out embryo, D- Callus initiation on Gamborg's B5 medium, E- Callus multiplication, F- Conversion of non embryogenic callus to embryogenic callus, and G- Development of somatic embryos on modified MS medium

Benefits of the research project: The project envisages the development of - a scalable technology for non-destructive production of natural guggulsterone-rich extract from the plant through a bioreactor that has high potential for commercial exploitability without putting pressure on already dwindling natural populations of this critically endangered species.

Scientific names of species with vernaculars in parenthesis: *Commiphora wightii* (Guggul)

Project 10: Clonal propagation, characterization and biochemical analysis of *Leptadenia reticulata* – A threatened medicinal plant. (AFRI-36/FGTB/Ext (NMPB)/2016-19).

During surveyed *Leptadenia reticulata* plants were selected from 4 sites in Jodhpur, Barmer and Pali. Collected nodal shoot segments were surface sterilized with detergent and were kept in chilled antioxidant solution for 3-4 hours then were treated with tetracycline, streptomycin and fungicide (Bavistin) and 0.1% Mercuric chloride for 8 minutes. These sterilized explants were inoculated on MS medium supplemented with cytokinins (BAP and Kn). Different range for BAP (1 to 5 mg/l) and Kn (1 to 5 mg/l) were tried. Out of which, 5mg/l BAP was found best for induction of shoots. Different experiments were set up for *in vitro* shoot multiplication. Best *in vitro* shoot multiplication was obtained on MS medium supplemented with 1.5 mg/l BAP and 0.5 mg/l Kn. For *ex vitro* rooting, *in vitro* raised shoots were pulse treated with different range of auxins (IBA and NOA). Best result was obtained by pulse treatment of *in vitro* raised shoot for 3 minutes with 200 mg/l IBA. Micro shoots were *in vitro*

rooted. Different ranges of auxins (IBA and NOA) alone and in combination were tried. IBA was found best for *in vitro* root induction (Fig 20). Best results were obtained on one fourth MS medium supplemented with 2.0 mg/l IBA and 100 mg/l activated charcoal. Various explants were tried for the induction of callus (leaves, flowers, immature seeds and internodal segments) and various PGR's were tested for callus induction. Out of this 2 mg/l 2, 4-D was found best for the initiation of callus. 2, 4-D (0.5 mg/l) + BAP (0.5mg/l) + additives were found suitable for proliferation of callus. Callus was found creamy to pale green, fast growing and organized. Further experiments were conducted for organogenesis and embryogenesis from the proliferated callus. 0.8 mg/l BAP and 0.1 mg/l NAA was found suitable for the induction of embryogenesis in callus from immature seeds and organogenesis in callus from leaf.

Figure 20. Tissue culture studies on *Leptadenia reticulata*

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

Scientific names of species with vernaculars in parenthesis: *Leptadenia reticulata* (Jivanti)

2.4 Forest Management

Nil

2.4.1 Overview

2.4.1.1 Project under the theme

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)

2.5 Wood Products

2.5.1 Overview

One project covered under this thrust area wherein value added wood Products from treated and seasoned wood of lesser utilized tree species like *Azadirachta indica* and *Acacia senegal* were prepared with the help of handicraft industry in Jodhpur.

2.5.1.1 Project under the theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2017-18
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

Rajasthan is well known for its woodwork and Jodhpur wooden furniture has been always in great demand across India and outside the country. The problem faced by the industry was highlighted in RAG meetings regarding short supply of traditionally used wood species. Wood from three species *viz*. *Acacia tortilis, Prosopis cineraria* and *Prosopis juliflora* treated with combinations of preservative chemicals Chromated copper Arsenate (CCA) and chloropyriphos in June 2004. Value added product like sofa set, utility box and pen/pencil stand showed resistance to insect pest and termites till September 2017, indicating their potential for use in handicraft industry. In continuation to that, work on *Azadirachta india* (Neem) and *Acacia*

senegal (Kumath), which are important but underutilized tree species of arid region, was initiated in 2014 with alternative treatments due to problems with CCA treatment. Sawn wood of both the species was treated with prevailing industrial method- a synthetic Biflex Tc used as chemical preservative by Sun Art Export Jodhpur and a complex mixture of Copper sulphate, potassium dichromate and *Prosopis juliflora* bark extract (prepared at IWST Bangalore) at 2.5% dilution with water. After treatment seasoning with standard method of wood was done at Sun Art Export Jodhpur. Value added products with carving were prepared. Coffee table with chip carving was prepared in April 2016. So far there is no sign of deterioration. After wards display boards of size 5' x3.5' and **Book shelf and small almirah** of Neem wood and photo frames and Side Table with carving from *A. senegal* wood were also prepared (Fig 21).

Figure 21. Utilization of Neem and *A. senegal* woods in preparation of different carved utensils. Items 1 to 4 are from *A.indica* wood and 5-6 from *A.senegal* wood.

Thus idententified alternate tree species as source of wood for making handicrafts may reduce the cost because of utilization of unutilized/plantation grown wood and improve the life of wood by simple chemical/preservative treatments and becomes a potential source of handicraft industry.

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

Scientific names of species with vernaculars in parenthesis: *Azadirachta indica* (Neem*)* and *Acacia senegal* (Kumat).

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

To increase utilization of NWFPs and enhance livelihood opportunities of local people six projects were executed. In this phytochemical analysis and value addition of wild fruits from arid and semiarid areas was carried out. Nutritional analysis of *Prosopis cineraria* (khejri) and *Capparis decidua* (kair) fruits at different developmental stages and seasons indicates that kair should be collected in March-April season, whereas Sangri should be collected when it is 2-2.5 mm thick. Demonstration cum training programme on value addition of *Manilkara hexandra* and *Momordica dioica* were also organized. Role of Neem products in socio-economic upliftment of rural livelihood through compost bins preparation and Neem litter compost were also demonstrated to farmers in Pali district that received a good response.

2.6.1.1 Project under the theme

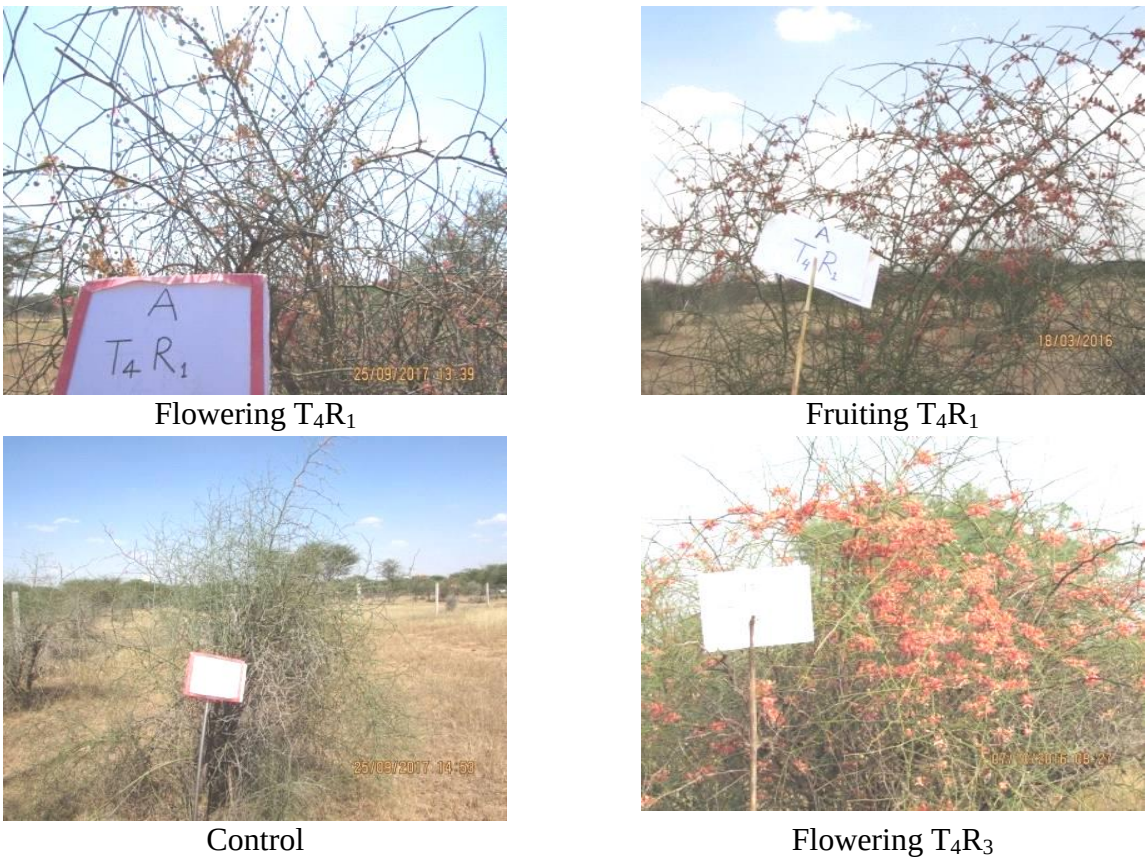
Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2017-18
Plan	1	-	1
Externally Aided	4	-	-
Total	5	-	1

2.6.2 Resource Development of NWFPs

Project 1: Productivity enhancement of Kair (*Capparis decidua*)) to generate livelihood in rural areas of Thar Desert" AFRI -07/NWFP/Ext (SFD, Raj) / (2013-18)

Capparis decidua is the most important indigenous NTFP yielding shrub species, the fruits of which yield supplementary income to the rural people as it is converted to pickles as value added product with very high demand. The market prices are continuously rising from 80-

100 Rs /kg in 1995 to 1000-1200 Rs/kg in 2017 respectively. The rate increases with decrease in size of fruits. However, they are mainly collected from the wild with no effort for its domestication. This project was taken in collaboration with SFD Rajasthan and after a survey experimental field was selected in July 2013 in Gogelao beed forest area in Nagaur. All the plants were divided into three blocks. Three trials were laid. Various treatments were: leaf compost (LCM), goat FYM (GM), and VAM in combination with SSP, SSP + K, K, Zn and SSP, K, + Zn and NPK etc., along with irrigation in October 2013 (Fig 22). The results of LCM with inorganic fertilizers gave best results.



Flowering T_4R_1 Fruiting T_4R_1

Control Flowering T_4R_3

Figure 22. Plants of *Capparis decidua* growing in the field condition under different treatments.

C. decidua growth suffered of frost damage during December 2013 – January 2014. Irrigation was provided for recovery and annual growth data collected. The growth recovery was slow and the mean height and crown increment was 8.01% and 8.45% respectively in 2013-14 under low total rainfall of less **457.7 mm.** The increment was 14% and 12.2% for height and

20.71 and 11.29 % for Crown diameter in 2014-15 and 2015-16 respectively. The total rainfall for 2014-15 was **535.5 mm** and 2015-16 was **464.2 mm** respectively. Two way ANOVA for cumulative data indicates significant ($P<0.05$) variations in mean height and crown diameter. Application of fertilizer enhanced the growth. Treatment effect was also significant in case of height ($P<0.05$) where all the treatments recorded more height than control and with 18.8% overall increment with LCM+ Zn followed by 13.06% with LCM, P, K and Zn combination and only 5.46% in the control. Increment for crown diameter was also higher in treated shrubs as compared to control.

Phenological observations indicated three times flowering and fruiting in a year. Phenological observations in April, July and October 2014 to 16 were recorded for per cent fruiting shrubs, total fruit yield and per shrub fruit yield for all the treatments. Three years cumulative data revealed that a combinations of LCM, P, K and Zn was best treatment recording almost 100% fruiting shrubs throughout seasons in all three years (Fig 23) followed by LCM+NPK combination with 88.9% and LCM + K combination with 74.5%, whereas in control it was only in 22.5% shrubs. Application of LCM only enhanced it to 44.5% but it was still significantly less than other treatments where LCM was applied with inorganic fertilizers. Seasonwise, April recorded 73.2% percent fruit shrubs closely followed by October 72.6%. Fruiting was only in 47.5% shrubs in July. Control shrubs recorded minimum values in all three seasons.

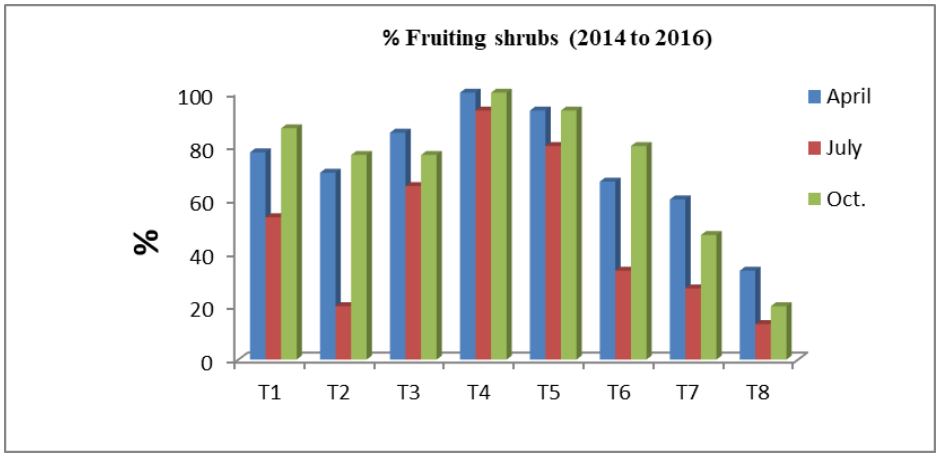


Figure 23. Per cent fruiting shrubs in different season under different treatments.

Average fruit yield was 1129.0 g for T_4 treatment (LCM +SSP+K+Zn) which was significantly high as compared to all treatments. T_5 (LCM+NPK)with 516.0 g was at second place and T_1 (LCM+SSP+K) with 491.9 g was third compared to 61.8 g for control. Application of LCM only in T_7 treatment (LCM) enhanced the yield to 114.1g only indicating the additive role of inorganic fertilizers (Fig 23). It resulted in maximum fruit yield per season for T_4 treatment which was 10.2 times more (796.32 g to 78.01 g)) than control in April , 2.24 times more in July (800.2 g to 35.71 g) and almost 100 times more in October (1790 .7 g to 71.7 g). Total fruit yield was high in October than April indicating the positive influence of moisture conservation (Fig 24).

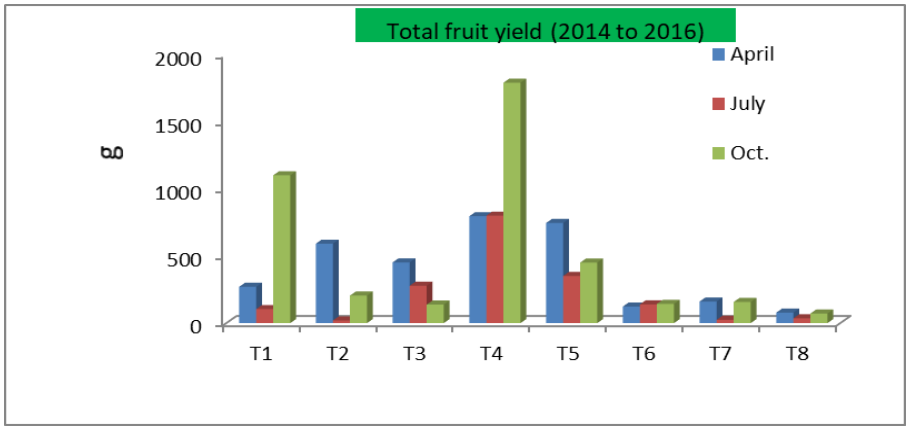


Figure 24. Total fruit in different years influenced by different treatments.

Under LCM treatment, per plant yield was maximum for T_4 (261.3g) followed by T_1 (168.5g), T_5 (114.3g) and 46.5g in control. Per plant yield values for T_7 LCM (41.9g) and LCM +Zn (35.3g) treatments were less than control indicating that treatments enhanced the number of fruiting shrubs but not the per shrub (Fig 24). Two ways ANOVA indicated the positive effects of treatments on per plant yield in all seasons and was mainly due to per shrub yield. The difference between T_4 and control was 5.32 times in April, 5.15 times in July and 5.98 times in October (Fig 25). A combination of LCM, P and K (T_1) was second best treatment followed by a combination of LCM and NPK (T_5).

Annual fruiting frequency i**n 2014** indicates that 20% shrubs fruited 3 times, 32.5% shrubs fruited 2 times and 27.5 % plants fruited only 1 time. There were 20% plants (8 nos) which did not fruit at all, four of which belonged to control (Fig 26). In **2015,** 35% shrubs fruited 3 times, 40% shrubs fruited 2 times and 20% plants fruited only 1 time. There were 2 plants

(5%) one each in control and LCM only treatments did not fruit. In 2**016,** 55% plants fruited 3 times, 17.5% plants fruited 2 times and 20% plants fruited only 1 time. There were 3 plants (7.5%) two in control and one in LCM only treatments did not fruit. These unfruited plants though belonged to T_7 and T_8 (Control) treatments but different than those in 2015.

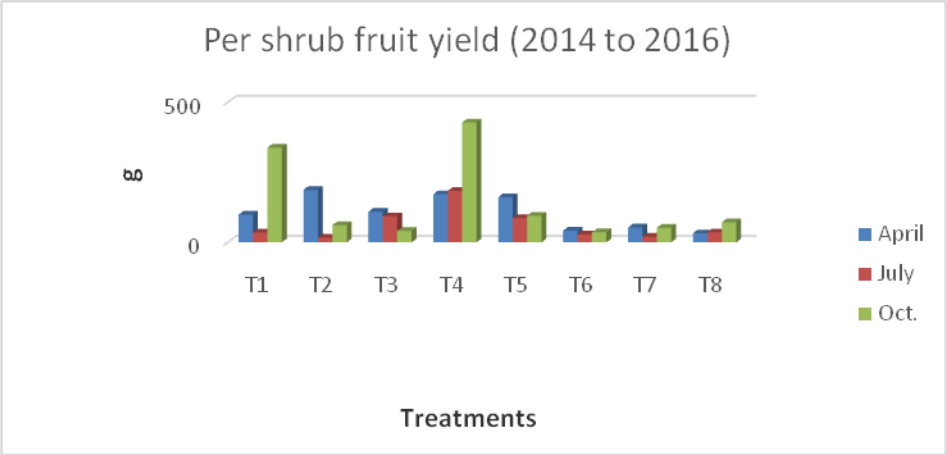


Figure 25. Per shrub fruit yields in different season influenced by different treatments.

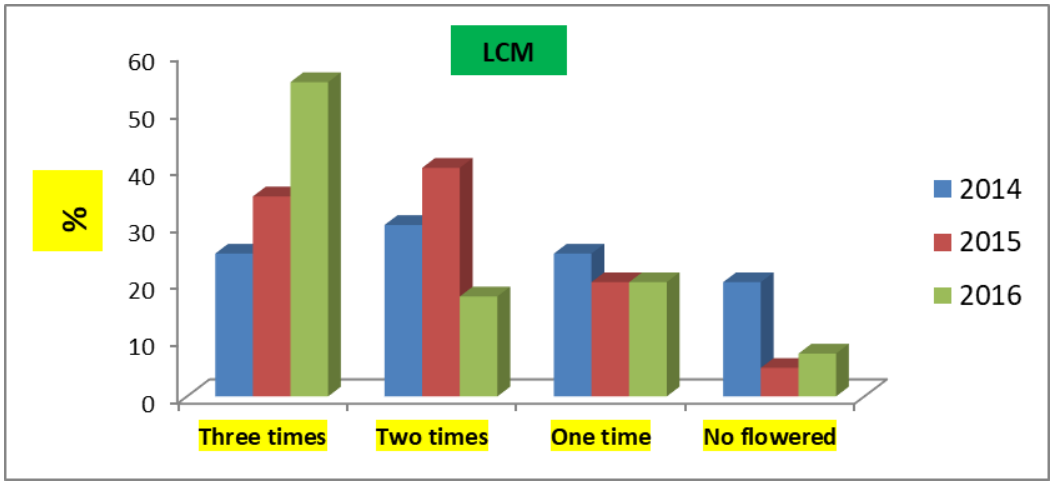


Figure 26. Per cent fruting shrubs in different years.

Initial soil pH values ranged from 7.82 to 8.39, EC 0.27 to 0.39 dSm^{-1} and organic carbon (0.28 to 0.51%) in 0-20 cm soil. Soil pH in 2016 was 7.83 (ranging from 7.74 to 8.17 in different treatments) in 0-20 cm soil layer and 7.90 (7.71 to 8.16) in 20-40 cm soil layer are in similar range to initial values indicating no adverse effect of the treatments even after three years in LCM combinations. Soils EC were 0.51 and 0.53 dSm^{-1} for 0-20 and 20-40 cm soil layers

respectively in 2016 which were slightly higher than initial values but were within the normal range. Per cent SOC was 0.143 in 2014 showing an increasing trend compared to initial values and rose to 0.373 in 2015 and 0.468% in 2016 in 0-20cm soil layer. These values were lesser for 20-40 cm soil layer.

Conclusively, integrated use of organic and inorganic fertilizers is helpful in enhancing the number of fruiting shrubs and per shrub yield. LCM in combination with inorganic fertilizer provided highest fruit yield. In the treated shrubs, three times fruiting was under a combination of LCM, P, K and Zn, closely followed by a combination of LCM and NPK. Moisture conservation led significant fruit yield recoded in October also. Protein, Sugar and Vitamin C contents were similar for the fruits obtained in April and October and hence can be utilized.

Benefits of the research project: Beneficial effects of soil and moisture conservation and unse of organic and inorganic fertilizer enhancing fruit yield and help conserve biodiversity and people levelihoods.

Scientific names of species with vernaculars in parenthesis: *Capparis decidua* (Kair)

Project 2: 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).

For preparation of neem litter compost Sonai Manji, Lundawas and Bilawas villages were identified as Model Villages. An interactive meeting with villagers was organized at Sonaimanji village for selection and finalization of site for construction of compost bins. After a detailed discussion with DST experts and concerned farmer, two sites in Sonai Manji and three site in Sojat were selected. Five compost bins of size 3m x 1.8 m x 0.9 m capacity were constructed in July 2017 and neem litter was dumped. The ingredients were neem litter, animal dung and soil in the ratio of 45:5:50 by weight. About 22-50 1itre of water was sprinkled twice a week for about 120 days for complete decomposition of the material (Fig 27). The compost was then sun dried, grinded and filled in gunny bags and is being used by farmers. This compost was used in one acre agriculture field and good response was obtained. The operational cost was Rs. 11,490/- for 1045 kg compost.

Figure 27. Various steps in neem litter compositing (top) and compost preparation and storage (bottom).

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 the midlleman.

Scientific names of species with vernaculars in parenthesis: *Azadirachta indica* (Neem)

2.6.3 Sustainable Harvesting and Management:

Project 3: Standardization of non-destructive harvesting practice of *Commiphora wightii* gum oleogum resin. (AFRI-01/NWFP/Ext (NMPB)/2014-17).

Commiphora wightii is a valuable oleo-gum-resin yielding plant widely used in Ayurvedic medicines. The traditional destructive guggul gum harvesting methods were one of the causes of its population decline and making this plant critically endangered. The traditional unscientific methods include making several deep incisions in stem and applying of a paste

containing guggul gum, horse urine and copper sulphate to increase the gum yield. Earlier, ethephon and bacterial treatments were also done to increase gum yield which results in mortality of the plant and weaken the plant growth. Therefore, it was a necessary to develop a non-destructive guggul gum harvesting technique. The scientific non-destructive gum tapping techniques was developed by standardizing precise depth, orientation and size of cut to optimize the gum yield (Fig 28). Annual pattern of gum yield, correlation with girth size and site factors were also studied. It includes horizontal 8 cm cuts with 2 mm depth on the primary branches that yielded about 10 g of guggul gum per plant when the gum harvested twice in winter (November and February). Guggul gum can be harvested recurrently year after year using this method without any mortality and loosing growth of the plant due to treatments. This gum yield can be further increased with application of fertilizer and irrigation management.

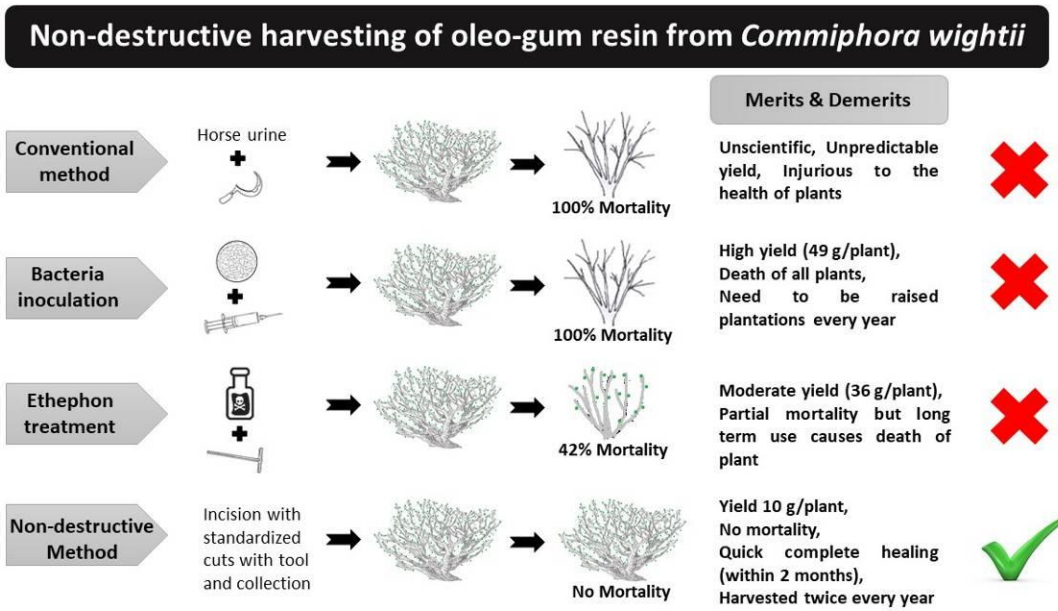


Figure 28. Non-destructive harvesting of oleo-gum resin from *Commiphora wightii*

Benefits of the research project: Development of non destructive oleo-gum harvesting method was required by SFDs of Rajasthan and Gujarat and NMPB, New Delhi for sustainable utilization. This method is benefical to SFDs and pharmacutical companies and the researchers to sacleup further for commercial application.

Scientific names of species with vernaculars in parenthesis: *Commiphora wightii* (Guggul)

2.6.4 Chemistry and NWFPs, Value Additional and Utilization:

Project 4: 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).

Sugar, protein and seed oil content were determined for *Capparis decidua* (Kair) and *Prosopis cineraria* (Khezri) fruits (Fig 29). In kair fruits sugar content was high in March-April season fruits (10.83 %) and minimum in fruits of July-August season (8.67%). Protein content was maximum in July-August season (13.56%) and minimum in March-April season fruits (10.15 %). Fatty oil content in kair seeds showed maximum oil for the fruits of winter season (19.15%) and minimum (13.51%) in case of fruits of April. Variation of sugar and protein in different categories of kair was also studied. In case of April season fruits, sugar increased from category (cat) 3 (19.99%) to cat 4 (11.58%), it then decreases in cat 5 (19.14%) and increased again in cat 6 (10.6%). Other season fruits also showed similar trend in sugar content. Protein content also varied in similar way. It increased from cat 3 (7.46 %) to cat 4 (10.96%), it then decreased in cat 5 (10.0 %) and increased again in cat 6 (12.2 %).

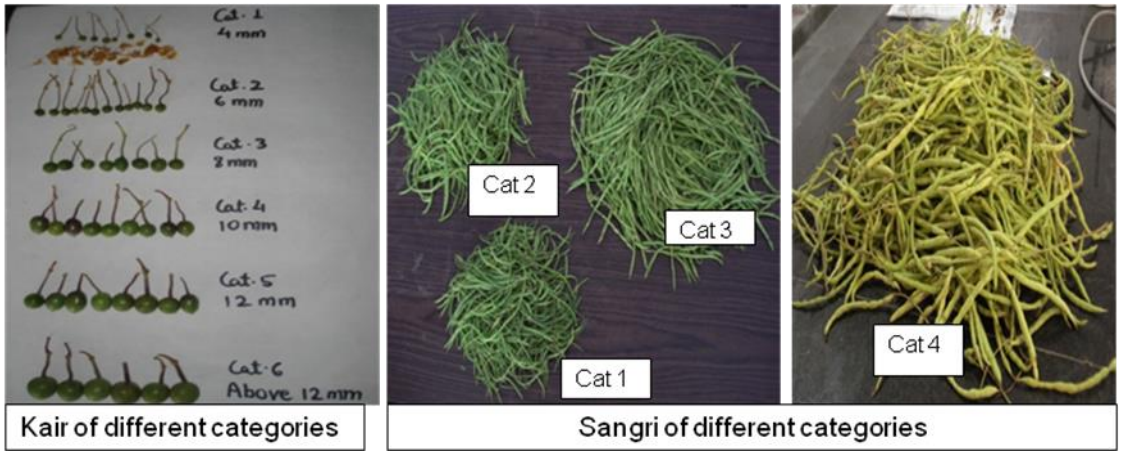


Figure 29. Variation in fruit size of Kair and Sangari collected from different locations.

Sugar and protein content of khezri fruits were also determined in different categories viz. Cat 1(Immature) < 2 mm, Cat 2 ((Immature) 2-2.5mm, Cat 3 (Mature) 2.5-3.5 mm, Cat. 4 (Ripe) 3.5-5.5 mm. The sugar content increased from cat 1 (11.57 %) upto cat 3 (14.8 %) and then decreased in cat 4 (10.81%). It increased again in ripe pods (13.06%). Protein content increased upto cat 2 (12.24%) and then decreased from cat 3 continuously.

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

Scientific names of species with vernaculars in parenthesis: *Prosopis cineraria* (Khejri) and *Capparis decidua* (Kair)

Project 5: 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).

For value addition of *Manilkara hexandra* (Khirni) fruits by SHG members in Jamboori village a training cum demonstration programme in Abu Road block of Sirohi district in Rajasthan was organised from 16th -18 th April 2017 and SHG members were linked with Zila Udhyog Kendra, Sirohi so that they may sell their value added products in various Kisan Mela etc (Fig 30). In off season, SHG member earned Rs. 1000/- to Rs. 1600/- per member by selling of value added fruits.

For value addition of *M. dioica* (Kankeda) fruits by SHG members in Jamboori three days training cum demonstration programme was organized during 4-9-16 to 6-9-16 and repeated in 20-8-17 to 22-8-17 or members of Bhurki Devi Mahila SHG, Jamboori (Fig 31). It was constituted with the help of SFD, Rajasthan and Prabhu Foundation, Sirohi in tribal dominated area of Abu Road (Sirohi district, Rajasthan). SHG members were linked with Zila Udhyog Kendra, Sirohi.

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

Scientific names of species with vernaculars in parenthesis: *Manilkara hexandra* (Khirni), *Momordica dioica* (Kankeda)

Sorting and washing of good quality fruits

Scanting off excess water **Deseeding after 48 hours**

Dried fruits **Packing of dry fruits**

Figure 30. Value addition of *Manilkara hexandra* for improved livelihood.

Cutting and weighing of fresh *M. dioica* fruits

Passing through boiled water

Drying of fruits

Preparation of pickle

Figure 31. Value addition of ***M. dioica*** for improved livelihood.

Project 6: Capacity building of VFPCs/SHGs through *v*alue addition of selected underutilized NTFPs for enhanced livelihood opportunities in arid and semiarid Rajasthan. (AFRI-44/NWFP/ICFRE/2017-2020)

Reconnaissance survey was done in Pali district for documentation of *Leptadenia reticulata* and *cordia gharaf.* Socio-economic data like population, land statistics, literacy status, means of livelihood and collection and selling *of L. reticulata* and *C. gharaf* were collected from State Forest Department, Zila Parishad, DSO and Revenue Department, Pali. It also included sources of fuelwood, collection of fodder from forest/Agricultureal fields, average monthly income, drinking water facility, social group, other NGO's, Govt. Dept. visiting village etc. About 10% villages in Pali district were shortlisted, village profile of the selected villages was extracted and semi-structured questionnaire prepared for people interaction. Field testing

and updation of of questionnaire was carried out. A detailed socio-economic survey in 103 villages (10 farmers in each village) in Pali district was conducted to assess the role of *Cordia gharaf* and *L. reticulata* in rural livelihood (Fig 32). Preliminary findings reveals that earlier *C. gharaf* fruits were used to prepare a dish called, 'Lapsi' but due to stone wall fencing around agriculture fields, the big trees were cut down resulting in reduction in its population. Natural regeneration was also not observed. Now-a- days, the fruits are consumed by cattle only. Pods of *L. reticulata* are consumed by Jain community as vegetable and its market rate varies from Rs. 600-800/- per kg.

Discussion with Key informants for documentation of role of *Cordia gharaf* and *Leptadenia reticulta* in rural livelihood

Socio-economic survey and discussion in farmers field for documentation of role of *C. gharaf* and *L. reticulta* in rural livelihood

Figure 32. Documentation of role of *C. gharaf* and *L. reticulata* in rural livelihood.

Benefit of the Project: It will be beneficial in increasing livelihood opportunities of VFPC/SHG members through value addition.

Scientific names of species with vernaculars in parenthesis: *Leptadenia reticulata* (Jivanti) *and cordia gharaf* (Gondi)

2.6.5 Biofuels and Bioenergy: NIL

2.7 Forest Protection

2.7.1 Overview

AFRI has undertaken seven research projects involving insect-pest and pathological problems in nursery and plantations. In this 61 pests and predators from seedlings of 35 tree species have been identified from forest nurseries of Rajasthan. Ten to 30% infestation of leaf blight disease from seedlings of 4 tree species and root rot disease from seedlings of 2 tree species up to 30 per cent have also been recorded. Integrated management through use of botanical extract and chemicals was successful in reducing mortality in Neem seedling due to snails and slugs. Another important study was status of flower gall of Khejri that was more severe in Phalaudi, Osian and Lohawat areas resulting in only 10-20 percent pod formation. The effect of consortium of *Azotobacter* spp., *Rhizobium*, *Piriformospora indica*, and VAM) was studied on Neem, Kheji, Isabgol and Senna. These microbes increased yield/ growth and vigour of the plant. Soil samples were collected from different areas. Two isolates of *Azospirillum*, one of *Azotobacter* and one isolate of *Bacillus* have been isolated from the soils collected from different agroclinatic regions while the soil was also used for trapping of *rhizobium* by sowing seeds of kjjri and babul.. *Glomus, Acaulospora, Gigaspora, Sclerocystis* and *Scutellospora* spp. have been observed in the rhizospher soils of *Dendrocalamus strictus* and *Bambusa bambos*.

2.7.1.2 Project under the theme

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During 2017-18
Plan	-	5	-
Externally Aided	2	-	-
Total	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)

All nurseries were surveyed in in different months and seasons covering eleven districts. Nearby forest areas were also surveyed for pest distribution and its status. Thirt two 32 species of leaf feeders, 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 on 35 tree species seedlings. Eight species of spiders, five species of ants, 2 species of beetles were collected as biological predators. Two species of mollusc *viz*. 1 species of slug and 1 species of snail were recorded mainly from temporary neem nursery beds. No damage was recorded due to the mollusc species however hand picking and killing of mollusc was suggested to keep the population in check. Host range of some of the insect pest studied and population recorded for determining the pest status *Terminalia arjuna* recorded as host for defoliator *Achaea janata* from Banswara and Jodhpur. *Dalbergia sissoo* was found infested by one species of leaf miner and one species of defoliator. The shisham defoliator was also recorded from *Anogeissus* species from Pratapgarh. *Millettia pinnata* was found infested by leaf miner, leaf galls and leaf defoliator. *Cordia gharaf* was found infested with leaf defoliator and leaf galls. Leaf galls were also recorded from *Cordia dichotoma, Emblica officinalis* and *Ficus racemosa*. Four species of Coleopteran and twenty eight species of Lepidopteran leaf defoliators identified from nurseries and around districts surveyed.

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.

Scientific names of species with vernaculars in parenthesis: *Dalbergia sissoo* (Shisham) *Cordia gharaf* (Gondi), *Emblica officinalis* (Amla) *Ficus racemosa* (Gular), *Terminalia arjuna* (Arjun), *Millettia pinnata* (Karanj), *Cordia dichotoma* (Gonda).

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

Khejdhali, Gudha Bishnoiyan, Phalodi, Lohawat Osian, Nagaur, Pali and Luni were surveyed to record the status of flower gall problem of Khejri (Fig 33). Formation of gall in Khejri flower was more severe in Phaludi, Osian and Lohawat areas resulting in loss of 80-90% pods in these areas as compared to the other areas under study. Biochemical analyses for carbohydrate and protein in leaves and seeds have been completed and analysis of samples for phenols is in progress.

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

Scientific names of species with vernaculars in parenthesis: *Prosopis cineraria* (Khejri)

Khejri infested with flower galls

Flower galls of Khejri

Collection of samples from gall infested Khejri trees

Collection of samples from gall infested Khejri trees

Fig 33. Khejri trees infested wth flower galls

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).

To manage the insect pests and diseases different species of *Trichoderma* (a beneficial fungi) were used along with extracts of different parts (leaf, bark, root, fruit) of Vilayati Babul (*Prosopis juliflora),* Lantana (*Lantana camara),* Neem (*Azadirachta indica),* Aak (*Calotropis procera*), Dhatura (*Dhatura metal*) and Hingota (*Balanites aegyptiaca*) and chemical fungicides like copper oxychloride, bavistin and mancozeb. Among these biological control agents, *T.*

viride inhibited growth of the tested pathogen (*Fusarium* spp., *Macrphomina phaseolina*, *Colletotrichum* spp. and *Rhizoctonia* spp.) by 65-70%, while 3% concentration of *P. juliflora* leaf extract inhibited growth of pathogens by 77-85%. The chemicals mancozeb and bavistin were able to retard the growth of the pathogen by 94% and 89% respectively. Thus *T. viride* and *P. juliflora* leaf extract are recommended as a supplement to the chemical fungicides. 32 combinations of 5 different biofertilizers were used in neem to test their efficacy in development of quality planting material. The concentration was kept at 20 ml /plant to maintain 10^8 colony forming units. These beneficial microbes improved growth making the plant immuned to various biotic and abiotic stresses. Most effective combination in terms of increase in biomass by 58.88% was *Azotobacter+Azospirillum+Trichoderma* for neem growth (Fig 34).

Figure 34. Mass production of neem seedlings using combination of *Azotobacter+Azospirillum+Trichoderma*

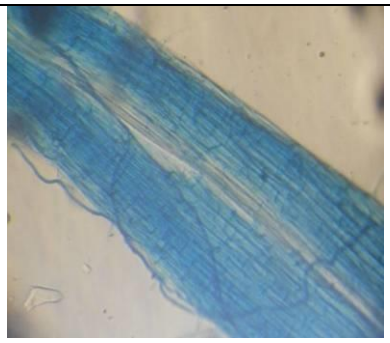
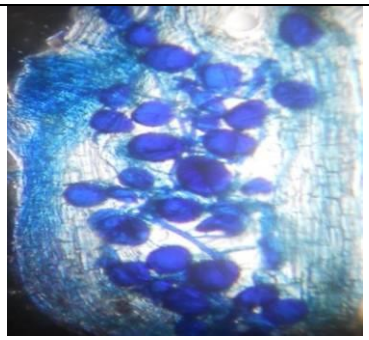
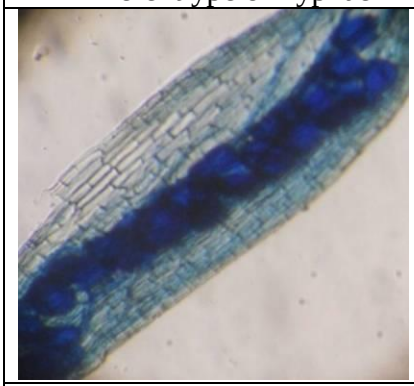
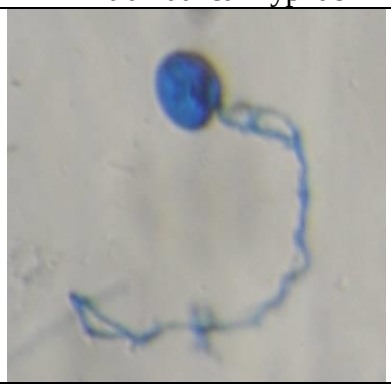
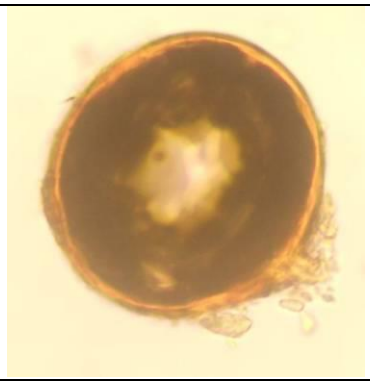
Benefits of the research projects: This technology will be benefitial to the end users in the form of package for developing large scale quality planting material.

Scientific names of species with vernaculars in parenthesis: *Azadirachta indica* (Neem)

2.7.3 Mycorrhizae, rhizobia and other useful microbes

Project 4: Rehabilitation of salt affected soil with amendments of biofertilizer (AM Fungi). (AFRI-23/AF&E/ICFRE/2016-19).

Survey was done in Jodhpur (Phalodi, Bilara, Jhak, Kala Una, Bhavi, Dhava and Gangani), Bikaner (Kotri, Jorbeed, Lunkaransar, Rajera and Binjwani), Jaisalmer (Pokaran, lathi and Jaisalmer range), Nagur (Kuchaman and Sambhar), Barmer (Kalyanpura, Balotra and Pachpadra), Jalore (Saledi area) and Pali (Jalore road, Rohit, Mukanpura) districts of Rajasthan for *Salvadora persica* (Khara jal, pilu) tree population. Rhizosphere soil and root samples were collected from the above-mentioned sites. Soil physico chemical properties like soil moisture, pH, EC, % Organic carbon and available phosphorus were estimated. Four genera like *Glomus, Acaulospora, Scutellospora* and *Sclerocystis* were identified (Fig 35). Among these, *Glomus* was the dominant genera. Different species of genera Glomus were *Glomus aggregatum, Glomus microaggregatum, Glomus constrictum, Glomus fasciculatum* and *Glomus mosseae.* Mass multiplication of consortium inoculum is in progress.

		
Different ype of hyphae	Extramatrical hyphae	Infestation of vesicles
		
Heavily infested vesicles	Spore formation	*Glomus* species

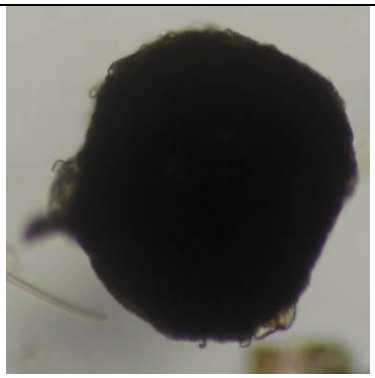
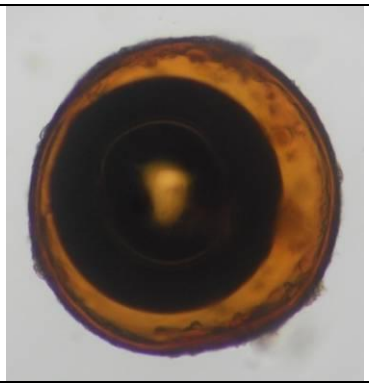
		
Scutellospora species	*Glomus* species	Mass multiplication

Figure 35. Different levels of infestation of roots of by Mycoorhizal association with root & soil of *Salvadora persica* and Mass production of inoculums

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

Scientific names of species with vernaculars in parenthesis: *Salvadora persica* (Meswak, Khara jal)

Project 5: Selection of efficient AM fungi, PSBs and Azospirillum for productivity enhancement of *Dendrocalamus strictus* & *Bambusa bambos.* (AFRI-25/FP/ICFRE/2016-20)

Rhizosphere soil and root samples of *Dendrocalamus strictus* (Solid Bamboo) and *Bambusa bambos* (Indian Thorny Bamboo**)** were collected from various forest nurseries of Gujarat *viz.*, Central High-tech nursery [Range-Limkheda], Dangria nursery [Range-Baria] and Garden nursery of Wadhai Range (Dang). Soil samples were also collected from ***D. strictus*** plantations at Dahod (5), Rajpipla (9), ChhotaUdaipur (6), Dang (9), Valsad (10) and Navsari (7) districts **of Gujarat.** For ***B. bambos*** samples were collected from Dahod (2), Dang (6), Valsad (7) and Navsari (1) districts **of Gujarat.** Soil samples were analyzed for soil moisture, pH, EC, (%) organic carbon (% OC), phosphorous (P). AM fungi isolated were identified as the enera *Glomus, Acaulospora, Gigaspora, Sclerocystis* and *Scutellospora* (Fig 36). Among these *Glomus* occurred most frequently. The different species of *Glomus* were recorded as *G. aggregatum, G. fasciculatum, G. mosseae, G. multicaulis, G.reticulatum* etc. *Glomus* species was dominant in nurseries as well as in plantations. The spore population varied from among the sites and ranged

between 159 and 394 propagules per 100 gm soil of *D. strictus* and 174 and 423 propagules per 100 gm rhizosphere soil of *B. Bambos* from **Rajasthan**. **W**ork on AM colonization in roots is in progress. Mass multiplication of consortium inoculum is also in progress.

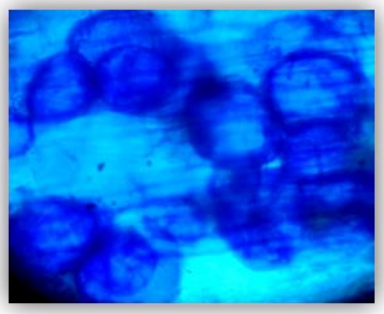
Benefits of the research projects: This study will provide information on beneficial effects of AM technology for its use in producing quality seedlings of *Dendrocalamus strictus* and *Bambusa bambos*.

Scientific names of species with vernaculars in parenthesis: *Dendrocalamus strictus* (Solid Bamboo) and *Bambusa bambos* (Indian Thorny Bamboo**)**.

D. strictus **at Dahod Gujarat.**

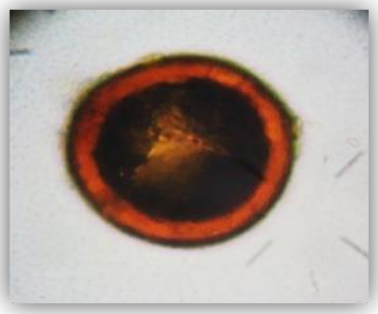
B. bambos **at Valsad, Gujarat**

D. strictus **at Dang, Gujarat.**

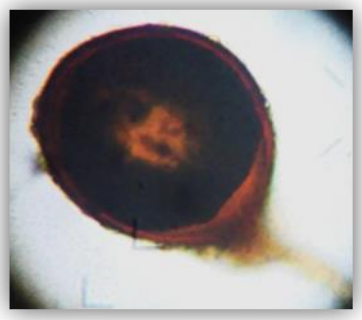


Root of *D. strictus* showing subglobose, globose, type of vesicles

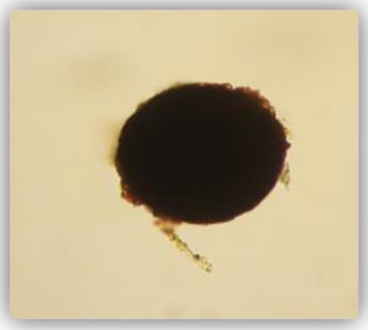
Extramatrical hyphae emerging from root of *B. bambos*



Glomus **species on *D. strictus***



***Gigaspora* species**



***Scutellospora* sp.**

Mass multiplication of inoculum

Figure 36. Different sites of of *D. strictus* & *B. bambos* at Gujarat States, Mycoorhizal association with root & soil and Mass production of inoculum

Project 6: 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).

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 these microbes to study their effect on the growth and development of the plant species. Growth parameters like collar diameter, shoot length, root length, biomass, sturdiness quotient, quality index and vigour index were calculated for neem and Khejri while yield was calculated for Isabgol and Senna. In case of Khejri, the consortia showed greater shoot length (28.7 cm), root length (48.2 cm), number of leaves (18.4) sturdiness quotient (9.4) and vigour (28.66) as compared to the respective value of 17.8 cm, 29.8 cm, 15.2, 14.7 and 13.5 in the control. These values were inbetween when treated with *P. indica* (Fig 37)

P. indica treated Isabgol

Control

P. indica treated senna

Control

Figure 37. Increase in yield of Isabogal and Senna in comparision to control

In neem seedlings, *P.indica* showed better results with high value of 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 the value of shoot length (11.54 cm), root length (19.92 cm), number of leaves (4.6), sturdiness quotient (11.376) and vigour (10.41) in the control. In annual plants Senna and isabgol, *P.indica* performed better than all other treatments. Mean yield in Isabgol seed and husk respectively, increased by 57% and 33% g in *P.indica* treated seeds followed by 36% and 14% in consortia of the fungus and bacterium, and by 23% and 4% in *Azotobacter* treated seeds as compared to control. Similarly, mean yield of senna seeds was maximum with *P. indica* treated

seeds (39.69 g), followed by consortia (20.04 g) and *Azotobacter* (19.16 g) as compared to control (16.30 g).

Benefits of the research projects: The technology will be benefitial to the users by improving productivity and value addition to agromedicinal plants with the use of a consortium of AM fungi.

Scientific names of species with vernaculars in parenthesis: *Azadirachta indica* (neem), *Prosopis cineraria* (Khejri), *Cassia angustifolia* (Senna), and *Plantago ovata* (Isabgol).

Project 7: 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).

Soil samples were collected from different areas. Seeds of Khejri have been shown to isolate *Rhizobium* from nodules. Till now no nodulation has been observed. Soil parameters have been studied. 2 isolates of *Azospirillum*, one of *Azotobacter* and one isolate of *Bacillus* have been isolated from the soil collected.

Benefits of the research projects: The study under this project will provide information on consortium of PGPR and other PGP rhizobacteria to end users in enhancing productivity.

Scientific names of species with vernaculars in parenthesis: *Prosopis cineraria* (Khejri)

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:

SNo	No. of Training organized	Duration in days	No. of participants
1	Innovations in Forestry and Dry land Forestry	3 (29 to 31 August 2017)	38
2	Role of Forestry in sustainable livelihood	3 (19 to 21 September 2017)	37
3	Dry land forestry : Propogation, Development and Conservation	3 (19 to 21 September 2017)	33
4	जैव उर्वरक एवं जैविक खाद तकनीक की कुटीर उद्धयोग में भूमिका	4 (25 to 29 September 2017)	19
5	Integrated approach for sustainable development of fragile desert eco-system	5 (18-22 December 2017)	24

3.3 Visit Abroad: NIL

3.4 Participation in Seminar/Symposia/Workshop/Trainings

SNo	No. of seminar/ symposia/ workshop/ trainings	Duration in Days	No. of participants
1.	Workshop on "Raising Stakes of Local Communities in Conservation of Forest and Wildlife Institutionalization of Eco-tourism" involving local communities.	22-23 August 2017	1
2.	Seminar on Weeds and invasive species- "*Prosopis juliflora* problems and solutions".	7 September 2017	1
3.	Training Programme on “Arid Forestry multiplication, Development and Conservation”.	12-14September 2017	1
4.	राजभाषा वैज्ञानिक संगोष्ठी,	29-30 October 2017	3
5.	International Conference on "Bio-Resource and Stress Management".	8-11 November 2017	1
6.	Global Research Initiatives For Sustainable Agriculture & Allied Sciences (GRISAAS).	2-4 December 2017	1

7.	International workshop on 'Biodiversity and Climate Change.	24-27 February 2018	3
8.	Workshop "To disseminate research findings pertaining to dry land afforestation and to identify research gaps".	13-14March 2018	1

4. Extension Panorama/Activities:

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

State wise locations of established and proposed VVKs

4.2 Technologies transferred: Nil

4.3 Research publications

Research articles published by the institute:

S.No.	Number of research artilcs published in scientific journals and books/proceedings		
	National Journal	Foreign Journal	Chapter in book/Proceedings
1	10	04	1

Research articles presented in seminar/conference / workshops and abstracts and popular articles published by the Institute:

SNo.	Number of artilcs presented in Seminar/Conference / Workshops and abstracts and popular articles published		
	Article Presented	Abstract published	Popular article
1	1	24	-

Books and Booklets, brochure/pamphlets published by Institute:

SNo.	No. of books and booklet, brochures/ pamphlets published	
	Books	Booklets/Brochures/ Bulletins/Pamphlets
1	1	-

4.4 Seminar/Symposia/Workshop organized:

SNo.	No. of Seminars/Symposia Workshops meeting organized	Days
1	Inception workshop on 'Biological diversity and people perception for developmental plan and awareness generation in different community reserve areas in Jodhpur district' on 16th October 2017	1
2	Dissemination workshop on 'Studies on the effects of MPOWER programme on mitigation and adaptation towards Climate Change in western Rajasthan-	1

	Phase II' on 4th December 2017.	
3	Institutional level seminar on 13 April 2018, 16 March 2018, 17 Oct 2017, 07 September 2017 were organized at AFRI	4
4	Plant Tissue Culture Association's Symposia on 16-18 Februray, 2018	3
5	Regional Research Conference and Directors meet on 23-24 November, 2018	2

4.5 Consultancies:

Project 1: Evaluation of forest protection, management and developmental activities under Compensatory Afforestation and Management Authority in Rajasthan

For evaluation of effectiveness and impacts of different activities and the works under CAMPA programme and the impact of these works activities carried out during 2010-14, this project was funded to Arid Forest Research Institute, Jodhpur to: (i) to evaluate the performance of different plantation models in different locations; (ii) to record and valuate percent survival and growth of the planted species; (iii) to verify documents, records and assets created under the programme; (iv) to verify and validate water conservation structures and eco- restoration closures and their impacts; and (v) to suggest areas of improvement and action to be taken.

Eighty six plantation sites and 156 assets were measured and verified. Total 3800.7 ha area planted during 2011-12, 2012-13 and 2013-14 under non-forest land (NFL), degraded forest land (DFL) and Assisted Natural Regeneration (ANR) models were evaluated and assessed. Among the assets, 19 Anicut type II, 18 Anicut type III, 5 Arboretums, 25 sites of boundary pillars, 39 sites of boundary walls (one 12' height, twenty five 4' height and thirteen 6' height), 29 forest Chowki, 14 Range Forest Office and 7 Rescue Centres were verified. A total 1651974 seedlings of 57 plus species were planted, wherein most commonly used species were *Acacia tortilis* (18.90%), *A. catechu* (11.55%), *Z. mauritiana* (10.84%), *A. leucophloea* (9.60%), *A. nilotica* (8.49%), *Dendrocalamus strictus* (8.24%), *A. senegal* (6.02%), *A. indica* (2.94%), *Albizia lebbeck, Gmelina arborea, P. pinnata, P. cineraria, C. wightii, H. integrifolia, Bombax ceiba, T. indica, S. oleoides, E. officinalis, B. monosperma, Ficus religiosa, D. sissoo, Cassia fistula* etc. Contributions of *P. cineraria* and *T. undulata* seedlings in total plantations were only 0.33% and 0.46%, respectively. About 28%, 50% and 22% seedlings were used in NFL, DFL and ANR plantation models. Most frequently used species was *Z. mauritiana* followed by *H. integrifolia, A. leucophloea* and *A. indica*. Under seed sowing, 26 species of trees and shrub have

been used along contour trenches, V-ditches, ditch fencing etc., wherein *Acacia senegal*, *A. leucophloea* and *A. catechu* were used at 69.8% sites, 33.7% sites and 30.2% sites, respectively.

Overall survival of plantation was 49.37% in Rajasthan. ANR, NFL and DFL plantation models showed 45.47%, 60.37% and 49.2% survival. Jodhpur, Jaisalmer and Bikaner divisions showed better survival than other areas under NFL. *Bauhinia variegata*, *M. azedarach*, *Neolamarkiana kadamba* and *Sterculia urens* did not survive; *T. arjuna*, *S. cummini*, *Mitragyna parviflora*, *B. ceiba*, *Madhuca indica* etc. showed poor survival; whereas species showing >49.4% survival were *A. catechu*, *A. senegal*, *A. tortilis*, *Ailanthus excelsa*, *Azadirachta indica*, *Anogeissus pendula*, *B. monosperma*, *Commiphora wightii*, *Cordia gharaf*, *D. strictus*, *F. benghalensis*, *Manilkara hexandra*, *Moringa oleifera*, *W. tinctoria* and *Z. mauritiana.* Plantation of 2011 showed 42.01% survival, whereas the plantations of 2012 and 2013 showed 25.2% and 55.53% survival, respectively. Species with lesser numbers of planted seedlings performed better. Out of twenty six species used under seed sowing, *A. senegal, Acacia catechu*, *A. nilotica*, *A. tortilis, Aegle marmelos, Butea monosperma, J. curcas* and *Z. mauritiana* were the best performing species. Despite of many associated problems like invasion by *Prosopis juliflora* or *Lantana camara*, increased biotic pressures and intrusion of animals in plantation area, problems in species selection, least concern of the staff about plantation maintenance and environmental and soil conditions affected growth and survival and overall performance of the plantation under CAMPA. Alwar, Banswara, Bharatpur, Baran, Bikaner, Dausa, Dholpur, Dungarpur, Jaipur, Jhunjhunu, Jhalawar, Pratapgarh, Rajsamand, Sikar, Sirohi, Mt Abu, Tonk and Udaipur division showed above average plantation performance.

Project 2: Designing development and performance of Uran forestry model for new campus of Rajasthan state judicial academy, Jodhpur.(AFRI-18/Silvi/RSJA/20015-20)

Plantation developed under Designing, development and performance of urban forestry model for Rajasthan state Judicial Academy, Jodhpur was maintained with regular weeding, soil working and watering. At the age of 30 months, *Azadirachta indica* (neem) attained an average height of 473 cm and collar diameter of 12.4 cm enhancing greenery and beauty of the campus along with benefits of shelterbelt. *Prosopis cineraria* (Khejri) and *Tecomella undulata* (Rohida) attained 139 and 169 cm height respectively (Fig 38).

Figure 38. 30-month old *Azadirachta indica* plantation at Rajasthan Judicial Academy, Jodhpur

4.6 Technical Services:

1. G. Singh (2018). Exposure visit to Karnataka organized under 'Neeranchal Programme of IWMP/WDSC of Government of Rajasthan during 19-20th January 2018.
2. G. Singh (2017). Participated in an interactive meeting for declaration of biosphere reserve in Rajasthan organized at Jaipur on 12th April 2017.

4.7 Activities of Rajbhasha:

राजभाषायी गतिविधियां (Activities of Official Language) 2017-18

2017-2018 के दौरान शुष्क वन अनुसंधान संस्थान,जोधपुर में दिनांक 14-28 सितम्बर 2017 तक की अवधि में 'हिन्दी पखवाड़ा' मनाया गया जिसमें 'हिन्दी दिवस'(14 सितम्बर) पर माननीय गृह मंत्री,भारत सरकार का संदेश पढ़ा गया तथा स्वरचित कविता पाठ से हिन्दी पखवाड़ा का समारंभ हुआ। हिन्दी वर्ग पहेली,टिप्पण-आलेखन सह प्रशासनिक ज्ञान, हिन्दी निबंध,हिन्दी टंकण,हिन्दी प्रश्नोत्तरी,हिन्दी अनुवाद प्रतियोगिताएं पखवाड़ा में सम्मिलित की गईं जिसका प्रयोजन राजभाषा नीति एवं नियमों के अनुसरण में सरकारी कामकाज में हिन्दी के प्रयोग को बढ़ावा दिया जाना है।

Fig 39.मुख्य अतिथि को स्मृति चिह्न प्रदान करते हुए डॉ. रंजना आर्या

वर्ष पर्यंत संस्थान की विभागीय राजभाषा कार्यान्वयन समिति की निर्धारित कुल 04 बैठकें राजभाषा मानकों के अंतर्गत आयोजित हुई। सरकारी कामकाज में हिन्दी को बढ़ावा देने के आशय से 2017 - 18 में 03 हिन्दी कार्यशालाएँ भी आयोजित हुई जिनमें मंत्रालयिक तथा तकनीकी कर्मचारी सम्मिलित हुए। तिमाही बैठकों के कार्यवृत्त तथा हिन्दी प्रगति की आवधिक रिपोर्ट यथासमय भिजवाई गईं।

Fig 40. संस्थान की तिमाही राजभाषा बैठक का दृश्य

Fig 41. हिंदी कार्यशाला

राजभाषा विभाग के उत्तरी क्षेत्रीय कार्यान्वयन कार्यालय-1 (दिल्ली) के सहायक निदेशक(कार्यान्वयन) श्री नरेंद्र सिंह मेहरा ने दिनांक 27/11/2017 को संस्थान का राजभाषा संबंधी निरीक्षण किया तथा हिन्दी के प्रगामी प्रयोग की स्थिति की समीक्षा की। राजभाषा निरीक्षण रिपोर्ट में संस्थान में राजभाषा कार्यान्वयन की स्थिति बहुत अच्छी होने का उल्लेख किया गया है वहीं कई मदों पर सराहना भी मिली है।

Fig 42. संस्थान में हुए राजभाषा निरीक्षण का दृश्य

4.8 Awards and Honours: Nil

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

Earth Day 2017 was celebrated on 22-04-17 on the theme "Environment and Climate Literacy". Clay water pots (Paridna) were installed on trees for birds at AFRI Nursery. A lecture session was organized at Conference Hall. Sh. U. R. Choudhary, Head Agroforestry and Extension introduced the importance of Earth Day. Director AFRI, Shri. N.K. Vasu stressed the need for proper management of the existing resources. Sh. G. S. Bharadwaj CCF, Jodhpur & Chief Guest emphasized on the proverb 'resources miser is wiser'. Various NGOs and Environmentalist participated and express their views regarding Earth Day.

International Biodiversity day was celebrated on 22 May 2017 on theme "Biodiversity and Sustainable Tourism". A brainstorming session was organized on this ocassion involving scientists and officers of the institute and Forest Dept. Director AFRI, Shri N.K. Vasu addressed the house on this ocassion and emphasized the development of forest fringe areas, national parks and sanctuaries through awareness among the indivisuals for sustainable tourism. The chief guest and CCF Jodhpur Shri Raghuveer Singh Shekhawat stressed on the role of community participation and their involvement in the sustainable tourism.

World Environment Day was celebrated on 5th June 2017 in association with SFD Rajasthan, Jodhpur. Director, AFRI emphasized the need of conservation of different component of eco-system. Shri R.S. Shekhawat, CCF, Jodhpur & Chief Guest emphasized the need of water conservation and people participation in tree planting. A nature walk was also organized in which students, their parent's and other environmentalist participated. A painting competition was also organized for school students on 4 June 2017.

World day to Combat Desertification was celebrated on 17th June 2017 at AFRI and Chief Guest of the occasion was Shri D.P. Sharma, PCCF and Director (Training), Rajasthan, who deliberated upon desert ecosystem and emphasized the need of ing desertification by plantation. Director, AFRI emphasized to work in accordance to desert ecosystem and involving scientific input in it. Earlier a plantation programme was taken up in CCF office campus Jodhpur.

Van Mahotsav was celebrated at AFRI, Jodhpur on July 2017. All staff members of AFRI, their family members, staff member of Forest Department, Jodhpur, member of NGO's and environmentalists participated. A ceremonial plantation was done by planting >100 plants of various species like Jamun, Badam, Chandan, Amaltas, Bauganveillea, Karanj, Gudhal etc. CCF, Jodhpur Shri R.S. Shekhawat emphasized on planting local and suitable tree species in afforestration programme in western Rajasthan. Director, AFRI Shri N.K. Vasu explained the role of trees/shrubs/grasses in eco-system and told about harmful effect of human activities to the environment. Dr. I.D. Arya, Group Coordinator (R) told the value of trees in terms of providing oxyzen and decreasing air pollution. Shri Uma Ram Choudhary, IFS, Head Agroforestry & Extension Division, told about importance of Van Mahotsav in present scenario.

World Ozone Day was celebrated on 16 September, 2017 on the theme " Caring For All Life Under the Sun". Chief Conservator of Forests, Jodhpur, Shri R.S. Shekhawat was chief guest on this occasion. Director, AFRI, Dr. Indra Dev Arya addressed staff on this occasion through a presentation "Ozone Layer Conservation". Director AFRI, Scientists and officials of AFRI also participated in Ozone Day Celebration organized by District Committees, Jodhpur.

International Day of Forests 2018 was celebrated at AFRI on 21 March 2018. Scientists, Officers and Employees of AFRI and representatives of NGOs participated in the celebration. Additional PCCF Shri Raghuveer Singh Shekhawat, Director AFRI, Dr. I.D Arya and Dr. G.Singh Scientist-G stressed on the need of incorporation of Forest trees in urban forestry. Head AF & E divison Shri Uma Ram Choudhary gave a power-point presentation on "Forest and Sustainable cities". Dr. Tarun Kant presented how plants can be used to make urban life more sustainable. Shri N. Bala Scientist-F gave presentation on various horticulture and forest tree species that can be used to enhance quality of life in cities. Representatives of NGOs also presented there views.

World Water Day 2018 was celebrated at AFRI on 22 March 2018. Scientists, Officers and Employees of AFRI, representatives of NGOs and officials of Public Health Engineering

Department, Watershed Development Department, Water resources department, Ground water department participated in this celebration. Shri Ishwar Chand Jain Superintendent Engineer, PHED, gave presentation about the demand and supply of water. Shri Gajendra Singh Chawla Superintendent Engineer, watershed Development Department presented on “Mukhya Mantri Jal Swavblamban Yojana”, Shri Jogendra Singh of Water Resources Department gave a lecture on water availability and management of it. Dr. Rama Kishan Ex. Engineer of Central Ground water Board talked about ground water situations. Dr. G. Singh talked about scientific aspect of water management. Shri Uma Ram Choudhary, Head, AF & E deliberated on "Nature for Water". The function was ended with a vole of thanks by Dr. Bilas Singh.

Vigilance Awareness Week was organized from 30-10-2017 to 04-11-2017 as per the Government of India mandate. The programme started with the oath-taking ceremony for Vigilance awareness by the Director AFRI, Dr.I.D.Arya. During this week, essay & slogan writing and poster making competition on the different aspects of the theme "**भ्रष्टाचार मुक्त भारत : एक परिकल्पना**’ were also organized. In the closing ceremony a lecture on " **भ्रष्टाचार उन्मूलन में हमारा योगदान** " was held. The chief guest of the closing ceremony was Shri R.S.Shekhawat, IFS who shared his experience of preventive vigilance enlightened the audience about the legal matters in vigilance. 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 43. Celebration of Vigilance Awareness Week.

5. Administration and Information Technology

Introduction

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. Several video conferencing sessions were organized during the year. The Hindi and English website of the institute was updated regularly throughout the year. The LAN of the Institute was upgraded with new network switches. 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 nine(9) tenders including six labourer contracts, one equipment one, annual rate contract of chemicals and glasswares and one tender related to publishing of books were finalized through it. Four new computers with UPS and printers were procured. Aadhar based Biometric attendance system with CCTV was implemented at the Institute. Other routine tasks related to the Information Technology were performed during the year.

5.2 Administration: A brief note on general administration activities along with information on the following:

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

5.2.1.1 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 stakeholders. The institute is implementing its research endeavors after duly recognizing the user's needs. 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.

Different procedures have been formulated for identifying the research problems of dry areas; formulating the projects based on the problems; and dissemination of the research results and technologies to the end users. In order to identify the research problems, institute level interaction workshops were organized involving various stakeholders like officials of state forests departments of Rajasthan and Gujarat , scientist of other sister organization like CAZRI

and University, progressive farmers and NGO's. Based on the research problems highlited during discussions are taken under projects formulations the scientists after the thorough review of scientific literature.

The projects are then 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 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 trials, extension trainings, Van Vigyan Kendras, Demo villege, printed material, radio talk, workshops, conferences and the publications uploaded to the website of the institute.

5.2.1.2 Action taken to implement the Charter

To fulfill the charter, research projects were prepared addressing the research mandate of the institute and submitted for funding to various donor agencies for implementing the Charter. Three new projects were approved for initiation in the next financial year by RPC held in Februray, 2018. Several extension trainings were held during the year for dissemination of the 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 and World Day for Combating Desertification and Van Mohotsava. The details of these have been mentioned above in this report.

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

5.2.1.4 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, workshops helped in publicity efforts made and awareness campaigns organized on Charter for the Citizen/Clients. The details are given under point No. 4.9.

5.2.1.5 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 made in 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 the 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 the Dr. Ambedkar Jayanti on14th April 2017 to commemorate the birthday of Babasaheb Ambedkar. Dr. N.K. Vasu IFS, Director, Dr. I.D. Arya, Group Cordinator Research, Dr. Ranjana Arya, Scientist-G, Dr. U.K. Tomar, Scientist-F, Dr. Sarita Arya, Scientist-F, Sh. N. Bala Scientist-F, Sh. S.R. Baloch, Scientist-C, Sh. K.C. Gupta Hindi Officer, Mrs. Anuradha Bhati, Librerian, spoke about on Dr. B. R. Ambedkar to pay homage to Baba Saheb Ambedkar on his 126nd Birth anniversary.

Scientists/officers/staff of A.F.R.I had assembled for the program.

Fig 44. Celebration of 126th birth anniversary of Baba Saheb Ambedkar at AFRI, Jodhpur.

6. Annexures

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 InformationOfficers	Subject matter(s) allocated
Arid Forest Research Institute	Dr.I.D.Arya, Director, AFRI 0291-2722764 Email: dir_afri@icfre.org Phone : 0291-2742549 FAX : 0291-2722764	Shri K.C.Gupta Email kcgupta@icfre.org Phone : 0291-2729163 FAX : 0291-2722764	All matters related to AFRI, Jodhpur

2. Information on vigilance cases: NIL

3. Information on audit objections:NIL

4. 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

5. Intellectual Property

5.1 Patent Property - NIL

5.2Others-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 (10^6 g)
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

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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.

RTI Annual Return Information System
Quarterly Return Form

Public authority : Ministry of Environment & Forests
Quarter – II (April, 2017 to June, 2017)
Year: 2017-18

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	Nil	01	01	Nil	Nil	02
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 –I C/o IT-Cell of the Institute

(Ramesh Kumar Malpani)
Public Information Officer,
AFRI, Jodhpur.

RTI Annual Return Information System
Quarterly Return Form

Public authority : Ministry of Environment & Forests
Quarter – III (july, 2017 to September, 2017)
Year: 2017-18

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	Nil	04	05	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)
50	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	Sh. Rajesh Meena	Technical Assistant C/o IT-Cell of the Institute

11/10/17
(Kailash Chand Gupta)
Public Information Officer,
AFRI, Jodhpur.

RTI Annual Return Information System
Quarterly Return Form

Public authority : Ministry of Environment & Forests
Quarter – IV (Oct., 2017 to Dec., 2017)
Year: 2017-18

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	03	03	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)
30/-	16/-	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	Sh. Rajesh Meena	Technical Assistant C/o IT-Cell of the Institute

(Kailash Chand Gupta)
Public Information Officer,
AFRI, Jodhpur

Research publications

Sl. No	Foreign Journals
1	Saini L.S, Rajput S. K, Rathore T.R. and Tomar, U. K. (2018). Non-destructive harvesting of oleo-gum resin in Commiphora wightii (Arnott) Bhandari—A critically endangered plant. Industrial Crops & *Products*, 113:259–265.
2	Gaur, A., Singhal, H. and Tomar, U. K (2017). Asexual Morphological Differences in Male and Female Plants of Commiphora wightii (Arn.) Bhandari - An Endangered Medicinal Plant. *Research in Plant Sciences*, 5:51-59.
3.	Singh, G. and Sharma, R. (2017). Effects of different land use changes and spatial variation in rainfall on soil properties and soil carbon storage in Western Rajasthan, India. *Annals of Advanced Agricultural Sciences*, 1(2): 43-53.
4.	Sharma, R., Mishra, D. and Singh, G. (2017). Spatial variations in floristic diversity and carbon storage in arid zone forests of western Rajasthan, India. *Adv. For. Sci., Cuiabá*, 4(4):203-210.

Sl. No	National Journals
1	Singh, G. and Singh, Bilas (2017). Biomass equations and assessment of carbon stock of *Calligonum polygonoides* L., a shrub of Indian Desert. ***Current Science***, 112(12): 2456-2462.
2	Bala, N., Singh, G., Bohra, N. K. and Limba, N.K. (2017). Soil nutrients and carbon stock in plantation of different age and species along canal command area of Indian Desert. ***Indian Forester***, 143(7): 641-647.
3	Rathi, N., Arya S. and Arya I.D. (2017). optimization of media constituents for regeneration via callus cultures of *Glycyrrhiza glabra* l. an endangered plant. ***Biochem. Cell. Arch***.17 (1):389-398.
4	Tripathi, Sangeeta and Dhaka, Devendra. (2018). Contribution of Neem leaves in Rural Livelihood in Sojat city of Pali District in Rajasthan. ***Int. J. of Adv. Res***. **6** (2). 1085-1089.
5	Rathore, Mala (2018). Variation in nutritional composition of flower buds of *Calligonum polygonoides* in different regions of Thar desert. ***Int. J. Adv. Res***. 6(3), 1005-1008.
6	Singh Bilas, Bishnoi, Mahipal and Singh, G. (2017). Effect of lopping and root barrier on pasture production in *Colophospermum mopane* based silvipastoral system in Western Rajasthan. ***International Journal of Bio-resource and Stress Management***, 8(5):674-678.
7	Bhatnagar, S., Singh, S., Khan A.U., Kumar, B., Srivastav, K. K, Ahmed, S. I. and Rathore, T. S (2017). Khejri tree mortality associated with infestation of *Acanthophorus serraticornis* (Olivier) and *Ganoderma lucidum* (Curtis) p. Karst. in Rajasthan. ***Journal of Agriculture and Ecology***, 4:33-36.
8	Singh, A., Bhatnagar, S., Singh S. and Rathore, L. S. (2017). Foliar disease infection on some forest trees. ***Journal of Agriculture and Ecology***, 3: 38-41.
9	Wankhede, S., Saini, M.K., Kothari, S.L., Bala, N., Singh, G. and Gour, V.S. (2017). Evaluation of Carbon Sequestration Potential in Amla (*Emblica officinalis* Gaertn.) Orchards in Semi-arid Region of India. ***Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci***., DOI 10.1007/s40011-017-0917-1.
10	Sharma Ritu, Arya I. D. and Arya S.2017. Tissue culture technology for multiplication of ringal bamboo *Drepanostachyum falcatum* (Nees keng.F. ***International Research Journal of Natural and Applied Sciences***. 4(2):73-82.

Sl. No	Chapter in Books/proceedings
1.	Singh, G. (2018). Traditional agroforestry systems for global warming adaptation in Arid Rajasthan. In: Climate Change and Agroforestry, Pandey, C. B., Gaur, M. K. and Goyal, R. K. (Eds.), pp. 325-344, New India Publishing Agency, New Delhi.

Sl. No	Article presented
1.	नीलम वर्मा, संगीता सिंह एवं रेखा दाधीच, (2018) '**महारूख *(एलियन्थस एक्सेलसा)* के रोग एवं उनकी रोकथाम**' 'राष्ट्र निर्माण के लिए विज्ञान' राजभाषा वैज्ञानिक/तकनीकी संगोष्ठी, रक्षा प्रयोगशाला, जोधपुर 12–13 मार्च, 2018 पृष्ठ सं. 51–54ए

Sl. No	Abstract published
1.	Jaiswal, S., Choudhary, M., Singh, R.S., Arya, S. and Kant, T. (2018). Control of *in vitro* shoot tip necrosis of pterocarpus marsupium roxb. In: Abstract volume of National Symposium on Plant Biotechnology, organized at AFRI from 16-18 Feb. 2018. Pp 26.
2.	Mehra, S., Parmar, A. K. and Kant, T. (2018). Comparison of responsiveness for somatic embryogenesis from explant derived from tissue culture-raised plant v/s seed-raised plants of Commiphora wightii (Guggul) (2018). In Abstract volume of National Symposium on Plant Biotechnology, organized at AFRI from 16-18 Feb. 2018. Pp. 66.
3.	Kant, T., Parmar, A. K., Shoyab, M., Iqbal, A. and Dave, N. (2018). Assessment Of Genetic Diversity In Prosopis Cineraria (Khejri) Populations Of Rajasthan Using Rapd Markers. In: Abstract volume of National Symposium on Plant Biotechnology, organized at AFRI from 16-18 Feb. Pp. 88.
4.	Dave, N., Iqbal, A., Tomar, U. K. and Kant, T.(2018). Optimization of in vitro contitions for Agrobacterium-mediated transformaion of Azadirachta indica A. Jus from leaf derived callus. In: Abstract volume of National Symposium on Plant Biotechnology, organized at AFRI from 16-18 Feb.2018. Pp.186.
5.	Mehra, S., Parmar, A. K, Tomar, U. K. and Kant, T. (2018). Establishment of cell suspension cultures of Commiphora wightii (guggul) for production if in vitro natural extract containing gugulsterones. In: Abstract volume of National Symposium on Plant Biotechnology, organized at AFRI from 16-18 Feb 2018. Pp186.
6.	Choudhary, M., Saini, L. S., Bano, S. and Tomar, U. K. (2018). Effect of season and genotype on viable seed production of Commiphorawightii (Arnott) Bhandari. In: Proceeding of National Symposium on Plant Biotechnology: Recent trends in Plant propagation, Genetic improvement and Industrial applications, 16-18 Feb, 2018, Arid Forest Research Institute, Jodhpur. Pp. 114.
7.	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: Proceeding of National conference: Tree improvement research in India: Current trends and future prospects. 2-3 February, IWST (Indian Council of Forestry Research and Education), Bangalore.
8.	Gaur, A., Singhal, H., Saini, L. S. and Tomar, U. K. (2017). Differentiation between Male and Female plants on the basis of Morphological Characters in *Commiphorawightii* (Arnott) Bhandari. In: XIX Commonwealth Forestry Conference. 3-7 April 2017, Forest Research Institute, Dehradun.
9.	Meena, D., Sharma, A. and Singh, A. (2018). Genetic diversity study of Tecomella undulata populations using ISSR primers. In National Conference on Advances in Life sciences 19-20 January 2018, organised by Savitribai Phule Pune University, Pune, Maharastra
10.	Meena, D., Kant, T., Sharma, A. and Singh, A. (2018). Genetic diversity analysis by ISSR primers in candidate plus trees of *Tecomella undulata*. In: National symposium on Plant Biotechnology : Recent trends in Plant Propogation, Genetic Improvement and Industrial Application organised by Arid Forest Research Institute, Jodhpur
11.	Arora, K., Singh, R., Arya I. D. and Arya S. (2017). *In vitro* studies on *Moringa concanensis* shoot proliferation 2017. XIX Commonwealth Forestry Conference, 3-7 April, FRI, Dehradun. Pp.30.
12.	Arya, I. D. and Arya, S. (2017). Tissue culture strategies for *in situ* conservation and propagation of important forest tress 2018. XIX Commonwealth Forestry Conference. , 3-7 April, 2017, FRI, Dehradun. Pp. 15.
13.	Singh, S., Arora, K., Gehlot, A., Choudhary, M. and Jaiswal, S. (2018). The effect of different pH level and carbon sources on *in vitro* shoot multiplication of *Barlaria prionitis* var. Dicantha. Recent trends in plant propagation, genetic improvement and industrial applications. National symposium on plant biotechnology, 16-18 Feb. 2018, Jodhpur. Pp. 155.
14.	Choudhary, M., Gehlot, A., Jaiswal, S., Singh, R. and Arya, I. D. (2018). An optimized protocol for *in vitro*

	plant regeneration from nodal explant of mature *Terminalia arjuna* tree. Recent trends in plant propagation, genetic improvement and industrial applications. National symposium on plant biotechnology, 16-18 Feb. 2018, AFRI, Jodhpur. Pp 23.
15.	Kanwar, N., Arya, S., Kataria, V. and Arya, I. D. (2018). *In vitro* studies on multiplication and *in vitro* shoot regeneration from callus of *Leptadenia reticulata.* Recent trends in plant propagation, genetic improvement and industrial applications. National symposium on plant biotechnology, 16-18 Feb. 2018, AFRI, Jodhpur, Pp. 195.
16.	Jaiswal, S., Choudhary, M., Singh, R., Arya, S. and Kant, T. (2018). Control of *in vitro* shoot tip necrosis of *Pterocarpus marsupium* ROXB. : An economically important medicinal tree. Recent trends in plant propagation, genetic improvement and industrial applications. National symposium on plant biotechnology, 16-18 Feb. 2018, AFRI,Jodhpur. Pp. 26
17.	Arora, K., Singh, R., Arya, I. D. and Arya, S. (2018). Effect of anti oxidants, PVP, activated charcoal and chill treatment on control of Phenolic exudation in *Millingtonia hortensis.* Recent trends in plant propagation, genetic improvement and industrial applications. National symposium on plant biotechnology, 16-18 Feb., AFRI, Jodhpur. Pp. 24.
18.	Singh, C., Kumar, S., Arya, I. D. and Arya, S. (2018). *In vitro* cloning of Eucalyptus F1 hybrid of FRI-10 (*E. grandis* X *E. tereticornis*) through tissue culture technique. Recent trends in plant propagation, genetic improvement and industrial applications. National Symposium on Plant Biotechnology, 16-18 Feb. 2018, AFRI, Jodhpur. Pp. 19.
19.	Arya S., Vijaya N. and Arya I. D. (2018). Biotechnological interventions for conservation and production of superior planting stock of desert plant *Capparis decidua.* Recent trends in plant propagation, genetic improvement and industrial applications. National symposium on plant biotechnology, 16-18 Feb. 2018, AFRI, Jodhpur. Pp. 21
20.	Gehlot, A., Arya I. D., Choudhary, M., Singh, R. and Arya S. (2018). Synergistic effect of tryptophan and auxin on early in vitro rooting of *Azadirachta indica* micro shoots. Recent trends in plant propagation, genetic improvement and industrial applications. National symposium on plant biotechnology, 16-18 Feb. 2018, AFRI, Jodhpur. Pp. 22.
21.	Arya, S., Joshi, P. and Arya I. D. (2018). Tissue culture studies on economically important bamboo-*Schizostachyum dullooa*. Recent trends in plant propagation, genetic improvement and industrial applications. National symposium on plant biotechnology, 16-18 Feb. 2018, AFRI, Jodhpur. Pp. 20.
22.	Singh, C., Kumar, S., Arya, S. and Arya I. D. (2018). Tissue culture studies in interspecifc F1 trihybrid of Eucalyptuus FRI-13 (*E. camaldulensis* DEHN. X *E. tereticornis* SM.)X *E. grandis* maiden ex Hill). Recent trends in plant propagation, genetic improvement and industrial applications. National Symposium on Plant Biotechnology, AFRI, Jodhpur, 16-18 Feb 2018. Pp. 18.
23.	Verma N., Sharma, B., Singh, S. and Jedia, K. C. (2017). Why our trees are un-healthy? International Conference on Global Research Initiateves for Sustainable Agriculture & Allied Sciences organised at Maharana Pratap University of Agriculture & Technology, Udaipur, Rajasthan, India from 02 to 04 December 2017 by Astha Foundation, Meerut (U.P.) in collaboration with MPUAT, Udaipur, (Rajasthan), CSAUAT, Kanpur (U.P., UAS, Raichur (Karnataka) and SSDAT, Meerut (U.P.). Pp. 137.
24.	Sharma B., Verma, N. and Singh, M. (2017). Antifungal potential of fruit extract of *Balanites aegyptiaca* l, against some important plant pathogenic fungi. International Conference on Global Research Initiateves for Sustainable Agriculture & Allied Sciences organised at Maharana Pratap University of Agriculture & Technology, Udaipur, Rajasthan, India from 02 to 04 December 2017 by Astha Foundation, Meerut (U.P.) in collaboration with MPUAT, Udaipur, (Rajasthan), CSAUAT, Kanpur (U.P., UAS, Raichur (Karnataka) and SSDAT, Meerut (U.P.). Pp.227.

Sl. No	**Popular articles: Nil**

Sl. No	**Books**
1	**Abstract Book** Arya, I.D, Arya, S. and Kant, T. (2018). Recent Trends in Plant Propagation, Genetic Improvement& Industrial Applications National Symposium on Plant Biotechnolog organized during 16-18th Feb 2018, AFRI, Jodhpur.