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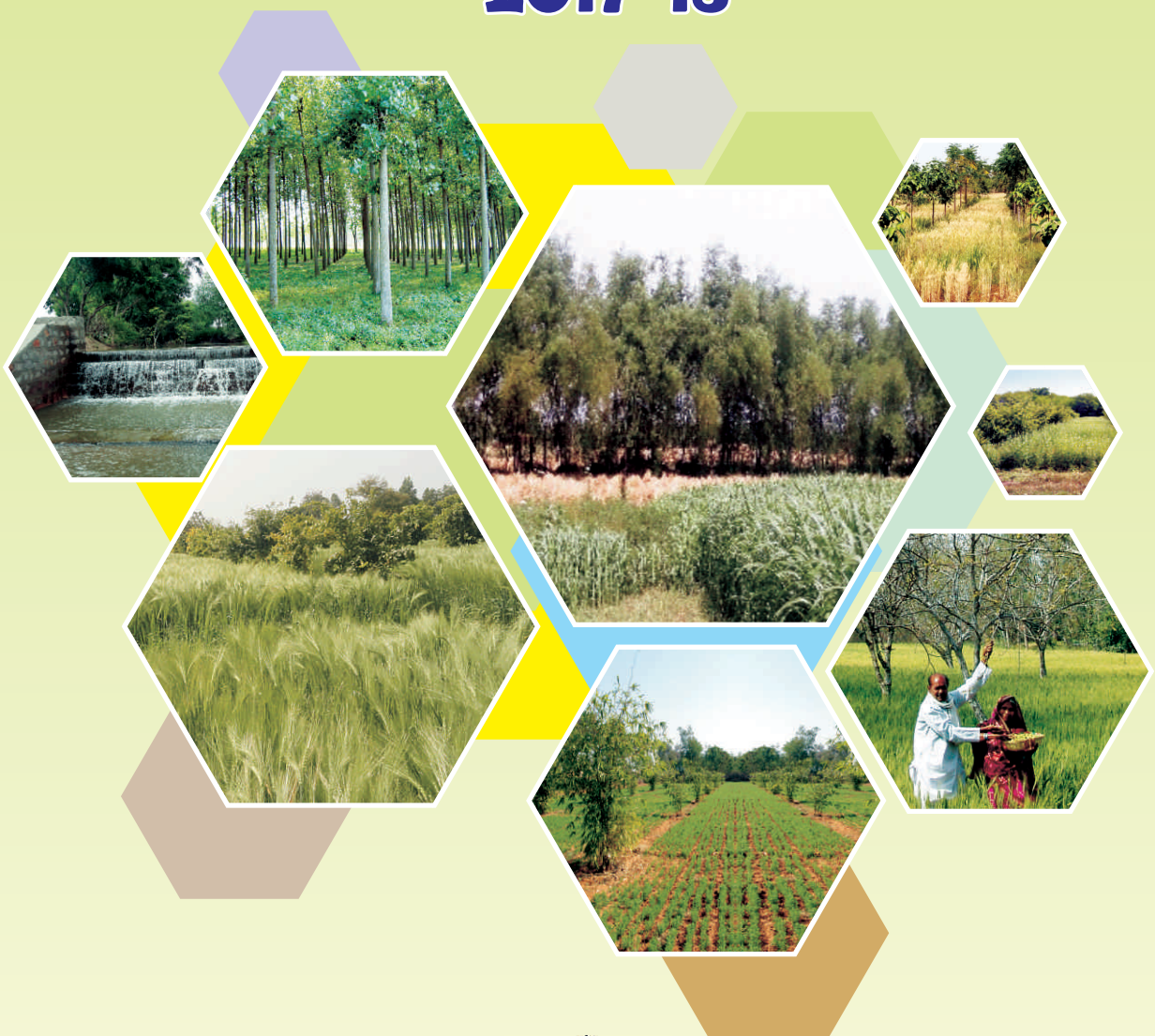
भाकृअनुप
ICAR

AGROFORESTRY

ANNUAL REPORT

2017-18



केकृवाअनुसं
CAFRI

ICAR-Central Agroforestry Research Institute
Jhansi-284 003 (U.P.) India

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Cover photographs

Various Agroforestry Systems

2018

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PREFACE

Agroforestry is emerging as a strategy for diverse production, profitable and sustainable land use. For climate change mitigation and adaptation, agroforestry has been considered as a cost-effective strategy, which sequesters carbon in the soil and woody biomass, besides reducing the greenhouse gas emissions. Furthermore, through the scientific interventions it has become an important tool to address global issues of land degradation, biodiversity, agricultural sustainability and climate change. Adoption of agroforestry on large scale offers great potential and appears to be the most desirable strategy for maintaining social, economic and ecological sustainability in the country. The importance of agroforestry has also taken a central role in the milieu of the recent adoption of National Agroforestry Policy in the country.

It is matter of gratification and great pleasure to present the Annual Report of ICAR-Central Agroforestry Research Institute, Jhansi for the period 2017-18. The report presents the salient findings and achievements of agroforestry and allied research undertaken through the in-house and external funded projects, network and inter-institutional collaboration, technology demonstrations, capacity building and various other activities during the reporting year. Along with research activities, the Institute has made significant contribution in capacity building of farmers and researchers by organizing various training programmes. Under the ICAR-ICRAF Collaborative Work Plan, the Institute organized International Training on "Ecosystem Services in Agroforestry in the context of Payment of Ecosystem Services: Concept, Theory and Practice" and one Workshop on "Assessment of Agroforestry Area in India".

ICAR-CAFRI, Jhansi organized 15 number of three days Training Programme on "Livelihood Security through Agroforestry and Organic Farming" for farmers and field functionaries of Bundelkhand region under *Pradhan Mantri Krishi Sinchai Yojna*-Watershed Development, State Level Nodal Agency, Govt. of U P, Lucknow. About 430 farmers were trained in these Training Programmes.

I express my gratitude to Dr. Trilochan Mohapatra, Hon'ble Secretary, DARE and Director General, ICAR, New Delhi for his constant guidance, encouragement and overwhelming support. I am very much pleased to Dr. K Alagusundaram, Deputy Director General (Agricultural Engineering & NRM), Krishi Anusandhan Bhawan - II, New Delhi for their constant supervision, inspiration and support. My appreciations are also due to Dr. S Bhaskar, ADG (Agron. AF/CC), Dr. S K Chaudhari, ADG (S&WM), NRM Division, ICAR, New Delhi and to all the staff members of NRM Division for continuous support. My special thanks to Dr. O P Chaturvedi, Former Director, ICAR-CAFRI, Jhansi. I appreciate the efforts made by the PME Cell and Editors in compiling and timely publication of the report. I am obliged to the Director, ICAR-IGFRI, Jhansi for continuous support in sharing the infrastructure and facilities from time to time available at ICAR-IGFRI, Jhansi.

Date 21.06.2018
Jhansi

(Anil Kumar)
Director (A)

EXECUTIVE SUMMARY

The executive summary of the research and development activities carried at ICAR-Central Agroforestry Research Institute during 2017 is presented here under:

In ber based agri-horti system the different parameters (plant growth, pruned material and fruit) of ber were influenced significantly except canopy spread, stone weight, pulp/stone ratio, TSS and number of fruits /plant and in most of the cases treatment T_3- Ber (75%RDF) was found significantly higher. In lentil (sown in *rabi*, 2016), the treatments T_{10} (pure crop) and T_6 (Ber with 75% RDF + VAM + Sesame - Lentil) recorded highest seed yield of 995 and 980 kg/ha and was significantly higher as compared to other treatments. In blackgram, T_{10} (pure crop) and T_6 (Ber with 75% RDF + VAM + Blackgram - Barley) recorded highest seed yield of 275 and 268 kg/ha and was significantly higher w.r.t. other treatments.

In agroforestry based IFS about 30,000 fingerlings were introduced in pond during August, 2017 and fingerlings were provided fish feed as per their requirement. After about four months, the fish weight was 350 to 400g. During November, 2017 fish was auctioned for ₹ 75,000. Other enterprises like vegetable and food grain crops was initiated as per proposed programme. The total income from different crops as well as fishery was ₹ 85,314 (net income ₹ 56,128/ha).

The experiment planned and executed in the field by planting lemongrass (vari. Krishna) in between the pomegranate plants at the spacing of 50 x 40 cm. In pomegranate, height ranged from 2.09 to 3.25 m, collar diameter from 4.69 to 7.33 cm, East-West spread from 1.36 to 2.05 m and North-South spread ranged from 1.43 to 1.99 m. The cumulative yield from two cuts of lemongrass yielded 5.14 to 11.68 t/ha green leaves having oil 26.54 to 131.18 kg oil/ha on fresh weight basis.

In evaluation and characterization of different leucaena germplasm studies, fodder quality parameters *viz.*, crude protein, ash content, acid detergent fiber, neutral detergent fibre, cellulose, organic matter and lignin percent were determined. The analysis revealed significant variations among the different germplasm. Crude protein (CP) was highest in *L. leucocephala* Conn-3 (28.85%) and lowest CP was recorded in *L. leucocephala* IGFRI-96 (19.22 %). The highest ash content was recorded in *L. leucocephala* S-13 (11.58%) and lowest in *L. leucocephala* K-29 (6.29%). The highest NDF was found in *L. leucocephala* S-1 (52.27%) and lowest in *L. leucocephala* Conn-3 (38.03%). Lowest ADF value was recorded in S-4 (16.42%) followed by *L. leucocephala* S-18 (16.46%) and highest ADF value was recorded in *L. diversifolia* -504 (23.04%) and lowest in *L. leucocephala* S-4 (16.42%). In case of cellulose highest content was recorded in *L. leucocephala* S-2 (12.96%) and lowest in *L. leucocephala* S-217 (6.06%). Lignin content was recorded lowest in *L. leucocephala* S-4 (6.12%) and highest in *L. leucocephala* K-340 (9.21%).

Generalized models for biomass of *Tectona grandis* have been developed and validated. The parabolic model $B = -22.2616 + 2.8447\ D + 0.1152\ D^2$ was found best fit ($R^2 = 0.951$, MSE = 15.47) among three models fitted. This model gave an error of only 3.89 kg/tree in stem biomass when validated on an independent dataset. Using this model carbon stock in stem, aboveground and total biomass have been estimated for different DBH classes. C-stock in aboveground and total biomass for 200 trees/ha was estimated to be 5.448 and 8.004 t/ha for 15-20 cm DBH class.

Study conducted on effect of arbuscular mycorrhizal inoculations on seedling growth of four *Leucaena* species namely, *L. collinsii*, *L. shannoni*, *L. diversifolia* and *L. leucocephala* for assessing increase in their growth, mycorrhizal dependency (MD) and seedling quality index (SQI) at nursery stage. Two AM species *viz.*, *A. scrobiculata* (As) and *R. intraradices* (Ri), which are

common in the Central India, used for inoculations has significantly increased the root length and Ri increased shoot length, root length, shoot dry weight and root dry weight. Most of these increase by mycorrhizal treatments were recorded in *L. collinsii* and *L. leucocephala* and very few in *L. diversifolia* and *L. shannoni*. Maximum mycorrhizal dependency (MD) was recorded for *Ri* (20.8%), which was significantly more than *As* (4.7%) and *As* + *Ri* (8.1%). *L. leucocephala* recorded maximum MD, followed by *L. collinsii*. *L. shannoni* and *L. diversifolia* recorded non-significant MD values. *Ri* increased *SQI* significantly. Among various *Leucaena* species, maximum growth was recorded in *L. shannoni*, followed by *L. collinsii*, *L. diversifolia* and *L. leucocephala*. Thus, the results suggested that the seeds of two Leucaena species *viz*., *L. leucocephala* and *L. collinsii* may be inoculated with Ri to obtain more vigorous seedlings.

The agroforestry based conservation agriculture for sustainable land use and Improved productivity consisted of three experiments *viz.* Bael based agroforestry system, Teak based agroforestry system and Bael + Teak based agroforestry system with 04 main plot treatments *i.e.*, Min. tillage-Blackgram-Mustard; Min. tillage-Greengram-Barley; CT-Blackgram-Mustard and CT-Greengram-Barley and 03 subplot treatments (with crop residue; without crop residue and with Leucaena (K-636) residue and are being conducted in split plot design.

It was observed that neither tillage treatments nor the residue treatments had significant influence on height and collar diameter of teak and bael. In Bael based conservation agriculture system, during *rabi*, the seed yield of mustard was recorded as 1347.1 kg/ha under minimum tillage (MT) and 1373.5 kg/ha in conventional tillage (CT). The grain yield of barley was recorded as 2137.9 kg/ha (MT) and 2184.4 kg/ha (CT) though were non-significant. During *kharif*, the blackgram seed yield was recorded as 349.6 kg/ha (MT) and 362.7 kg/ha (CT). The seed yield of greengram was recorded as 724.8 kg/ha in MT plots and 739.7 kg/ha in CT plots.

In Teak based conservation agriculture system, during *rabi*, the seed yield of mustard was recorded as 1294.9 kg/ha (MT) and 1327.6 kg/ha (CT). In case of barley crop, the grain yield was recorded as 2059.5 kg/ha in MT and 2101.2 kg/ha in CT system. During *kharif*, performance of blackgram was better under MT (407.8 kg/ha) than CT (418.8 kg/ha). Similar trend was observed in greengram and the seed yield was recorded as 733.5 kg/ha (MT) and 756.8 kg/ha (CT).

In Bael + Teak based conservation agriculture system, similar trends were recorded as observed in teak and bael based system. The growth and yield of mustard, barley, blackgram and greengram improved with CT practice over MT. Among the residue treatments, crop residue retention had performed better as compared to other treatments.

The basic infiltration rate was recorded more than two times in agroforestry based conservation agriculture over conventional tillage with residue. Basic rate of infiltration under conservation agriculture with residue was recorded as four time higher than the rate of 2016.

The incidence of *H. purea* was observed from May to September. The intensity ranged from 0.13 to 13.23/plant in teak based and 0.10 to 11.50/plant in teak + bael based CA system. However, peak activity was recorded during second fortnight of June to first fortnight of July (11.20 to 13.23/plant and 9.40 to 11.50/plant in teak and teak plus bael based systems, respectively). Total life cycle of male and female was completed in about 33 to 39 and 35 to 41 days with an average of 35.90±2.13 and 39.30±2.21 days, respectively.

In relation to physiological efficiency, clonal plants indicated better adaptability than seedling plants of *Pongamia pinnata* in field. Comparative physiological efficiency has also been reflected in growth and yield attributes of clonal plants.

Physiological, biochemical and leaf spectral traits were identified for their role in regulating shade tolerance in mustard and greengram. Highly detrimental impacts of shade were found in 50% shade or above providing consistent indication that 33% shade would be the critical limit for the select crops. Various responsive traits and their inter-traits relationship were

observed in relation to shade tolerance of the crops like mustard and greengram.

Biomass, carbon and carbon sequestration potential (CSP) of agroforestry system in two districts of Jharkhand and three districts of Odisha were estimated. Tree density played an important role in biomass production as well as carbon sequestration. Tree density varied from 7.5 to 16.0 trees/ ha in three districts (Puri, Dhenkanal and Sundergarh) Odisha. However, in two districts (Gumla and West Singh bhum) of Jharkhand, tree density is almost equal in both the districts. The CSP of agroforestry system in Jharkhand is about 0.17 t C ha/year and in case of Odisha, CSP varied from 0.12 to 0.20 t C ha/year.

Based on data of 51 districts from 17 states the CSP was 0.35 t C/ha/year. Looking to the area under agroforestry (17.45 million ha) in the country, the total carbon stock will be 6.10 million tones and CO_2 equivalent C will be 22.41 million tones. In this way the agroforestry can offset 22.41 million tones CO_2 from total CO_2 Equivalent GHG emission (1831.64 million tonnes). In other words, contribution of agroforestry to offset total GHG emission is 1.22%. Similarly, an estimation is made on contribution of different carbon pools in total C stock available in agroforestry at country level. The maximum contribution in total C stock is come from soil organic carbon followed by aboveground biomass, belowground biomass and litter.

Comprehensive effects of elevated temperature were observed on physiological traits of *Albizia procera* and *Azadirachta indica*. Leaf chlorophyll content index (CCI) declined remarkably in the elevated temperature in comparison to the ambient temperature, which suggests it as good indices for evaluating thermotolerance.

During pre-monsoon period, soil fauna was abundant in aonla (av.39.29) and shisham (av. 35.63) based agroforestry systems. Whereas, the lowest fauna was recoded in mono-cropping systems. Soil organism's activity was positively correlated with the soil organic carbon and organic matter.

During monsoon season, the highest faunal activity was noticed in shisham (av.159.2) and ber (av.143.55) based agroforestry systems, whereas less faunal activity was in greengram (av.78.8) and blackgram (av. 88.84). During post-monsoon season, the highest faunal activity was noticed in shisham (av.176.36) based agroforestry systems, whereas less faunal activity was in mustard (av.79.86) and barely (av. 92.46).

The highest glomulin content, dehydrogenase activity, soil organic carbon and organic matter content was recorded in ber based agroforestry systems in monsoon and post-monsoon season compared to other agroforestry systems. Micro fauna, meso fauna and macro fauna population was abundant in agroforestry systems compared to mono-cropping systems.

In agri-horti-silviculture model maximum GBH (cm), plant height (cm) and survival (%) was recorded in *A. senegal* and maximum canopy diameter (m^2) in *A. marmelos*. In this model, fruit yields were recorded from 14 plants of *C. lemon*, 17 *A. marmelos* and 19 *C. carandas*. A total of 115 kg lemon, 21 kg karonda and 118 kg bael fruits were harvested. The average weight of bael var. CISH B1 was 0.784 kg and var. CISH B2 was 1.575 kg. During *rabi* season of 2016-17, wheat (var. DBW 17) was cultivated and during *kharif* season (2017-18), moong (var. Sweta) was cultivated as intercrop. This year in *rabi* season, mustard (var. RH749) has been sown. After seven years of planting, natural oozing of gum (average 38.77 g/tree) from *A. senegal* was recorded. Plant growth and yield attributes of wheat were measured at different distances *viz*., 1.0, 2.5 and 4.5 m distances from tree trunk of *A. senegal*, *A. marmelos* and *C. limon*. Results revealed that planted tree species did not affect any growth and yield related parameters of intercrop (wheat), irrespective of distance. Irrespective of plant species, distances from tree trunk significantly affect plant population, biomass, grain yield and straw yield of wheat. Higher values of these parameters were recorded at 4.5 m distance from tree trunk and minimum values under the tree canopy *i.e.* at 1.0 m distance. During *kharif*, moong (var. Sweta) was sown under the recommended package of practices. Planted tree species did not affect plant height, seed yield and biomass. Maximum plant

population was recorded under *A. marmelos*, which was at par with *C. limon* and *A. senegal*. On the other hand, plant population, seed yield and biomass was found to be affected by distance. Maximum values of these parameters were recorded at 4.5 cm distance from the tree trunk while their minimum values were recorded under the tree canopy *i.e.* at 1.0 cm.

In horti-silviculture model-I, *Terminalia arjuna* showed maximum survival (100%), followed by *A. senegal* and *A. nilotica*. Growth parameters *i.e.* GBH and height were recorded maximum in *A. senegal*. In horti-silviculture model-II, *T. arjuna* showed maximum survival (100%), while higher GBH and plant height was recorded in *A. nilotica*. Survival and growth of *A. nilotica* was better than *A. senegal* in this model. Survival of *A. senegal* in block plantation on rocky site was 100% and plants attained mean height of 464.3 cm with girth at breast height (GBH) of 21.9 cm. In agri-silvi model, maximum survival was recorded by *A. nilotica* at 5 m × 5 m spacing while least in *A. senegal* at 10 m × 10 m spacing. After five years of plantation, higher GBH and plant height were recorded in *A. nilotica* than *A. senegal* in all spacing.

During summer season (2017), natural oozing of gum in different fields of *A. senegal* were observed. Natural oozing of gum ranged from 26.44 – 51.09 g/tree in field number 25 (average yield: 38.77 g), 11.16 – 16.07 g/tree in field number 40 & 41 (average yield: 14.08 g) and 3.81 – 220.38 g/ tree (average yield: 29.99 g) in gum garden.

Similarly, natural oozing of gum in different fields of *A. nilotica* was also observed. It ranged from 8.20 – 133.27 g/tree in field number 20 (average yield: 58.76 g) and 2.36 – 17.09 g/tree in field number 40 & 41 (average yield: 12.22 g).

During first year, height and collar diameter of teak (*Tectona grandis*) were recorded between 109.3 to 165.7 cm and 27.79 to 35.29cm, respectively. The corresponding values for mahagony (*Swietenia mahagoni)* were 61.8 to 77.6 cm and 14.83 to 18.96 cm, respectively. After one year of planting, maximum height and CD of teak and mahagoni were recorded in T_7 (T+M+P+ CST). During first year, the biomass of *C. ciliaris* were not influenced by soil and water conservation measures. After first rainy season (Sept. 2017), contour staggered trenches (CST) and half-moon basin (HMB) trapped sediments at the rate of 38.30 t/ha and 7.644 t/ha, respectively.

The grain yield of wheat grown in *Hardwickia binata* based AFS during *rabi,* 2016-17 ranged from 1550 kg/ ha at 3 m horizontal distance from tree base to 1150 kg/ha at 0.5 m distance. The variation in seed yield of mustard in Aonla based AFS was from 620 kg /ha at 0.5 m distance to 900 kg/ha at 3.0 m horizontal distance. The seed yield of greengram in Aonla based AFS in *kharif,* 2017 varied from 344 kg/ha at 0.5 m distance from tree base to 382 kg/ha at 3.0 m distance. The seed yield of blackgram in *Hardwickia binata* based AFS in *kharif,* 2017 varied from 258 kg/ha at 0.5 m distance from tree base to 296 kg/ha at 3.0 m distance.

In *Phyllanthus emblica* based agroforestry system (22 years old having a density of 100 trees/ha). It was found that during summer season the fine root length varies from 43.83 cm in 0-15 cm soil depth at a distance of 0.5 m from tree base to 2.47 cm in 75-90 cm soil depth at a distance of 1.0 m from tree base. The fine root length density (FRLD) varied from 0.046 cm/cm^3 in 0-15 cm depth to 0.003 cm/cm^3 in 75-90 cm depth. In *Hardwickia binata* based agroforestry system, 27 years old having a density of 200 trees/ha, it was found that during summer season the fine root length varies from 133.34 cm in 0-15 cm soil depth at a distance of 0.5 m from tree base to 14.20 cm in 75-90 cm soil depth at a distance of 3 m from tree base. The fine root length density (FRLD) varied from 0.14 cm/cm^3 in 0-15 cm depth to 0.015 cm/cm^3 in 75-90 cm depth. The soil organic carbon (SOC) stock varied from 31.55 Mg/ha in pure crop to 77.63 Mg/ha in *Hardwickia binata* based AFS. Similarly, in Aonla based AFS, the variation of SOC stock was from 30.22 Mg/ha in control plots to 59.33 Mg/ha in Agroforestry plots.

CHAPTER 1 GENERAL

Mission

To improve quality of life of rural people through integration of perennials on agriculture landscape for economic, environmental and social benefits.

Vision

Integration of woody perennials in the farming systems to improve land productivity through conservation of soils, nutrients and biodiversity to augment natural resource conservation, restoration of ecological balance, alleviation of poverty and to mitigate risks of weather vagaries.

Mandate

- Develop sustainable agroforestry practices for farms, marginal land and wastelands in different agroclimatic zones of India.
- Coordinate network research for identifying agroforestry technologies for inter-region.
- Training in agroforestry research for ecosystem analysis.
- Transfer of agroforestry technology in various agro climatic zones.

Library

Library is an integral part of the institute. The Institute's Library is well furnished and equipped with LAN facilities. Library operations are automated using Koha Library Management Software. List of library holdings are given in the below table:

On request references were supplied to the researchers on individual basis as well as through **CERA (Consortium for E-Resources in Agriculture)** servers through e-mail as well as soft/hard copies. Library also provided Services like Borrowing Facility, Reference Service and Inter Library Loan.

Laboratories and other facilities

ICAR- CAFRI has a main office building with six well-equipped laboratories. The Institute has conference hall, computer laboratory, committee room and Agroforestry Technology Information Centre (ATIC).

Agriculture Knowledge Management Unit

ICAR-CAFRI obtained 100Mbps Leased Line Internet Connectivity from RailTel Corporation of India Limited. New web server based Ubuntu LINUX has been installed for hosting Institute's web site (www.cafri.res.in). The entire network administration of computers, internet and website management is looked after by the Agriculture Knowledge Management Unit (AKMU).

Academic

Institute has been recognized by the Bundelkhand University as a study Institute to conduct Ph.D. programme. The Institute conducts M.Sc. dissertation and Ph.D. courses

Holding	Total Collection
Books (including Hindi books)	4549
Periodical subscribed (Indian)	15
Bound back volumes of research journals	2335
Dissertation -M.Sc.	102
Thesis- Ph.D.	29
CD- ROM (Forest Science Database, ICAR, ICFRE)	135
Maps	251
News Paper	06

Organizational Setup

DIRECTOR & PROJECT COORDINATOR

- Q R T
- I M C
- RAC
- IRC
- IJSC

Research Programmes

- System Research
- Natural Resource and Environment Management
- Tree Improvement, Post Harvest & Value Addition
- HRD, Technology Transfer & Refinement

Service Sections

- PME Cell
- Agriculture Knowledge Management Unit
- Liabrary & Documentation
- Administration & Finance
- Farm cum Workshop
- IPR Cell
- Public Information Cell

Network Systems

- AICRPAF

State Agricultural University : Solan, Srinagar, Kahikuchi, Palampur, Ludhiana, Pantnagar, Pusa (Bihar), Faizabad, Jhargram, Bhubaneshwar, Ranchi, Sardarkrushinagar, Fatehpur-Shekhawati, Hisar, Rahuri, Nagpur, Hyderabad, Jabalpur, Dharwar, Mettupalaym, Thrissur, Dapoli, Kattuapakkam, Bengaluru, Jammu (J&K), Shimoga

ICAR Institute : Dehradun, Umiam, Imphal, Gangtok, Karnal, Agartala, Ranchi, Jodhpur, Hyderabad, Jhansi

ICFRE Institute : IFGTB, Coimbatore

- IPR Management
- NICRA
- HPVA of IINRG

in Agroforestry, Horticulture, Environmental Sciences, Plant Protection, Soil Science, Biotechnology and Soil & Water Conservation from different recognized Universities. Institute contributing to education through UG teaching under collaborate programme with Rani Laxmibai Central Agricultural University, Jhansi.

Research Farm and facilities

The Institute possess about 86 ha land. Out of this about 12 ha (30 acres) land earmarked and handed over for the establishment of Rani Laxmi Bai Central Agricultural University, Jhansi. Now Institute has about 74 ha land only. Major area is rocky and degraded land, which has been gradually developed. About 85% arable land has been utilized after phase development for various agroforestry experiments, bulk cropping and block plantations. Research farm possess seven shallow dug wells but their recharge is very poor due to hard pan (3-5 m below ground). Cultivation is totally dependent on rainfall and operation of canal. During *kharif* season major area was put under green manuring to improve the soil health. This area experienced draught during rainy season. With little rain showers and long dry spell in the region green manuring crops were sown during *kharif,* 2017-18. During *rabi* 2017-18 major area was put under low water requirement crops with uncertainty of canal operation and poor discharge from shallow wells. Crop wise area and production during *rabi*, 2016-17 (received in 2017-18) and *kharif,* 2017-18 are given below :

Season / Crop & Variety	Area (ha)	Production (tones)
***Rabi*, 2016-17 (received in 2017-18)**		
Wheat HUW-234/HD2967/ DBW17	4.45	13.869
Barley DWRB73/RD2552	5.20	6.75
Gram Jaki 9218	3.10	2.52
Mustard RH749	4.40	1.76
Lentil DPL62/ Mallika	1.75	0.15
Pea Arkel/IPF4-9	2.15	0.51
Straw	-	21.00
***Kharif*, 2017-18**		
Dhaincha	4.80	0.030 + green manuring
Urd T-9/IPUZ43	4.20	1.03
Moong PDM-139/Shweta/IPM2-14	5.25	0.862 + green manuring
Cowpea Gomati	1.40	green manuring
Ragi	0.13	0.097
Jowar CSV-17	0.08	failed due to draught
Bajra Pioneer 86M88	0.01	failed due to draught
Straw	-	10.00

During *Rabi,* 2017-18 about 20.05 ha area have been sown which include 7.90 ha experimental and 12.15 ha general cropping in concluded agroforestry projects. Crop wise area sown in Rabi season is given in the next table:

During the year, a revenue to the tune of ₹ 8.24 lakhs have been generated from CR Farm. The Central Research Farm facilitated with most improved farm machineries and implements for mechanized farm operations. During the year, one four wheeled Reaper-Binder machine, one four wheeled Water Tanker cap. 4500 litres, one Multi Crop Thresher and two Electronic Balances(cap. 50kg & 300 kg) were added in farm facilities. A mini workshop equipped with welding plants, drill machine, car washer, grinder etc. besides other tools for repair and maintenance of farm machineries is available at

Crop	Sown Area (ha)		Total (ha)
Rabi, 2017-18	Experimental	General	
Wheat HUW-234/ DBW17	1.40	2.80	4.20
Barley BHS400/RD2552	2.80	2.90	5.70
Gram Jaki 9218	-	2.85	2.85
Mustard RH749	2.30	3.20	5.50
Lentil DPL62/ Mallika	-	0.40	0.40
Pea Arkel/IPF4-9	1.40	-	1.40
Total	7.90	12.15	20.05

the Institute. Irrigation facilities was strengthen adding 100 Nos. HDPE irrigation pipes (90mm) besides extending 520 meters (40/50 mm) pipelines to newly planted to experiments.

Budget (2017-18)

(₹ in Lakhs)

Sl.	Head	RE(2017-18) (other than NEH & TSP expenditure)	Expenditure Other than NEH	(TSP)	Expenditure (NEH)	Total Expenditure
	1	2	3	4	5	6 (3+4+5)
(A) ICAR-CAFRI						
1	CAPITAL (grant for creation of Capital Assets)	105.00	104.45	0.00	0.00	104.45
2	Establishment Expenses (Grant in Aid-Salaries)	683.00	682.19	0.00	0.00	682.19
3.	Grant in Aid-General					
	1. Pension Benefits	73.00	65.40	0.00	0.00	65.40
	2. Others	260.00	257.33	0.00	0.00	257.33
	Grand Total	**1121.00**	**1109.37**	**0.00**	**0.00**	**1109.37**
4.	Loans & Advances	2.00	1.50	0.00	0.00	1.50
(B) AICRP-Agroforestry						
	1. CAPITAL (grant for creation of Capital Assets)	65.00	42.50	0.00	22.50	65.00
	2. Establishment Expenses (Grant in Aid-Salaries)	1000.00	1000.0	0.00	0.00	1000.00
	3. Grant in Aid-General	80.0	79.49	20.00	10.00	109.49
	Grand Total	**1175.0**	**1121.99**	**20.00**	**32.50**	**1174.49**
(C) Plan Schemes						
1.	Harvest and post-harvest processing and value addition of natural resins, gums and gum resins (HPVA; ICAR, New Delhi)					16.09
2.	National Initiative on Climate Resilient Agriculture (NICRA; ICAR, New Delhi)					18.72
3.	IPR Management in agroforestry (ICAR, New Delhi)					0.00

(D) Externally Funded Projects			
1	Development of Nursery of TBOs for Quality Planting Material Production (NMOOP-MM-III Project)		3.68
2.	Development of insecticide resistant strain of Trichogramma for the management of lepidopterous pest in semi-arid Central India (DST Project)		8.57
3.	National Mission for Sustaining the Himalayan Ecosystems (NMSHE-Taskforce 6 for Himalayan Agriculture)		6.36
	Revenue Receipt	**Target**	**Achievement**
		13.50	19.04
	Expenditure as incurred on Swachhata Action Plan	0.00	7.10 (approx.)

CHAPTER 2 RESEARCH ACHIEVEMENTS

2.1: System Research Programme

NRMACAFRISIL201000200085

Nutrient management in ber based agri-horticulture System

(Sudhir Kumar, Anil Kumar, Rajendra Prasad, Inder Dev and Veeresh Kumar)

As per modified technical program (2012) ten treatments, *viz* T_1- Ber (100% RDF), T_2- Ber (100% RDF) + Sesame- Lentil, T_3- Ber (75% RDF), T_4- Ber (75% RDF) + Sesame- Lentil, T_5- Ber (75% RDF) + VAM, T_6- Ber (75% RDF) + VAM + Sesame- Lentil, T_7- Ber (75% RDF) + *Trichoderma,* T_8- Ber (75% RDF) + *Trichoderma* + Sesame- Lentil, T_9- Ber (75% RDF) + VAM + *Trichoderma* + Sesame- Lentil and T_{10}- Sesame- Lentil, were imposed before the onset of monsoon by adopting RBD with three replications at the spacing of 6 x 8m. In each treatment, there were six plants. During IRC 2017, it was decided to change the cropping system and accordingly sesame and lentil replaced by blackgram and barley. Accordingly, *kharif,* 2017 onwards the technical program is as T_1- Ber (100% RDF), T_2- Ber (100% RDF) + Blackgram - Barley, T_3- Ber (75% RDF), T_4- Ber (75% RDF) + Blackgram - Barley, T_5- Ber (75% RDF) + VAM, T_6- Ber (75% RDF) + VAM + Blackgram - Barley, T_7- Ber (75% RDF) + *Trichoderma,* T_8- Ber (75% RDF) + *Trichoderma* Blackgram - Barley, T_9- Ber (75% RDF) + VAM + *Trichoderma* + Blackgram - Barley and T_{10}- Blackgram - Barley. The main objective of the experiment is to find out suitable nutrient management schedule for enhanced system productivity, profitability and sustainability under semi- arid conditions and also to observe whether by incorporating the bio- inoculants one can save fertilizer without compromising the production and quality of produce.

The observations recorded on fruits during 2016-17 (plant age 6½ years) are presented in Table 1. It is evident from the data that all the fruit characters were influenced significantly except stone weight, pulp/stone ratio, TSS and number of fruits per plant. Maximum average fruit weight (20.89 g) was found significantly higher in treatment T_3, whereas it was minimum (17.50 g) in T_9. Average bigger size fruits were harvested in treatment T_3 (3.33 x 3.30 cm) followed by T_8 (3.28 x 3.25 cm). Fruit volume ranged from 17.75 cc in T_4 to 20.95 cc in T_3 and found significant. Likewise pulp weight was maximum in treatment T_3 (19.50 g) and minimum was recorded in T_9 (16.13 g) and found significant between the treatments. Stone weight, pulp/stone ratio, Total Soluble Solids (TSS) and number of fruit plant^{-1} were found non-significant. Fruit yield was significantly higher in treatment T_8 (70.19 kg/plant) but found at par with T_3 (70.00 kg/plant) and T_6 (65.54 kg/plant).

Table 1: Effect of treatments on fruit characters and yield of ber (cv Seo) fruits

Treat	Weight (g)	Size (cm) L	Size (cm) W	Volume (cc)	Pulp wt (g)	Stone wt. (g)	Pulp/ stone ratio	TSS ^{0}B	No. of fruit plant^{-1}	Yield (kg pl^{-1})
T_1	18.32	3.22	3.14	18.35	16.98	1.34	12.66	15.01	3203.83	57.75
T_2	17.67	3.14	3.11	17.86	16.37	1.30	12.62	15.15	2615.17	45.60
T_3	20.89	3.33	3.30	20.95	19.50	1.39	14.08	13.52	3349.06	70.00
T_4	17.63	3.14	3.13	17.75	16.22	1.41	11.56	15.63	2603.47	45.41
T_5	18.51	3.22	3.16	18.55	17.17	1.34	12.81	15.38	2536.39	46.96
T_6	18.77	3.21	3.18	18.82	17.42	1.35	12.92	14.80	3543.72	65.54
T_7	18.30	3.18	3.16	18.27	16.90	1.40	12.06	14.88	2885.40	52.31
T_8	19.87	3.28	3.25	19.97	18.48	1.39	13.30	13.43	3883.89	70.19

T_9	17.50	3.13	3.12	17.76	16.13	1.37	11.76	15.45	2838.90	49.32
CD (0.05)	1.89	0.11	0.11	1.98	1.87	NS	NS	NS	NS	17.99

T_1: Ber (100%RDF), T_2: Ber (100%RDF) + Sesame-Lentil, T_3: Ber (75%RDF), T_4: Ber (75%RDF) + Sesame-Lentil, T_5: Ber (75%RDF) + VAM, T_6: Ber (75%RDF) + VAM + Sesame-Lentil, T_7: Ber (75%RDF) + Trichoderma, T_8: Ber (75%RDF) + Trichoderma + Sesame-Lentil and T_9: Ber (75%RDF) + VAM + Trichoderma + Sesame-Lentil

The plants were pruned in the month of May, 2017 (in VIIth year after planting) and the pruned material ranged from 10.52 kg to 15.65 kg/plant on fresh weight basis, and 6.30 to 9.55 kg/plant on dry weight basis. In both the cases treatments were found significant (Table 2). After pruning 100% survival was observed in the field. The observations recorded in the month of December, 2017 are presented in Table 2. The data revealed significantly maximum collar diameter in treatment T_1 (12.35 cm) which was at par with T_3, T_5, T_6, T_8 and T_9. Minimum collar diameter was recorded in treatment T_4 (9.59 cm), while canopy spread was non-significant.

Table 2: Effect of treatments on pruned material and plant growth characters of ber fruits (cv Seo)

Treatment	Pruned Material (kg/plant)		Collar diameter	Canopy Spread (m)	
	Fresh	Dry	(cm)	EW	NS
T_1	15.57	9.53	12.35	4.67	4.68
T_2	10.54	6.42	10.83	4.28	4.57
T_3	14.58	8.45	11.58	4.49	4.52
T_4	12.32	7.54	9.59	4.08	4.03
T_5	14.27	8.68	11.03	4.72	4.89
T_6	15.40	9.34	11.83	4.56	4.66
T_7	13.35	8.36	10.82	4.53	4.76
T_8	15.65	9.55	11.48	4.73	4.77
T_9	10.52	6.30	11.32	4.33	4.50
CD (0.05)	3.77	2.24	1.36	NS	NS

Ber pruning

New flush after pruning

Ber based agrihorticulture system

Lentil (K 75) was sown (@ 40 kg/ha) during *rabi,* 2016 season on residual fertility under rainfed condition and harvested during 2017. Lentil recorded seed yield in the range of 738 to 995 kg / ha and corresponding straw yield was recorded in the range of 1095 to 1481 kg/ha in different treatments. The treatments T_{10} (pure crop) and T_6 (Ber (75% RDF) + VAM + Sesame - Lentil) recorded the seed yield of 995 and 980 kg/ha, respectively and were significantly higher as compared to other treatments. Similar trend was observed in corresponding straw yield (Table 3). Data indicated that treatments T_{10} and T_6 also recorded significantly higher number of pods/plant and seeds/pod. During *rabi,* 2017 barley (var. BHS-400 C/S) was sown at the seed rate of 100 kg / ha on residual fertility under rain-fed condition.

Table 3: Yield and yield contributing characters of Lentil during *rabi*, 2016-17

Treat-ment	Plant population (per m^2)	Plant height (cm)	Biomass (DW g/plant) (shoot+root)	Seeds/ pod	Pods/ plant	Test weight (g)	Seed yield (kg/ha)	Straw yield (kg / ha)
T_2	18.14	30.92	0.51	2.48	35.27	45.62	758	1129
T_4	19.12	28.15	0.49	2.51	36.71	43.28	763	1137
T_6	19.43	31.44	0.48	2.75	40.08	45.47	980	1462
T_8	17.28	28.94	0.47	2.47	35.75	46.08	738	1095
T_9	17.46	30.57	0.46	2.39	35.18	47.33	751	1116
T_{10}	18.27	29.12	0.49	2.85	41.75	48.92	995	1481
CV (%)	17.59	19.05	18.75	18.29	18.95	19.02	18.09	19.25
CD (0.05)	NS	NS	NS	0.16	1.7	NS	141	205

T_2: Ber (100%RDF) + Sesame-Lentil, T_4: Ber (75%RDF) + Sesame-Lentil, T_6: Ber (75%RDF) + VAM + Sesame-Lentil, T_8: Ber (75%RDF) + Trichoderma + Sesame-Lentil, T_9: Ber (75%RDF) + VAM + Trichoderma + Sesame-Lentil and T_{10}: (control) Sesame-Lentil

During *kharif*, 2017, Blackgram variety Azad-3 (Foundation seed) was sown in July, 2017 (15 kg/ha) with recommended dose of nutrients. Data presented in Table 4 indicated that plant population, plant height and dry matter accumulation were observed to be non-significant, however pods $plant^{-1}$ and seeds pod^{-1} were significantly influenced by different treatments. The seed yield varied in the range of 245 to 275 kg/ha. The treatments T_{10} (pure crop) and T_6 (Ber (75% RDF) + VAM + Blackgram - Barley) recorded highest seed yield of 275 and 268 kg/ha and was significantly higher over other treatments. Similar trend was observed for corresponding straw yield.

Table 4: Yield and yield contributing characters of Blackgram during *kharif*, 2017

Treat-ment	Plant population (per m^2)	Plant height (cm)	Dry matter accumulation (DW g/m^2)	Seeds/ pod	Pods/ plant	1000 seed weight (g)	Seed yield (kg/ha)	Straw yield (kg / ha)
T_2	20.8	39.02	126.4	4.70	7.16	31.5	245	538
T_4	21.3	37.74	129.8	4.67	7.23	31.9	247	541
T_6	19.4	36.08	132.1	4.78	7.34	34.7	268	554
T_8	21.7	40.75	127.5	4.65	7.21	31.4	259	533
T_9	22.4	41.03	128.7	4.66	7.20	32.2	262	540
T_{10}	23.6	38.45	135.9	4.82	7.42	35.2	275	565
CV (%)	19.08	18.95	18.76	19.07	18.65	19.02	18.48	17.80
CD (0.05)	NS	NS	NS	0.07	0.09	NS	12.2	14.5

T_2: Ber (100%RDF) + Blackgram - Barley, T_4: Ber (75%RDF) + Blackgram - Barley, T_6: Ber (75%RDF) + VAM + Blackgram - Barley, T_8: Ber (75%RDF) + *Trichoderma* + Blackgram - Barley, T_9: Ber (75%RDF) + VAM + *Trichoderma* + Blackgram - Barley and T_{10}: (control) Blackgram – Barley

Ber + Blackgram

Ber + Lentil

Management of ber fruit fly, *Carpomyia vesuviana* Costa (Diptera: Tephritidae)

A study was conducted to assess the efficacy of organic, conventional and newer insecticides against ber fruit fly, *Carpomyia vesuviana*. Efficacy of three groups of insecticides were evaluated *viz.*, Organic (Neem oil (3 ml/lt), Panchyagavyya (0.3ml/lt), NSKE (5%) and Agniastra (0.2ml/lt)), Conventional insecticides (Profenophos (2ml/lt), Monocrotophos (1.6ml/lt), Dimethoate (2ml/lt) and DDVP (2ml/lt)) and newer insecticides (Lambda Cyhalothrin (1ml/lt), Deltamethrin (1ml/lt) and Emamectin benzoate(0.6gm/lt)). Treatments were imposed at 15 days intervals and observation was recorded on the fruit damage (%).

The lowest infestation (16%) was recorded in newer insecticide treatments (Fig. 1). This was followed by conventional insecticide treatments (28.69%) and organic insecticides (36.26%). The highest fruit infestation was observed in control (50.36%).

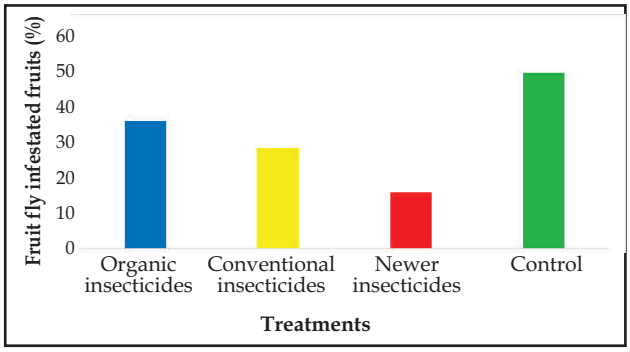

Fig. 1: Fruit infestation efficacy

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Structural and functional analysis of short rotation tree based Agroforestry system

(Naresh Kumar, A K Handa, Asha Ram, A R Uthappa, Dhiraj Kumar, Inder Dev, Veeresh Kumar and Mahendra Singh)

This project has been initiated in the year 2016 and main objectives of the project are to assess growth, biomass and carbon sequestration trends in tree components, to evaluate tree-crop interactions and its impact on crop productivity, and to study the wood properties in relation to fuel wood, pulp & paper industries and small timber. In this project, three fast growing tree species *viz.*, *Anthocephalus cadamba, Melia dubia* and *Leucaena leucocephala* have been planted at 4 x 5 m and 8 x 2.5 m spacings under seven treatments *viz.*, T_1-*Anthocephalus cadamba*+ *crop*, T_2 - *Melia dubia* + *crop*, T_3 - *Leucaena leucocephala* + *crop*, T_4 - *Anthocephalus cadamba (Pure plantation)*, T_5 - *Melia dubia (Pure plantation)*, T_6 - *Leucaena leucocephala (Pure plantation)* and T_7 - *Pure crop (Kharif/Rabi)* with three replications under RBD. blackgram – wheat crop sequence is being taken. Sixteen numbers of plants of each tree species have been planted in each plot (16 m x 20 m = 320 m^2). Although additional rows of trees have been planted for calculation of carbon sequestration in trees through destructive method. The rotation age of eight years has been fixed for final harvesting of trees.

The growth data of tree species was recorded and through destructive method the carbon stock in different parts of *Anthocephalus cadamba, Melia dubia* and *Leuucaena leucocephala* was calculated during 2017. During the *kharif* season blackgram was grown as intercrop and tree-crop interactions were studied.

Survival, Height and Collar Diameter of tree species

Data presented in Table 5 showed that at 4 x 5m spacing, the survival of tree species varied from 87.50% to 93.75%. The average height and collar diameter of *Anthocephalus cadamba, Melia dubia* and *Leuucaena leucocephala* were 2.10 m and 55.47 mm, 5.08 m and 94.86 mm, and 3.81 m and 39.75 mm, respectively when intercrop was taken under these species. Whereas, when these tree species were grown as pure plantations, their height and collar diameter were 1.93 m and 54.12 mm (cadamba), 4.7 m and 90.42 mm (melia) and 3.90 m and 43.60 mm (leucaena).

The survival of tree species varied from 79.16% to 89.58% in 8x2.5 m spacing. When intercrop was taken under Cadamba, Melia and Leuucaena planted at 8x2.5m spacing, their average height and collar diameter were 1.41 m and 33.72 mm, 3.71 m and 62.86 mm and 3.59 m and 34.62 mm, respectively. However, when these tree species were grown as pure plantation the respective values of height and collar diameter were 1.48 m and 27.31 mm, 3.50 m and 65.42 mm and 3.40m and 31.83 mm (Table 6).

Table 5: Average height and collar diameter of Cadamba, Melia and Leucaena

Tree species	4 x 5 m spacing					
	Survival (%)	Height (m)	Collar dia. (mm)	Survival (%)	Height (m)	Collar dia. (mm)
	With crop (AF)			Pure plantation		
Cadamba	91.66	2.10	55.47	87.50	1.93	54.12
Melia	93.75	5.08	94.86	87.50	4.7	90.42
Leucaena	91.66	3.81	39.75	87.50	3.90	43.60

Table 6: Average height and collar diameter of Cadamba, Melia and Leucaena

Tree species	8 x 2.5 m spacing					
	Survival (%)	Height (m)	Collar dia. (mm)	Survival (%)	Height (m)	Collar dia. (mm)
	With crop (AF)			Pure plantation		
Cadamba	79.16	1.41	33.72	87.50	1.48	27.31
Melia	83.33	3.71	62.86	87.50	3.50	65.42
Leucaena	89.58	3.59	34.62	87.50	3.40	31.83

Biomass and carbon stock in *A. cadamba, M. dubia and L. leucocephala*

Tree height and collar diameter were measured before uprooting trees. Excavation was done by manual digging and up-rooting and use high pressure water to detach soil from roots. Prior to excavation the area around the tree was watered thoroughly to soften the ground and make it possible to excavate without damaging the tree roots and also to extract entire root system.

Above ground parts were separated into stem, leaves and branches. Below ground parts were separated into tap root/primary roots, secondary roots, tertiary roots, quaternary roots and fibrous roots. Fresh weight of above ground parts was taken separately. These parts were then kept in oven for drying at 70± 2°C till constant weight and then their oven dry weight was measured. Similarly, fresh and dry weight of below ground parts was measured. Carbon stock in all the above ground and below ground parts was calculated by following formula:

Carbon stock = 50% of the oven dry biomass (IPCC, 2006)

Data presented in Table 7 showed that in A. cadamba, fresh biomass, dry biomass and carbon stock were found to be 2320.00, 1017.42, 508.71 g/plant. Among different parts of the tree, stem contributed maximum to biomass and carbon stock. The maximum carbon stock (45.70%) was found in the stem. Above ground plant parts contributed 72.54% share in total carbon stock whereas below ground parts formed 27.46% share (Table 8). In *Melia dubia*, fresh biomass, dry biomass and carbon stock were found to be 8550.50, 4453.50, 2226.75 g/plant. Carbon stock in leaves, stem, branches and primary root were found to be 310, 1027, 439.9 and 208.5 g/plant, respectively. The secondary, tertiary, quaternary and fibrous roots collectively contributed 241.35 g carbon stock per tree which is 10.84% of total carbon stock. The maximum carbon stock share *i.e.* 46.12% was found in the stem (Table 9). Above ground plant parts contributed 79.80% share in total carbon stock whereas below ground parts formed 20.20% share (Table 10). In *L. leucocephala*, fresh biomass, dry biomass, carbon stock was found to be 3180.00, 2118.50, 1059.25 g/plant. The maximum carbon stock (587.5 g/plant) and % share of total carbon stock (55.46%) was found in stem (Table 11). Above ground plant parts contributed 76.80% share in total carbon stock whereas below ground parts formed 23.20% share (Table 12).

Table 7: Biomass and carbon stock in *A. cadamba*

S.N.	Part	Fresh biomass g/plant	Dry biomass g/plant	Carbon stock g/plant	% share of total carbon stock
1.	Leaves	445	215	107.50	21.13
2.	Stem	1145	465	232.50	45.70
3.	Branches	120	58	29.00	5.70
4.	Tap/Primary root	405	180	90.00	17.69
5.	Secondary, Tertiary, Quaternary and Fibrous roots	205	99.42	49.71	9.77
	Total	2320	1017.42	508.71	100

Table 8: Share of above ground and below ground parts in carbon stock in *A. cadamba*

S.N.	Part	Fresh biomass g/plant	Dry biomass g/plant	Carbon stock g/plant	% share of total carbon stock
1.	Above ground	1710	738	369	72.54
2.	Below ground	610	279.42	139.71	27.46
	Total	2320	1017.42	508.71	100

Table 9: Biomass and carbon stock in *M. dubia*

S.N.	Part	Fresh biomass g/plant	Dry biomass g/plant	Carbon stock g/plant	% share of total carbon stock
1.	Leaves	1200	620	310	13.92
2.	Stem	3995	2054	1027	46.12
3.	Branches	1660	879.8	439.9	19.76
4.	Tap/Primary root	825	417	208.5	9.36
5.	Secondary, Tertiary, Quaternary and Fibrous roots	870.5	482.7	241.35	10.84
	Total	8550.50	4453.50	2226.75	100.00

Table 10: Share of above ground and below ground parts in carbon stock in *M. dubia*

S.N.	Part	Fresh biomass g/plant	Dry biomass g/plant	Carbon stock g/plant	% share of total carbon stock
1.	Above ground	6855.00	3553.80	1776.90	79.80
2.	Below ground	1695.5	899.70	449.85	20.20
	Total	8550.50	4453.50	2226.75	100.00

Table 11: Biomass and carbon stock in *L. leucocephala*

S.N.	Part	Fresh biomass g/plant	Dry biomass g/plant	Carbon stock g/plant	% share of total carbon stock
1.	Leaves	425	308	154	14.54
2.	Stem	1855	1175	587.5	55.46
3.	Branches	225	144	72	6.80
4.	Tap/Primary root	430	320	160	15.11
5.	Secondary, Tertiary, Quaternary and Fibrous roots	245	171.5	85.75	8.1
	Total	3180	2118.5	1059.25	100

Table 12: Share of above ground and below ground parts in carbon stock in *L. leucocephala*

S.N.	Part	Fresh biomass g/plant	Dry biomass g/plant	Carbon stock g/plant	% share of total carbon stock
1.	Above ground	2505	1627	813.5	76.80
2.	Below ground	675	491.5	245.75	23.20
	Total	3180	2118.5	1059.25	100.00

Tree-crop interactions

Data presented in the table 13 showed that the growth and yield of blackgram was minimum at 1 m distance (*i.e.* nearest to the tree row) from the plants of all the tree species under study. When blackgram was intercropped with cadamba, the grain yield of blackgram increased from 2.25 g/plant (at 1 m distance) to 2.55 g/plant (at 2.5 m distance). Similar trend was observed when blackgram was intercropped with melia. The minimum grain yield per plant (2.05 g) was observed at 1 m distance and the maximum yield 2.25 g/plant was observed at 2.5 m distance from tree rows of *Melia dubia*. Although the same crop yield trend was observed when the blackgram was intercropped with leucaena, but the yield per plant was higher as compared with the intercropping with cadamba and melia. The grain yield per plant ranges from 2.60 g/plant at 1 m distance to 2.86 g/plant at 2.5m distance from the tree rows.

Almost same trend was observed when blackgram was intercropped with cadamba, melia and leucaena planted at 8 x 2.5m spacing. The yield per plant ranged from 2.32 g (at 1 m distance) to 2.78 g (at 4 m distance), 2.19 g (at 1 m distance) to 2.45 g (at 4 m distance) and 2.35 (at 1 m distance) to 2.72 g (at 4 m distance) when intercropped with cadamba, melia and leucaena, respectively (Table 14).

Data presented in Table 13 showed that when blackgram was intercropped under cadamba, melia and leucaena planted at 4 x 5 m spacing, the average yield per plant was 2.38 g, 2.15 g and 2.73 g, respectively. Similarly, under 8 x 2.5 m spacing the average yield was 2.61 g, 2.34 g and 2.60 g, respectively (Table 14). However, when the blackgram was planted in open, yield of 2.78 g per plant was recorded (Table 13 and 14).

Table 13: Yield of blackgram crop at different distances from the tree species planted at 4 x 5 m spacing

Distance from tree row	Yield per plant (g)		
	A. cadamba	*M. dubia*	*L. leucocephala*
1 m	2.25	2.05	2.60
1.5 m	2.34	2.10	2.68
2.0 m	2.40	2.23	2.78
2.5 m	2.55	2.25	2.86
Average	2.38	2.15	2.73
Control	2.78		

Table 14: Yield of blackgram crop at different distances from the tree species planted at 8 x 2.5 m spacing

Distance from tree row	Yield per plant (g)		
	A. cadamba	*M. dubia*	*L. leucocephala*
1 m	2.32	2.19	2.35
1.5 m	2.46	2.26	2.48
2.0 m	2.48	2.32	2.62
2.5 m	2.72	2.34	2.65
3.0 m	2.75	2.39	2.70
3.5 m	2.77	2.43	2.72
4.0 m	2.78	2.45	2.72
Average	2.61	2.34	2.60
Control	2.78		

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Studies on soil biodiversity & nutrient dynamics in different agroforestry & mono-cropping system

(Veeresh Kumar, Anil Kumar, Dhiraj Kumar, Mahendra Singh, Naresh Kumar and N Manjunath (ICAR-IGFRI))

The study was conducted to estimate the soil fauna in different agroforestry and mono-cropping systems at the experimental farm of CAFRI-Jhansi during 2017-18. Soil samples were collected in ber, aonla, bamboo and shisham based agroforestry systems along with four mono-cropping systems *viz.*, blackgram, greengram, mustard & barley. Sampling period was divided into pre-monsoon, monsoon and post-monsoon period. Observations were recorded on micro fauna, meso fauna, macro fauna, soil organic carbon (%), organic matter (%), glomulin content (µg/gram of soil) and dehydrogenase activity (%). During pre-monsoon period, soil fauna was abundant in aonla (av. 36.29) and shisham (av. 35.63) based agroforestry systems. Whereas, the lowest fauna was recoded in mono-cropping systems. Soil organisms' activity was positively correlated with the soil organic carbon and organic matter (Fig. 2). During monsoon season, the highest faunal activity was noticed in shisham (av.159.2) based agroforestry systems, whereas lowest faunal activity was in monocropping system (Fig. 3). During post-monsoon season, the highest faunal activity was noticed in shisham (av.175.36) based agroforestry systems, whereas lowestr faunal activity was in monocropping system (Fig. 4). The highest glomulin content, dehydrogenase activity, soil organic carbon and organic matter content was recorded in ber based agroforestry systems in

monsoon and post-monsoon season compared to other agroforestry systems. Micro fauna, meso fauna and macro fauna population was abundant in agroforestry systems compared to

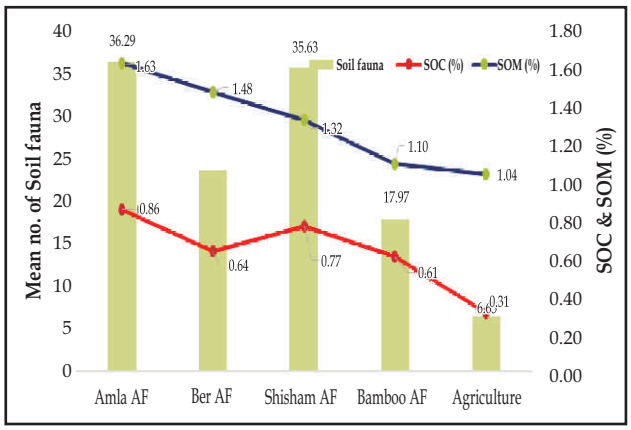

Fig. 2: Soil fauna population, Soil Organic Carbon (SOC) & Soil Organic Matter (SOM) in different agroforestry and mono-cropping systems in pre-monsoon season during 2017.

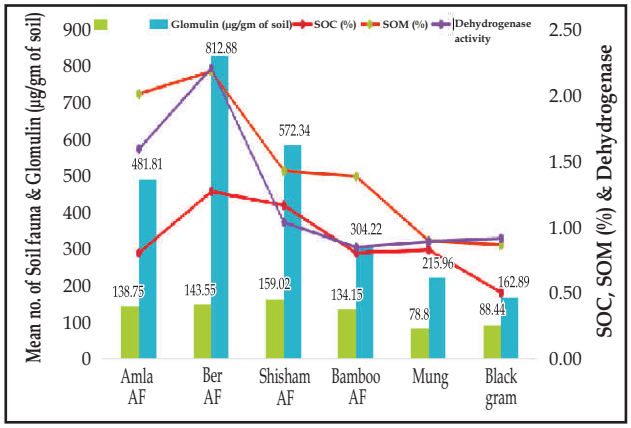

Fig. 3: Soil fauna population, Soil Organic Carbon (SOC), Soil Organic Matter (SOM), dehydrogenase & glomulin content in different agroforestry and mono-cropping systems in post-monsoon season during 2017-18.

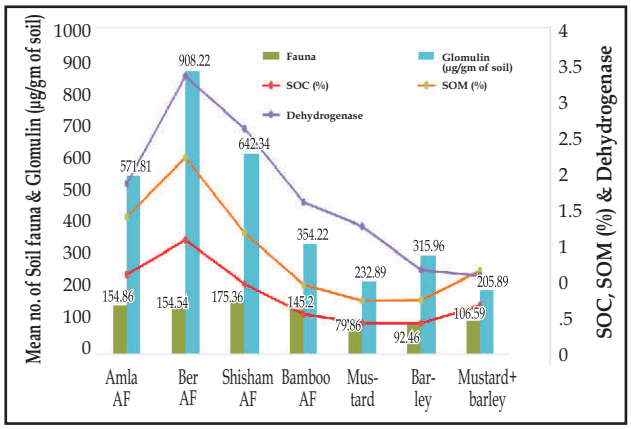

Fig. 4: Soil fauna population, Soil Organic Carbon (SOC), Soil Organic Matter (SOM), Dehydrogenase & glomulin content in different Agroforestry and mono-cropping systems in Monsoon season during 2017.

Other Research Achievement

Plant-pollinator interaction in *Grewia flavescens* Juss

(Veeresh Kumar)

Floral traits display is one of the evolutionary strategies adopted by plants to acquire reproductive fitness and to optimize resource allocation by choosing effective pollinators. In present study, *Grewia flavescens* Juss. was studied for its floral display mechanisms in relation to pollinators interaction and pollination efficiency. At anthesis, *G. flavescens* flowers exhibited two types of adaptation (horizontal and vertical) to avoid selfing and favouring cross pollination. The nearest distance between anthers and stigma was 2.12 ± 0.84 mm (horizontal) and 1.23±0.28 mm (vertical) at flower opening. Anthers come in contact with stigmatic surface only after four hours of anthesis. A total of 25 species of flower visitors were recorded, of which Megachilidae (48.35 %) was the most abundant group followed by Apidae (27.21%), Halictidae (10.29%) and others (14.15%). Fruit set was highest (71.42 %) in open pollinated flowers followed by hand cross pollinated flowers (68.33%). Hand self-pollinated flowers and pollinator excluded flowers resulted in 22.22 and 8.95% fruit set, respectively. Floral trait modification appears to have evolved for cross pollination by megachilid bees than other flower visitors.

Characterization of baramasi jack fruit tree identified in Tikamgarh (M.P.)

*(R K Tiwari, Lal Chand and S K Singh**
**KVK, Tikamgarh, MP)*

Jack fruit (*Artocarpus heterophyllus Lam.*) belongs to family Moraceae and is an evergreen tree of tropics. It comes up well in sub-tropics as well up to an evaluation of 1500 m amsl. The species owe its origin from Malaysia and Western Ghats of India. The species is very common in home gardens of South India. It is well naturalized to sub-tropical conditions of Central and North India. The fruit is consumed as vegetable when unripe and as table fruit after ripening. In North Indian conditions, jack fruit flowers once in a year. Raw fruits are available in the market from April to June. In Bundelkhand region, jack trees

are not very common. However, they are grown in home gardens and near wells. A tree with long fruiting span is highly desirable as they fetch good market price during off-season. A tree with long fruiting span has been identified at latitude 25°30' N, longitude 78°32' E and an altitude of 384 m amsl on farmer's field in Tikamgarh District of M.P. This tree is about 30 years old and over 10 m tall with erect growing habit. Basal diameter and DBH of the tree were measured during February, 2018 which were 130 cm and 155 cm, respectively. The leaf blade length and width varied from 12.2 to 19.0 cm (mean 15.28 cm) and from 7.3 to 9.5 cm (mean 8.1 cm), respectively with elliptic leaf shape. In this tree, flowering and fruiting starts from September onwards and continues till June. For vegetable purpose fruits available from January onwards and ripening starts from first fortnight of March. Mean fruit weight, length, and diameter were recorded as 2.97 kg, 35 cm, 21.5 cm, respectively. The fruit is having ellipsoid shape and yellow flesh on ripening. Mean flake thickness and length were measured as 2.32 and 4.54 cm, respectively. The mean number of seeds per fruit, seed length and seed thickness were measured as 40, 3.26 cm and 1.58 cm, respectively. Ripe fruit has very high TSS (31°Brix). This tree yielding fruits around 120 Kg per year. Due to long fruiting span, tree fetches high returns from fruits during off-season. The farmer informed that this mother tree fetches ₹ 3000.00 per year in local market. At spacing of 8 x 8 m., it can fetch over ₹ 4,50,000.00 per ha/year.

This necessitated need for multiplication of identified mother plant. Initial attempts are being made on vegetative propagation in mother plant employing soft wood cleft with capping technique and observed encouraging results.

2.2: Natural Resource & Environment Management Programme

NRMACAFRISIL 200700100068

Evaluation of shade tolerance of crop species for agroforestry systems

(Badre Alam, Ram Newaj and Lal Chand)

Plant biomass index in mustard (*Brassica juncea*) decreased with increase in shade intensity and the lowest biomass index was in 75% shade (Fig. 5). Leaf area being a source of carbon gain to the crop, leaf area index (LAI) showed decreasing trend with in shade intensity (Fig. 6). Impact of different regimes of shade were obviously reflected in the physiological efficiency of the crop. There was reduction of yield with increasing in shade intensity in comparison to the crop grown in open field under full sunlight. Comparative alarming reduction of yield was noticed in 50% shade and above (Fig. 7).

In mustard leaf, spectral traits have also been observed to be closely associated with the physiological process of the crop. Inter-traits relationship with physiological and leaf spectral traits under various regimes of shade has been noted (Figs. 8 & 9). The good linear trend of the leaf spectral traits with physiological attributes hold much importance for deciphering the physiological efficiency from the leaf spectral analysis.

Differential responses in relation to physiological and leaf spectral traits under various regimes of shade have been evaluated in greengram (*Vigna radiata*) also. As expected, there were decreasing trends in plant biomass index and yield with increase in shade intensity (Figs. 10 & 11). Altough, there was marginal reduction in yield in 33% shade, huge reduction in yield was noted in 50% shade and above. LAI decreased with increase in shade (Fig. 12). In greengram also, there was very good inter-traits relationship among the leaf spectral traits and physiological attributes under various regimes of shade (Figs. 13 & 14).

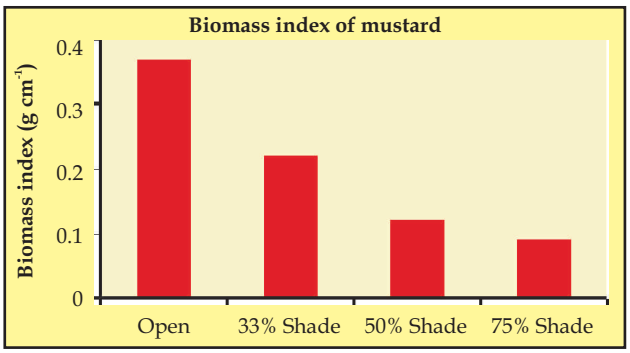

Fig. 5: Biomass index of mustard crop grown under varying regimes of shade and in open field

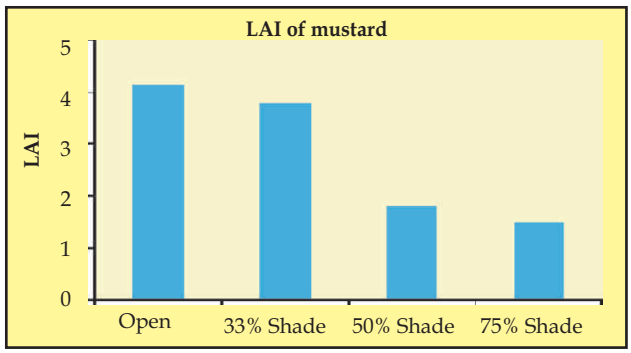

Fig. 6: Leaf area index (LAI) of mustard grown under varying regimes of shade

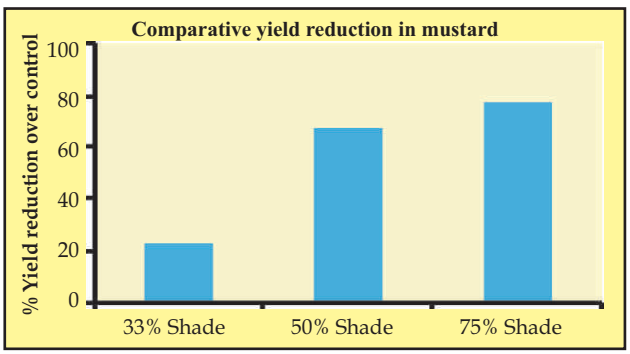

Fig. 7: Comparative yield of mustard grown under varying regimes of shade

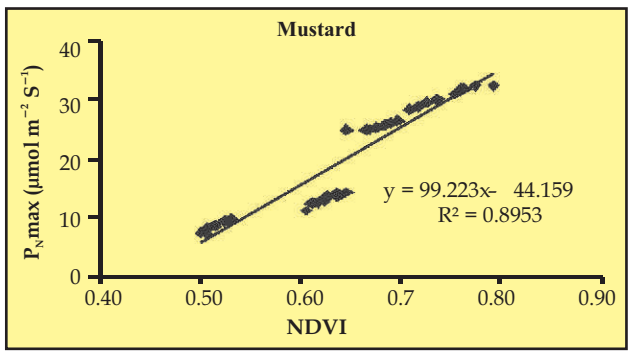

Fig. 8: Normalized difference vegetation index (NDVI) versus net CO_2 assimilation rate (P_N max) of mustard grown under varying regimes of shade

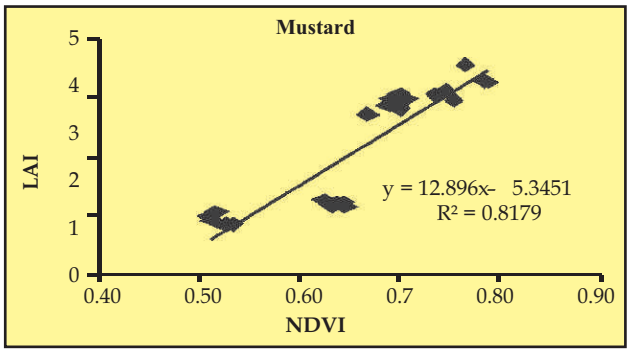

Fig. 9: Correlation of normalized difference vegetation index (NDVI) and LAI of mustard grown under varying regimes of shade

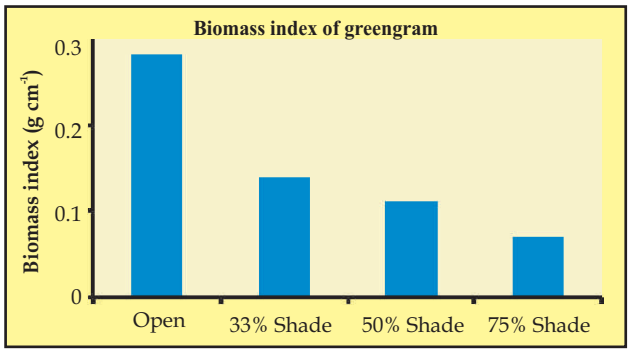

Fig. 10: Biomass index of greengram grown under varying regimes of shade

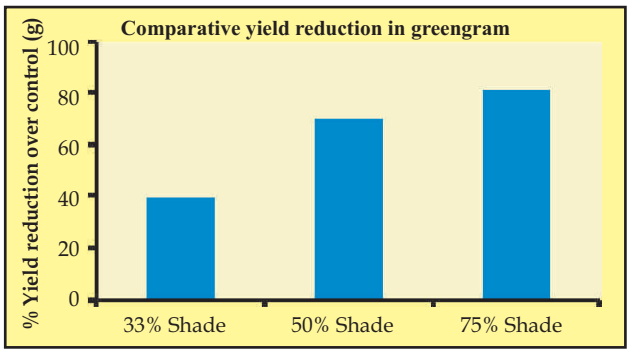

Fig. 11: Comparative yield of greengram grown under varying regimes of shade

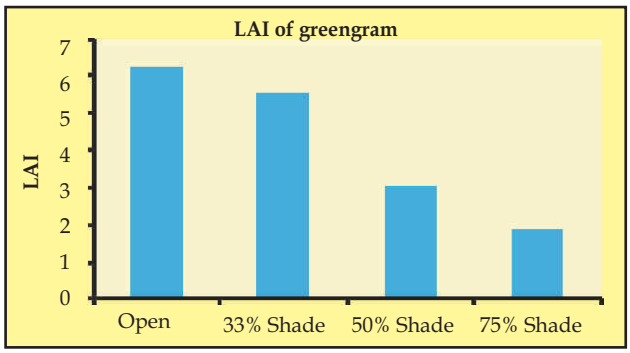

Fig. 12: Leaf area index (LAI) of greengram grown under varying regimes of shade

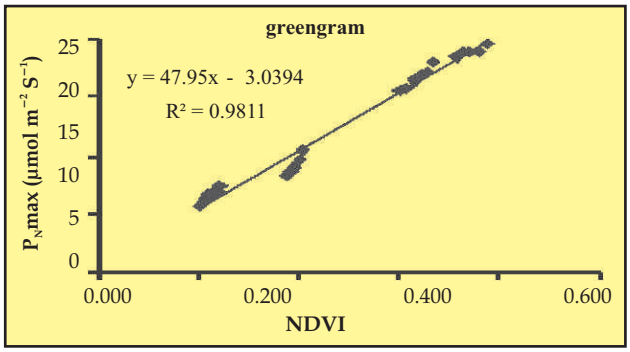

Fig. 13: Normalized difference vegetation index (NDVI) versus net CO_2 assimilation rate (P_N max) of green gram grown under varying regimes of shade

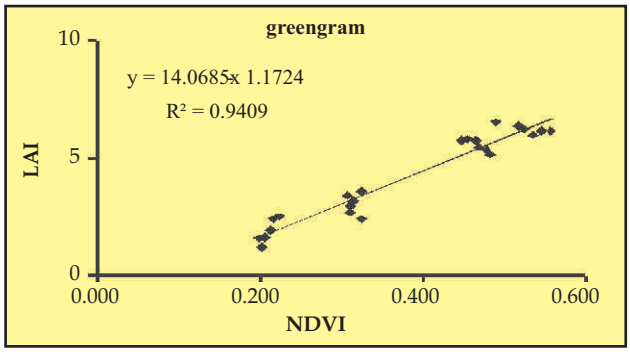

Fig. 14: Correlation of normalized difference vegetation index (NDVI) and LAI of greengram grown under varying regimes of shade

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Studies on arbuscular mycorrhizal fungi of important agroforestry plant species of Bundelkhand region

(Anil Kumar, Rajendra Prasad and Naresh Kumar)

The present study was initiated during 2007-08 to identify suitable AM fungi for inoculation of arbuscular mycorrhizal fungi (AMF) in important agroforestry tree species and intercrops. To achieve this, experiments on effect of arbuscular mycorrhizal fungi, azotobacter and phosphorus solubilizing bacteria on growth and yield of linseed and *S. seabrana* and effect of arbuscular mycorrhizal inoculations on seedling growth of four species of *Leucaena* were conducted during last year.

Effect of arbuscular mycorrhizal fungi, azotobacter and phosphorus solubilizing bacteria on growth and yield of linseed: Effect of AM fungi, azotobacter and phosphorus solubilizing bacteria on growth and yield of linseed was studied under net-house and field conditions. None of the treatments significantly increased different studied parameters (Table 15 and 16). Earlier similar experiments were carried

out on two important oil seed crops of Central India namely, groundnut and sesame, where moderate but significant increase in growth and yield were recorded.

Table 15: Effect of AM fungi on growth and yield of linseed under net-house conditions

Treatments	Shoot length (cm)	Number of tiller per plant	Number of capsule per plant	Dry shoot weight (g)	Dry root weight (g)	Yield per plant (g)
A. scrobiculata (As)	78.5	5.6	67.0	5.31	1.30	1.95
R. intradices (Ri)	74.7	5.7	72.2	5.31	1.35	1.74
As+Ri	78.3	5.3	70.8	5.35	1.44	1.87
Control	71.9	5.9	67.1	5.36	1.52	1.86
LSD	NS	NS	NS	NS	NS	NS

Table 16: Effect of inoculants on growth and yield of linseed under field conditions

Treatments	Shoot length (cm)	Number of tiller per plant	Number of capsule per plant	Number of seed per capsule	Thousand seed weight (g)	Plot yield (g)
(As)	69.7	6.4	108.3	7.1	5.69	531.7
R. intradices (Ri)	67.6	6.2	99.6	7.1	5.29	484.3
As+Ri	66.6	7.0	102.8	7.1	5.34	483.7
As + Azo + PSB	67.1	6.4	100.4	7.2	5.22	479.3
Ri + Azo + PSB	67.4	6.9	96.1	7.6	5.51	539.0
As + Ri +Azo + PSB	67.9	6.1	99.7	6.8	5.44	475.0
Control	68.3	5.8	86.8	7.2	5.30	534.7
LSD	NS	NS	NS	NS	NS	NS

Azo- Azotobacter, PSB- phosphorus solubilizing bacteria

Effect of arbuscular mycorrhizal fungi on growth and yield of *S. seabrana*: Effect of three mycorrhizal treatments *viz. Acaulospora scrobiculata* (As), *Rhizophagus intraradices* (Ri) and As+Ri on *S. seabrana* was studied last year. As and Ri significantly increased shoot length, number of tertiary branches, number of leaves and shoot dry weight. As+Ri increased only shoot weight. None of treatments increased number of secondary branches. Maximum MD was recorded in As (34.4%), followed by Ri (23.4%) and As+Ri (7.3%). Thus negative synergy was recorded between As and Ri. Similar interaction between above mentioned fungi was recorded in bael, parkia and leucaena during last year (Table 17).

Table 17: Effect of AM fungi on growth of *Stylosanthes seabrana* after 75 days of sowing under net-house conditions

Treatments	Shoot length (cm)	Number of secondary branches	Number of tertiary branches	Number of leaves	Shoot dry weight	Mycorrhizal dependency (%)
A. scrobiculata (As)	58.0	14.3	44.8	226.6	6.94	34.4
R. intradices (Ri)	55.1	14.0	43.7	213.7	5.94	23.4
As + Ri	51.0	12.7	37.1	180.4	4.91	7.3
Control	48.3	12.9	31.1	172.6	4.55	-
LSD	4.2	NS	6.1	27.7	1.07	

Effect of arbuscular mycorrhizal inoculations on seedling growth of four species of Leucaena: An experiment was conducted to study the suitability of arbuscular mycorrhizal (AM) fungi for inoculation of four *Leucaena* species namely, *L. collinsii*, *L. shannoni*, *L. diversifolia* and *L. leucocephala* for assessing increase in their growth, mycorrhizal dependency (MD) and seedling quality index (SQI) at nursery stage. Two AM species *viz.*, *A. scrobiculata* (As) and *R. intraradices* (Ri), which are common in the Central India were used for inoculations. These significantly increased the root length and Ri increased shoot length, root length, shoot dry weight and root dry weight. Most of these increases by mycorrhizal treatments were recorded in *L. collinsii* and *L. leucocephala* and very few in *L. diversifolia* and *L. shannoni* (Table 18 and 19). Maximum mycorrhizal dependency (MD) was recorded for *Ri* (20.8%), which was significantly more than *As (4.7%)* and *As + Ri (8.1%)*. *L. leucocephala* recorded maximum MD, followed by *L. collinsii*. *L. shannoni* and *L. diversifolia* recorded non-significant MD values (Fig. 15). *Ri* increased *SQI* significantly (Fig. 16). Among various *Leucaena* species, maximum growth was recorded in *L. shannoni*, followed by *L. collinsii*, *L. diversifolia* and *L. leucocephala*. Thus, the results suggested that the seeds of two Leucaena species *viz.*, *L. leucocephala* and *L. collinsii* may be inoculated with Ri to obtain more vigorous seedlings.

Table 18: Effect of arbuscular mycorrhizal inoculations on growth of *Leucaena* species

Treatments	Growth of different species				Mean
	L. diversifolia	*L. shannoni*	*L. collinsii*	*L. leucocephala*	
Shoot length (cm)					
A. scrobiculata (As)	67.0	77.2	77.0	58.0	69.8
R. irregularis (Ri)	80.3	83.3	84.0	59.2	76.7
As+Ri	61.7	73.7	83.0	55.2	68.4
Control	72.0	80.5	71.0	38.7	65.5
Mean	70.3	78.7	78.8	52.8	
Root length (cm)					
A. scrobiculata	33.8	42.0	32.3	33.8	35.5
R. irregularis	28.3	41.2	37.2	33.7	35.1
As+Ri	25.3	30.7	34.2	28.5	29.7
Control	29.3	36.7	35.3	25.5	31.7
Mean	29.2	37.6	34.8	30.4	
Collar diameter (mm)					
A. scrobiculata	6.65	8.93	7.31	7.42	7.58
R. irregularis	7.91	8.59	8.23	7.28	8.00
As+Ri	7.18	8.04	8.00	6.94	7.54
Control	7.76	8.23	7.51	6.41	7.48
Mean	7.37	8.45	7.76	7.01	
		LSD			
	Shoot length	Root length	Collar diameter		
Treatment	5.5	2.7	NS		
Species	5.5	2.7	0.54		
Interaction	11.0	5.5	NS		

Table 19: Effect of arbuscular mycorrhizal inoculations on shoot and root dry weights of *Leucaena* species

Treatments	*L. diversifolia*	*L. shannoni*	*L. collinsii*	*L. leucocephala*	Mean
Shoot dry weight (g)/plant					
A. scrobiculata (As)	9.95	9.69	8.64	8.01	9.07
R. irregularis (Ri)	11.89	12.43	12.40	7.73	11.11
As+Ri	9.76	9.52	11.67	7.49	9.61
Control	10.80	10.33	8.90	4.73	8.69
Mean	10.60	10.49	10.40	6.99	
Root dry weight (g)/plant					
A. scrobiculata	5.23	5.96	4.84	4.65	5.17
R. irregularis	5.66	6.58	6.34	5.21	5.95
As+Ri	4.55	5.49	5.51	4.69	5.06
Control	5.34	5.35	4.95	2.90	4.64
Mean	5.20	5.85	5.41	4.36	
Total dry weight (g)/plant					
A. scrobiculata	15.18	15.65	13.47	12.66	14.24
R. irregularis	17.55	19.01	18.73	12.94	17.06
As+Ri	14.31	15.01	17.18	12.18	14.67
Control	16.14	15.68	13.85	7.63	13.32
Mean	15.79	16.34	15.81	11.35	
		LSD			
	Shoot dry weight	Root dry weight	Total dry weight		
Treatment	1.14	0.61	1.45		
Species	1.14	0.61	1.45		
Interaction	2.28	NS	2.89		

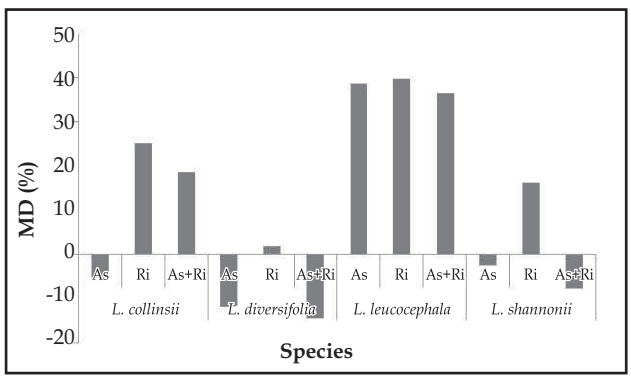

Fig. 15: Mycorrhizal dependency (MD) of Leucaena species on different mycorrhizal treatments

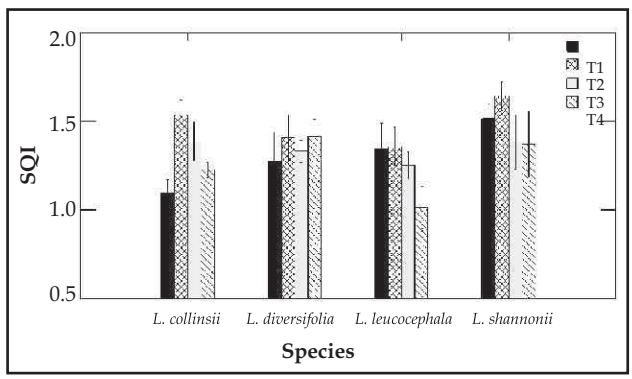

Fig. 16: Effect of mycorrhizal species (T1- *A. scrobiculata*; T2- *R. irregularis*; T3- *A. scrobiculata* + *R. irregularis*; T4- Control) on seedling quality index (SQI) of *Leucaena* species

NRMACAFRISIL201100200088

Multi-Source inventory methods for quantifying carbon stocks through generalized volume/ biomass equations for prominent agroforestry species in India

(R H Rizvi and A K Handa)

Two equations were found in literature on bole biomass of *Tectona grandis*. One equation was for Madhya Pradesh and other for Tamil Nadu. Both the equations were based on diameter at breast height (dbh). From these equations, dataset on bole biomass and dbh has been simulated, with a high correlation between them (0.973). This dataset was then used for development of generalized model for biomass of *T. grandis.*

Generalized models for biomass of *Tectona grandis*

Three types of non-linear equations were fitted for bole/ stem biomass of *T. grandis* (Table 20). Out of three, parabolic equation B = -22.2616 +2.8447 D +0.1152 D^2 ; where B- biomass (kg/tree) and D- diameter at breast height; was found best fit because it has highest value of R^2 and lowest value of mean square error (MSE). These models were validated on an independent dataset and mean absolute error (MAE) was computed. The parabolic model gave smallest error of 3.896 among three. Hence this model may be used for estimation of bole biomass of *T. grandis* in any region.

Estimation of Carbon stock

From developed generalized model, stem and aboveground biomass were estimated. From literature it is found that stems biomass is about 67 per cent of aboveground biomass. Then dry stem and dry aboveground biomass were calculated by considering 60 percent of fresh biomass. From dry biomass, carbon stock in stem and above ground biomass has been worked out by formula C = 0.47*B; where C- carbon stock (kg/ tree) and B – biomass (kg/ tree).

C-stock per tree was multiplied with tree densities (100, 200, 400 trees /ha) to get C-stock per ha for different DBH classes (Fig. 17). C-stock in aboveground and total biomass for 200 trees /ha was estimated to be 5.448 and 8.004 t /ha for 15-20 cm DBH class, which increased to 8.607 and 12.644 t /ha for 20-25 cm DBH class, respectively. This shows that *Tectona grandis* has good potential of carbon storage in its biomass.

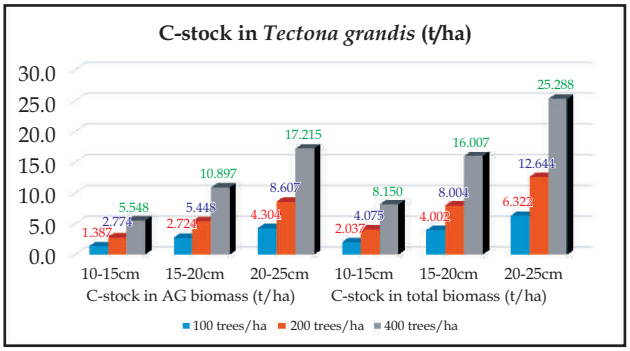

Fig. 17: Estimated carbon stock in aboveground and total biomass of T. grandis

Table 20: Equations for stem biomass of *T. grandis*

S. No.	Equation	Adj. R^2	MSE	MAE
1.	B = - 4.2438 + 0.2216 D^2	0.947	16.496	4.108
2.	B = -22.2616 +2.8447 D +0.1152 D^2	0.951	15.466	3.896
3.	B = 0.1212 $D^{2.1861}$	0.943	17.853	4.438

NRMACAFRISIL201300100091

Agroforestry based conservation agriculture for sustainable land use and improved productivity

(Inder Dev, Asha Ram, Ramesh Singh, KB Sridhar, AR Uthappa, Dhiraj Kumar, Mahendra Singh, Veeresh Kumar and Lal Chand)

The project on "Agroforestry based conservation agriculture for sustainable landuse and improved productivity" was initiated during July, 2014 with 03 experiments *viz.*, Bael based Agroforestry system; Teak based Agroforestry system and Bael + Teak based Agroforestry system with 04 main plot treatments *i.e.*, Min. tillage-Blackgram-Mustard (CS-1); Min. tillage-Greengram-Barley (CS-2); CT-Blackgram-Mustard (CS-1) and CT-Greengram-Barley (CS-2) and 03 subplot treatments (with crop residue; without crop residue and with Leucaena residue) replicated 3 times in split plot design.

During *rabi*, 2016-17, mustard (RH 749) and barley (DWR D73) and in *kharif*, 2017 greengram (IPM 2-3) and blackgram (IPU 243) were sown as per the treatment details in all the three experiments, and the results of which are presented here as under:

Growth parameters of bael and teak

The collar diameter of both bael and teak during 2017 revealed that, the effect of both tillage and crop residue incorporation in both bael and teak based agroforestry system were non-significant (Fig. 18). The collar diameter of bael ranged from 22.52 mm under minimum tillage with greengram-barley rotation to 24.34 mm under minimum tillage with blackgram-mustard rotation. Similarly, the collar diameter of teak were found to varied from 53.75 mm under minimum tillage with blackgram-mustard rotation and 60.22 mm under conventional tillage with greengram-barley rotation. In bael based agroforestry system, the collar diameter ranged from 20.60 mm (with crop residue) to 26.19 mm (without crop residue). The collar diameter of teak varied from 56.09 mm (with leucaena residue) to 59.15 mm with crop residue addition.

The height of bael and teak under bael and teak based agroforestry system depicts that, height of both bael and teak were highest under conventional tillage main plot treatment with blackgram-mustard rotation (Fig. 19). The height of bael ranged from 202.29 cm with crop residue to 271.04 cm without any crop residue incorporation. The teak height varied from 274.04 cm in leucaena residue addition and 281.42 cm without any crop residue addition. Neither tillage treatments nor the residue treatments influenced the height as well as collar diameter of bael and teak significantly.

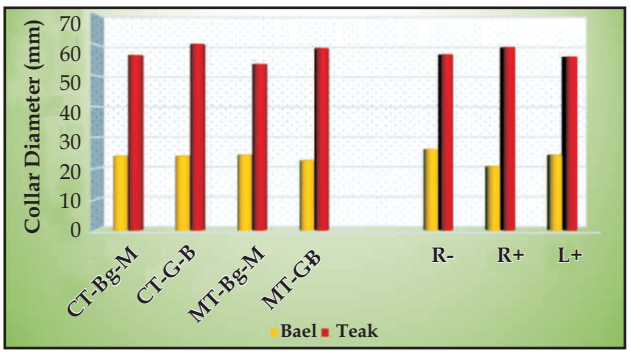

Fig. 18: Collar diameter of bael and teak in bael and teak based agroforestry system

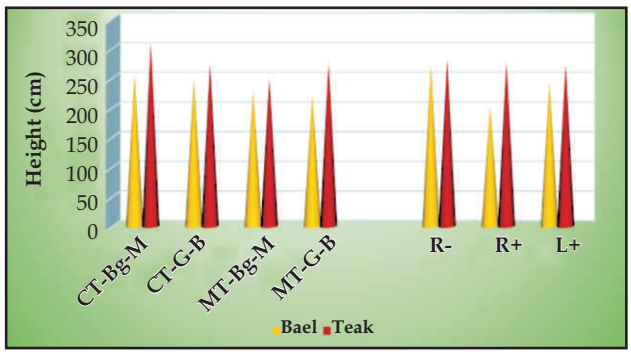

Fig. . 19: Height of bael and teak in bael and teak based agroforestry system

**CT-Conventional tillage, MT-Minimum tillage, G-Greengram, B-Barley, Bg-Blackgram, M-Mustard, WCR-Without crop residue, CR-With crop residue, LR-With leucaena residue*

Experiment 1: Bael (*Aegle marmelos*) based conservation agriculture system

In bael based conservation agriculture system, during *rabi*, 2016-17, the seed yield of mustard varied significantly among tillage treatments (Fig. 20). It varied from 1347 kg /ha under minimum tillage (MT) to 1373 kg /ha in conventional tillage system (CT). Among the residue treatments, the highest seed yield was recorded in crop residue plots followed by leucaena residue and no residue added plots. Further, the growth and yield contributing

characters of mustard varied among tillage types and residue incorporation, except, dry matter accumulation at harvest in main plot treatments, the pods per plant and seeds per pod were non-significant across tillage treatments (Table 21). Nevertheless, CT tillage treatments and crop residue incorporation have brought about improvement in growth as well as yield attributes.

The grain yields of barley ranged from 2138 kg/ha (minimum tillage) to 2184 kg/ha (conventional tillage) though were non-significant (Fig. 21). The effect of residue addition brought significant change in yield of barley, the addition of leucaena residue and crop residue increased yield to the tune of 8 and 7%, respectively over no residue addition. The residue incorporation brought about significant improvement in growth and yield characters (Table 22).

Seed yield of blackgram varied from 350 kg /ha in MT plot to 363 kg /ha in CT plots (Fig. 22). Addition of residue improved the seed yield of blackgram and it was recorded as 378 kg /ha (crop residue addition), 368 kg /ha (leucaena residue addition). Among the growth and yield indicators of blackgram, in main plot treatments, except no. of pods per plant, the dry matter accumulation at harvest and seeds per pod were found to be non-significant. The residue addition has increased the dry matter accumulation as 270 g/m^2 (crop residue addition) and 262 g/m^2 (leucaena residue addition) (Table 23).

The seed yield of greengram was found to be non-significant among tillage treatments, but was higher in CT plot than MT (Fig. 23). The residue addition significantly increased the yield of greengram from 11% (leucaena residue incorporation) to 14% (crop residue addition) over no residue addition. Data presented in Table 24 depicts the growth and yield attributing characters of greengram where, except no. of pods per plant, the dry matter accumulation at harvest and seeds per pod were non-significant with tillage treatments. While, the residue addition improved the yield attributing characters significantly among different sub plot treatments. The dry matter accumulation at harvest increased from 12% in leucaena residue addition plots to 18% in crop residue addition over control (Table 24).

Experiment II: Teak (*Tectona grandis*) based conservation agriculture system

In teak based conservation agriculture system, during *rabi*, 2016-17, the seed yield of mustard varied from 1295 kg/ha in MT plot to 1328 kg/ha in CT plot (Fig. 20). Seed yield varied significantly with different residue treatments and it was recorded as 1372 kg /ha (crop residue), 1355 kg /ha (leucaena residue) and 1207 kg /ha (no residue). The yield attributing characters of mustard were mostly non-significant with tillage effects though were higher in CT over MT. The residue addition have brought significant difference in all the growth and yield parameters (Table 21). The dry matter accumulation at harvest showed 11% increase with crop residue addition and 8.3% increase with leucaena residue addition over control.

The grain yield of barley ranged from 2059 kg /ha in MT to 2101 kg /ha in CT main plot treatment (Fig. 21). Among the residue addition sub plot treatments, the crop residue and leucaena residue addition have increased the grain yield of barley substantially over control. The effect of varying tillage treatments on growth and yield attributing characters of barley have non-significant effect though all the studied parameters were better in CT over MT (Table 22). The dry matter accumulation at harvest was recorded as 912.5 g/m^2 (no residue treated sub plot), 948.8 g/m^2 (leucaena treated sub plots) and 966.6 g/m^2 (crop residue addition).

The blackgram seed yield varied from 408 kg/ha in MT to 419 kg /ha in CT plots (Fig. 22). Among residue addition the seed yield was recorded as 374 kg/ha (in control) to 425 kg /ha (in leucaena residue addition) and 442 kg /ha (crop residue addition). Except seeds per pod, the dry matter accumulation at harvest and pods per plant significantly improved with residue incorporation (Table 23). The dry matter accumulation was recorded as 287.9 g/m^2 (in

control), 345.2 g/m^2 (in crop residue sub plots) and 361 g/m^2 (in leucaena residue treated sub plots).

The seed yield of greengram ranged from 733 kg /ha (MT main plot) to 757 kg /ha (in CT plots) though were non-significant (Fig. 23). The variation in seed yield of greengram among residue addition treatments ranged from 678 kg /ha in control to 765 kg /ha with leucaena residue and 792 kg /ha with crop residue addition. The growth and yield attributing characters of greengram varied in similar fashion as observed in case of blackgram (Table 24). The effects of tillage were found to be non-significant, but the residue incorporation has significantly improved the yield parameters.

Experiment III: Bael (*Aegle marmelos*) + Teak (*Tectona grandis*) based conservation agriculture system

During *rabi* 2016-17, the seed yield of mustard ranged from 1387 kg /ha (in MT plots) to 1406 kg/ha (in CT plots) (Fig. 20). The growth and yield attributes revealed that, tillage options had non-significant effect (Table 21). Addition of crop residues and leucaena residues, increased seed yield by 13 and 10.5%, respectively over control. The no. of pod per plant and no. of seed per pod were also recorded significantly higher with crop and leucaena residue addition.

In case of barley, the grain yield ranged from 2209 kg/ha in CT to 2160 kg /ha in MT plots (Fig. 21). The grain yield was recorded as 2084 kg/ha (in control), 2220 kg/ha (in leucaena residue plots) and 2250 kg/ha (in crop residue addition).

The conventional tillage recorded better performance of yield parameters than minimum tillage. The no. of tillers/m^2 were recorded as 224.8 (in control), 238.2 (leucaena residue) and 243.5 (crop residue addition) (Table 22). The dry matter accumulation was recorded as 909 g/m^2 (in control), 954 g/m^2 (leucaena residue addition) and 972 g/m^2 (in crop residue addition).

The seed yield of blackgram was non-significant among tillage treatments. It ranged from 340 kg/ha in MT to 347 kg /ha in CT (Fig. 22). The residue addition had influenced seed yield of blackgram. The growth and yield attributes were non-significant among tillage treatments. The dry matter accumulation at harvest ranged from 235.6 g/m^2 in control to 275.5 g/m^2 on crop residue addition and 262.8 g/m^2 on leucaena residue addition. Similarly, the no. of pods/plant varied from 11.32 in control to 11.43 in leucaena residue addition and 11.92 in crop residue addition sub plots (Table 23).

The performance of greengram under varying tillage and residue incorporation were found to be in line with the performance of blackgram. It varied from 696 kg/ha in MT to 722 kg/ha in CT though were non-significant (Fig. 23). The seed yield of greengram was recorded as 648 kg/ha (in control), 749 kg/ha (in crop residue addition) and 730 kg/ha (in leucaena addition) sub plots. The dry matter accumulation at harvest increased upto 17.3% (in crop residue addition) and 15.6% (in leucaena residue addition) over no residue addition (Table 24).

Table 21: Growth and yield attributes of mustard as influenced by tillage practices under bael, teak and bael+teak based agroforestry system

Treatments	Bael			Teak			Bael + Teak		
	Dry matter accumulation at harvest (g/m^2)	Pods/ plant	Seeds/ pod	Dry matter accumulation at harvest (g/m^2)	Pods/ plant	Seeds/ pod	Dry matter accumulation at harvest (g/m^2)	Pods/ plant	Seeds/ pod
Main									
CT-Blackgram-Mustard	998	199.5	12.78	980	201.3	11.9	954	200.5	12.0
CT-Greengram-Barley									
MT- Blackgram-Mustard	961	192.9	12.64	954	196.4	11.9	924	194.9	12.0

MT- Greengram-Barley									
SEm±	8	1.1	0.03	10	2.6	0.0	12	3.8	0.1
LSD (*P*= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub									
Without crop residue	901	181.7	11.99	904	185.2	11.1	863	184.1	11.3
With crop residue	1027	205.9	13.15	1011	205.8	12.4	990	207.3	12.5
With Leucaena residue	1011	200.9	13.00	986	205.6	12.2	964	201.7	12.3
SEm±	14	2.7	0.13	15	3.4	0.2	13	3.0	0.2
LSD (P= 0.05)	47	8.8	0.44	49	11.2	0.6	41	9.9	0.49
Main x Sub									
SEm±	20	3.8	0.19	21	4.8	0.3	18	4.3	0.2
LSD (*P*= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

CT-Conventional tillage; MT-Minimum tillage

Table 22: Growth and yield attributes of barley as influenced by tillage practices under bael, teak and bael+teak based agroforestry system

Treatments	Bael			Teak			Bael + Teak		
	No. of tillers/ m^2	Dry matter accumu-lation at harvest (g/m^2)	No. of grains / spike	No. of tillers/ m^2	Dry matter accumu-lation at harvest (g/m^2)	No. of grains/ spike	No. of tillers/ m^2	Dry matter accumu-lation at harvest (g/m^2)	No. of grains/ spike
Main									
CT- Blackgram -Mustard									
CT- Greengram -Barley	239.6	962	29.8	226.8	946.7	29.81	240.8	950	32.5
MT- Blackgram -Mustard									
MT- Greengram -Barley	232.3	945	29.4	214.6	938.6	29.00	230.3	940	32.2
SEm±	4.7	3	0.3	3.3	4.9	0.24	3.3	3	0.3
LSD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub									
Without crop residue	222.8	924	27.2	207.7	912.5	27.52	224.8	909	30.3
With crop residue	246.1	970	31.1	226.3	966.6	30.13	243.5	972	33.6
With Leucaena residue	238.9	968	30.6	228.1	948.8	30.57	238.2	954	33.2
SEm±	4.2	9	0.4	4.2	4.7	0.40	3.7	8	0.4
LSD (P= 0.05)	13.7	30	1.1	13.8	15.4	1.32	12.1	26	1.1
Main x Sub									
SEm±	6.0	13	0.5	6.0	6.7	0.57	5.3	11	0.5
LSD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

CT-Conventional tillage; MT-Minimum tillage

Table 23: Growth and yield attributes of blackgram influenced tillage practices under bael, teak and bael+teak based agroforestry system

Treatments	Bael			Teak			Bael + Teak		
	Dry matter accumulation at harvest (g/m^2)	Pods/ plant	Seeds/ pod	Dry matter accumulation at harvest (g/m^2)	Pods/ plant	Seeds/ pod	Dry matter accumulation at harvest (g/m^2)	Pods/ plant	Seeds/ pod
Main									
CT-Blackgram-Mustard	261.2	12.73	5.72	334.3	12.37	5.53	264.5	11.45	5.25
CT-Greengram-Barley									
MT- Blackgram-Mustard	252.7	12.69	5.67	328.4	12.42	5.43	251.5	11.66	5.24
MT- Greengram-Barley									
SEm±	7.3	0.08	0.08	8.0	0.08	0.02	2.2	0.16	0.03
LSD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub									
Without crop residue	238.2	12.23	5.66	287.9	11.69	5.34	235.6	11.32	5.19
With crop residue	270.0	12.91	5.71	345.2	12.81	5.54	275.5	11.92	5.35
With Leucaena residue	262.5	12.99	5.71	361.0	12.69	5.55	262.8	11.43	5.19
SEm±	4.1	0.08	0.08	7.0	0.14	0.06	4.5	0.12	0.09
LSD (P= 0.05)	13.5	0.26	NS	22.9	0.46	NS	14.7	0.41	NS
Main x Sub									
SEm±	5.8	0.11	0.12	9.9	0.20	0.09	6.4	0.18	0.12
LSD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

CT-Conventional tillage; MT-Minimum tillage

Table 24: Growth and yield attributes of greengram as influenced by tillage practices under bael, teak and bael+teak based agroforestry system

Treatments	Bael			Teak			Bael + Teak		
	Dry matter accumulation at harvest (g/m^2)	Pods/ plant	Seeds/ pod	Dry matter accumulation at harvest (g/m^2)	Pods/ plant	Seeds/ pod	Dry matter accumulation at harvest (g/m^2)	Pods/ plant	Seeds/ pod
Main									
CT- Blackgram -Mustard									
CT- Greengram -Barley	488.4	13.73	13.76	445.4	14.11	11.54	372.8	13.52	13.61
MT- Blackgram -Mustard									
MT- Greengram -Barley	463.9	13.43	13.60	434.0	13.70	11.60	355.0	13.25	13.46
SEm±	5.3	0.07	0.08	3.0	0.19	0.17	3.8	0.05	0.05
LSD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub									
Without crop residue	425.2	13.06	13.37	414.6	13.41	11.36	321.6	12.64	13.27
With crop residue	519.4	13.90	13.95	462.2	14.32	11.61	389.0	13.93	13.77
With Leucaena residue	483.8	13.79	13.73	442.3	13.98	11.73	381.2	13.60	13.58
SEm±	4.3	0.13	0.12	7.6	0.14	0.06	5.2	0.12	0.08
LSD (P= 0.05)	14.1	0.41	0.39	24.9	0.46	0.20	17.0	0.40	0.25
Main x Sub									
SEm±	6.1	0.18	0.17	10.8	0.20	0.09	7.4	0.17	0.11
LSD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

CT-Conventional tillage; MT-Minimum tillage

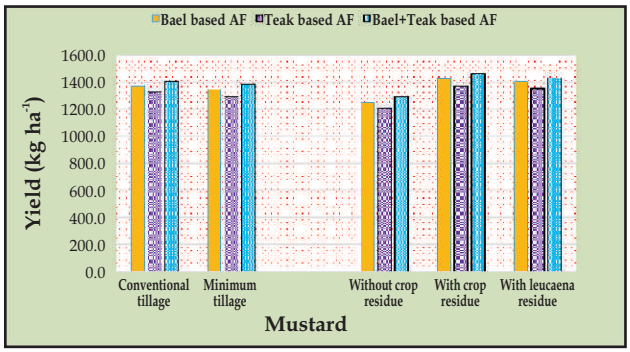

Fig. 20: Yield of mustard as influenced by tillage and residue management practices under bael, teak and bael+teak based agroforestry systems

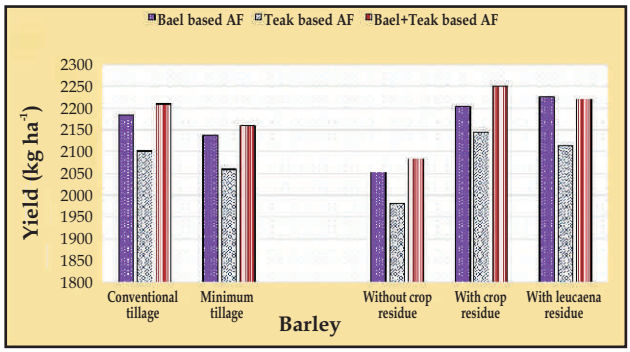

Fig. 21: Yield of barley as influenced by tillage and residue management practices under bael, teak and bael+teak based agroforestry systems

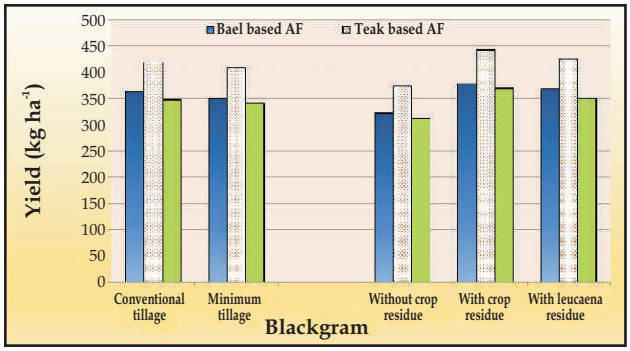

Fig. 22: Yield of blackgram as influenced by tillage and residue management practices under bael, teak and bael+teak based agroforestry systems

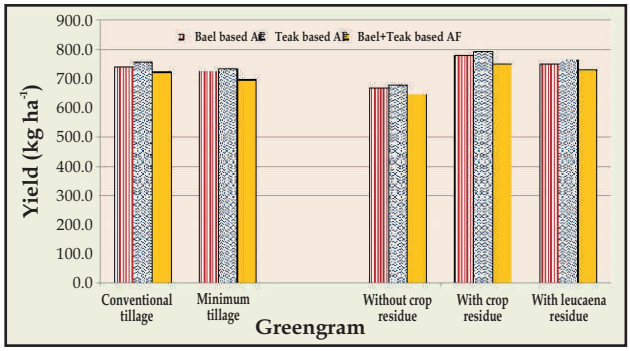

Fig. 23: .Yield of greengram as influenced by tillage and residue management practices under bael, teak and bael+teak based agroforestry systems

Soil fertility in teak based CA system

The initial level of soil organic carbon and N, P, and K were 0.21%, 130, 4.7 and 185 kg/ha, respectively at 0-30 cm soil depth while, in subsurface (30-60 cm) corresponding values for these nutrients were 0.17%, 117, 4.15 and 175 kg/ha. After harvesting of mustard and barley during 2017, the soil samples in different tillage and residue management treatments were analyzed for soil organic carbon and N, P, and K (Table 25). The available nitrogen content in 0-30 cm depth of soil ranged from 150 kg/ha in CT (Bg-M) to 168 kg/ha in MT (Bg-M), though they were in low range. The available phosphorus and potassium ranged from 5.8 to 7.5 kg/ha and 215 to 233 kg/ha, respectively. In subsurface layer (30-60 cm), OC, N, P, and K were declined with depth and followed similar trend as recorded in case of 0-30 cm depth. The residue addition or retention in experimental plots showed a remarkable change in status of N, P and K. The available N in leucaena and crop residue added plots increased 31.25 and 15.62%, respectively over without crop residue plots. Further, available P ranged from 7.2 to 8.4 kg/ha in same treatment combination. No major change was observed in available K with residue addition. Similar was the pattern in subsurface (30-60 cm) soil depth. Thus, the residue addition brought about a good change in soil fertility status of major nutrients than tillage treatments.

The minimum tillage practice had improved the organic carbon status in both surface and subsurface layers over conventional tillage. It varies from 0.35 % in CT (G-B) to 0.44% in MT (G-B) in 0-30cm soil layer. The addition of crop and leucaena residue increased 20.0 and 42.5%, respectively, organic carbon in soil over without crop residue plots. In 30- 60 cm depth, there was decrease in soil organic carbon concentration, may be due to less amount of organic matter and residue addition (Table 25).

Soil fertility in bael based CA system

The initial soil organic carbon and available N, P, K in bael based CA system were 0.15%, 107, 2.8 and 122 kg/ha in 0-30 cm depth and 0.09%, 94, 2.4 and 111 kg/ha, in 30-60cm depth, respectively. After three years of experiment, OC

and available N, P, and K were increased in both the tillage treatments, however these were observed higher in minimum tillage as compared to conventional tillage (Table 26). Application of residue in the experimental plots had brought about remarkable changes in soil fertility status. Organic carbon and available N, P and K were found to be higher in leucaena residue plots followed by crop residue applied plots. The nutrients status was lower in subsurface layers, though followed similar trend as observed in 0-30cm depth.

Table 25: Effect of varying tillage and residue management practices on depth wise distribution of Organic carbon (%), Nitrogen (kg/ha), phosphorus (kg/ha) and potassium (kg/ha) in teak based agroforestry system

Soil depth (cm)	Parameters	Initial	Teak based AFS						
			Tillage practice				Residue management		
			CT		MT		WCR	CR	LR
			(BgM)	(GB)	(BgM)	(GB)	BgM	BgM	BgM
0-30	OC	0.21	0.38	0.35	0.42	0.44	0.40	0.48	0.57
	N	130	150	156	168	165	160	185	210
	P	4.7	5.9	5.8	7.5	7.3	7.2	7.9	8.4
	K	185	215	222	227	233	225	230	234
30-60	OC	0.17	0.29	0.26	0.36	0.34	0.32	0.41	0.42
	N	117	145	149	158	152	155	175	178
	P	4.15	5.5	5.3	7.1	7.2	6.9	7.3	8.0
	K	175	200	214	224	226	217	235	240

*CT-Conventional tillage, MT-Minimum tillage, G-Greengram, B-Barley, Bg-Blackgram, M-Mustard, WCR-Without crop residue, CR-With crop residue, LR-With leucaena residue

Table 26: Effect of varying tillage and residue management practices on depth wise distribution of Organic carbon (%), Nitrogen (kg/ha), phosphorus (kg/ha) and potassium (kg/ha) in bael based agroforestry system

Soil depth (cm)	Parameters	Initial	Bael based AFS						
			Tillage practice				Residue management		
			CT		MT		WCR	CR	LR
			(BgM)	(GB)	(BgM)	(GB)	BgM	BgM	BgM
0-30	OC	0.15	0.26	0.21	0.29	0.25	0.26	0.33	0.36
	N	107	119	127	139	131	136	145	156
	P	2.8	3.6	3.9	4.9	4.2	4.0	4.2	4.9
	K	122	146	154	169	172	147	158	169
30-60	OC	0.09	0.17	0.15	0.22	0.2	0.22	0.25	0.29
	N	94	116	123	126	119	119	125	132
	P	2.4	3.2	3.8	4.1	3.9	3.1	3.5	3.9
	K	111	129	124	142	138	129	134	143

*CT-Conventional tillage, MT-Minimum tillage, G-Greengram, B-Barley, Bg-Blackgram, M-Mustard, WCR-Without crop residue, CR-With crop residue, LR-With leucaena residue

Infiltration Study

The infiltration study in different treatments was carried out during 2017. The basic infiltration rate was more than two times in conservation agriculture over conventional tillage with residue. It was also observed that basic rate of infiltration under conservation agriculture with residue was four time higher than the rate of 2016.

Role of soil fauna in teak based CA system

Soil organisms are essential components of agro-ecosystems, making vital contributions to soil functions and soil processes. Without soil organisms, the soil would be a sterile medium that could not sustain crop production. Soil biota provides essential benefits for the functioning of agro-ecosystems, which are important for the long term sustainability of agriculture. They support essential soil processes and play a key role in improving the soil fertility and thereby enhance the crop productivity. Soil organisms help in decomposition of crop residues, increase the availability of nutrients for plant growth and contribute to soil carbon storage. In agroforestry system, tree species significantly add leaf litter in the soil which improve the soil fertility through the actions of soil fauna**.** Maintaining soil biodiversity for a sustainable agriculture is connected with maintaining available organic matter and essential nutrient sources in the soil.

A study was conducted at experimental farm of ICAR-CAFRI, Jhansi to estimate the soil fauna in different residues application treatments in AF based CA system during pre-sowing and pre-harvesting of the crops. It has been observed that before sowing of the crop, the population of micro, meso and macro fauna was maximum in the soil with the application of crop residue as compared to application of leucaena residue and without any residue application. (Fig. 24) and similar trend was noticed during pre-harvesting of the crops (Fig. 25).

However, micro fauna population was more in minimum tillage compared to conventional tillage. Whereas, meso and macro fauna population did not differ significantly in minimum tillage and conventional tillage (Fig. 26). Interestingly, actinomycetes population was low in *leucaena*residues added treatments in pre-sowing as well as pre harvesting treatments. Therefore, long term studies are necessary to carry out the effect of *leucaena* residues on actinomycetes population.

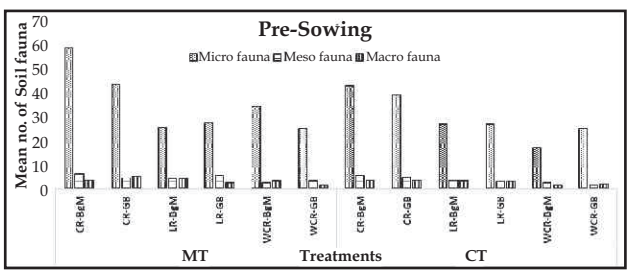

Fig. 24: Abundance of soil fauna in different tillage and residue management practices during pre-sowing of the crops

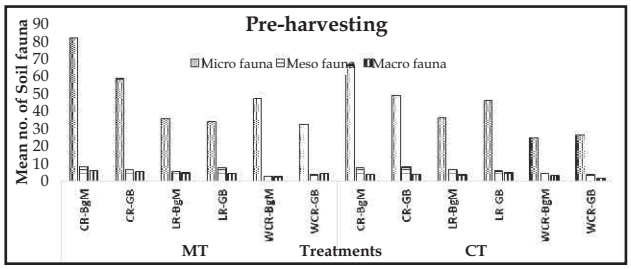

Fig. 25: Abundance of soil fauna in different tillage and residue management practices during pre-harvesting of the crops

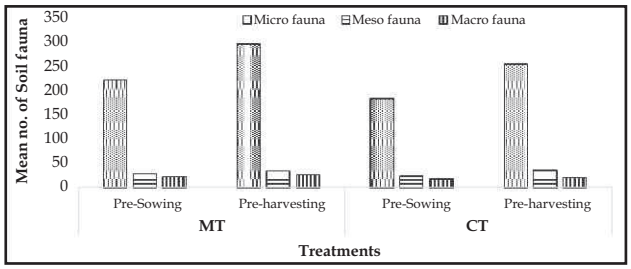

Fig. 26: Abundance of soil fauna in minimum tillage (MT) & Conventional Tillage (CT) during pre-sowing & pre-harvesting period

**CT-Conventional tillage, MT-Minimum tillage, G-Greengram, B-Barley, Bg-Blackgram, M-Mustard, WCR-Without crop residue, CR-With crop residue, LR-With leucaena residue*

NRMACAFRISIL201600400102

Agroforestry based integrated farming system for small and marginal farmers in semi-arid region

(Ram Newaj, Asha Ram, Sudhir Kumar, Naresh Kumar, Ramesh Singh, Dhiraj Kumar, Veeresh Kumar and Mahendra Singh)

Agroforestry based Integrated Farming System (AF-IFS) model was initiated during November, 2016. The enterprises proposed for AF-IFS model and land area allotted for each enterprises is given in Table 27. The different enterprises will be integrated in different phases. Under agroforestry system, mango and teak were planted in the first week of November, 2016 on the bunds of a field at 6m spacing which having 0.9 ha area. In the same field, under fruit based system, guava was planted at 10 m x 10 m spacing in 0.4 ha area during first week of November, 2016. After planting of trees, pea (variety Arkel) was sown in mid-November, 2016. The work proposed for first phase was completed within time. Fishery and poultry are proposed for 2nd phase. In this phase pond existed in IFS area was deepened in May, 2017 and treated as per guideline/practices given in literature prior to introducing fingerlings. In August, 2017, 30,000 fingerlings were introduced and provided fish feed as per their requirement. After three/four

months the fish weight was 350 to 400 g. During November, 2017, fish was auctioned for ₹ 75,000. Poultry rearing could not be initiated due to lack of poultry house. Other enterprises like vegetable and food grain based were initiated as per proposed programme. The total production and revenue generated from AF-IFS model is given in Table 28, which revealed that the cost of cultivation varied from crop to crop and it depends on area occupied by a particular crops. The total income from different crops as well fishery was ₹ 85,314. If net income is estimated on hectare basis, then it would be ₹ 56,128/ha.

Table 27: Agroforestry based IFS model for 1.83 ha land

Enterprise		Area (ha)
1	Agroforestry	1.15
I	Fruit based	0.65
II	Vegetable based	0.52
III	Crop based	0.25
2	Poultry	0.03
3	Fishery	0.22
4	Goat keeping	0.075
5	Composting	0.01
	Total of cultivation	1.83

I Phase

1. Agroforestry :

Boundary plantation: Teak + Mango at 6m plant to plant distance

2. Fruit based (Agri-horticulture):

Guava plantation (10 m X 10 m spacing)

Papaya as filler (in between two plant of guava)

Cowpea (Green manure)-Pea (vegetable)

Pomegranate (5m x 3m spacing) var. Ganesh and Bhagwa planted in Feb., 2013 +Lemon grass at (50 cm x 40 cm spacing)

II. Vegetable based:

Cowpea (vegetable purpose)-Pea (vegetable) – Bhindi/cucurbit (Summer)

III. Crop based: Crop sequence:

Cowpea (green manure)-Wheat/mustard

II phase

Poultry & Fishery

III Phase

Goat keeping & Composting of farm waste

Table 28: Economic of AF-IFS model (November, 2016 to November, 2017)

S.No.	Crop	Area (ha)	Production (kg/ha)	Cost of cultivation (₹)	Gross return (₹)	Net return (₹)	Net return (₹/ha)
1	Bhindi	0.10	350	2848	5250	2402	24020
2	Vegetable cowpea	0.30	1500 green pod + 32kg seed	4078	9740	5662	18873
3	Pea	0.90	625 green pod+ 350 seed	16000	23250	7250	8056
4	Fish	0.22		5000	75000	70000	318182
	Total	1.52		27926	113240	85314	56128

(B) Performance of pomegranate integrated with lemongrass under organic regime- NRMACAFRISIL201600100099

(Sudhir Kumar, Rajendra Prasad and Veeresh Kumar)

An experiment was laid out during July 2016 in an established pomegranate orchard planted at 5 m x 3 m spacing during February, 2013. The experiment was designed in CRBD with two cultivars of pomegranate (V_1- Ganesh & V_2- Bhagwa), four levels of fertilizer (T_1- Vermi-compost 30 kg/plant, T_2- FYM 30 kg/plant, T_3- T_1 + T_2/plant and T_4- Recommended doses of chemical fertilizers/plant) along with control (T_5) of pure lemongrass. The experiment was replicated thrice and each treatment is having four plants of each cultivars. During July-August 2016, Krishna variety of lemongrass, procured from CIMAP Lucknow, was planted in between the pomegranate plants at the spacing of 50 x 40 cm in a plot size of 60 m^2 with the area covered in plant basins. Since, every plant basin is covering 1.0sqm area and not planted lemongrass in such area therefore the net plot size is 56 m^2.

The observations recorded on growth & fruit yield of pomegranate and oil yield of lemongrass on fresh weight basis are presented in Table 29. The Table reveals that mean height ranged from 2.09 m (T_2V_2) to 3.25 m (T_2V_1), collar diameter from 4.69 cm (T_2V_2) to 7.33 cm (T_1V_1), East-West spread from 1.36 m (T_2V_2) to 2.05 m (T_2V_1) and North-South spread ranged from 1.43 m (T_2V_2) to 1.99 m (T_2V_1). However, fruit yield was ranged from 2.85 (T_2V_2) to 5.62 kg/plant (T_2V_1) in the beginning of the fruit setting. In general, cv Ganesh is having vigorous growth in comparison to cv Bhagwa and also yielding higher than the cv Bhagwa. The cumulative fresh yield from two cuts (May & October) of lemongrass, yielded 5.14 (T_1V_2) to 11.68 (T_5) t/ha green leaves and 26.54 to 131.18 kg oil/ha on fresh weight basis in the same treatment.

Table 29: Effect of nutrient management treatments on growth & yield of pomegranate and green leaves & oil yield of Lemongrass (Lg) on fresh weight basis during 2017

Treat	Ht (m)	CD (cm)	EW (m)	NS (m)	Ft. yield (kg/pl)	Lg Green leaves (t/ha)	Oil on fresh weight basis (kg/ha)
T_1V_1	2.95	7.33	1.82	1.87	4.64	10.15	49.15
T_1V_2	2.60	5.28	1.79	1.68	3.00	5.14	26.54
T_2V_1	3.25	7.14	2.05	1.99	5.62	7.15	33.54
T_2V_2	2.09	4.69	1.36	1.43	2.85	6.73	35.71
T_3V_1	2.74	5.47	1.78	1.67	5.34	6.73	32.32
T_3V_2	2.45	5.24	1.53	1.52	4.05	9.48	44.71
T_4V_1	3.10	6.79	1.82	1.80	4.54	-	-
T_4V_2	2.19	5.46	1.52	1.67	3.82	-	-
T_5 (Lg pure)	-	-	-	-	-	11.68	131.18

T_1V_1- cv. Ganesh with 30 kg vermicompost, T_1V_2- cv. Bhagwa with 30 kg vermicompost, T_2V_1- cv. Ganesh with 30 kg FYM, T_2V_2- cv. Bhagwa with 30 kg FYM, T_3V_1- T_1 + T_2, T_3V_2- T_1 + T_2, T_4V_1- cv. Ganesh with RDCF, T_4V_2- cv. Bhagwa with RDCF and T_5- Pure lemongrass (control).

NRMACAFRISIL201600500103

Impact of watershed and agroforestry interventions on hydrology and nutrient loss at Garhkundar-Dabar watershed in Bundelkhand region of Central India

(Ramesh Singh and Dhiraj Kumar)

Monitoring system for runoff and soil loss was installed at five locations in Garhkundar-Dabar watershed (treated), however untreated watershed was gauged for the same at the outlet. Besides this, manual and self-recording rain gauges were also installed in the watershed to measure the rainfall. Total 451.2 mm rainfall, (48.5% deficit than normal), was received.

Most of the checkdams constructed in upper and middle reaches filled once in monsoon season but no events of runoff and soil loss was recorded at any location. All open shallow dug

wells in treated (116 nos.) and untreated (42 nos.) watershed were monitored monthly for water level. During the month of October average water column was 2.76 m which is 10.5% higher than the average water column of open wells situated in untreated watershed. *Rabi* crops were sown in only 11% of agricultural land due to insufficient water availability. However, open well are catering the needs of drinking water.

NRMACAFRISIL201600700104

Relevance of soil and water conservation measures in enhancing productivity and sustainability of silvipastoral system in semi-arid conditions

(Asha Ram, Ramesh Singh, Naresh Kumar and Dhiraj Kumar)

The project on "Relevance of soil and water conservation measures in enhancing productivity and sustainability of silvipastoral system in semi-arid conditions" was initiated in *Kharif* season of 2016 with seven treatments comprising of T_1 - Sole Pasture; T_2 - Sole Teak (*Tectona grandis*); T_3 - Sole Mahagoni (*Swietenia mahagoni*); T_4 - Teak + Mahagoni + Pasture; T_5 - Teak + Mahagoni + Pasture+halfmoon basin (HMB); T_6 - Teak + Mahagoni + Pasture + Vegetative Hedge (VH); T_7-Teak + Mahagoni + Pasture + Contour Staggered Trenches (CST). The experiment was laid out in Randomized Block Design and replicated thrice.

The survival of the teak and mahagoni after one year of planting were observed to be 92 and 83%, respectively. During first year, height and collar diameter (CD) of teak was observed between 109.3 cm to 165.7 cm and 27.79 cm to 35.29 cm, respectively. The corresponding values for mahagoni were 61.8 cm to 77.6 cm and 14.83 cm to 18.96 cm, respectively (Table 30). After one year of planting, minimum height and collar diameter of teak were observed in sole teak and maximum height and CD were recorded in T_7 (T+M+P+ CST). Similarly, maximum plant height and CD of mahagoni plants were recorded in T_7.

Table 30: Height and collar diameter of Teak and Mahagoni at initial stage and after one year of planting

Treatment	Teak				Mahagoni			
	Height (cm)		Collar Diameter (mm)		Height (cm)		Collar Diameter (mm)	
	Initial	After One Year	Initial	After One Year	Initial	After One Year	Initial	After One Year
T_1-Sole pasture	-	-	-	-	-	-	-	-
T_2-Sole Teak	34.79	109.3	3.84	27.79	-	-	-	-
T_3-Sole Mahagoni	-	-	-	-	31.88	65.6	6.87	17.81
T_4- T+M+P	29.83	136.3	6.86	30.60	31.33	63.4	8.26	14.83
T_5- T+M+P+VH	34.03	158.3	6.88	30.10	32.94	61.8	7.55	15.97
T_6- T+M+P+HMB	30.22	148.1	5.88	34.31	25.44	73.6	5.79	18.91
T_7- T+M+P+CST	28.24	165.7	6.88	35.29	32.11	77.6	7.80	18.96

*P-Pasture; T-Teak; M-Mahagoni; VH-Vegetative Hedge; HMB-Half Moon Basin; CST-Contour Staggered Trenches

Growth and yield of *Cenchrus ciliaris* was recorded at the time of harvesting (October, 2017). During first year, the biomass of *C. ciliaris* were not influenced by soil and water conservation measures (Table 31).

After first rainy season (Sept. 2017), the sedimentation trapped in soil and moisture conservation measures were recorded and it was observed that contour staggered trenches (CST) and half-moon basin (HMB) trapped sediments at the rate of 38.30 t/ha and 7.644 t/ha, respectively.

Table 31: Growth and biomass of *C. ciliaris*

Treatments	Height (cm)	No. of tiller tussock^{-1}	Tussock Diameter (cm)	Grass yield (g) (Dry weight/tussock)
T_1-Sole pasture	111.4	65.38	28.50	361
T_2-Sole Teak	-	-	-	-
T_3-Sole Mahagoni	-	-	-	-
T_4- T+M +P	114.6	70.12	35.00	385
T_5- T+M +P +VH	114.0	53.83	28.25	323
T_6- T+M +P +HMB	108.6	61.17	31.92	354
T_7- T+M +P +CST	116.5	57.92	27.83	346

NRMACAFRISIL201600800105

Horizontal and vertical distribution of fine roots of tree and nutrients content in well-established Aonla and *Hardwickia binata* based agroforestry system

(Dhiraj Kumar, Ram Newaj, Rajendra Prasad, Asha Ram and Veeresh Kumar)

The present study was initiated during 2016-17. The spacing in Aonla and *Hardwickia binata* was 10x10 m and 10 m x 5 m, respectively. The Aonla were planted in the year 1996 and *Hardwickia binata* in the year 1991. The crop cycle in Aonla based AFS was greengram-mustard and in *Hardwickia binata*, blackgram-wheat. Horizontal stratified sampling was done from six distances 0.5m, 1.0m, 1.5m, 2.0m, 2.5m and 3.0 m. Similarly, in vertical stratified sampling, soil samples were collected from six depths *i.e.*, 0-15cm, 15-30 cm, 30-45 cm, 45-60cm, 60-75 cm and 75-90 cm, respectively.

The grain yield of wheat (Fig. 27) during *rabi*, 2016-17 in *Hardwickia binata* based AFS, revealed that it varied from 1550 (kg/ha) at 3.0 m distance from tree base as compared to 0.5 m distance where, it was 1150 (kg /ha). Similarly, the straw yield varied from 1750 (kg /ha) at 0.5 m distance to 2325 (kg /ha) at 3.0 m horizontal distance from tree base. The other yield attributing characters varied in similar fashion as observed in case of grain and straw yield.

Fig. 28 depicts the seed and straw yield of mustard in Aonla based AFS during *rabi*, 2016-17, where the variation was significant among different distances from tree base. The data suggest that seed yield ranged from 620 (kg/ha) at 0.5 m distance to 900 (kg/ha) at 3.0 m distance. While, the straw yield varied from 1189 (kg/ha) at 0.5 m distance from tree base to 1720(kg/ha) at 3.0 m distance.

The data of greengram (Fig. 29) in *Kharif*, 2017 in Aonla based AFS showed 344 (kg /ha) as seed yield at 0.5m distance and at 1.5 m. it was 358 (kg/ha) then decreased to 351 (kg /ha) at 2.0 m distance but we observed 382 (kg/ha) of seed yield at 3.0 m distance. Similarly, straw yield was highest at 3.0 m distance with value of 717 (kg/ha) and lowest at 1.5 m horizontal distance from tree base with 670 (kg/ha) of yield.

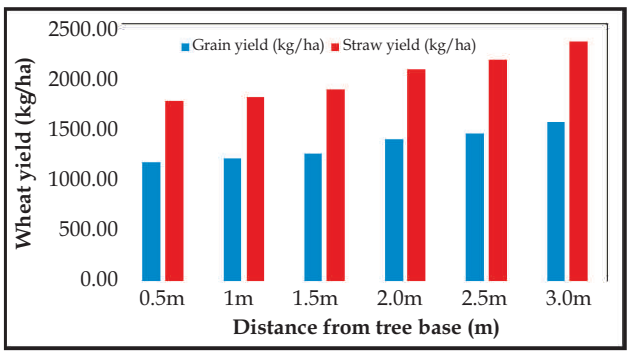

Fig. 27: The grain and straw yield of wheat (kg ha^{-1}) as influenced by horizontal distance from tree base in *Hardwickia binata* based agroforestry system

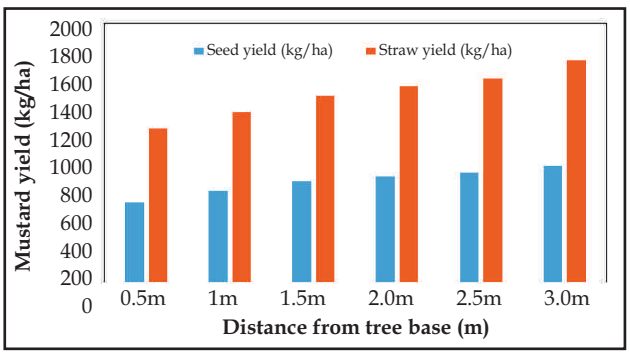

Fig. 28: The seed and straw yield of mustard (kg ha^{-1}) as influenced by horizontal distance from tree base in Aonla based agroforestry system

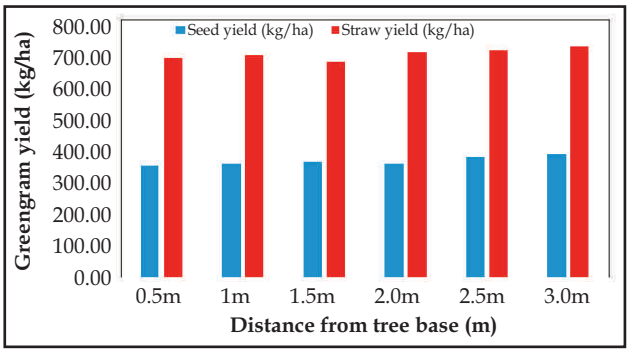

Fig. 29: The seed and straw yield of greengram (kg/ha) as influenced by horizontal distance from tree base in Aonla based agroforestry system

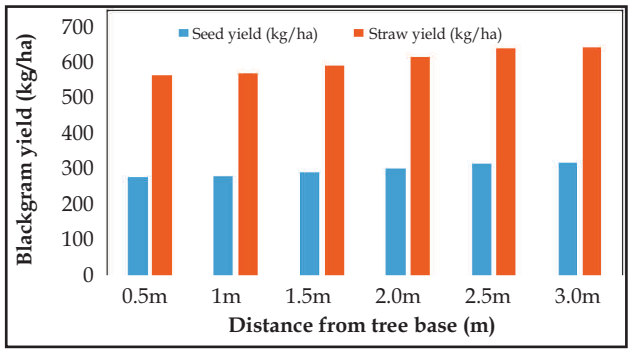

Fig. 30: The seed and straw yield of blackgram (kg/ha) as influenced by horizontal distance from tree base in *Hardwickia binata* based agroforestry system

The seed and straw yield of blackgram during *Kharif*, 2017 under *Hardwickia binata* based AFS is presented in (Fig. 30). The data revealed that the range of seed productivity was from 258 (kg/ha) at 0.5 m distance to 296 (kg /ha) at 3.0 m distance. Similarly, the straw yield varied from 529 (kg/ha) to 604 (kg/ha) from 0.5 m to 3.0 m horizontal distance.

In *Hardwickia binata* based agroforestry system, (Fig. 31) 27 years old having a density of 200 trees/ha, it was found that during summer season the fine root length varies from 133.34 cm in 0-15 cm soil depth at a distance of 0.5 m from tree base to 14.20 cm in 75-90 cm soil depth at a distance of 3 m from tree base. The fine root length density (FRLD) varied from 0.14 cm/cm^3 in 0-15 cm depth to 0.015 cm/cm^3 in 75-90 cm depth.

In *Phyllanthus emblica* based agroforestry system, (Fig. 32) (22 years old) having a density of 100 trees/ha, it was found that during summer season the fine root length varies from 43.83 cm in 0-15 cm soil depth at a distance of 0.5 m from tree base to 2.47 cm in 75-90 cm soil depth at a distance of 1 m from tree base. The fine root length density (FRLD) varied from 0.046 cm/cm^3 in 0-15 cm depth to 0.003 cm/cm^3 in 75-90 cm depth.

In case of *Hardwickia binata* based agroforestry system, (Fig. 33) the SOC stock was found to be 77.63 Mg /ha as compared with control (pure crop) 31.55 Mg /ha. Similarly, in case of Aonla based AFS, we observed 59.33 Mg /ha SOC stock over control *i.e.*, 30.22 Mg /ha.

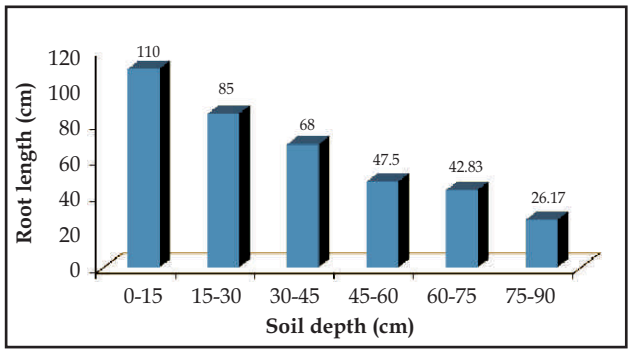

Fig. 31: The fine root length (cm) of *Hardwickia binata* based agroforestry system as influenced by soil depth

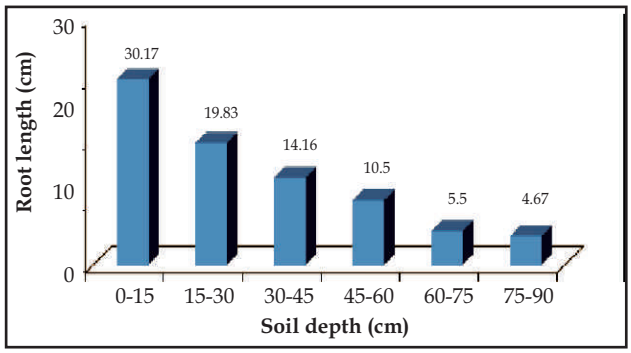

Fig. 32: The fine root length (cm) of Aonla based agroforestry system as influenced by soil depth

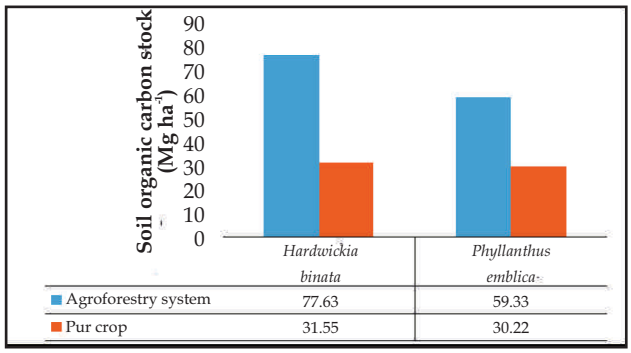

Fig. 33: Soil Organic carbon (SOC) stock (Mg/ha) in *Hardwickia binata* and *Phyllanthus emblica* based AFS

2.3: Tree Improvement, Post-Harvest and Value Addition Programme

NRMACAFRISIL200700400071

Comparative studies on seedling and clonal plants of *Pongamia pinnata* with special reference to their adaptability to rainfed dry agroclimate

(Badre Alam and A K Handa)

Comparative better growth attributes have been noticed in clonal plants (Figs. 34 & 35). Physiological efficiency has been clearly observed in the rate of CO_2 assimilation (P_N max). During peak summer, P_N max in clonal plants were much higher in comparison to seedling plants (Fig. 36). Higher P_N max in clonal plants in hot peak summer in the semi-arid agroclimate indicated its potential to maintain better leaf physiological functions. Higher P_N max has been supported by higher thylakoid electron transport rate (ETR) in clonal plants during peak summer (Fig. 37). There were evidences for comparatively better maintenance of diurnal leaf water potentials in clonal plants during peak summer (Fig. 38).

There were differential responses in number of pod formation in clonal and seedlings plants. In general, pod formation was comparatively lesser in this year than in last year. Number of pods per tree was more in clonal plants than in seedlings. Per plant pod yield and per plant pod weight were clearly more in clonal plants in comparison to seedling plants (Fig. 39).

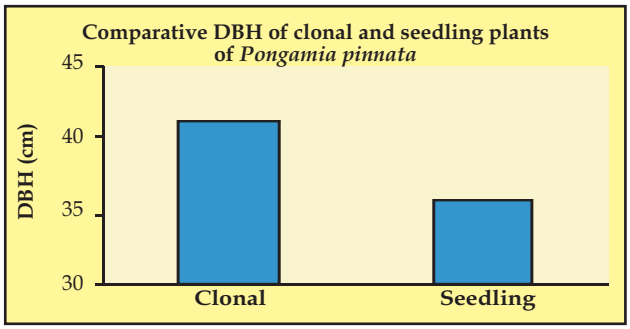

Fig. 34: Comparative girth (DBH = diameter at breast height) in clonal and seedling plants of *Pongamia pinnata*

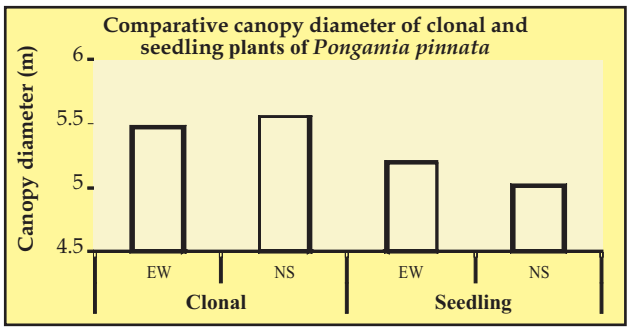

Fig. 35: Canopy diameter of clonal and seedling plants of *Pongamia pinnata* in east-west and north-south directions

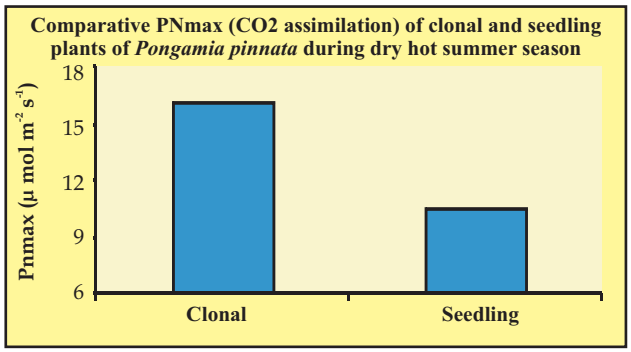

Fig. 36: Maximum rate of CO_2 assimilation (P_N max) of clonal and seedling plants of *Pongamia pinnata* under dry hot summer season

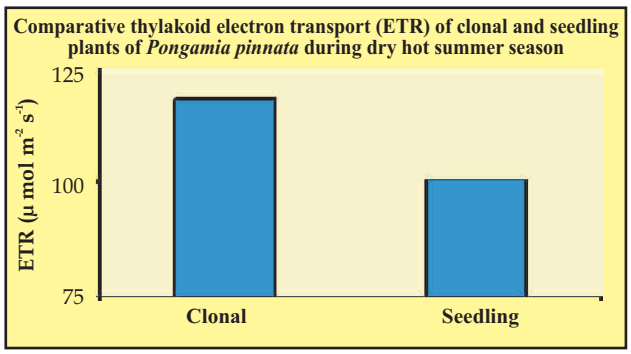

Fig. 37: Thylakoid electron transport rate (ETR) of clonal and seedling plants of *Pongamia pinnata* under dry hot summer season

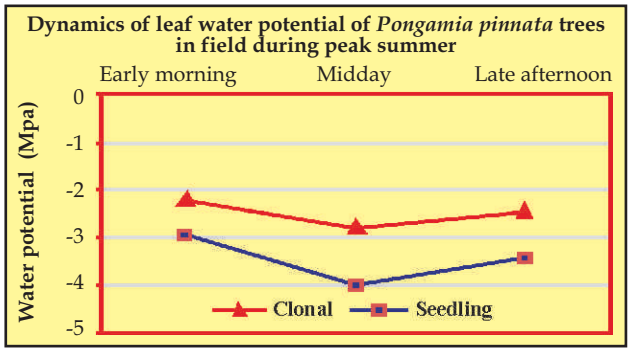

Fig. 38: Diurnal leaf water potential of clonal and seedling plants of *Pongamia pinnata* under dry hot summer season

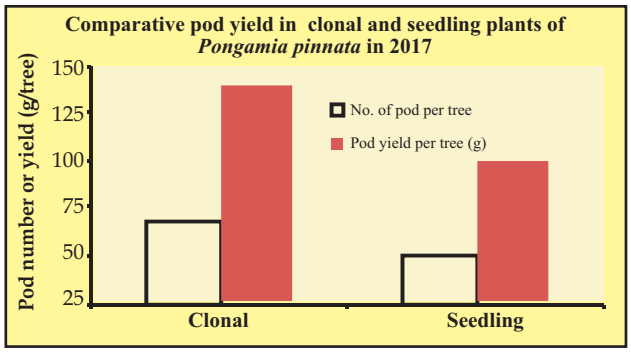

Fig. 39: Number of pods and pod weight per plant in clonal and seedling plants of *Pongamia pinnata*

NRMACAFRISIL 200400100054

Genetics and breeding of *Jatropha* species

(Naresh Kumar and K Rajarajan)

In hybrid evaluation trial, 45 different intraspecific crosses of *Jatropha curcas* were established in July, 2006. Although this experiment was terminated in 2015-16, but 29 crosses are being maintained at tree improvement nursery for further breeding programmes. However, these lines under nursery conditions had no seed set in the reporting year (2017), hence only growth attributes of these hybrid lines have been recorded and presented in Table 32.

Jatropha genotypes maintained at Tree Improvement nursery

Table 32: Performance of *Jatropha* hybrid lines maintained in nursery

Sl. No.	Name of the hybrid crosses	Plant height (cm)	Collar dia. (mm)	Sl. No.	Name of the hybrid crosses	Plant height (cm)	Collar dia. (mm)
1.	29	88.5	22.98	16.	14	81.5	17.32
2.	28	84.0	16.07	17.	13	92.0	20.68
3.	27	80.5	20.39	18.	12	85.0	18.80
4.	26	58.5	17.96	19.	11	77.5	16.80
5.	25	73.0	15.59	20.	10	85.0	21.17
6.	24	74.0	15.12	21.	9	74.0	16.44
7.	23	69.0	19.08	22.	8	84.5	16.60
8.	22	62.5	15.17	23.	7	83.0	19.26
9.	21	74.0	16.55	24.	6	108.0	22.16
10.	20	62.5	15.57	25.	5	108.0	22.44
11.	19	63.5	14.76	26.	4	90.0	16.80
12.	18	77.5	19.52	27.	3	102.5	24.80
13.	17	96.0	19.35	28.	2	90.0	19.32
14.	16	99.0	20.22	29.	1	78.5	17.21
15.	15	79.5	15.06				

NRMACAFRISIL201500100092

Evaluation and characterization of different Leucaena germplasm at ICAR-CAFRI

(A R Uthappa/K Rajarajan, Naresh Kumar, A K Handa, A K Singh - IGFRI and Maneet Rana - IGFRI)

The study to evaluate and characterize the leucaena germplasm was initiated in the year 2015. Subabul accessions belonging to five different species *viz.*, *Leucaena diversifolia, L. shannoni, L. lanceolata, L. collinsii, L. leucocephala* and a hybrid (*L. shannoni* x *L. leucocephala*) were planted at CAFRI, experimental field during August, 2006. The seedlings were planted at a spacing of 3 x 3 m with three replications. For fodder quality analysis leaf samples were collected during rainy season and oven dried. The oven dried samples were analyzed for

crude protein, ash content, neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose and lignin (ADL) using standard methodology. The analysis revealed significant variations among the different germplasm (Table 33). Crude protein (CP) was highest in *L. leucocephala* Conn-3 (28.85%) and lowest CP was recorded in *L. leucocephala* IGFRI-96 (19.22 %). The highest ash content was recorded in *L. leucocephala* S-13 (11.58%) and lowest in *L. leucocephala* K-29 (6.29%). The highest NDF was found in *L. leucocephala* S-1 (52.27%) and lowest in *L. leucocephala* Conn-3 (38.03%). Highest ADF value was recorded in *L. diversifolia*-504 (23.04%) and lowest in *L. leucocephala* S-4 (16.42%) . In case of cellulose highest content was recorded in *L. leucocephala* S-2 (12.96%) and lowest in *L. leucocephala* S-217 (6.06%). Lignin content was recorded lowest in *L. leucocephala* S-4 (6.12%) and highest in *L. leucocephala* K-340 (9.21%).

Table 33: Fodder quality of different leucaena accessions

Genotype	CP %	NDF %	ADF %	Cellulose %	Ash %	ADL %
L. diversifolia-504	23.49	41.45	23.04	12.55	7.64	7.91
L. diversifolia- 83/92	25.72	41.69	22.97	11.00	8.86	8.98
L. diversifolia-46/87	21.76	41.64	22.06	11.68	8.95	7.91
L. shannoni-22/83	21.98	41.50	20.03	11.34	7.39	6.24
L. lanceolata	24.09	41.76	20.85	11.40	8.67	6.73
L. lanceolata-49/37	20.42	46.53	20.56	10.64	9.73	6.60
L. collinsii-18/84	26.30	43.98	18.62	8.97	9.43	6.31
L. collinsii-56/88	22.05	41.15	16.77	7.04	10.21	6.34
L. collinsii- 15/83	22.46	41.15	16.84	9.14	10.62	6.44
L. shannoni x *L. leucocephala*	22.42	41.76	17.00	9.16	10.05	6.22
L. leucocephala S-1	23.31	52.27	20.30	10.47	10.11	8.04
L. leucocephala S-2	23.15	51.80	21.65	12.96	10.95	7.06
L. leucocephala S-4	25.10	48.74	16.42	8.32	11.36	6.12
L. leucocephala S-6	25.10	41.18	16.66	10.57	9.59	7.65
L. leucocephala S-7	22.18	46.94	17.06	7.48	10.96	7.06
L. leucocephala S-10	22.02	50.68	20.49	10.74	10.80	7.78
L. leucocephala S-11	21.74	39.72	19.70	8.74	8.38	6.96
L. leucocephala S-12	21.40	44.62	17.44	6.58	9.94	6.40
L. leucocephala S-13	21.81	49.20	19.05	9.50	11.58	7.30
L. leucocephala S-14	21.79	39.08	18.47	6.44	10.53	6.26
L. leucocephala S-15	23.78	43.83	17.28	10.42	9.86	7.26
L. leucocephala S-18	22.18	44.51	16.46	8.17	10.40	6.98
L. leucocephala S-22	23.50	44.06	17.30	12.62	9.72	7.81

L. leucocephala S-23	23.81	43.41	18.35	8.95	8.91	6.50
L. leucocephala S-24	23.68	50.98	16.65	9.77	9.05	6.14
L. leucocephala IGFRI-23-1	22.19	41.46	16.53	9.20	10.36	6.49
L. leucocephala IGFRI-78	26.43	41.03	19.33	7.00	9.42	6.27
L. leucocephala IGFRI-96	19.22	41.86	21.56	7.90	8.49	6.56
L. leucocephala Conn-3	28.85	38.03	22.65	11.97	6.66	8.16
L. leucocephala Silvi-4	26.44	46.63	17.70	11.37	9.45	8.60
L. leucocephala K-29	22.31	44.19	20.30	9.47	6.29	8.09
L. leucocephala K-217	25.77	41.80	18.33	6.06	9.53	6.32
L. leucocephala K-340	24.50	41.98	19.70	12.78	10.49	9.21
Max.	28.85	52.27	23.04	12.96	11.58	9.21
Min.	19.22	38.03	16.42	6.06	6.29	6.12
Mean	23.36	43.96	19.03	9.71	9.53	7.11

NRMACAFRISIL201600900107

TBOs based agroforestry models

(K B Sridhar and Inder Dev)

To demonstrate and promote TBOs based agroforestry model, an experiment was laid out at the experimental farm of ICAR-CAFRI, Jhansi. Experiment was laid out using RBD as experimental design. The trees selected for the study includes *Pongamia pinnata, Simaruba glauca* and *Azadirachta indica*. Six month-old seedlings were planted in the pits. The seedlings were watered regularly. Percentage survival and biometric observations were recorded at monthly interval. The castor crop was sown as intercrop during the cropping season.

The average height and collar diameter of seedlings was found highest in *Pongamia pinnata* (2.15 m and 4.77 cm) followed by *Azadirachta indica* (2.10 m and 4.43 cm) and the lowest was noticed in *Simaruba glauca* (1.08 m and 2.99 cm) (Table 34).

The average height of seedlings was found highest in treatment Castor + *Simaruba glauca* (1.65 m) followed by Castor + *Azadirachta indica* (1.60 m) and the lowest height was noticed in Castor + *Pongamia pinnata* (1.30 m). But in case of primary branches, the maximum were observed in Castor + *Pongamia pinnata* (6) followed by Castor + *Azadirachta indica* (5). In case of number of primary spikes, the highest was recorded in Castor + *Simaruba glauca* (2.40) and the lowest in Castor + *Pongamia pinnata* (1.73). In case of secondary spikes, the highest was noticed in Castor + *Azadiracht indica* (3.60). The number of nodes were maximum in Castor + *Pongamia pinnata* (12.26) followed by Castor + *Azadirachta indica* (11.33) (Table 35).

Table 34: Growth performance of seedlings after one year planting

Species	Avg. height (cm)	Avg. collar diameter (cm)	Maximum height(m)	Maximum collar diameter (cm)
Azadirachta indica	2.10	4.43	2.35	5.23
Pongamia pinnata	2.15	4.77	3.00	4.86
Simaruba glauca	1.08	2.99	1.10	3.16

Table 35: Growth performance of castor crop

Treatment	Plant height (m)	No. of primary branches	No. of primary spikes	No. of secondary spikes	Number of nodes
Castor + Neem	1.60	5	2.33	3.6	11.33
Castor + Pongamia	1.30	6	1.73	2.46	12.26
Castor + Simaruba	1.65	4	2.40	2.40	10.73
Control	1.44	4	2	2.46	10.66

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Mass propagation of industrial trees *viz. Eucalyptus tereticornis, Casuarina junghuhniana* Miq. *Melia dubia* and *Populus deltoides* using micro and mini clonal cuttings

(K B Sridhar and Lal Chand)

Standardized vegetative propagation protocol for *Populus deltioides, Eucalyptus tereticronis Casuarina junjuniana* and *Melia dubia* using minicuts (Fig. 40).

The clones of *Casuarina junjuniana* (MTP-1 & 2) and *Melia dubia* (MTP-1&2) were brought from FC & RI Mettupalayam, Tamil Nadu. Plants of Eucalyptus, Poplar, Mahogony, *Casuarina junjuniana* (L), Kadamba and *Dalbergia sissoo* (CAFRI Clones PT 6 & PT 2) were raised at ICAR-CAFRI. The species were planted at the spacing of 2 x 2m and replicated thrice. These clones were cut back from the base after one year to obtain new shoots. The obtained shoots will be used to further multiply the clones (Table 36).

Effective Nutrient Management of Hedge plants

Effective nutrient management of clonal plants were carried out by using Hoagland No 2 Basal Salt Mixture. It was found that effective nutrient management led to continued production (5–6 harvest cycles) of mini cuttings from the hedge plants (Table 37).

Table 36: Establishment of clonal mother garden (outdoor) of important industrial trees collected from different places

Sissoo (PT6)	Casuarina (MTP 2)	Casuarina (L)
Casuarina (MTP1)	Melia MTP 5	Sissoo (PT 6)
Melia (MTP5)	Sissoo (PT 6)	Casuarina (MTP2)
Casuarina (MTP2)	Casuarina (MTP 1)	Melia (MTP 5)
Kadamba	Melia MTP 1	Sissoo (PT2)
Sissoo (PT2)	Eucalyptus	Kadamba
Casuarina (L)	Mahogony	Poplar
Melia (MTP 1)	Sissoo (PT2)	Eucalyptus
Mahogony	Poplar	Casuarina (MTP1)
Eucalyptus	Kadamba	Melia (MTP1)
Poplar	Casuarina (L)	Mahogony

Table 37: Hoagland Solution

Nutrient	Mg/litre
Pottassium nitrate	606.60
Calcium nitrate	656.40
Magnesium sulphate	240.76
Ammonium phosphate	115.03
Manganese chloride	1.81
Boric acid	2.86
Molybdenum trioxide	0.016
Zinc sulphate	0.22
Copper sulphate	0.08
Ferric tartarate	0.50
EDTA	2.0
Total	1.63 g /litre

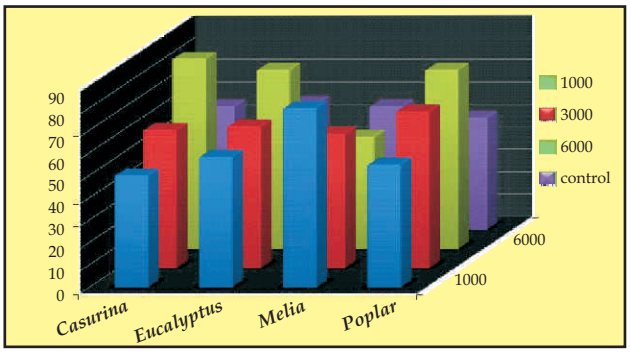


Fig. 40: Effect of different concentration of IBA on rooting percentage

Plate: Clonal mother garden (outdoor)

2.4. HRD, Technology Transfer & Refinement Programme

NRMACAFRISIL201500200093

Socio-economic, energetic and environmental impact assessment of watershed and agroforestry interventions at Garhkundar-Dabar watershed in Tikamgarh district of Madhya Pradesh

(R P Dwivedi, R K Tewari, Ramesh Singh, R H Rizvi and Mahendra Singh)

The data on fuel and fuelwood were collected from targeted villages *i.e.* Kundar, Rautiana, Shivrampur, Sakuli and Dabar. The details are given below:

In village Kundar 93% of required fuelwood is collected from adjacent forest areas and 7% from own field. The available tree species are Butea, Neem, Subabul and Dhaunkara. The consumption of fuelwood is 4.5 kg/day during rainy, 6.5 kg/day during winter and 4.00 kg/day during summer season. It is found that the collection of fuelwood is being performed mostly by women (82%). Cow & Buffalo dung cake is another important fuel being used for cooking. The amount is 5 to 7 kg/day as per requirement.

In village Rautiana 92% of required fuelwood is collected from adjacent forest areas and 8% from own field. The available tree species are Butea, Neem, Subabul and Dhaunkara. The consumption of fuelwood is 6 kg/day during rainy, 7 kg/day during winter and 5kg/day during summer season. It is found that the collection of fuelwood is being performed mostly by women (80%). Cow & Buffalo dung cake is another important fuel being used for cooking. The amount is 6 to 7 kg/day as per requirement.

About 96% required fuelwood is collected from adjacent forest areas and 4% from own field in village Shivrampur. The available tree species are Palash (*Butea monosperma*), Kardhai *(Anogeissus pendula)* and Besharam (*Ipomoea carnea*). The consumption of fuelwood is 10 kg/day during rainy, 12-15 kg/day during winter and 8 kg/day during summer season. Cow & Boffalo dung is also used @ 5-7 kg/day as per requirement. Average family size is 8 members in Shivrampur.

About 72% required fuelwood is collected from adjacent forest areas and 28% from own field in village Sakuli. The available tree species are Butea, Neem, Kardhai, Babul, Chirol and Akola. The consumption of fuelwood is 6 kg/day during rainy, 7 kg/day during winter and 5 kg/day during summer season. Cow & Boffalo dung is also used @ 5-6 kg/day as per requirement. There are about 25-30 LPG connection in village Sakuli. Only 55% women do the collection of fuelwood.

In village Dabar, about 76% required fuelwood is collected from adjacent forest areas and 24% from own field. The available tree species are Babul, Butea and Ber. The consumption of fuelwood is 6 kg/day during rainy, 7 kg/day during winter and 5 kg/day during summer season. Cow & Boffalo dung is also used @ 5-7 kg/day as per requirement. There are about 10-12 LPG connection in village Sakuli.

NRMACAFRISIL201500300094

Economic evaluation of Poplar and Eucalyptus based agroforestry systems prevalent in Indo-Gangatic Plains, India

(Mahendra Singh, R P Dwivedi, Inder Dev, R H Rizvi, K B Sridhar, A R Uthappa and Dhiraj Kumar)

Poplar and eucalyptus are enormously contributing to supply of raw material to wood-based industries in the state of Haryana, through extensively adoption of these two short rotation species in the state. The wood price of poplar and eucalyptus, household size, educational level, farm holding size and access to credit were identified major determinants for adoption of agroforestry system. The NPV (@12% discount rate) was ₹ 2,00,194 / ha., B:C ratio 1.55, IRR 22% and AEV of ₹ 33,366 was estimated for poplar based agroforestry.

There are 3 major marketing channels for poplar were:

a) Farmer→ Commission agent→ Wood based industry

b) Farmer→Pre-harvest contractor→ Commission agent→Wood based industry

c) Farmer→ Wood market (Manakpur and Yamunanagar, Haryana State Agricultural Marketing Board →Wood based industry

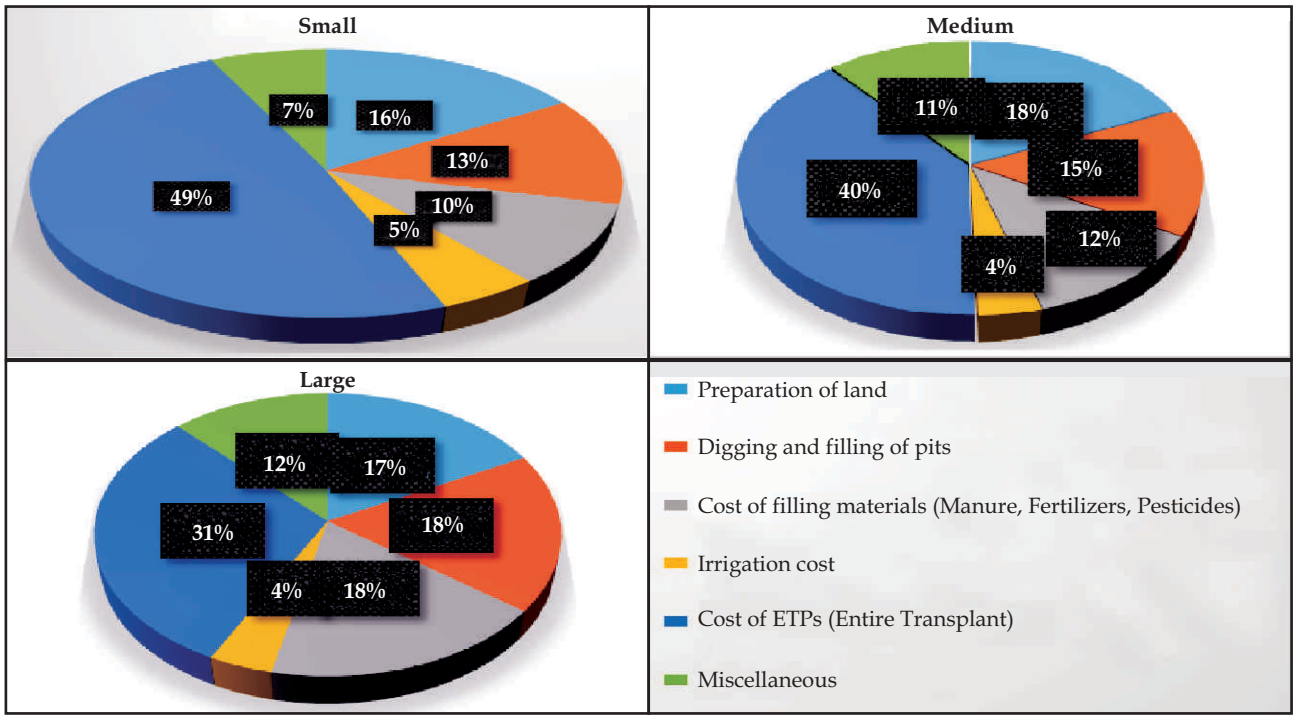


Fig. 41: % Share of various establishment costs of poplar-based agroforestry system on various size of holdings in Yamunanagar (Life cycle 2012-13 to 2017-18)

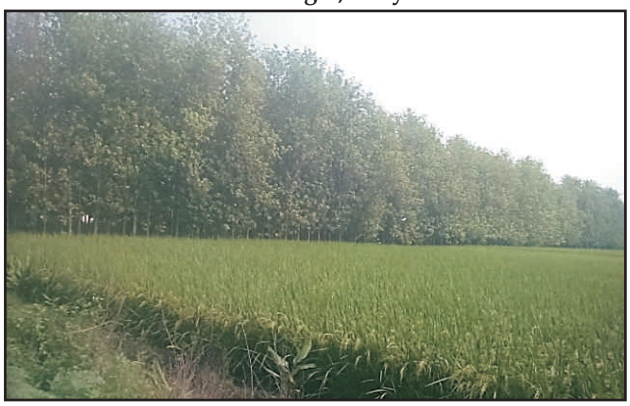
Remunerative price for wood would be important determinant for adoption of agroforestry. Agroforestry can be an ideal option for doubling farmers' income in Indo-Gangetic Plains. It is evident from the pie-chart that the share of ETPs' cost is highest among other establishment cost across all category of farmers. The share of ETPs ranged from one third in large to half in the small category of farmers (Fig. 41).

The comparative economic viability of poplar-based agroforestry system (Table 38) with prominent rice-wheat system showed that agroforestry system is able to enhance farmers' income more than double in seven years and triple, if farmers get value of carbon sequestered by their agroforestry system.

Table 38: Comparison of net income from rice-wheat system and poplar-based agroforestry system in Yamunanagar, Haryana, 2008-09 to 2014-15

Year	Net income (₹/ha) Source: CACP, Govt. of India			Net income (₹/ha)	Projected net income with value of carbon sequestered by Poplar-based agroforestry system (₹/ha)	
	Rice	Wheat	Total	Poplar + sugarcane/ wheat	Value of carbon sequestered/ ha @ ₹ 333/t CO_2e	Total net income
2008-09	17074	18195	35269	-1087	0	-1087
2009-10	20966	11831	32797	71389	0	71389
2010-11	24134	20613	44747	162	40197	40359
2011-12	8779	25165	33945	8577	51268	59845
2012-13	26581	26581	53163	8416	62716	71132
2013-14	56084	20648	76732	6800	69298	76098
2014-15	41030	10021	51050	623971	80247	704218
Total	194648	133054	327703	718228	303726	1021954

Poplar + Turmeric model of agroforestry in Yamunanagar, Haryana



Poplar plantation in Yamunanagar, Haryana

Farmer harvesting Poplar trees in Yamunanagar, Haryana

Interaction with Veneer manufacturer in Yamunanagar, Haryana

Farmers awaiting customers for their wood in Manakpur Mandi, Yamunanagar

Kisan Gosthi, Farmers' Visits, Training and Exhibitions

The Institute organized a number of Farmers' activities for transfer of technologies of agroforestry and increase the awareness for speedy adoption of agroforestry. These are as below:

Kisan gosthi

ICAR-CAFRI, Jhansi organized *Kisan Gosthi* cum Field Day at village Veerpura, Block-Bamour, Tehsil-Garoutha in Jhansi district on 7th March, 2017. The purpose of Gosthi was to create awareness amongst the farmers about coping up the drought situation in Bundelkhand. About 125 farmers participated in this Gosthi. At this occasion, soil health cards were distributed to 23 farmers.

Farmers' Workshop

ICAR- Central Agroforestry Research Institute, Jhansi on 8th May, 2017 organized a farmers' workshop entitled "Doubling the farmers income of Bundelkhand region through natural resource management and alternative land use systems". The workshop was organized in

collaboration with World Agroforestry Centre, South Asia Regional Office, New Delhi, SPANDAN, New Delhi, ICAR-CAFRI, Jhansi and Indian Society of Agroforestry, Jhansi. Total 165 farmers from U. P. & M. P. participated in the workshop. Six progressive farmers including one women farmer were honoured for adopting agroforestry technologies and setting example for other farmers in the Bundelkhand region. An exhibition was organized on 8th May, 2017 at ICAR-CAFRI, Jhansi, in which ICAR institutes, KVKs and Line Departments of Jhansi (U.P.) and IISWC regional station, Datia (M.P.) showcased their technologies and products for the benefit of farmers. In this event scientists and officers from State line-departments, KVKs, NGOs, IGFRI, Jhansi; Reginal Station of IISWC, Datia and NABARD were also present.

Farmers Meetings

Farmers meetings to create awareness to deal with the current situation of drought in the Bundelkhand were arranged with the farmers of villages Dhaurra, block Mauranipur, Jhansi district on 10th May, 2017. A multidisciplinary team of Scientists from ICAR-CAFRI, Jhansi visited these villages and interacted with farmers on problems related to agriculture and agroforestry and suggested the suitable technologies and management practices to get benefit in the cultivation. The farmers were also made aware of alternative systems which can provide maximum benefits in terms of production and livelihood during this drought situation as prevailing presently. During interaction and gosthi farm women, rural youth, marginal and small farmers were actively participated in group discussion and question-answer session. A total 65 farmers participated in the programme.

Exhibitions

ICAR-Central Agroforestry Research Institute, Jhansi participated in following different exhibitions during the year-2017 and showcased the technology developed by the Institute through exhibitions:

Date	Programme	Places	Farmers visited the stall
07th January, 2017	Kisan Gosthi	Regional Station of ICAR-IISWC, Datia (M.P.)	262 farmers
15th-17th March, 2017	Krishi Unnat Mela-2017	ICAR- IARI, New Delhi	150 farmers
07th March, 2017	Krishak Gosthi & Exhibition	Village Veerpura, Block Babaur, Tahsil Garautha, Jhansi (U.P.)	197 farmers

17th March, 2017	Kisan Mela organized by KVK, Bharari, Jhansi	Naveen Mandi, Chirgaon, Jhansi (U.P.)	100 farmers
25th-27th March, 2017	Virat Kisan Mela and Krishi Pradarshani	Mahoba (U.P.)	50 farmers
15th-19th April, 2017	Kisan Kalyan Mela at Motihari	ICAR-IRCE, Patna (Bihar)	100 farmers
08th May, 2017	Institute Foundation day	ICAR-CAFRI, Jhansi (U.P.)	100 farmers
27th May, 2017	Divisional Kharif Gosthi (Mandaliya Kharif Utpadakta Gosthi)	Para-Medical College Auditorium, Jhansi (U.P.)	100 farmers
18th-20th September, 2017	Antodaya Mela	Deendayal Sabhagar, Jhansi	250 Farmers

Farmers Training

ICAR-CAFRI, Jhansi organized fifteen batches of three days training on "Livelihood Security through Agroforestry and organic farming" for farmers and field functionaries of Bundelkhand region under *Pradhan Mantri Krishi Sinchai Yojna*-Watershed Development, State Level Nodal Agency, Govt. of U.P., Lucknow. A total 435 farmers and Regional Workers from Lalitpur, Chitrakoot, Banda, Mahoba and Jhansi districts were trained. These farmers were exposed to different agroforestry intervention including field visits to on-farm agroforestry intervention in Parasai-Sindh watershed of Jhansi district.

Visits

A number of farmers, students and Govt./NGOs officers from different parts of the country, *e.g.* Farmers from Bamour (Jhansi), IWMP, Damoh (M.P.), Rajgarh (M.P.), Seondha (M.P.), Shahgarh, Sagar (M.P.), Tikamgarh (M.P.), Vidisha (M.P.), Datia (M.P.), Agriculture Department, Niwari, Tikamgarh (M.P.), Officials from Forest Department, FTI, Kanpur (U.P.) and State department official of different parts of the country visited the Institute and demonstration sites. These visits have increased the awareness of farmers towards the agroforestry practices.

2.5.Externally Funded Projects

NICRA
National Innovations in Climate Resilient Agriculture

NRMACAFRISOL201100300087

I- Assessment of carbon sequestration potential of agroforestry systems existing on farmer's field in different agro-climatic regions

(Ram Newaj, Rajendra Prasad, A K Handa, Badre Alam and R H Rizvi)

The assessment of carbon sequestration potential (CSP) was undertaken in three districts (Puri, Dhenkanal and Sundergarh) of Odisha and two districts (Gumla and West Singh bhum) of Jharkhand. The general description of study area, major crops and their productivity and dominant tree species in total tree population is given in Table 39. Tree species and their population varied from one districts to another district within the state. Similarly, crops and their productivity also varied between the districts in the same state. Tree population in these districts varied from 7.5 to 16.0 tree/ha and medium growing trees are more as compared to slow and fast growing tree species (Table 39). Biomass, carbon and carbon sequestration potential (CSP) of agroforestry system in two districts of Jharkhand and three districts of Odisha are given in Table 40 and 41, which clearly showed that tree density play an important role in biomass production as well as carbon sequestration. The CSP of agroforestry system in Jharkhand is about 0.17 t C/ha/year and in case of Odisha, CSP varied from 0.12 to 0.20 t C/ha/year.

Table 39: General description of study area

State	District	Longitude & Latitude, soil type	Major crops and productivity (t/ha)	Dominant tree species among total tree population (%)
Jharkhand	Gumla	22° 35' N , 84° 40' E Red sandy loam deep soil	*Oryza sativa* (2.44), *Eleusine coracana* (0.67), *Zea mays* (1.687), *Triticum aestivum* (1.37), etc.	*Shorea robusta* (12.80), *Mangifera indica* (9.48) *Gmelina arborea* (8.52), *Litsea monopetala* (6.31), *Artocarpus heterophyllus* (5.66), *Tamarindus indica* (4.96), *Vitex nuganda* (3.13), *Schleichera oleosa* (0.57)
	West Singh Bhum	22° 33' N, 85° 48' E Red sandy and loamy soil, Black soil	*Oryza sativa* (2.23), *Zea mays* (0.84), *Triticum aestivum* (1.42), etc.	*Gmelina arborea* (8.62), *Leucaena leucocephala* (7.62), *Mangifera indica* (6.89), *Psidium guajava* (7.20), *Acacia nilotica* (6.41), *Terminalia arjuna* (6.33), *Butea monosperma* (4.99), *Vitex nuganda* (4.73).
Odisha	Puri	19° 47' N, 85° 49' E Alluvial, laterite, black soil	*Oryza Sativa* (2.32), *Zea mays* (2.11), *Arachis hypogaea* (1.05), *Vigna mungo* (0.48), *Vigna radiata* (0.44)	*Acacia auriculiformis* (22.53,) *Erythrina indica* (12.86), *Bambusa vulgaris* (10.9), *Cocos nucifera* (12.23), *Mangifera indica* (7.80), *Anacardium occidental* (5.70)
	Dhenkanal	20° 84' N, 85° 43' E Red and laterite soils	*Oryza Sativa* (2.32), *Zea mays* (2.11), *Arachis hypogaea* (1.05)	*Acacia auriculiformis* (18.53), *Bambusa vulgaris* (16.9), *Tectona grandis* (12.16) *Erythrina indica* (12.86), *Cocos nucifera* (12.23), *Mangifera indica* (7.80), *Anacardium occidental* (9.70)

Sundargarh	220° 05' N, 84° 68' E Red sandy soil, red loamy soil and black soil	*Oryza sativa* (1.37), *Zea mays* (1.24), *Vigna radiata* (.417), *Vigna mungo* (.408), *Triticum aestivum* (1.3)	*Mangifera indica* (11.91), *Artocarpus heterophyllus* (7.67), *Madhuca indica* (6.60), *Tectona grandis* (6.17), *Psidium guajava* (6.15), *Leucaena leucocephala* (5.87), *Gmelina arborea* (5.76), *Vitex nuganda* (5.12)

Table 40: Tree density in agroforestry existing on farmer's field in different districts of Odisha and Jharkhand

District	State	Slow	Medium	Fast	Total
Gumla	Jharkhand	4.06	7.33	1.01	12.4
West Singh Bhum		3.09	5.44	2.72	11.25
Sundergarh	Odisha	4.19	6.90	3.92	15.01
Dhenkanal		1.32	4.06	2.12	7.50
Puri		4.84	7.91	3.35	16.00

Table 41: Biomass, carbon and carbon sequestration potential of agroforestry system existing on farmer's field in two districts of Jharkhand

Parameters			Gumla (12.4 trees/ha)	West Singh Bhum (11.25 tree/ha)
Tree Biomass (above and below ground) in Mg DM/ha	Baseline	Biomass	6.81	6.83
	Simulated		15.44	10.99
Total biomass (tree+ crop) in Mg DM/ha	Baseline		11.97	10.10
	Simulated		21.22	18.97
Soil carbon (Mg C/ha)	Baseline	Carbon	11.56	10.66
	Simulated		12.24	11.74
Biomass carbon (Mg C/ha)	Baseline		5.71	4.84
	Simulated		10.18	9.10
Total carbon (biomass + soil) (Mg C/ha)	Baseline		17.27	15.50
	Simulated		22.48	20.84
Net carbon sequestered in agroforestry systems over the simulated period of thirty years (Mg C/ha)		Carbon sequestered	5.15	5.34
Estimated annual carbon sequestration potential of agroforestry system (Mg C/ha/yr)			0.17	0.17

Table 42: Biomass, carbon and carbon sequestration potential of agroforestry system existing on farmer's field in three districts of Odisha

Parameters			Puri (16 trees/ha)	Dhenekanal (7.5 trees/ha)	Sundergarh (15.01trees/ha)
Tree Biomass (above and below ground) in Mg DM/ha	Baseline	Biomass	16.16	5.42	12.75
	Simulated		27.63	10.92	19.82
Total biomass (tree+ crop) in Mg DM/ha	Baseline		27.00	16.06	18.50
	Simulated		38.77	22.78	27.50
Soil carbon (Mg C/ha)	Baseline	Carbon	13.63	10.57	12.06
	Simulated		14.14	11.31	13.60

Biomass carbon (Mg C/ha)	Baseline	12.42	7.56	8.88
	Simulated	18.05	10.33	13.20
Total carbon (biomass + soil) (Mg C/ha)	Baseline	26.05	18.13	20.94
	Simulated	32.19	21.64	26.80
Net carbon sequestered in agroforestry systems over the simulated period of thirty years(Mg C/ha)	Carbon sequestered	6.14	3.15	5.86
Estimated annual carbon sequestration potential of agroforestry system (Mg C/ha/yr)		0.20	0.12	0.19

Based on data of 51 districts from 17 states the CSP is 0.35 t C/ha/year. Looking to the area under agroforestry (17.45 million ha) in the country, the total carbon stock will be 6.10 million tones and CO_2 equivalent C will be 22.41 million tones. In this way the agroforestry can offset 22.41 t CO_2 of total CO_2 equivalent GHG emission (1831.64 million tonnes). In other word, contribution of agroforestry to offset total GHG emission is 1.22% (Table 43). To make comparison with forests in offsetting CO_2 from atmosphere. The forests is able to offset 69.73 million t CO_2 carbon from atmosphere every year (Table 44). Similarly, an estimation is made on contribution of different carbon pools in total C stock available in agroforestry at country level (Table 44 and Fig. 42). The maximum contribution in total C stock comes from soil organic carbon followed by aboveground biomass, belowground biomass and litter.

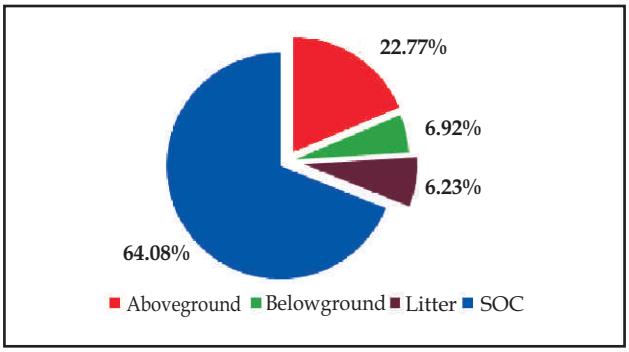


Fig. 42: Contribution of different carbon pools in total carbon stock

Table 43: Role of agroforestry to offset CO_2 in total CO_2 Equivalent GHG emission (1831.64 million tonnes)

Land use (area)	Carbon Sequestration potential (CSP) t C/ha/year A	Total CSP potential million t C B	CO_2 equivalent C million tones C (AxB)	Contribution to offset in total GHG emission (%) (Cx3.67)
Agroforestry (17.45 million ha)	0.35	6.10	22.41	1.22
Forest (69.16 million ha)	2,74,725.27	19.0	69.73	3.80

Table 44: Total carbon stock available in different carbon pools under agroforestry existing on farmers field in the country (figure in parentheses are carbon t/ha)

Carbon pool	Total C stock (million tones)
Aboveground biomass	91.32 (5.23)
Belowground biomass	27.76(1.59)
Litter	24.97 (1.43)
SOC	257.01 (14.72)
Total	401.06 (22.97)

II- Mapping of agroforestry area using GIS and Remote Sensing technique

Mapping of agroforestry area in 11 agro-climatic Zone has already been completed and status map is presented here. Land Use and land Cover analysis (LULC) for the selected districts (Table 45 and Fig. 43) of zone -7 was done using RS2/ LISS-3 data. The total area under agroforestry in six district of this zone was estimated to be 0.6185 million ha of total geographical area (4.679 million ha).

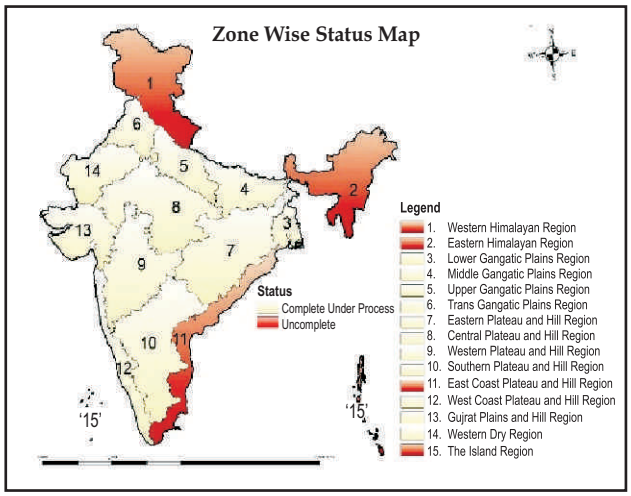


Table 45: LULC analysis of different districts of Agro-climatic zone -7

S. No.	Selected district	Geographical area (M ha)	Agroforestry area (M ha)	Agroforestry area (%)
1.	Shehdol (M.P.)	0.568	0.0675	11.90
2.	Bilaspur (Chattisgarh)	0.831	0.234	28.10
3.	Bijapur (Chattisgarh)	0.905	0.050	5.58
4.	Dhamtari (Chattisgarh)	0.408	0.026	6.48
5.	Raigarh (Chattisgarh)	0.706	0.135	19.19
6.	Gumla (Jharkhand)	0.537	0.060	11.22
7.	Paschim Singh Bhum (Jharkhand)	0.724	0.046	6.40
	Total	4.679	0.6185	12.697

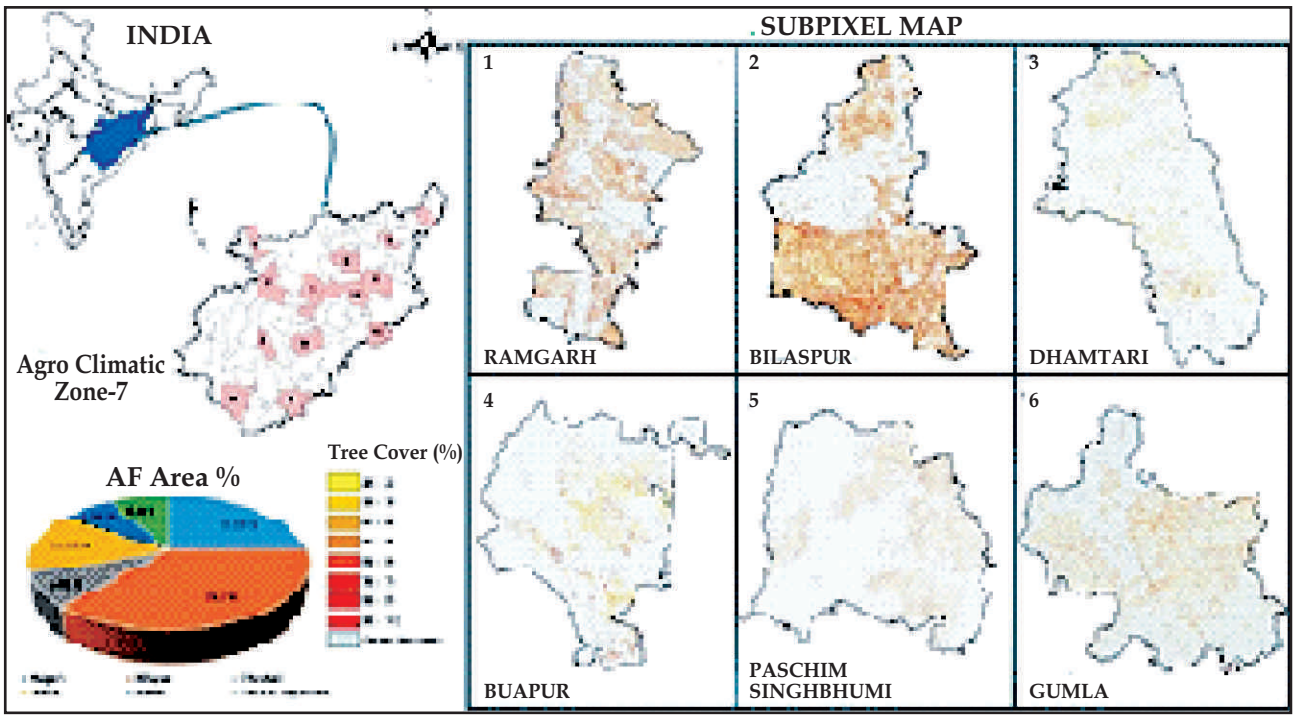


Fig. 43: LULC map of selected districts of agro-climatic zone-7

III- Studies on thermotolerance in MPTs of agroforestry importance

Experiments were conducted with *Albizia procera* (safed siris) and *Azadirachta indica* (neem) by growing the seedlings in polybags under elevated temperature inside a temperature gradient tunnel (TGT) and under ambient condition outside the TGT. Alarming effects of elevated temperature on the leaf physiological status have been observed. Adjusting leaf temperature for its physiological functions is highly important. The leaf temperature adjustment gets perturbed with the increase in surrounding temperature. This becomes more critical when growth temperature increases as it occurred inside TGT under elevated temperature conditions. Thus, the temporal changes in canopy temperature depression (CTD) was clearly noted in both the tree species under ambient and elevated temperature (Figs. 44 & 45). There were temporal changes in winter and post-winter period in the leaf temperature maintenance by the tree species as observed in the CTD (Figs. 46 & 47).

With increase in temperature, there was obvious

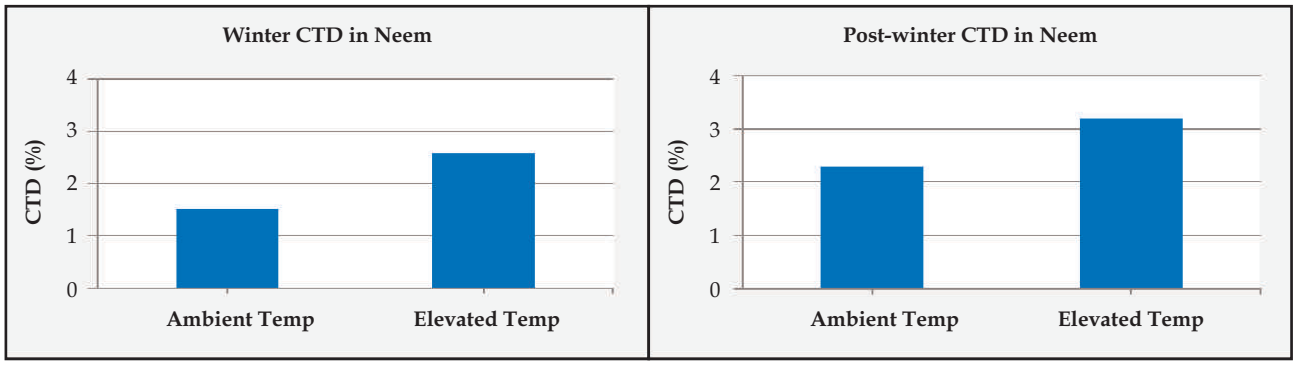


Fig. 44 & 45: Temporal changes in canopy temperature depression (CTD) of neem (*Azadirachta indica*) in winter and post-winter under ambient and elevated temperature

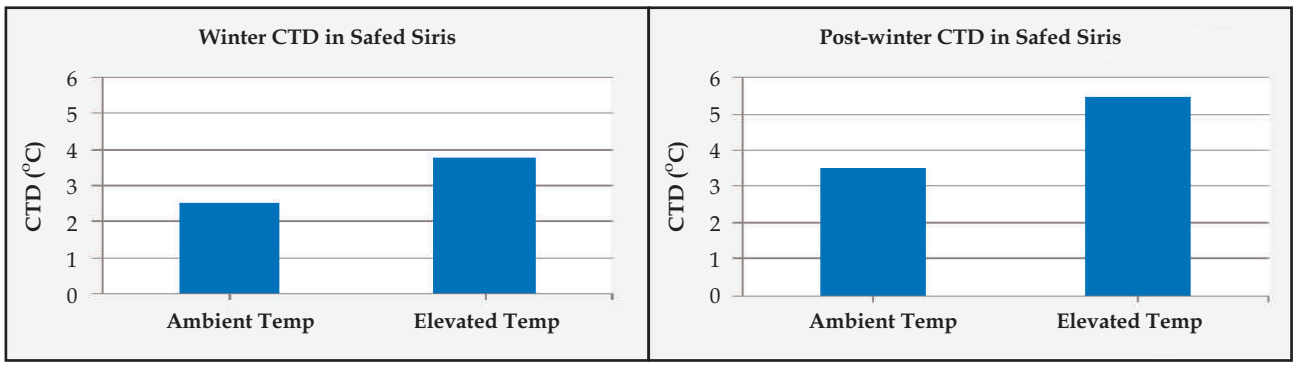


Fig. 46 & 47: Temporal changes in canopy temperature depression (CTD) of safed siris (*Albizia procera*) in winter and post-winter under ambient and elevated temperature

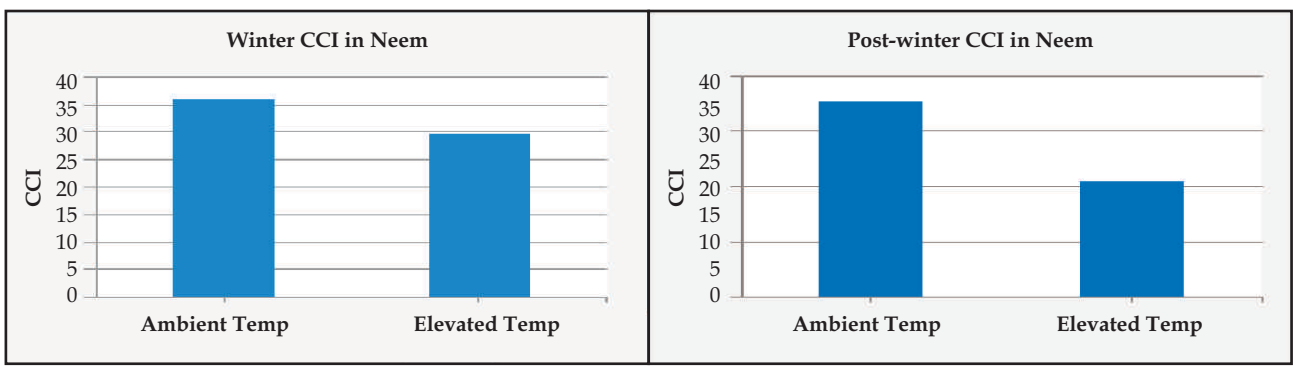


Fig. 48 & 49: Temporal changes in leaf chlorophyll content index (CCI) of neem (*Azadirachta indica*) in winter and post-winter under ambient and elevated temperature

reduction in leaf chlorophyll content index (CCI) in both neem and safed siris under elevated temperature (Figs. 48 & 49). Temporal changes in CCI was also prominent and it was adversely affected under elevated temperature (Figs. 50 & 51). Thus, dynamics of CCI exhibits its functional importance in relation to increasing atmospheric temperature in tree species. In this direction, experimental data collection and analysis are in progress.

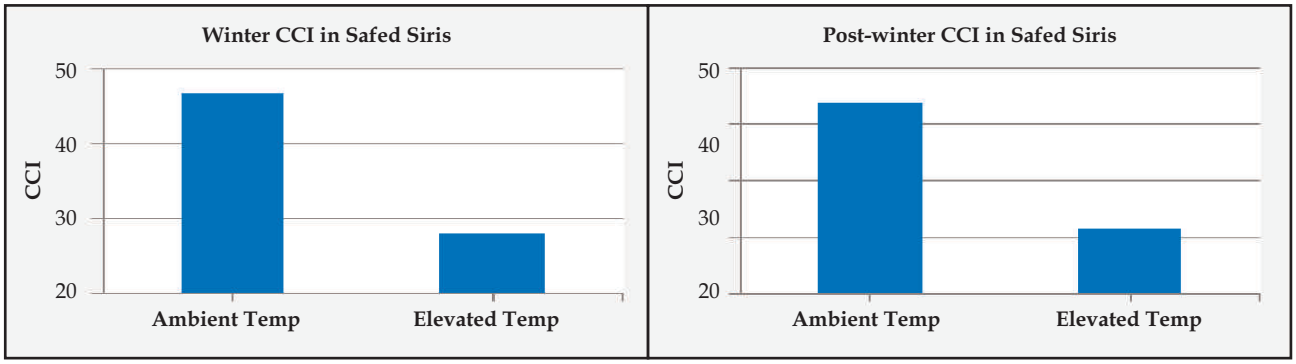


Fig. 50 & 51: Temporal changes in leaf chlorophyll content index (CCI) of safed siris (*Albizia procera*) in winter and post-winter under ambient and elevated temperature

Network Project

NRMACAFRISOP200800100075

Harvest and post-harvest processing and value addition of natural resins, gums and gum resins

(Rajendra Prasad, A K Handa, Ramesh Singh and Badre Alam)

The main objective of the project is to develop agroforestry models including gum- and resin-yielding trees for livelihood security and horizontal dissemination of technologies. For conducting research at ICAR-CAFRI, Jhansi, the major themes are i) growth and productivity of gum yielding tree based agroforestry models, ii) demonstration and development of gum yielding tree based agroforestry models on farmers' fields, and iii) indigenous traditional knowledge(ITK) on gum and resin tapping, applications and post harvest value addition. During the year, recorded growth and productivity data from established gum-yielding tree based agroforestry models, motivated farmers to plant agroforestry models on their farm, and surveyed tribal areas in Shivpuri, Sheopur and Datia for ITK information on gum tapping and uses. Effect of leaf extract of *Anogeissus pendula* (important gum-yielding tree) on germination of important *rabi* season crops of the region was also studied. Besides, trials were also conducted to standardize gum tapping techniques for *Butea monosperma* and ethephon induced gummosis in *A. pendula*. Soil health of gum- and resin- yielding tree based agroforestry model was assessed.

A. Growth and productivity of agroforestry models

A.1. Agroforestry models on-farm

Data on survival and tree growth in different agroforestry models established at central research farm of ICAR-CAFRI, Jhansi are presented in Table 46.

In agri-horti-silviculture model (field no. 25), casualty replacement was done. Maximum GBH (cm), plant height (cm) and survival (%) was recorded in *A. senegal* and maximum canopy diameter (m^2) in *A. marmelos* (Table 46). In this model, fruit yields were recorded from 14 plants of *C. lemon*, 17 *A. marmelos* and 19 *C. carandas* . A total of 115 kg lemon, 21 kg karonda and 118 kg bael fruits were harvested. The average weight of bael var. CISH B1 was 0.784 kg and var. CISH B2 was 1.575 kg. During *rabi* season of 2016-17, wheat (var. DBW 17) was cultivated and during *kharif* season (2017-18), moong (var. Sweta) was cultivated as intercrop. This year *i.e.* 2017-18 (*rabi* season), mustard (var. RH749) has been sown. During 2017-18 *i.e.* after seven years of planting, natural oozing of gum (average 38.77 g/tree) from *A. senegal* was recorded.

Table 46: Growth and survival of trees in agroforestry models at ICAR-CAFRI, Jhansi

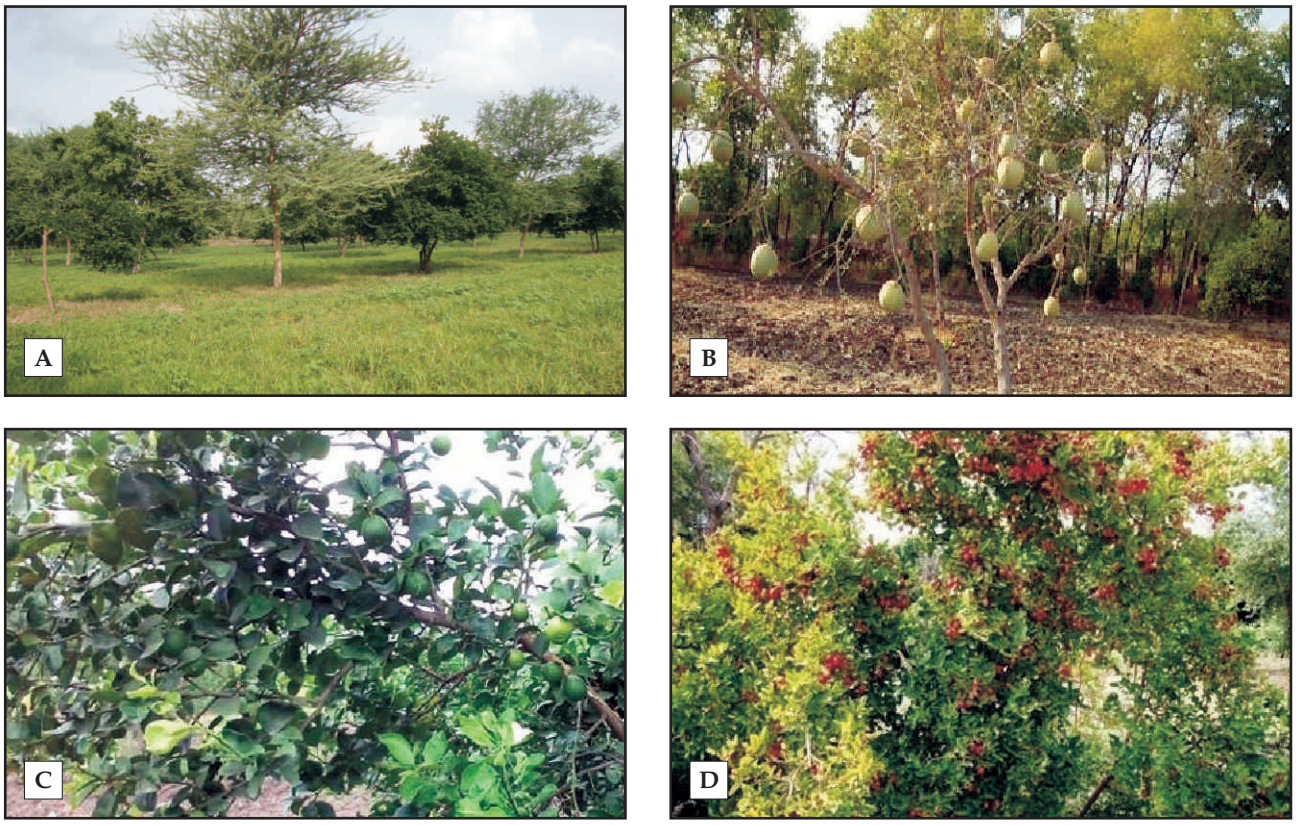
Agroforestry models	GBH (cm)	Height (cm)	Canopy (m^2)	Survival (%)	Pruned biomass (kg/tree)
Agri-horti-silviculture (field no. 25)					
Acacia senegal	38.5	567.1	11.7	100	4.4
Citrus limon	20.1	376.9	12.1	83.3	3.2
Aegle marmelos	31.4	523.6	13.3	89.3	2.5
Carissa carandas	2.3 (CD)	172.5	1.5	93.5	--
Horti-silviculture I (field no. 20)					
Acacia nilotica **	15.9	344.5	6.1	69.0	--
Terminalia arjuna	26.4	500.3	8.4	100.0	--
A. senegal (at boundary)	33.4	563.0	13.0	90.0	--
Horti-silviculture II (field no. 20)					
A. nilotica	77.7	929.2	94.4	85.7	--
T. arjuna	25.2	418.8	5.9	100.0	--
A. senegal (at boundary)	23.8	397.0	8.9	80.0	--
Block plantation					
A. senegal	21.9	464.3	11.0	100.0	--
Field no. 40 & 41 (2012 plantation)					
A. senegal (10 × 10 m)	21.1	388.4	6.4	84.2	6.2
A. nilotica (10 × 10 m)	21.6	437.0	0.5	85.7	6.8
A. senegal (10 × 5 m)	13.7	299.8	4.7	87.5	6.6
A. nilotica (10 × 5 m)	18.0	387.8	0.1	84.8	6.7
A. senegal (5 × 5 m)	18.5	339.7	5.6	92.7	6.7
A. nilotica (5 × 5 m)	22.8	435.4	6.7	96.0	7.6

* Plantation in July 2014; CD- Collar Diameter

In horti-silviculture model I (field no. 20), *Terminalia arjuna* showed maximum survival (100%), followed by *A. senegal* and *A. nilotica*. Growth parameters *i.e.* GBH and height were recorded maximum in *A. senegal*. In horti-silviculture model II (field number 20), *T. arjuna* showed maximum survival (100%) while higher GBH and plant height was recorded in *A. nilotica*. In general, survival and growth of *A. nilotica* was better than *A. senegal* in this model.

Survival of *A. senegal* in block plantation on rocky site was 100% and plants attained mean height of 464.3 cm with girth at breast height (GBH) of 21.9 cm.

In agri-silvi model (field no. 40 & 41), maximum survival was recorded by *A. nilotica* at 5 × 5 m spacing while least in *A. senegal* at 10 ×10 m spacing. After five years of plantation, higher GBH and plant height were recorded in *A. nilotica* than *A. senegal* in all spacings.



***Acacia senegal* based agri-horti-silvi model at research farm of CAFRI (A. Intercrop-wheat, B. *Aegle marmelos*, C. *Citrus limon*, and D. *Carissa carandas*)**

During summer season (2017), natural oozing of gum in different fields of *A. senegal* were observed (Table 47). Natural oozing of gum ranged from 26.44 – 51.09 g/tree in field number 25 (average yield: 38.77 g), 11.16 – 16.07 g/tree in field number 40 & 41 (average yield: 14.08 g) and 3.81 – 220.38 g/ tree (average yield: 29.99 g) in gum garden.

Similarly, natural oozing of gum in different fields of *A. nilotica* was also observed (Table 47). It ranged from 8.20 – 133.27 g/tree in field number 20 (average yield: 58.76 g) and 2.36 – 17.09 g/tree in field number 40 & 41 (average yield: 12.22 g).

During *rabi* season of 2016-17, wheat (var. DBW 17) was sown in agri-horti-silvi model (field no. 25) and the recommended package of practices was followed. Plant growth and yield attributes of wheat were measured at different distances *viz.*, 1.0, 2.5 and 4.5 m distances from tree trunk of *A. senegal*, *A. marmelos* and *C. limon*. Results revealed that planted tree species did not affect any growth and yield related parameters of intercrop (wheat), irrespective of distance (Table 49). Irrespective of

Table 47: Descriptive statistics of gum yield from *A. senegal* tree (naturally oozing)

Particulars	Field no. 25			Field no. 40 & 41			Gum garden		
	GBH (cm)	Total no. tear/tree	Gum yield (g/tree)	GBH (cm)	Total no. tear/tree	Gum yield (g/tree)	GBH (cm)	Total no. tear/tree	Gum yield (g/tree)
Count	2.0	2.0	2.0	4.0	4.0	4.0	23.0	23.0	23
Mean	31.0	4.0	38.8	16.0	2.5	14.1	45.5	2.2	30.0
Range	28.0	6.0	24.7	22.0	3.0	4.9	33.7	4.0	216.6
Minimum	15.0	1.0	26.4	9.0	1.0	11.2	31.6	1.0	3.8
Maximum	47.0	7.0	51.1	31.0	4.0	16.1	65.3	5.0	220.4
SD	16.0	3.0	12.3	3.91	0.5	0.96	1.94	0.27	9.15

plant species, distances from tree trunk significantly affect plant population, biomass, grain yield and straw yield of wheat. Higher values of these parameters were recorded at 4.5 m distance from tree trunk and minimum values under the tree canopy *i.e.* at 1.0 m distance.

Table 48: Descriptive statistics of gum yield from *A. nilotica* trees (naturally oozing)

Particulars	Field no. 20			Field no. 40 & 41		
	GBH (cm)	Total no. tear/tree	Gum yield (g/tree)	GBH (cm)	Total no. tear/tree	Gum yield (g/tree)
Count	5	5	5	4	4	4
Mean	80.0	12.6	58.8	27.8	4	12.2
Range	36.0	23.0	125.1	16.0	4	14.7
Minimum	61.0	3.0	8.2	20.0	2	2.4
Maximum	97.0	26.0	133.3	36.0	6	17.1
SD	5.8	5.3	27.18	4.2	0.9	5.53

Table 49: Growth and yield attributes of wheat (var. DBW 17) in agri-horti-silvi model (2016-17)

Growth parameters	Distance (m)	Tree species			Mean
		A. senegal	*C. limon*	*A. marmelos*	
Plant population/m^2	1.0	29.0	31.0	31.0	30.0
	2.5	39.0	35.0	37.0	37.0
	4.5	43.0	37.0	40.0	40.0
	Mean	**37.0**	**34.0**	**36.0**	
No. of tillers/plant	1.0	9.6	7.4	6.5	7.8
	2.5	9.6	7.9	8.6	8.7
	4.5	10.1	9.7	10.1	10.0
	Mean	**9.8**	**8.3**	**8.4**	
Plant height (cm)	1.0	79.1	85.9	72.5	79.2
	2.5	78.3	84.4	78.6	80.4
	4.5	77.6	74.3	78.8	76.9
	Mean	**78.3**	**81.5**	**76.6**	
Ear length (cm)	1.0	7.9	8.2	8.9	8.3
	2.5	9.2	9.5	8.5	9.1
	4.5	7.9	8.3	8.4	8.2
	Mean	**8.3**	**8.7**	**8.6**	
Total biomass (g/m^2)	1.0	913.3	710.0	586.7	736.7
	2.5	990.0	943.3	983.3	972.2
	4.5	1016.7	1010.0	1116.7	1047.8
	Mean	**973.3**	**887.8**	**895.6**	
Grain yield (g/m^2)	1.0	453.3	345.0	280.0	359.4
	2.5	478.3	465.0	466.7	470.0
	4.5	496.7	506.7	543.3	515.6
	Mean	**476.1**	**438.9**	**430.0**	

Straw yield (g/m^2)	1.0	460.0	365.0	306.7	372.2
	2.5	511.7	478.3	516.7	502.2
	4.5	520.0	503.3	573.3	532.2
	Mean	**497.2**	**448.9**	**465.6**	
		Tree species	**Distance**	**Interaction**	
Plant population/m^2		NS	7.0	NS	
No. of tillers/plant		NS	NS	NS	
Plant height (cm)		NS	NS	NS	
Ear length (cm)		NS	NS	NS	
Total biomass (g/m^2)		NS	137.7	NS	
Grain yield (g/m^2)		NS	83.1	NS	
Straw yield (g/m^2)		NS	64.4	NS	

Table 50: Growth and yield attributes of moong (var. Sweta) in agri-horti-silvi model (2017)

Growth parameters	Distance (m)	Tree species			Mean
		A. senegal	*C. limon*	*A. marmelos*	
Plant population/m^2	1.0	18	18	220	19
	2.5	19	24	24	22
	4.5	25	25	25	25
	Mean	**20**	**22**	**23**	
Plant Height (cm)	1.0	59.8	51.8	60.5	57.4
	2.5	57.7	61.4	60.1	59.7
	4.5	55.9	64.6	59.9	60.1
	Mean	**57.8**	**59.3**	**60.2**	
Seed yield (g/m^2)	1.0	32.7	46.0	33.0	37.2
	2.5	69.2	60.8	59.3	63.1
	4.5	79.0	68.2	67.1	71.4
	Mean	**60.3**	**58.4**	**53.1**	
Dry biomass (g/m^2)	1.0	180.6	194.3	150.0	175.0
	2.5	216.1	213.6	211.3	213.7
	4.5	238.8	264.6	239.2	247.5
	Mean	**211.8**	**224.2**	**200.2**	
		Tree species	**Distance**	**Interaction**	
Plant population/m^2		2	2	3	
Plant height (cm)		NS	NS	NS	
Seed yield (g/m^2)		NS	9.6	NS	
Total biomass (g/m^2)		NS	31.3	NS	

During *kharif* season of 2017, moong (var. Sweta) was sown in agri-horti-silviculture model (field number 25) and the recommended package of practices was followed. Planted tree species did not affect plant height, seed yield and biomass. Maximum plant population was recorded under *A. marmelos*, which was at par with *C. limon* and *A. senegal* (Table 50). On the other hand, plant

population, seed yield and biomass was found to be affected by distance. Maximum values of these parameters were recorded at 4.5 cm distance from the tree trunk while their minimum values were recorded under the tree canopy *i.e.* at 1.0 cm.

Gum garden

Gum garden of *A. senegal* was established in July, 2014 at central research farm of ICAR-CAFRI, Jhansi, which was further extended during 2015. A total of 353 plants of *A. senegal* and *B. monosperma* were planted at 3 × 3 m spacing in the garden. The growth and survival data are given in Table 51. Survival percentage was higher in *A. senegal* than *B. monosperma* in both the fields. The planted saplings of *B. monosperma* showed very poor performance.

Growth of *Anogeissus pendula* plantation

The growth of existing plantations of *A. pendula*, which is now used for standardizing gum tapping techniques, was monitored (progeny trial). This plantation of September 1994 consisting of tissue culture raised progenies of five plus trees of *A. pendula*, planted in randomised block design with four replications. Each progeny had 25 plants in a plot. Net plot size was 15 m × 10 m with the spacing of 3 m × 2 m. On an average, the recorded GBH of AP-12, AP-52, AP S-2, AP-28 and AP-35 progenies were 31.27, 31.38, 32.67, 32.05 and 34.02 cm, respectively (Fig. 52A). The maximum GBH was recorded in AP-35 progeny while minimum in AP-12.

Growth of trees was also recorded in experimental field (plus tree trial) wherein seven progenies of *A. pendula* raised through tissue culture were planted in August 1995 along with check in randomised block design in four replications having plot size of 15 × 10 m with a spacing of 3 × 2 m. Plus trees were selected from plants of Haryana (Bandwari) and Rajasthan (Jodhpur and Udaipur) based on fast growth. The GBH of AP-20, J-241, J-124, J-205, NRC-5, J-185 and J-62 progenies were 30.25, 31.07, 33.19, 39.04, 29.01, 36.11 and 36.84 cm, respectively (Fig. 52B). Maximum GBH was recorded in J-205 progeny while minimum in NRC-5.

Growth of another plantation consisting of *A. pendula* and *A. latifolia* was also monitored (field number 34 and 35). This plantation was established in 1990, which is now being used as

Table 51: Growth parameters of *Acacia senegal* and *Butea monosperma* in gum gardens

Tree species	Collar diameter (cm)	Height (cm)	Canopy (m^2)	Survival (%)	Pruned biomass (kg/tree)
Gum garden part-I (Planted in July, 2014)					
A. senegal	5.14	254.4	2.89	73.7	2.0
B. monosperma	1.15	50.6	--	33.3	--
Gum garden part-II (Planted in July, 2015)					
A. senegal	3.41	175.4	1.98	94.2	1.1
B. monosperma	0.80	51.1	0.15	64.6	–

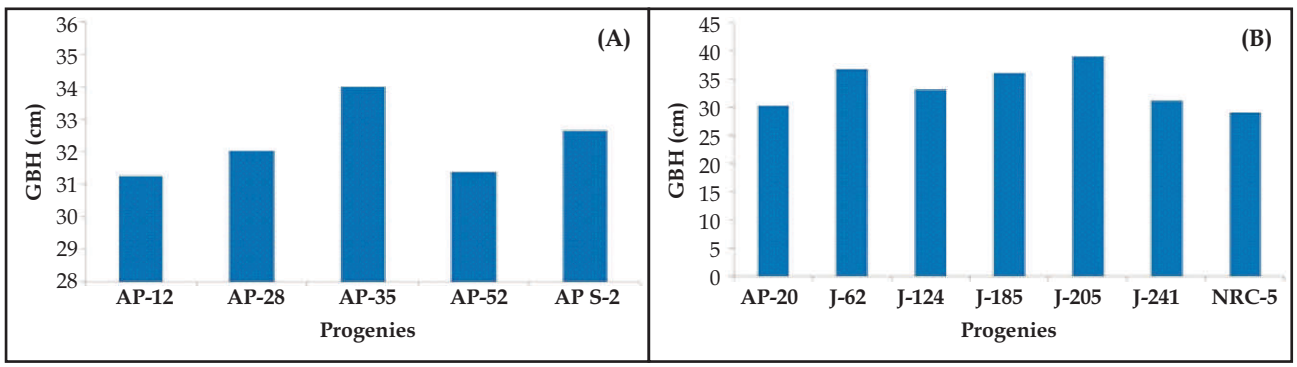


Fig. 52: (A) GBH (cm) of different progenies of *Anogeissus pendula* after 23 years of plantation and (B) 22 years of plantation

agroforestry models for tapping gum and raising intercrops. The trees were planted at 5 m × 5m spacing. After 26 years, the better survival (87.5%) was recorded in *A. pendula*, while better GBH, canopy spread and height was recorded in *A. latifolia* (Table 52).

A2. Agroforestry models on farmers' fields

After eight years of planting, *A. senegal* recorded relatively more survival (57%) than *A. nilotica* (50%) in Garhkundar watershed. At the farm of Shri Thakur Das, casuality in guava plants has been reported. Only 10.5% survival noticed. Similarly, at farm of Shri Himmat, mortality in kumat and karonda plants noticed. At village Ambabai, mortality in *A. senegal* was recorded. This year 37% survival of *A. senegal* with average plant height of 267.1 cm and average collar diameter of 7.5 cm has been observed. Natural oozing of gum from *A. senegal* was observed during 2017 at farm of Shri Himmat (Table 53).

Table 52: Growth of *A. pendula* and *A. latifolia* after 26 years

Gum yielding tree soeciesTree species	GBH (cm)	Height (cm)	Canopy (m^2)	Survival (%)
Anogeissus pendula	41.9	736.1	23.3	87.5
Anogeissus latifolia	44.2	767.1	25.4	82.4

Table 53: Growth of trees in agroforestry models at Garhkundar watershed (8 years old) and village Ambabai (6 years old)

Plant species	GBH (cm)	Height (cm)	Canopy (m^2)	Survival (%)
Thakur Das				
Acacia nilotica (Babul)	31.0	545.0	10.3	50.0
Psidium guajava (Guava)	20.5	412.5	11.0	10.5
Carissa carandus (Karonda)	0.8 (CD)	135.0	0.5	12.5
Himmat				
Acacia senegal (Kumat)	30.9	389.4	4.0	57.0
Emblica officinalis (Anola)	51.4	509.4	22.1	54.0
Carrisa carandus (Karonda)	3.1 (CD)	130.0	0.2	1.8
Ghanshyam				
Acacia senegal (Kumat) (boundary) (Planted in 2012)	2.2	145.6	--	59.5
Mani Ram (Village Ambabai)				
Acacia senegal (Kumat)	7.5 (CD)	267.1	4.8	37.0

CD- Collar Diameter

A3. Assessment of allelopathic effect through bioassay

The allelopathic effects of leaf extracts of *Anogeissus pendula* on seed germination (%) of important *rabi* season crops (*Cicer arietinum*, *Lens culinaris*, *Brassica compestris* and *Triticum aestivum*) was assessed. Leaves of *A. pendula* were collected, washed with distilled water, dried under shade and ground with help of electronic grinder to make fine powder. The leaf extract was prepared by immersing 150 g powder in 1 L double distilled water in a beaker for 24 h at room temperature. The extract was then filtered with double layer of muslin cloth followed by Whatman filter paper No. 1. This extract of 15% concentration was further diluted to 10 and 5% (v/v) aqueous leaf extracts. Distilled water served as control (0% concentration). Certified seeds of chickpea, lentil, mustard and wheat were surface-sterilized with 0.1% mercuric chloride, washed (4-5 times) with distilled water and dried prior to use. For germination test, 20 sterilized seeds of

lentil, mustard and wheat, and 10 seeds of chickpea were evenly placed on two layers of filter paper in sterile petri-dishes (9 cm). Thereafter, 2 ml of different concentration of leaf extracts (0, 5, 10 and 15%) were added to petri-dish, containing seeds of test crops. All petri-dishes were placed in laboratory at room temperature in a completely randomized design and each treatment was replicated four times. Germination was determined by counting the number of germinated seeds at 24 hours intervals over 7 days. Maximum reduction in germination and growth related parameters were recorded in 15% concentration when compared with 10 and 5% (Fig. 53). Irrespective of concentrations, the germination of tested crops in leaf extracts of *A. pendula* was recorded in the following order: *C. arietinum*>*T. aestivum*>*L. culinaris*>*B. compestris*. Apart from this, the extracts inhibited the plumule length, radical length and shoot and root dry weight in all test crops.

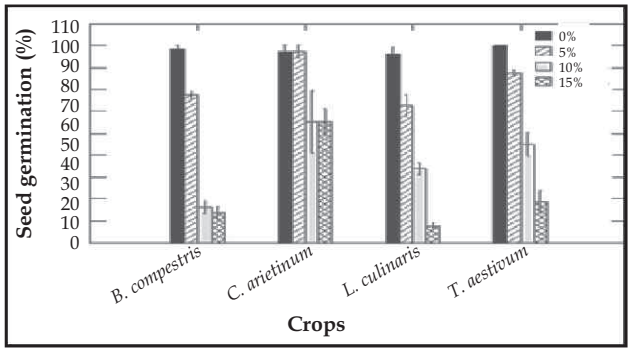


Fig. 53: Effect of different concentrations of leaf extracts of *Anogeissus pendula* on seed germination (%) of *rabi* crops

A4. Assessment of soil health of agroforestry models

Soil sampling from two depth (0-15 and 15-30 cm) was done from all the gum-yielding tree based agroforestry models. For collecting representative samples from each field, soil was collected from 4-5 spots and mixed to get a composite sample. The analysis for different soil properties was done in laboratory and data has been presented in Table 54. In general, most of the soil properties were having higher value in surface soil (0-15 cm) than the sub-surface soil (15-30 cm), except Fe and Cu.

Dynamics of soil characteristics in agri-horti-silvi model

To assess effect of tree component (*A. senegal*, *A. marmelos*, *C. limon* and *C. carandas*) on dynamics of soil properties in agri-horti-silvi model, soil sampling was done from various distances from tree lines (0.5, 1.0, 2.0, 4.0 and 6.0 m) and two depths (0-15 and 15-30 cm). Soil samples were dried and processed in laboratory and analyzed for various soil properties. The detailed results in respect of macro and micro-nutrients are discussed below.

Macro-nutrients: Results of three-way ANOVA showed that different plant species significantly affected electrical conductivity (EC), organic carbon (OC), available nitrogen (N) and available phosphorus (P). Distance from tree trunk significantly affected pH, EC, OC and available potassium (K). Soil depth did not show significant effect on any parameter, except available K (Table 55). Among different plant species, maximum pooled means of pH, EC, P and K were recorded in soil collected from *C. limon*, while maximum N and OC were recorded in soil collected from *A. marmelos* and *C. carandas*, respectively (Table 56). Pooled mean of all recorded parameters (except P) were found higher near the tree base (0.5 m) which was found to be decreasing with the increase in the distance from tree base. Similarly, values of all recorded parameters were higher in soil collected from surface (0-15 cm) than sub-surface soil (15-30 cm).

Micro-nutrient: Results of three-way ANOVA showed that different plant species and distance from tree trunk significantly affected all the micro-nutrients (Cu, Fe, Mn and Zn). Soil depth did not affect any parameter (Table 57). Among plant species, pooled mean of Cu content was maximum in soil collected from *A. marmelos*, Fe in soil of *A. senegal*, Mn in soil of *C. limon* and Zn in soil of *C. carandas* (Table 58). Distance wise results were found variable. Pooled means of Cu, Fe and Mn were comparatively higher in soils collected from sub-surface (15-30 cm) while higher content of Zn was recorded from surface soil (0-15 cm).

Table 54: Soil characteristics of gum yielding tree based agroforestry models

Gum fields	pH (1:2.5)		EC (µ S/cm)		Organic carbon (%)		Available N (kg/ha)		Available K (kg/ha)	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
A. nilotica (field no. 20)	7.70	7.66	327	359	1.01	0.87	225.79	225.79	386.61	360.40
A. senegal (old gum garden)	5.89	5.77	224	188	0.78	0.46	275.97	238.34	203.13	196.58
A. senegal (new gum garden)	5.92	5.20	138	132	0.55	0.43	250.88	225.79	235.90	209.68
A. nilotica/A. senegal (field 40)	7.58	7.73	383	337	0.75	0.62	238.34	250.88	255.55	229.34
A. nilotica/A. senegal (field 41)	6.94	7.37	297	303	0.61	0.61	263.42	225.79	288.32	242.45
A. pendula (plus tree trial)	6.35	6.01	316	213	0.61	0.53	313.60	213.25	262.11	255.55
A. pendula (progeny trial)	5.88	5.72	192	139	0.87	0.85	263.42	150.53	281.76	242.45
A. pendula (field no. 33)	6.53	6.02	158	135	0.56	0.29	301.06	137.98	255.55	196.58
A. latifolia (field no. 34)	6.45	6.72	206	139	0.76	0.73	213.25	150.53	281.76	307.97
A. senegal based agri-horti model (field no. 25)	7.04	6.45	364	144	0.56	0.55	351.23	238.34	249.00	242.45

Gum fields	Available P (kg/ha)		Zinc (ppm)		Iron (ppm)		Manganese (ppm)		Copper (ppm)	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
A. nilotica (field no. 20)	23.08	16.54	2.26	1.65	12.13	20.01	20.70	20.81	2.41	2.11
A. senegal (old gum garden)	2.55	1.87	0.62	0.12	37.16	30.58	21.68	18.87	1.53	1.22
A. senegal (new gum garden)	3.84	3.81	0.38	0.31	16.38	29.45	18.65	18.74	0.94	0.83
A. nilotica/A. senegal (field 40)	2.33	1.65	ND	ND	5.98	5.64	19.40	18.51	1.21	1.13
A. nilotica/A. senegal (field 41)	2.58	2.33	0.27	0.16	21.05	33.18	19.89	18.09	1.28	1.19
A. pendula (plus tree trial)	4.18	3.23	0.94	0.75	11.87	21.31	20.55	19.31	0.89	0.94
A. pendula (progeny trial)	8.57	6.91	1.00	1.04	21.05	46.25	20.72	20.49	1.06	1.19
A. pendula (field no. 33)	17.29	12.61	0.68	0.13	10.05	18.37	21.03	21.36	1.08	1.26
A. latifolia (field no. 34)	19.76	17.56	0.89	0.83	16.72	19.49	21.47	21.05	1.49	1.43
A. senegal based agri-horti model (field no. 25)	22.94	19.51	0.64	1.03	5.21	19.94	19.46	20.46	1.40	1.49

Table 55: Soil characteristics of gum yielding tree based agroforestry models

Factors	pH (1:2.5 H_20)	Electrical conductivity (µ S/cm)	Organic carbon (%)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
Species	0.836	<0.001	<0.001	0.015	<0.001	0.061
Distance	<0.001	<0.001	<0.001	0.265	0.669	0.044
Depth	0.519	0.272	0.497	0.520	0.502	0.028
Species × distance	<0.001	0.026	0.007	0.987	0.942	0.547
Species × depth	0.985	0.764	0.321	0.974	0.879	0.279
Distance × depth	0.553	0.994	0.852	0.959	0.662	0.906
Species × distance × depth	0.987	0.595	0.869	0.897	0.932	0.596

Table 56: Effect of tree species, distance from tree trunk and depth on soil properties

Particulars	pH (1:2.5 H_20)	Electrical conductivity (µ S/cm)	Organic carbon (%)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
Plant species						
C. limon	7.70	196.23	0.58	262.59	24.09	260.36
A. senegal	7.67	182.53	0.50	269.28	17.26	244.41
A. marmelos	7.69	179.43	0.71	305.66	18.53	249.22
C. carandas	7.66	126.83	0.92	292.28	18.12	238.74
$LSD_{0.05}$	NS	33.27	0.10	29.67	2.89	NS
Distance (m)						
0.5 m	8.00	221.67	0.94	297.40	18.79	264.02
1.0 m	7.74	160.50	0.71	293.74	18.48	250.09
2.0 m	7.65	155.92	0.61	263.42	19.92	247.91
4.0 m	7.49	174.12	0.58	279.98	19.73	240.88
6.0 m	7.51	132.35	0.55	277.61	20.62	237.89
$LSD_{0.05}$	0.12	37.19	0.11	NS	NS	18.13
Depth (cm)						
0-15 cm	7.69	176.80	0.69	286.00	19.88	254.46
15-30 cm	7.66	165.72	0.66	278.90	19.12	241.90
$LSD_{0.05}$	NS	NS	NS	NS	NS	11.47

Table 57: Summary of three-way ANOVA (*p* values), assessing the effect of plant species, distance and depth as main and interactive effects on micro-nutrients

Factors	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
Species	0.001	<0.001	<0.001	0.004
Distance	0.001	0.004	0.540	0.008
Depth	0.823	0.733	0.168	0.657
Species × distance	0.019	0.227	0.201	0.178
Species × depth	0.658	0.581	0.910	0.673
Distance × depth	0.035	0.847	0.889	0.457
Species × distance × depth	0.215	0.985	0.867	0.630

Table 58: Effect of tree species, distance from tree trunk and depth on micro-nutrients

Particulars	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
Plant species				
C. limon	1.294	9.506	17.971	0.797
A. senegal	1.337	13.169	15.256	0.647
A. marmelos	1.509	9.709	14.224	0.792
C. carandas	1.319	5.906	13.819	0.995
$LSD_{0.05}$	0.102	2.290	1.229	0.185
Distance (m)				
0.5 m	1.280	6.796	15.259	1.063
1.0 m	1.274	9.155	14.877	0.782
2.0 m	1.422	9.691	14.946	0.710
4.0 m	1.488	11.789	15.820	0.747
6.0 m	1.354	10.370	15.679	0.737
$LSD_{0.05}$	0.114	2.560	NS	0.207
Depth (cm)				
0-15 cm	1.356	9.393	15.012	0.828
15-30 cm	1.373	9.752	15.623	0.788
$LSD_{0.05}$	NS	NS	NS	NS

B. Demonstration and development of gum yielding tree based agroforestry models on farmers' fields

To motivate farmers and disseminate technology related to development of gum yielding tree based agroforestry models on farmers fields, regular field visits were conducted in villages to prepare socioeconomic profile of villagers and assess their preferences for species, type & pattern of planting etc. All these data will be used to draw inferences and identify drivers for scaling up adoption of agroforestry among farmers, especially small holders in Bundelkhand region of Central India. For development and demonstration of agroforestry models on farmers fields a total of 2200 seedlings of *A. senegal*, 150 *C. limon*, 100 *P. guajava* and 22 *Punica granatum* were distributed and planted on the fields of 14 farmers of village Parasai during rainy season of 2017 (Table 59). Most of the farmers have planted *A. senegal* on field bunds and horticulture component as row plantation in the fields. After six months of planting, the survival of *A. senegal* ranged from 80-93% and horticulture species 60-88%.

Table 59: Distribution of gum-yielding and horticultural plants to farmers of village Parasai (2017)

Farmer's name	Plant species							
	A. senegal (kumat)		*C. limon* (lemon)		*P. guajava* (guava)		*P. granatum* (pomegranate)	
	No. of plants	Survival (%)	No. of plants	Survival (%)	No. of plants	Survival (%)	No. of plants	Survival (%)
Arjun Yadav	400	82.3	-	-	-	-	-	-
Sukhnandan	350	85.1	5	80.0	5	60.0	-	-
Rajveer Yadav	300	91.0	-	-	-	-	-	-
Bisunnath	250	88.0	50	86.0	-	-	-	-
Mahendra	150	92.0	-	-	-	-	-	-

Komal Singh	250	86.0	50	88.0	55	83.6	22	63.6
Bantoo	100	93.0	-	-	-	-	-	-
Prema	100	86.0	-	-	5	80.0	-	-
Jahar Singh	50	92.0	-	-	-	-	-	-
Ashok	150	91.3	5	60.0	-	-	-	-
Vinod	100	93.0	-	-	-	-	-	-
Sushil	-	-	5	60.0	-	-	-	-
Mathura Prasad	-	-	15	73.3	15	73.3	-	-
Narendra Yadav	-	-	20	65.0	20	70.0	-	-

C. ITK on gum and resin's tapping, applications and post harvest value addition

To collect information on ITK of tapping gums and resin, post harvest value addition and their uses, survey of tribal villages was conducted in three districts, namely Shivpuri, Sheopur and Datia of Madhya Pradesh (Plate-I). For conducting survey, close liaisoning was maintained with the officers of State Forest Department and the villages dominantly inhabited by Saharia tribes were selected with the help of local forest staff. During survey, the forest staff being well acquainted with the local languages, helped in communicating and filtering information from the Saharia tribes. All information was collected as per an interview schedule prepared for the purpose. The information given by individuals was refined by having group discussion in each village involving 5-10 elderly villagers. The details of villages surveyed for ITK are given in Table 60. The main occupation of Saharia tribes in Datia district was agricultural wages, as most of the families were land less labourers. In Shivpuri and Sheopur, the tribal families were also involved in cultivating rainfed agricultural crops on the land allotted to them on *patta* basis. In Sheopur district, collection of NTFPs was a major livelihood option for the tribal peoples. In all the districts, seasonal migration for earning livelihood was a common practice (Table 61). Major NTFPs collected by Saharia are listed in Table 62.

Table 60: Tribal villages surveyed for ITK on gum tapping and uses

District	Forest range	Beat	Village	Total no. of tribal families	No. of respondents	GPS coordinate	
Shivpuri	Pohari	Madkheda	Madkheda	300	40	25°34'33" NL	77°17'29"EL
		Pohari	Kakra	65	8	25°32'34" NL	77°18'20" EL
		Pohari	Dehde	450	45	25°30'57" NL	77°15'58" EL
		Lokhari	Kolhapur	75	13	25°25'36"NL	77°40'52" EL
		Sarvani	Chak	40	8	25°31'36" NL	77°23'46" EL
Sheopur	Karhal	Khori	Khori	100	15	25°29'47"NL	77°03'25" EL
		Meharbani South	Meharbani	80	19	25°29'45" NL	77°03'23" EL
		Shema	Baankuri	100	10	25°29'10" NL	77°03'22" EL
	Sheopur	Kakardha	Kakardha	300	32	25°37'32" NL	77°42'43" EL
		Kalmi	Kalmi	157	18	25°37'32" NL	76°42'43" EL
Datia	Datia	-	Neevari	150	18	-	-
		-	Govindpuri	75	9	-	-
		-	Aadivasi dera (Sevnda chungi)	35	5	-	-

Table 61: Occupations of tribal peoples in surveyed districts

Districts	Main occupation	Secondary occupation
Shivpuri	Marginal farmers and land-less agricultural labourers	Collection of NTFPs, seasonal migration to Agra, Morena and Etawah, basket making
Sheopur	Collection of NTFPs and marginal farming	Seasonal migration to Agra, Morena and Etawah for agricultural wages
Datia	Land-less agricultural labourers	Livestock, seasonal migration in search of agricultural wages, seasonal migration to Agra for potato and wheat harvesting, collection of NTFPs from forest

Table 62: List of gum and other non timber forest produces (NTFPs) in surveyed districts

Districts	Trees tapped for gum	Other NTFPs
Shivpuri	*Boswellia serrata* (salai/cheed gum) *Anogeissus latifolia* (dhawra gum) *Anogeissus pendula* (kardhai gum) *Acacia catechu* (khair gum)	*Asparagus racemosus* (sataavar), *Phyllanthus emblica* (bhuiamla), *Tridex procumbens* (kala ghamra), *Nyctanthes arbotristis* (harsingar) for basket making, *Aegle marmelos* (bael pulp), *Cassia fistula* pod, *Diospyros melanoxylon* leaves for beedi making), *Canscora decussate* (shankha holi), darkani, gunisar, honey
Sheopur	*Boswellia serrata* (salai/cheed gum) *Anogeissus latifolia* (dhawra gum) *Acacia catechu* (khair gum)	*Cassia tora* (punwar), *Ocimum gratissimum* (van tulsi), *Tinospora cordifolia* (giloy), billaiyan, *A. marmelos* (bael fruit's pulp), *A. racemosus, Madhuca indica, Zizyphus mauritiana* (ber root), *Vitex negundo* (nirgundi), ganger
Datia	*Butea monosperma* (kamarkas) *Acacia nilotica* (babool gum)	*A. racemosus* and afoye

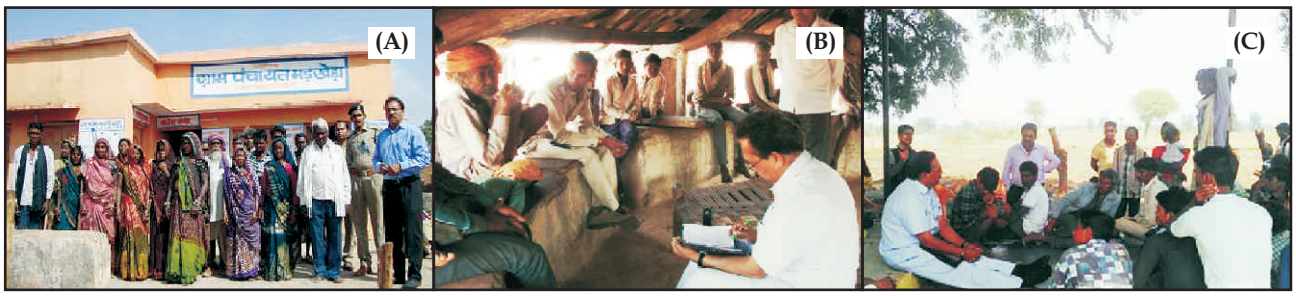


Plate-I: Interaction with Saharia tribes during survey for collecting ITK information on gums and resins in district Shivpuri (A), Sheopur (B) and Datia (C)

Indigenous tapping techniques for gums

In Shivpuri and Sheopur districts, tribals generally peel off the bark (2-3 inches) of *Boswellia serrata* and make a ring along the tree girth and collect gum after 4-5 days. For peeling off the stem bark, they use a special tool called *"Saluli"* (PLate-II A) and for collection of the salai gum they use a special tool called *"Gaantri"* (Plate-II B). On an average, they collect 200-400 g salai gum from a single tree. Normally, they start peeling off tree bark at men's height and slowly move upwards as the season of gum exudation progresses from September to April. They peeled off tree bark 20-25 times in a season. The tribals do not give any cut or injury to *Anogeissus latifolia* for inducing gummosis. They collect gum tears naturally exuded from the trees. Normally, dhawra gum is collected during summer season. Similarly, natural exudes of *Acacia catechu* gum is collected from the trees during summer season. For tapping gum-butea, the tribals make cuts or incisions on the stem bark of *Butea monosperma* with the help of "Bill hook" and collect gum after 3-4 days of knotching. The method of tapping gum from *B. monosperma* is same in all surveyed areas of Shivpuri, Sheopur and Datia.

Plate-II: Tools used by Saharia tribes for tapping (A. Saluli) and collecting (B. Gaantri) salai/cheed gum

Constraints faced by tribals of surveyed areas

Traditionally, in district Datia, the surveyed tribal villages tap only gum-butea since long time. However, now these people face crisis of employment, as the plants of *B. monosperma* are disappearing and they have to move long distances for collection of gum from their native villages. Most of them are land less labourers, hence compelled to migrate in nearby areas of Jhansi, Agra, Etawah, Morena and Dhaulpur for earning wages particularly in harvesting season of wheat and potato.

The tribal villages surveyed in Shivpuri and Sheopur districts enjoy full rights on forest for tapping gums and collection of other Non Timber Forest Produces (NTFPs). Traditionally, the tribal families exercise their rights of ownership on trees of *B. serrata* and passed on to their next generation in inheritance. This division of forest trees among the tribal families is mutually agreed with the consensus of all villagers. Every year the tribal families tap the trees which are owned by them and do not encroach on the trees possessed by other families. For collection of other NTFPs such as dhawra gum, khair gum, kardhai gum, bael fruit, amaltas pods, medicinal herbs etc, there is no such ownership of forests area and trees. The drought was the main constraints faced by the villagers of Shivpuri. Due to consequence of poor rainfall in last two years, the villagers face crisis of drinking water and have to travel distance of 0.5 to 1.0 km to fetch drinking water. The severe drought condition have affected the exudation of gums in trees and hence decreased gum yield. The villagers informed that during good monsoon years, the quantum of gum collected is more and thus they get more income. The moisture stress also affected the collection of other NTFPs (medicinal herbs etc), as there is no growth and regeneration of ground vegetation. The health of grazing animals was very poor, as there was no grass on grounds for their grazing. In Sheopur district, the condition of moisture stress was alike Shivpuri, except the availability of drinking water. The villagers in Sheopur district were also involved in rainfed farming and cultivated *kharif* crops *viz*., til, bajra, urd, soybean etc.

In search of the livelihood, more than 75% of the families in surveyed villages of Shivpuri and Sheopur migrated to Gujarat, Delhi, Rajasthan, Uttar Pradesh, Punjab etc. The migration of families is more dominant in harvesting season of *rabi* crops (January to April).

Value addition of gums and other NTFPs

Normally tribals of surveyed areas sell collected

produce to local traders in original form *i.e.* without any post harvest value addition process. The main reason for selling produce as harvested/collected from the forest is lack of skills and knowledge and compulsion to meet their both ends meat. However, some tribal women were seen to doing processing of *Asparagus racemosus* (satawar) herbs before selling to local traders (Plate-III A). The main value addition to satawar is peeling of its bark which yields white finished produce readily accepted by the traders. In case of *Aegle marmelos* (bael), they boil the fruits of bael in water and separate pulp from its hard shell. The pulp fetches more value than the whole fruit. For storage of salai gum, traders make small balls from the *salai ras* (Plate-III B) with the help of *selkhadi* (chalk powder). As far as value addition to gum dhawra is concerned, they perform cleaning, grading and packaging for proper storage ((Plate-III & IV). For segregating and grading of tree gums, the local traders employ specific trained women labourers, who have been doing this job for years.

Plate-III : Value addition processes adopted by Saharia tribes for gum, resins and NTFPs (A. Bark peeling of satawar roots, B. Making balls of *salai gum*, and C. Grading of gum dhawra).

Plate-IV: Value additions through grading of gum dhawra (Grade IV- Mixed gum (as collected from forest), Grade III-Segregated gum dhawra (after physical impurities), Grade II- Pure gum tears of dhawra, and Grade I- Gum crystal (*jalebi*))

Marketing of gums and other NTFPs

The villagers surveyed in Datia district sell (@ Rs. 60-80/kg) their produce (mainly gum-butea) to traders in Datia city. The villagers of Pohari range in Shivpuri transport their produce to Shivpuri city for selling to traders. Sometimes, they sell their produce to local vendors in village itself at low prices. The villagers in Sheopur district have advantage of nearby trading centre in Karhal and Sheopur for selling their produce, hence they get good price (Table 63). In some villages, collection centre of NTFPs are also operated by the traders, wherein tribals sell their produce. In general, the price of produce is decided by the traders, not by the collectors (tribals) of produce. The tribals are bound to sell their produce at the prices fix by traders and hence generally get exploited.

Table 63: List of NTFPs and their prices in surveyed areas of Datia, Shivpuri and Sheopur

District	Forest produce	Price (₹/kg)
Datia	Gum-butea	60 to 80
Shivpuri	Salai gum	100 to 150
	Dhawra gum	60 to 80
	Khair gum	50 to 60

	Kardhai gum	100
	Basket (small size)	5 to 7/- piece
	Basket (big size)	25 to 30/- piece
Sheopur	Salai gum	180 to 250
	Dhawra gum	50 to 80
	Khair gum	150 to 160
	Kardhai gum	100 to 160
	Katira gum (kullu)	160 to 170
	Bael fruit's pulp	25 to 30
	Bael fruit shell	3 to 5
	Amaltas pods	5
	Amaltas pulp	25 to 30
	Amaltas pod shell	3 to 5
	Satawar roots	100 to 170
	Darkani	7 to 10
	Kala ghamra	7 to 8
	Tendu patta	95 per 100 bundles of 60 leaves each
	Sankha holi (shankhpushpi)	10 to 12
	Ganger	10 to 15
	Ber root	5 to 7
	Van tulsi	50 to 60
	Punwar seed	10
	Billaiyan	100
	Giloy	5 to 10
	Mahua fruit	20
	Honey	40 to 50

D. Standardization of gum tapping techniques

D1. Effect of density of incisions/cuts on yield of *gum-butea*

During month of January, 2017 and 2018, trials were conducted on naturally occurring *B. monosperma* trees, for assessing the effect of density (*i.e.* number) of incisions/cuts on yield of *gum-butea*. The depth and length of the cuts were restricted to 1.0 cm. Before making cuts on stem, dead bark of the stem was removed. During 2017, trial consisted of four treatments *viz.*, T_1 (15 cuts/feet^2), T_2 (25 cuts/feet^2), T_3 (35 cuts/feet^2) and T_4 (45 cuts/feet^2) while during 2018, one more treatment *i.e.* T_5 (60 cuts/feet^2) was included in the study. Trial was replicated on nine different trees. The exuded gum was collected and yield was evaluated. During 2017, maximum *gum-butea* was collected from the treatment where 45 cuts/ feet^2 were made (Fig. 54) and during 2018, it was recorded maximum in T_5 (60 cuts/feet^2). Thus, results suggested that yield of *gum-butea* increased with the increase in the number of cuts/feet^2.

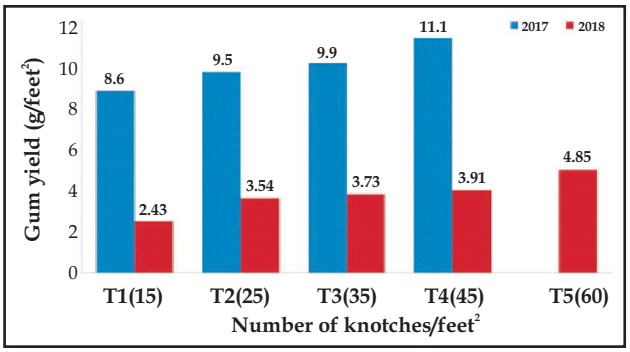


Fig. 54: Effect of number of knotches *i.e.* density of cuts/ feet^2 on gum yield (g/feet^2) in *Butea monosperma* during 2017 and 2018

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D2. Effect of ethephon on gum yield from *Anogeissus pendula*

To determine the effect of application of ethephon (gum inducer) on gum yield, a trial was conducted in a well established 26 years old plantation of *A. pendula* at research farm of CAFRI. The study consisted of seven accessions of tissue culture raised progenies of *A. pendula* (AP-20, J-62, J-124, J-185, J-205, J-241 and NRC-5) and four different concentrations of ethephon (10, 20, 30 and 40%). Thus, a total of 28 treatment combination was employed in the study and each treatment was replicated three times. Based on the past research carried out at CAFRI, Jhansi, present study was undertaken during month of October in 2017. 4 ml dose of different concentrations of ethephon was injected in trees of all the progenies. Out of seven progenies, four progenies (J-124, J-185, J-205 and AP-20) responded towards ethephon applications. Result showed that maximum amount of gum yield was recorded in J-205 accession, which was significantly higher than other accessions (Table 64). On the other hand, among different concentrations, maximum gum yield was recorded in 30% concentration, which was at par with 40 and 20% concentrations. The gum yield

in J-205 and J-124 accessions increased with the increases in ethephon concentrations. While in J-185 and AP-20, maximum gum yield was recorded at 20% concentration, which reduced with the increase in the concentration of

Table 64: Effect of ethephon application on gum yield from different accessions of *Anogeissus pendula* (2017)

Accessions	Concentrations of ethephon				Mean
	10%	20%	30%	40%	
J-185	19.95	39.42	21.01	15.11	22.62
J-205	9.52	14.59	45.60	52.70	30.60
AP-20	17.14	24.09	18.11	11.13	17.62
J-124	12.96	17.52	26.82	31.13	22.11
Mean	13.64	23.91	27.89	27.52	
	Accessions	Concentration	Interaction		
$LSD_{0.05}$	3.49	3.49	6.99		

NRMACAFRISOL201601100110

Development of Nursery of TBOs for Quality Planting Material Production

(K B Sridhar)

Standardized vegetative propagation protocol for *Azadiractha indica*, *Simarouba glauca*, *Madhuca longifolia* and *Pongamia pinnata*.

Pongamia pinnata

Clonal propagation was carried out using top cuts and semi hardwood cuttings. Cleft grafting was carried out to improve seed propagated plant. Clonal hedge garden was established from stumps, tops and hardwood cuttings.

Madhuca longifolia

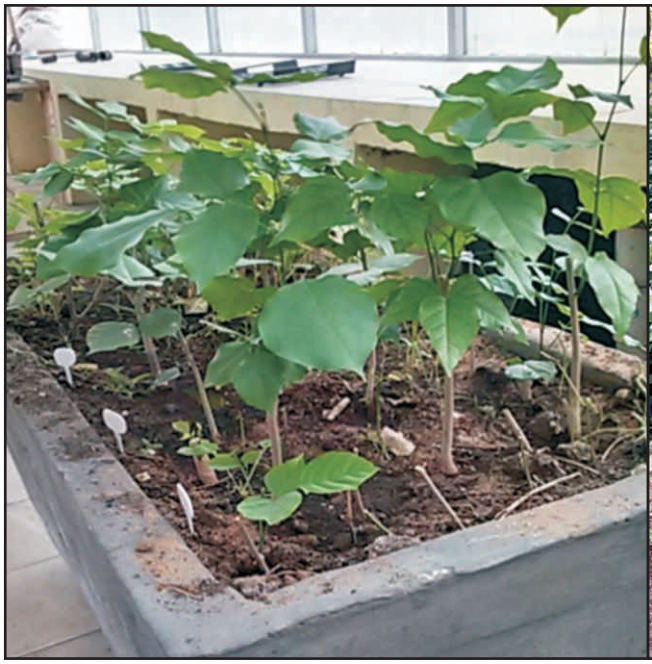
Planting material of *Madhuca longifolia* was produced through seeds and grafting.

Olea europea

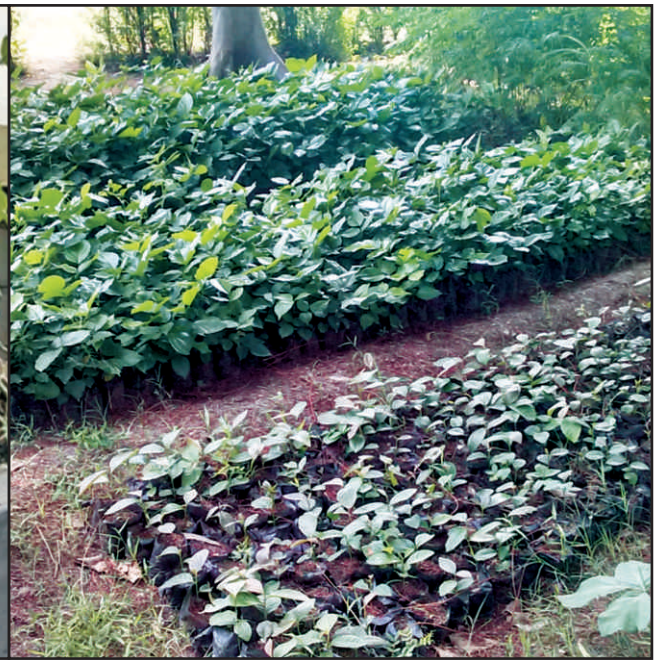
150 seedlings of olive was procured from Center of Excellence, Olive, ROCL, Bassi, Jaipur,

Azadirachta indica* and *Simaruba glauca

Semi hardwood, hardwood and top cuttings were used as planting material for propagation.



Production of *Pongamia pinnata* through seeds



Clonal hedge garden of *Pongamia pinnata*

Farmer with *Simaruba glauca* seedling

TBOs

Azadirachta indica

Melletia pinnata

Top cuts

Simaruba glauca

Stem cutting

Clonal propagation in Tree Borne Oil seeds

Plate : Procurement of Olive plants for regeneration at Centralized nursery of ICAR- CAFRI

ICRISAT, Hyderabad

Enhancing groundwater recharge and water use efficiency in SAT region through watershed interventions-Parasai-Sindh Watershed, Jhansi

(Ramesh Singh, R K Tewari, Inder Dev, R H Rizvi, R P Dwivedi, K B Sridhar, Dhiraj Kumar and Mahendra Singh)

Parasai-Sindh watershed has been developed in consortia mode with ICAR-Central Agroforestry Research Institute (CAFRI), Jhansi and International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Hyderabad. The watershed comprises three villages namely Parasai, Chhatpur and Bachhauni and located between 25^0 23' 56" to 25^0 27' 9.34" N and 78^0 19' 45.71" to 78^0 22' 42.57" E in Babina block of Jhansi district.

Runoff and groundwater recharge, agroforestry interventions, productivity enhancement and capacity building are discussed hereunder:

Runoff and groundwater recharge

To improve the situation of water resources, three *nallah* plugs (small checkdam), nine checkdams, one haveli (traditional rainwater harvesting structure), one community pond and one farm pond were constructed by 2015. Runoff and soil loss were gauged at 11 locations including field scale monitoring. Total rainfall during the year was 582.2 mm, 33.6% less than the normal (877 mm), spread over in 28 rainy days. Only one hydrograph recorded on September 22, 2017 against rainfall of 157.2 mm at checkdam no. 10 with catchment size of about 950 ha is depicted in Fig. 55. The peak discharge of 0.15 cum/sec was recorded, which is 23.2 times lower than untreated watershed. The peak discharge in treated watershed was delayed by 2 hrs 20 minutes as compared to untreated watershed. Total runoff from the treated watershed was 13707 cum, which is 0.92% of event rainfall.

All the open shallow dug wells (388 Nos.), which are only means of irrigation in the watershed were monitored for water table on monthly interval. The average water column during the year varied from 2.27 m in June to 6.08 m in September with 4.78 m in October. Average groundwater recharge during rainy season was 21% higher in treated watershed as compared to untreated watershed.

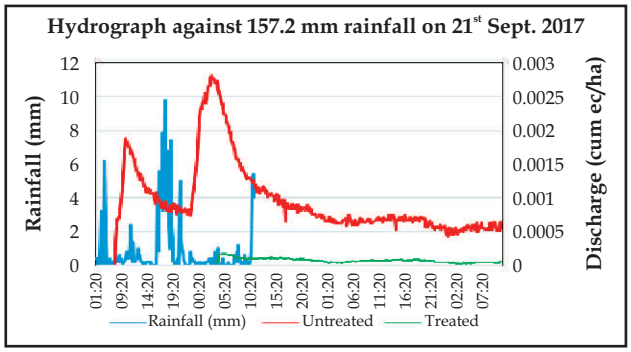


Fig. 55: Hydrograph recorded at outlet in treated and untreated watershed

Assessment of soil quality

Assessment of soil quality was carried out for Parasai-Sindh watershed in Bundelkhand region of Central India using remote sensing and geo-statistical methods of GIS. Total 56 soil samples

were collected and were analyzed for soil acidity (pH), electrical conductivity (EC), organic carbon (OC), phosphorus (P) and potassium (K) and subsequently used for soil quality assessment. Soil samples were geographically referenced and soil maps were generated using Geo-statistical interpolation method in Arc GIS 10. The geostatistical tools like Universal Kriging and Inverse Distance Weighing (IDW) were used for interpolation of values. IDW proved superior over universal kriging as it has got less RMSE for soil parameters. Further, results showed that more than 50% watershed area has soil quality in the category of good or very good, indicating that soil is suitable for both *kharif* and *rabi* crops.

Development of agroforestry interventions and top working of *desi* ber

To bring more area under permanent vegetal cover, 750 and 355 seedlings of teak and bamboo, respectively, were planted by 19 farmers at the field boundaries. Besides, 2200 seedlings of *Acacia senegal* (kumat) from Gum & Resin project were also planted as live fence on farmers' farm boundary. Survival of teak was 70% by the end of December, 2017, however survival of other species was very poor due to deficit rainfall.

Productivity enhancement (as per farmer practice)

The major crops grown by the farmers of Parasai-Sindh watershed during 2017 were groundnut, greengram and blackgram (*kharif*) and wheat, chickpea and mustard (*rabi*). In order to substantiate the crop productivity enhancement samples were taken from upper, middle and lower reaches of each village. 72 samples {3(lower, middle and upper reaches) x 3 (villages) x 8 (replications)} were taken for groundnut and wheat. 27 {3(lower, middle and upper reaches) x 3 (villages) x 3 (replications)} were taken for assessment of each crop of greengram, blackgram, chickpea and mustard. Each unit of sample was harvested from an area of 3 x 3m. The productivity levels recorded in treated watershed are presented in Table 65. Average crop productivity during rabi 2016-17 in treated and untreated is depicted in Fig. 55. The productivity of wheat, mustard and chickpea was 22.3, 21 and 21.6%, respectively, higher in treated watershed as compared to untreated watershed.

Table 65: Productivity of different crops in Parasai-Sindh (treated) watershed

Rabi, 2016-17		*Kharif*, 2017	
Crop	**Productivity (kg/ha)**	**Crop**	**Productivity (kg/ha)**
Wheat	2620	Groundnut	789
Chickpea	985	Blackgram	121
Mustard	1192	Greengram	102

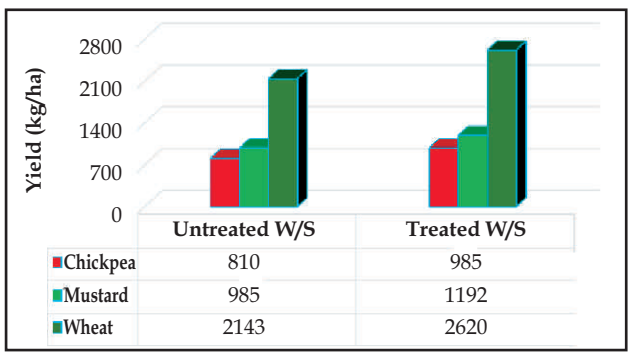


Fig. 55: Av. crop productivity during *rabi*, 2016-17 in treated and untreated watersheds

Capacity building of watershed dwellers

Forty five farmers from the watershed had participated in foundation day celebration of the Institute on May 08, 2017. Visit of experimental farm was organized to impart various agroforestry techniques. Community was sensitized towards *Swachh Bharat Abhiyan* and plantation of tress on bunds under MGMG programme.

CHAPTER

3 AICRP ON AGROFORESTRY

A. Research Achievements

Research Achievements

The Srinagar centre developing apple and apricot based hortipasture system with suitable grass species to overcome the high demand of fodder during lean periods. The studies showed about 20-24 t/ha of green fodder during third year. During the year about 2000 seedling of different multipurpose trees were distributed to the farmers. Under survey, collection, multiplication and evaluation of best clones of cricket bat willow, centre extensively surveyed Srinagar and Ganderbal districts and identified ten trees for multiplication and evaluation in the nursery. Centre organized one boundary plantation awareness day under TSP programme. Ten ploy houses, about 3000 seedlings of important agroforestry tree species including fruit trees and 30 kg seed of different fodder grasses were distributed among the farmers for fodder production and for development of different agroforestry systems. New agroforestry experiments and arboretum are in the process of establishment at Benhama, Ganderbal new campus and college building, where they moved two years back.

During last year Solan centre collected the germplasm of the important multipurpose tree species for the region *viz; Grewia optiva*, *Morus alba*, *Morus laviegata*, *Bauhinia variegata*, *Melia composita*, *Terminalia chhebula*, *Sapindus mukorossii, Albizia chinensis, Terminalia bellerica* and *Leucaena leucocephala* from the H.P., J & K and Uttarakhand for their further evaluation in the nursery. Agroforestry systems of two districts (Bilaspur and Hamirpur) of Himachal Pradesh were studied for their productivity and carbon storage. Among different zones, zone III (800-1000 m ASL) recorded higher carbon storage as compared to zone I and II of sub-tropical region of Himachal Pradesh. Similarly, in different farmer categories, higher carbon stock was recorded in medium category farmers. On the basis of economic returns agri-horti-silviculture system (₹ 2,03,046) was found to be best and can be recommended for subtropical region of Himachal Pradesh.

At Palampur centre, continuous evaluation of eight Toona ciliata seed sources revealed that HP 5(b) 48, HP 5(b) 71 and HP1 (c) 22 best perform under field conditions. Out of the earlier eight collections of Sapindus mukorossi, three seed sources S3, S5 and S1 are performing best under field conditions. Centre developed *Leucaena* based silvi-pastoral agroforestry system for its varietal evaluation as a potential tree fodder. Centre initiated work on common experiment for the region finalized last year on development of *Terminalia* based silvi-pastoral agroforestry systems to increase the productivity potential of the grasslands under mid hills of Himachal Himalayas. Grass component has been fully established and trees are in establishment phase. Two one day agroforestry trainings were organized under TSP for 100 farmers including 35 women, in Distt. Lahaul & Spiti and Kinnaur. Trainings covered various aspects of agroforestry with main emphasis on silvi-pasture system for the reclamation of waste lands and also for improving the productivity of the natural grasslands.

The Diagnostic & Design exercise in different blocks (10) of Jammu district has been completed by Jammu centre and compilation of data is in progress. The centre also conducted one awareness training on Boundary Plantation of Trees. Study was undertaken to assess the growth and yield of four intercrops *viz.*, ginger, turmeric, kalmegh and stevia with 30 years old mango orchard spaced 9 x 9 m. From initial two years of experimentation, it was observed that three intercrops *viz.* ginger, turmeric and kalmegh recorded fair survival percentage of 90-91%, whereas stevia had 12% survival. In open (without mango), ginger had a lowest survival of 13% as compared to other three crops (80-90%). The yield of turmeric, stevia and kalmegh was recorded higher in open compared to that under

the canopy of mango whereas, ginger yielded maximum under mango with very poor performance in open.

The timber volume of 14 years old *Gmelina arborea* of seed sources AAU18 (Silchar) and AAU15 (Byrnihat) was observed as 0.897 and 0.812 $m^{3/}$tree at HRS, Kahikuchi. Under *Acacia mangium* based agroforestry system, maximum tree height (12.60 m) and timber volume (215.18 m^3/ha) was observed in 5 x 4 m spacing, whereas, maximum dbh (26.93 cm) was observed in 5 x 5 m spacing in 11 year old plantation. Fodder crops *viz.,* hybrid napier and setaria grass yielded 32 and 26 t/ha, respectively. Mrs. Henna Marrak, Village Hakumari Boko district Kamrup successfully adopted the Khasi mandarin based system in 10 ha hilly area. Pineapple, areca nut and banana were planted as intercrops in the orange plantation.

During last year two recommendations of Ludhiana centre were approved for farmers by the Research Evaluation Committee of PAU. Wheat varieties PBW 725, PBW 677 and WH 1105 should be preferred for sowing in poplar plantations. In addition to high yielding, these varieties were tolerant to yellow rust. These varieties should be sown in first fortnight of November for getting higher productivity. During the year, centre produced 1.30 lakh plants of different tree species mainly Poplar, Eucalyptus, Shisham and Burma dek (*Melia composita*) for distribution to the farmers. Centre is working for improvement of Poplar, Eucalyptus, Shisham and *Melia composita*. In Poplar zonal trial, significant differences among the poplar clones were observed for growth parameters (clones from Pantnagar, Ludhiana and HAU) after 3 years of planting. Superior genotypes of shisham and eucalyptus were cloned. The initial screening of eucalyptus clones showed that C-413 performed well in water-logged soils. Twenty four progenies of *Melia composita* are in their 7^{th} year of growth at two locations and these have significant variation in growth parameters.

In an intercropping trial, significantly higher herb yield of lemon grass was observed under poplar spacing of 8 x 2.5 m and 7 x 3 m paired at 2.5 m than 5 x 3 m in 5 year old poplars. The yield of Punjab haldi-2 (12.0 t/ha) was significantly higher than Punjab Haldi-1 when averaged over all the spacing. Sixteen wheat varieties being developed by the Department of Plant Breeding and short listed for pre adaptive trials have also been planted in poplar plantation at three locations in current *rabi* season. In addition to it, six potato varieties have been planted under poplar plantation to find out their suitability for planting under poplar. In a trial on sewage sludge, the average dbh and the height after three year of growth was the highest in case of eucalyptus (14.37 cm and 17.63 m, respectively). Among various treatments, the average dbh was the highest (14.49 cm) in case of inorganic application of fertilizers and the height in case of 100% sludge application (15.67 m).

The long term adoption of poplar based agroforestry led to improvement in stable pools of organic carbon in the soil. Growing of poplar plantations for 6 years had 7.28 t/ha recalcitrant pool of organic carbon in 0-45 cm soil layer which increased to 12.92 t/ha after continuously growing of poplar for about 24 years.

Effect of organic fertilizers on growth and yield of paddy (var. Sarjoo-52) and wheat (var. NW-2036) under *Dalbergia sissoo* based agri-silviculture system was studied at Faizabad. Under this system, highest paddy grain yield (2.08 t/ha) was obtained with the application of FYM 10 t/ha which was 20.31% lower as compared to control. The highest wheat grain yield (2.21 t/ha) was also highest with the application of FYM 10 t/ha and was 13.00% lower compared to control. The CO_2 output was found maximum during September, 2016 (43.95 g/m^2/month) while lowest CO_2 output was observed during the month of April, 2016 (15.84 g/m^2/month). Under this system, soil improvement has been noticed up to some extent.

Pantnagar centre produced a total of 1,15,000 nursey plants and other tree produces of different tree species generated an amount of ₹ 10.64 lakhs for development of the agroforestry centre during the year. Poplar hybrids PH-7 and PH-9 showed promising results for height and diameter growth and borer resistance after 3 years testing. Fungus *Talaromyces pinophilus* and

Talaromyces verruculosus were found to cause necrotic spots and wilting in shisham. This fungus is being reported first time for shisham mortality. For the process development for extraction of fruits of chalta (*Dillenia indica*), it can be concluded that amongst the four treatments *viz.,* hot water treatment, steaming, microwave and enzymatic treatment it was found that enzymatic extraction method (using pectinase, cellulase and suitable incubation period) was found best to obtain chalta extract with good physico-chemical characteristics. Therefore, enzymatic method was selected to obtain extract from chalta fruit and ultimately its utilization in the preparation of functional beverage.

Under 12 to 15 year old aonla based agri-horticultural system at Pusa Samastipur, the average yield data of last four years indicated that the production of fruits (15.97-16.13 t/ha) significantly increased due to intercrops. On an average over all increase varied between 28 to 29% as compared to pure orchard (without intercrop). On the other hand, reductions in yield of turmeric were 37.9% (Rajendra Sonali), 28.9% (Rajendra Sonia) and 17.8% (NDH-92) as compared to the yield in open area. Thus, loss in crop yield can be compensated by the increased fruit yield of the orchard. Turmeric yield and light intensity under canopies of aonla orchard showed highly significant and positive relationship (r^2 = 0.819** to 0.940**). By and large, aonla orchard intercropped with NDH-92 is the most profitable system on the basis of Land Equivalent Ratio (2.12), aonla Equivalent Weight (32.74 t/ha) and B: C ratio (4.22). Different morphological growth parameters for one year old 18 poplar clones were recorded in terms of sprouting percentage, height and collar diameter. Sprouting, height and collar diameter varied from 56 – 100%, 2.90 – 4.27 m and 1.95 – 3.03 cm, respectively. Clone number S1 showed the maximum height followed by PH-6, while collar diameter was maximum for clone number PP 9-25 followed by S1.

In fruit based agri-silvi-horticultural system at Bhubaneshwar during second year of experimentation, arhar was the best suitable crop with net returns of ₹ 38,200, ₹ 37,000 and ₹ 29,880/ha/year when intercropped with Mango + Eucalyptus, Jackfruit + Eucalyptus and Cashew + Eucalyptus having B:C ratios of 2.53, 2.48 and 2.19, respectively, as against a net return of ₹ 43,960 with B:C 2.76 when grown as sole crop. Cowpea is the next best intercrop which recorded net return of ₹ 11,360, ₹ 9,720 and ₹ 7,860 /ha/year with B:C ratios 1.45, 1.39 and 1.31 when intercropped with Mango + Eucalyptus, Jackfruit + Eucalyptus and Cashew + Eucalyptus respectively, as against a net return of ₹ 14,820 /ha and B:C ratio 1.59 when grown as sole crop. In Guava with arrowroot system the highest Guava fruit of 2788 kg/ha, fresh arrowroot yield of 6534 kg/ha, net return ₹ 66,330/ha and BCR of 2.23 was recorded with STD (100%) + FYM + biofertiliser followed by STD (100%) + FYM (2692 kg/ha and 6340 kg/ha, net return of ₹ 62,862/ha and BCR 2.17) and STD (75%) + FYM + biofertiliser (2555 kg/ha and 6196 kg/ha, net return of ₹ 59,677/ha and BCR 2.13), respectively. Among the silvipasture systems the maximum green forage yield was obtained from guinea (22.7 t/ha) with *A. mangium* from three cuttings followed by thin napier with *A. mangium* (20.3 t/ha). All the three grasses recorded yield recovery above 84% as compared to sole crops. The highest net return of ₹ 19,050 / ha/year and B:C ratio of 2.77 was obtained from guinea grass in association with *A. mangium* followed by thin napier with *A. mangium* with net return of ₹ 16,350/ha/year and B:C ratio 2.09.

Studies by Jhargram centre showed that in rainfed uplands under Red and Laterite zone of West Bengal fruit based agroforestry systems not only provide security to environment by organic carbon built-up in carbon depleted soils, increasing water infiltration rate, moderating climate change related risks, enriching nutrient status of soil, etc. but also improving and maintaining good health of local people and maximizing the gross monetary returns from those erosion prone areas of West Bengal. Crops like cereals, pulses, oilseeds and vegetables can be successfully grown there in the interspaces of fruit based agroforestry system. Gmelina + Mango + Vegetable in *kharif* followed by Mustard/any crops in *rabi* can profitably be

grown. Among various fruit-based agroforestry systems Mango + Gmelina + Legume crops are the best to improve soil health. From Economic analysis among various fruit-based (Mango + Gmelina) agroforestry systems Mango + Gmelina + pigeon pea can yield maximum equivalent productivity.

In provenance trial of *Gmelina arborea* at Ranchi, collected from eight different states, the maximum average height of *Gmelina arborea* in three years old plantation was observed in Raipur (Chattisgarh) provenance followed by Madhya Pradesh (Jabalpur) and Jhargram, which was significantly superior over others. Significantly the highest collar diameter was recorded in Raipur (Chattisgarh) followed by Bihar (Samastipur) provenance. Studies on silvipasture system showed that the growth performance of eight years old plantation of Gamhar is better with hybrid napier and also with Sudan grass. The yield of sole crop of forage (hybrid napier and Sudan grass) is better than intercrops combination of Gamhar + hybrid napier and Gamhar + Sudan grass. Centre organised training cum workshop on "Appropriate Agroforestry Models for Jharkhand" for technological backstopping of KVKs of Jharkhand.

Ailanthus excelsa germplasm evaluation studies under rainfed conditions at SK Nagar revealed that Mithivavadi and Soneripura villages seed sources is the best performing in terms of major growth parameters *viz.* plant height (8.70 m) and collar diameter (22.7 cm), respectively after six years of plantation. Collar diameter ranged from 11.70 to 22.7 cm among the thirty source of *Ailanthus excelsa* evaluated. Significant difference among the ten elite progenies of neem along with a local check was observed for growth parameter in the multi-locational co-ordinates trial after twelve years of plantation. Progeny No.110 gave highest plant height (7.45 m) and collar diameter (24.44 cm). Identified thirty progenies of plus trees of Neem under rainfed conditions among these Progeny No.7 gave highest plant height (9.40 m) and progeny No.14 gave highest collar diameter (26.91cm). The Centre produced 10,000 plants of different MPTs and Medicinal tree species in the agroforestry adi nursery for distributing to the farmers. Tribal Sub Plan was implemented in Vagdadi and Gavra villages of Banaskantha district comprising of 53 farmers. Under the programme a Kisan gosthi was organized and major activities implemented were supply of Date palm offshoot (Var. Barahee), improved seeds of various intercrops (castor, moongbean, clusterbean, fennel, oat, barley and mustard), fertilizers, cakes, insecticides and Polythene Sheet (Tadpatri) to selected farmers of Vagdadi and Gavra villages.

Fatehpur Shekhawati centre conducted survey work in different district of Rajasthan for selection of Candidate plus trees (CPT's) of *P. cineraria*. Total 100 CPT's of *P. cineraria* were selected from Sikar (20), Jhujhunu (20) Churu (20) Nagaur (20) and Bikaner (20) district. Data revealed that maximum tree height, crown diameter and clean bole length registered for CPT BI-5, 10.5 m, 12.9 m and 4.6 m, respectively, however maximum dbh registered for CPT SI-1, 0.26 m. In rainfed condition experiment under *P. cineraria* tree, highest yield 802 kg/ha recorded in Clusterbean RGC 1066 variety and lowest yield 310 kg/ha recorded in Pearl millet variety HHB 67 and significant variation were seen between crop and variety when intercropped with tree species in comparison to open field. Aonla based agri-horticulture system at farmers field recorded higher income (₹ 12,040/ha) in comparison to sole cropping system (without Aonla trees). Under TSP 100 new tribal farmers were selected in Ghatol, Bagidora and Anandpuri tehsil of Banswara district and organised two training on Agroforestry and supplied inputs in form of Moong seeds of 8 kg IPM 02-03, Fertilizers 10 kg Urea and 40 kg DAP, Insecticides and Pesticides and Napsec sprayer distributed to each farmer.

Significantly higher grain and straw yield of wheat was observed in agri-horti (Kinnow + Wheat) system as compared to agri-silvi-horti (Kinnow + Eucalypts + Wheat) system at Hisar. An increase of 83.6 and 91.0% in straw and grain yield, respectively of wheat was recorded under Kinnow + Wheat system as compared to Kinnow + Eucalypts based agroforestry system. Recommended dose of fertilizer + additional 10%

dose of N significantly increased the grain yield over recommended dose of fertilizer in both agri-horti (Kinnow + Wheat) and agri-silvi-horti (Kinnow + Eucalypts + Wheat) systems. Among different Eucalyptus clones (C-3, C-7, C-10, C-52, C-83, C-130, C-271, C-1, C-72, C-288, C-316, C-405, C-413, C-526, HC-2045, HC-2049, HC-2070 and control), clone HC-2070 was found promising w.r.t plant height (23.3 m) and dbh (31.1 cm) after 7.0 years of transplantation in the field. Fourteen poplar clones from UH&F, Nauni, Solan have been observed for growth performance in field as multi-location trial. In addition, sixty eight clones of poplar from WIMCO, PAU and GBPUA &T, Pantnagar has been raised in field nursery. In problematic soils (having soil salinity and high water table trouble) of southern Haryana, farmers are getting remunerative benefits by adopting clonal eucalyptus based agroforestry. In this area, farmers are growing eucalypts either in blocks or as boundary plantation and they are fetching 1.5 to 2.0 times more income from eucalyptus based agroforestry in comparison to traditional agriculture.

Under germplasm evaluation study at Nagpur, the height of *A. excelsa* varied from 4.70 m to 7.90 m. Maximum height 7.90 m was attained by ACN/MHK/1 followed by ACN/MHK/9 *i.e.* 7.63 m. The diameter at breast height (DBH) varied from 7.96 cm to 11.71cm. Maximum dbh (11.71 cm) was attained by ACN/MHK/1. Maximum standing tree volume ($0.067M^3$) was estimated for ACN/MHK/1. Maximum carbon sequestration 19.937 t/ha was estimated for ACN/MHK/1. In teak based agroforestry system it was observed that medicinal plant *Andrographis paniculata* performed better under wide spacing 12 x 2 m. The addition of teak leaf litter level @ of 5 t/ha leaf litter + CDS culture @ 50% of Teak Leaf Litter) proved better for improving yield of medicinal plants and residual soil fertility. Centre signed a MoU for providing advisory and planting material for development of National Green Highway Corridor Project.

In the agricultural sector, one of the most water intensive crops is rice. The increasing demand for rice in combination with increasing water scarcity is a threat for food security and of sustainability of rice cultivation. The impact of rice consumption on global water resources can be mapped with the water footprint, a concept introduced by Hoekstra in 2002. This water footprint is defined as the total volume of fresh water that is used to produce the foods. Study was carried out under eighteen year old *Dalbergia sissoo* based agroforestry system at Jabalapur to determine the water footprint of different paddy varieties and to search the best paddy variety which can give more yield with less water. Three paddy varieties *viz.* Danteshwari (90-95 days), MTU 1010 (100-110 days) and Kranti (120-135 days) were selected for the study. Total water footprint of Danteshwari, MTU 1010 and Kranti were 6.214 m^3/kg, 3.427 m^3/kg and 4.455 m^3/kg, respectively. Green, blue and grey water footprint of MTU 1010 was lowest among the three varieties. In view of water resource conservation and yield potential MTU 1010 was found an ideal paddy variety. In farmers field among different cropping system, growing of Arhar with Eucalyptus gave higher net profit (₹ 96,260/ha/yr) as compared to Eucalyptus + paddy + mustard (₹ 74,980/ha/yr) Eucalyptus + paddy + wheat (₹ 74,385/ha/yr), Eucalyptus alone (₹ 42,060/ha/yr), Arhar alone (₹ 60,500/ha/yr), paddy + mustard alone (₹ 5,150/ha/yr) and paddy + wheat alone (₹ 52,335/ha/yr).

Among the germplasm of *Acacia nilotica* var. indica, at Rahuri, entry RHRAN-36 recorded significantly highest plant height (6.11 m) and No. of branches (3.32). The entry RHRAN-57 recorded significantly highest collar diameter (16.40 cm) and DBH (12.28 cm). The entry RHRAN-6 recorded significantly highest bole height (2.54 m). The treatment Tamarind + Custard Apple recorded maximum plant height (143.58 cm) followed by Tamarind sole treatment (128.7cm) in agri-horticulutral system. Centre successfully demonstrated drumstick based agroforestry system in farmers field in Nasik district in which var. Odishi of drumstick was cultivated in 0.20 ha area under drip irrigation with spacing 10 x 5 ft with total net income is ₹ 4, 10,000/ha.

In Neem germplasm, line-117 recorded higher plant height of (7.76 m) with mean girth (62 cm)

cm) at Hyderabad. The Line-115 recorded higher fruit yield and Azadirachtin content (0.53%). This entry needs to be popularized among farmers. In mango based agri-horti system, the Sorghum–safflower–cowpea cropping sequence along with filler crops of curry leaf and moringa in sandy loam soils is successful by adopting integrated nutrient management practices in obtaining higher grain yield and returns from system. Among the treatments, the integrated use of 75% RDN + 25% N through poultry manure to sorghum is superior in obtaining higher grain yield and stover yield (2240 and 4700 kg/ha) mean of two years, followed by 75% RDN + 25% N to safflower (768 kg/ha). The maximum net returns recorded with entire system (₹ 54,500/ha) followed by sole crop without trees (₹ 49,295/ha). In *Melia azadirach* based agri-silvi system the application of 75% RD N + 25% N poultry manure was best nutrient management practice recorded higher grain and straw yield of foxtail millet (1690 and 2766 kg/ha) and net returns (₹ 28,933/ha) as well as organic carbon (0.53%) and available N P, which was on par with sole crop of foxtail millet without tree system in marginal lands.

The Dharwad centre has fourteen germplasm collections of *Tamarindus indica*. Among them, NTI-14 and SMG-13 were superior and were vegetatively propagated for large scale demonstration under farmer fields. The centre also collected 10 clones of *Tamarindus indica* which are suitable for degraded soil conditions. In *Azadirachta indica* there are twenty collections of different provenances and among these 4 provenances (Bijapur, Raichur, Gulbarga and Dharwad) with better growth and suitability for agroforestry in the northern transitional zone are identified and are being used for developing Agroforestry models. In sapota – timber tree species based agroforestry models, the height and DBH was significantly higher in the *Pterocarpus marsupium* (9.25 m and 25.08 cm) and lowest in the *Lagerstroemia lanceolata* (8.25 m and 19.42 cm) as compared to other tree species. Growth of Sapota was significantly higher in association with Sapota + *Lagerstroemia lanceolata* followed by Sapota + *Pterocarpus marsupium* as compared to sapota with other tree species. Fruit yield of sapota was significantly higher when sapota grown alone (12.63 kg/plant) followed by Sapota + *Pterocarpus marsupium* (9.08 kg/plant) and Sapota + *Tectona grandis* (8.85 kg/plant) and lowest in *Terminalia alata* (5.90 kg/plant). Soybean grain and haulm yield was significantly higher with Sapota + field crops (575.**5** kg/ha and 460.2 kg/ha, respectively) followed by field crops with Sapota + *L. lanceolata* (495.6 kg/ha and 392.6 kg/ha). Safflower yield was significantly higher when grown with sapota (220.6 kg/ha) followed by Sapota + *Terminalia alata* (174.4 kg/ha) when compared to other systems. With the technical support of Dharwad centre Shri. Malleshappa Y. Hakkalad, a small farmer from Kamplikoppa in Hubli taluk having 3.5 acres of land adopted tree based farming system under rainfed condition. He planted the species like Teak, Casuarina, Subabul, Eucalyptus, Acacia, Glyricidia, Bamboo, Drumstick in the borders. His annual income from 3 acres from this integration of horticulture, milk production, vermi-compost production, sale of fodder root slips and crops is around ₹ 4,00,000 and became sustainable through agroforestry system.

Mettupalayam centre shortlisted two drought tolerant, high yielding clonal progenies in *Ceiba pentandra.* During last year under rainfed condition, Arachalur progeny (MTPCP 18) recorded the highest pod yield of 264 pods tree^{-1} accounting for 73,128 pods/ha and floss yield of 365 kg/ha. In *Albizia lebbek,* 30 plus trees were identified from different parts of Tamil Nadu and progenies were raised from seeds and progeny trial was established. Integrated tree fodder model with *Casuarina junhghuhniana* as the main crop and *Sesbania sesban, Leucaena leucocephala, Gliricidia sepium* and *Melia dubia* as intercrops was established at TNPL unit –II, Mondipatti, Trichy district. The intercrops are being maintained as hedges and are being evaluated for their green fodder yield and soil properties. Among the four intercrops, *Leucaena leucocephala* recorded the maximum green fodder yield of 378.12 kg/ha. In an agri-silvicultural experiment with *Dalbergia sissoo* as the main crop and cassava and chileis as

intercrops with different manurial treatments, the highest mean yield of cassava and chilies was recorded to be 20.0 t/ha and 2.10 t/ha respectively in the treatment S_5 (STCR-IPNS recommendation) followed by the treatment S_4 (150% RDF) (17.2 t/ha and 1.95 t/ha, respectively). Two villages *viz.* Semmanarai village in Kothagiri taluk and Pugalur village in Mettupalayam taluk were selected for on farm demonstration of various agroforestry models. *Casuarina* MTP 2 based windbreak was established in Pugalur village and *Melia dubia* based boundary plantations were established in Sri Duraisamy, agroforestry farmer's field. Seeds of vegetables, seedlings of spices, saplings of aonla and coconut, seedlings of important industrial tree species were provided to farmers of Semmanarai village to establish agri-silvicultural, silvi-pastoral and agri-silvipastoral models.

Field trial on the Provenance evaluation of *Acacia mangium* at Thrissur showed consistent results after 15 years of establishment with Papua New Guinean provenances Kuranda, Upper Aramia and Arufi Village showing the best performance. The trials on multitier silvopastoral systems suitable for tropical homegardens reveals that intensive silvopasture systems with high yielding grass species and densely planted fodder tree hedges under intensively managed cut and carry systems shows good potential to provide quality feed for ruminants as against 3-tier grass-tree-legume combinations and conventional grass monoculture practices. Based on our trials, two- tier silvopastoral systems with hybrid napier grass (variety CO4) + trees (mulberry + calliandra; @ total 11,111 trees/ha), yields higher dry matter (31.5 t/ha) and almost double crude protein (4.75 t/ha) than grass monoculture (30.18 t/ha of dry yield and 2.83 t/ha of crude protein) in Kerala. Assessment of the standing stock of timber in the homegardens of Thrissur district, Kerala showed mean standing stock as 55.12 m^3/ha and total standing stock for the Thrissur district as 1,66,85,096 m^3. Among the timber trees *Mangifera indica* represented maximum standing stock of 12.76 m^3/ha followed by *Tectona grandis* (10.65 m^3/ha) and *Artocarpus hetrophyllus* (10 m^3/ha). As part of the common experiment "Revitalization of tropical homegardens, 122 homegardens were evaluated at Arimbur Panchayath. Nine homegardens were subjected to detailed analysis. Farm plans were prepared for the systematic development of these homegardens which will be subjected to long term monitoring for three years.

Twenty three years old plantation of ten nitrogen fixing tree species at Dapoli showed that *Acacia mangium* was found to be superior in respect of buildup of soil fertility and higher microbial population along with maximum height and dbh. Centre established *Melia dubia* based medicinal agroforestry system and collected germplasm of fifteen endangered tree species from Sahyadri hilly tract of Western India for conservation. Under TSP centre, distributed Male Goat along with fodder seedlings to tribal farmers for the improvement in their local breed.

Under tree improvement programme on *Gliricidia sepium* at Kattupakkam, stem cuttings of three pure germplasms of *Gliricidia sepium* collected from Tirukazhukundram, Mettupalayam and Dharapuram were established. Cumbu napier hybrid grass Co (BN) 5 was established in the *Cocus nucifera* based hortipasture. Biomass yield of 15.8 to 38.5 t/ha per cutting was recorded as influenced by different planting material and manuring. The grass had a high feeding value, dry matter intake amounting to 2.17 ± 0.10% body weight was recorded in cross bred calves, with an average daily gain (ADG) of 304.76 ± 7.78 g/day and feed conversion ratio of 7.14 ± 0.10. One hectare of this pasture in a year can support the active growth of 30 cross bred calves. The centre has successfully produced total mixed ration using extrusion technique for rabbits and small ruminants. The extruded feed has been distributed to farmers in the neighboring area for adoption.

Bangalore centre developed transferable technologies on *Melia dubia* based (bund, boundary & block plantation), perennial tree based agroforestry systems for sustainable fodder production and integrated farming system for small and marginal farmers. These technologies help in sustaining production, profitability and soil health besides sustaining the livelihood security of the farmers by

providing nutritious food, fodder and fuel *etc*. In addition, this centre is giving much importance on improvement in mandate trees, identifying existing agroforestry systems through district tree survey in southern districts of Karnataka, developing and conducting demonstrations on agroforestry based integrated farming system for sustainable livelihood security under rainfed and irrigated ecosystem.

During current year, tree survey was conducted in Mysore and Ramanagara District of Southern Karnataka. The results revealed that bund planting, boundary planting and block plantations are the common agroforestry systems in the arable lands. In bund and boundary plantation *Pongamia*, Coconut, *Melia*, *Sesbania*, *Syzygium*, Teak, *Albizia*, Silveroak, Tamarind, Neem, *Ficus*, and *Terminalia* were planted on all along farm boundaries and inter spaced in arable lands. Coconut, Teak, *Melia* and Mango are the common trees planted in the block plantations.

The centre also released one tamarind variety GKVK-17 in collaboration with scientist working at ARS, Chintamani. In addition clonal seed orchard of *Simarouba* and tamarind was established, comprising of 14 germplasms, 7 each in Kaali and Gowri in *Simarouba* and 40 selections of tamarind. In tree borne oil seed based agroforestry system associated crops like fingermillet, soybean and cowpea were evaluated. The results indicated that these crops could be grown economically up to four years, subsequently drastic reduction in yield of intercrops were noticed. However, agroforestry system as a whole improved soil health, system productivity and profitability. Fruit tree based agroforestry system has given sustained productivity and profitability even during drought and low rainfall condition as observed during last three years.

Tribal sub plan was also very effectively implemented in Sollepura village, H.D. Kote Taluk, Mysore District comprising of 61 farm families. The Major activities implemented were initial land preparation through tractor, distribution of seeds, fertilizers, plant protection chemicals, tarpaulins, construction of farm ponds and supply of agroforestry seedlings including fruit trees *viz*., *Melia, Silver oak, Syzygium cumini, Mangifera indica,* Tamarind, Seetapal and Jamum were planted and their establishment was satisfactory. In addition part of the convergence activities, bee hive boxes, honey extractor, improved sheep breeds and poultry birds were supplied. Soil analysis of individual farmer's field for issue of soil health card is under progress.

Ponnampet centre studied diversity of Coffee based Agroforestry of Kodagu in Western Ghats and observed that Kodagu district in Southern India is country's largest shade growing coffee region. Area under coffee agroforests constitute 33% of the landscape with high density and diversity of trees. Around 330 different shade trees have been documented which includes some of the Red listed trees. In addition to diverse floral resources, coffee plantations host 135 birds and large number of elephants. In addition to rich biodiversity coffee based agroforests have diverse economic crops like black pepper, cardamom, fruits, medicinal plants and Coorg Honey. Centre initiated efforts to supply quality planting materials and establish value addition facilities for *Garcinia gummigatta* an important medicinal tree of Western Ghats. The centre initiated work on integration of apiculture and agroforestry to promote bee keeping in coffee plantations which will help in increasing yield and production of high quality honey.

Wokshop of AICRP on Agroforestry

The Workshop of All India Coordinated Research Project on Agroforestry was organized at University of Agricultural Sciences, Bangalore from 23rd-26th May, 2017 with inauguration by Dr. H. Shivanna, Hon'ble Vice Chancellor of the University. In his inaugural speech Dr. Shivanna stressed upon restoration of degraded lands through natural resource management and agroforestry interventions. He emphasized the need for integrating livelihood options in the agroforestry models. Dr. S Bhaskar, ADG (Agron., AF and CC), NRM Division, ICAR, New Delhi highlighted the gaps in the research programmes and future thrust areas and to implement Government programmes and

Policies such as boundary / bund plantation and Tribal Sub Plan strictly as per the guidelines. He also emphasized upon to have a close linkage with other AICRPs under NRM division such as Dryland Agriculture and Integrated Farming System. Dr. O P Chaturvedi, Project Coordinator and Director, Central Agroforestry Research Institute, Jhansi presented the Coordinators Report and the brief summary of the research achievements of the project for the year. Dr Javed Rizvi, Regional Director of World Agroforestry Centre, South Asia programme was the Chief Guest of valedictory session. In the beginning, Dr. N R Gangadharappa, Director of Research of the host University welcomed the dignitaries and delegates. During the occasion a publication on "Colour Atlas of Agroforestry Systems Integrating Livestock / Poultry" published by coordinating centre located at Kattupakkam centre, Tamil Nadu Veterinary and Animal Sciences University was released. The group meet was attended by 26 coordinating centres located in SAUs. During the meeting there were ten technical sessions including inaugural and valedictory sessions and field visit to Biofuel Centre at Hassan and on station and on farm projects. There was a special session on interaction with Farmers and Industry representatives to discuss the implementation of Agroforestry Policy in the State. During the meeting it was decided that each centre will submit detailed information about the adoption and impact of the technology developed by the centre; the soil conservation measures to be integral component of silvipasture systems in Himalayan region. The best presentation award was presented to coordinating centre PAU, Ludhiana and UAS, Bangalore.

CHAPTER 4 AWARDS AND RECOGNITIONS

- Dr. Veeresh Kumar awarded by DST-SERB for Early Carrier Research Award- 2017.
- Dr. Veeresh Kumar awarded by National Environmental Science Academy, New Delhi for Junior Scientist of the Year Award-2016.
- Dr. Naresh Kumar awarded by 3rd Best paper presentation award in National Conference on "Alternate Farming Systems to Enhance Farmers' Income" during 19th-21st September, 2017 organized by Indian Ecological Society-Himachal Chapter, Directorate of Research, YSP University of Horticulture and Forestry Nauni, Solan (H.P.) at Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (H. P.).
- Dr. Naresh Kumar awarded "Distinguished Service Award – 2017" from Society of Biological Sciences & Rural Development, Allahabad–211019 (U.P.) during "National symposium on Nutritional Security, Environmental Protection : Present Scenario and Future Prospects" during 10th-11th November, 2017 organized by Society of Biological Sciences & Rural Development at Allahabad (U. P.).
- Dr. R H Rizvi, Dr. Ram Newaj, Dr. Rajendra Prasad, Dr. A K Handa, Dr. Badre Alam, Sh. S B Chavan, Sh. Abhishek Saxena, Sh. P S Karmakar, Sh. Amit Jain and Sh. Mayank Chaturvedi were awarded 'Best Research Paper Award' during Institute Foundation Day (8th May, 2017) for the year 2015-16 for the paper "Assessment of carbon storage potential and area under agroforestry systems in Gujarat Plains by CO2FIX model and remote sensing techniques" published in *Current Science*, 110(10): 2005-2011.
- Dr. Asha Ram, Dr. Inder Dev and Dr. Dasharath Prasad were awarded best popular article award during Institute Foundation Day (8th May, 2017) for hindi popular article entitled "Krishivaniki Badaltey Vatavaran Main Naye Asha Kee Kiran" published in Kheti December, 2016.
- Dr. Asha Ram received "Young Scientist Award" by International Society of Bioresource and Stress Management. This awarded was given on the eve of "3rd International Conference on Bioresource and stress management" held during 8th-11th November, 2017 at Jaipur (Rajasthan).
- Dr. Asha Ram awarded "Outstanding Thesis Award-2017". This award was given by Society for Scientific Development in Agriculture and Technology on the eve of International conference on "Global research initiatives for sustainable agriculture and allied sciences (GRISAAS)" held during 2nd-4th December, 2017 at Udaipur (Rajasthan).
- Dr. Inder Dev awarded 'Best Worker Award' for outstanding contribution in the Science and Institution development during Institute Foundation Day (8th May, 2017).
- Dr. Ramesh Singh awarded 'Best Worker Award' for Field Operation for outstanding contribution in the Science and Institution development during Institute Foundation Day (8th May, 2017).
- Dr. Ramesh Singh awarded "Dr. K G Tejwani Award (2016-17)" for Excellence in Agroforestry Research and Development by ISAF, ICAR-CAFRI, Jhansi.
- Dr. Ramesh Singh nominated by ICAR, New Delhi as Expert member of Technical and Financial Sub-committee (TFSC) of National Natural Resource Management System (NNRMS) Scheme in the Ministry of Environment, Forest and Climate Change.
- Dr. Inder Dev awarded "Distinguished Scientist Award-2017" by the Society for Scientific Development in Agriculture & Technologies
- Dr. Inder Dev awarded for "Excellence in Research" through EET CRS 6th Science & Technology Awards-2017 at Mumbai.

- Dr. C K Bajpai awarded "Best Worker Award" in the technical category during Institute Foundation Day (8th May, 2017).
- Sh. A K Chaturvedi awarded "Best Worker Award" in the administrative category during

Institute Foundation Day Award

CHAPTER 5 ON GOING PROJECTS (2017-18)

Project Code No.	Title of the Project	Leader & Associates
(A) SYSTEM RESEARCH PROGRAMME		
NRMACAFRISIL 201000200085	Nutrient management in ber based agri-horti. system	**Sudhir Kumar,** Anil Kumar, Rajendra Prasad, Inder Dev & Veeresh Kumar
NRMACAFRISIL 201600200100	Structural and functional analysis of short rotation tree based agroforestry system	**Naresh Kumar,** A K Handa, Asha Ram, A R Uthappa*, Dhiraj Kumar, Inder Dev, Veeresh Kumar & Mahendra Singh
NRMACAFRISIL 201600300101	Studies on soil biodiversity & nutrient dynamics in different agroforestry & mono-cropping system	**Veeresh Kumar,** Anil Kumar, Dhiraj Kumar, Naresh Kumar Mahendra Singh & N Manjunath (IGFRI)
(B) NATURAL RESOURCE & ENVIRONMENT MANAGEMENT PROGRAMME		
NRMACAFRISIL 200700100068	Evaluation of shade tolerance of crop species for agroforestry systems	**Badre Alam,** Ram Newaj & Lal Chand
NRMACAFRISIL 200800200078	Studies on arbuscular mycorrhizal fungi of important MPT's	**Anil Kumar,** Rajendra Prasad & Naresh Kumar
NRMACAFRISIL 201100200088	Multi-source inventory methods for quantifying carbon stocks through generalized volume/ biomass equations for prominent agroforestry species in India	**R H Rizvi** & A K Handa
NRMACAFRISIL 201300100091	Agroforestry based conservation agriculture for sustainable land use and improved productivity	**Inder Dev,** Asha Ram, Ramesh Singh, K B Sridhar, A R Uthappa*, Dhiraj Kumar, Mahendra Singh, Veeresh Kumar & Lal Chand

NRMACAFRISIL 201600400102	a) Agroforestry based integrated farming system for small and marginal farmers in semi-arid region	**Ram Newaj,** Asha Ram, Sudhir Kumar, Naresh Kumar, Ramesh Singh, Dhiraj Kumar, Veeresh Kumar & Mahendra Singh
NRMACAFRISIL 201600100099	b) Performance of pomegranate integrated with lemongrass under organic regime	**Sudhir Kumar,** Rajendra Prasad & Veeresh Kumar
NRMACAFRISIL 201600500103	Impact of watershed and agroforestry interventions on hydrology and nutrient loss at Garhkundar-Dabar watershed in Bundelkhand region of Central India	**Ramesh Singh** & Dhiraj Kumar
NRMACAFRISIL 201600700104	Relevance of soil and water conservation measures in enhancing productivity and sustainability of silvipastoral system in semi-arid conditions	**Asha Ram,** Ramesh Singh, Naresh Kumar & Dhiraj Kumar
NRMACAFRISIL 201600800105	Horizontal and vertical distribution of fine roots of tree and nutrients content in well-established Aonla and *Hardwickia binata* based agroforestry system	**Dhiraj Kumar,** Ram Newaj, Rajendra Prasad, Asha Ram & Veeresh Kumar
NRMACAFRISIL 201600800106	Effect of Abuscular Mychorizal inoculation on productivity of agroforestry systems	**Anil Kumar,** Sudhir Kumar, Naresh Kumar, Dhiraj Kumar & Inder Dev
(C) TREE IMPROVEMENT, POST-HARVEST & VALUE ADDITION PROGRAMME		
NRMACAFRISIL 200700400071	Comparative studies on seedling and clonal plants of *Pongamia pinnata* with special reference to their adaptability to rainfed dry agroclimate	**Badre Alam** & A K Handa
NRMACAFRISIL 200400100054	Genetics and breeding of Jatropha species	**Naresh Kumar**/ K Rajarajan**
NRMACAFRISIL 201500100092	Evaluation and characterisation of different Leucaena germplasm at ICAR- CAFRI	**A R Uthappa***/ K Rajarajan** Naresh Kumar, A K Handa, A K Singh & Maneet Rana (IGFRI)
NRMACAFRISIL 201600900107	TBOs based agroforestry models	**K B Sridhar** & Inder Dev
NRMACAFRISIL 201601000108	Mass propagation of industrial trees *viz.* Eucalyptus tereticornis, Casuarina junghuhniana Miq. *Melia dubia* and *Populus deltoides* using micro and mini clonal cuttings	**K B Sridhar** & Lal Chand

(D) HRD, TECHNOLOGY TRANSFER & REFINEMENT PROGRAMME		
NRMACAFRISIL 201500200093	Socio-economic, energetic and environmental impact assessment of watershed and agroforestry interventions at Garhkundar-Dabar watershed in Tikamgarh district of Madhya Pradesh	**R P Dwivedi,** R K Tewari, Ramesh Singh, R H Rizvi & Mahendra Singh
NRMACAFRISIL 201500300094	Economic evaluation of Poplar and Eucalyptus based agroforestry systems prevalent in Indo-Gangatic Plains, India	**Mahendra Singh,** R P Dwivedi, Inder Dev, R H Rizvi, K B Sridhar, A R Uthappa* & Dhiraj Kumar
PROJECT CONCLUDED DURING 2017		
NRMACAFRISOL 201500500094	Microclimate dynamics, advanced ecophysiological, physio-biochemical traits and indicators for evaluating component limitations in agroforestry system with special reference to understory crops. Funding Agency- ICAR Extramural Project	**Badre Alam** & A R Uthappa*
NRMACAFRISOL 201500600095	Development of digital library of spectral signatures for major agroforestry tree species. Funding Agency- ICAR Extramural Project	**R H Rizvi,** A K Handa & K B Sridhar
NRMACAFRISOP 200900200083	Model Watershed for sustaining agricultural productivity and improved livelihoods- Domagor Pahuj Watershed- Funding Agency- ICRISAT, Hyderabad,	**Ramesh Singh,** R K Tewari & R H Rizvi

EXTERNALLY FUNDED PROJECT			
Project Code No. (RPP No.)	**Title of the Project**	**Leader & Associates**	**Funding of the Project**
NRMACAFRISOL 201100300087	Assessment of carbon sequestration potential of agroforestry systems (NICRA)	**Ram Newaj** Rajendra Prasad, A K Handa, Badre Alam & R H Rizvi	ICAR Network Project
NRMACAFRISOP 200800100075	Harvest and post-harvest processing and value addition of natural resins, gums and gum resins	**Rajendra Prasad** A K Handa, Ramesh Singh & Badre Alam	HPVA of IINRG, Ranchi
NRMACAFRISOL 201500700096	National Mission for Sustaining the Himalayan Ecosystems (NMSHE-Taskforce 6 for Himalayan Agriculture)	**A K Handa** Inder Dev, Badre Alam, Mahendra Singh, Asha Ram & A R Uthappa*	DST, New Delhi
NRMACAFRISOL 201601100110	Development of Nursery of TBOs for Quality Planting Material Production	**K B Sridhar**	NMOOP MM-III Project

NRMACAFRISOL 201700100111	Studies on Pollination Dynamics, Pod yield and oil content in *Pongamia pinnata*	**Veeresh Kumar**	SERB- DST Project
INTER INSTITUTIONAL AND INTERNATIONAL COLLABORATIVE PROJECT			
----	Water requirement of grass based intercropping system in semi-arid area	**J B Singh,** IGFRI, Jhansi, Ramesh Singh, Mahendra Prasad, Amit Kumar Singh (IGFRI, Jhansi)	Inter-institutional (IGFRI-Jhansi)
----	Enhancing Groundwater Recharge and Water Use Efficiency in SAT Region through Watershed Interventions-Parasai-Sindh Watershed, Jhansi	**Ramesh Singh** R K Tewari, Inder Dev, R H Rizvi, R P Dwivedi, K B Sridhar, Dhiraj Kumar & Mahendra Singh	ICRISAT, Hyderabad
----	Farmer FIRST programme (FFP): Scaling up and integration of fodder technologies in existing farming system for sustainable livestock productivity in Bundelkhand	**Purshottam Sharma** Sunil Seth, S K Mahanta, Harsh Vardhan Singh, Mukesh Choudhary & R P Dwivedi	Inter-institutional (IGFRI-Jhansi)

* *Associated upto 18th August, 2017;*
***Associated from 5th February, 2018*

CHAPTER 6 PUBLICATIONS

(A) Research Journals

Ajit, Dhyani, S K, Handa, A K, Newaj, Ram, Chavan, S B, Alam, Badre, Prasad, Rajendra, Asha Ram, Rizvi, R H, Jain, Amit Kumar, Uma, Tripathi, Dharmendra, Shakhela, R R, Patel, A G, Dalvi, V V, Saxena, A K, Parihar, A K S, Backiyavathy, M R, Sudhagar, R J, Bandeswaran, C and Gunasekaran, S (2016). Estimating Carbon Sequestration Potential of Existing Agroforestry Systems in India. *Agroforestry Systems*, DOI 10.1007/s10457-016-9986-z.

Ajit, Handa, A K, Dhyani, S K, Bhat, G M, Malik, A R, Dutt, V, Masoodi, T H, Uma and Jain, Amit (2017). Quantification of Carbon Stocks and Sequestration Potential through Existing Agroforestry Systems in the Hilly Kupwara District of Kashmir Valley in India. *Current Science*, 113(4): 782-785.

Ahmad, Suheel, Khan, P A, Verma, D K, Mir, Nazim, Singh, J P, Dev, Inder and Roshetko, James, M (2017). Scope and Potential of Hortipasture for Enhancing Livestock Productivity in Jammu and Kashmir. *Indian Journal of Agroforestry,* 19 (1): 48-56.

Alam, B, Singh, R, Uthappa, A R, Chaturvedi, M, Singh, A K, Newaj, R, Handa, A K and Chaturvedi, O P (2017). Different Genotypes of *Dalbergia sissoo* Trees Modified Microclimate Dynamics Differently on Understory Crop Cowpea (*Vigna unguiculata)* as Assessed through Ecophysiological and Spectral Traits in Agroforestry System. *Agricultural and Forest Meteorology,* 249: 138-148.

Amala, U, Shivalingaswamy, T M and Kumar, Veeresh (2017). An Unusual Nesting Site by Leaf Cutter Bee *Megachile (Aethomegachile) laticeps* Smith. *Journal of the Kansas Entomological Society*, 90(1):77-81.

Asha Ram, Kumar, Dinesh, Babu, Subhash, Prasad, Dasharath and Dev, Inder (2017). Effect of Sulphur on Soil Biological Properties, Residual Soil Fertility and Yield of Aerobic Rice Grown under Aerobic Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system in Inceptisols. *Journal of Environmental Biology, 38:* 587-593.

Chakravarty, N, Shukla, A, Kumar, A, Dhyani, S K and Nagori, T (2017). Effect of Arbuscular Mycorrhizal Inoculation on Growth of *Stylosanthes seabrana*. *Range Management and Agroforestry*, 38(1): 139-142.

Chand, Lal, Singh, D B, Sharma, O C, Mir, J I, Kumawat, K L, Rai, K M, Rather, S A, Qureshi, I, Lal, S and Dev, Inder (2017). Lateral Bearing Trait in Indian Walnut (*Juglans Regia* L.) Germplasm: A Potential Yield Contributing Trait in Early Age of the Tree. *International Journal of Bio-resource and Stress Management*, 8(5): 605-610.

Chavan, S B, Keerthika, Uthappa, A R, Sridhar, K B, Newaj, R, Handa, A K and Saroj, N (2017). Traditional Knowledge of Broom Making From Date Palm (*Phoenix sylvestris* Roxb) For Sustainable Livelihood in Madhya Pradesh, India. *Indian Forester,* 143 (12): 1321-1324.

Dev, Inder, Asha Ram, Ahlawat, S P, Palsaniya, D R, Newaj, Ram, Tewari, R K, Singh, Ramesh, Sridhar, K B, Dwivedi, R P, Srivastava, Madhulika, Chaturvedi, O P, Kumar, R V and Yadav, R S (2017). Bamboo (*Dendrocalamus strictus*) + sesame (*Sesamum indicum*) based Agroforestry Model: A Sustainable Livelihood Option for Farmers of Semi-Arid Region. *Indian Journal of Agricultural Sciences,* 87 (11): 1528–1534.

Dhillon, R S, Bangarwa, K S, Bhardwaj, K K, Handa, A K, Beniwal, R S, Kumari, Sushil, Chavan, S B, Rizvi, R H, Sirohi, Chhavi and Sheokand, R N (2017). Effect of Spacing on Crop Yield and Soil Nutrient Status under Poplar Based Agroforestry Systems in Semi-Arid Ecosystem. *Indian Journal of Agroforestry,* 19(1): 42-47.

Jha, A, Shukla, A, Kumar, A and Chaturvedi, O P (2017). Effect of Arbuscular Mycorrhizae on Growth and Seedling Quality Index of Biofuel Species. *Indian Journal of Agroforestry*, 19(2): 23-28.

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Kumar, Veeresh, Griswold, Terry and Belavadi, Vasuki V (2017). The Resin and Carder Bees of South India (Hymenoptera: Megachilidae: Anthidiini). *Zootaxa,* 4317 (3):436–468.

Kumar, Veeresh, Uthappa, A R, Srivastava, Madhulika, Vijay, D, Kumaranag, K M, Manjunatha, N, Rana, Maneet, Newaj, Ram, Handa, A K and Chaturvedi, O P (2017). Floral Biology of *Grewia flavescens* Juss.: An Underutilized Crop. *Genetic Resources and Crop Evolution,* 64:1789-1795.

Kumar, Vinod, Kumar, Vikas, Singh, R K, Sanjiv, Kochewad, A and Singh, Mahendra (2017). Impact of Socio-Economic Variables on Disbursement of Agricultural Loan. *Agro Economist - An International Journal*, 4(2): 55-59.

Newaj, Ram, Chaturvedi, O P, Kumar, Dhiraj, Prasad, R, Rizvi, R H, Alam, B, Handa, A K, Chavan, S B, Singh, A K, Chaturvedi, M, Karmakar, P S, Maurya, A, Saxena, A, Gupta, G and Singh, Kedari (2017). Soil Organic Carbon Stock in Agroforestry Systems in Western and Southern Plateau and Hill Regions of India. *Current Science*, 112(11): 2191-2193.

Newaj, Ram, Chaturvedi, OP and Kumar, Dhiraj (2017). Role of Agroforestry in Improving Sustainability of Smallholders under Climate Change Scenario. *Current Advances in Agricultural Sciences,* 9(2): 231-237.

Prasad, Rajendra, Mertia, R S, Chaturvedi, O P, Tewari, R K, Shukla, Ashok, Singh, Prashant (2017). Need to Revitalize Grazing Resource Management Practices for Sustainable Use of Forage in Arid Rajasthan. *Indian Journal of Agroforestry,* 19(1):24-31.

Prasad, Rajendra, Newaj, Ram, Singh, R, Ajit, Saroj, N K, Tripathi, V D, Shukla, Ashok, Singh, Prashant and Chaturvedi, O P (2017). Soil Quality Index (SQI) for Assessing Soil Health of Agroforestry System: Effect of *Hardwickia binata* Roxb. Tree Density on SQI in Bundelkhand, Central India. *Indian Journal of Agroforestry,* 19(2):38-45.

Ram, D, Kumar, S, Babu, D,KPrasad, I Dev (2017). Effect of Sulphur on Soil Biological Properties, Residual Fertility and Yield of Aerobic Rice Grown under Aerobic Rice-Wheat Cropping System in Inceptisols. *Journal of Environmental Biology,* 38(4): 587-593.

Rizvi, R H, Newaj, R, Chaturvedi, O P, Prasad, R, Alam, B, Handa, A K, Karmakar, P S, Saxena, A, Chaturvedi, M, Singh, A And Singh, K (2017). Mitigating Climate Vagaries through Adoption of Agroforestry Land Use in Maharashtra, India. *Indian Journal of Agricultural Sciences,* 87(11): 1524-27.

Rizvi, R H, Newaj, Ram, Karmakar, P S, Saxena, A, Maurya, A and Jain, Amit (2017). Agroforestry and Grassland Mapping In Two Districts of Uttarakhand through Geospatial Technology. *Range Management & Agroforestry,* 38(2): 254-258.

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Singh, Prashant, Tripathi, V D, Shukla, Ashok, Prasad, Rajendra and Chaturvedi, O P (2017). Pruning Regimes and Productivity of *Eruca Sativa* Mill. In *Anogeissus pendula* Edgew. Based Agroforestry System. *Indian Journal of Agroforestry,* 19(1):63-68.

Srivastava, M, Singh, A K, Parihar, S G, Gautam, R D and Kumar, Veeresh (2017). Comparative Effect of Formulated Kairomonal Dusts on Parasitization Efficiency of *Trichogramma* spp. *Journal of Environmental Biology*, 38(4) 641-648.

(B) Technical Journals

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Kumar, Naresh, Handa, A K, Dev, Inder, Asha Ram and Chand, Lal (2017). Standardization of Growing Media for Quality Seedling Production of *Albizia lebbeck* (L.) Benth. *Agroforestry Newsletter,* 29(4): 2.

Prasad, Rajendra, Singh, Ramesh, Handa, A K, Alam, B, Tewari, R K, Chaturvedi, O P, Shukla, Ashok, Singh, Prashant, Tripathi, V D and Singh, Anand Kumar (2017). Performance of Gum Arabic (*Acacia senegal* L.) Based Agroforestry Models in Bundelkhand: Potential for Livelihood Option and Increasing Farmers' Income. *Agroforestry Newsletter,* 29(3): 2-4.

Rizvi, R H, Handa, A K and Ajit (2017). Estimation of Carbon Stock under *Acacia nilotica* trees using Generalised Models. *Agroforestry Newsletter,* 29(1): 3-4.

Tewari, R K, Singh, S P, Sridhar, K B and Singh, Mahendra (2017). Baramasi Jack Fruit Located in Tikamgarh (M.P.). *Agroforestry Newsletter,* 29(1): 2.

(C) Popular Articles

Arya, Renu, Arya, Sonam, Kumar, Sudhir and Arya, R L (2017). Jaivik Khad Ka Paigam Unnat Kheti Samridh Kisan. *Chara Patrika*, ICAR-IGFRI, Jhansi, 19: 74-75.

Arya, Sonam, Arya, Renu, Kumar, Sudhir and Arya, R L (2017). Shahri Kshetron Mein Bhugarbh Jal Sanchayan Evam Bhu-Jal Sambharan. *Chara Patrika*, ICAR-IGFRI, Jhansi, 19: 72-73.

Chaturvedi, O P, Rizvi, R H and Handa, A K (2017). Role of Geospatial Technologies in Agroforestry Research and Development. *Agriculture Today:* 180-182.

Kumawat, K L, Raja, W H, Chand, Lal and Rai, K M (2017). Nutritional Value and Health Benefits of Nuts. *Indian Farmer,* 4 (08): 627-637.

Lal, S, Singh, D B, Sharma, O C, Padder, B A and Chand, Lal (2017). Exploring Olive Potential. *Indian Horticulture*, March-April, 2017: 6-10.

Sharma Purushottam , Mahanta, S K, Kumar, Sunil, Singh, H V , Choudhary, Mukesh, Dwivedi, R P, Upadhayay, J P, Chandra, Avinash, Varma, R K and Gupta, Rajeev (2017). Lobia (In English & Hindi). *Farmer First Programme*, ICAR-IGFRI, Jhansi.

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Sharma Purushottam, Mahanta, S K, Kumar, Sunil, Singh, H V, Choudhary, Mukesh, Dwivedi, R P, Upadhayay, J P, Chandra, Avinash, Varma, R K and Gupta, Rajeev (2017). Clusterbean (In English & Hindi). *Farmer First Programme*, ICAR-IGFRI, Jhansi.

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Sharma, Purushottam, Mahanta, S K, Kumar, Sunil, Singh, H V, Choudhary, Mukesh, Dwivedi, R P, Upadhayay, J P, Chandra, Avinash, Varma, R K and Singh, Upendra (2017). Hybrid Bajra Napier (In English & Hindi). *Farmer First Programme*, ICAR-IGFRI, Jhansi.

Sharma Purushottam, Mahanta, S K, Kumar, Sunil, Singh, H V, Choudhary, Mukesh, Dwivedi, R P, Upadhayay, J P, Chandra, Avinash, Varma, R K and Prashant (2017). Gini (In English & Hindi). *Farmer First Programme*, ICAR-IGFRI, Jhansi.

Sharma Purushottam, Mahanta, S K, Kumar, Sunil, Singh, H V, Choudhary, Mukesh, Dwivedi, R P, Upadhayay, J P, Chandra, Avinash, Varma, R K and Gupta, Rajeev (2017).Dudharu Pashuon Kae Liye Poshtic Avam Sasta Pashu Ahar. *Farmer First Programme*, ICAR-IGFRI, Jhansi.

Sharma, Purushottam, Mahanta, S K, Kumar, Sunil, Singh, H V, Choudhary, Mukesh, Dwivedi, R P, Upadhayay, J P, Chandra, Avinash, Varma, R K and Singh, Upendra (2017). Chara Sanrakchan Vidhiyan Avam Upyogita. *Farmer First Programme*, ICAR-IGFRI, Jhansi.

Sharma Purushottam , Mahanta, S K, Kumar, Sunil, Singh, H V , Choudhary, Mukesh, Dwivedi, R P, Upadhayay, J P, Chandra, Avinash and Varma, R K (2017).Bhartiya Charagah Avam Chara Anusandhan Sansthan Key Pramukh Utpad. *Farmer First Programme*, ICAR-IGFRI, Jhansi.

Sharma Purushottam, Mahanta, S K, Kumar, Sunil, Singh, H V, Choudhary, Mukesh, Dwivedi, R P, Upadhayay, J P, Chandra, Avinash, Varma, R K and Prashant (2017). Varsh Bhar Chara Utpadan Taknike. *Farmer First Programme*, ICAR-IGFRI, Jhansi.

(D) Chapters in Book

Asha Ram, Dev, Inder, Uthappa, A R, Kumar, Dhiraj, Kumar, Naresh, Chaturvedi, O P, Dotaniya, M L and Meena, B P (2017). Reactive Nitrogen in Agroforestry Systems of India. ***In:*** The Indian Nitrogen Assessment: Sources of Reactive Nitrogen, Environmental and Climate Effects, Management Options, and Policies. (Eds. Y P Abrol, T K Adhya, Viney P Aneja, N Raghuram, Himanshu Pathak, Umesh Kulshrestha, Chhemendra Sharma and Bijay Singh). Elsevier Inc.: Pp 207-218.

Chand, Lal, Kumawat, K L and Bahera, S (2017). Tree Canopy Architecture Management In Temperate Fruits. ***In:*** Compendium Of ICAR-Winter School on Hi-Tech Interventions in Fruit Production Towards Hastening Productivity, Nutritional Quality and Value Addition (Eds. J Singh, P Bhatnagar and C B Meena): Pp 563-574.

Handa, A K and Chaturvedi, O P (2017). Community-Based Non-Wood Forest Products Enterprise: Successful Model in India, 89-109. ***In:*** Community-Based Non-Wood Forest Products Enterprise: A Sustainable Business Model (Eds. T R Gurung). Dhaka: SAARC Agriculture Centre: Pp 196.

Newaj, Ram, Chaturvedi, O P, Uthappa, A R, Chavan, S B, Kumar, Dhiraj and Shridhar, K B (2017). Agroforestry, Livestock Production and Climate Change Adaptation and Mitigation. ***In:*** Approaches Towards Fodder Security in India. (Eds. P K Ghosh, S K Mahanta, J B Singh, D Vijay, RV Kumar, V K Yadav and Sunil Kumar). Studera Press, New Delhi. Pp 565-582.

Saini, Pawan, Gani, Mudasir, Kaur, J J, Godara, Lal Chand, Singh, Charan, Chauhan, S S, Francies, Rose Mary, Bhardwaj, Ajay, Kumar, N Bharat and Ghosh, M K (2018). Reactive Oxygen Species (ROS): A Way to Stress Survival in Plants. ***In:*** Abiotic Stress-Mediated Sensing and Signaling in Plants:

an Omics Perspective. (Eds. Zargar S and Zargar M). Springer, Singapore.

Singh, Mahendra (2017). Agroforestry: Farm Linked Activities and Secondary Agriculture: Doubling Farmers' Income. ***In:*** Report of The Committee on Doubling Farmers' Income. Document Prepared by the Committee on Doubling Farmers' Income. Volume-IX. Department of Agriculture, Cooperation and Farmers' Welfare, Ministry of Agriculture and Farmers' Welfare, February, 2018: Pp 97-104.

(E) Symposia/Seminar/ Workshops (Abstract/ Full Paper)

Proceedings of National Review Meeting on Cactus held during 16th-18th January, 2017 at KSKV Kachchh University, Bhuj.

Asha Ram, Dev, Inder, Tiwari, R K, Kumar, Naresh, Chaturvedi, O P and Bajpai, C K (2017). Potential of Edible Cactus (*Opuntia ficus-indica*) in Bundelkhand Region of Central India: An Over View.

International Symposium on "Eco – Efficiency in Agriculture & Allied Research" held during 21st -23rd January, 2017 at BCKV, Kalyani, Nadia, West Bengal, India.

Dev, I, Asha Ram, Srivastava, M, Chaturvedi, O P, Kumar, Naresh and Kumar, Dhiraj (2017). Agroforestry: A Climate Smart Land Use System*:* 95-97.

National Symposium on "New Directions in Managing Forage Resources and Livestock Productivity in 21st Century: Challenges and Opportunities" held during 3rd -4th March, 2017 at RVSKVV, Gwalior.

Alam, B, Uthappa, A R, Singh, R, Chaturvedi, M, Singh, A K, Newaj, R, Handa, A K and Chaturvedi, O P (2017). Performance of Cowpea (*Vigna unguiculata)* under *Dalbergia sissoo* based Agroforestry System*:* 96.

Dev, I, Ram, A, Sridhar, K B, Palsaniya, D R, Singh, Ramesh, Kumar, Dhiraj, Singh, Mahendra, Chaturvedi, O P, Tiwari, Rupali and Rai, P (2017). *Albizia procera* based Silvipastoral System for Sustainable Forage Production in Wastelands of Semi-Arid Region: 87.

Kumar, Dhiraj, Ram, A, Dev, I, Uthappa, A R, Kumar, Veeresh, Sridhar, K B, Singh, Mahendra, Kumar, Naresh, Newaj, Ram and Chaturvedi, O P (2017). Soil Quality Service an Important Component of Silvipastoral System: 103.

Prasad, R, Handa, A K, Alam, B, Singh, R, Shukla, A, Singh, P and Chaturvedi, O P (2017). Integrating Gum Arabic (*Acacia Senegal* L.) in Grazing Grounds for Increasing Economic Viability of Grasslands and Pastures in Bundelkhand Region of Central India: 166.

Ram, A, Dev, I, Kumar, Naresh, Kumar, Dhiraj, Uthappa, A R, Kumar, Veeresh, Sridhar, K B, Tewari, R K, Kumar, Anil and Chaturvedi, O P (2017). Edible Cactus (*Opuntia ficus-indica*): A New Hope as Fodder in Bundelkhand Region: 102.

Singh, Mahendra, Kumar, Vikas, Dwivedi, R P, Sridhar, K B, Dev, I, Ram, A, Uttappa, A R, Kumar, Dhiraj, Tewari, R K and Chaturvedi, O P (2017). Doubling Farmers' Income through Improving Livestock Productivity in India: 165.

Sridhar, K B, Kumar, Veeresh, Dev, Inder, Tewari, R K, Singh, Mahendra, Dwivedi, R P, Uthappa, A R, Kumar, Naresh, Asha Ram, Pandey, Ajay and Chaturvedi, O P (2017). *Sesbania grandiflora*: A Promising Back Yard Forage Tree for Cattle and Small Ruminants of Bundelkhand Region of Central India.

Uthappa, A R, Ram, Asha, Handa, A K, Mahanta, S K, Singh, A K, Rana, Maneet and Chaturvedi, O P (2017). Leucaena- An Important Tree Fodder in Bundelkhand Region of India.

International Symposium on "Horticulture: Priorities & Emerging Trends" held during 4th - 8th September, 2017 at Indian Institute of Sciences, Tata Auditorium, Bengaluru.

Chand, Lal, Singh, D B, Sharma, O C, Kumawat, K L, Rather, S A, Qureshi, I, Mir, J I, Rai, K M and Saini, Pawan (2017). Genetic Variability and Trait-Specific Characterization of Walnut Genetic Resources for Future Improvement Programme: 232.

Kumar, Sudhir, Prasad, Rajendra and Kaurav, G S (2017). Hifoliar and Potassium Nitrate Spray Influence Fruit Characters and Production of Ber (*Zizyphus mauritiana* Lamk.) Cv Seo in Central India.

National Seminar on "Application of Remote Sensing and GIS in Indian Scenario Special Reference to Agriculture and Forestry" held during 15th -16th September, 2017 at UAS, Dharwad.

Rizvi, R H, Sridhar, K B, Handa, A K, Chaturvedi, O P, and Singh, Mohit (2017). Identification and Mapping of Poplar Species on Farmlands through Hyperspectral Remote Sensing: 102-103.

National Conference on "Alternate Farming Systems to Enhance Farmers Income" held during 19th -21st September, 2017 organized by the Indian Ecological Society at YSP University of Horticulture & Forestry, Nauni, Solan, HP, India.

Dev, Inder, Asha Ram, Singh, Ramesh, Kumar, Dhiraj, Sridhar, K B, Uthappa, A R, Kumar, Veeresh, Singh, Mahendra, Chand, Lal and Chaturvedi, O P (2017). Practicing Conservation Agriculture in Teak Based Agroforestry System: An Innovative Idea for Climate Resilience and Improved Productivity: 194.

Rani, A, Kumar, N, Kumar, A, Shukla, A, Uthappa, A R, Handa, A K and Chaturvedi, O P (2017). Effect of Growing Media and Arbuscular Mrcorrhizal Fungi on Seedling Growth of *Leucaena leucpcephala* (Lam) De Wit: 71.

National Conference of Plant Physiology on "Emerging Role of Plant Physiology for Food Security and Climate Resilient Agriculture" held during 23rd-25th November, 2017 at IGKV, Raipur.

Alam, B (2017). Tree Physiology and Microclimate Dynamics in Agroforestry Perspectives: Xvii.

Alam, B, Handa, A K, Chaturvedi, M, Singh, A K, and Chaturvedi, O P (2017). Physiological Traits, Flowering Phenology and Fruit Set Pattern of Clonal and Seedling Plants of *Pongamia pinnata.*

National Symposium on "Nutritional Security, Environmental Protection: Present Scenario and Future Prospects" held during 10th -11th November, 2017 Organized by Society of Biological Sciences & Rural Development at Allahabad.

Kumar, Naresh, Kumar, Anil, Shukla, Ashok, Ram, Asha, Ram Bahadur and Chaturvedi, O P (2017). Effect of Bio - Inoculents on Growth and Yield of *Arachis hypogaea* and *Sesamum indicum.*

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CHAPTER 7 IMPORTANT MEETINGS/ACTIVITIES

Research Advisory Committee

19th RAC meeting of ICAR-CAFRI was held on 27th & 28th April, 2017 under the chairmanship of Dr. Tej Partap, Former Vice-Chancellor, Sher-E-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar. Dr. S Bhaskar, ADG (A, AF/CC), NRM Division, ICAR, New Delhi, Dr. J C Dagar, Emeritus Scientist, ICAR-CSSRI, Karnal, Dr. M A Shankar, Ex. Director of Research, University of Agricultural Science, Bangalore, Dr. O P Chaturvedi, Director, ICAR-CAFRI, Jhansi (Members of RAC) and Dr. Anil Kumar (Member Secretary) participated in this RAC meeting. The Committee interacted with the Scientists and reviewed the ATR. After that, all the project leaders presented significant research findings of their research project and actively participated in the discussions.

Foundation Day

ICAR- Central Agroforestry Research Institute, Jhansi celebrated its 29th Foundation Day on 8th May, 2017. Shri Chandrika Prasad Upadhyay Hon'ble MLA, Chitrakoot dham Karwi (U.P.) was the Chief Guest of the function. Shri Upadhyay, in his foundation day lecture highlighted the development of downtrodden farmers by transferring the agricultural and agroforestry technologies to their field. He asked scientists to undertake research which is pro-active, anticipatory, problem-solving, result-oriented and farmer participatory in approach. He emphasized on protection and optimum utilization of natural resources as well as diversification of production in Bundelkhand region, while working with farmers and solving the problems in real field situations.

International Yoga Day

International Yoga Day was organized on 21st June, 2017 at the Institute. On the eve of Yoga Day Scientific, administrative, technical and supporting staff participated in the different activities.

Institute Research Council

Institute Research Council (IRC) meeting was held on 23rd & 24th June, 2017. All the Scientists of the Institute participated in the meeting and

presented the progress and significant findings of their projects.

ICAR- ICRAF Work Plan Meeting

An exposure visit and a meeting were held for Formulation/development and implementation of "National Agroforestry Policy" for Nepal during 11th -12th August, 2017. In this meeting Senior officials from different Ministries, Government of Nepal, officials from ICRAF and ICAR- CAFRI participated. This interaction meeting was conducted by ISAF, ICAR- CAFRI and ICRAF (New Delhi Centre) under ICAR-ICRAF Work plan.

Workshop on "Assessment of Agroforestry Area in India"

One day workshop on "Assessment of Agroforestry Area in India" was organized by ICAR- Central Agroforestry Research Institute, Jhansi on 6th October, 2017. The workshop was sponsored by Dept. of Agriculture, Cooperation & Farmers Welfare, Min. of Agriculture & Farmers Welfare, Govt. of India. Total 50 participants from ICAR- CAFRI, ICAR- IGFRI, ICAR-IISWC, Research Centre, Datia; Bundelkhand University, Jhansi; World Agroforestry Centre, South Asia office, New Delhi; Network for Certification & Conservation of Forests (NCCF), Noida; Green Initiatives Certification & Inspection Agency (GICIA), Delhi, National Remote Sensing Centre (NRSC), Hyderabad participated in this workshop.

Vigilance Awareness Week

Vigilance Awareness Week was organized from 31st October to 5th November, 2017. During this week, slogan competition, lectures were delivered. Oath was taken by all staff members to discourage act of corruption in India.

International Training

International Training on "Ecosystem Services in Agroforestry in the context of Payment of Ecosystem Services: Concept, Theory and Practice" was jointly organized by ICAR-CAFRI with ICRAF, New Delhi under ICAR-ICRAF Collaborative Work Plan from 20th - 24th November, 2017 at Jhansi. The participants were Scientists from AICRPAF Centers, ICRAF and ICAR-CAFRI, Jhansi.

World Soil Day

Institute celebrated World Soil Day on 05th December, 2017. On this day a Krishak Gosthi was organized to create awareness among farmers about importance of soil health in changing climatic scenario. On this occasion, the chief guest distributed soil health cards to 30 farmers belonging to six villages. One innovative farmer who has done appreciable agroforestry work on his field, was honoured by the chief guest.

Swachh Bharat Abhiyan

Various awareness programmes about cleanliness were organized during 16th to 30th May, 2017 and 17th to 30th September,2017 in the campus and nearby villages (Simardha, Karari,

Hastinapur, Ambabai, Parasai). Institute staff alongwith villagers cleaned obnoxious weeds from village school, removed plastic wastes and persuaded villagers particularly youth and children to take oath for swachchta in habitat, school and village common land. Farmers were motivated for tree plantation, organic farming and cleanliness. In every training program organized at the institute, there was a brief session on enthusing cleanliness habit in participants.

Republic Day and Independence Day

Republic Day (26th January, 2017) and Independence Day (15th August, 2017), respectively were celebrated at ICAR-CAFRI, Jhansi. Flag hoisting ceremony was observed on both the occasions. Cultural programmes and sport events were organized for the staff along with their family members on the occasions.

CHAPTER

8 PARTICIPATION IN WORKSHOP/ COORDINATION/MEETINGS/SYMPOSIA

Event	Duration	Venue	Participants
25th Biennial Workshop of All India Coordinated Research Project for Dryland Agriculture (AICRPDA)	18th-19th January, 2017	AICRPDA Center, Dr. PDKV, Akola (M.H.)	Dr. A K Handa
National review meeting on Cactus	16th-18th January, 2017	KSKV Kachchh University, Bhuj (Raj.)	Dr. Asha Ram
ECO -Efficiency in Agriculture & Allied Research (EEAAR 17)	20th-23rd January, 2017	BCKV, Kalyani (W.B.)	Dr. Inder Dev
Regional workshop on "Doubling farmers' income in Bundelkhand"	05th March, 2017	ICAR-IGFRI, Jhansi (U.P.)	Dr. Mahendra Singh
National Symposium on "New Direction in Managing Forage Resources and Livestock Production in 21st Century: Challenges and Opportunities" organized by RMSI, IGFRI, Jhansi	3rd-4th March, 2017	RVSKVV, Gwalior (M.P.)	Dr. O P Chaturvedi, Dr. Rajendra Prasad, Dr. A K Handa, Dr. Badre Alam, Dr. Inder Dev, Dr. R H Rizvi, Dr. Mahendra Singh, Dr. Naresh Kumar, Dr. Asha Ram, Dr. K B Sridhar, Dr. Dhiraj Kumar and Dr. C K Bajpai
Workshop on "Aquifer mapping and Groundwater Management"	18th May, 2017	Jointly organised by CGWB, Northern Zone, Lucknow, Deptt of Groundwater and Minor Irrigation, Jhansi (U.P.)	Dr. Ramesh Singh
Annual Workshop of AICRPAF	23rd-26th May, 2017	UAS, Bengaluru (Karnataka)	Dr. O P Chaturvedi, Dr. A K Handa, Dr. Anil Kumar, Dr. Inder Dev, Dr. Ramesh Singh and Dr. C K Bajpai
First meeting of Technical Group for Implementation of Sub Mission on AF	19th June, 2017	New Delhi	Dr. A K Handa

37th Central Joint Staff Council meeting	21st June, 2017	NASC Complex, New Delhi	Sh. Virendra Singh
Workshop on "Drought Research and Management"	21st July, 2017	NASC Complex, DPS Marg, New Delhi and organised by NRM Division, ICAR, New Delhi	Dr. Ramesh Singh
Standard Development Group meeting of Trees Outside Forest	5th August, 2017	New Delhi	Dr. A K Handa
Lecture delivered in Summer School sponsored by ICAR	25th August, 2017	ICAR-IARI, New Delhi	Dr. Inder Dev
Meeting on modalities for implementation of sub-Mission on Agroforestry (SMAF)	12th August, 2017	Krishi Bhavan, New Delhi	Dr. A K Handa
Review Meeting of the Vigilance Officers	18th August, 2017	ICAR-CIAE, Bhopal (M.P.)	Dr. Sudhir Kumar
Regional Workshop on "Development of SAARC Regional Project on Community based Non Wood Forest Product Enterprise: A sustainable business model"	24th-26th August, 2017	Thimpu, Bhutan	Dr. A K Handa
Meeting on the topic of Ever Greening India	31st August & 1st September, 2017	ICRAF-South Asia Program, New Delhi at the NASC Complex, Pusa, New Delhi	Dr. Inder Dev and Dr. R H Rizvi
International Conference on "Horticulture: Priories & Emerging Trends"	5th-8th September, 2017	IIHR, Bengaluru (Karnataka)	Dr. Sudhir Kumar and Sh. Lal Chand
Review Meeting of DST project on NMSHE	8th-9th September, 2017	Leh (J&K)	Dr. A K Handa
National Symposium on "Application of Remote Sensing & GIS in Indian Scenario with Special Reference to Agriculture & Forestry"	15th-16th September, 2017	UAS, Dharwad held at College of Forestry, Sirsi (Karnataka)	Dr. R H Rizvi
Review Meeting of Agroforestry Sub Mission	18th September, 2017	Krishi Bhavan, New Delhi	Dr. A K Handa
National Conference on "Alternate Farming Systems to Enhance Farmers' Income"	19th-21st September, 2017	Y.S. Parmar, UHF, Nauni, Solan (H.P.)	Dr. Inder Dev and Dr. Naresh Kumar

EFC meeting of AICRPAF and CAFRI Jhansi at NRM Division	27th-28th September, 2017	Krishi Bhavan, New Delhi	Dr. A K Handa
National symposium on "Nutritional Security, Environmental Protection : Present Scenario and Future Prospects"	10th-11th November, 2017	Society of Biological Sciences & Rural Development at Allahabad (U.P.)	Dr. Naresh Kumar
Third International Conference on "Bioresource and Stress Management"	8th-11th November, 2017	Jaipur (Raj.)	Dr. Asha Ram
4th International Symposium on "Minor Fruits, Medicinal & Aromatic Plants (ISMF, M & AP) organized by International Society of Minor Fruits, Medicinal & Aromatic Plants"	5th-6th December, 2017	College of Horticulture & Forestry, Central Agricultural University, Pasighat (Arunachal Pradesh)	Dr. Naresh Kumar
National Conference of Plant Physiology on "Emerging Role of Plant Physiology for Food Security and Climate Resilient Agriculture"	23rd-25th November, 2017	IGKV, Raipur, (Chhattisgarh)	Dr. Badre Alam
Workshop on "Assessment of agroforestry area in India"	6th October, 2017	ICAR-CAFRI, Jhansi(U.P.)	All Scientists and Technical Officers
Delivered a lecture on "Tree Canopy Architecture Management in Temperate Fruits"	16th November, 2017	Winter School, College of Horticulture and Forestry, Jhalawar (Rajasthan)	Sh. Lal Chand
National workshop on "Doubling Farmers' Income by 2022"	03rd November, 2017	NASC Complex, New Delhi	Dr. Mahendra Singh
Midterm Review of Regional Committee VII of ICAR	10th November, 2017	Bhopal (M.P.)	Dr. A K Handa

CHAPTER 9 TRAINING AND CAPACITY BUILDING

A. Participation in Trainings

Event	Duration	Venue	Participants
Advanced Remote Sensing and GIS Applications in Integrated Land Resource Management	17th-29th July, 2017	ICAR-NBSS & LUP, Nagpur (M.H.)	Dr. Dhiraj Kumar, Scientist (Soil Science)
Competence Enhancement programme on "Motivation and Positive Thinking for Technical Officers of ICAR"	13th-22nd September, 2017	ICAR-National Academy of Agricultural Research Management, Hyderabad (Telangana)	Dr. C K Bajpai & Sh. Rajendra Singh (CTOs)
Advance Faculty Training (CAFT) programme on "Policy and Technological Options for Enhancing Farmers' Income"	23rd September-13th October, 2017	ICAR-IARI, New Delhi	Dr. Mahendra Singh, Pr. Scientist (Agril. Economics)
Soil Biodiversity Identification and Quantification	22nd-28th September, 2017	Department of Entomology, University of Agricultural Sciences, GKVK, Bangalore(KA)	Dr. Veeresh Kumar, Scientist (Entomology)
Winter school on "Hi-tech Intervention in Fruit Production towards Hastening Productivity, Nutritional Quality and Value Addition"	1st November-21st November, 2017	College of Horticulture and Forestry, Jhalawar (Rajasthan)	Sh. Lal Chand, Scientist (Fruit Science)
Automobile Maintenance, Road Safety and Behavioral Skills	27th November-01st December, 2017	ICAR-CIAE, Bhopal (M.P.)	Sh. Het Ram, Driver

B. Trainings organized for Various Categories of Employees

Event	Duration	Venue	Participants
International Training on "Ecosystem Services in Agroforestry in the Context of Payment of Ecosystem Services: Concept, Theory and Practice"	20st-24st November, 2017	ICAR-CAFRI, Jhansi	Scientists from AICRPAF Centers, ICRAF and ICAR-CAFRI, Jhansi

C. HRD funds Allocation and Utilization

Year	Allocation	Utilization
2017-2018	1.50	1.03

CHAPTER

10 राजभाषा गतिविधियाँ

हिन्दी सप्ताह

दिनांक 14 सितम्बर, 2017 को हिन्दी सप्ताह की शुरूआत आई.सी.ए.आर. कुलगीत से हुई। हिन्दी सप्ताह के अवसर पर हिन्दी को बढ़ावा देने के लिए माननीय केन्द्रीय कृषि मंत्री, भारत सरकार का संदेश एवं भारतीय कृषि अनुसंधान परिषद, नई दिल्ली के महानिदेशक डा. त्रिलोचन महापात्रा जी की अपील को पढ़कर उपस्थित सभी लोगों को अवगत कराया गया। इस अवसर पर संस्थान के वैज्ञानिकों, अधिकारियों एवं कर्मचारियों ने हिन्दी को बढ़ावा देने के लिए अपने विचार व्यक्त किये। उद्घाटन सत्र के उपरान्त दूसरे सत्र में हिन्दी कार्यशाला का आयोजन किया गया।

दिनाँक 20 सितम्बर, 2017 को हिन्दी सप्ताह का समापन कार्यक्रम के मुख्य अतिथि डा. आर.वी. कुमार, प्रभारी निदेशक, भाकृअनुप–भारतीय चरागाह एवं चारा अनुसंधान संस्थान, झाँसी (उ.प्र.) ने अपने उद्बोधन में कहा कि शोध कार्यों में विशेषकर प्रकाशन, संदर्भ–संग्रह, कृषि उपयोगी जानकारी इत्यादि में हिन्दी के प्रयोग को बढ़ाये जाने की आवश्यकता है। उन्होंने कहा कि फ्रांस, जर्मनी, रूस, जापान तथा चीन ऐसे उदाहरण है जो कि अपने अनुसंधान कार्य के लिए राष्ट्रभाषा का प्रयोग करते हैं, इसी कारण अन्य देशों में विज्ञान एवं अनुसंधान जन–जन तक राष्ट्रभाषा के माध्यम से पहुँचा है। हमारे देश भारत में हिन्दी को राजभाषा से राष्ट्रभाषा करने हेतु प्रयास की जरूरत है तभी आम आदमी को विज्ञान एवं अनुसंधान कार्य हिन्दी में समझने में आसानी होगी।

कार्यक्रम की अध्यक्षता करते हुए संस्थान के कार्यवाहक निदेशक ने राजभाषा के व्यवहारिक प्रयोग पर बल दिया। उन्होनें समस्त वैज्ञानिकों, अधिकारियों एवं कर्मचारियों से अपील किया कि हिन्दी में पत्राचार को बढ़ाने में अपना सहयोग प्रदान करें जिससे राजभाषा विभाग द्वारा दिये गये लक्ष्यों को पूरा किया जा सके।

हिन्दी कार्यशालायें

संस्थान में वर्ष 2017 के दौरान चार हिन्दी कार्यशालाओं का आयोजन किया गया। इन कार्यशालाओं के आयोजन का मुख्य उद्देश्य हिन्दी में सरकारी कामकाज करने में अधिकारियों एवं कर्मचारियों को होने वाली झिझक को दूर करना था। कार्यशालाओं में संस्थान के समस्त वैज्ञानिकों, अधिकारियों एवं कर्मचारियों ने भाग लिया।

राजभाषा कार्यान्वयन समिति की बैठकें

संस्थान में वर्ष 2017 के दौरान राजभाषा कार्यान्वयन समिति की कुल चार बैठकें सम्पन्न हुई जिसमें सरकारी कामकाज में राजभाषा को बढ़ावा देने हेतु अनेक बिन्दुओं पर विस्तृत विचार–विमर्श किया गया और सर्वसम्मत से निर्णय लिया गया। बैठकों की अध्यक्षता करते हुए निदेशक द्वारा संस्थान के सभी वैज्ञानिकों, अधिकारियों एवं कर्मचारियों से धारा 3(3), पत्राचार एवं फाइलों पर टिप्पणियाँ हिन्दी में लिखने के लिए अपील की गयी।

राजभाषा कार्यान्वयन समिति की बैठक में लिए गये निर्णय के अनुसार सप्ताह भर विभिन्न प्रतियोगिताओं को सफल बनाने हेतु निदेशक महोदय द्वारा प्रत्येक किया गया। इसके साथ

ही साथ यह भी निर्णय लिया गया कि सरकारी कामकाज में राजभाषा को बढ़ावा देने हेतु प्रशासनिक, तकनीकी एवं वैज्ञानिक वर्ग से जिन अधिकारियों एवं कर्मचारियों द्वारा पिछले एक वर्ष के कार्यकाल में 20,000 या उससे अधिक शब्द हिन्दी में लिखा गया हो उनको प्रथम पुरस्कार रू. 1000.00, द्वितीय पुरस्कार रू. 600.00 तथा तृतीय पुरस्कार रू. 300.00 दिया गया। इसके मूल्याँकन के लिए निदेशक महोदय द्वारा एक समिति का गठन किया गया।

CHAPTER 11 DISTINGUISHED VISITORS

- Sh. Swatantra Dev Singh, Hon'ble Minister of State with Independent Charge for Transport & Protocol and Minister of State for Power, Government of Uttar Pradesh, Lucknow (U.P.).
- Sh. Chandrika Prasad Upadhyay, Hon'ble MLA, Chitrakoot dham, Karwi (U.P.).
- Shri Rajeev Singh Parichha, Hon'ble member of Uttar Pradesh Legislative Assembly (Babina), Jhansi (U.P.).
- Dr. T Mohapatra, Hon'ble Secretary (DARE), & Director General, ICAR, New Delhi.
- Dr. J S Sandhu, Deputy Director General (Crop Science), ICAR, New Delhi.
- Dr. Tej Partap, Former Vice-Chancellor, Sher-E-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar (J & K).
- Dr. Javed Rizvi, Regional Director, South Asia Progarmme, ICRAF, New Delhi.
- Dr. S Bhaskar, ADG (A, AF & CC), NRM Division, ICAR, New Delhi.
- Dr. J C Dagar, Emeritus Scientist, ICAR-CSSRI, Karnal (H. R.).
- Dr. M A Shankar, Ex. Director of Research, University of Agricultural Science, Bangalore (K.A.).
- Dr. Ben Boxer, DDG, Corporate Services, ICRAF, Narobi (Kenya).
- Dr. P K Ghosh, Director, ICAR-IGFRI, Jhansi (U. P.).
- Dr. Rajendra Choudhary, Sr. Liaison & Monitoring Officer, South Asia Programme, ICRAF, New Delhi.

CHAPTER 12 PERSONNEL

Dr. O P Chaturvedi, Director - up to 31st January, 2018			
Dr. Anil Kumar, Director (A)			
Scientific			
1.	Dr. R K Tewari	Pr. Scientist (Horticulture/ Fruit Science)	
2.	Dr. Ram Newaj	Pr. Scientist (Agronomy)	
3.	Dr. Rajendra Prasad	Pr. Scientist (Soil Science)	
4.	Dr. Sudhir Kumar	Pr. Scientist (Horticulture/ Fruit Science)	
5.	Dr. A K Handa	Pr. Scientist (Forestry/ Agroforestry)	
6.	Dr. R P Dwivedi	Pr. Scientist (Agriculture Extension)	
7.	Dr. Inder Dev	Pr. Scientist (Agronomy)	
8.	Dr. Badre Alam	Pr. Scientist (Plant Physiology)	
9.	Dr. (Er.) Ramesh Singh	Pr. Scientist (SWC Engs.)	
10.	Dr. R H Rizvi	Pr. Scientist (Computer Application)	
11.	Dr. Mahendra Singh	Pr. Scientist (Agriculture Economics)	
12.	Dr. Naresh Kumar	Sr. Scientist (Agroforestry)	
13.	Dr. K B Sridhar	Scientist (Forestry)	
14.	Dr. K Rajarajan	Scientist (Genetics & Plant Breeding)	
15.	Sh. S B Chavan	Scientist (Forestry)	(on study leave)
16.	Dr. Asha Ram	Scientist (Agronomy)	
17.	Sh. A R Uthappa	Scientist (Forestry)	(on study leave)
18.	Dr. Dhiraj Kumar	Scientist (Soil Science)	
19.	Sh. Lal Chand	Scientist (Fruit Science)	
20.	Dr. Veeresh Kumar	Scientist (Entomology)	
Technical			
1.	Sh. B Singh	Chief Technical Officer (Farm Manager)	
2.	Dr. Rajeev Tiwari	Chief Technical Officer	
3.	Dr. C K Bajpai	Chief Technical Officer	
4.	Dr. A Datta	Chief Technical Officer	
5.	Sh. Sunil Kumar	Chief Technical Officer	
6.	Sh. Rajendra Singh	Chief Technical Officer	
7.	Sh. Rajesh Srivastava	Asstt. Chief Technical Officer (Art & Photo)	
8.	Sh. R K Singh	Sr. Technical Officer	
9.	Sh. S P Singh	Sr. Technical Officer	
10.	Sh. Ram Bahadur	Sr. Technical Officer	

11. Sh. Ajay Kumar Pandey	Technical Officer	(on study leave)
12. Km. Shelja Tamrkar	Technical Assistant (Library)	
13. Sh. Het Ram	Sr. Technical Assistant (Driver)	
14. Sh. Kashi Ram	Sr. Technical Assistant (Driver)	
15. Sh. Prince	Technical Assistant, Mechanic	
Administration		
1. Sh. J L Sharma	Administrative Officer	
2. Sh. S B Sharma	Asstt. Finance & Accounts Officer	
3. Sh. A K Chaturvedi	Private Secretary	
4. Sh. Hoob Lal	Personal Assistant	
5. Sh. Om Prakash	Personal Assistant	
6. Sh. Mahendra Kumar	Assistant	
7. Sh. Birendra Singh	Assistant	
8. Sh. Jai Janardan Singh	Assistant	
9. Sh. Deepak Vij	Stenographer (Grade-III)	
10. Sh. Tridev Chaturvedi	Stenographer (Grade-III)	
11. Sh. Vir Singh Pal	Sr. Clerk	
12. Smt. Kaushalya Devi	Jr. Clerk	
Skilled Supporting Staff		
1. Sh. Attar Singh		
2. Sh. Ram Singh		
3. Sh. Jagdish Singh		
4. Sh. Ram Din		
5. Sh. Pramod Kumar		
6. Sh. Munna Lal		

CHAPTER

13 MISCELLANEOUS

Promotion

- Dr. Mahendra Singh, Sr. Scientist promoted to Pr. Scientist w.e.f. 05th August, 2016.
- Dr. K B Sridhar, Scientist promoted to Scientist (Sr. Scale) w.e.f. 27th April, 2015.
- Dr. Asha Ram, Scientist promoted to Scientist (Sr. Scale) w.e.f. 01st January, 2017.
- Sh. Kashi Ram, Driver (Tech. Assit.) promoted to Driver (Sr. Tech. Assit.) w.e.f. 18th September, 2017.

Institute Joint Staff Council

New IJSC has been constituted for the period of 01/03/2016 to 28/02/2019.

Internal Inspection by the Team of IPAI

Internal Inspection was conducted by the Team of Institute of Public Auditors of India (IPAI), for the period of 2016-17 of the Institute.

Retirement

- Dr. O P Chaturvedi, Director Retired on 31st January, 2018.
- Smt. Shyamwati, EPL retired on 31st March, 2017.

ANNEXURE-I

RESEARCH ADVISORY COMMITTEE

Dr. Tej Partap (Chairman) Former Vice-Chancellor, Sher-E-Kashmir University of Agricultural Sciences and Technology of Kashmir, Kashmir (J & K)	**Dr. J C Dagar** Emeritus Scientist, ICAR-CSSRI, Zarifa Farm, Kachawa Road, Karnal (H R)
Dr. M A Shankar Former Director of Research, University of Agricultural Science, GKVK, Bangaluru (K R)	**Dr. P Kaushal** Vice-Chancellor, Birsa Agricultural University, Kanke, Ranchi (Jharkhand)
Dr. V K Mishra Ex-Dean, College of Horticulture & Forestry, Solan (H P)	**Dr. O P Chaturvedi** Director, ICAR- CAFRI, Jhansi (U P)
Dr. S Bhaskar Assistant Director General (Agron./AF & CC), NRM Division, ICAR, Krishi Anushandhan Bhawan-II, New Delhi	**Dr. Anil Kumar** Pr. Scientist & Member Secretary, ICAR- CAFRI, Jhansi (U P)

ANNEXURE-II

INSTITUTE JOINT STAFF COUNCIL

Chairman : Anil Kumar (Director-Acting)				
Category	**Staff Side**		**Office Side**	
Technical	Sh. Kashi Ram, Driver, Tech. Asstt.	Member	Dr. Ram Newaj, Pr. Scientist	Member
			Dr. A K Handa, Pr. Scientist	Member
Administration	Sh. Tridev Chaturvedi, Stenographer	Secretary	Dr. R H Rizvi, Sr. Scientist	Member
	Sh. Birendra Singh, Assistant	Member, CJSC	Sh. Rajendra Singh, CTO	Member
Supporting	Sh. Attar Singh, SSS	Member	Sh. J L Sharma, AO & HO	Member Secretary
	Sh. Ram Singh, SSS	Member	Sh. S B Sharma, AF & AO	Member

स्वच्छ भारत
एक कदम स्वच्छता की ओर

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भारतीय कृषि अनुसंधान परिषद
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