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ICAR

कृषिवानिकी
Agroforestry

वार्षिक प्रतिवेदन
ANNUAL REPORT
2013-14

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NRCAF

राष्ट्रीय कृषिवानिकी अनुसंधान केन्द्र, झाँसी
National Research Centre for Agroforestry, Jhansi

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COVER PHOTOGRAPHS

Albizia procera based Agroforestry system

2014

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PREFACE

It is a matter of great satisfaction and privilege to present the Annual Report of National Research Centre for Agroforestry, Jhansi for the period 2013-14. During the reporting year National Research Centre for Agroforestry (NRCAF), Jhansi celebrated its Silver Jubilee of establishment and observed National Agroforestry Day on 8th May, 2013. The Centre has strengthened its research activities and significant achievements of agroforestry research undertaken through the in house and external funded projects, network and inter-institutional collaboration, technology demonstrations and capacity building.

The Centre continued its research activities by strengthening and updating the data collection, analysis, interpretation and reporting the results for all the projects. In addition it demonstrated agroforestry technologies through watershed programmes and a series of sponsored training programmes. During the year, fourteen trainings were conducted for Integrated Watershed Management Programme on Natural Resource Management and Agroforestry, production system and micro-enterprises, livelihood support activities and accounting. These trainings were organized in response to request from Land Development and Water Resources and Department of Agriculture (PIAs of IWMP) from Jhansi, Lalitpur and Banda district. NRCAF developed appropriate technologies for designing Cost-effective Rainwater Harvesting Structures (RHS) and leak proofing technique for existing structures. These technologies *viz.* cost effective design of RHS and leak proofing were adopted by Govt. and non-governmental agencies for the benefit of stakeholders.

I am deeply indebted to Hon'ble Dr. S Ayyappan, Secretary, DARE and Director General, ICAR, New Delhi for his encouragement, guidance and support. I am grateful to Dr. A K Sikka, DDG (NRM), ICAR, New Delhi for his constant direction, inspiration and backing. My appreciation is also due to Dr. B Mohan Kumar, ADG (Agronomy/AF) and others staff members of NRM division of ICAR, New Delhi for their cooperation and help. The services of the PME Cell and Editorial Committee in compiling and timely publication of the report is highly appreciated. I am thankful to Director, IGFRI, Jhansi for sharing the infrastructure from time to time.

(SK Dhyani)

EXECUTIVE SUMMARY

NRCAF was established during 1988 to initiate organized research in Agroforestry. Since last 25 years interdisciplinary research efforts are in progress to meet the needs of farmers, farmwomen and other stakeholders. Executive summary of continuing projects is given below.

Different clones of Eucalyptus namely C-3, C-6, C-7 and C-10 were evaluated during the year for growth parameters of coppice shoots. Under different plantation systems the minimum dbh (11.4 cm) was recorded for block plantation (3x3 m) and maximum under 5x4 m spacing in agrisilviculture system (13.1 cm). Monthly increment in dbh observed similar trend to last year and it ranged from 0.29 to 0.73 cm. In general, the increments were higher in those months receiving sizeable precipitation. The increment values in summer varied from 0.35 to 0.63 cm, whereas in winter 0.29 to 0.48 cm. All growth and yield parameters of wheat crop were maximum under control compared to other systems except for straw yield, which was maximum under boundary plantation. Under agrisilviculture system the spacing of 10x2m registered better growth and yield as compared to 5x2m spacing, although the tree geometry is same.

Aonla plants subjected to year round irrigation in basin recorded maximum fruit yield of 60.5 kg tree^{-1} followed by those irrigated in summer with crops in *rabi* registering 57.7 kg plant^{-1}. Aonla plants under rainfed conditions recorded minimum (45.6 kg tree^{-1}) fruit yield closely followed by those irrigated in summer without crop.

Modified treatments were imposed in ber based agri-horticulture system and observations recorded on ber were found non-significant. Sesame was grown in *kharif*. Lentil was sown in *rabi,* 2012 recorded seed and straw yield significantly higher in sesame- lentil treatment and ber (75% RDF) + VAM + sesame- lentil, respectively. Soil surface soil had higher SOC, dehydrogenase activity and available N than sub-surface soil samples.

In *Albizia procera* based silvipastoral system, the tree component was pruned (25, 50 and 75% intensity) in 2nd, 3rd, 4th, 5th and 6th year pruning initiation treatments during December. By and large most of the growth parameters of the tree and pasture components were not affected significantly due to age of pruning initiation and its intensity. *A. procera* gained height in the range of 11.51 to 13.30 m, dbh (14.18 to 16.21 cm), canopy spread (1.87 to 3.38 m). Various growth parameters of *C. fulvus* varied in the range of 1.52-1.59 m (height), 30.80-32.11 cm (tussock dia), 61.38-67.37 tillers tussock^{-1}, whereas *S. seabrana* gained 1.28-1.35 m (height) and 59.68-65.12 branches plant^{-1}. Leaf fodder production was significantly affected by levels of pruning. Total biomass production from the silvipastoral system varied in the range of 7.87 – 9.04 D.W. t ha^{-1} and was significantly affected by the levels of pruning intensity.

Performance of *Ailanthus excelsa* and *Grewia optiva* during 7th year recorded average height of 5.38 m (*A. excelsa*) and 4.92 m (*G. optiva*) and dbh of 11.01 cm (*A. excelsa*) and 6.27 cm (*G. optiva*). Biomass production from understorey *S. seabrana* was recorded as 4.88 D.W. t ha^{-1} (*A. excelsa*) and 4.69 D.W. t ha^{-1} (*G. optiva*).

Dendrocalamus strictus, *Bambusa vulgaris* and *B. tulda* planted under National Bamboo Mission project during 2007 (rainy season) were harvested during 2012 (Nov. / December). During 2013 average height recorded was 7.20 m (*B. vulgaris*), 5.43 m (*D. strictus*) and 2.92 m (*B. tulda*). *B. vulgaris*, *D. strictus* and *B. tulda* recorded 3.80, 2.77 and 2.26 cm dbh, respectively. New culm emergence was less in *B. tulda* (1.6 culms

clump^{-1}) and *B. vulgaris* (3.5 culms clump^{-1}) as compared to *D. strictus* (4.4 culms clump^{-1}). Average numbers of rhizomes were 3.0, 2.2 and 1.67 in *B. vulgairs, D. strictus* and *B. tulda*, respectively. The average number of internodes was found to be 11 (*B. vulgaris*), 15.7 (*D. strictus*) and 8.82 (*B. tulda*). The average internodal length recorded in new culms was 24.53 cm (*B. vulgaris*), 20.88 cm (*D. strictus*) and 21.03 cm (*B. tulda*), respectively.

Shade tolerance of pea (*Pisum sativum*) and pigeon pea (*Cajanus cajan*) under different regimes of shade and without shade (in open field) were evaluated. Various impacts of shade on the physiological and biochemical traits were delineated. Some important physiological traits like CO_2 assimilation and photochemical efficiency clearly indicated the salient impact of shade on crop and resulted in reduction of crop yield. Due to down regulation in some physio-biochemical traits, maximum yield reduction was noted in the 75% shade, followed by 50% shade, while a moderate reduction was recorded in 33% shade in comparison to open grown plants.

Effect of shade on efficiency of bio-fertilizers in important *Kharif* pulse crops *(Phaseolus mungo* and *Vigna radiata)* indicated that efficiency of bio-fertilizers was greater with no shade, however their combined application with chemical fertilizer is likely to increase the growth and yield of studied pulses under and outside tree canopy in agroforestry systems.

Inoculations with Arbuscular Mycorrhizal fungi were found beneficial in *kharif* crops *viz.*, blackgram, greengram, soybean and sesame. Colonization index was increased by DAP and AMF. Among treatments, DAP + AMF recorded maximum increase. Values of colonization index decreased from 2nd to 3rd month in control and DAP, but not in AMF or DAP + AMF. Effect of AMF inoculations on nodulation was found variable. DAP and AMF both stimulated nodulation in blackgram; only DAP + AMF increased it in greengram and DAP and DAP + AMF increased it in soybean. Nodules also decreased from 2nd and 3rd month in blackgram and soyabean, but not in greengram.

Soil health indicator values generated from aonla (*E. officinalis)* based agroforestry (AF) systems were assigned functional scores (0.0 to 1.0 scale) and soil quality index was calculated. Also, the dynamics of soil organic carbon decomposition in different agroforestry system was studied. The soil indicator values obtained from aonla based AF system loaded with four soil moisture conservation (SMC) treatments *viz.* control, stone mulch, deep basin and deep basin + deep ploughing, indicated that in comparison to control different SMC techniques had varying effects on soil properties. In general, the soil indicator values were more in tree-rhizophere than that in non rhizospher zone. Like values, the different SMC treatments had caused variations in functional scores of soil health indicators. The values of unified soil quality index (SQI) reveals that in relation to baseline reference (0.267), SMC techniques had brought an improvement in soil quality index. Maximum SQI (0.477) was found in treatment of deep basin followed by deep basin + deep ploughing (0.452), while minimum in stone mulch. The improvement in SQI brought by different SMC treatments over regional baseline SQI ranged from 34.7 to 44.1% in tree-rhizosphere soil and from 31 to 37% in non rhizosphere.

A laboratory experiment was conducted to study dynamics of soil organic carbon decomposition in different agroforestry systems, under constant temperature (25^{0}C) and moisture (70% of water holding capacity) for 90 days. Irrespective of different agroforestry systems, there were two distinct

bursts when soil organic carbon was released. The first was rapid decomposition and the other was slow decomposition. Total release of CO_2-C varied from 265 to 452 mg CO_2-C kg^{-1} soil in different agroforestry systems which accounted for 4.1 to 8.0% of SOC. The maximum SOC was mineralized in open crop field while minimum in *H. binata* (black soil) AF system. It indicates that SOC in open crop field had more size of active pool, which decomposed rapidly in short time, whereas AF system contained more size of slow pool decomposing steadily over a long period.

About 2250 saplings of important tree species were planted during 2013 on farmer's field. Overall survival of species in watershed indicated that kumat, teak and bamboo to be the most promising in the region. Hydrological analysis of watershed indicated reduced storm flow (21% Vs 34% and increased base flow (4.5 Vs 1.2%) in treated watershed as against untreated, 11% of rainfall enriched ground water as against 7% in untreated. Weathered zone was 85% saturated with 600 mm rainfall in treated watershed which was achieved after 1100 mm in untreated watershed.

A total of 19 published equations on biomass of Poplar spp. could be traced for the states of Uttar Pradesh, Haryana and Bihar. These equations pertain to Samastipur, Karnal, Hisar and Yamunanagar. The simulated data point (dbh and Biomass) for these equations were clubbed into one data set for Country Level as a whole, fitted model Biomass = a/ $[1+e^{(p-b*dbh)}]$ was fitted on this Country level data set. The equations Biomass = $252.1000/[1+e^{(6.0766-0.2674dbh)}]$ with (R^2 =0.75395) is proposed to be used for predicting or estimating the Biomass of the tree on the basis of their observed values. Residual diagnostics plots for the fitted model clearly elaborate that the fitted equation can be used to predict the Biomass for the dbh range of 1 to 50 cm.

The extent of agroforestry area in India was estimated as preliminary estimates through Bhuvan Land Use/ Land Cover data of 2011-12. The area under cropland and fallow lands were considered for estimation purpose and 10 % of these areas were calculated as agroforestry based on the available information. In this way, extent of agroforestry in India was estimated to be 14.46 m ha excluding fallow land. Potential area under agroforestry was estimated to be about 17.45 m ha, including fallow land. In order to give more precise data on area under agroforestry, land use and land cover analysis of the selected districts in a particular agro-climatic zone was done using RS2/ LISS-3 data. The district level data was used to extrapolate the area under agroforestry for agro-climatic zone. The area under agroforestry in upper Gangetic plains, Trans Gangetic plains and Gujarat plains & hill region was estimated to be 0.27, 0.14 and 0.15m ha or 9.5, 4.38 and 6.14% of total geographical area (2.87,3.32 and 2.45 m ha), respectively. Soil organic carbon in existing agroforestry system on farmers field in different districts of Gujarat, Bihar, West Bengal and Uttar Pradesh indicates that in Gujarat, Dahod district have maximum soil orgaic carbon (42.2 t C ha^{-1}) followed by Junagarh. In other two districts (Anand and Patan), soil organic carbon was about 18.0 t C ha^{-1}. In other states, soil organic carbon varied from 22.4 to 26.5 t C ha^{-1}.

The biomass, biomass carbon, total carbon and net carbon sequestered in existing agroforestry system at district level in Gujarat, Bihar, West Bengal and Uttar Pradesh was estimated using CO_2FIX model and extrapolated for next 30-years. The tree biomass, soil carbon and total carbon in baseline was 1.30 to 3.43 t dry matter ha^{-1}, 10.02 to 24.13 t C ha^{-1} and 13.04 to 26.73 t C ha^{-1}, respectively in different districts of Gujarat and expected to increase up to 2.16 to 4.92 t dry matter ha^{-1}, 11.17 to 29.66 t C

ha^{-1} and 14.54 to 32.99 t C ha^{-1} in 30 years. Net carbon sequestered in agroforestry systems over the simulated period of 30 years would be 1.5 to 6.26 t C ha^{-1} in different districts of Gujarat. In case Nawada, Darbhanga and Purnia districts of Bihar, total carbon stock available in baseline varied from 9.54 to 21.32 t C ha^{-1} and expected to over 30-years it would be 18.89 to 28.11 t C ha^{-1}. Net carbon sequestered over the simulated period of 30 years would be 2.91 to 17.71 t C ha^{-1}. The total carbon available in existing agroforestry system in Bardhman dsitrict (West Bengal) and Mirzapur district (Uttar Pradesh) is 15.21 and 5.25 t C ha^{-1} and its corresponding value over the simulated period of 30 years would be 18.77 and 11.47 t C ha^{-1}.

The thermotolerance and carbon assimilation was studied for selected multipurpose tree species (MPTs) *viz. Pongamia pinnata* and *Dalbergia sissoo* and crops (wheat and mustard) in Temperature Gradient Tunnel (TGT). Differential responses to elevated temperature was reflected in the growth and physiology of the MPTs and the crops of agroforestry importance. Collar diameter of both *Pongamia pinnata* and *Dalbergia sissoo* relatively decreased at elevated temperature of about 5° C above ambient temperature. Although the adverse effects on CO_2 assimilation ($A_{maxPPFD}$) was relatively less at the 2^0 C elevated temperature than the ambient, but alarming effects were noted at the elevated level of 5°C above ambient. Rate of CO_2 assimilation ($A_{maxPPFD}$) decreased with increase in temperature.

Twenty six SHGs are working in watershed. Their total saving was recorded more than 2.60 lakhs. Wells recorded 93% higher water column during post intervention in October month. Two checkdams were successfully renovated in the watershed. In *kharif* 170 demonstrations and in *rabi* 70 demonstrations were conducted on various crops. Animal health camp was organized besides exposure visit of farmers and vermi-composting activity.

In Parasai-Sindh watershed all the open shallow dug wells (388 Nos.) are only means of irrigation in the watershed. The average depth and water level during October, 2013 of open wells were 9.66 and 2.56 m, respectively. The water column varied in the range of 0.39 to 13.14 m with average value of 7.10 m. These water columns are indeed sufficient to cater needs of drinking and irrigation. To develop agroforestry interventions in the watershed, 9954 seedlings of different species were planted on 57 farmers' fields and its survival varied from 55 to 72 % by the end of December, 2013.

During *rabi* 2012-13, wheat was shown in majority of the agricultural land (88.4%) followed by mustard and chickpea and Participatory demonstrations of wheat (30 No.) (HI-1418, HI-1479, HI-1531, HI-1544) and chickpea (15 No.) (JG-11 and JG-130) were laidout. During *kharif*, 2013, participatory demonstrations of soybean (15 No.) (var. PUSA-9712); groundnut (02 No.) (ICGV-9346 and *Jhumku*) and 80 demonstrations of agribore application in groundnut and soybean were conducted. About 90,000 rooted slips of napier bajra hybrid and guinea grass were transplanted in an area of about 2.0 ha (on bunds, near checkdams and around *haveli*) during rainy season. Two cuts at an interval of 60 days were obtained from the established areas. On an average Napier bajra hybrid and guinea grass recorded 4.57 and 3.35 DMY t ha^{-1}, respectively.

Weed density and biomass recorded during *rabi* (2012-13) in seven different agroforestry systems revealed that *Chenopodium album*, *Anagallis arvensis*, *Melilotus indica*, *Lathyrus sativus* and *Fumaria parviflora* were some of the most dominant

weeds. During *kharif,* 2013, *Commelina benghalensis, Cyperus rotundus, Celosia argentia, Cynodon dactylon, Echinochloa crusgalli, Digitaria sanguinalis* and *Tridex procumbens* were some of the most dominant weeds observed in different agroforestry systems. Under wasteland conditions during *rabi* season *Chenopodium album, Cirsium arvensis, Euphorbia hirta* and *Fumaria parviflora* were observed as dominant weeds with average density of 25.33 No. m^{-2} and average biomass of 40.64 D.W g m^{-2}. During *kharif,* the wastelands were heavily infested with *Cynodon dactylon* (19.62 No. m^{-2}) and under overall situation, the average density of weeds was 39.49 No. m^{-2}.

Growth chemicals like Ethephon, á-NAA, Gibberellic acid (GA_3), Salicylic acid and 6-Benzyl aminopurine (6BAP) have been used for increasing number of female flowers in the inflorescence. Similar to GA_3, and á-NAA, 6BAP has some positive effects on flowering initiation.

Clonal plants of *Pongamia pinnata* have shown consistent higher annual increment in height and coller diameter than seedling plants. Better adaptibility of clonal plants to dry hot summer has been reflected through its sustained photochemical efficiency in the form of diurnal leaf water potential, rate of CO_2 assimilation (CO_2 capture), thylakoid electron transport rate (ETR) and better management of cellular level oxidative stress.

In *Acacia nilotica* one provenance progeny trial (20) and two candidate plus tree trial (33 + 11 CPTs) are being evaluated. Of the 20 Provenance progenies, PR 1, 4, 15 and 20 from Sagar, Mandla, Shajapur and Jhansi showed better performance for the three characters. Among the CPT trials, plus trees from Sagar, Damoh, Buldhana, Khadwa, Indore and Shajaur showed superior performance.

In Jatropha breeding program, the mean performance of the hybrids was slightly higher than the parents for plant height, bole diameter, number of primary, secondary and total branches, branch length and the productive and non-productive branch diameter, while no difference was observed for the average productive branches and canopy diameter. New F_2 and BC_1 seeds were obtained after selfing and backcrossing in some of the potential hybrids.

Fifteen families of *Acacia nilotica* have been evaluated on the basis of their growth performance. Maximum height (11.50 m) and dbh (8.76 cm) was observed for a tree of family 14. Mean height, dbh and wood biomass was also highest for family 14 at the age of 8-years. Mean annual increment (MAI) in height and dbh was found maximum (0.81 m and 0.87 cm) for family 14. Significantly high age-age correlations were obtained for height between 6&7 and 6&8 (0.989 and 0.975) and also for diameter at breast height. This indicated that selection of trees may be done at younger age rather than at an older age.

In the candidate gene based analysis of the *Pongamia* genotypes, the gene specific primers have been synthesized for 22 genes involved in oil biosynthesis pathway through to silico analysis from different public data base domains.

The lac inoculation was done during first week of June. A total of 48.1 kg of brood lac was inoculated during June – July (Katki Crop) covering around 51 matured trees and 70 young trees and saplings. Harvesting was done at the end of October. The production of stick lac was 94.16 kg as against the production at farm (98.85 against 45.6 kg of brood lac). The production ratio was 1: 1.95 at the site as against 1: 2.16 in farm covering 40 mature trees and 6 young saplings. It was found that on an average a managed single tree of 80 cm girth and 13 m height can produce around 5.4 kg of stick lac as against 1.8 kg of brood lac inoculated. From 5.8 kg

of stick lac, 3 kg of valuable lac will fetch ₹1500 @500 kg^{-1} in local market and the same is repeated for the next cycle.

Among the five progeny trials of Jatropha, the potential genotypes for the current year are NRCJ 43, 36, 55, 64, 65, 70, 92, 111, 115,116, 146, 158 and 159 in terms of seed yield. Under the National Trial-II (Aug-2008) plantation, having 18 selected genotypes of 14 different centers. The superior performing genotypes are PDKV Nov 3, TNCJC 20, LBJJ 23, NRCJ 2 and TNCJC 19.

In *Pongamia*, the evaluation of germplasm accession in three candidate plus tree trials showed significant differences among genotypes for tree height and number of primary and total branches. Tree height ranged from 2.72 to 6.08 m across the trials, giving wide variation for selection of the plant type.

During the year besides monitoring growth of established agroforestry models, new boundary plantations on farmer's field, characterization of gum-butea for physico-chemical properties and study on effect of lac cultivation on gum yield and vice versa were taken up. In general, survival and growth of *A. nilotica* was better than *A. senegal*. During summer season (2013) natural oozing of gum in *A. nilotica* was observed and gum yield ranged from 0.59 to 294.14 g $tree^{-1}$ with an average of 38.27 g $tree^{-1}$. The gum tears varied in shape and size. During monsoon season, 1340 seedlings of *A. senegal* were planted on field boundaries of 26 farmers in Shivram Pur, Binwara and Rohtiyana villages in Tikamgarh District of Madhya Pradesh. Survival of planted seedlings of *A. senegal* ranged from 67 to 93%. The yield of mustard (var. varuna) grown in agri-horti-silviculture model (*Acacia senegal*, *Aegle marmelos* and *Citrus limon*) had significantly reduced up to 1.0m distance from tree trunk, while yield at 2.5m and 4.5 m distance was not affected. Maximum grain yield was obtained from the control plot (68.72 g m^{-2}) followed by *Aegle marmelos* (42.12 g m^{-2}) while minimum under *Acacia senegal* (30.64 g m^{-2}).

The physico-chemical properties of gum-butea were studied in relation to application of ethephon for inducing gum. Application of ethephon had varied effects on gum properties. Gum was partially soluble in water (0.26%), acetone (1.62%) and ethanol (1.24%), acidic in pH (5.7 to 5.9) and had EC from 1.74 to 1.96 dSm^{-1}. Significant variation in moisture content, bulk density and compressibility index of gum-butea was found due to method of application of ethephon. However, various doses of ethephon solution did not affect these properties. Gum obtained by spray of ethephon on surface of tree stem had maximum moisture (4.18%) and compressibility index (12.5%), while gum from injection of ethephon had minimum moisture and compressibility index. Tap density of gum-butea was neither affected by method of ethephon application nor by doses. However, gum obtained from control had higher bulk density (0.65 g cm^{-3}) than the gum obtained from ethephon treated trees. Method of application of ethephon has caused significant variation in nitrogen, protein, sugar and ash content of gum-butea while doses affected nitrogen and protein content only.

The studies on effect of lac cultivation on gum yield and vice versa in Butea trees revealed that settlement of lac insect was slightly better (26.7%) on trees with only lac insect inoculation than trees where both lac and gum production were taken (24.7%). It was concluded that simultaneous production of gum and lac from Butea trees yields more gum but less lac. However, decline in yield of lac was noticed only when gum yield goes beyond 400g $tree^{-1}$ of Butea.

1. INTRODUCTION

Climate change accompanied with land degradation on account of unabated forest destruction worldwide is a serious threat to very sustenance of mankind. Increasing population pressure and its associated demands limit expansion of forests which is already insufficient for healthy ecosystem. The choice of species varies in accordance with soil and climate. The universe has unique buffering capacity, keeping this fact in mind, piecemeal approach is not supposed to give desired results. This warrants landuse change on wider scale.The problem can be addressed through agroforestry which has proven potential of climate moderation, halting land degradation and increasing biomass production per unit area and time without demanding additional land. Agroforestry landuse is only viable option to avert degradation and bring back agricultural economy in harmony with nature. This is only option to slow down pace of imminent climate change which is threatening very survival of mankind. The chemical use and abuse in agriculture can be regulated through agroforestry. This will pave way for organic farming.

Agroforestry is region specific approach, hence, selection of components vary with region. However, process involved in companionship of components remain the same. Therefore, physiological and biochemical studies, tree improvement and environmental implications are being paid due attention to advance research and knowledge in the field of agroforestry. NRCAF has championed watershed studies in recent past and still working on overall development through watershed approach with due emphasis on agroforestry development. Concerted efforts are being made to workout area under agroforestry in India and carbon sequestration potential of agroforestry system.

National Research Centre for Agroforestry,in its national agroforestry mandate, has almost for more than twenty five years helped to systematize the science of agroforestry and has developed tools and methods to conduct agroforestry research. India has developed robust agroforestry science, innovations and practices that are attracting global interest.

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.

Mission

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

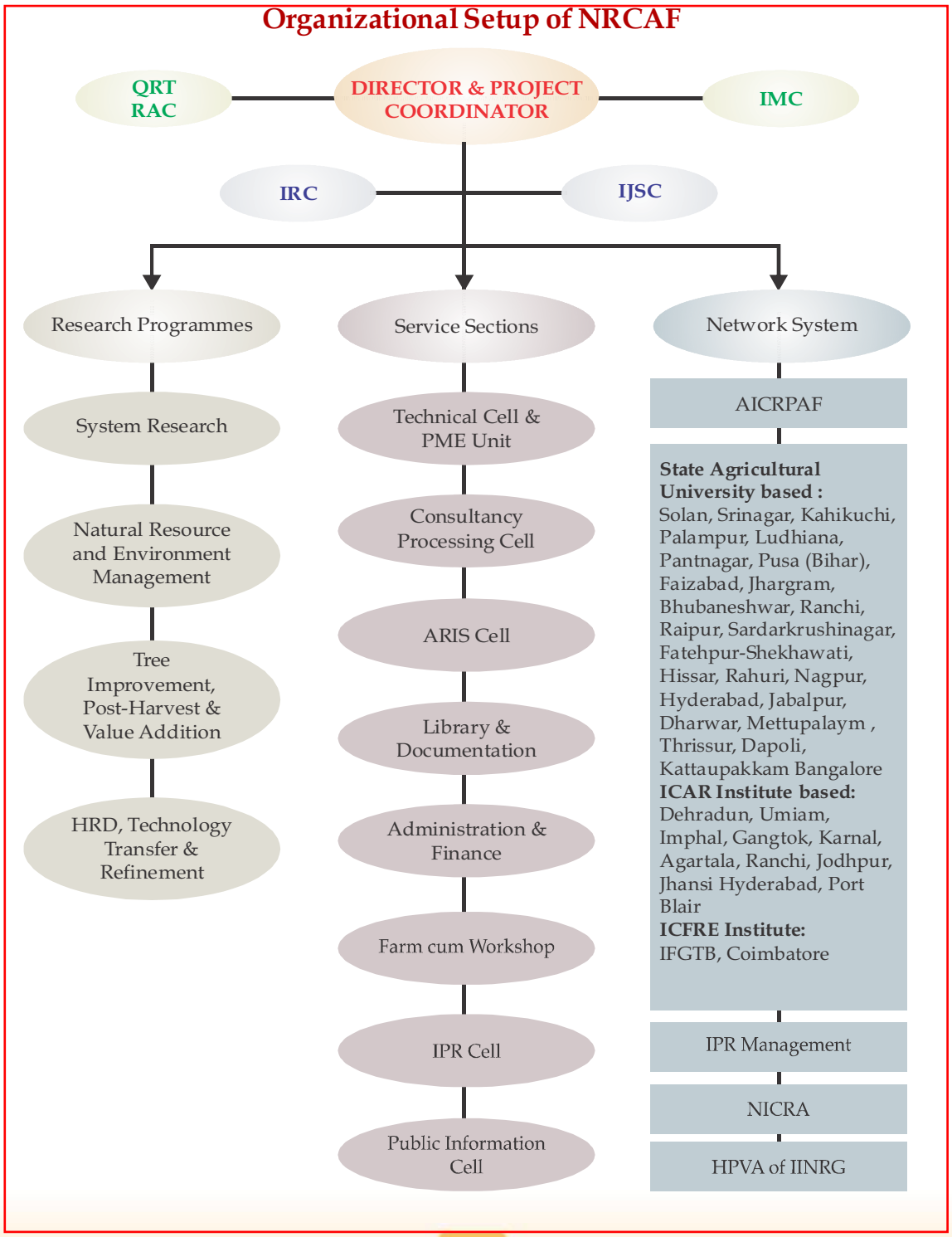
Mandate

- To undertake basic and applied research for developing and delivering technologies based on sustainable agroforestry practices for farms, marginal land and wastelands in different agroclimatic zones in India.
- To coordinate network research with the State Agricultural Universities/ICAR Institutes/other related research Institutes for identifying technologies which can be transferred from one region to another.
- To provide training in (a) research

methodologies and (b) use and application of technologies developed, at various levels.

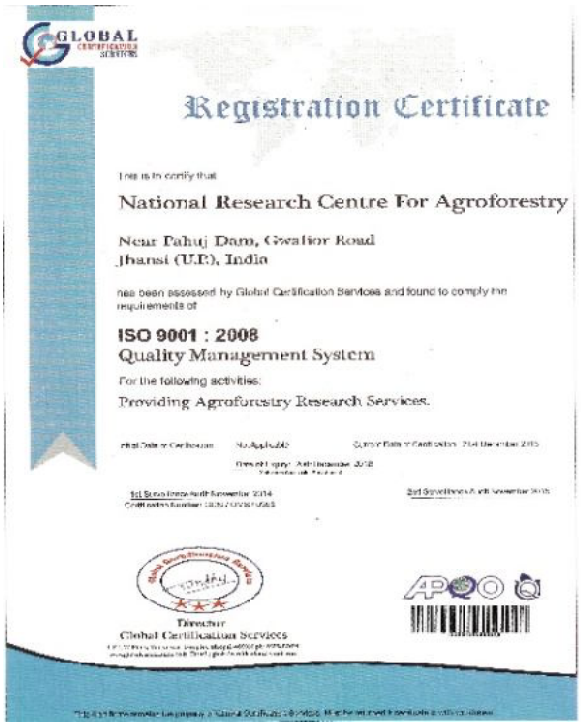
- To develop technological packages of different agroforestry practices for various agroclimatic zones for transfer to farm, field and wastelands.
- To act as repository of information on the subject.
- To collaborate with relevant national and international agencies for achieving the mandate.
- To provide consultancy.

Organizational Setup of NRCAF



ISO 9001:2008 Certification

NRCAF has been accredited ISO 9001-2008 certificate for its management standards on 18th December, 2013. The certificate was awarded in a simple function organized at the Centre.



INFRASTRUCTURE

Academic: NRCAF has a main office-cum laboratory building with conference hall, Computer room, library, 40- seat- capacity air-conditioned committee room with video-conferencing facility and one air-conditioned conference room of 100 sitting- capacity. Centre has been recognized by the Bundelkhand University as a study centre to conduct Ph.D. programme. The Centre conducts M.Sc. dissertation and Ph.D. coursesin Agroforestry, Horticulture, Environmental Sciences, Plant protection, Soil Science, Biotechnology and Soil – Water Conservation from differentrecognized Universities.

Laboratories: The Centre has state-of-the-art infrastructural facilities and has six well equipped laboratories (Agroforestry laboratory; Horticulture laboratory; Plant Protection laboratory; Agronomy & Plant Physiology laboratory and Tree Improvement laboratory). There is also an engineering workshop and photographic laboratory. The Centre has its own web server and regularly updated website (www.nrcaf.res.in). The entire network administration of computers internet and website management is looked after by the ARIS Cell, which also accommodatesa fully developed GIS laboratory.

Library: It has more than 4327 books (including Hindi books) and subscribes 16 Indian journals. It also maintains a CD-ROM Server with a bibliographic database from the CERA (Consortium for E- Resources in Agriculture). These databases are accessible toan individual scientist through LAN.

Photography, Meetings and Training: A well-equipped photography unit meets the day-to-day photographic and reprographic needs of the scientists. Provision also exists for the preparation of charts and posters. Photography unit is also equipped with digital cameras for still & video photography with audio recording options. Conference Hall/Committee/Training Room with modern facilities are available for scientific meetings and group discussions.

Research Farm and Facilities: The central research farm possess about 86 ha land. Major area is rocky and degraded land which was gradually developed. About 15% area occupied for office infrastructures, residential complex, roads etc. and rest 80% arable land have 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 hard pan (3-5 m below ground). Cultivation is totally dependent on rainfall. The area received

good rainfall. Due to continuous rainfall and water logging condition crops sown during *kharif* were badly affected and production almost failed. *Rabi* crops were sown in maximum available fields on account of availability of irrigation water from Pahuj canal as well as from shallow wells. Corp wise area and production during *rabi* 2012-13 and *kharif* 2013 and area sown during *rabi* 2013-14 are given below ;

Season / Crop & Variety	Area (ha)	Production (Tones)	Season / Crop & Variety	Area (ha)	Production (Qtls)
***Rabi* 2012-13**			***Kharif* 2013-14**		
Wheat - WH-147/PBW502/ 550/343/17	11.80	21.29	UrdT-9/Azad-2	2.50	0.02 (crop failed)
Barley-Jagrati	0.90	1.66	Moong-PDM-139/SML668	1.5	0.03 (green manure)
Gram-Samrat/KGD1168	2.35	0.88	Arhar-UPAS-120	2.30	-awaited
Pea-Sapana	0.44	0.25	Til - Shekhar	5.0	0.005 (crop failed)
Mustard – T-59 (varuna)	1.40	0.54	Jowar –CSV-15	0.80	Not germinated
Lentil –K-75	0.66	0.08	Maize-PHEM-2	0.20	Not germinated
Taramira-Karan	3.65	0.32	Dhaincha	4.35	Scattered Germination & green manure
Straw	-	35.90			

During *rabi* 2013-14 about 24.66 ha area was sown which include 2.97 ha experimental and 21.70 ha general cropped area. Due to prolong rainy days most of *rabi* season's crop were sown on residual moisture. Crop wise area sown in *rabi* season is given below :

Crop	Sown Area (ha)		Total (ha)
***Rabi* 2013-14**	**Experimental**	**General**	
Wheat WH147/PBW550/HI-1168	1.75	7.90	9.65
Gram samrat/KGD1168	-	3.45	3.45
Mustard Varuna	0.50	1.95	2.45
Lentil K-75	0.7184	0.40	1.11
Taramira Karan	-	3.00	3.00
Barley Jagrati	-	4.45	4.45
Pea Sapana	-	0.55	0.55
Total	**2.9684**	**21.70**	**24.66**

During the year a revenue to the tune of Rs. 4.49 lakhs could be generated from CR Farm and details thereof is as under;

S. No.	Farm Produce	Rs
1.	Grains	3,06,646
2.	Straw	92000
3.	Fruits (aonla/bael/ber/lemon)	14110
4.	Timber/Fuel wood/Bamboo	33420
5.	Grasses	2700
	Grand Total	**4,48,876**

The Research farm facilitated with most improved farm machineries and implements for mechanized farm operations. *viz.* tractors, trailers, reaper cum binder, rotovator, multicrop seed drill, HD cultivators, offset disc plough, gang harrow, hydraulic trolley, tractor with back hoe loader, shrubmaster, multicrop thrasher, bund/channel former, garden tractor with attachments, water tankers with pumping facility. A mini workshop cum implement shed have been facilitated with welding plants, drill machine, car washer, grinder, etc. besides other tools for repair and maintenance of farm machineries.

Budget (2013-14)

(Rs. in Lakhs)

S.N.	Head of Account	NON- PLAN		PLAN	
		Allocation	**Expenditure**	**Allocation**	**Expenditure**
A.	**Main Institute**				
1.	Establishment charges including LSP & PF	412.45	412.44	0.00	0.00
2.	Wages	5.50	5.50	0.00	0.00
3	Overtime allowance	0.05	0.05	0.00	0.00
4.	Traveling expenses	3.00	3.00	5.00	5.00
5.	Other charges including equipment & HRD	96.34	95.53	117.00	116.85
6.	Works	0.00	0.00	0.00	0.00
	Major(Original)	0.00	0.00	6.00	1.61
	Miner incl. R & M	10.00	10.00	17.00	16.99
	Total	**527.34**	**526.52**	**145.00**	**140.45**
1	Pension	11.40	11.03	0.00	0.00
2	P-Loans & Advances	1.00	0.78	0.00	0.00
B.	**Plan Scheme**				
1.	AICRP on Agroforestry, Coordinating Unit: NRCAF, Jhansi				1078.93
2.	Harvest and post-harvest processing and value addition of natural resins, gums and gum resins (ICAR, New Delhi)				5.51
3.	IPR Management in agroforestry (ICAR, New Delhi)				4.04
4.	National Initiative on Climate Resilient Agriculture (NICRA; ICAR, New Delhi)				29.68
5.	NAIP				38.09
C.	**Externally Funded Projects**				
1.	National network on integrated development of Jatropha and Karanj (NOVOD Board Project)				5.20
2.	Integrated Nutrient Management in Blackgram and Bengalgram in Central Indian Conditions (Science and Engineering Research Board, DST, India)				3.05
D	**Revenue Receipt**			**Target**	**Achievement**
				25.70	**59.70**

100% budget utilization under Plan and Non-Plan, higher revenue generation.

2. RESEARCH ACHIEVEMENTS

2.1. System Research Programme

AF01.17: Analysis of Eucalyptus based Agroforestry for Crop-lands in Jhansi

(A K Handa, Ram Newaj, Badre Alam, Anil Kumar, Ajit & Ramesh Singh)

Growth performance of coppice shoots of four different clones (C-3, C-6, C-7 and C-10) of Eucalyptus was evaluated based on dbh. The mean maximum dbh was recorded for clone C-10 (12.6 cm) and minimum for C-7 (11.8 cm). Under different plantation systems the minimum dbh (11.4 cm) was recorded for block plantation (3x3 m) and maximum under 5x4 m spacing in agrisilviculture system (13.1 cm). The monthly increment in dbh was also evaluated and the trend was similar to last year and ranged from 0.29 to 0.73 cm. In general, the increments were higher in those months receiving sizeable precipitation. The increment values in summer varied from 0.35 to 0.63 cm, whereas in winter 0.29 to 0.48 cm. The variations in rainy season increments were almost constant with values ranging from 0.64 to 0.73 cm. Maximum value of average monthly increment in dbhwas recorded in rainy season (0.68 cm) followed by summer (0.54 cm) and winter season (0.41 cm), supporting the hypothesis that increased moisture and optimum temperature during a month promotes tree growth.

Wheat was taken as intercrop during *rabi* season and blackgram during *kharif* season. The *kharif* crop was a failure due to continuous rains during the period. Growth, yield attributes and yield of wheat is given in Table 1, which clearly indicate that growth performance and yield attributes of crop were better when more open space was available to the intercrop. All growth and yield parameters were maximum under control compared to other systems except for straw yield which was maximum under boundary plantation. Under agrisilviculture system the spacing of 10 x 2 m registered better growth and yield parameters compared to 5 x 2 m spacing, although the tree geometry is same.

Diurnal variation in the photosynthetic photon flux density (PPFD) was noted. The diurnal variation in PPFD is one of the major determinants of the microclimatic effects at temporal scale. However, due to young canopy of tree, considerable reduction of the PPFD was not observed over the season under the canopy (summer and post monsoon). The diurnal PPFD in peak hot summer and post monsoon season has been recorded for comparative analysis. The

Table 1: Growth and yield parameters of wheat under different systems

Character	Agrisilviculture 5x4 m	Agrisilviculture 10x2 m	Boundary Plantation 2.5 x 2.5 m	Control
Plant height (cm)	85.62	86.17	83.63	94.70
Tillers plant^{-1}	4.78	4.63	4.55	5.70
Ear length (cm)	8.27	8.81	8.27	9.57
Plant population m^{-2}	63.63	60.71	69.46	67.30
Grain yield (t ha^{-1})	1.93	2.03	2.38	2.50
Straw yield (t ha^{-1})	3.47	4.29	4.84	4.19
Test weight (g)	3.12	2.84	3.09	3.27

average PPFD in peak hot summer season reached up to 1570 µmol m^{-2} s^{-1}, whereas in post monsoon season the maximum PPFD was 1380µmol $m^{-2}s^{-1}$ (Fig.1). Diurnal canopy temperature depression (CTD) of *Eucalyptus* trees was also measured in both the seasons. CTD was higher in peak hot summer than post monsoon season (Fig. 2). Chlorophyll content index (CCM index) of *Eucalyptus* trees was also relatively higher in post monsoon season than peak hot summer (Fig. 3).

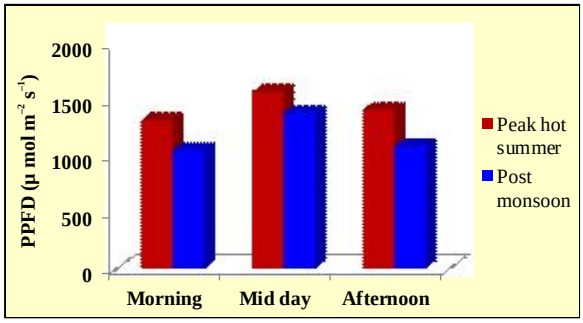


Fig.1: Diurnal PPFD in peak hot summer and post monsoon season

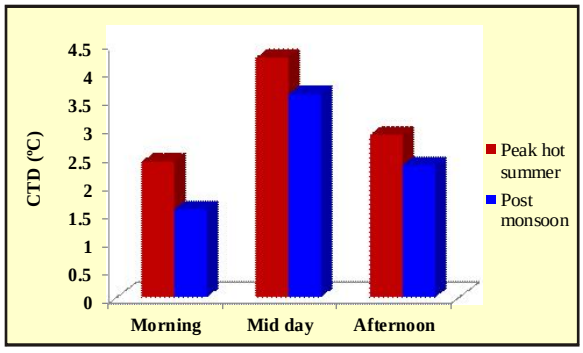


Fig. 2: Diurnal CTD of Eucalyptus trees in peak hot summer and post monsoon season

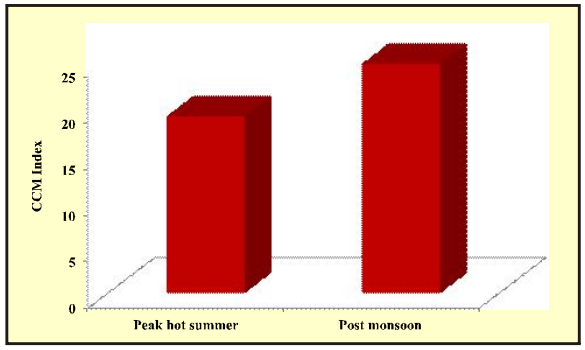


Fig. 3: CCM index of Eucalyptus trees in peak hot summer and post monsoon season

AF02.12: Effect of Irrigation on Performance of Aonla under Agroforestry Systems

(R K Tewari & Ramesh Singh)

Plant growth across the treatment did not show any definite trend partly because of high rainfall distributed evenly over the months and partly due to advanced age of the tree. Seventeen years old trees in experiment did not respond to basin irrigation, however, fruit yield per plant showed variation. Aonla plants subjected to year round watering in basin (T_3) recorded maximum 60.5 kg $tree^{-1}$ fruit yield followed by those irrigated in summer with crops in *rabi* (T_5) registering 57.7 kg $plant^{-1}$. Aonla plants under rainfed conditions (T_1) recorded minimum (45.6 kg $tree^{-1}$) fruit yield closely followed by those irrigated in summer (T_2) without crop. No crop during *kharif* could be sown due to continuous rainfall. In *rabi* 2013, wheat crop was sown in interspaces (Table 2). Leaf litter under various treatments was

Table 2: Plant growth and fruit yield of aonla as influenced by irrigation and crop

Treatment	Height (m)	Collar diameter (cm)	Canopy diameter (m)	Fruit yield (kg $plant^{-1}$)	Leaf litter (kg $tree^{-1}$)
T_1 Rainfed	5.78	57.1	5.80	45.6	7.64
T_2 Summer irrigated	5.40	63.2	5.80	48.2	6.86
T_3 Year round irrigated	6.25	78.7	6.40	60.5	8.12
T_4 (T_1 + Crop)	5.26	58.3	6.10	51.2	6.55
T_5 (T_2 + Crop)	6.20	77.8	7.20	57.7	7.90

recorded between 6.55 to 8.12 kg tree^{-1}. Agroforestry landuse in general favoured fruiting in aonla.

AF 02.14: Nutrient Management in Ber based Agri-horti System

(Sudhir Kumar, Anil Kumar, Rajendra Prasad & Inder Dev)

The experiment was laid out during August 2010 and as per the recommendation of RAC and due approval of IRC 2012, the technical programme was modified and 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 on set of monsoon. The main objective 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 observation recorded on fruits during 2013 reveled that (plant age 2½ years) all the fruit characters including yield were found non-significant. However, maximum fruit weight, fruit size, pulp weight, stone weight, pulp/stone ratio, TSS, number of fruits plant^{-1} and yield plant^{-1} was observed in treatment T_2, T_6, T_2, T_8, T_4, T_6, T_3 and T_3, respectively (Table 3).

Ber plants were pruned in the month of May (in 3rd year after planting). The pruned material ranged from 0.52 to 1.64 kg plant^{-1} being minimum in T_4 and maximum in T_8 on fresh weight basis and 0.29 to 0.84 kg plant^{-1} on dry weight basis. After pruning 100% survival was observed. The observations on collar diameter and canopy spreadin the month of December, 2013 revealed that collar diameter and canopy spread were non-significant as the modified treatments were imposed during July 2013 (Table 4).

Effect on Crop Production

Lentil (var. Malika masoor K-75) harvested in March, 2013 recorded seed yield in the range of 812 to 1075 kg ha^{-1} and straw yield of 1127 to 1428 kg ha^{-1} under different treatments. The treatments T_{10} (pure crop) and T_6 {Ber (75% RDF) + VAM + Sesame +

Table 3: Effect of treatments on ber (cv Seo) fruit characters and yield in 2013

Treat	Weight (g)	Size (cm)		Pulp weight (g)	Stone weight (g)	Pulp/ stone ratio	TSS ^{0}B	No. of fruits plant^{-1}	Yield (kg plant^{-1})
		L	W						
T_1	16.57	3.34	2.98	15.31	1.26	12.27	13.57	158.47	2.63
T_2	**19.12**	3.52	3.16	**17.93**	1.20	15.06	14.37	163.97	3.14
T_3	17.49	3.43	3.12	16.18	1.31	12.40	12.08	**237.98**	**4.16**
T_4	18.82	3.33	2.98	17.75	1.06	**16.84**	15.64	196.38	3.62
T_5	16.48	3.31	3.00	15.32	1.15	13.38	15.44	159.88	2.63
T_6	18.61	**3.55**	**3.18**	17.33	1.28	13.52	**17.33**	193.93	3.49
T_7	15.57	3.26	3.02	14.38	1.19	12.52	13.79	135.80	2.12
T_8	18.17	3.43	3.04	16.77	**1.40**	12.13	13.77	153.50	2.80
T_9	17.01	3.43	2.96	15.91	1.09	14.91	14.06	137.17	2.31
C.D. (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Effect of treatments on plant growth characters of ber (cv. Seo) fruits

Treatment	Collar diameter (cm)	Canopy spread (cm)	
		East-West	North-South
T_1	5.89	280.78	292.89
T_2	5.86	268.19	264.03
T_3	5.79	270.11	273.45
T_4	5.26	223.47	227.50
T_5	6.10	280.94	280.06
T_6	5.87	266.67	251.67
T_7	5.97	261.56	256.50
T_8	6.25	250.27	272.78
T_9	6.28	273.94	284.33
C.D. (0.05)	NS	NS	NS

Lentil} recorded highest seed yield of 1075 and 1034 kg ha^{-1} and were found significant as compared to other treatments. Similar trend was observed in straw yield (Table 5). During *kharif* 2013, sesame variety T-78 was sown on July, 2013, however, the crop failed due to continuous rainfall.

During *rabi* 2013, lentil was sown on 21stOctober, 2013 on residual fertility under rainfed condition. Plant population varied in the range of 24.1 to 27.2 plant m^{-2} at 60 days after sowing. Other parameters such as plant height, root length and root + shoot dry matter accumulation varied in the range of 15.89 to 18.19 cm, 6.54 to 8.07 cm and 0.45 to 0.51 g plant^{-1}, respectively.

Effect on soil characteristics

Soil samples were drawn at 0-15 and 15-30 cm depths from tree-rhizosphere (0.5m away from tree trunk) in October 2013. Significant variations in soil organic carbon (SOC) content, dehydrogenase activity and available N in surface soil was observed while in subsurface soil all the treatments were at par in respect to studied soil properties. On an average, application of nutrient treatments increased SOC, available N and dehydrogenase activity, and decreased EC of soil in comparison to control. In general, surface soil had higher SOC, dehydrogenase activity and available N than sub-surface soil samples. The increase in SOC and N, and decrease in EC values might be due to decomposition of FYM, which was added in soil (plant saucer) as part of nutrient management (Table 6).

Table 5: Lentil yield (*rabi* 2012) and growth parameters (*rabi* 2013) at 60 DAS

Treatments	*Rabi* 2012		*Rabi* 2013			
	Yield (kg ha^{-1})		Growth parameters 60DAS			
	Seed	Straw	Plant population (m^{-2})	Plant height (cm)	Root length (cm)	Biomass (DW g plant^{-1})
T_1						
T_2	812	1127	24.1	19.86	7.18	0.51
T_3						
T_4	934	1316	23.4	17.60	7.41	0.46
T_5						
T_6	1034	1418	26.2	18.40	7.05	0.49
T_7						
T_8	868	1262	26.8	17.30	6.54	0.48
T_9	879	1195	24.5	16.74	7.51	0.45
T_{10}	1075	1428	27.2	15.89	8.07	0.45
CV (%)	18.46	14.26	16.44	18.19	13.61	18.12
C.D. (0.05)	202	235	NS	NS	NS	NS

Table 6: Effect of nutrient management treatments on soil properties (rhizosphere soil taken 0.5m away from tree trunk in tree-saucer)

Treatments	Surface soil (0-15 cm)					Sub-surface soil (15-30cm)				
	pH 1:2	EC (μSm^{-1})	SOC (g kg^{-1})	Dehydor genase ($\mu gTPFg^{-1} d^{-1}$)	Available N ($kgha^{-1}$)	pH 1:2	EC (μSm^{-1})	SOC (gkg^{-1})	Dehydor genase ($\mu gTPFg^{-1} d^{-1}$)	Available N (kg ha^{-1})
T1	7.17	131.00	7.32	158.69	479.25	7.07	157.67	4.44	102.95	168.00
T2	7.08	141.00	6.83	160.66	229.50	7.12	146.33	4.59	105.48	153.75
T3	7.05	115.67	7.90	122.46	222.75	7.19	79.33	5.12	86.90	169.50
T4	7.01	108.33	7.27	119.01	198.75	6.84	173.00	5.17	131.78	178.50
T5	7.17	150.33	7.17	143.67	296.25	7.07	155.67	5.07	92.08	180.00
T6	6.68	181.00	6.10	137.68	226.50	7.15	84.67	3.76	108.43	150.00
T7	6.64	176.33	6.83	146.42	222.75	6.73	158.33	3.51	96.14	154.50
T8	7.53	164.33	6.20	122.89	204.00	7.38	58.33	4.73	88.42	174.00
T9	7.39	108.00	6.83	149.29	228.00	7.29	109.67	4.54	105.90	148.50
T10	6.65	245.00	4.20	127.36	212.25	7.05	185.67	3.83	84.17	174.15
C. D. (0.05)	NS	NS	0.05	0.05	0.02	NS	NS	NS	NS	NS

AF03.9: Initiation of Pruning and Its Intensity on Productivity of *Albizia procera*

(Inder Dev & K B Sridhar)

The experiment on initiation of pruning and its intensity on productivity of *A. procera* based silvipastoral system was initiated during August, 2006. *A. procera* saplings were planted during 2006 and the pasture component (*Chrysopogon fulvus* and *Stylosanthes seabrana*) was established during July-August, 2007. *A.procera* was pruned (25, 50 and 75% intensity) in 2nd, 3rd, 4th, 5th and 6th year pruning initiation treatments during December, 2013. Observations were recorded on various growth parameters *viz.*, survival (%), growth and biomass production and the data presented in Table 7, 8 and 9. By and large most of the growth parameters of tree and pasture components were not affected significantly due to age of pruning initiation and its intensity. *A. procera* gained height in the range of 11.51 to 13.30 m, dbh (14.18 to 16.21 cm), canopy spread (1.87 to 3.38 m). Canopy spread was significantly affected by initiation of pruning (Table 7). Various growth parameters of *C. fulvus* varied in the

Table 7: Survival and growth of *A. procera* influenced by age and intensity of pruning

Treatments	Survival (%)	Height (m)	dbh (cm)	Canopy spread (m)
Initiation of pruning				
2nd year	66.92	13.07	15.96	1.87
3rd year	56.85	13.22	14.84	2.13
4th year	50.87	13.30	14.18	2.43
5th year	50.28	12.39	16.21	2.88
6th year	34.20	11.51	14.55	3.38
CD (0.05)	NS	NS	NS	0.90
Intensity of pruning				
25%	53.88	12.03	15.21	2.35
50%	56.54	12.80	15.01	2.55
75%	45.05	13.27	15.21	2.71
C.D. (0.05)	NS	NS	NS	NS

Table 8: Growth of pasture component influenced by age and intensity of pruning in *A. procera* based silvipastoral system

Treatment	*Chrysopogon fulvus*			*Stylosanthes seabrana*	
	Height (m)	Tussock dia (cm)	Tillers/ tussock	Height (m)	Branches per plant
Initiation of pruning					
2nd year	1.54	31.88	65.37	1.35	65.05
3rd year	1.53	31.33	67.37	1.34	61.86
4th year	1.52	31.77	64.91	1.28	66.42
5th year	1.59	32.11	63.17	1.32	64.80
6th year	1.58	31.88	61.38	1.30	59.68
CD (0.05)	NS	NS	NS	NS	NS
Intensity of pruning					
25%	1.54	32.33	64.81	1.32	63.76
50%	1.55	32.26	64.31	1.33	65.12
75%	1.58	30.80	64.21	1.31	61.78
C.D. (0.05)	NS	NS	NS	NS	NS

Table 9:Fuelwood and forage production (D.W t ha^{-1}) influenced by age and intensity of pruning

Treatments	Tree		Pasture			Total	
	1	2	3	4	5 (3+4)	6 (2+3+4)	7 (1+6)
	Fuelwood	Leaf fodder	Grass fodder	Legume fodder	Total pasture	Fodder	Biomass
Initiation of pruning							
2nd year	1.28	0.73	2.51	3.34	5.85	6.58	7.87
3rd year	1.32	0.73	3.13	3.33	6.46	7.19	8.55
4th year	1.40	0.74	2.80	3.58	6.38	7.12	8.53
5th year	1.40	0.67	2.91	3.61	6.52	7.19	8.59
6th year	1.62	0.82	2.93	3.66	6.59	7.41	9.04
C.D. (0.05)	0.11	NS	NS	NS	NS	NS	NS
Intensity of pruning							
25%	1.24	0.58	2.87	3.24	6.11	6.69	7.93
50%	1.39	0.71	2.82	3.24	6.06	6.95	8.54
75%	1.58	0.92	2.89	4.12	7.01	7.65	9.08
C.D. (0.05)	0.05	0.03	NS	NS	NS	NS	0.57

***A. procera* based silvipastoral system under wasteland conditions**

range of 1.52-1.59 m (height), 30.80-32.11 cm (tussock dia), 61.38-67.37 tillers tussock^{-1}, whereas *S. seabrana* gained 1.28-1.35 m (height) and 59.68-65.12 branches plant^{-1} (Table 8). Leaf fodder production was also significantly affected by levels of pruning. Total biomass production from the silvipastoral system varied in the range of 7.87–9.04 (D.W.) t ha^{-1} and was significantly affected by the levels of pruning intensity (Table 9).

AF 3.9 B: Evaluation of *Ailanthus excelsa* and *Grewia optiva* in Alfisols (*Rakar* soil)

(Inder Dev & K B Sridhar)

Ailanthus excelsa and *Grewia optiva* planted during 2006 were evaluated for growth and biomass potential under alfisol (*Rakar* soil). Average height gained was 5.38 m (*A. excelsa*) and 4.92 m (*G. optiva*) and dbh was 11.01 cm (*A. excelsa*) and 6.27 cm (*G.optiva*). Biomass production from understorey *S. seabrana* was recorded as 4.88 D.W. t ha^{-1} (*A.excelsa*) and 4.69 (D.W.) t ha^{-1} (*G.optiva*)(Table 10).

Table 10: Performance of *A. excelsa* and *G. optiva* in Rakar soil (2013)

Parameters	*A. excelsa*	*G. optiva*
Survival (%)	72.3	79.4
Height (m)	5.38	4.92
dbh (cm)	11.01	6.27
Canopy spread (m)	3.49	2.76
Leaf fodder (kg ha^{-1})	96.6	128.5
Fuel wood (kg ha^{-1})	-	538.5
Stylosanthes (branches plant^{-1})	4.88	4.69
Stylosanthes biomass (DW t ha^{-1})	58.4	55.7
Total No. of surviving plants	38	47

A. exelcesa based silvipastoral system

Observational Trial

Development of Bamboo Based Agroforestry Systems in Six Agroclimatic Zones

(Inder Dev & K B Sridhar)

Development of bamboo based agroforestry systems in six agroclimatic zones of India was a part of the National Bamboo Mission project till 2012. Presently the same project is continuing as an observational trial at NRCAF. Plantation of *D. strictus*, *B. vulgaris* and *B. tulda* was done during 2007 (rainy season). The mature culms of *D. strictus*, *B. vulgaris* were harvested during 2012 (Nov./December). Average number of retained culms were 21.1 (*B. vulgaris*) and 24.2 (*D. strictus*) clump^{-1}.

Data presented in the Table 11 reveals that the average height was recorded 7.2 m (*B. vulgaris*), 5.43 m (*D strictus*) and 2.92 m (*B. tulda*). *B. vulgaris*, *D. strictus* and *B. tulda* recorded 3.8, 2.77 cm and 2.26 cm dbh, respectively. New culms emergence was less in *B. tulda* (1.6 culms clump^{-1}) and *B. vulgaris* (3.5 culms clump^{-1}) as compared to *D. strictus* (4.4 culms clump^{-1}). Average numbers of rhizomes were 3.0, 2.2 and 1.67 numbers in *B. vulgairs*, *D. strictus* and *B. tulda*, respectively. The average number of internodes was found to be 11 (*B. vulgaris*), 15.7 (*D. strictus*) and 8.82 (*B. tulda*). The average internodal length recorded in new culms was 24.53 cm (*B. vulgaris*), 20.88 cm (*D. strictus*) and 21.03 cm (*B. tulda*), respectively.

Table 11: Growth parameters of bamboo based agroforestry systems

Parameters	*Bambusa vulgaris*	*Dendrocalaums strictus*	*Bambusa tulda*
Average Height (m)	7.2	5.43	2.92
Average dbh (cm)	3.8	2.76	2.26
Average number of new culms	3.5	4.4	1.6
Average number of old culms	21.1	24.2	11.2
Average number of rhizomes	3	2.2	1.67
Average number of internodes per culm			
New culms	11.01	15.7	8.82
Old culms	29.40	26.72	17.6
Internodal length (cm)			
New culms	24.53	20.88	21.03
Old culms	25.38	16.0	21.0

Growth of (a) ***Bambusa vulgaris,*** ***(b) Dendrocalamus strictus***

2. RESEARCH ACHIEVEMENTS

2.2. Natural Resource & Environment Management Programme

AF01.16: Evaluation of Shade Tolerance of Crop Species for Agroforestry Systems

(Badre Alam & Ram Newaj)

Comparative shade adaptive traits through physio-biochemical responses in pea (*Pisum sativum*; Var. - Sapna) under varying regimes of shade *viz.* 33, 50 and 75% of incident sunlight or without shade (open) were studied. Conspicuous effects of different regimes of shade on crop phenology, physiological and biochemical properties including germination, plant growth, pigment profile as well as internal or cellular biochemistry of the crop like enzymatic activities etc. were noted. Germination pattern was different under different shades (Fig. 4). The lowest biomass index was observed in 75% shade, whereas it was highest in open grown plants (Fig. 5).

A definite trend was found in leaf chlorophyll under varying regimes of shade. Chlorophyll a, chlorophyll b and total chlorophyll increased with increase in shade intensity (Fig. 6). Anthocyanin, an antioxidant decreased with increase in shade intensity (Fig. 7). Certain enzymes like Nitrate reductase, which are the key factors to nitrogen metabolism, reduced significantly under shade (Fig. 8). Ascorbate oxidase activity increased and Catalase enzyme activity decreased with increase in shade intensity (Fig. 9 and 10).

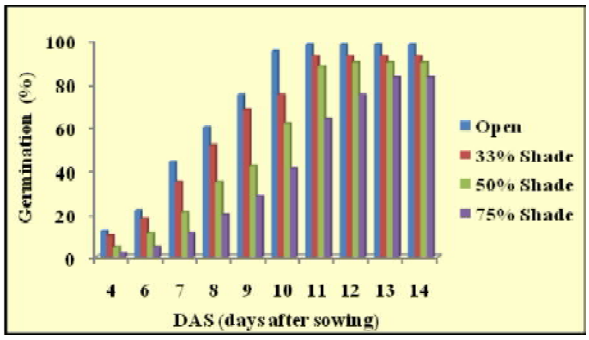


Fig. 4: Impact of varying regimes of shade on germination phenology of pea

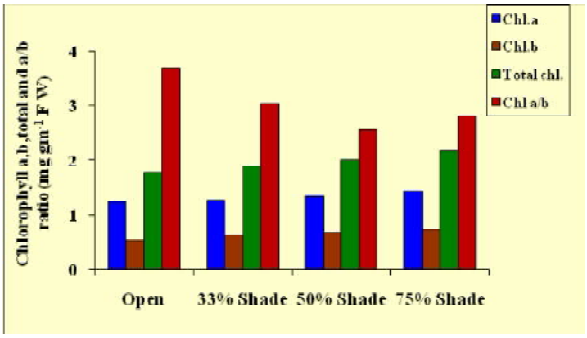


Fig.6: Effect of different levels of shades on pigment profile in pea leaves

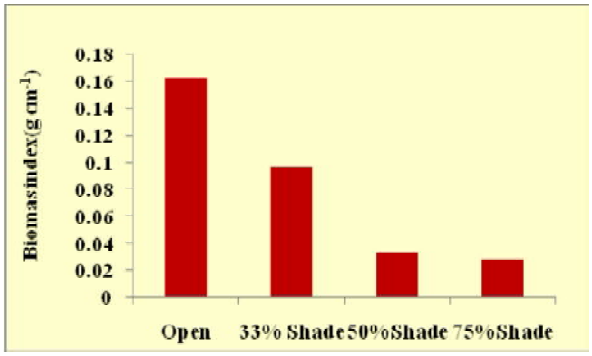


Fig. 5: Biomass index of pea after 60 DAS under varying regimes of shades

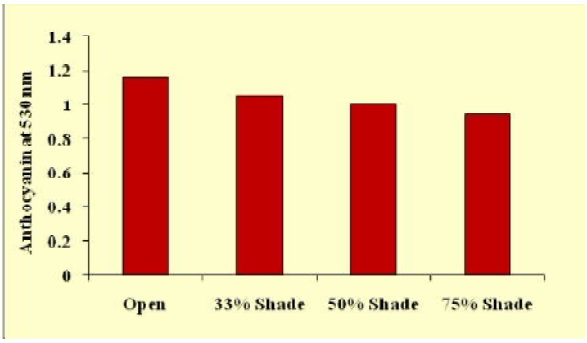


Fig.7: Anthocyanin an antioxidant alters under varying regimes of shade

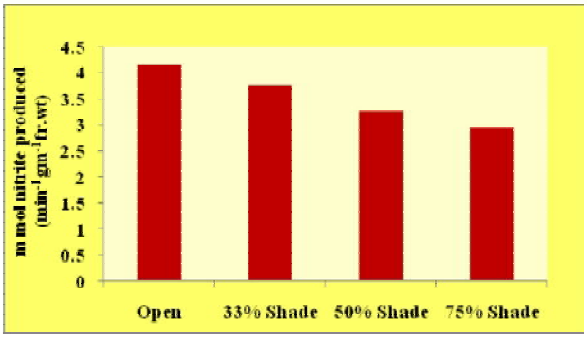


Fig.8: Effect of varying regimes of shades on nitrate reductase enzyme activity in pea leaves

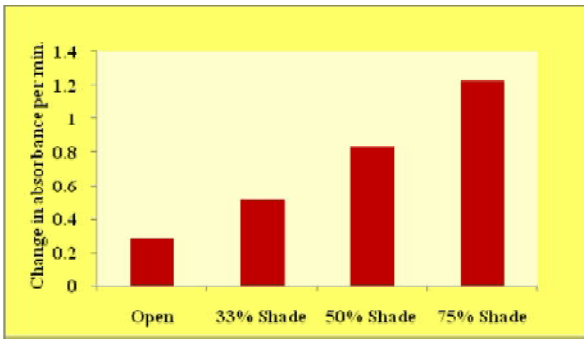


Fig.9: Effect of varying regimes of shades on Ascorbate enzyme activity of pea leaves

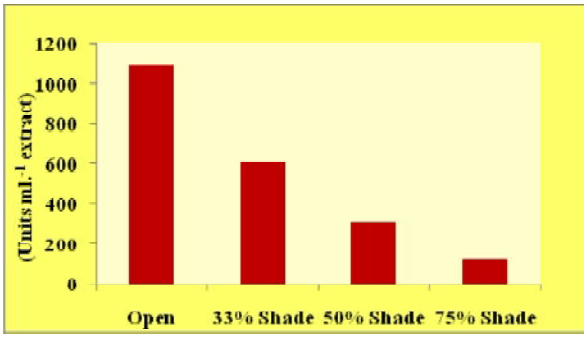


Fig. 10: Activity of catalase enzyme under varying regimes of shades

Systematic study of CO_2 assimilation ($A_{maxPPFD}$), thylakoid electron transport rate (ETR) and other related photosynthetic traits of pea crop under varying regimes of shade and in open were also done through advanced portable photosynthesis system. $A_{maxPPFD}$ was very low in deep or extreme shade conditions (Fig. 11). Electron transport rate (ETR) of open grown crop was higher than shade grown crop and gradually decreased with increase in shade intensity (Fig. 12). Due to limited rate of CO_2 assimilation and supply of thylakoid electron transport (ETR) across photosystem-2 (PS2), photochemical efficiency of the shade grown crops decreased, which ultimately reflected in the loss of seed yield under shade. Maximum reduction in yield was noted in 75% shade followed by 50% and 33% shade in comparison to open (Fig. 13). Impact of varying regimes of shade on leaf protein of pea was clearly noted when studied through SDS-PAGE (Plate-1).

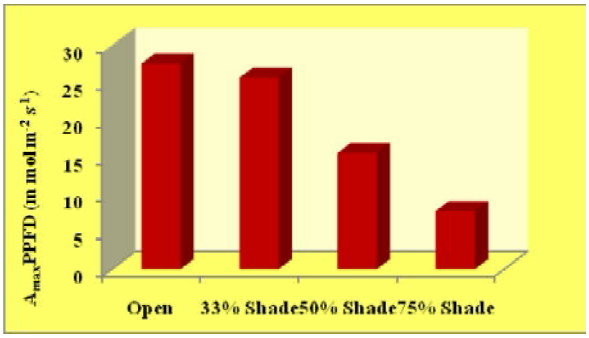


Fig.11: Effect of varying regimes of shade on maximum rate of CO_2 assimilation

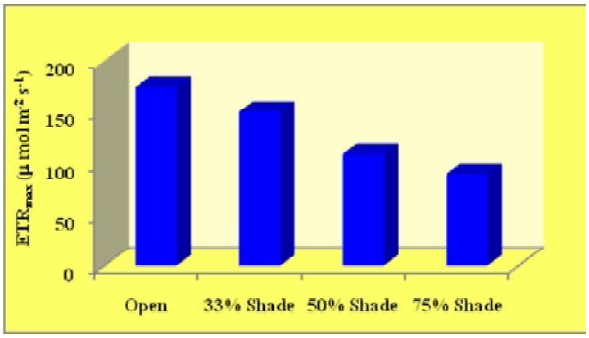


Fig.12: Effect of varying shade intensities on thylakoid electron transport rate of pea plants

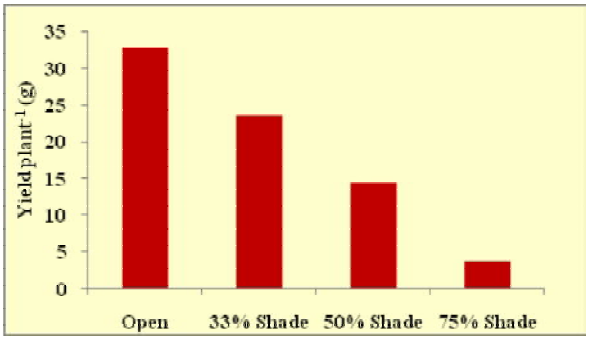


Fig. 13: Yield plant^{-1} of pea affected under varying regimes of shades

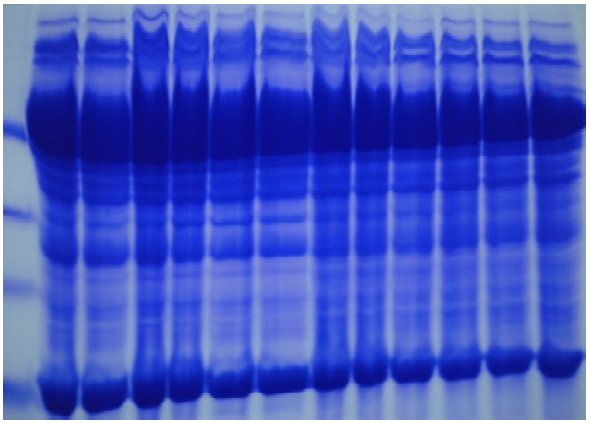


Plate1: Impact of varying regimes of shade on proteins of pea leaves studied through SDS-PAGE (M= molecular marker, Lane 1-3 indicating open, lane 4-6 = 33% shade, lane 7-9 = 50% shade and lane 10-12= 75% shade grown plants)

Similar experiments with pigeon pea (*Cajanus cajan*) under varying shade in *kharif* season is in progress with various physio-biochemical aspects towards assessing shade adaptability. Crop phenology and other related traits were affected because of excess and untimely rainfall in this season too. Impact of varying regimes of shade was clearly observed through biomass index (Fig.14). Various other experiments related to photosynthetic traits and cellular biochemistry have also been conducted. Cumulative effect of shade and adverse climatic factors was reflected plant yield (Fig.15).

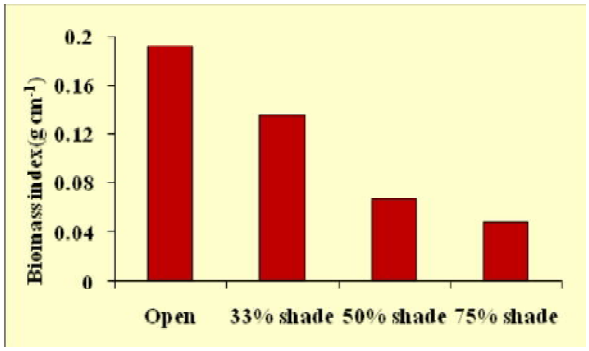


Fig.14: Effect of varying regimes of shade on biomass index of pigeon pea

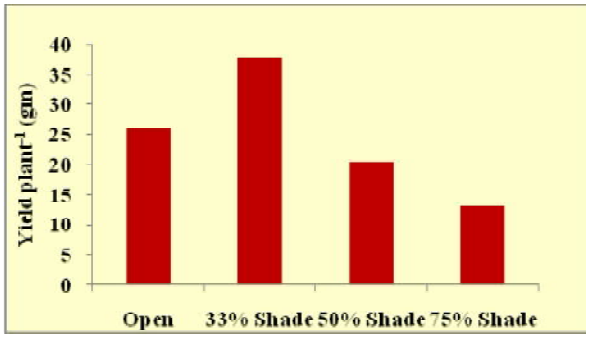


Fig.15: Effect of varying shades on yield (g plant^{-1}) of pigeon pea

AF01.24: Studies on Arbuscular Mycorrhizal Fungi of Important MPT's

(Anil Kumar & Rajendra Prasad)

This study was initiated during 2007-08 to develop suitable technology for inoculation of arbuscularmycorrhizal fungi (AMF) for inoculation of important agroforestry tree species and intercrops. To achieve this, experiments on integration of chemical fertilizers with bio-fertilizers, P saving on account of AM inoculations, effect of date of sowing and shade on efficacy of bio-fertilizers, effect of AM inoculations on root colonization by AMF and nodulation, allelopathic effects of weed/intercrops on AM colonization of main crop were conducted during 2013.

Effect of shade on efficiency of bio-fertilizers in important *Kharif* pulse crops: Effect of shade on efficacy of bio-fertilizers when combined with chemical fertilizers was studied in pulses *Phaseolus mungo, Vigna radiata* and *Glycine max*. Factorial experiments were carried out on effect of shade on efficiency of bio-fertilizers under net-house conditions. Each experiment consisted of four factors *viz.*, shade, arbuscularmycorrhizal fungi (AMF; *Acaulospora scrobiculata* + *Glomus intraradices*), rhizobium (Rhi) and phosphate solubilizing bacteria (PSB), each at two levels: shade (0 and 25%) and bio-fertilizers (applied and not applied).

Observations on plant growth parameters, yield, root colonization by AMF and nodulation indicated that plant height increased significantly by shade in all studied pulses. All bio-fertilizer based treatment combinations increased significantly plant height in *G. max*, and the values were comparable in *P. mungo* and *V. radiata* in different treatment combinations. Dry weight was reduced significantly by shade and most of the bio-fertilizer based treatment combinations increased it in all pulses, with few exceptions. Flowering and pod formation started earlier when un-shaded. Creeping behavior was recorded in *P. mungo* under shade. Yield was adversely affected by shade however bio-fertilizer based treatment combinations yieldincreased significantly in *P. mungo* and *V. radiata*, but not in *G. max*. Shade significantly increased number of nodules per plant and it did not affect root colonization by AMF.

In general, efficiency of bio-fertilizers was greater with no shade; however, their combined application with chemical fertilizer is likely to increase the growth and yield of studied pulses under and outside tree canopy in agroforestry systems (Fig.16).

Effect of AM inoculations on colonization index and nodulation: AM inoculations under sterile conditions have given good results at the Centre, especially in pulses. Local soils under different edaphic conditions are quite rich in AM microflora. To study the relevance of field inoculations, AM populations were monitored as root colonization index in different important *kharif* and *rabi* crops in inoculated and un-inoculated plants with and without P application at monthly intervals.

During *rabi* season observations in three pulses (bengal-gram, pea and lentil) and two cereals (wheat and barley) showed that DAP did not increase colonization index. AM inoculations significantly increased colonization index after one, two and three months barring few exceptions. Thus, the results indicated that inoculations with AMF in *rabi* crops are useful. Apart from it, DAP increased nodulations in all *rabi* crops and AM stimulated it only in lentil. Significant increase in nodulation was recorded after two and three months in bengal-gram and pea, while it was recorded after three months in lentil (Table 12).

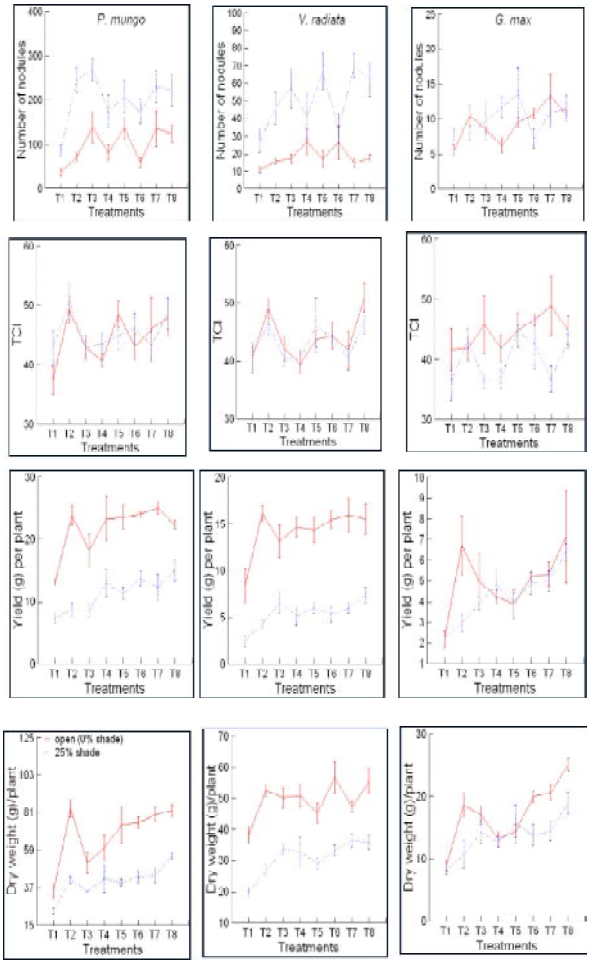


Fig. 16: Effect of shade on efficiency of bio-fertilizers in *P. mungo*, *V. radiata* and *G. max*. TCI- arcsine transformed value of colonization index. T1- Recommended dose of di-ammonium phosphate (DAP), T2- DAP + AMF, T3- DAP + Rhi, T4- DAP + PSB, T5- DAP + AMF + Rhi, T6- DAP + AMF + PSB, T7- DAP + Rhi + PSB, T8- DAP + AMF + Rhi + PSB.

Table 12: Effect of arbuscular mycorrhizal (AM) inoculations on root colonization and nodulation of important *rabi* crops with and without DAP application

Treatments	Colonization index* after				Number of nodules			
	One month	Two months	Three months	Mean	One month	Two months	Three months	Mean
Cicer arietinum								
Control	8.3	17.4	19.3	15.0	2	2	7	4
DAP	10.9	15.3	16.6	14.3	7	63	204	91
AMF	13.0	29.6	39.1	27.2	4	3	11	6
DAP + AMF	18.7	25.6	39.1	27.8	5	118	184	102
Mean	12.7	22.0	38.5		4	46	102	
Pisum sativum								
Control	8.8	20.5	28.4	19.2	24	40	49	38
DAP	8.8	20.0	25.0	17.9	65	171	692	309
AMF	12.8	35.2	38.6	28.9	48	47	46	47
DAP + AMF	16.5	36.5	42.2	31.7	63	233	612	303
Mean	11.7	28.1	33.5		50	123	350	
Lens culinaris								
Control	9.2	29.0	29.0	18.3	8	41	152	67
DAP	7.9	17.9	30.7	18.8	51	72	955	359
AMF	15.8	49.9	49.4	38.4	17	55	595	222
DAP + AMF	13.8	47.6	52.7	38.1	23	108	108	305
Mean	11.7	33.0	40.4		25	69	621	
Triticum aestivum								
Control	11.0	15.6	36.3	21.0				
DAP	10.4	13.0	27.5	17.0				
AMF	23.1	27.7	52.3	34.4				
DAP + AMF	22.6	26.7	46.0	31.8				
Mean	16.8	20.7	40.5					
Hordeum vulgare								
Control	14.2	17.5	32.5	21.4				
DAP	14.5	17.5	33.3	21.7				
AMF	23.4	37.7	50.1	37.1				
DAP + AMF	25.5	40.4	44.5	36.8				
Mean	19.4	22.3	40.1					
	$LSD_{0.05}$							
	Colonization index					Number of nodules		
	C. arietinum	*P. sativum*	*L. culinaris*	*T. aestivum*	*H. vulgare*	*C. arietinum*	*P. sativum*	*L. culinaris*
Treatment	3.8	3.0	2.4	2.5	1.6	27	60	95
Date of sampling	3.3	2.6	2.0	2.1	1.9	23	24	82
Interaction	6.6	5.3	4.1	4.3	3.3	46	104	164

*Arcsine transformed values of colonization index

During *kharif* season inoculations with AMF were also found beneficial in blackgram, greengram, soybean and sesame. Colonization index increased by DAP and AMF. Among treatments, DAP + AMF recorded maximum increase. Values of colonization index decreased from 2nd to 3rd month in control and DAP, but not in AMF or DAP + AMF. Effect of AMF inoculations on nodulation was found variable. DAP and AMF both stimulated nodulation in blackgram; only DAP + AMF increased it in greengram, and DAP and DAP + AMF increased it in soybean. Nodules also decreased from 2nd and 3rd month in blackgram and soybean, but not in greengram. This could be due to loss of AM colonized rootlets and nodules at maturity of crops (Table 13).

Allelopathic effects of weeds on AM colonization of crops: Effect of some

Table 13: Effect of arbuscular mycorrhizal (AM) inoculations on root colonization and nodulation of important *kharif* crops with and without DAP application

Treatments	Colonization index* after				Number of nodules			
	One month	Two months	Three months	Mean	One month	Two months	Three months	Mean
Phaseolus mungo								
Control	25.2	41.2	27.1	31.2	54	30	20	35
DAP	36.7	40.6	40.9	39.4	73	54	28	52
AMF	49.9	46.9	64.2	53.7	48	56	37	47
DAP + AMF	41.2	46.7	73.9	53.9	58	101	49	70
Mean	38.2	43.9	51.5		58	60	33	
Vigna radiata								
Control	66.1	22.5	16.3	35.0	38	13	28	26
DAP	76.4	16.2	22.9	38.5	26	12	28	22
AMF	72.2	35.1	59.7	55.7	31	17	22	23
DAP + AMF	73.6	36.8	63.8	58.1	43	20	55	39
Mean	72.1	27.6	40.6		34	15	33	
Glycine max								
Control	40.7	51.8	18.7	37.1	7	22	18	16
DAP	42.4	53.5	26.8	40.9	4	43	24	23
AMF	57.1	52.9	57.4	55.8	8	21	17	15
DAP + AMF	63.1	48.9	76.2	62.7	6	37	20	21
Mean	50.8	51.8	44.8		6	31	20	
Sesamum orientale								
Control	55.4	29.8	19.8	35.0				
DAP	58.1	46.2	36.6	47.0				
AMF	74.4	49.0	61.2	61.5				
DAP + AMF	58.7	52.8	68.5	60.0				
Mean	61.7	44.4	46.5					
	C.D. 0.05							
	Colonization index				Number of nodules			
	P. mungo	*V. radiata*	*G. max*	*S. orientale*	*P. mungo*	*V. radiata*	*G. max*	
Treatment	1.0	3.5	1.5	1.9	5	4	2	
Date of sampling	0.8	3.0	1.3	1.6	4	4	2	
Interaction	1.7	6.0	2.5	3.2	9	7	4	

*Arcsine transformed values of colonization

common weeds on arbuscularmycorrhizal colonization of important *rabi* crops was studied. Field observations were recorded on several weed/intercrop + main crop combinations. Initial results indicated that some weeds may be reducing AM colonization in wheat and bengalgram.

AF 01.25: Development of Soil Quality Index for Assessing Soil Health of Different Agroforestry Systems

(Rajendra Prasad, Ram Newaj & Ramesh Singh)

Soil health indicator values generated from aonla (*E. officinalis)* based agroforestry (AF) system were assigned functional scores and soil quality index was calculated. Also, the dynamics of soil organic carbon decomposition in different agroforestry system was studied.

Effect of soil moisture conservation techniques on soil health indicator values

The aonla based agroforestry system comprised of four soil moisture conservation (SMC) treatments *viz*. control, stone mulch, deep basin and deep basin+deep ploughing. For soil indicator values soil samples were drawn at 0-30 cm depth from tree-

rhizosphere (under tree canopy) and non rhizosphere zone (outside tree canopy). The data on soil indicator values presented in Table 14 indicated that in comparison to control, different SMC techniques had varying effects on soil properties. Similarly, irrespective of SMC techniques, tree-rhzospheric zone also influenced soil health indicator values. In general, the soil indicator values were more in tree-rhizophere than that in non rhizospher zone.

Effects of SMC techniques on functional scores and soil quality index

Based on regional threshold values for soil quality indicators, linear scoring function (LSF) *viz.* more is better, less is better and optimum were generated to assign scores to indicator values.

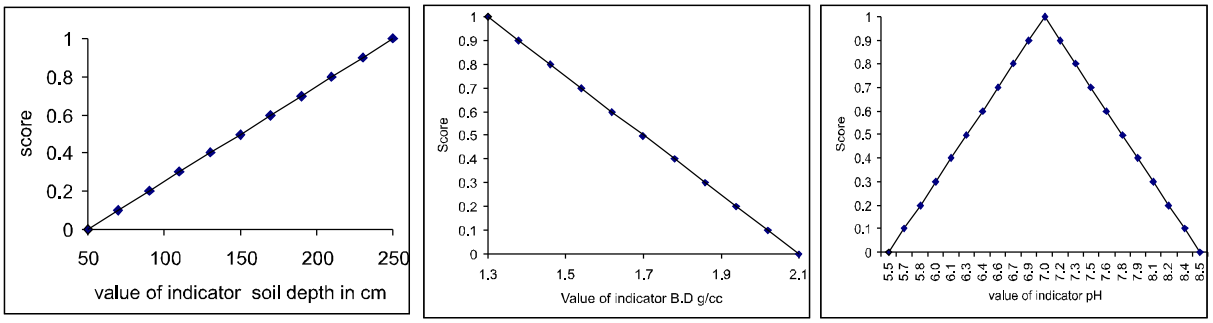
$$LSF\ (Y) = (x-s)/(t-s) \quad \text{---------- (1)}$$

$$LSF\ (Y) = 1-[(x-s)/(t-s)] \quad \text{------ (2)}$$

Where, 'Y' is the linear score, 'x' the soil property value, 's' the lower threshold value and 't' the upper threshold value. Equation 1 is for 'more is better' scoring function, equation 2 for 'less is better' and a combination of both for 'optimum' scoring function. Representative scoring functions, for example, for soil depth'more is better',

Table 14: Effect of soil moisture conservation techniques on soil health indicator values of aonla based AF System

Indicator	Rhizosphere soil indicator values					Non-Rhizosphere soil indicator values				
	Control	Stone mulch	Deep basin	Deep basin+ Deep ploughing	Mean	Control	Stone mulch	deep basin	Deep basin+ Deep ploughing	Mean
Rooting depth (cm)	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
Field capacity (%)	12.2	10.9	14.3	13.1	12.2	11.9	10.2	13.1	12.5	11.9
SOC (%)	0.6	0.6	0.6	0.5	0.6	0.5	0.5	0.5	0.4	0.5
CEC (Cmol kg^{-1})	10.3	9.5	15.4	13.1	10.3	8.6	8.7	11.4	10.1	8.6
Available N ($kgha^{-1}$)	279.1	272.8	250.9	257.2	265.0	276.0	269.7	235.2	238.3	254.8
Available P ($kgha^{-1}$)	9.1	9.8	11.9	11.7	10.6	7.9	8.0	9.7	8.5	7.9
Available K ($kgha^{-1}$)	154.2	148.3	162.5	173.5	159.6	140.3	131.1	147.5	163.5	145.6
Microbial biomass (μgg^{-1})	142.0	117.5	167.3	170.5	149.3	132.0	107.5	157.6	158.5	138.9
Dehydrogenase activity (μg TPFg^{-1} day^{-1})	99.9	102.2	159.6	135.2	124.2	104.8	94.4	105.7	86.7	97.9
Porosity (%)	39.9	40.2	39.8	41.8	40.4	36.6	37.2	37.0	37.7	37.1
Infiltration rate ($cmhr^{-1}$)	1.7	1.8	1.8	1.8	1.8	1.7	1.8	1.8	1.8	1.8
pH	7.2	7.1	7.3	7.3	7.2	6.8	7.0	7.0	7.1	7.0
EC (dSm^{-1})	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
Bulk density (gcm^{-3})	1.4	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4



a) b) c)

Fig. 17: Linear scoring function for, a) soil depth, b) bulk density and c) soil pH

bulk density 'less is better' and pH 'optimum' are depicted in Fig 17. Using these equations, functional scores were worked out for each observed indicator values and an unified value of SQI calculated (Table 15).

The different SMC treatments showed variations in functional scores of soil health indicators. The values of unified soil quality index (SQI) reveals that in relation to baseline reference (0.267), SMC techniques had brought an improvement in soil quality index of tree-rhizosphere in aonla based AF system. Maximum SQI (0.477) was found in treatment of deep basin followed by deep basin+ deep ploughing (0.452), while minimum in stone mulch. Similar trend in improvement of soil quality was observed in non rhizophere soil also. In all SMC treatments the soil from tree-rhizophere had more SQI values than the soil from non-rhziosphere (Fig.18).

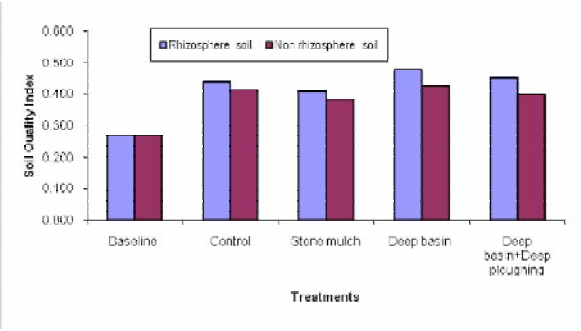


Fig.18: Effect of tree-rhizosphere on soil quality index in aonla based AF system

The improvement in SQI brought by different SMC treatments over regional baseline SQI ranged from 34.7 to 44.1% in tree-rhizosphere soil and from 31 to 37% in non rhizosphere (Table 16). Among SMC treatments, deep basin treatment brought maximum improvement in SQI, while stone mulch the least.

Table 15:Effects of soil moisture conservation techniques on functional scores for soil quality indicators of aonla based AF system

Soil Indicator	Baseline functional score	Functional score for Rhizosphere soil				Functional score for Non-Rhizosphere soil			
		Control	Stone mulch	Deep basin	Deep basin +Deep ploughing	Control	Stone mulch	Deep basin	Deep basin +Deep ploughing
Rooting depth (cm)	0.050	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
Field capacity (%)	0.133	0.149	0.059	0.289	0.205	0.127	0.016	0.205	0.167
SOC (%)	0.250	0.547	0.444	0.481	0.313	0.394	0.420	0.430	0.238
CEC ($Cmolkg^{-1}$)	0.400	0.412	0.379	0.616	0.522	0.344	0.348	0.455	0.402
Available N ($kgha^{-1}$)	0.353	1.000	1.000	1.000	1.000	1.000	1.000	0.913	0.931
Available P ($kgha^{-1}$)	0.118	0.063	0.108	0.227	0.215	0.001	0.001	0.099	0.028
Available K ($kgha^{-1}$)	0.200	0.271	0.242	0.313	0.367	0.202	0.156	0.238	0.317
Microbial biomass (μgg^{-1})	0.071	0.263	0.193	0.335	0.344	0.234	0.164	0.307	0.310
Dehydrogenase activity (μ g $TPFg^{-1}$ day^{-1})	0.100	0.299	0.309	0.538	0.441	0.319	0.278	0.323	0.247
Porosity (%)	0.183	0.495	0.337	0.330	0.363	0.383	0.286	0.284	0.295
Infiltration rate ($cmhr^{-1}$)	0.071	0.111	0.114	0.114	0.114	0.111	0.114	0.114	0.114
Soil pH	0.333	0.425	0.465	0.398	0.400	0.578	0.511	0.492	0.477
Soil EC ($dS\ m^{-1}$)	0.921	1.029	1.034	1.029	1.032	1.032	1.013	1.039	1.034
Bulk density (gcm^{-3})	0.550	0.838	0.841	0.813	0.815	0.866	0.842	0.838	0.833
Soil Quality Index	0.267	0.436	0.409	0.477	0.452	0.413	0.382	0.424	0.400

Table 16: Effects of SMC techniques on soil quality index in aonla based AF system

Treatments	Rhizosphere zone		Non-Rhizosphere zone	
	Soil Quality Index	% Over Baseline	Soil Quality Index	% Over Baseline
Baseline	0.267		0.267	
Control	0.436	38.7	0.413	35.4
Stone mulch	0.409	34.7	0.382	30.1
Deep basin	0.477	44.1	0.424	37.0
Deep basin+ Deep ploughing	0.452	40.9	0.400	33.2
Mean	0.434	38.5	0.400	33.3

Dynamics of soil organic carbon decomposition in different agroforestry systems

To study dynamics of soil organic carbon decomposition in different agroforestry systems, a laboratory experiment was conducted under constant temperature (25^0C) and moisture (70% of water holding capacity) for 90 days. Soil sample (100g) was incubated in glass jars. Jars were normally closed, but opened periodically to maintain moisture/aerobic conditions. The evolved CO_2 was trapped in 20 ml 0.5 N NaOH solution and precipitated by addition of $BaCl_2$ and measured by titration of residual NaOH to pH 7.0 with 0.5 N HCl. The evolved CO_2 was measured daily for 3 days, every 3-4 days in the following two weeks and every 7 days (week) till end of the incubation period *i.e.* 90 days. The change curve of daily mineralization of organic carbon was obtained by using the total burst of CO_2 during interval of measured time divided by days (Fig 19). The change curve reveals that irrespective of different agroforestry systems, there were two distinct bursts when soil organic carbon was released. The first was rapid decomposition and the other was slow decomposition. Duration of rapid decomposition was short, however, owned a large quantity of decomposition. The slow decomposing owned relatively smaller quantity but took a long time.

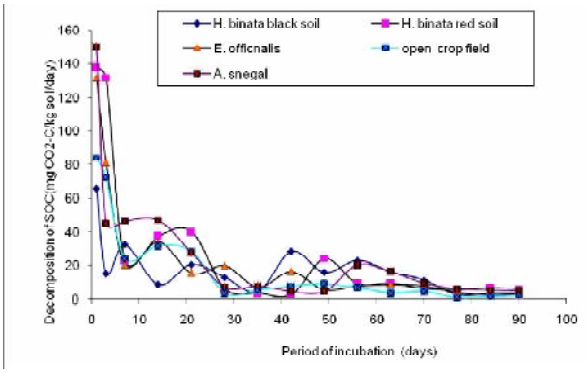


Fig.19: Decomposition rate of SOC in different agroforestry systems

Total release of CO_2-C varied from 265 to 452 mg CO_2-C kg^{-1} soil in different agroforestry systems, which accounted for 4.1 to 8.0% of SOC (Table 17). The maximum SOC was mineralized in open crop field while minimum in *H. binata* (black soil) AF system. It indicates that SOC in open crop field had large size of active pool, which decomposed rapidly in short time, whereas agroforestry system contained more size of

Table 17: Total soil organic carbon mineralization in AF systems

Agroforestry System	SOC (gkg^{-1} soil)	Total SOC mineralization (mg CO_2-Ckg^{-1} soil)	Total SOC (%) mineralization accounted for SOC (%)
***H. binata*-black soil**	6.45	265.09	4.11
***H. binata* -red soil**	7.32	452.55	6.19
E. officinalis	7.45	369.99	4.97
A. senegal	7.14	405.52	5.68
Open crop field	3.55	284.81	8.02

slow pool decomposing steadily over a long period.

AF05.6: Model Watershed Project on Natural Resource Management through Agroforestry Interventions at Garhkundar, Tikamgarh, M.P.

(S K Dhyani, R K Tewari, Ramesh Singh, R P Dwivedi & R H Rizvi)

National Research Centre for Agroforestry, Jhansi selected Garhkundar-Dabar watershed in 2005-06 to improve rural livelihood through participatory watershed management by cost-effective integrated natural resource management and to establish a site for learning for farmers, rural community and also for researchers and other stakeholders (development agencies and policy makers) to understand the impact of integrated watershed management interventions in Bundelkhand region. Progress made during the year 2013 under different heads is as follow:

Hydrological Monitoring

Datalogger based automatic stage level recorders were installed at six sites, including control watershed, to measure runoff during rainy season. Besides this, manual and self-recording rain gauges were also installed in the watershed to measure the rainfall. Total 1101.2 mm rainfall was received spread over 58 rainy days (Fig. 20).

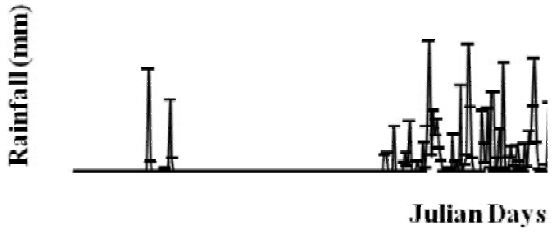


Fig. 20: Rainfall recorded at Garhkundar-Dabar watershed during 2013

All open shallow dug wells in treated (109 Nos.) and untreated (42 Nos.) watershed were monitored fortnightly for water level. The average depth of the wells is 8.54 and 8.71 m in treated and untreated watershed, respectively. Due to conservation measures in treated watershed, the water column varied from 1.5 to 11.02 m with average of 5.75 m during month of October, 2013. However, average water column in control watershed was 25 per cent lower than treated watershed (Fig. 21). Majority of the open wells support continuous operation of water pump. Due to availability of water, *rabi* sowing was done in entire cultivable land of the watershed.

It was observed that groundwater recharge in treated watershed reached 86 per cent capacity with 600 mm annual rainfall, however, this situation could be arrived at with 1100 mm annual rainfall in control watershed (watershed without any interventions). Probability analysis based on last 69 years annual rainfall suggests getting annual rainfall of 600 (32% less than the average annual rainfall) and 1100 mm (25% higher than avg.) is 86 and 20 per cent, respectively. Probability analysis shows that there are maximum chances to get 600 mm rainfall during the year. Therefore, even with deficit rainfall by about 32 per cent, water

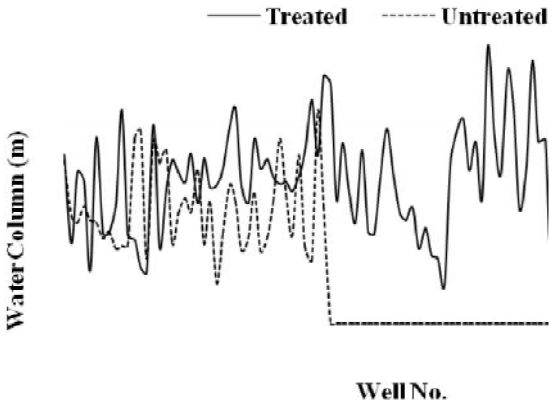


Fig. 21: Water column in open wells of treated and untreated watershed during October, 2013

crisis in drought prone Bundelkhand region can be averted by adopting agroforestry based watershed interventions as it will recharge the weathered zone by 86 per cent which will serve the purpose of drinking and irrigation.

Crop and Agroforestry Demonstration

During the period under report 2250 plants of sagoun, kumat, babool, bamboo and custard apple were planted under agroforestry system on more than 60 farmer's field. Due emphasis was given on boundary plants taken with species which are most tolerant to biotic pressure (Table 18).

Table 18: Plantation on farmer's field under agroforestry system 2013

Species	Common Name	No. Plants
Tectona grandis	Sagoun	1041
Acacia senegal	Kumat	910
Acacia nilotica	Babool	185
Bambusa valgaris	Bamboo	19
	Sitaphal	135

Productivity of wheat, gram, pea and groundnut under sloe cropping was recorded as 3.52, 1.68, 1.69 and 0.87 tha^{-1}, respectively (Table 19). Til and blackgram crops failed in watershed due to continuous high rainfall. Under agrihorticulture system, wheat yielded 2.75 to 2.96, gram 1.18 to 1.29 and groundnut 0.695 to 0.0.785 tha^{-1}. Yield of groundnut affected severely due excess rainfall.

Growth of fruit plants under agroforestry system was recorded and presented in Table 20. Growth of guava plants on Shri Dhani Ram field is poor than that of Shri Salim's field due to better soil depth on latter's field. All the fruit plants have started bearing fruits and contributing to farmer economy. The fruit are sold in local market. Shri Dhani Ram is also earning from sale of *lasoda* planted along his field boundary. The plants are regularly pruned and fruits are marketed.

Table 19: Crop yield in Garhkundar-Dabar watershed

Rabi 2012-13		*Kharif* 2013	
Crop	**Yield (tha^{-1})**	**Crop**	**Yield (tha^{-1})**
Wheat	3.52	Groundnut	0.87
Gram	1.68	Til	0.065
Pea	1.69	Blackgram	0.17

Table 20: Growth of fruit plant under agroforestry system (after 6 years in plantation)

Farmer	Fruit plant	Avg. Height (m)	Collar Diameter (cm)	Spread (m)	Fruit yield (kg $plant^{-1}$)
Shri Dhani Ram	Guava	3.42	10.2	3.58	24.80
	Citrus	3.88	9.76	4.24	11.20
Shri Salim	Guava	4.20	11.74	4.7	28.26
Shri Himmat	Anola	4.10	12.80	4.42	15.80

A survey of 4 hamlets of the watershed was conducted to know the status of home garden plantation of fruit trees. A total of 179 families were surveyed, out of which 70 (39%) families had fruit plants in their home garden (Table 21). They mostly included papayas, citrus, guava, ber, pomegranate and moringas (drumstick).

Table 21: Families possesses fruit plants in their home yards.

Hamlet Name	Family Surveyed	Family with fruit plants
Ravtiyana	33	23 (69.7%)
Shivrampur	41	21 (51.2%)
Dabar	47	1 (2.5%)
Kundar	58	25 (43.1%)
Total	179	70 (39%)

Village Ravtiyana being tribal village has maximum households with fruit plants in their home yard followed by Shivrampur which is SC village, village Dabar, dominated

by OBC has least households with fruit plants while village Kundar, a habitat with mixed population showed fruit plantation in home yards of 43% families. Observation on overall plants survival in the watershed is given in Table 22. It is observed that overall survival in watershed over the year is quite low due to open grazing in summer, moisture stress and harsh weather condition.

Table 22: Species wise survival of plants in GKD watershed (Planted during 2006-13)

Species	Total No. of Plants	Total Survival (Nov. 2013)
Anola	864	51 (5.9%)
Guava	1527	189 (12.4%)
Citrus	638	77 (12.1%)
Babul	700	118 (16.9%)
Kumat	1925	764 (39.7%)
Teak	3734	1356 (36.3%)
Bamboo	457	122 (26.7%)
Neem	877	07 (1.0%)
Shisham	456	16 (3.5%)
Eucalyptus	222	2 (1.0)
Other	4005	458 (11.4%)

Guava and citrus registered around 12% survival on two farmer field and in home yard while kumat, teak and bamboo recorded highest survival (around 26.7-39.7%) on field bunds, hence in great demand. They can with stand high biotic pressure in addition to abiotic stress while others failed. Based on overall survival of plants in the watershed, it is concluded that kumat as live fence, teak as boundary plantation and bamboo along water courses may be encouraged in the region for increasing permanent vegetal cover. Fruits plants should be encouraged as home yard plantation for institutional security. Babul is another species that can be promoted in Bundelkhand region.

Industriousness in watershed was studied. It was learned that during the year one SHG member (*Maab Shitla Swayam Sahayata Samooh*) Shri Gulab Singh S/O Smt. Chanda started idol making during durga puja, 2013. He made 11 idols while Shri Shyam H/O Smt Shashi made 16 idols. Shri Narendra Prajapati S/O Smt. Urmila is running cycle repair shop in village while his younger brother Ravi is undergoing training on motor cycle repair.

AF 05.11: Multi-Source Inventory Methods for Quantifying Carbon Stocks through Generalized Volume/ Biomass Equations for Prominent Agroforestry Species in India

(Ajit, A K Handa & R H Rizvi)

Generalized models for predicting biomass of Poplar spp.

A total of 11 published equations on biomass could be traced for the state of Haryana. The equation pertains to Ambala, Karnal, Hisar and Yamunanagar. The observed range of dbh values for the harvested trees varied from 14.6 to 30 cm and the observed dbh range for the biomass varied from 28.60 to 622.64 (kg tree^{-1}).

A total of three published equations on biomass could be traced for state of Uttar Pradesh. The equation pertains to Saharanpur and Yamunanagar. The observed range of dbh values for the harvested trees varied from 13.7 to 26.7 cm and the observed dbh range for the biomass varied from 23.82 to 104.27 (kg tree^{-1}). Although some papers pertaining to the data of Punjab state, discussed age wise values of biomass, however the fitting of equation was not attempted and accordingly not included for development of generalized equations.

A total of five published equations on biomass could be traced for state of Bihar.

The equation pertains to Samastipur. The observed range of dbh values for the harvested trees varied from 1 to 50 cm and the observed dbh range for the Biomass varied from 4.79 to 194.05 (kg tree^{-1}).

Country level stem biomass generalized equation

A total of 19 published equations on biomass could be traced for the states of Uttar Pradesh, Haryana and Bihar. These equations pertain to Samastipur, Karnal, Hisar and Yamunanagar. The observed range of dbh values for the harvested trees varied from 1 to 50 cm and the observed range for the stem biomass varied from 4.79 to 622.64 (kg tree^{-1}).

The simulated data point (dbh and Total biomass) for these equations were clubbed into one data set for Country Level as a whole, fitted model **Biomass = a/ [1+e$^{(p-b*dbh)}$]** was fitted on this country level data set. The parameter estimates (a, p and b) along with their approx. standard error and approximate confidence limit has been compiled. The equations **Biomass = 252.1000/ [1+e$^{(6.0766-0.2674dbh)}$]** with **(R^2 =0.75395)** is proposed to be used for predicting or estimating the biomass of the tree on the basis of their observed value. Residual diagnostics plots for the fitted model were prepared and the graphs (Fig. 22) clearly elaborate that the fitted equation can be used to predict the biomass for the dbh range of 1 to 50 cm.

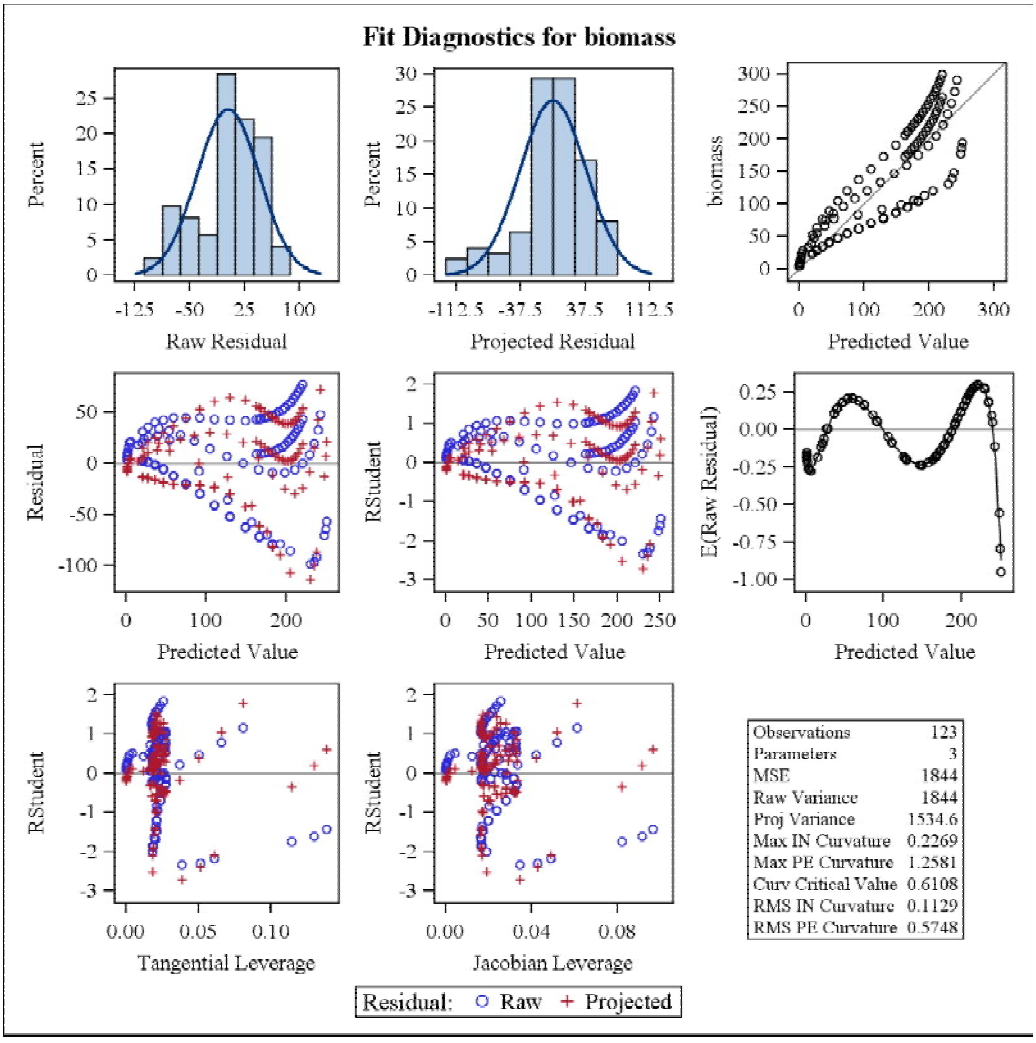


Fig.22: Fit diagnostics plot for the fitted generalized biomass model

ICAR Net Work Project

National Initiative on Climate Resilient Agriculture

(S K Dhyani, Ram Newaj, Rajendra Prasad, A K Handa, Badre Alam, Ajit & R H Rizvi)

During 3rd year (2013) of the project, mapping of agroforestry in three agro-climatic zone, assessment of carbon sequestration potential of existing agroforestry system on farmers field in four districts of Gujarat, three districts in Bihar, and one district each in West Bengal and Uttar Pradesh, soil organic carbon in agroforestry system in these districts and thermotolerance study in TGT were undertaken. The results of each activity are as follows:

1. Mapping of agroforestry area using GIS and Remote Sensing

Preliminary Estimates of Area under Agroforestry in India

Extent of area under agroforestry in India was estimated usingBhuvan Land Use/ Land Cover data of 2011-12. The map service was on Land use/ Land cover map of India on 1:250000 scale and under Bhuvan– Thematic Services of NRSC, ISRO. The LULC maps were generated using multi-temporal satellite data of IRS AWiFS sensor for the year 2011-12. The area under cropland and fallow land were considered for estimation purpose and 10% of these areas were calculated as agroforestry based on the available information. Therefore, extent of agroforestry in India was estimated to be 14.46 m ha when fallow land was not included (Table 23). Potential area under agroforestry was estimated to be about 17.45 m ha, when fallow land was included. Similarly the area under agroforestry in different states was also estimated. Among all the states, Uttar Pradesh, Maharashtra and Rajasthan are ranked first, second and third in terms of area under agroforestry *i.e.*1.86, 1.61 and 1.55 m ha, respectively. These preliminary estimates may be considered for state and country level planning. Thematic map showing different agroforestry systems in India is depicted in Fig.23.

Table 23: Preliminary estimates of area under agroforestry in India

(Figures in Lakh ha)

State/ UT	Cropland	Fallow land	AF area (excluding fallow)	AF area (including fallow)
Andhra Pradesh	117.52	49.83	11.75	16.73
Arunachal Pradesh	1.76	0.06	0.18	0.18
Assam	25.90	0.81	2.59	2.67
Bihar	75.65	3.85	7.56	7.95
Chhattisgarh	60.07	9.90	6.01	6.99
Delhi	0.49	0.08	0.05	0.06
Goa	0.93	0.17	0.09	0.11
Gujarat	81.26	27.71	8.13	10.89
Haryana	33.59	1.58	3.36	3.52
Himachal Pradesh	3.27	--	0.33	--
J & K	8.83	0.53	0.88	0.94
Jharkhand	29.32	24.04	2.93	5.34
Karnataka	92.42	36.94	9.24	12.93
Kerala	8.60	0.83	0.86	0.94
Madhya Pradesh	117.24	17.27	11.72	13.45
Maharashtra	160.67	30.95	16.07	19.16
Meghalaya	2.19	--	0.22	--
Manipur	1.82	--	0.18	--
Mizoram	0.40	--	0.04	--
Nagaland	0.47	0.01	0.05	0.05
Orissa	56.49	23.91	5.65	8.04
Puducherry	0.12	0.05	0.01	0.02
Punjab	41.30	0.73	4.13	4.20
Rajasthan	155.11	50.01	15.51	20.51
Sikkim	0.68	0.11	0.07	0.08
Tripura	2.56	0.03	0.26	0.26
Tamil Nadu	64.99	3.82	6.50	6.88
Uttar Pradesh	186.41	10.71	18.64	19.71
Uttarakhand	7.06	0.39	0.71	0.74
West Bengal	36.00	4.56	3.60	4.05
All India	**1445.88**	**298.95**	**144.59**	**174.48**

Source: Bhuvan LULC (2011-12), NRSC, Hyderabad, (**Error! Hyperlink reference not valid.**)

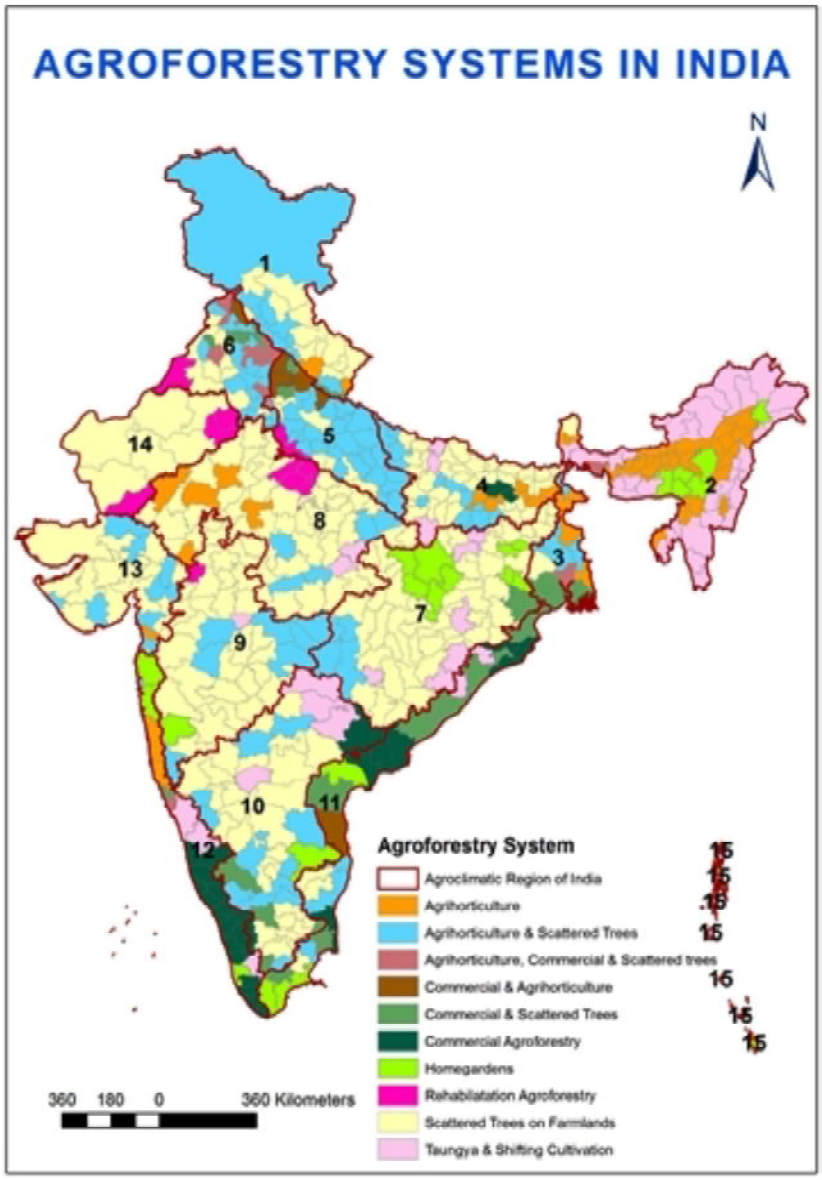


Fig. 23: Thematic map showing various agroforestry systems in India

Districts surveyed

During year 2013-14, selected districts in Uttar Pradesh, Gujarat, Bihar and West Bengal were surveyed and data on existing agroforestry systems were collected through GPS. The growth (dbh at 1.37m) data were also recorded during field survey (Table 24).

Table 24: Districts surveyed in different states for agroforestry systems

State	District (s)
Uttar Pradesh	Bulandshahar, Firozabad, Gorakhpur, Mirzapur, Shahjahanpur
Gujarat	Junagarh, Anand, Dahod, Patan
Bihar	Darbhanga, Purnia, Nawada
W. Bengal	Bardhman

Agro-climatic zone wise estimated area under agroforestry

Estimation of area under agroforestry at country level requires huge data processing. So keeping this in view, 20% districts from each agro-climatic zone were selected representing states falling in that particular zone. Land use and land cover analysis of the selected districts was done using RS2/ LISS-3 data and agroforestry area was estimated. From Upper Gangetic plains, Trans Gangetic plains and Gujarat plains & hill region; 8, 11 and 6 districts were selected, respectively for mapping agroforestry area in these agro-climatic zones. The area under agroforestry was estimated at district level and it was extrapolated for whole agro-climatic zone (Table 25). The area under agroforestry in Upper Gangetic plains, Trans Gangetic plains and Gujarat plains & hill region was estimated to be 0.27, 0.14 and 0.15m ha, respectively. Land use land cover maps of selected districts of different agro-climatic zones are given in Fig. 24-26.

Table 25: Estimates of area under agroforestry for different agro-climatic zones of India

Agro-climatic zone and their Number	No. of districts (selected)	Geographical area of selected districts (ha)	Agroforestry area in selected districts (ha)
Upper Gangetic plains (5)	42 (8)	2872300.00	273187.62 (9.51%)
Trans-Gangetic plains (6)	54 (11)	3324357.81	145659.75 (4.38%)
Gujarat plains & hill region (13)	29 (6)	2454102.86	150762.63 (6.14%)

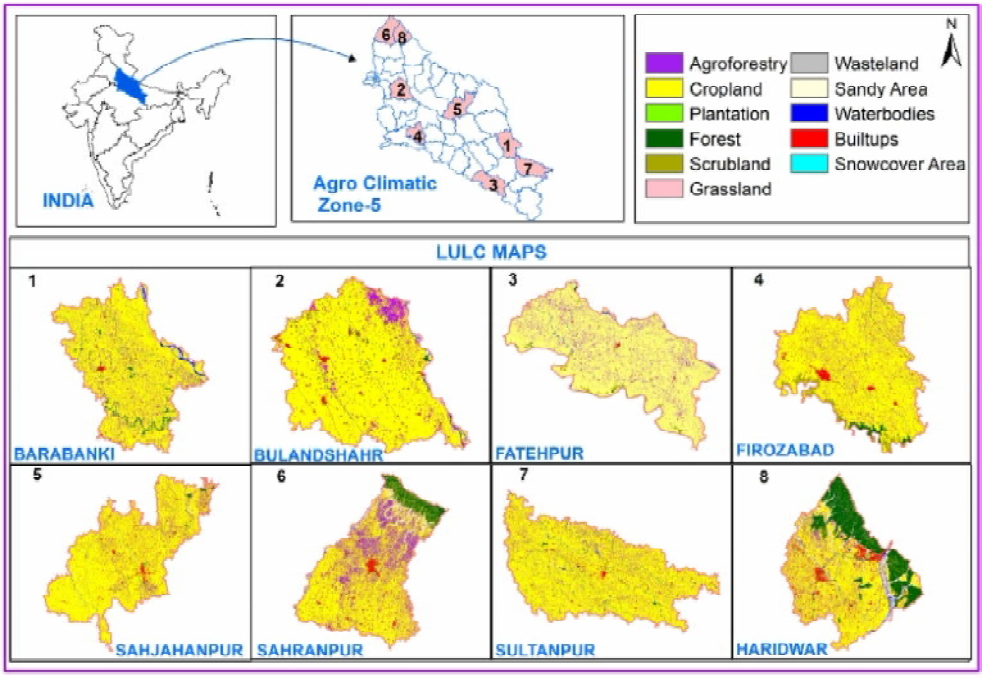


Fig.24: Land uses and land covers in selected districts of agro-climatic zone-5

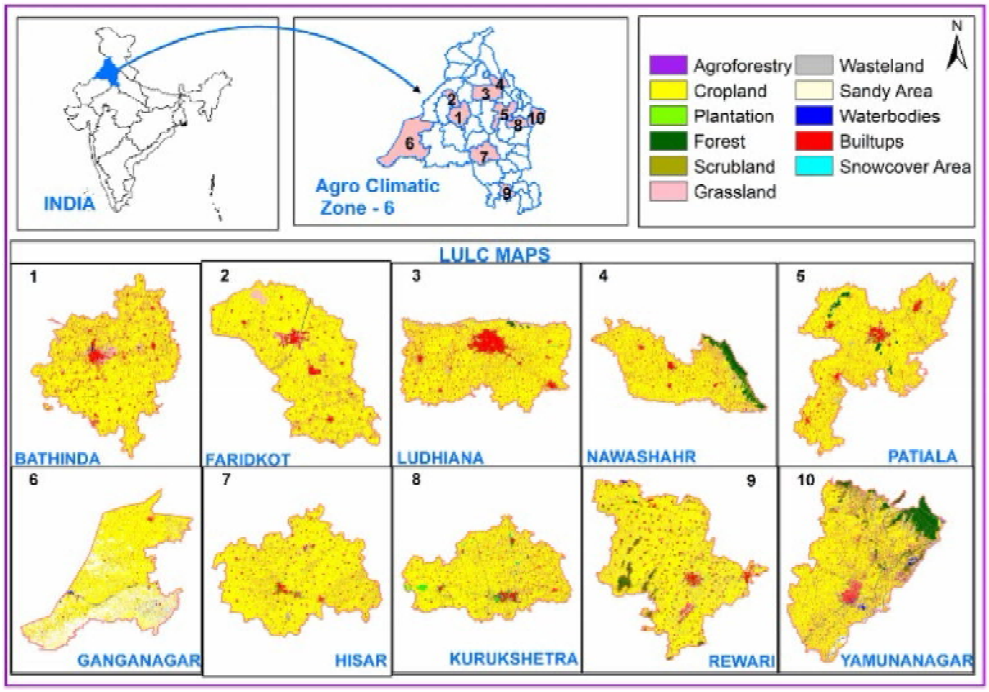


Fig. 25: Land uses and land covers in selected districts of agro-climatic zone-6

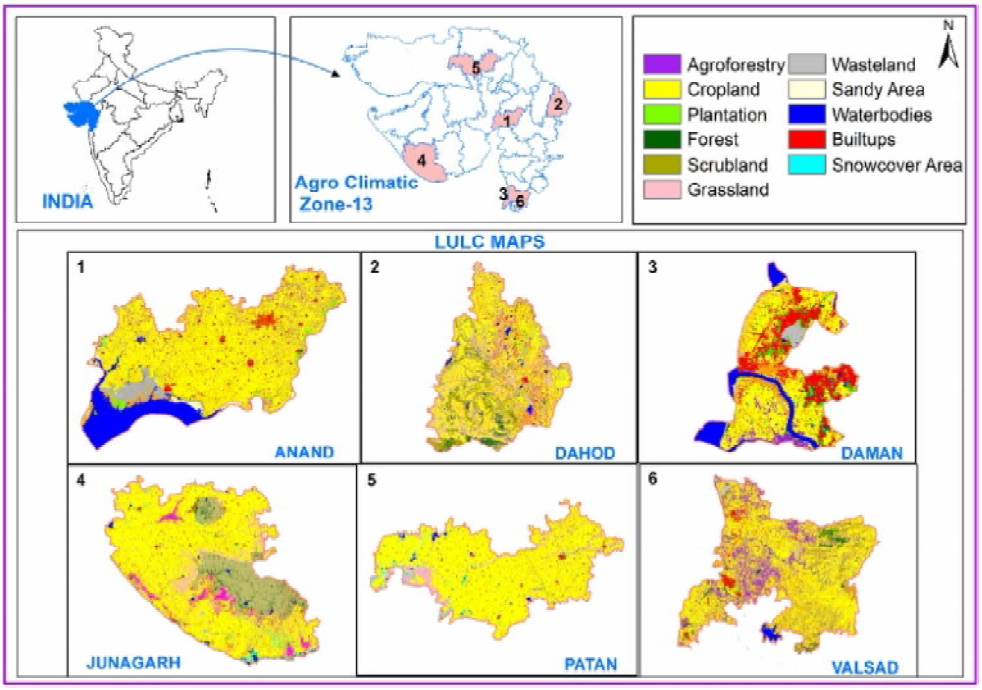


Fig. 26: Land uses and land covers in selected districts of agro-climatic zone-13

2. Soil organic carbon in surveyed districts

Soil samples were collected at 0-30 cm soil depth from existing agroforestry system on farmer's fields in different districts of Gujarat, Bihar, West Bengal and Uttar Pradesh. The soil organic carbon is given in Fig. 27, which indicates that in Gujarat, Dahod district has maximum soil orgaic carbon (42.20 t C ha^{-1}) followed by Junagarh. In other two districts (Anand and Patan), soil organic carbon was about 18.0 t C ha^{-1}. In other states, soil organic carbonvaried from 22.4 to 26.5 t C ha^{-1}.

3. Assessment of carbon sequestration potential of existing agroforestry systems on farmer's field

Carbon sequestration potential of existing agroforestry on farmer's fields in sampled districts of Gujarat, Bihar, West Bengal and Uttar Pradesh was assessed using CO_2 FIX model. The required input data like tree density, tree species existing on farmer's field, tree growth (dbh), crop productivity and soil organic carbon was generated after conducting the field survey. A sample of six villages per block were selected for field survey in such a way that these truly represent the whole block to which they belong. The survey was conducted on the basis of transect walk in these village.

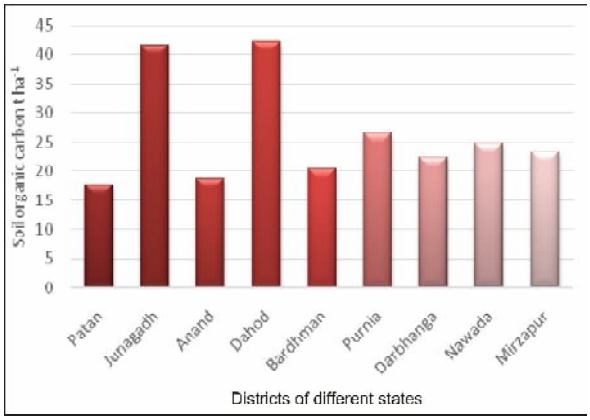


Fig. 27: Soil organic carbon at 0-30cm soil depth

General description of study area

Carbon sequestration potential of existing agroforestry system was studied in four districts of Gujarat, three districts of Bihar and one district of Uttar Pradesh and

West Bengal (Table 26) in which forest cover varied from 0 to 26.97% of total geographical area (0.24 to 0.88 m ha) of the districts. Dahod and Junagarh districts of Gujarat had 26.97 and 19.80% forest cover of total geographical area. In rest of the districts, Mirzapur (Uttar Pradesh) had maximum (24.15%) forest cover of total geographical area. The major crops of *kharif* and *rabi* varied in different districts, even in the same state (Table 26). Similarly in case of tree, major tree species also varied in each district and their preparation under each category (slow, medium and fast growing) were also different. Major tree species existing on farmer's fields in different districts of Gujarat were *Cordia dichotoma*, *Azadirachta indica*, *E. tereticornis*, *Zyziphus mauritiana*, *Tectona grandis*, *Manilka razapota*, *Mangifera indica*, *Dendracalamus strictus*, *Ailanthus excelsa*, *Albizia procera* and *Prosopis juliflora*. In Bihar, major tree species on farmer's fieldswere *Madhuca latifolia*, *Borassus flabellifer*, *Albiziap rocera*, *Dendrocalamus strictus*, *Leucaena leucocephala*, *Artocarpus heterophyllus*, *Dalbergia sissoo*, *Tectona grandis* and *Azadirachta indica*. In Bardhman district (West Bengal), the common trees occur on farmer's field were *Prunus persia*, *Albizia procera*, *Eucalyptus tereticornis*, *Artocarpush eterophyllus*, *Zyziphus mauritiana* and *Mangifera indica*. The major tree species existing on farmer's field in Mirzapur district (Uttar Pradesh) were *Madhuca latifolia*, *Mangifera indica*, *Eucalyptus tereticornis*, *Azadirachta indica*, *Tectona grandis* and *Artocarpus heterophyllus*. In four districts of Gujarat, tree density was maximum (7.10 tree ha^{-1}) in Dahod and lowest (1.79 tree ha^{-1}) in Patan. In three districts of Bihar,

Poplar based agroforestry in Indo-Gangetic plains

Ber based silvipastoral system in Gujarat

***Ailanthus excelsa* based agroforestry in Gujarat**

Mango based agroforestry in Indo-Gangetic plains

Nawada had 29.27 tree ha^{-1} however other two districts had 2 to 4 tree ha^{-1}. In West Bengal, Bardhman district had 4.69 tree ha^{-1} and district Mirzapur (Uttar Pradesh) had 10.15 tree ha^{-1} (Fig. 28). It indicated that tree density and dominance on farmer's fields varied in different districts, even in same state depending upon soil type, topography, rainfall etc.

soil carbon and total carbon would increase up to 7.18 to 11.94 t D Mha^{-1}, 11.17 to 29.66 t C ha^{-1} and 14.54 to 32.99 t C ha^{-1}, respectively over the simulated period of 30-years (Fig. 29). Net carbon sequestered in agroforestry systems over the simulated period of 30- years would be 1.5 to 6.26 t C ha^{-1} in different districts of Gujarat. In

Table 26: Major crops in surveyed districts

State	District	Kharif crop	Rabi crop
Gujarat	Anand	Paddy, Bajara and Tobacco	Wheat, Potato and Maize
	Dahod	Maize, Paddy, Pulse and Soyabean	Wheat, Gram and Maize
	Junagarh	Groundnut, Bajra, Blackgram, Chickpea, Castor and Cotton	Wheat, Garlic, Cumin, Bajra and Chickpea
	Patan	Bajra, Cotton, Castor and Sesamum	Mustard, Wheat, Cumin, Pulses
Bihar	Nawada	Paddy	Wheat, Pea, Chickpea
	Darbhanga	Paddy	Wheat, Chickpea, Pea and Maize
	Purnia	Jute, Paddy	Wheat
West Bengal	Bardhman	Paddy and Jute	Wheat, Pea, Chickpea and Mustard
Uttar Pradesh	Mirzapur	Paddy, Pigeonpea, Bajra	Wheat, Chickpea

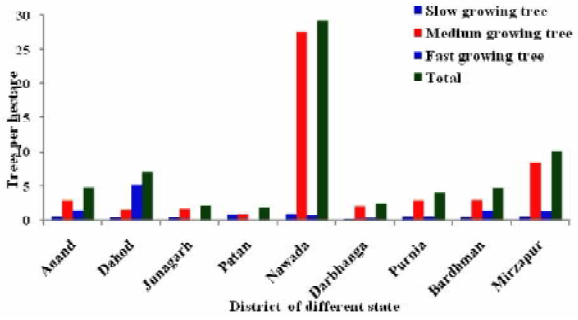


Fig. 28: Tree density in existing agroforestry system at district level in different states

The total biomass, biomass carbon, total carbon and net carbon sequestered in existing agroforestry system at district level was estimated (Fig. 29) using CO_2FIX model and extrapolated for next 30-years, which indicated that total biomass, soil carbon and total carbon in baseline was 5.63 to 6.85 t D M ha^{-1}, 10.02 to 24.13 t C ha^{-1} and 13.04 to 26.73 t C ha^{-1}, respectively in different district of Gujarat. It is expected that total biomass,

Nawada, Darbhanga and Purnia districts of Bihar, total carbon stock available in baseline varied from 9.54 to 21.32 t C ha^{-1} and it is expected that over the simulated period of 30-years, the total carbon stock in agroforestry in these districts would be 18.89

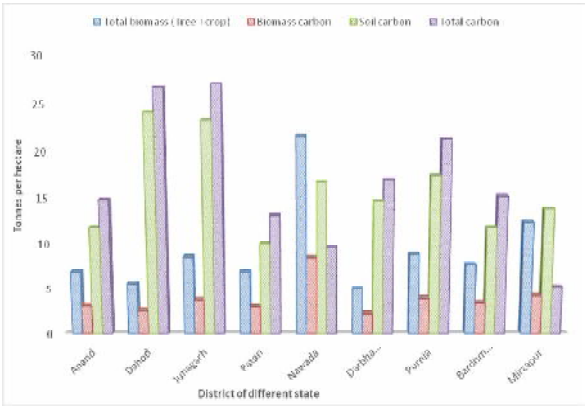


Fig. 29: Biomass, biomass carbon, soil carbon and total carbon in base year of study under existing agroforestry system at district level in different state

to 28.11 t C ha^{-1}. Net carbon sequestered over the simulated period of 30-years would be 2.91 to 17.71 t C ha^{-1}. In case of Bardhman district (West Bengal) and Mirzapur (Uttar Pradesh), total carbon stock in baseline was 15.21 and 5.25 t C ha^{-1} and it would be 18.77 and 11.47 t C ha^{-1} over the simulated period of 30-years (Fig. 30).

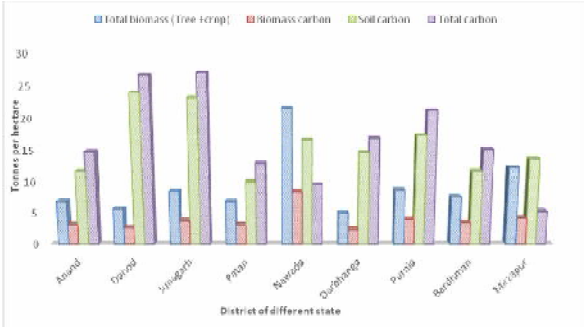


Fig. 30: Biomass, biomass carbon, soil carbon and total carbon over the simulated period of 30-year of study under existing agroforestry system at district level in different state

Studies on thermotolerance under TGT

In the context of basic and strategic aspects of climate resilient agriculture through agroforestry, various experiments related to thermotolerance and carbon assimilation were conducted with selected multipurpose tree species (MPTs) *viz. Pongamia pinnata* and *Dalbergia sissoo* and crops (wheat and mustard) of agroforestry importance under Temperature Gradient Tunnel (TGT). Differential responses to overall elevated temperature inside the TGT were reflected in the growth and physiology of MPTs and crops of agroforestry importance. Collar diameter of both *P. pinnata* and *D. sissoo* relatively decreased at elevated temperature of about 5°C above than ambient temperature (Fig.31). Although the adverse effects on CO_2 assimilation ($A_{maxPPFD}$) was relatively less at the elevated temperature of about 2°C than the ambient, but alarming effects were noted at the elevated level of 5°C above ambient. Rate of CO_2 assimilation ($A_{maxPPFD}$) decreased with increase in temperature (Fig.32). Similar observations were recorded in thylakoid electron transport rate (ETR) and effective PSII quantum yield of both the MPTs (Fig.33 and 34). Increase in biochemical traits like Malondialdehyde (MDA) concentration in the leaves of *P. pinnata* and *D.sissoo* reflected the higher cellular level oxidative stress mechanism under elevated temperature (Fig.35). Canopy temperature depression (CTD) increased under elevated temperature than the ambient indicating adaptive responses. The increase in CTD of *D. sissoo* was higher than *P. pinnata* (Fig.36). Biomass index of *P. pinnata* and *D. sissoo* decreased with the increase in temperature, which clearly indicated the adverse effect of elevated temperature (Fig.37).

Similar comprehensive studies conducted on MPTs were also extended on the select crops. Biomass index of crops (wheat and mustard) decreased with increase in temperature (Fig.38). Components of crop phenology like leaf area index (LAI) werealso influenced with increase in temperature (Fig. 39). Temperature above 5°C than ambient atmospheric temperature adversely regulated the cellular physiology and biochemistry of plants. Activity of antioxidant enzymes like catalase, peroxidase and the leaf nitrate reductase decreased at the increment of 5°C above ambient temperature (Fig.40, 41 and 42). Comprehensive impacts of higher temperature on crop physiology and biochemistry were reflected on the yield of the crops (Fig.43). Experiments are in progress to study the impact of increasing temperature on various aspects of physiological and biochemical adaptation of the select tree and crop species of agroforestry importance for their relevance to climate resilience, carbon sequestration and climate change.

Ongoing experiments with MPTs like *P. pinnata* and *D. sissoo* and seasonal crops like wheat and mustard inside TGT.

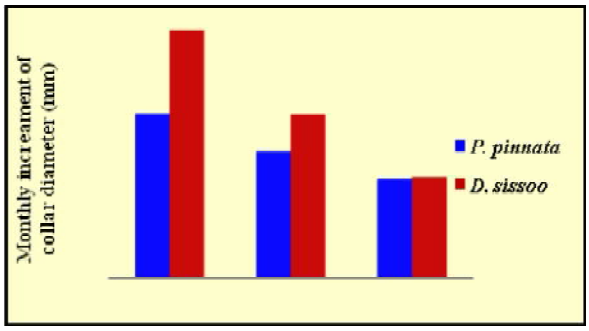


Fig. 31: Impact of elevated temperature (above ambient) on collar diameter of *P. pinnata* and *D. sissoo*

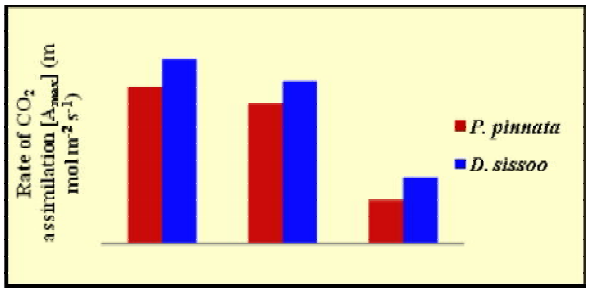


Fig. 32: Effect of elevated temperature (above ambient) on maximum rate of CO_2 assimilation ($A_{maxPPFD}$) of MPTs

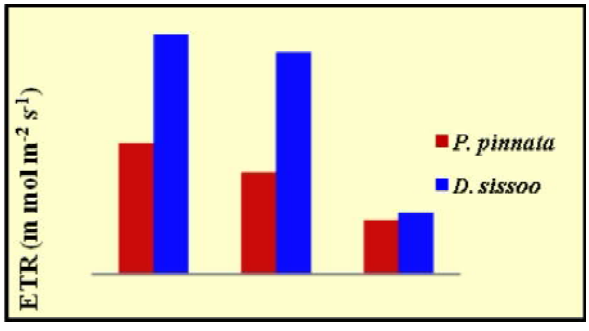


Fig.33: Effect of elevated temperature (above ambient) on thylakoid electron transport rate of MPTs

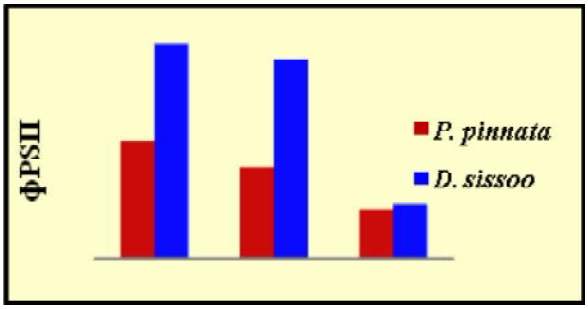


Fig.34: Effect of elevated temperature (above ambient) on effective PSII quantum yield of of MPTs.

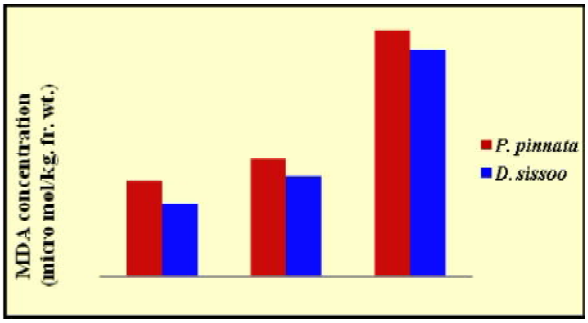


Fig.35: Impact of elevated temperature (above ambient) on malondialdehyde (MDA) concentration of MPTs

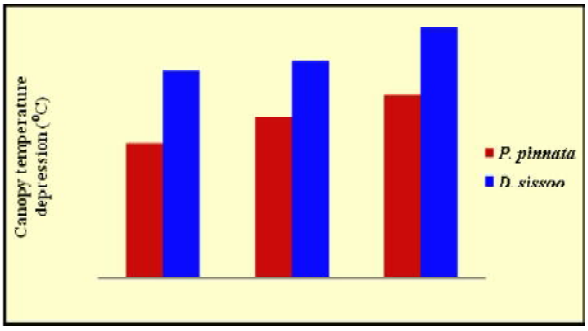


Fig.36: Effect of elevated temperature (above ambient) on canopy temperature depression (CTD) of MPTs

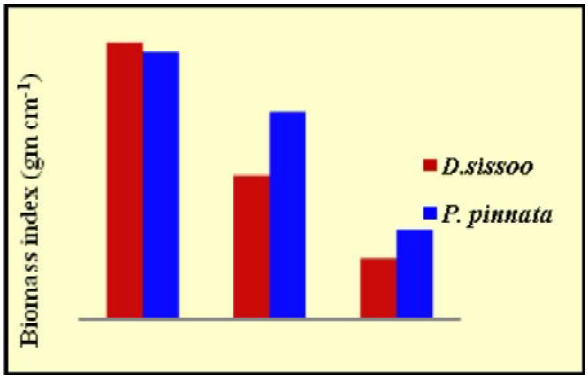


Fig. 37: Effect of elevated temperature (above ambient) on biomass index of *P. pinnata* and *D. sissoo*

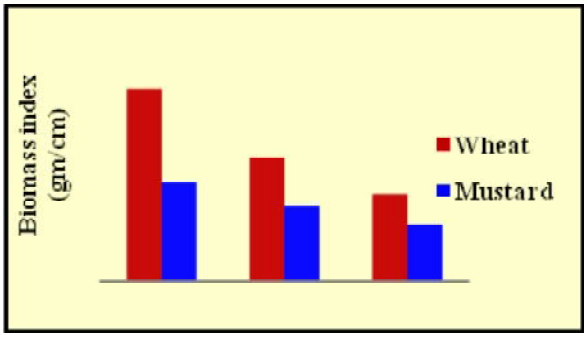


Fig. 38: Effect of elevated temperature (above ambient) on biomass index of wheat and mustard

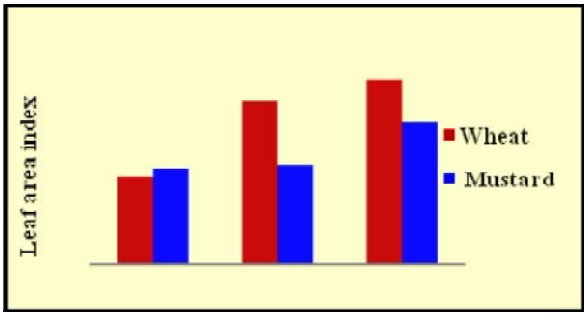


Fig.39: Effect of elevated temperature (above ambient) on leaf area index of wheat and mustard

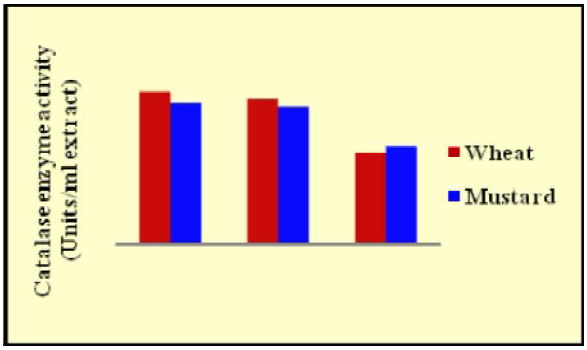


Fig. 40: Effect of elevated temperature (above ambient) on catalaes enzyme activity of wheat and mustard

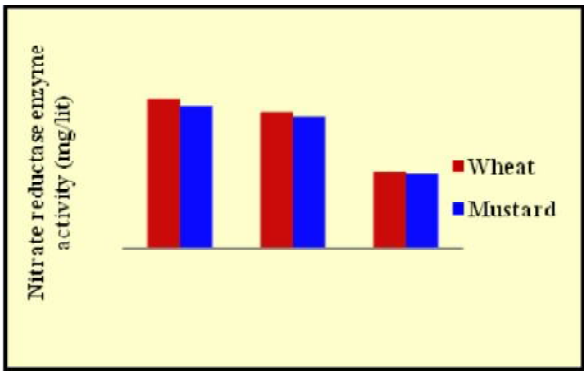


Fig. 41: Effect of elevated temperature (above ambient) on nitrate reductase enzyme activity of wheat and mustard

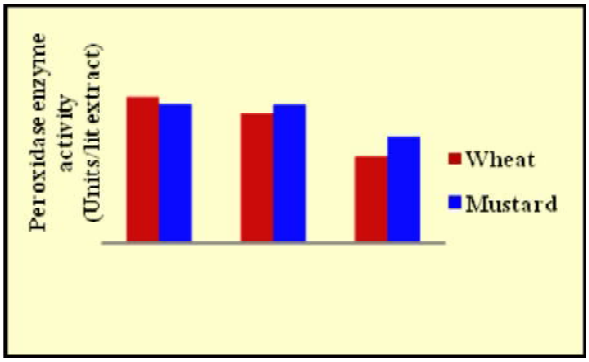


Fig. 42: Effect of elevated temperature (above ambient) on peroxidase enzyme activity of wheat and mustard

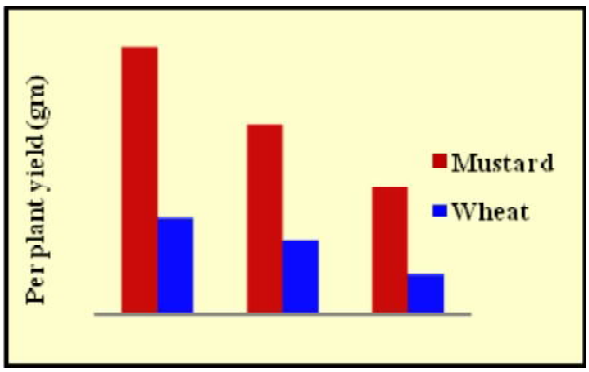


Fig. 43: Effect of elevated temperature (above ambient) on per plant yield of wheat and mustard

Results of significant value

The extent of agroforestry in India was 14.46 m ha when fallow land was not included and potential area under agroforestry was estimated to be 17.45 m ha, when fallow land was included. The total carbon available in existing agroforestry system was estimated to be 13.04 to 26.73 t C ha^{-1} in different districts (Anand, Dhaod, Junagarh and Patan) of Gujarat. In Nawada, Darbhanga and Purnia districts of Bihar, total carbon stock available in existing agroforestry varied from 9.54 to 21.32 t C ha^{-1}. The collar diameter of *P. pinnata* and *D. sissoo* relatively decreased at elevated temperature of about 5°C above ambient temperature. Although the adverse effects on CO_2 assimilation ($A_{maxPPFD}$) were relatively less at the elevated temperature of about 2°C over the ambient, however alarming effects

were noted at the elevated level of 5°C above ambient.

MoRD, New Delhi

(a) Model Watershed for Sustaining Agricultural Productivity and Improved Livelihoods-DomagorPahuj Watershed

(S K Dhyani, Ramesh Singh, R K Tewari & R H Rizvi)

On the basis of criteria mentioned in Common Guidelines for Watershed Development Projects, GOI, 2008, Domagor-Pahuj watershed has been selected to improve rural livelihood through watershed interventions and act as a site for learning. The details of its background and basic information were indicated in previous Annual reports. During the period under report, works on the aspects of Strengthening of livelihood through Women Self Help Groups (WSHGs), water resource development, Productivity enhancement, exposure visit and convergence was taken up. The brief report under different heads is as follows:

Strengthening of livelihood through Women Self Help Groups (WSHGs)

Total 26 WSHGs have been formed in three villages of model watershed area comprising 269 members. All WSHGs are linked with bank. Total saving of WSHGs is ₹ 2,60,020 and inter loaning amount is ₹ 81,500. They are mainly involved in goat rearing and vegetable cultivation. Village wise no. of WSHGs and their activities are given in Table 27.

Water resource development

Open shallow dug wells are the only means of irrigation to the crops in watershed. These wells are situated in weathered zone (unconfined aquifer) above granite rock and have slow rate of recharge due to low water column. To augment the ground water recharge, total 11 rainwater harvesting structures (9 in 2010-11 and 2 in 2011-12) were constructed mainly on first and second order drains. To see the impact of rainwater harvesting (RWH), all the open shallow dug wells (351 Nos.) are being monitored for water table on monthly basis. The average water column during October for pre and post interventions was recorded as 2.57 and 4.95 m, respectively (Fig. 44). It is observed that, about 93% higher water column was recorded in open wells during the month of October for post-interventions scenario as compared to pre-interventions. Water column buildup improves the water yield of the open wells, in turn, productivity has improved in the watershed.

Productivity enhancement

Crops and fodder

To promote vegetables, forty participatory trials (each in 0.5 acre, tomato and chili grown together) were conducted in the watershed during *Kharif*-2013. Besides, 100 families were encouraged to start kitchen gardening by providing seeds of tomato, chilli, brinjal, ladies finger, pumpkin and ridge guard. Details of *kharif* demonstrations are given in Table 28.

Table 27: Village-wise WSHGs and their activities

S.N.	Village	Total Group	Utilization of revolving fund through SHGs for creating enterprise			
			Goatary	Vegetable	Stiching	Vegetable Trolley
1	Nayakheda	4	2	2		
2	Dhikoli	11	5	2	1 member	1 member
3	Domagor	11	2	1		
Total		**26**	**9**	**5**	**1**	**1**

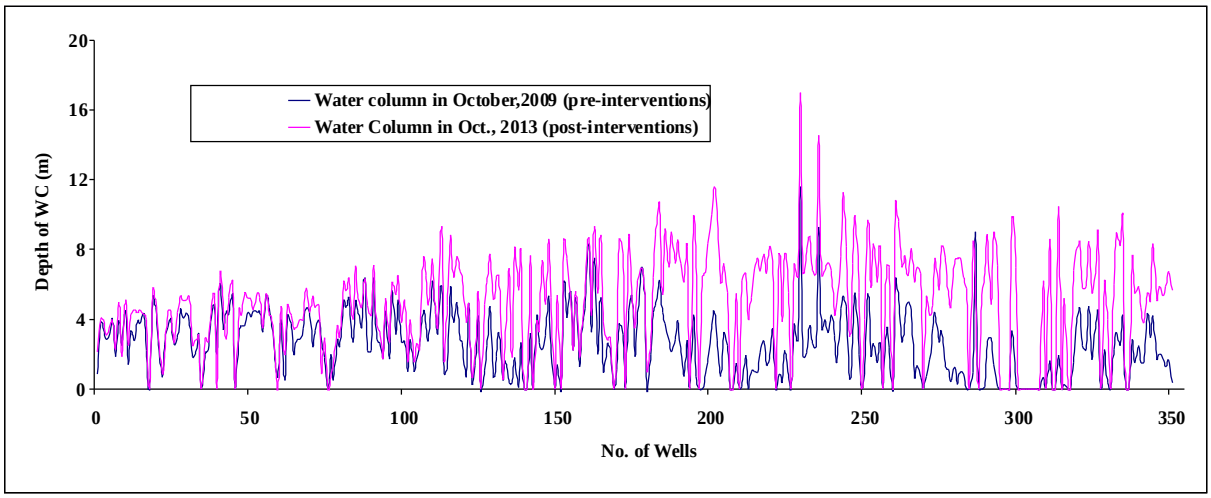


Fig. 44: Water level in open wells at Domagor Pahuj watershed during Dec. 2012

Table 28: Details of crop demonstrations during *kharif* 2013

S. No.	Seed	Variety	Quantity	No of beneficiaries	Total Area
1.	Tomato and Chilly	US 440, US 800, Crystal Laxmi-5005, Sinova, Vnr seeds	2 Kg (Hybrid seed)	40	20 acre (Through Watershed Committee)
2.	Kitchen Garden	Tomato, Chilly, Bringal, Lady finger, lauki, Torai	5 Kg	100	Backyard area (Through WC)
3.	Blackgram	Uttara- 2	50 Kg	10	10 acre (Through KVK Jhansi)
4.	Sesamum	Sekhar	10 kg	10	10 acre (Through KVK Jhansi)
5.	Moong	Samrat	7.5 Kg	5	5 Acre
6.	Fodder Grass	Napier bajra hybrid and guinea grass	2000 Meter bund	5	1000 Meter (Through IGFRI Jhansi)

It was observed that about fifty per cent beneficiaries of vegetable cultivation earned more than ₹20,000 besides home consumption. Blackgram, sesamum and moong demonstrations failed in its purpose due to excess rainfall. During *rabi*, 2013, demonstrations on chickpea (20), wheat (12 no. in 20 acre), barseem and oat were conducted. The details of demonstrations are given in Table 29.

Table 29: Details of crop demonstrations during *rabi* 2013-14

S. No.	Type of seed	Variety	Qty.	No of beneficiaries	Total Area
1.	Gram	J G - 16	600 KG	20 farmers	20 acre (Through WC)
2.	Wheat Seed	WH- 147	200 KG	5 Farmers	5 Acre (Convergence through Agriculture Department)
3.	Wheat Seed	WH- 147	200 KG	5 Farmers	5 Acre (Convergence through KVK Jhansi)
4.	Wheat Seed	L- 1, MP- 1203, MP- 1406, HI- 1479, Purna, Navin Chandosi, Sarvti	500 KG	2 Farmers	10 Acre (Though Development Alternatives)
5.	Fodder (Barseem and Oat)	Vardaan	Barseem (113 kg) and Oat (100 kg)	38	16 Acre

The samples of different crops are being analysed.

Animal health camp

An animal health camp was organized in model watershed at Dhikoli village. A lecture was delivered by veterinary doctors on improved livestock practices with special emphasis on goat farming and related issues. Animal husbandry has been identified as a major livelihood generating activity other than agriculture and goats contribute greatly in the agrarian economy particularly in semi-arid areas like Bundelkhand. Therefore this sector needs to be given special attention and care. Goats are easy to rear as they can be maintained on natural vegetation, common grazing lands, waste lands and fallow lands. Being small sized animals, goats can be easily managed by rural women and children. Goat farming is as a viable and cost-effective business model requiring less investment but having high return value. But to establish goatary as a money-making business the animals have to have sufficient care on disease control & vaccination, better feeding and breeding strategies

Vermi-compost units

Total fifteen vermi-compost units have been constructed in watershed for production of eight quintal per cycle per unit. The 7 no. mobile tetra bed also introduced with farming community in watershed.

Exposure Visit

An exposure visit was organized for thirty members from all the villages of watershed to IGFRI, Jhansi, KVK, CSAU&T, Jhansi and TaragramPahuj to get knowledge on scientific information and animal husbandry.

Convergence of different schemes

To improve the quality of vegetables' seedlings, two green shed net has been established at Nayakheda and Dhikaoli villages through convergence from Development Alternatives. Shed net ensures high quality and better productivity vegetables. Department of Horticulture and Agriculture had demonstrations in the watershed. Details are given in Table 30.

Table 30: Details of demonstrations by line departments

S. No.	Seed	Variety	Qty.	No of beneficiaries	Total Area
1.	Garlic	G-50	500 KG	25 Farmers	12.5 Acre (Horticulture Department)
2.	Capsicum	Syngenta	150 Gram	5 Farmers	2 Acre (Agriculture Department)

Fodder demonstrations in watershed

Animal health camp in watershed

(b) Enhancing Groundwater Recharge and Water Use Efficiency in SAT Region through Watershed Interventions- Parasai-Sindh Watershed, Jhansi

(S K Dhyani, Ramesh Singh, R K Tewari, Inder Dev, K B Sridhar, R H Rizvi & R P Dwivedi)

Background

Bundelkhand region is prone to severe drought leading to huge migration towards metros in search of livelihood. A watershed namely, Parasai-Sindh watershed was selected in Jhansi district of Uttar Pradesh in 2011 with a view to develop through watershed interventions in consortia mode of International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Hyderabad and NRCAF, Jhansi. The watershed is located about 25 km west of the district headquarter. The project villages– Parasai, Chhatpur and Bachauni lie beteen 25^0 23' 56'' to 25^0 27' 9.34'' N and 78^0 19' 45.71'' to 78^0 22' 42.57'' E. The overall objectives and other details were presented in previous annual reports.

All the fields were digitized in GIS environment and areal extent under different landuse was worked out and presented in Table 31. Land use was categorized in six types. Maximum area is under agriculture (88.7%) followed by scrub land (5.29%) and drainage network (3.6%).

Table 31: Areal extent of different landuse in the Parasai-Sindh watershed

S No.	Landuse	Area (ha)	Per cent of total Area
1	Agricultural	1105.5	88.7
2	Drainage Network	43.4	3.6
3	Forest	5.6	0.45
4	Habitat	11.1	0.89
5	Road	14.3	1.15
6	Scrub land	66	5.29
	Total	1245.9	100

Water resources development, development of agroforestry interventions, top working of ber and lac cultivation, productivity enhancement and capacity building are discussed in subsequent section.

Water Resources Development

Construction of rainwater harvesting structures

To augment groundwater recharge, three more cost-effective checkdams were constructed during 2013 at main ephemeral drain of the watershed. Till now, about one lakh cubic meter surface water storage has been created in the watershed through 10 rainwater harvesting structures (7 checkdams and 3 nallah plugs). All RWHS were cost-effective.

Monitoring runoff and water table

To measure runoff, six gauging stations were constructed and runoff was measured using Divers. Hydrographs received on August 30, 2013 from 349 and 1246 ha catchments were shown in Fig. 45. Peak discharge (cumecha^{-1}) was 32 per cent lower and delayed by 50 minutes in case of bigger catchment as compared to the smaller one. Surface runoff was 29.5 and 35.9 per cent of rainfall (83.8 mm) in case of bigger and smaller catchments, respectively. On hectare basis, 17.7 per cent lower runoff was recorded in bigger catchment as compared to smaller catchment.

All the open shallow dug wells (388 nos.) are situated in unconfined aquifer and these are only means of irrigation in the watershed. These wells are monitored for water table on monthly interval. The average depth and water level during October, 2013 of open wells were 9.66 and 2.56 m, respectively (Fig. 2). The water column varied in the range of 0.39 to 13.14 m with average value of 7.10 m. These water columns are

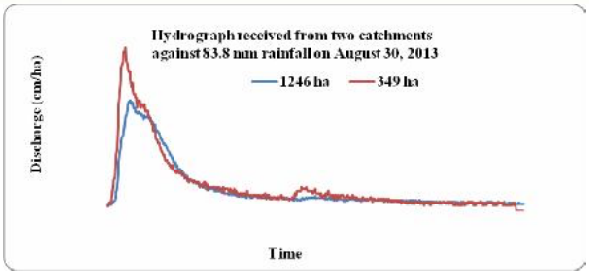


Fig. 45: Hydrographs from two catchments of 349 and 1246 ha in watershed

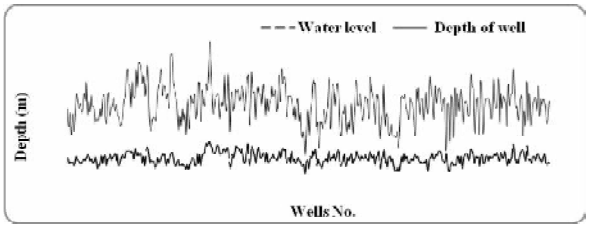


Fig. 46: Water level in open wells during October 2013

indeed sufficient to cater needs of drinking and irrigation.

Development of Agroforestry Interventions, Top Working of Ber and Lac Cultivation

To develop agroforestry interventions in the watershed, 9954 seedlings of different species were planted on 57 farmers' fields during 2013. Brief account of seedling of different species planted in watershed is given in Table 32.

Survival of different species varied from 55 to 72 per cent by the end of December 2013. Apart from this, total 95 desiber were budded with improved varieties and survival was about 51 per cent by December 2013. Farmers of the watershed were exposed to NRCAF lac demonstration site, briefed about its advantages, benefits, and management and cultivation practice. Many farmers showed interest in adopting the technology. The Survey and marking of trees were done during the month of January, selected both young trees 4-6 yrs of age and highly matured tree 10-16 years. Trees were prunned at the end of January. Brood lac was procured from Indian Institute of Natural Resins and Gums (Jharkhand, India). In total 8 farmers were selected for Katki crop and 4 for Baisakhi crop. Brood lac inoculation was done during June. The production statistics of Katki crop (June to October 2013) is given in Table 33.

Table 32: Details of seedlings planted in watershed during 2013

Village Name	No. of Beneficiaries	Teak	Lemon	Jack-Fruit	Bamboo	Anola	Karonda	Jamun	Mango	Shisham	Eucalyptus	Guava -Kalmi
Parasai	29	2450	529	215	519	237	149	10	118	98	74	185
Chhatpur	19	2750	130	109	110	208	92	37	52	43	42	121
Bachhuni	9	1250	145	36	44	51	36	23	23	17	18	33
Total	57	6450	804	360	673	496	277	70	193	158	134	339

Table 33: Lac production in watershed

Village	Farmer name	No. of trees inoculated	Young trees saplings^{-1}	Brood lac inoculated (kg)	Stick lac Harvested (kg)
Chhatpur	Sh. Gulab	20	6	16	40.26
Chhatpur	Sh. Balbir	11	-	6	12.50
Chhatpur	Sh. Balaram	1	40	10	18.20
Parasai	Sh. Rajbir	7	16	5	9.70
Parasai	Sh.Jagdish	1	1	1.4	2.50
Parasai	Sh.ShivDayal	2	3	1.2	2.00
Parasai	Sh. Kalyan Singh	1	-	1	2.00
Parasai	Sh. Manoj Yadav	8	-	5	7.00
Total		**51**	**74**	**48.1**	**94.16**

Productivity Enhancement

Crops

During *rabi* 2012-13, wheat was shown in majority of the agricultural land (88.4%) followed by mustard and chickpea (Fig. 3). About 70 ha land was fallow due to lack of irrigation water. In order to improve the productivity of Parasai-Sindh watershed various participatory crop demonstrations were undertaken during *rabi* 2012-13 and *kharif* 2013. During *rabi* 2012-13 participatory demonstrations of wheat (30 No.) (HI-1418, HI-1479, HI-1531, HI-1544) and chickpea (15 No.) (JG-11 and JG-130) were laidout. During *kharif* 2013, participatory demonstrations of soybean (15 No.) (var. PUSA-9712); groundnut (02 No.) (ICGV-9346 and *Jhumku*) and 80 demonstrations of agribore application in groundnut and soybean were conducted. Wheat varieties of HI-1544, HI-1531, HI-1479 and HI-1418 out yielded the Lok-1. I-1544 recorded highest grain yield of 3.59tha-1, whereas Lok-1 yielded only 2.25. Chickpea variety JG-11 recorded grain yield of 2.65 t ha^{-1}, whereas local chickpea produced only 1.24 t ha^{-1}. Due to heavy rainfall during *kharif* season no significant effect of agribore application was observed in groundnut and soybean. On an average groundnut variety ICGV-9346 produced pod yield of 1.90 t ha^{-1} (with agribore), whereas the local variety *Jhumku* produced only 1.48 t ha^{-1} (with agribore). Soybean var. PUSA-9712 recorded seed yield of only 0.72 t ha^{-1} (with agribore), and 0.65 t ha^{-1} (without agribore) as pod formation stage coincided with the untimely rain in this region (Table 34).

Table 34: Grain yield and pod yield of different participatory demonstrations (*rabi*-2012-13 and *kharif* 2013)

Rabi-2012-13	Crop variety	Av. grain yield (tha^{-1})
Wheat	HI-1418	2.67
	HI-1479	3.35
	HI-1531	3.02
	HI-1544	3.59
	Lok-1 (Local)	2.25
Chickpea	JG-11	2.65
	JG-130	2.29
	Local	1.24
***Kharif*-2013**		**Av. Pod yield (tha^{-1})**
Groundnut	ICGV-9346 with agribore	1.90
	ICGV-9346 with no agribore	1.84
	Jhumku (Local) with agribore	1.48
	Jhumku with no agribore	1.42
Soybean		**Av. Seed yield (tha^{-1})**
	PUSA-9712 with agribore	0.72
	PUSA-9712 with no agribore	0.65

Forage resource

Napier bajra hybrid and guinea grass are the important pasture species suitable for higher forage production. These have profuse tillering and regeneration capacity, high leaf-stem ratio and provides highly nutritious fodder to the livestock. About 90,000 rooted slips of napierbajra hybrid and guinea grass

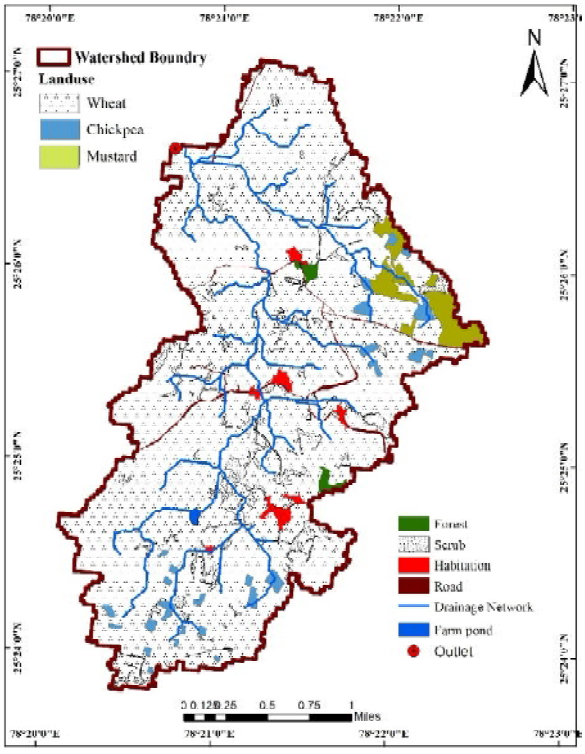


Fig. 47:Landuse in Parasai - Sindh watershed during *rabi*-2012-13

were transplanted in an area of about 2.0 ha (on bunds, near checkdams and around *haveli*) during rainy season. Two cuts at an interval of 60 days were obtained from the established areas. On an average Napier bajra hybrid and guinea grass recorded 4.57 and 3.35 DMY t ha^{-1}, respectively.

Weeds study during *rabi* 2012-13 and *kharif* 2013

Weed density and biomass studies (at harvest stage) were carried out in different participatory demonstration trials and are presented in Table 35 and 36. A perusal of the data presented in Table 35 reveals that *Ageratum conyzoides, Anagalli sarvensis, Chenopodium album, Cynodon dactylon* and *Lathyrus aphaca* among many others were some of the most dominant weeds observed in wheat and chickpea. Average density of weeds was observed as 2.19 No. m^{-2} (wheat) and 2.37 No. m^{-2} (chickpea) with average biomass accumulation of 2.78 D.W. g m^{-2} (wheat) and 3.13 D.W. g m^{-2} (chickpea). Data presented in Table 4 reveals that during *kharif* season *Ageratum conyzoides, Alternanthera sessilis, Celosia argentea, Chrysopogon fulvus, Commelina benghalensis* and *Cyperus rotundus* among were some of the dominant weeds observed in different crops. On an average weed infestation was 7.71 No. m^2 (groundnut var. *Jhumku*), 11.03 No. m^{-2} (groundnut var. ICGV-9346), 6.20 No. m^{-2} (soybean var. PUSA-9712), 13.48 No. m^{-2} (greengram), 12.97 No. m^{-2} (sesamum) and 6.43 No. m^{-2} (blackgram).

Capacity building

Farmers of the villages Parasai, Chhatpur and Bachhauni were motivated to adopt agroforestry practices at their fields. A farm innovation day and free health camp was organized at village Chhatpur (Parasai-Sindh watershed) on 16.11.2013, in which farmers were made aware and motivated about the role of agroforestry in the rural livelihood. A three days training cum exposure visit programme on Vermi composting was organized during 12-14 March, 2013 at village Ganeshgarh in Jhansi

Table 35: Weed density (No. m^{-2}) and biomass (D.W. g m^{-2}) of weeds at harvest stage during *rabi* 2012-13 in Parasai-Sindh watershed

Weed species	Wheat		Chickpea	
	Density	Biomass	Density	Biomass
Ageratum conyzoides	2.37(10.81)	4.51	3.56(16.67)	5.08
Anagalli sarvensis	0.15 (0.68)	0.12	-	-
Chenopodium album	9.78(44.59)	12.03	11.78(55.21)	12.01
Cynodon dactylon	4.44(20.27)	2.73	-	-
Lathyrus aphaca	0.74(3.38)	1.10	0.67(3.13)	0.62
Lathyrus sativus	0.89(4.05)	0.96	-	-
Parthenium hysterophorus	-	-	0.67(3.13)	0.98
Rumex dentatus		--	0.22(1.04)	1.18
Sonchus oleraceus	1.63(7.43)	4.67	1.33(6.25)	2.74
Spergula arvensis	1.19(5.41)	0.46	2.67(12.50)	2.62
Solan umxanthocarpum	0.44(2.03)	0.81	-	-
Vicia sativa	-	-	0.22(1.04)	1.22
Unidentified broad leaved	0.30(1.35)	0.44	0.22(1.04)	1.69
Average	2.19	2.78	2.37	3.13

Figures in parenthesis shows the (%)

Rainwater harvesting at Haveli near Parasai village

First time shown area in upper reach due to enhanced yield of open wells

Napier slips planted at the bank of main drain in Parasai-Sindh watershed

Boundary plantation of teak in Parasai-Sindh watershed

Table 36: Weed density (No. m^{-2}) and biomass (D.W g m^{-2}) of weeds at harvest stage during *kharif* -2013 in Parasai-Sindh watershed

Weed species	Groundnut				Soybean		Greengram		Sesamum		Blackgram	
	Jhumku		ICGV-9346		PUSA-9712		Local		Local		Local	
	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
Ageratum conyzoides	21.78 (35.33)	35.33	41.33 (46.85)	43.91	-	-	17.33 (25.72)	14.3	17.33 (22.27)	16.07	12.42 (32.05)	9.73
Alternanthera sessilis	-	-	-	-	1.78 (3.59)	3.29	6.67 (9.90)	15.18	-	-	6.13 (15.82)	14.75
Celosia argentea	8.00 (12.98)	36.69	9.33 (10.58)	43.87	4.21 (8.49)	14.75	-	-			5.33 (14.27)	18.63
Chrysopogon fulvus	13.33 (21.63)	4.18	10.67 (12.10)	3.27	6.16 (12.42)	2.84	13.33 (19.78)	4.79	28.0 (35.98)	9.61	11.21 (28.93)	3.42
Commelina benghalensis	6.21 (10.07)	1.12	7.34 (8.32)	2.75	4.00 (8.06)	5.00	-	-	-	-	2.13 (5.50)	0.52
Cyperus rotundus	4.34 (7.04)	3.16	6.42 (7.28)	4.57	1.46 (2.94)	0.92	21.33 (31.66)	16.08	8.00 (10.28)	4.16	-	-
Digitaria sanguinalis	4.48 (7.27)	3.73	6.52 (7.39)	4.26	16.00 (32.25)	10.82	-	-	6.75 (8.67)	9.24	-	-
Echinochloa crusgalli	2.1 (3.41)	1.75	3.50 (3.97)	2.19	1.33 (2.68)	1.17	-	-	5.3 (6.81)	4.72	-	-
Jussiea suffruiticosa	-	-	-	-	14.67 (29.57)	6.71	8.72 (12.94)	4.33	12.45 (16.00)	7.33	-	-
Leucasa spera	1.4 (2.27)	2.43	3.10 (3.51)	3.84	-	-	-	-	-	-	1.33 (3.43)	3.47
Average	7.71	11.05	11.03	13.58	6.20	5.69	13.48	10.94	12.97	8.52	6.43	8.42

Figures in the parenthesis shows the (%)

district in which farmers from Parasai-Sindh watershed villages *i.e.* Parasai, Chhatpur and Bachhauni participated. Six Self Help Groups (SHGs) were formed namely Shrihit Swayam Sahayata Samooh, Parasai, Jai Mata Di Swayam Sahayata Samooh, Bachhauni (Tribal), Jai Pathan Baba Swayam Sahayata Samooh, Bachhauni, Jai Khati Baba Swayam Sahayata Samooh, Chhatpur, Shri Ganeshay Namah Swayam Sahayata Samooh, Bachhauni (Tribal) and Shri Radhe-Radhe Swayam Sahayata Samooh, Bachhauni.

Observational trial

Weed Dynamics Studies in Different Agroforestry Systems

(Inder Dev)

The observational trial to study the weed dynamics in different agroforestry system was initiated during 2012. The observations recorded on weed density and biomass for *rabi* 2012-13 and *kharif* 2013 is presented hereunder.

Weed density and biomass during *rabi* season (2012-13)

The observations on weed density and biomass were recorded in seven different agroforestry systems and under wasteland conditions. Data revealed that *Chenopodium album*, *Anagallis arvensis*, *Melilotus indica*, *Lathyrus sativus* and *Fumaria parviflora* were some of the most dominant weeds prevalent in different agroforestry systems including the wasteland conditions during *rabi* season.

Weed density and biomass in Aonla + wheat agroforestry system

Data revealed that *Chenopodium album* (32 No. m^{-2}), *Melilotus indica* (18.67 No. m^{-2}) and *A. arvensis* (14.67 No. m^{-2}) were the most dominant weeds (Table 37). At harvest stage the density of *C. album* has increased upto 64 No. m^{-2} followed by *M. indica* (52 No. m^{-2}), and *Rumex acetosella* (36 No. m^{-2}). At 60 DAS, *C. album* gained maximum biomass on dry weight basis (28.91 g m^{-2}) followed by *M. indica* (14.89 g m^{-2}), however at harvest stage *M. indica* (12.80 g m^{-2}) gained maximum biomass followed by *R. acetosella* (9.39 g m^{-2}). Average density of weeds was 76.67 and 200 No. m^{-2} at 60 DAS and at harvest stage, respectively.

Weed density and biomass in Bamboo (*D. strictus*) + chickpea agroforestry system

Data revealed that *C. album* was the most dominant weed with an average density of 13 No. m^{-2} followed by *Anagalli sarvensis* (11.33 No. m^{-2}) at 60 DAS (Table 38). Similarly

Table 37: Weed density and biomass in Aonla + wheat agroforestry system

Name of the weeds	Av. density (No. m^{-2})		Av. biomass (D.W. g m^{-2})	
	60 DAS	At Harvest	60 DAS	At Harvest
Anagalli sarvensis	14.67(19.65)	8 (4.00)	4.60	0.16
Chenopodium album	32.00(42.86)	64 (32.00)	28.91	8.65
Melilotus indica	18.67(25.00)	52 (26.00)	14.89	12.80
Parthenum hysterophorus	-	32 (16.00)	-	5.27
Rumex acetosella	5.33(7.14)	36 (18.00)	7.95	9.39
Sonchus oleraceous	0(0.00)	8 (4.00))	0	3.76
Vicia sativa	4.00(5.36)	00.00	3.57	0
Total	74.67 (100)	200 (100)	59.9	40

Figures in parenthesis indicate the percent

Table 38: Weed density and biomass in Bamboo (*D. stricuts*) + chickpea agroforestry system

Name of the weeds	Av. density (No. m^{-2})		Av. biomass (D.W. g m^{-2})	
	60 DAS	At Harvest	60 DAS	At Harvest
Anagallis arvensis	11.33 (22.36)	-	29.32	-
Antirrhinum orontium	8.67 (17.11)	0.67(1.83)	21.20	0.41
Chenopodium album	13.00 (25.66)	18.67 (50.91)	15.28	32.12
Fumaria parviflora	6.50 (12.83)	0.00 (0.00)	33.77	0
Parthenum hysterophorus	0.00 (0.00)	2.67 (7.28)	0	1.52
Rumex acetosella	4.33 (8.55)	-	13.70	-
Sonchus oleraceous	0.00 (0.00)	1.33 (3.63)	0	1.23
Spergula arvensis	5.00 (9.87)	13.33(36.35)	12.16	10.11
Vicia sativa	1.83 (3.61)	-	1.52	-
Total	50.66 (100.00)	36.67(100.00)	126.95	45.39

Figures in parenthesis indicate the percent

at 90 DAS the *C. album* (64 No. m^{-2}), *Melilotus indica* (52 No. m^{-2}) were the most dominant weeds. Biomass accumulation was maximum in *Fumaria parviflora* (33.77 g m^{-2}) followed by *Anagallis arvensis* (29.32 g m^{-2}) and *Antirrhinum orontium* (21.20 g m^{-2}) at 60 DAS. Average density of weeds was 50.66 and 36.67 No. m^{-2} at 60 DAS and at harvest stage, respectively.

Weed density and biomass in Ber + lentil based agroforestry system

Data revealed that in ber + lentil agroforestry system *C. album* was the most dominant weed with an average density of 53 and 26.67 m^{-2} at 60 DAS and harvest stage, respectively (Table 39). Similarly maximum biomass accumulation was recorded in *C. album, Spergula arvensis, Cynadon dactylon* and *Sonchus oleraceous*. Average density of weeds was 72.00 and 33.34 m^{-2} at 60 DAS and at harvest stage, respectively.

Weed density and biomass in Eucalyptus + wheat agroforestry system

Data presented in Table 40 reveals that *Fuamria parviflora* (18.67 m^{-2}), *C. album* (13.33 m^{-2}) and *P. hysterophorus* (13.33 m^{-2}) were the most dominant weed at 60 DAS. At harvest stage *C. album* and *Sonchus oleraceous* were the most dominant weeds. Maximum biomass accumulation (D.W.) was observed in *F. parviflora* (17.09 g m^{-2}) followed by *Lathyrus aphaca* (9.49 g m^{-2}). Average density of weeds was 69.32 and 24 m^{-2} at 60 DAS and at harvest stage.

Table 39: Weed density and biomass in Ber + Lentil agroforestry system

Name of the weeds	Av. density (No. m^{-2})		Av. biomass (D.W. g m^{-2})	
	60 DAS	At Harvest	60 DAS	At Harvest
Chenopodium album	53.33 (74.07)	26.67(79.99)	77.60	20.09
Cynodon dactylon	6.67 (9.26)	6.67(20.01)	2.29	6.33
Sonchus oleraceous	1.33(1.85)	-	1.81	-
Spergula arvensis	10.67(14.82)	-	3.95	-
Total	72.00(100)	33.34(100)	85.65	26.42

Figures in parenthesis indicate the percent

Table 40: Weed density and biomass in Eucalyptus+ wheat agroforestry system

Name of the weeds	Av. density (No. m^{-2})		Av. biomass (D.W. g m^{-2})	
	60 DAS	At Harvest	60 DAS	At Harvest
Anagallis arvensis	5.33 (7.69)	-	2.24	-
Chenopodium album	13.33 (19.23)	10.00(41.67)	9.27	17.95
Fumaria parviflora	18.67(26.93)	-	17.09	-
Lathyrus aphaca	9.33(13.46)	1.33(5.54)	9.49	3.00
Melilotus indica	4.00 (5.77)	-	4.81	-
Parthenum hysterophorus	13.33 (19.23)	2.67(11.13)	1.45	1.71
Sonchus oleraceous	5.33 (7.66)	10.00 (41.67)	2.24	15.03
Total	69.32 (100.00)	24(100.00)	46.59	37.69

Figures in parenthesis indicate the percent

Weed density and biomass in Acacia+ Lemon+ sarsonbased agroforestry system

Data presented in the Table 41 reveals that *C. album* was the most dominant weed with an average density of 69.33 No. m^{-2} (60 DAS) and 14.00 No. m^{-2} (at harvest stage). *Lathyrus sativus* (9.33 No. m^{-2}), *Antirrhinum orontium* (5.33 m^{-2}) and *C. rotundus* (5.33 m^{-2}). Similarly, maximum biomass accumulation was recorded in *C. album*, *Spergula arvensis*, *Cynodon dactylon* and *Sonchus oleraceous* at 60 DAS. At harvest stage different weeds like *Parthenium, Physalis, Sonchus* and *Solanum* had infested the field. Average density of weeds was 89.32 and 24 m^{-2} at 60 DAS and at harvest stage.

Weed density and biomass in Shisham + wheat based agroforestry system

Data presented in Table 42 reveals that *Anagallis arvensis* (10.67 m^{-2}), *Melilotus indica* (9.33 m^{-2}) were the most dominant weeds at 60 DAS. At harvest stage *Cynodon dactylon* (7.33 m^{-2}), *C. album* (4.67 m^{-2}), *P. hysterophorus* (4.67 m^{-2}) and *Sonchus oleraceous* (4.67 m^{-2}) were the most dominant weeds at harvest stage. By and large similar trend was observed with respect to biomass accumulation by different weeds. Average density of weeds was 32.0 and 28.67 m^{-2} at 60 DAS and at harvest stage.

Table 41: Weed density and biomass in *Acacia* + Lemon + Sarson agroforestry system

Name of the weeds	Av. density (No. m^{-2})		Av. biomass (D.W. g m^{-2})	
	60 DAS	At Harvest	60 DAS	At Harvest
Antirrhinum orontium	5.33 (5.97)	1.33 (5.54)	2.52	0.93
Chenopodium album	69.33 (77.62)	14.00 (58.33)	38.36	16.37
Cynodon dactylon	-	0.67 (2.79)	-	0.15
Cyperus rotundus	5.33 (5.97)	-	0.55	-
Lathyrus sativus	9.33 (10.45)	1.33 (5.54)	13.01	6.53
Parthenum hysterophorus	-	2.00 (8.33)	-	5.45
Physalis minima	-	1.33 (5.54)	-	2.41
Sonchus oleraceous	-	2.67 (11.13)	-	3.17
Solanum nigrum	-	0.67 (2.79)	-	1.22
Total	89.32 (100)	24 (100)	54.44	36.23

Figures in parenthesis indicate the percent

Table 42: Weed density and biomass in Shisham + wheat agroforestry system

Name of the weeds	Av. density (No. m^{-2})		Av. biomass (D.W. g m^{-2})	
	60 DAS	At Harvest	60 DAS	At Harvest
Anagallis arvensis	10.67 (33.34)	-	4.76	-
Chenopodium album	2.67 (8.34)	4.67 (16.29)	1.16	2.71
Cynodon dactylon	-	7.33 (25.57)	-	3.32
Fumaria parviflora	-	3.33 (11.61)	-	3.12
Lathyrus aphaca	1.33(4.16)	-	2.95	1.75
Melilotus indica	9.33(29.16)	1.33 (4.64)	1.09	4.15
Parthenum hysterophorus	-	4.67 (16.29)	-	3.99
Rumex acetosella	4.00 (12.50)	2.67 (9.31)	4.33	5.41
Sonchus oleraceous	4.00 (12.50)	4.67 (16.29)	9.43	6.71
Total	32 (100)	28.67 (100)	23.72	28.04

Figures in parenthesis indicate the percent

Weed density and biomass in Neem + wheat based agroforestry system

In neem + wheat agroforestry system *C. album* was the most dominant weed with an average density of 30.67 m^{-2} at 60DAS and 10.67 m^{-2} at harvest stage. At harvest stage weeds like *Euphorbia*, *Sonchus*, *Spergula* and *Solanum* were some of the most dominant weeds. Average density of weeds was 40.0 and 28.0 m^{-2} at 60 DAS and at harvest stage (Table 43).

Weed density and biomass in wasteland conditions

Data presented in Table 44 reveals that *Fumaria parviflora* (10.67 m^{-2}), *C. album* (8.0 m^{-2}) and *P. hysterphorus* (4.0 m^{-2}) were the most dominant weeds under wasteland conditions. Maximum biomass accumulation was recorded in *P. hysterophorus* (12.40 g m^{-2}) followed by *C. album* (11.29 g m^{-2}) at maximum growth stage. Average density of weeds was 25.33 m^{-2} and with an average biomass accumulation of 40.64 g m^{-2}.

Table 44: Wasteland weeds (at max growth stage)

Name of the weeds	Av. density (No. m^{-2})	Av. biomass (D.W. g m^{-2})
Anagallis arvensis	1.33 (5.25)	0.69
Chenopodium album	8.00 (31.58)	11.29
Crisum arvensis	1.33 (5.25)	7.55
Euphorbia hirta	-	-
Fumaria parviflora	10.67 (42.12)	8.71
Parthenium hysterophorus	4.00 (15.79)	12.40
Total	25.33 (100.0)	40.64

Figures in parenthesis indicate the percent

Table 43: Weed density and biomass in Neem + wheat agroforestry system

Name of the weeds	Av. density (No. m^{-2})		Av. biomass (D.W. g m^{-2})	
	60 DAS	At Harvest	60 DAS	At Harvest
Chenopodium album	30.67 (76.68)	10.67(38.11)	27.96	12.89
Fumaria parviflora	9.33(23.33)	-	2.85	-
Euphorbia hirta	-	8.67(30.96)	-	9.43
Sonchus oleraceous	-	1.33(4.75)	-	1.13
Spergula arvensis	-	6.00 (21.43)	-	4.25
Solanum nigrum	-	1.33 (4.75)	-	5.15
Total	40 (100.0)	28 (100.0)	30.81	32.85

Figures in parenthesis indicate the percent

Weed density and biomass during *kharif* 2013 under different agroforestry systems

Due to continuous heavy rainfall during *kharif* 2013, the observations on weeds was recorded in four different agroforestry systems and in wasteland conditions.

Weed density and biomass in Bamboo (*D. strictus*) + blackgram agroforestry system

Data presented in Table 45 reveals that *E. crusgalli* (39.33 m^{-2}) and *D. sanguinalis* (13.33 m^{-2}) were the most dominant weeds at 60 DAS. Average density of weeds was 52.66 m^{-2} with an average biomass accumulation of 100.98 g m^{-2} at 60 DAS.

Table 45: Weed Density in biomass in Bamboo (*D. strictus*) + blackgram agroforestry system at 60 DAS

Name of the weeds	Av. density (No. m^{-2})	Av. biomass (D.W. g m^{-2})
Digitaria sanguinalis	13.33 (25.31)	24.27
Echinochloa crusgalli	39.33 (74.68)	76.71
Total	52.66 (100)	100.98

Figures in parenthesis indicate the percent

Weed density and biomass in Bamboo (*B. vulgaris*) + til agroforestry system

Data presented in the Table 46 reveals that the *B. vulgaris* based agroforestry system was infested predominantly by *C. benghalensis* (16 No. m^{-2}), *D. sanguinalis* (60 No. m^{-2}) and *E. crusgalli* (16 weeds m^{-2}). Average density of weeds was 92.8 No. m^{-2} with an average biomass accumulation of 83.38 g m^{-2} at 60 DAS.

Table 46: Weed Density in biomass in Bamboo (*B. vulgaris*) + til agroforestry system at 60 DAS

Name of the weeds	At 60 days after sowing	
	Average density (No. m^{-2})	Av. biomass (D.W. g m^{-2})
Commelina benghalensis	16.00 (17.24)	13.94
Digitaria sanguinalis	60.80(65.52)	55.44
Echinochloa crusgalli	16.00(17.24)	14.00
Total	92.80 (100)	83.38

Weed density and biomass in *Pongammia pinnata* + blackgram agroforestry system

Data presented in the Table 47 reveals that *C. rotundus* (28.00 m^{-2}) *D. sanguinalis* (12.00 m^{-2}) and *E. crussgalli* (8.67 m^{-2}) were most dominant weeds at 60 DAS. *C. rotundus* (11.61 g m^{-2}) and *T. procumbens* (10.56 g m^{-2}) recorded maximum biomass at 60 DAS. Average density of weeds was 52.67 No. m^{-2} with an average biomass accumulation of 32.47 g m^{-2} at 60 DAS.

Table 47: Weed Density in biomass in *Pongamia pinnata* + blackgram agroforestry system

Name of the weeds	Av. density (No. m^{-2})	Av. biomass (D.W. g m^{-2})
Commelina benghalensis	4.00 (7.60)	10.08
Cyprus rotandus	28.00 (53.16)	11.61
Digitaria	12.00(22.78)	6.07
Echinochloa crusgalli	8.67(16.46)	4.71
Total	52.67(100)	32.47

Figures in the parenthesis indicate the %

Weed density and biomass in Shisham + Pigeonpea agroforestry system

Data presented in Table 48 reveals that *Celosia argentia* (8.67 m^{-2}) and *C. benghalensis* (4.00 m^{-2}) were most dominant weeds at 60 DAS and biomass gained by weeds also recorded the same trend. Average density of weeds was 22.67 No. m^{-2} with an average biomass accumulation of 16.41 g m^{-2} at 60 DAS.

Weed density and biomass under wasteland conditions

Weed density and biomass under wasteland conditions were recorded at maximum growth stage. Data presented in

Table 48: Weed Density and biomass in Shisham + pigeonpea based agroforestry system at 60 DAS

Name of the weeds	Av. density (No. m^{-2})	Av. biomass (D.W. g m^{-2})
Borreria hispida	2.67 (11.76)	0.61
Borreria pusilla	0.67 (2.94)	1.33
Celosia	8.67 (38.24)	6.33
Commelina benghalensis	4.00 (17.65)	2.53
Echinochloa crusgalli	1.33 (5.88)	0.79
Oldenlandia	0.67 (2.94)	1.27
Unidentified grass	4.00 (17.65)	3.19
wild til	0.67 (2.94)	0.37
Total	22.67(100)	16.41

Figures in the parenthesis indicate the %

Table 49 reveals that *Cynodon dactylon* was the most dominant weed with an average density of 19.62 m^{-2}, however *Ageratum conyzoides* (13.74 g m^{-2}) attained maximum biomass. Average density of weeds was 39.49 m^{-2} with an average biomass accumulation of 38.89 g m^{-2}.

Table 49: Wasteland weeds during *kharif* season at maximum growth stage

Name of the weeds	Av. density (No. m^{-2})	Av. biomass (D.W. g m^{-2})
Alysicarpus	1.90(4.83)	3.50
Ageratum conyzoides	4.00(10.14)	13.74
Borreria hispida	0.76(1.93)	2.02
Cyerprus rotandus	2.86(7.25)	0.80
Cynadon dactylon	19.62(49.76)	7.80
Echinochloa crusgalli	0.57(1.45)	0.40
Euphorbia geniculata	0.95(2.42)	1.12
Mollugo pentaphylla	0.38(0.97)	1.84
Tridex procumbens	7.62(19.32)	8.24
Unidentified broad leave weeds	0.76 (1.93)	3.68
Total	39.43(100)	38.89

Figures in the parenthesis indicate the %

2. RESEARCH ACHIEVEMENTS

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

AF01.22: Studies for Augmenting Pistillate Flowers with Exogenous Application of Growth Regulators and Chemicals in *Jatropha curcas*

(Badre Alam & Sudhir Kumar)

Five different growth regulators were used for exogenous application as spraying. A new growth regulator namely 6-benzylaminopurine (6BAP) was added for spraying only from 2013 in two concentrations (100 and 200 ppm). Ethephon was used in three different concentrations (500, 1000 and 2000 ppm) ; α-NAA in the range of 50, 100 and 200 ppm, Salicylic acid in the three different ranges like 1, 2.5 and 5 mM, whereas it was 10, 30 and 60 ppm of Gibberellic acid used for spraying. Positive effects on relative increasing number of female flowers were observed after spraying of α-NAA, GA_3 and 6BAP as well at varying concentrations (Fig.48). In general, it was observed that number of flowers in the inflorescence was less than the previous year. Drying up and shedding of flowers were conspicuous and more at terminal stages.

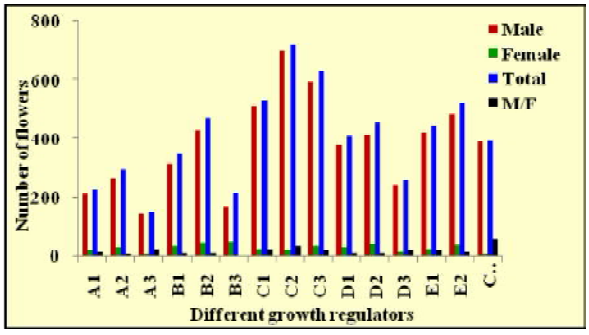


Fig. 48: Effect of exogenous spraying of growth regulators on flowering in *Jatropha curcas*

AF01.23: 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 & Vimala Devi)

The comparative adaptability of clonal and seedling plants of *Pongamia pinnata* to rainfed dry agroclimate several physio-biochemical traits were studied and examined. The consistent trends were observed in higher annual growth increment in clonal plants than seedling plants (Fig. 49 and 50). Canopy diameter of seedling plants was recorded relatively less than clonal plants (Fig. 51). Temporal changes in canopy temperature depression (CTD) were also found higher in seedling plants than clonal plants of *P. pinnata* (Fig. 52). Number of pods $plant^{-1}$ was less in seedling plants than clonal plants indicating better adaptability of clonal plants to dry agroclimate (Fig. 53). Leaf area index of clonal plants were higher in comparison to seedling plants (Fig. 54).

Malondialdehyde (MDA) concentrations in leaves of seedling plant indicated higher cellular level oxidative stress under peak hot summer and dry agroclimatic conditions (Fig. 55). The maximum rate of CO_2 assimilation ($A_{maxPPFD}$) in clonal plant was higher than seedling plants under peak hot summer. The $A_{maxPPFD}$ under postmonsoon season was higher than peak hot summer season (Fig. 56). Similar trend was observed in photochemical efficiency namely thylakoid electron transport rate and dark adapted Fv/Fm (Fig. 57 & Fig. 58).

Leaf water potential is a unique tool to understand adaptability to rainfed dry agroclimate. Pre-dawn and late evening leaf water potential of clonal and seedling plants

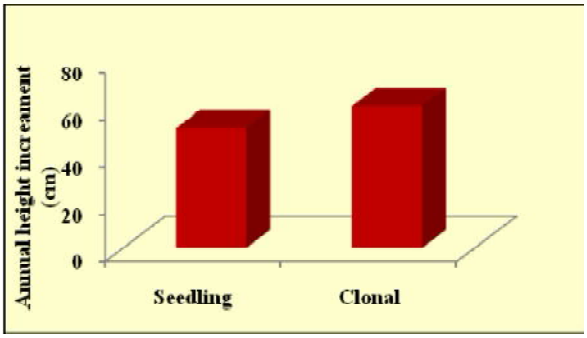


Fig.49: Annual height increment of *P. pinnata*

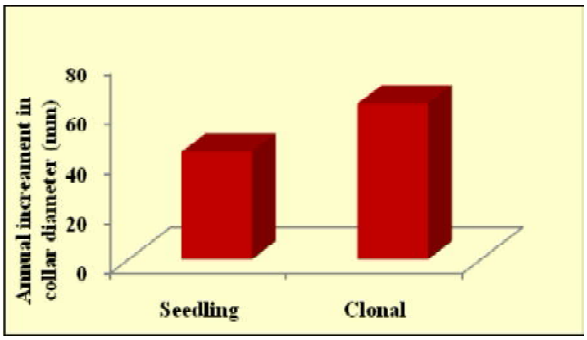


Fig. 50: Annual increment in collar diameter of *P. pinnata*

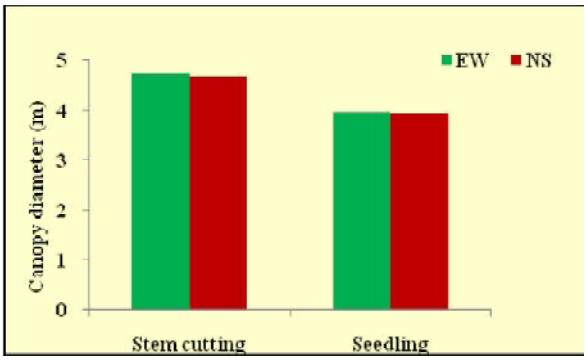


Fig.51: Canopy diameter of stem cutting (Clonal) and seedling plants of *P. pinnata*

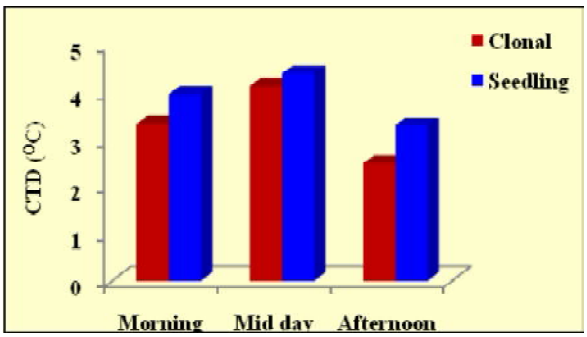


Fig.52: Temporal changes in canopy temperature depression (CTD) of *P. pinnata*

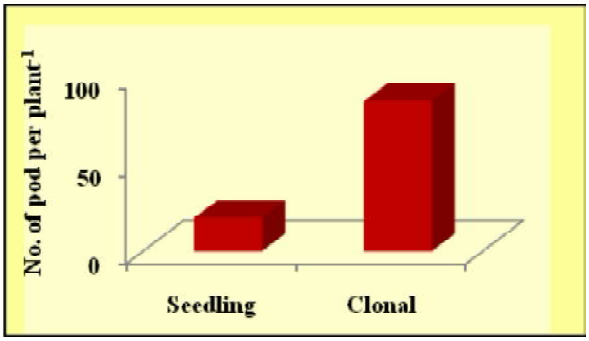


Fig.53: Pods plant^{-1} of *P. pinnata*

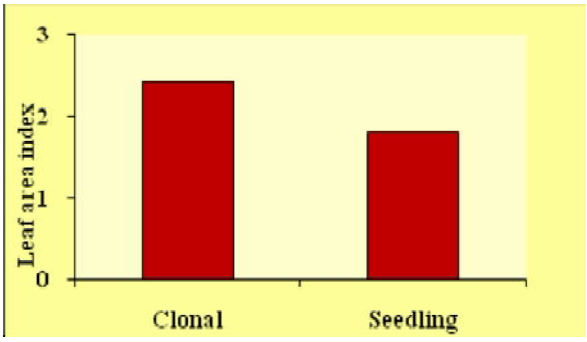


Fig. 54: Leaf area index of *P. pinnata*

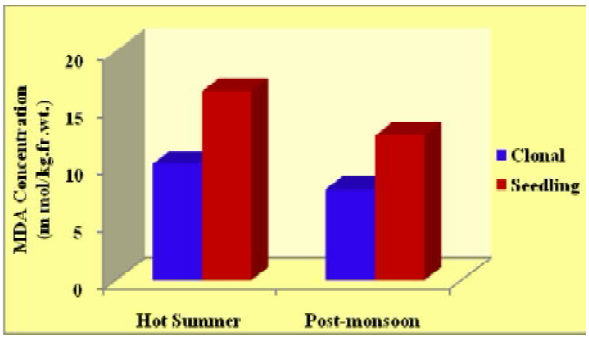


Fig. 55: Malondialdehyde (MDA) concentrations in leaf of *P. pinnata* under peak hot summer

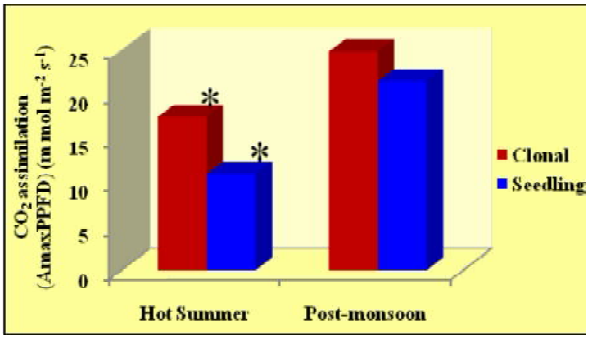


Fig.56: Rate of CO_2 assimilation (Amax PPFD) of *P. pinnata* under peak hot summer and post monsoon season

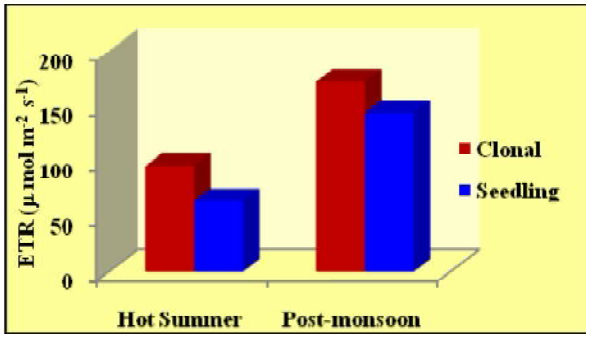


Fig. 57: Thylakoid electron transport rate (ETR) of *P. pinnata* under peak hot summer and post monsoon season

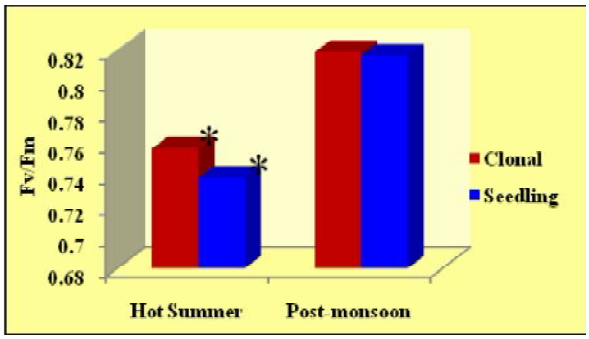


Fig. 58: Dark adapted value (F_v/F_m) of *P. pinnata* under peak hot summer and post monsoon season

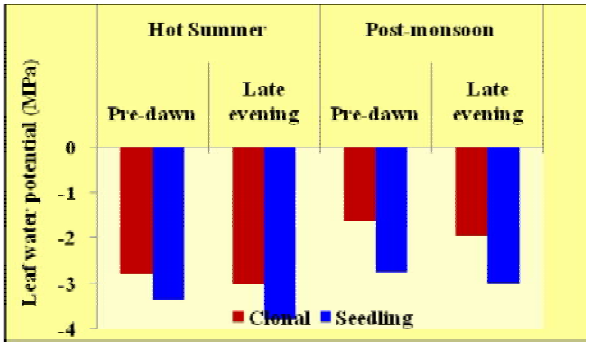


Fig. 59: Pre-dawn and late evening leaf water potential of *P. pinnata* under peak hot summer and post monsoon season

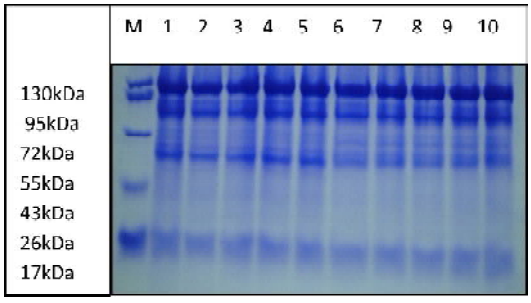


Plate-2: Leaf protein profile of clonal and seedling plants of *P. pinnata* through SDS-PAGE (M= molecular marker, Lane 1-5 indicating clonal plants and lane 6-10 indicating seedling plant)

of *P. pinnata* under peak hot summer and post monsoon season were studied. Pre-dawn leaf water potential in post monsoon and peak hot summer season indicated better adaptability of clonal plants (Fig. 59). Some differential responses in leaf protein profile of clonal and seedling plants were studied through SDS-PAGE (Plate-2).

AF 04.1b: Exploration, Evaluation and Conservation of Germplasm of *Acacia nilotica* spp. *indica*

(S Vimala Devi & Badre Alam)

A. Provenance Progeny Trial (Established in 2004)

Data on growth parameters *viz.*tree height, dbh, canopy diameter and clean bole height of 20 provenance progenies were recorded during 2013. Significant differences between all the progenies for tree height, dbh and canopy diameter were observed (Table 50). The clean bole height and number of branches were observed non-significant. The average tree height was 5.71 m and 7 progenies recorded higher than the population mean height. The significant maximum tree height was observed in MH-prov2, MP-prov 8 and UP-Prov. 1. The average dbh was 14.29 cm and 5 provenance progenies showed above the population mean diameter. The significant maximum DBH was observed in MP-prov 8 and UP-Prov. 1. The canopy diameter was maximum in UP-Prov. 1 from Jhansi. Of the 20 Provenance progenies, PR 1, 4, 15 and 20 from Sagar, Mandla, Shajapur and Jhansi showed better performance by recording the higher value than population mean for all the three characters.

B. Plus tree progeny trial (Established in 2004)

Data on growth parameters *viz.* tree height, clean bole height, dbh, canopy diameter and number of primary branches

Table 50: Growth performance of promising Provenance progenies at the age of 9.5 years

Provenance code	Provenance	State	Tree height (m)	Clean bole height (m)	dbh (cm)	Canopy diameter (m)	No. of branches plant^{-1}
MP-Prov-1	Sagar	Madhya Pradesh	6.23^{abc}	1.47	16.83	6.38	6.27
MP-Prov-2	Damoh	Madhya Pradesh	5.66^{cde}	1.32	13.86	5.23	5.93
MP-Prov-3	Jabalpur	Madhya Pradesh	5.09^{ef}	1.33	12.05	4.79	6.60
MP-Prov-4	Mandla	Madhya Pradesh	5.77^{bcd}	1.28	15.65	5.85	6.87
CH-Prov-1	Kawardha	Chattisgarh	5.27^{def}	1.22	13.59	5.33	6.60
CH-Prov-2	Raipur	Chattisgarh	5.34^{def}	1.30	13.77	5.24	6.07
CH-Prov-3	Rajnandgaon	Chattisgarh	5.26^{def}	1.36	14.01	4.97	6.07
MH-Prov-1	Nagpur	Maharashtra	5.51^{def}	1.41	12.79	4.85	6.14
MH-Prov-2	Wardha	Maharashtra	**6.34^{a}**	1.74	14.97	5.76	7.27
MH-Prov-3	Akola	Maharashtra	5.40^{def}	1.39	14.10	5.28	6.07
MH-Prov-4	Malkapur	Maharashtra	6.29^{ab}	1.86	12.77	5.46	6.40
MP-Prov-5	Khandwa	Madhya Pradesh	5.74 ^{bcd}	1.53	14.05	5.62	7.27
MP-Prov-6	Indore	Madhya Pradesh	5.48^{def}	1.54	12.86	4.98	4.93
MP-Prov-7	Ujjain	Madhya Pradesh	5.00 ^{f}	1.49	10.71	4.57	5.27
MP-Prov-8	Shajapur	Madhya Pradesh	**6.66^{a}**	1.54	**21.23**	5.63	7.07
MP-Prov-9	Rajgarh	Madhya Pradesh	5.61d^{e}	1.40	14.17	5.51	7.07
MP-Prov-10	Bhopal	Madhya Pradesh	5.74 ^{bcd}	1.35	13.29	5.36	9.47
MP-Prov-11	Guna	Madhya Pradesh	5.69^{cde}	1.66	13.86	5.31	9.27
TN-Prov-1	Coimbatore	Tamil Nadu	5.67^{cde}	1.56	13.49	4.89	5.40
UP-Prov-1	Jhansi	Uttar Pradesh	**6.45^{a}**	1.53	**17.81**	**7.52**	7.47
Mean	--	**--**	**5.71**	**1.46**	**14.29**	**5.43**	**6.68**
SE ±			**1.04**	**0.53**	**6.28**	**1.23**	**4.18**
SE			**0.06**	**0.03**	**0.36**	**0.07**	**0.24**
Significance			**	**NS**	*	**	**NS**

plant^{-1} were recorded for accession progenies collected from U.P., M.P., Chhattisgarh and Maharashtra during 2013. Significant differences were observed for all the major traits recorded (Table 51). Average tree height of the progenies was 6.70 m, average clean bole height was 1.62 m, average dbhof the plus tree progenies was 12.99 cm, average canopy diameter was 4.89 m and average number of branches plant^{-1} was 5.83.

A comparative study of growth performance of individual plus tree progeny with the population mean of tree height, dbh, Canopy diameter and Number of primary branches plant^{-1} revealed that the progenies of 7 plus trees *viz.*, PT 1, 2, 3, 8, 12, 13, 14, 15 & 16 from Sagar, Damoh, Buldhana, Khadwa, Indore and Shajaur, respectively showed superior performance for all the four characters than their population means.

C. Plus tree Progeny trial (Established in 2006)

The trial consisted of 11 Plus tree progenies collected from Madhya Pradesh and Rajasthan planted in 2006. Non-significant differences recorded for tree height, clean bole height, dbh and number of branche stree^{-1}. Significant difference was observed only for canopy diameter (Table 52). The average canopy diameter was 3.91m and the maximum was observed in the plus tree progenies 1, 4, 5, 6, 8 and 10.A comparative analysis of plus tree means over the population mean for all the four traits revealed that the performance of PT 25, 27, 28 and 30 were superior.

Table51: Growth performance of promising plus tree progenies at the age of 9.5 years

Plus tree Code	Tree height (m)	Clean bole height (m)	dbh (cm)	Canopy diameter (m)	No. of branches plant^{-1}
1	7.76	1.69	16.24	5.95	6.61
2	7.40	1.68	13.68	5.11	6.06
3	6.36	1.38	12.94	4.96	6.44
4	6.43	1.80	11.66	4.10	5.11
5	6.51	1.50	12.89	4.77	5.94
6	6.35	1.36	14.67	5.30	6.00
7	6.16	1.66	11.84	4.25	5.17
8	6.74	1.72	12.27	4.82	5.89
9	6.08	1.53	12.19	4.59	5.56
10	6.74	1.62	12.16	4.69	4.94
11	6.27	1.49	11.69	4.28	5.22
12	7.42	1.94	14.91	5.47	6.61
13	7.33	1.72	13.73	5.05	5.56
14	6.92	2.10	14.02	5.07	6.11
15	7.15	1.79	13.91	5.91	6.61
16	7.51	1.74	15.74	6.73	6.65
17	6.06	1.59	11.62	4.28	5.00
18	6.65	1.52	12.58	4.95	5.94
19	5.98	1.55	10.96	3.93	5.33
20	6.70	1.47	12.36	4.60	7.33
21	6.90	1.50	12.58	4.36	4.89
22	6.11	1.34	11.26	4.61	5.17
Mean	**6.7**	**1.622**	**12.992**	**4.89**	**5.83**
SD	**112.281**	**64.06**	**3.1171**	**141.3424**	**1.792**
SE ±	**5.664**	**3.231**	**0.1572**	**7.1298**	**0.09**
Significance	**	*	**	**	**

Table52: Growth performance of promising plus tree progenies at the age of 7.5 years

Progenies	Tree height (m)	Clean bole height (m)	dbh (cm)	Canopy diameter (m)	No. of branches plant^{-1}
PT 23	6.08	1.71	9.42	**4.19**	4.58
PT 24	5.81	1.86	8.05	3.70	4.67
PT 25	5.81	1.96	**9.66**	**4.13**	5.50
PT 26	6.09	1.75	8.93	**3.94**	5.33
PT 27	**6.38**	**2.20**	9.86	**4.53**	4.75
PT 28	**6.51**	1.64	**10.72**	**3.96**	5.75
PT 29	6.14	1.60	8.88	3.46	4.50
PT 30	**6.59**	**1.85**	**9.72**	**4.23**	4.75
PT 31	5.83	2.05	7.32	3.18	3.67
PT 32	**6.89**	1.63	9.72	**4.33**	5.25
PT 33	6.18	2.13	7.71	3.40	4.00
Mean	**6.21**	**1.85**	**9.09**	**3.91**	**4.80**
SD	**0.95**	**0.68**	**2.78**	**0.99**	**1.70**
SE ±	**0.08**	**0.06**	**0.24**	**0.09**	**0.15**
Significance	**NS**	**NS**	**NS**	**	**NS**

AF 04.5: Genetics and breeding of *Jatropha* species

(S Vimala Devi, Sudhir Kumar & K Rajarajan)

A. Evaluation of hybrids in *Jatropha curcas*

In hybrid evaluation trial, 45 different intraspecific crosses of *Jatropha curcas* were established in July, 2006. The crosses were made in half-diallel method using ten best parents. Progeny of all the 45 crosses along with 10 parents were planted. During 2013 plants were evaluated for morphological, fruit and seed yield parameters. However, the long period of rainfall during 2013 affected the yield. The mean and the range for the parents and hybrids for all the morphological data collected is given in the table 53a & 53b.

The mean performance was slightly higher than the parents for plant height, bole diameter, number of primary, secondary and total branches plants^{-1}, branch length and the productive and non-productive branch diameter, while no significant difference was observed for the average productive branches and canopy diameter. The minimum and maximum heterosis range in hybrids was observed for plant height, bole diameter, number of primary, total and productive branches and branch length. This kind of heterotic response was not observed for canopy diameter, productive and non-

Table 54: The fruit and seed yield plant^{-1} of the *Jatropha* hybrids

Hybrids	Fruit yield (gplant^{-1})	Seed yield (gplant^{-1})
Hybrid 2	35.00	24.00
Hybrid 3	49.33	29.67
Hybrid 4	50.00	28.00
Hybrid 6	29.00	16.00
Hybrid 7	61.00	40.00
Hybrid 8	54.50	34.50
Hybrid 11	74.00	40.00
Hybrid 12	57.50	35.50
Hybrid 13	70.00	43.40
Hybrid 14	75.00	55.00
Hybrid 15	57.00	30.00
Hybrid 16	50.00	37.00
Hybrid 17	84.00	54.40
Hybrid 18	90.67	56.00
Hybrid 22	110.00	65.50
Hybrid 23	86.00	58.33
Hybrid 24	43.00	26.00
Hybrid 25	50.00	35.00
Hybrid 26	49.00	34.00
Hybrid 28	115.50	68.50
Hybrid 32	68.50	42.00
Hybrid 33	69.00	45.67
Hybrid 34	126.00	83.00
Hybrid 38	101.50	65.00
Hybrid 42	88.00	56.00
Mean	**73.41**	**46.47**

Table 53a: Mean Performance in Parents and Hybrids in *J. curcas*

	PH(m)	BD (mm)	PB#	SB #	TB #	PrB #	BL (m)	CD (m)	PBD (mm)	N-PBD (mm)
Parent	2.87	77.16	7.02	43.96	74.64	15.75	2.87	3.09	46.66	21.88
Hybrid	2.92	80.33	7.24	44.14	89.91	15.86	2.92	3.09	48.37	22.54

Table 53b: The range of Performance in Parents and Hybrids in *J. curcas* for different morphological traits

	PH(m)	BD (mm)	PB#	SB #	TB #	PrB #	BL (m)	CD (m)	PBD (mm)	N-PBD (mm)
Parents	1.65-3.97	17-114	2-13	6-280	9-160	1-50	1.65-3.97	1.09-2.09	20.05-90.84	6.97-58.82
Hybrid	1.09-4.49	10-117	1-16	2-152	7-183	2-60	1.09-4.49	1.09-2.09	17.39-87.67	5.61-50.77

PH-Plant height; BD-Bole diameter, PB-No. of Primary branches, SB-No. of Secondary branches, TB- No. of total branches, PrB- No. of Productive branches, BL-Branch length, CD-Canopy diameter, PBD- Productive branch Diameter, N-PBD-Non-Productive branch diameter.

Table55: Outcome of selfing and crossing in some of the selected Jatropha hybrids

Hybrid crossess	Total Selfing attempted	Total backcross attempted	No. of fruit set in Selfing	No. of fruit set after back cross	No. of seeds obtained in Selfing	No. of seeds in back cross
Cross 14	2	11	3	1	3	0
Cross 15	4	9	3	1	5	2
Cross 16	10	13	3	2	21	1
Cross 18	14	16	5	7	7	0
Cross 23	10	14	7	1	12	2
Cross 28	4	11	8	8	16	4
Cross 36	6	7	4	1	10	2
Cross 38	4	6	13	7	23	3
Cross 43	5	4	4	1	6	4
Total	**59**	**91**	**47**	**29**	**103**	**18**

productive branch length. The mean fruit and seed yield of the hybrids were 73.41 and 46.47 g plant^{-1}. This high reduction in terms of yield is attributed to the rains during the harvest period, which led to fruit drop (Table 54).

B. Initiation of New crosses

Based on the performance of the past five years, nine promising hybrids were selected and selfing and back crossing was attempted during the Sept.-Oct. flowering, to generate F_2 and BC_1 generations (Table 55). The seed set % was higher in selfing than in the crossing process. A total of 103 F_2 and 18 BC_1 seeds were obtained.

C. Molecular Characterization of *J. curcas*

In order to initiate some new crosses, the existing germplasm wascharacterized for morphological and seed yield data of the past three years. Superior performing genotypes (15) were selected and are being characterized at molecular level using RAPD primers. So far, 45 primers were used for PCR amplification, out of which 20 primers have amplified with one or more polymorphic bands (Plate 3).

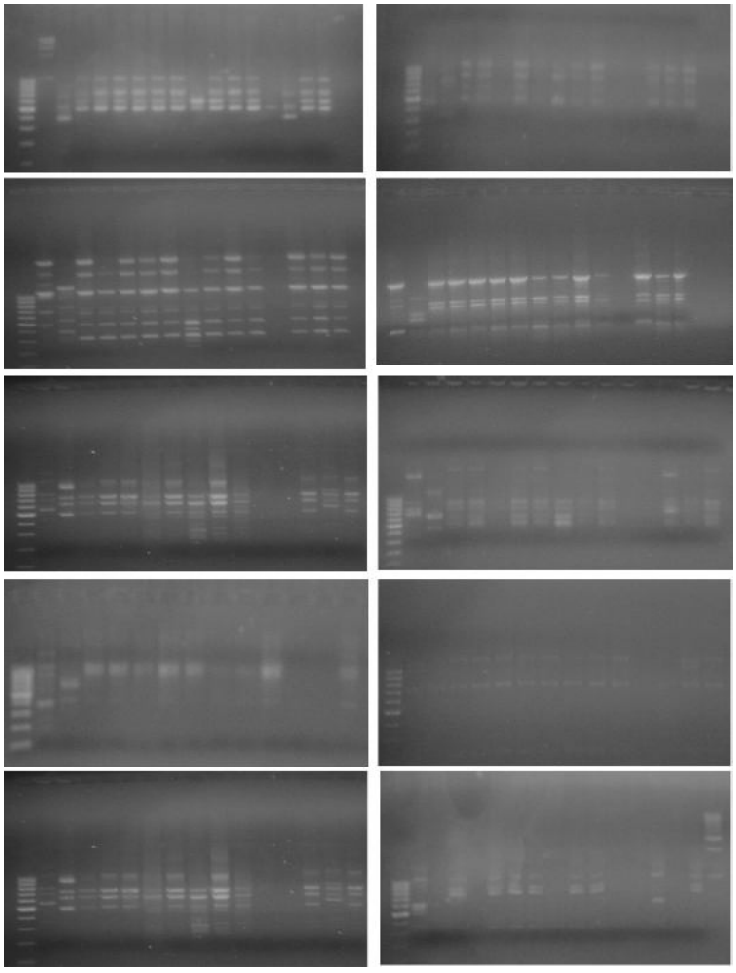


Plate 3: Molecular characterization of *J. curcas* using RAPD primers OPA 13, OPM04, OPC 06, OPD 01, OPA 13, OPN 07, OPM 10, OPN 04, OPM 01 and OPF 13

AF 04.6: Age-Age Correlation Model for Juvenile Selection of Trees in Agroforestry

(R H Rizvi, Ajit & K B Sridhar)

Growth Performance of *Acacia nilotica*

Growth data of *A. nilotica* families recorded at the age of 8-years was compiled, analysed and wood biomass was estimated using developed equation (Table 56). Maximum plant height i.e. 11.50m was obtained for a tree of family 14, for which mean height was also highest among 15 families. Mean dbh was also highest for family 14 (8.76 cm) followed by family 5 (8.44 cm). Maximum wood biomass was obtained for a plant of family 8 (116.45 kg tree^{-1}) but the mean biomass was highest for family 14 (43.77 kg tree^{-1}). Thus, family 14 performed well at the age of 8-years followed by family 12. Mean annual increment (MAI) in height and dbh is depicted in Fig. 60. MAI in height was found maximum (0.81 m) for family 14 followed by family 12 (0.77 m) and MAI in dbhwas found maximum (0.87 cm) for family 14 followed by family 15 (0.85 m).

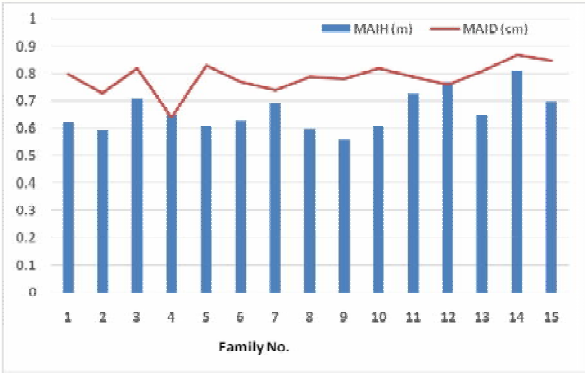


Fig. 60: Mean annual increment in height and dbh of *A. nilotica* trees

Mean height of the trees increased from 3.96 m at 4-years to 6.72 m at 8-years of age. Similarly, dbh increased from 4.18 cm at 4-years to 7.51 cm at 8-years of age. Estimated average wood biomass was assessed to be 10.92 kg tree^{-1} at 4-years of age which become almost three times at the 8-years of age (Table 57).

Age-Age Correlation Analysis

Significantly high age-age correlations were obtained for all three traits (Table 58).

Table 56: Tree height and diameter at breast height of *A. nilotica* families at 8-years

Family No.	Plant height (m)		dbh (cm)		Wood biomass (kg tree^{-1})	
	Max	Mean	Max	Mean	Max	Mean
1	10.10	7.02	12.75	8.41	89.20	41.02
2	8.25	5.87	10.60	6.36	61.38	24.00
3	10.35	7.07	14.40	7.97	114.04	39.95
4	10.75	6.91	13.90	7.59	106.19	35.63
5	10.60	7.12	14.05	8.44	108.52	41.15
6	8.90	5.93	11.10	6.37	67.39	23.39
7	7.95	6.06	10.10	6.32	55.64	22.94
8	9.60	6.50	14.55	7.40	116.45	32.96
9	10.50	6.89	11.05	7.44	66.77	31.88
10	8.95	6.07	9.95	6.94	53.98	27.75
11	10.75	7.43	13.00	8.29	92.77	39.95
12	10.80	7.51	12.30	8.43	82.95	41.28
13	7.80	6.12	10.60	6.73	61.38	25.68
14	11.50	7.76	13.50	8.76	100.12	43.77
15	9.25	6.33	11.00	6.83	66.16	27.54

Table 57: Growth parameters and wood biomass of *A. nilotica* at different ages

Plantation Age (years)	Height (m)		dbh (cm)		Wood biomass (kg tree^{-1})	
	Mean	C.V. (%)	Mean	C.V. (%)	Mean	C.V. (%)
4	3.96	29.0	4.18	45.0	10.92	81.7
5	4.81	25.7	5.27	37.6	16.82	76.7
6	5.38	26.7	6.61	33.9	26.21	67.8
7	6.10	24.4	7.05	31.9	29.54	64.8
8	6.72	23.9	7.51	30.7	33.39	62.7

Table 58: Age-age Correlations for three traits of *A. nilotica*

Age (year)	Height			dbh			Wood biomass		
	5	6	7	5	6	7	5	6	7
5	1.000			1.000			1.000		
6	0.962	1.000		0.952	1.000		0.955	1.000	
7	0.960	0.989	1.000	0.952	0.971	1.000	0.960	0.981	1.000
8	0.949	0.975	0.991	0.923	0.943	0.979	0.938	0.957	0.984

Age-age correlations for height between 6&7 and 6&8 were worked out to be 0.989 and 0.975, respectively. Similarly age-age correlations for dbh between 6&7 and 6&8 were worked out to be 0.971 and 0.943, respectively. This confirms the fact that selection may be done at early age of 6-eyars instead at 8-years.

AF 04.9: Assessment of Candidate Genes for Oil Biosynthesis in *Pongamia pinnata* using Eco-Tilling Approach

(S Vimala Devi, A K Handa, Sudhir Kumar & K Rajarajan)

Genes involved in fatty acid biosynthesis, modification and oil body formation are expected to be conserved in structure and function in different plant species. However, significant differences in the composition of fatty acids and total oil content in seeds are observed across the diverse oil bearing plants, which indicate the possible gene structure variations. With this hypothesis some of the major genes in oil biosynthesis are proposed as candidate genes and the project was initiated to assess these candidate genes in *Pongamia pinnata*.

Silico analysis using the public domain database *viz.*, Castor, Soybean, Brassica and NCBI database was carried out for critical genes involved in the oil biosynthesis. During 2013 for 22 genes, the gene sequence from *Arabidopsis thaliana* genome data base was retrieved from the public domain and it was blasted in Castor, soybean, brassica and NCBI genome database. The similar sequences thus retrieved from different genomes were analyzed in Clustal W and conserved sequences were identified. Primers were designed accordingly for amplifying in *Pongamia pinnata*. In addition the morphological data were recorded for all the 53 germplasm accessions available at the Centre and the oil content and fatty acid profile was also estimated in 13 seed bearing accessions. DNA extraction is in process for further studies.

AF 05.10: Lac based Agroforestry in Bundelkhand Region: Introduction and Evaluation

(K B Sridhar, Sudhir Kumar, Rajendra Singh, S Ghosal & Md. Monobrullah, IINRG)

Successful introduction and evaluation at different sites since 2008, the lac cultivation technology has been introduced on trial basis

for the first time at watershed site – Parasai Sind Watershed, Jhansi. Prior to this farmers were exposed toits advantages, benefits, and management and cultivation practiceat NRCAF lac demonstration site. Many farmers showed interest in adopting the technology. The Survey and marking of trees were done during January, selected both young trees (4-6 years) and matured trees (10-16 years). Trees were prunned at the end of January. Brood lac was procured from Indian Institute of Natural Resins and Gums (Jharkhand, India). In total 8 farmers were selected for Katki crop and 4 for Baisakhi crop. Brood lac inoculation was done during June.

Katki or winter season crop

The lac inoculation was done by tying bundles of brood lac on the new shoots from the pruned trees during first week of June. A total of 48.1 kg of brood lac was inoculated during June – July (Katki Crop) covering around 51 mature trees and 70 young trees and saplings. Harvesting was done at the end of October. Total stick lac was 94.16 kg as against the production at farm (98.85 against 45.6 kg of brood lac). The production ratio was 1: 1.95 at the site as against 1: 2.16 in farm covering 40 mature trees and 6 young saplings (Table 59). It was found that on an average a managed single tree of 80 cm girth and 13 m height can produce around 5.4 kg of stick lac against 1.8 kg of brood lac inoculated.

Baisakhi or Summer season crop

The lac inoculation was done by tying bundles of brood lac on the new shoots from the pruned trees during first week of June. A total of 55 kg of brood lac was inoculated during October – November (Baisakhi Crop) covering 81 mature trees and 25 young trees and saplings. In the farm a total of 53.7 kg of brood lac was inoculated in 41 mature trees and 7 young trees and saplings (Table 60). The crop is yet to be harvested.

Table 59: Katki (June- October) 2013 – Watershed site (Tree: *Butea monosperma*)

Village	Farmer name	# of trees inoculated	Young trees/ saplings	Brood lac inoculated (kg)	Stick lac harvested (kg)
Chatpur	Gulab	20	6	16	40.26
Chatpur	Balbir	11	-	6	12.50
Chatpur	Balaram	1	40	10	18.20
Parasai	Rajbir	7	16	5	9.70
Parasai	Jagdish	1	1	1.4	2.50
Parasai	Shiv Dayal	2	3	1.2	2.00
Parasai	Kalyan Singh	1	-	1	2.00
Parasai	Manoj Yadav	8	-	5	7.00
Total		**51**	**74**	**48.1**	**94.16**
NRCAF Farm	---	40	6	45.6	98.85

Table 60: Baisakhi or Summer season crop (October – June) 2013-2014

Village	Farmer name	# of trees inoculated	Young trees/ saplings	Brood lac inoculated (kg) Katki
Chatpur	Gulab	17	-	15
Chatpur	Babulal	44	9	17.50
Parasai	Rajbeer	20	8	17.2
Parasai	Kalicharan	-	8	3
	Total	**81**	**25**	**52.7**
NRCAF Farm	*Butea monosperma*	41	7	53.7+

NOVOD Board Project

National Network on Integrated Development of Jatropha and Karanja

(S Vimala Devi, Sudhir Kumar & K Rajrajan)

[I] *Jatropha curcas*

A. Progeny trials

Explorations were conducted during 2003-2005 in different eco-geographical regions of the country and seeds of *Jatropha curcas* were collected from various parts of U. P., M. P., Gujarat, Rajasthan, Maharashtra, A. P. and Chhattisgarh. Seedlings of different sources were raised in nursery and planted in field for progeny evaluation. A total of 5 progeny trials with 27, 23, 9, 12 and 85 accessions were raised between 2004-06. The progenies were evaluated for morphological traits as well as for seed yield and oil content every year. The results obtained during 2013 are summarized in Table 61 for plant height, collar girth, primary branches plant^{-1}, secondary branches plant^{-1}, average branch length and canopy diameter. The fruit and seed yield for different progeny trials is given in Table 62. The mean plant height varied from 2.75 to 3.77m among the 7-9 year old progenies, but the range of plant height in different trials indicated that there was no correlation between age and plant height. The variability was observed among the accessions. Similar trend was noted for collar girth, number of primary branches/plant, number of secondary branches/plant, branch length and canopy diameter. The fruit and seed yield also showed similar trends, *i.e.*, the age of the plants did not show any effect while large variability was observed in each progeny trials. The fruit yield varied from as low as 20.00 to 945.00 g plant^{-1} across trails and the seed yield varied from 12.00 to 470.00 g plant^{-1}.

Table 61: The mean and range in different progeny trails for the morphological traits in *Jatropha curcas*

Progeny Trials		Plant height (m)	Collar girth (cm)	Prim. br./ Plant	Sec. br./ plant	Branch length (m)	Canopy diameter (m)
PT (Aug, 04) 9 year old	Mean	3.57	63.61	5.18	29.14	3.51	3.39
	Range	1.90-4.50	44.00-91.00	2.00-11.00	7.00-46.00	0.76-4.46	1.40-5.43
PT-I (Aug, 05) 8 year old	Mean	3.30	70.29	6.46	27.85	3.23	3.46
	Range	1.70-4.15	18.00-99.00	2.00-11.00	5.00-49.00	1.64-4.09	1.18-5.00
PT-II (Aug, 05) 8 year old	Mean	2.89	43.00	5.58	28.38	2.86	1.73
	Range	2.06-3.68	45.00-88.00	2.00-8.00	7.00-44.00	2.04-3.06	0.75- 2.03
PT-III (Aug, 05) 8 year old	Mean	2.99	66.61	6.00	21.60	2.93	3.19
	Range	2.05-4.99	26.00-105.00	2.00-10.00	6.00-47.00	1.99-4.09	1.40-5.01
PT-IV (Aug, 06) 7 year old	Mean	2.75	61.33	5.25	25.94	2.67	2.79
	Range	1.30-4.15	12.00-106.00	2.00-17.00	4.00-270.00	0.58-4.10	0.52-4.28

Table 62: The range of fruit and seed yield in different progeny trials of *J. curcas*

Establishment	Genotypes (No.)	Fruits yield (g plant^{-1})	Seeds fruit^{-1}	100 seed wt. (g)	Seed yield (g plant^{-1})
PT (Aug, 04)	27	40.00-315.00	2.20 -3.00	47.14-59.94	20.00-179.00
PT-I (Aug, 05)	23	65.00-235.00	2.36 -3.00	48.00-57.30	30.00-128.00
PT-II (Aug, 05)	9	160.00-645.00	2.10 -3.00	60.80-75.60	89.00- 317.00
PT-III (Aug, 05)	12	68.00-945.00	2.35 -3.00	48.80-58.80	32.50 -470.00
PT-IV (Aug, 06)	85	20.00-495.00	2.22 -3.00	37.00-72.00	12.00 – 275.00

The fruit harvest was severely affected by extensive rains during the harvesting period hence good yields could not be realized during 2013.

B. National Multilocation trial II (2007)

The seeds of selected 17 superior genotypes of 14 different research centers (including NRCAF) of the network project were raised in nursery during 2007. Their progeny was planted in field during August 2007. Each replication had 16 plants of each genotypes. During 2012, due to heavy rains three accessions died and hence the data for the current year is recorded for fourteen genotypes. The morphological and yield parameters were recorded and results are being presented here at the age of six years (Table 63).

Data revealed significant differences ($p>0.05$ level) among the genotypes for number of primary, secondary and total branches, canopy diameter and diameter of the productive branches. Positive correlations were observed between all the traits with each other (plant height, collar girth, number of primary and secondary branches, branch length and canopy diameter).

C. National Multilocation Trial III (2008)

The seeds of selected 18 superior genotypes of 12 different centers (including NRCAF) of the network project were received in March, 2008 and raised nursery. Each replication had 16 plants of each genotype. All the accessions were evaluated at the age of five years and data recorded for different morphological and yield parameters (Table 64). Data revealed no significant differences ($p>0.05$ level) among the genotypes for all the growth traits. Positive correlations were observed between all the traits with each other.

[II] Karanja (*Pongamia pinnata* L.)

(A) Plus Tree Progeny Trial (August, 2005)

Seeds of 18 CPT of Karanja collected during April, 2005 from different parts of U.P., M.P. Rajasthan and Haryana were planted in the field during August, 2005 for

Table 63: Growth performance of *J. curcas* under NMT II

Genotypes	Plant height (m)	Bole girth (cm)	NOPRIB	NOSB	Branch length (m)	Canopy dia (m)
NRCJ2	3.02	52.86	5.71	27.57	2.97	2.71
PantJ03103	2.60	50.50	3.50	20.00	2.54	2.47
MPJ55	2.91	53.20	3.80	20.80	2.86	2.61
PDKVNov3	2.94	53.50	5.79	27.00	2.88	2.61
JA9	2.97	57.33	5.00	16.00	2.89	2.59
Bawal Sel	2.45	38.00	3.43	12.43	2.40	2.01
Orissa2	2.66	58.67	4.33	12.33	2.59	2.19
SKNJ2-1	3.16	62.00	5.50	25.00	3.10	3.24
NBJ1	2.96	63.50	5.50	25.50	2.88	2.48
HAUJ39	2.95	60.00	6.00	16.00	2.84	2.55
JawaharJ1	2.93	70.50	4.00	25.00	2.85	3.10
NBJ9	2.89	55.13	6.00	23.88	2.80	2.92
TNMC8	2.86	40.50	4.50	13.50	2.80	2.58
TNMC19	2.98	52.64	4.36	26.27	2.93	2.79

NOPRIB: No. of primary branches plant^{-1}; NOSB: No of secondary branches plant^{-1}

Table 64: Growth performance of *J. curcas* under NMT III

Source center	Genotype	Plant height (m)	Bole girth (cm)	NOPRIB	NOSB	Branch length (m)	Canopy dia (m)
PDKV Akola	PDKV Nov19	2.53	50.81	5.38	20.69	2.45	2.82
NRCAF Jhansi	NRCJ2	2.40	43.79	4.32	16.89	2.28	2.28
NRCAF Jhansi	NRCJ18	2.46	44.00	5.50	18.42	2.37	2.37
NRCAF Jhansi	NRCJ89	2.51	44.44	5.44	20.11	2.42	2.39
TFRI Jabalpur	TFRI07	2.75	53.25	5.38	24.00	2.64	2.85
JNKVV Jabalpur	JJ2	2.65	53.43	6.21	26.79	2.58	3.08
CRIDA Hyd	CRJ29	2.66	46.00	5.25	19.88	2.58	2.46
BAU Ranchi	LBJJ23	2.69	44.07	5.00	23.86	2.64	2.72
CSFER Allahabad	CALD14	2.60	49.82	6.55	23.20	2.45	2.39
TNAU Metupalym	TNCJC19	2.53	54.05	6.00	25.95	2.49	2.62
TNAU Metupalym	TNCJC20	2.63	51.15	6.12	21.88	2.55	2.90
TNAU Metupalym	TNCJC25	2.37	44.57	4.71	16.86	2.29	2.36
GBPAUT Pantnagar	PantJCP1	2.34	47.50	5.75	21.73	2.25	2.49
GBPUAT Pantnagar	PantJCP2	2.54	56.20	6.53	22.93	2.47	2.77
RCNEH Tripura	TR4	2.39	46.25	4.63	19.88	2.28	2.49
RCNEH Manipur	MNJ001	2.23	55.00	6.17	20.67	2.16	2.15
RCNEH Manipur	MNJ006	2.23	46.00	4.40	16.00	2.16	1.83
NDUAT Faizabad	NDJC1	2.32	36.50	5.00	16.20	2.22	2.16
Mean		**2.52**	**48.69**	**5.55**	**21.35**	**2.43**	**2.58**

evaluation on the basis of growth and yield parameters. The growth and yield data were recorded during December, 2012 pertaining to morphological traits and presented in table 65. The traits like plant height, bole GBH, canopy diameter and number of primary branches showed significant differences among the genotype. At the age of eight years, average tree height was 5.18 m, average clean bole height was 55.58 cm with average GBH of 60.52 cm.The average canopy diameter was 5.59 m with average primary branchesplant^{-1}of 2.48. A total of 10 accessions were recorded above population mean with respect to plant height.

Correlation study revealed significant positive correlation between the morphological traits *viz.*, tree height, collar girth, number of primary branches and canopy diameter. The clean bole height showed negative correlation for all the traits except the number of primary branches.

(B) Plus Tree Progeny Trial (July, 2006)

Seeds of 20 CPTs of *Pongamia* were collected in 2005 from different places and nursery seedlings were raised in July, 2006. The growth parameters were recorded in year 2013 at the age of 7 years and presented in Table 66. The analysis of variance showed significant differences between the genotypes for tree height and number of primary branches. The mean tree height was 4.74m and 9 accessions showed tree height above the population mean. The minimum tree height was of 3.36 m in NRCK 4, which may be considered as dwarf type after further evaluation. The average GBH and clean bole height was 60.70cm and 41.39cm, respectively. The mean canopy diameter was 5.19m and the mean number of primary and secondary branches plants^{-1} is 2.93 and 67.5, respectively.

The correlation studies revealed that plant height was positively correlated with

Table 65: The mean of different morphological traits in *P. pinnata* germplasm accessions

Germplasm accessions	Plant height (m)	Clean bole height (cm)	GBH (cm)	# Pri. branches plant^{-1}	Canopy diameter (m)
NRCP6	4.76	79.75	64.0	2.60	5.11
NRCP7	5.44	45.00	54.5	2.43	6.06
NRCP9	5.57	56.20	58.8	**3.07**	5.64
NRCP10	4.64	64.40	47.7	2.50	4.96
NRCP11	4.86	41.50	56.7	2.18	5.79
NRCP12	5.12	48.50	66.7	2.50	5.87
NRCP13	5.53	34.00	72.2	2.50	5.71
NRCP14	4.37	55.57	48.7	2.22	4.10
NRCP16	**6.08**	41.14	71.7	2.47	6.71
NRCP17	5.08	56.17	53.3	2.88	5.35
NRCP18	4.65	47.75	56.8	2.46	4.84
NRCP20	5.55	**101.00**	57.0	2.14	5.27
NRCP21	4.61	38.75	69.1	2.75	5.95
NRCP22	5.11	67.40	53.5	2.50	4.97
NRCP23	5.43	85.50	62.5	2.00	5.01
NRCP24	5.54	71.00	63.8	2.22	5.39
NRCP25	5.27	26.00	90.5	2.50	6.76
NRCP26	5.48	35.00	68.8	2.22	5.90
Mean	**5.18**	**55.58**	**60.5**	**2.48**	**5.59**

Table 66: Growth performance of different CPTs of *P. pinnata*

Germplasm accessions	Tree height (m)	Clean bole height (cm)	GBH (cm)	Canopy diameter (m)	# Pri. br. plant^{-1}	# Total br. plant^{-1}
NRCK1	3.78	58.75	48.4	4.23	2.22	44.56
NRCK 2	5.05	35.00	65.1	5.04	3.10	67.30
NRCK 4	3.36	40.00	52.2	4.90	5.00	60.00
NRCK 5	3.67	42.50	42.9	4.12	2.80	35.20
NRCK 6	4.58	41.50	41.0	5.33	2.00	62.50
NRCK 7	5.50	31.00	73.7	5.66	2.67	85.16
NRCK 9	5.03	36.00	74.6	5.88	2.33	99.00
NRCK 10	5.11	39.37	68.5	5.81	3.17	78.50
NRCK 11	4.69	32.44	55.6	4.99	2.23	55.38
NRCK 12	4.35	35.50	50.5	4.86	2.25	62.75
NRCK 13	3.90	59.80	52.7	4.43	3.20	65.60
NRCK 14	4.66	45.00	56.5	5.30	2.67	71.00
NRCK 15	5.61	36.66	78.6	5.93	3.00	101.40
NRCK 16	5.13	36.25	63.8	5.43	4.20	81.20
NRCK 17	4.54	42.25	59.3	5.56	3.11	66.11
NRCK 19	4.94	29.00	64.1	5.31	2.55	67.27
NRCK 20	4.69	52.00	57.7	5.28	3.87	62.50
NRCK 21	5.31	53.37	74.4	5.42	3.23	69.46
NRCK 22	5.16	49.33	57.4	5.50	2.63	75.37
NRCK 23	4.93	32.75	56.0	5.15	2.43	64.85
Mean	**4.74**	**41.39**	**60.7**	**5.19**	**2.93**	**67.50**

all other traits except clean bole height and number of primary branches. GBH was positively correlated with all other traits except clean bole height and number of primary branches. Clean bole height was negatively correlated with all other traits.

Plus Tree Progeny Trial (July, 2007)

Seeds of 41 CPTs of *Pongamia* from different places were collected in 2006 and nursery seedlings were raised in July, 2007. Growth parameters were recorded in 2013 and presented in Table 67. Results showed that only plant height and number of total branches showed significant variation for all genotypes.

Mean tree height was 4.74m and 9 accessions showed tree height above population mean. The minimum tree height was 3.36 m in NRCK 4, which may be considered as dwarf type after further evaluation. Average GBH and clean bole

Table 67: Growth performance of the candidate plus tree progenies in *P. pinnata*

Germplasm accessions	Tree height (m)	Clean bole height (cm)	GBH (cm)	Canopy dia (m)	# Pri. br. plant^{-1}	# Tot. br. plant^{-1}
NRCK 24	3.58	35.00	32.0	3.18	2.00	37.60
NRCK 32	5.04	29.83	53.2	4.39	2.67	75.89
NRCK 37	3.44	50.00	34.5	2.88	2.50	43.50
NRCK 41	4.60	37.75	35.6	3.52	2.60	34.80
NRCK 44	3.80	31.67	32.1	3.09	2.42	42.00
NRCK 48	4.12	-	59.0	4.14	3.00	61.00
NRCK 62	3.90	49.40	38.5	3.57	2.67	38.83
NRCK 63	3.79	34.33	37.7	3.23	2.00	38.50
NRCK 64	4.07	55.67	38.9	3.29	2.13	35.50
NRCK 65	3.47	43.00	35.3	3.05	2.29	36.29
NRCK 67	3.80	36.50	37.9	3.35	2.38	42.75
NRCK 68	4.35	48.00	45.2	3.92	2.62	50.69
NRCK 71	3.54	44.50	38.0	3.19	2.20	39.00
NRCK 72	3.46	26.50	36.8	3.04	2.20	36.40
NRCK 73	3.81	67.25	38.4	3.43	2.50	34.38
NRCK 75	4.11	33.00	37.4	3.65	2.25	47.00
NRCK 76	3.15	62.50	38.5	3.01	2.33	38.00
NRCK 77	2.98	38.00	31.3	3.35	2.00	36.00
NRCK 78	4.00	-	44.6	3.69	2.60	52.40
NRCK 82	2.90	42.00	31.5	2.88	2.75	21.50
NRCK 83	3.38	24.50	36.0	3.26	2.00	27.50
NRCK 87	4.20	86.25	44.9	3.84	2.38	47.38
NRCK 88	4.44	48.80	45.4	3.91	2.83	55.92
NRCK 90	4.02	25.33	43.2	3.70	2.70	48.60
NRCK 91	3.86	65.60	44.8	3.76	2.31	40.00
NRCK 93	2.72	-	29.0	2.40	3.00	27.00
NRCK 94	3.51	49.00	41.0	3.27	2.00	47.00
NRCK 100	4.76	40.67	41.5	3.48	2.75	45.00
NRCK 102	3.91	51.00	41.6	3.46	2.13	48.88
NRCK 104	3.42	-	41.0	2.27	3.00	38.00
NRCK 106	3.87	32.20	49.3	3.48	2.90	42.00
NRCK 107	3.93	58.13	38.8	3.41	2.23	44.23
NRCK 108	3.85	68.00	36.3	3.17	2.00	39.71
Mean	**3.93**	**46.89**	**40.4**	**3.48**	**2.43**	**43.64**

height was 6.07cm and 41.39cm, respectively. Mean canopy diameter was 5.19m, and the mean numbers of primary and secondary branches are 2.93 and 67.5, respectively.

Tree height had positive correlation with all other traits except clean bole height. All other traits had positive correlation with each other, except clean bole height, which showed negative correlations with all traits.

ICAR, IINR&G, Ranchi

Harvest and Post-Harvest Processing and Value Addition of Natural Resins, Gums and Gum Resins

(Rajendra Prasad, A K Handa, Ajit, Ramesh Singh & 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. During the year growth of established gum yielding tree based AF models were monitored. New agroforestry boundary plantations were done on farmer's field. Besides, gum-butea was characterised for physico-chemical properties and effect of lac cultivation on gum yield and vice versa was studied.

1. Development of Agroforestry Model

Data on survival and plant growth in AF models (54 months old) at on NRCAF farm have been given in Table 68.

In agri-horti-silviculture model, maximum survival and plant height was recorded in *Acacia senegal* while minimum survival and growth in *Carrisa carandus*. In

Table 68: Growth and survival of trees in the agroforestry models at NRCAF farm (54 MAP)

Agroforestry Models	Collar diameter (cm)	Height (m)	Canopy (m^2)	Survival (%)
Agri-horti-silviculture(Field No 25)				
Acacia senegal (Kumat)	10.52	3.97	16.55	100
Citrus limon (Lemon)	6.67	2.52	6.47	91
Aegle marmelos (Bael)	9.86	3.21	4.17	96
Carrissa carandus (Karonda)	1.67	1.10	0.33	75
Horti-Silviculture I (Field 20)				
Acacia senegal (Kumat)	7.49	3.78	14.66	21
Terminalia arjuna (Arjun)	5.20	2.74	4.43	100
Acacia senegal (Kumat) (boundary)	8.61	3.12	8.89	90
Horti-Silviculture II (Field 20)				
Acacia nilotica (Babul)	54.53 (GBH)	6.64	44.22	100
Terminalia arjuna (Arjun)	5.28	2.76	5.32	100
Acacia senegal (Kumat) (boundary)	5.73	2.69	6.83	90
Block plantation				
Acacia senegal (Kumat)	3.84	2.73	5.92	100
Field No. 40 & 41 (2012 planation)				
Acacia senegal (Kumat) (10x10m)	2.10	1.03	--	77
Acacia nilotica (Babul) (10x10m)	1.16	0.87	--	91
Acacia senegal (Kumat) (10x5m)	1.74	0.82	--	55
Acacia nilotica (Babul) (10x5m)	1.57	1.07	--	74
Acacia senegal (Kumat) (5x5m)	1.95	0.84	--	70
Acacia nilotica (Babul) (5x5m)	2.20	1.36	--	83

horti-silviculture-I model, *Acacia senegal* planted in rows showed less survival (21%) than on boundary (90%). In term of plant height and other growth parameters, row plantation attained better growth than boundary. *Terminalia arjuna* showed 100% survival. In horti-silviculture –II model, *Acacia nilotica* showed maximum growth. Survival of *Acacia senegal* in block plantation on rocky site was 100% and plants attained mean height of 2.73 m with collar diameter of 3.84 cm. In general, survival and growth of *A. nilotica* was better than *A. senegal*. During summer season (2013) natural oozing of gum in *A. nilotica* was observed in horti-silviculture –II model. Data on gum yield and its characteristics is given in Table 69. The gum yield ranged from 0.59 to 294.14 g tree^{-1} with an average value of 38.27 g tree^{-1}. The gum tears varied in shape and size. The numbers of gum tear varied from 1 to 69 per tree with mean 11.59 tears tree^{-1} while its weight varied from 0.12g to 10.56 g tear^{-1} with an average of 4.37 g tear^{-1}.

Table 69: Descriptive statistics of gum yield from *A. nilotica* (4 years old) tree (naturally oozing)

Parameter	GBH (cm)	Height (m)	Canopy (m^2)	Gum yield (g tree^{-1})	Weight tear^{-1} (g)	Total No. tear tree^{-1}
Mean	41.94	6.08	35.54	38.27	4.37	11.59
Range	29.00	2.50	25.21	293.55	10.14	60.00
Minimum	27.00	4.70	24.40	0.59	0.12	1.00
Maximum	56.00	7.20	49.61	294.14	10.56	69.00
SD	9.30	0.63	7.47	74.58	3.31	18.69

In newly planted agri-silvi model (Field No. 40 and 41), maximum survival was recorded by *A. nilotica* at 10 × 10 m spacing, while least by *A. senegal* at 10 × 5 m spacing. On an average, *A. nilotica* showed better survival (83%) than *A. senegal* (67%).

During the *rabi* season mustard (var. varuna) was sown in agri-horti-silviculture model and the recommended package of practices were followed. Plant growth and yield attributes were measured at different distances *viz.*, 1.0, 2.5 and 4.5m distances from each tree line (*Acacia senegal*, *Aegle marmelos* and *Citrus limon*) and control. Growth and yield data of mustard in agri-horti-silvi model are given in Table 70. Different tree species significantly reduced grain yield up to 1.0m distance from tree trunk, while yield at 2.5 m and 4.5 m distance was not affected. More plant population was observed under *Aegle marmelos* (20 plants m^{-2}), while the control (30 plants m^{-2}) recorded maximum plant population. Similar trend was observed for total biomass and grain yield. Maximum grain yield was obtained from the control plot (68.72 g m^{-2}) followed by *Aegle marmelos* (42.12 g m^{-2}), while minimum under *Acacia senegal* (30.64 g m^{-2}). Lesser values for all the parameters were recorded near the tree line compared to farthest distance.

Data on survival and growth of various species planted in different agroforestry model at farmers' field in GKD watershed and Ambabai village have been given in Table 71.

After 54 months of planting, *Acacia senegal* recorded higher survival (78%) than *A. nilotica* (53%) in GKD watershed. Out of planted horti-cultural species, guava had shown maximum survival (98%), while karonda the least (12%). In terms of plant height *A. senegal* was better than *A. nilotica* whereas reverse was true in case of collar diameter (Table 72). In Ambabai village after 30 months of planting, survival of *A. senegal*

Table 70: Growth and yield attributes of mustard (var. varuna) under agroforestry model including gum and resin yielding trees (2013-14)

Growth parameters	Distance from tree line (m)	Tree species				
		Acacia senegal	*Citrus limon*	*Aegle marmelos*	Control	Mean
Plant population (No. m^{-2})	1.0	12	10	11	30	16
	2.5	19	20	22	30	23
	4.5	24	25	27	30	27
	Mean	18	19	20	30	
Plant height (m)	1.0	148.0	151.9	152.3	166.7	154.7
	2.5	148.8	153.3	161.8	166.7	157.6
	4.5	152.5	158.5	164.5	166.7	160.5
	Mean	149.8	154.6	159.5	166.7	
Total biomass (g m^{-2})	1.0	133.3	133.8	142.0	270.9	170.0
	2.5	219.9	229.6	230.9	270.9	237.9
	4.5	226.7	254.3	269.0	270.9	255.2
	Mean	193.3	205.9	214.0	270.9	
Grain yield (g m^{-2})	1.0	15.85	15.93	16.29	68.72	29.20
	2.5	36.28	42.55	45.20	68.72	48.19
	4.5	39.79	52.40	64.86	68.72	56.45
	Mean	30.64	36.96	42.12	68.72	

Table 71: Growth parameters of trees the agroforestry models at GKD Watershed (54 MAP) and Village Ambabai (30 MAP)

Plantation/Farmer	Collar diameter (cm)	Height (m)	Canopy (m^2)	Survival (%)
Thakur Das				
Acacia nilotica (Babul)	3.80	2.61	2.97	53
Psidium guajava (Guava)	2.33	1.41	0.97	98
Carrissa carandus (Karonda)	0.69	0.81	0.15	12
Himmat				
Acacia senegal (Kumat)	6.48	3.01	7.84	78
Emblica officinalis (Anola)	10.41	4.1	12.01	54
Carrissa carandus (Karonda)	0.72	0.56	0.14	18
Ghanshyam				
Acacia senegal (Kumat) (boundary)	1.30	0.58	--	96
Mani Ram (Village Ambabai)				
Acacia senegal (Kumat)	5.82	1.91	3.67	54

was 54% with plant height of 1.91m and collar diameter 5.82 cm. Newly planted *A. senegal* recorded 60 to 96% survival in GKD watershed.

During monsoon season (2013), *A. senegal* seedlings were planted on farmers field in Shivram Pur, Binwara and Rohtiyana villages in Tikamgarh District of Madhya Pradesh. In all about 1340 seedlings spread over field boundaries of 26 farmers were planted at 2.5 to 3 m apart. Survival of planted seedlings of *A. senegal* ranged from 67 to 93%.

Physical and chemical properties of gum-butea

The physico-chemical properties of gum-butea were studied in relation to application

Table 72: Survival of boundary plantation of gum yielding tree *A. senegal* (Kumat) planted at farmers field in GKD watershed in 2012

S. No.	Farmer's Name	No. of tree planted	Spacing	Survival (%)
1	Lakhan	50	2.5 m apart	80
2	Shambhu	50	2.5 m apart	84
3	Gangadhar	50	2.5 m apart	80
4	Soni Pal	50	2.5 m apart	86
5	Saligram	10	4 m apart	90
6	Ghanshyam	50	2.5 m apart	96
7	Ram Swarup	20	3 m apart	75
8	Sumer	20	3 m apart	70
9	Manoj	10	4 m apart	60
	Total	310		

of ethephon for inducing gum. The analysed physico-chemical properties of the gum include moisture, ash, nitrogen, protein, sugar, pH, EC, bulk density, tap density and compressibility index.

Effect of ethephon on physical and chemical properties of gum-butea

The gum exuded from *Butea* trees was of dark brown to brittle ruby colour and size of gum beads varied from 0.71 to 2.6 g. It was partially soluble in water (0.26%), acetone (1.62%) and ethanol (1.24%). The observed pH ranged from 5.7 to 5.9 and electrical conductivity (EC) from 1.74 to 1.96 dSm^{-1}.

Data on physical properties *viz.* moisture, bulk density, tap density and compressibility index are presented in Tables 73, 74, 75 and 76, respectively. Significant variation in moisture content, bulk density and compressibility index of gum-butea was found due to method of application of ethephon. However, various doses of ethephon solution did not affect these properties. Gum obtained by spray of ethephon on surface of tree stem had maximum moisture (4.18%) and compressibility index (12.5%). The minimum moisture and compressibility index was noticed in gum produced by injection of ethephon and control, respectively.

Tap density of gum-butea was neither affected by method of ethephon application nor by doses. However, gum obtained from control had higher bulk density (0.65 g/cm^{-3}) than the gum obtained from ethephon treated trees.

Data on chemical properties *viz.* nitrogen, protein, sugar and ash content of gum-butea are presented in table 77, 78, 79 and 80, respectively. Method of application of ethephon has caused significant variation in all the above said chemical properties, while doses affected nitrogen and protein content only. In case of nitrogen, protein and ash content, interaction effects were also significant. As compared to control, gum obtained from ethephon treated plants had lesser nitrogen and protein content and maximum reduction was noticed when

Table 73: Effect of ethephon on moisture (%) of gum-butea

Method of ethephon application	Dose of ethephon			
	4 ml of 10%	4 ml of 20%	4 ml of 30%	Mean
Spray of ethephon on tree surface before knotching	3.74	3.55	4.17	3.82
Spray of ethephon on tree surface after knotching	4.15	4.35	4.05	4.18
Injection of ethephon at the base of tree trunk+ knotching	1.65	1.71	1.62	1.66
Control (only knotching)	2.77	2.75	2.74	2.75
Mean	3.08	3.09	3.15	
Level of significance (P-value) for method				1.253E-19
Level of significance (P-value) for ethephon dose				0.63434
Level of significance (P-value) for interaction				0.01349

Table 74: Effect of ethephon on bulk density (g cm^{-3}) of gum-butea

Method of ethephon application	Dose of ethephon			
	4 ml of 10%	4 ml of 20%	4 ml of 30%	Mean
Spray of ethephon on tree surface before knotching	0.64	0.65	0.64	0.64
Spray of ethephon on tree surface after knotching	0.63	0.63	0.63	0.63
Injection of ethephon at the base of tree trunk+ knotching	0.63	0.63	0.63	0.63
Control (only knotching)	0.65	0.65	0.65	0.65
Mean	0.64	0.64	0.64	
Level of significance (P-value) for method				3.03E-05
Level of significance (P-value) for ethephon dose				0.820081
Level of significance (P-value) for interaction				0.973518

Table 75: Effect of ethephon on tap density (g cm^{-3}) of gum-butea

Method of ethephon application	Dose of ethephon			
	4 ml of 10%	4 ml of 20%	4 ml of 30%	Mean
Spray of ethephon on tree surface before knotching	0.71	0.71	0.72	0.72
Spray of ethephon on tree surface after knotching	0.71	0.71	0.71	0.71
Injection of ethephon at the base of tree trunk+ knotching	0.71	0.71	0.71	0.71
Control (only knotching)	0.71	0.71	0.71	0.71
Mean	0.71	0.71	0.72	
Level of significance (P-value) for method				0.409841
Level of significance (P-value) for ethephon dose				0.382697
Level of significance (P-value) for interaction				0.448051

Table 76: Effect of ethephon on compressibility index (C%) of gum-butea

Method of ethephon application	Dose of ethephon			
	4 ml of 10%	4 ml of 20%	4 ml of 30%	Mean
Spray of ethephon on tree surface before knotching	10.62	9.68	11.69	10.66
Spray of ethephon on tree surface after knotching	12.5	12.5	12.5	12.5
Injection of ethephon at the base of tree trunk+ knotching	11.60	11.60	11.60	11.60
Control (only knotching)	9.68	9.68	9.68	9.68
Mean	11.09	10.85	11.36	
Level of significance (P-value) for method				7.16E-05
Level of significance (P-value) for ethephon dose				0.522017
Level of significance (P-value) for interaction				0.676223

ethephon was sprayed after knotching. In contrast, ash content increased due to ethphon treatment and maximum value was noticed in gum-butea obtained from trees that received spray of ethephon after knotching. Maximum value of sugar in gum-butea was found when ethephon was sprayed after knotching, which was at par with control. Minimum sugar content was noticed in gum-butea produced by injection of ethephon.

Effect of Lac production on gum yield and vice versa in *Butea monosperma*

To find out effect of lac cultivation on gum yield and vice versa in Butea trees, a field trial was conducted on naturally occurring 15-20 years old trees of Butea atresearch farm of NRCAF, Jhansi. Lac insect was inoculated in the month of November, 2012 and lac yield was harvested in July, 2013. For exudation of gum, trees were knotched in December and exuded gum was collected. The growth

Table 77: Effect of ethephon on nitrogen content (%) of gum-butea

Method of ethephon application	Dose of ethephon			
	4 ml of 10%	4 ml of 20%	4 ml of 30%	Mean
Spray of ethephon on tree surface before knotching	0.04	0.21	0.22	0.15
Spray of ethephon on tree surface after knotching	0.05	0.14	0.04	0.07
Injection of ethephon at the base of tree trunk+ knotching	0.134	0.090	0.122	0.115
Control (only knotching)	0.21	0.21	0.22	0.21
Mean	0.109	0.162	0.148	
Level of significance (P-value) for method				0.00015
Level of significance (P-value) for ethephon dose				0.072178
Level of significance (P-value) for interaction				0.012715

Table 78: Effect of ethephon on protein content (%) of gum-butea

Method of ethephon application	Dose of ethephon			
	4 ml of 10%	4 ml of 20%	4 ml of 30%	Mean
Spray of ethephon on tree surface before knotching	0.23	1.29	1.36	0.96
Spray of ethephon on tree surface after knotching	0.32	0.84	0.23	0.46
Injection of ethephon at the base of tree trunk+ knotching	0.83	0.80	0.73	0.79
Control (only knotching)	1.34	1.28	1.22	1.28
Mean	0.68	1.05	0.88	
Level of significance (P-value) for method				0.00018
Level of significance (P-value) for ethephon dose				0.03014
Level of significance (P-value) for interaction				0.00985

Table 79: Effect of ethephon on sugar content (mg g^{-1}) of gum-butea

Method of ethephon application	Dose of ethephon			
	4 ml of 10%	4 ml of 20%	4 ml of 30%	Mean
Spray of ethephon on tree surface before knotching	24.40	24.40	24.48	24.43
Spray of ethephon on tree surface after knotching	25.14	24.87	24.52	24.84
Injection of ethephon at the base of tree trunk+ knotching	21.06	23.51	23.62	22.73
Control (only knotching)	24.61	24.44	25.45	24.83
Mean	23.81	24.31	24.52	
Level of significance (P-value) for method				0.04539
Level of significance (P-value) for ethephon dose				0.58654
Level of significance (P-value) for interaction				0.67843

Table 80: Effect of ethephon on ash content (%) of gum-butea

Method of ethephon application	Dose of ethephon			
	4 ml of 10%	4 ml of 20%	4 ml of 30%	Mean
Spray of ethephon on tree surface before knotching	2.77	2.33	2.67	2.59
Spray of ethephon on tree surface after knotching	3.27	2.30	4.33	3.30
Injection of ethephon at the base of tree trunk+ knotching	2.13	3.70	2.80	2.88
Control (only knotching)	2.90	3.03	2.97	2.97
Mean	2.69	2.73	3.10	
Level of significance (P-value) for method				0.05089
Level of significance (P-value) for ethephon dose				0.11282
Level of significance (P-value) for interaction				0.00074

parameters of trees are given in Table 81 and the moisture content of shoots on which lac insect was inoculated ranged from 40 to 72%. The results revealed that settlement of lac insect was slightly better on trees with only lac insect inoculation than trees where both lac and gum production were taken (Table 82). The gum exudation has reduced lac insect settlement, which was reflected in lac yield. The trees where both lac and gum production were taken yielded less lac than trees having inoculated with only lac insect. Gum yield enhanced in trees having inoculation of lac insect as compared to those trees, where only gum production was taken. It is concluded that simultaneous production of gum and lac from Butea trees yields more gum but less lac (Table 83). However, interesting observation is the fact that in the beginning yield of both gum and lac increases when taken simultaneously; and decline in yield of lac is noticed only when gum yield goes beyond 400 g tree^{-1} of Butea (Fig.61). Yields of both gum and lac were positively correlated with GBH of trees (Table 84).

Table 81: Tree growth parameters (mean) for gum yield and lac production

Treatments	Tree Growth parameters			
	GBH (m)	Basal Diameter (m)	Tree height (m)	Bole height (m)
Lac + gum production	0.84	1.03	8.17	1.67
Only gum production	0.82	0.70	7.38	0.9
Only Lac production	0.73	1.60	10.80	2.7

Table 82: Insect population and sex ratio on Butea branches

Treatments	Branch Diameter (mm)	Branch Length (cm)	Sex ratio (Male : Female) (cm^2)	Settlement (cm^2)
Lac + Gum	8.26	69.26	1:3.03	24.66
Only Lac	8.46	70.67	1:3.08	26.67

Table 83: Gum yield and stick lac production

Treatments	GBH (cm)	Gum Yield (g tree^{-1})	Harvested Stick lac (g tree^{-1})
Lac + Gum Production	84.88	251.00	1327.22
Only Gum production	82.33	75.33	--
Only Lac production	73	--	2083.33

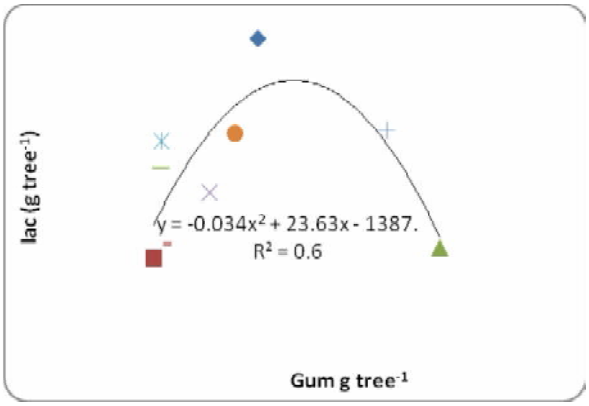


Fig. 61: Relation between lac production and gum yield

Table 84: Correlation matrix of GBH, gum yield and stick lac production

Parameter	GBH (cm)	Gum Yield (g)	Stick lac (g tree^{-1})
GBH (cm)	1		
Gum yield (gm)	0.64	1	
Stick lac (gtree^{-1})	0.41	0.067	1

Different shapes of naturally oozed gum from *A. nilotica* gum

Naturally gum oozing form different places of A. *nilotica* gum

2. RESEARCH ACHIEVEMENTS

2.4. HRD, Technology Transfer & Refinement Programme

Centre organized number of Farmer's training programmes and other activities for transfer of agroforestry technologies to increase the awareness and knowledge for speedy adoption of agroforestry.

Training on Vermicomposting

Center organized a training programme of preparation of Vermi-compost atVillage Ganeshgarh of Block-Babina District Jhansi (U.P.) from 12th -14th March,2013. In this training programme twelve farmers from Chhatpur, Bachhauni and Parasai villages of Block-Babina District Jhansi (U.P.) were participated. Progamme was organized on progressive farmer's field.

Training on Ber Pruning and Budding

Centre organized ber pruning from 22nd to 24th May at village Ganeshgarh and ber budding from 26th -27th & 29th July, 2013 atvillages-Chhatpur, Bachhauni and Parasai of Block-Babina District Jhansi (U.P.). More than 50 farmers, farm women and members of NGOs participated in the programme.

Training on Agroforestry Models for Improving Soil Health by Promoting Vegetation in M.P."

Centre organized three days training from 15th to 17th July, 2013 on "Agroforestry Models for Improving Soil Health by Promoting Vegetation in M.P." coordinated by I T C, Bhopal for different NGOs working on watersheds in Malwa and Mahakaushal region of M.P. In the training 29 participants participated.

Parthenium Awareness Week

NRCAF observed the "*Parthenium* awareness week" during 16th-22nd August,

2013. During the week's awareness movement a *Parthenium* awareness programme was organized at Parasai (Parasai-Sindh Watershed) in Babina Block of Jhansi district on 17th August, 2013. This programme was organized in collaboration with ICRISAT, Hyderabad and DWSR, Jabalpur. A practical demonstration was given on how to release the Mexican beetle on *Parthenium*. Mexican beetle "42 boxes" were distributed to the farmers of three villages' *viz*., Parasai, Chhatpur and Bachhauni (Parasai-Sindh Watershed); subsequently these beetles were released by the farmers in their fields in the presence of watershed team. On this occasion on 17th August, 2013 a lecture and video film on *Parthenium* and its management was organized at the Centre.

Trainings on Agroforestry

During the year fourteentrainings were conducted for Integrated Watershed Management Programme on Natural Resource Management and Agroforestry, production system and micro-enterprises, livelihood support activities and accounting. These trainings were organized in response to request from Land Development and Water Resources and Department of Agriculture (PIAs of IWMP) from Jhansi, Lalitpurand Banda districts. They were sponsored by respective IWMP. Farmers, office bearers of watershed committee, self-help groups, users group, watershed development team members (contractual) field functionaries and BSAs were imparted training. Trainings conducted under IWMP at the Centre during 2013 as follows:

S. No.	Subject	Sponsored By	Duration	Number of Trainings & Participants
1	Analysis of production system and Micro-enterprises, alternatives avenues and Livelihood Action Plan	BSA, LDWR, Jhansi, Lalitpur	17th January to 23rd February, 2013	Five (150 Participents)
2.	Production System, Live-Stock, Agroforestry and Micro-enterprises- Its analysis and operative guidelines	National Watershed, Jhansi	28th February to 13th March, 2013	Two (50 Participants)
3.	Natural Resource Management and Agroforestry	Deputy Director, LDWR, Jhansi &Lalitpur	28th January to 20th February, 2013	Two (60 Participants)
4.	Natural Resource Management and Agroforestry	BSA, LDWR, Lalitpur	20th to 22nd May, 2013	One (30 Participants)
5.	Watershed Management and Planning and execution	BSA, LDWR, Lalitpur	18th to 24th July, 2013	Two (60 Participants)
6.	Planning and Execution of Watershed project under IWMP Scheme	BSA, LDWR, Maidani II Banda	2nd to 18th August, 2013	Two (62 Participants)

Exhibitions

NRCAF participated in PUSA Krishi Vigyan Mela and exhibited the Center's technology during 6th - 8th March, 2013, at IARI, New Delhi. The theme of the Kisan Mela was **"Agricultural Technologies for Farmer's Prosperity"**. Sh. Sharad Pawar, Hon'ble Union Minister for Agriculture and Food Processing Industries inaugurated the Mela and Sh. Tariq Anwar Hon'ble Minister

of State for Agriculture chaired the inaugural programme. Center organized exhibition during district level *Kharif* Kisan mela at Baruasagar on 03rd October, 2013 and during IGFRI foundation day Jhansi on 01st November, 2013 at Jhansi.

Technology Transferred

Drought Proofing of Bundelkhand Region through Integrated Watershed Interventions

There was severe drought in Bundelkhand region from 2004-07. More than 81% wells became dry resulting into severe scarcity of drinking water. There was huge migration towards metros in search of livelihoods. The regions possess undulating topography with hillocks and semi-arid climate. The region depends upon perched water as it rests on vast granite massif. Shallow open dug wells situated in unconfined aquifer (weathered zone) are the major source of drinking and irrigation water. Therefore, saturation of weathered zone is the only option for assured supply of water for various purposes.

National Research Centre for Agroforestry has initiated aagroforestry based watershed development project at Garhkundar-Dabar watershed in participatory mode in drought prone Bundelkhand region since 2005. Gabions in 1st and 2nd order stream followed by series of scientifically and technically designed cost effective water harvesting structures (checkdams) across the drains and different kind of agroforestry interventions in watershed resulted in drought proofing with enhanced and sustained rural livelihoods. It was observed that groundwater recharge in treated watershed reached 86 per cent capacity with 600 mm annual rainfall, however, this situation could be arrived at with 1100 mm annual rainfall in control watershed (watershed without any interventions). Probability analysis based on last 69 years annual rainfall suggests getting annual rainfall of 600 (32% less than the average annual rainfall) and 1100 mm (25% higher than avg.) is 86 and 20 per cent, respectively. Probability analysis shows that there are maximum chances to get 600 mm rainfall during the year. *Therefore, even with deficit rainfall by about 32 per cent, water crisis in drought prone Bundelkhand region can be averted by adopting agroforestry based watershed interventions as it will recharge the weathered zone by 86 per cent which will serve the purpose of drinking and irrigation. The research results are being replicated in two more watersheds in the region.*

NRCAF Technologies Adopted by Line Departments and NGOs

In India, the needed increase in food grain production to meet increasing demand has to come largely from 94 m ha of rainfed areas, as there is little scope to expand large-scale irrigation in the country. In turn, Government of India has to invest huge sum

towards rainwater harvesting structures to augment water availability in such regions. Therefore, any efforts for cost effective design of rainwater harvesting structure and extending the life of existing structures through leak proofing leads to significant saving of public money. NRCAF developed appropriate technologies for designing Cost-effective Rainwater Harvesting Structures (RHS) and leak proofing technique for

existing structures. A brief note of adoption of these technologies is give here.

The technique of construction of low cost RHS was applied in the checkdams constructed in the Garhkundar-Dabar and Parasai-Sindh watersheds.These checkdams are serving the community efficiently for more than seven years without any repair and maintenance. The technique can potentially reduce 15-25% cost of construction without affecting efficacy and life of RHS particularly checkdams.

- This technique was popularized through trainings/workshops/exposure visits/ lectures etc. A number of government agencies/NGO successfully adopted the technology and therefore, saved significant amount of government exchequers.
- Rainwater harvesting was in practice in Bundelkhand region since ages and it was done through construction of large structure across the flow of water. Rainwater stored against such structure was used for drinking, irrigation and ground water recharge. Usually, site of such structure was very strategic. Large areas draining between two adjacent hillocks were ideal for construction of such structure. The two hillocks were joined together with huge earthen structure and fortified with stone masonry. Water accumulates on the upstream. Usually such structures were provided with masonry spillway to drain out excess water for safety of structures. The submergence area of such structures ranged from 50 to 500 ha. Large structures were never completely drained. They were used for fish culture and sometimes for cultivation of water chestnut and lotus. Such huge structures were even equipped with canal for providing for irrigation in downstream. Small to medium structures were completely drained off in October to facilitate growing of wheat/gram/peas/ mustard during *rabi* season in impounded bed area. It was observed that spillway of small to medium structures, with time, started leaking. Similarly checkdams constructed in water courses to store small quantities of rainwater in drains were also found leaking due to faulty construction particularly below ground. Thus, the very purpose of construction of such structures was lost. Therefore, it was thought essential to develop a technology to check leakage. The Center developed a technique to check leakage of such old structure while working in Garhkundar-Dabar watershed and advocated the use of this technology at various platforms by line departments engaged in soil and water conservation.

These technologies *viz.* cost effective design of RHS and leak proofing were adopted by govt. and non-governmental agencies for the benefit of stakeholders. Alist of line departments those adopted and narrated success of technologies with location is given below:

List of agencies adopted technologies developed by NRCAF, Jhansi

S. No.	Name of agencies	Village Panchayat (Nos.)	Name of Tehsil/ District	State
1.	Deptt. of Land Development and Water Resources, Govt. of U.P.	12	Jhansi	U.P.
2.	Dept. of Agriculture, Govt. of U.P.	11	Mahoba (in Kulpahad, Charkhari and Mahoba tehsils)	U.P.
3.	Development Alternatives (DA), Taragram, Pahuj, Jhansi (NGO)	07 (43 structures)	Datia and Jhansi	M.P. and U.P.
4.	Banaras Hindu University, Varanasi	02	Rajeev Gandhi South Campus, BHU, Barkachha	U.P.

A number of agencies are approaching NRCAF for training and demonstration of these technologies.

Impact of Rainwater Harvesting Structures on Groundwater Recharge in Parasai-Sindh watershed of Central India

Study was carried out at Parasai - Sindh watershed located in Babina block of Jhansi (Bundelkhand region) Uttar Pradesh. This watershed was selected in 2011 to enhance water availability, water use efficiency and agricultural productivity through agroforestry and improved management of land and water resources. The open shallow dug wells, situated in unconfined aquifer, are the major source of irrigation throughout Bundelkhand region of Central India. These wells due to dependence on perched water are characterized by very low specific yield do not support continuous operation of pumps to irrigate the agricultural fields in a single stretch. This warrants immediate need of water harvesting to ensure quick recharge in wells and thereby facilitate irrigation and in turn crop productivity.

Total area of the watershed is 1246 hectares comprising three villages namely Parasai, Chhatpur and Bachhauni. It is located between 25 ^{o} 23′ 47.6″ - 25 ^{o} 27′ 05.1″ latitude and 78^{o} 20′ 06.5″ - 78^{o} 22′ 33.0″ longitude. The watershed has a semi- arid sub-tropical climate and characterized by dry and hot summer, warm and moist rainy season and cool winter with occasional rain showers. Mean annual temperature ranges from 24 to 25^{0}C. The mean summer (April-May-June) temperature is 34^{0}C which may rise to a maximum of 46 to 49^{0}C during the month of May and June. Majority of the area is under agriculture (88.7%) followed scrub land (5.7%). However, about 200 ha of agricultural land are generally kept fallow during *rabi* due to lack of irrigation water. Majority of agricultural land in the watershed comprises shallow gravelly red soil (82%) with patches of light black soil. Red soil has very low water holding capacity (7 to 16%) and poor in organic carbon (0.2 to 0.4%). As such, they suffer badly on account of water scarcity, hence, low productive. To improve the water resources in the watershed about 1,00,000 cum. rainwater harvesting facility was created through 10 cost-effective structures during 2012 and 2013. The open wells were monitored for water level once in a month since May, 2011 to capture the trend of water level as influenced by rainwater harvesting structures. Depth of wells varies from 2.95 to 17.8 m with average of 9.7 m.

The Water table Fluctuation (WTF) method was applied in the Parasai-Sindh watershed during pre (2011, 1289.2 mm rainfall) and post (2013, 1396 mm rainfall) intervention phase to quantify groundwater recharge. Specific yield was estimated in the range between 0.5 and 1.5% with average

value of 1.0% for Bundelkhand hard rock region. Underlying deep percolation is assumed negligible due to presence of impervious granite layers. Evaporation losses from the groundwater aquifer were calculated as 5-10 mm year^{-1} for the study area using Coudrain-Ribstein's depth–evaporation relationship. The average difference in hydraulic head of 200 open wells for the months of May and October during pre and post interventions was 3.54 and 5.01 m, respectively. Net groundwater recharge during monsoon season of pre and post interventions was estimated at 53.7 and 82.6 mm, respectively, which is 53.7 per cent higher than pre intervention phase. The significant increase in groundwater recharge is attributed to rainwater harvesting through cost-effective structures. Improved yield of open wells reduced *rabi* fallow by about 70 ha besides, ensuring irrigation water through dug wells to *rabi* crops predominantly wheat in entire treated area of the watershed. The study has proved beyond doubts the efficacy of rainwater harvesting for groundwater recharge in Bundelkhand region of Central India. The findings of Parasai-Sindh watershed are in conformity with that of Garh Kundar–Dabar watershed. This has established replicability of watershed management programmes in Bundlkhand region for resolving issue of ground water recharge and availability for irrigation and drinking as well.

3. AICRP ON AGROFORESTRY

A. Research Achievements

Tree-crop interaction studies were carried out in plum based agroforestry systems in Kullu valley of temperate Himalaya by YSPUH&F, Solan and exhibited that plum tree suppressed maize growth and yield significantly at 1 m distance and north direction as compared to other distances and directions. Soil fertility was higher in agrihorticulture system than sole cropping. Addition and removal of nutrient were higher in agrihorticulture system than sole cropping. Agrihorticulture system gave higher values for biomass productivity and net returns than sole cropping. The CSK HPKV, Palampur centre successfully screened important grasses and established slivipastotral system best suited for the Himalayan region especially for the marginal farmers of the region. Green fodder yield of 45 t ha^{-1} for Napier NB 37 was obtained in 4 cuts. The studies have shown that production of tea yield under the plantation of *Albizia* as shade tree was about 56% higher compared to control.

The SKUAST, Srinagar centre has evaluated apple based agroforestry system under temperate conditions. The yield of apple was recorded maximum 21.57 t ha^{-1} in combination with *Artemesia absinthium* followed by 17.34 t ha^{-1} in combination with Lucerne. Apple + Lucerne recorded maximum yield (Fresh weight) of fodder crop 20.84 t ha^{-1}.

AAU, HRS centre at Kahikuchi studied Coconut and *Acacia mangium* based agroforestry systems and found that coconut yield was 7.3 to 17.8% higher when cultivated in association with intercrops compared to sole coconut plot (6828 nuts ha^{-1}). In addition to coconut, french bean yielded 106.5 and 12.07 t ha^{-1}, okra yielded 78.5 and 9.10 t ha^{-1} and cowpea yielded 38.0 and 4.49 t ha^{-1} as intercrop and in open conditions. The agroforestry system also resulted in built up of organic matter (1.83 to 1.93 %), available N (317.6 to 322.9 kg ha^{-1}), available P_2O_5 (29.4 to 31.9 kg ha^{-1}) as compared to sole coconut plot. In *Acacia mangium* experiment the maximum plant height (12.32 m), dbh (22.74 cm) and annual increment of timber volume (23.08%) was recorded in 5x5 m spacing in 9 year old trees. In this experiment the organic C increased from 0.81 to 1.22%, available N from 208.5 to 304.2 kg ha^{-1}, available P_2O_5 from 12.4 to 26.8 kg ha^{-1} and available K_2O from 142.2 to 299.1 kg ha.

In Tamarind + Custard apple + redgram system higher tamarind pod yield (1.5 to 2.12 t ha^{-1}) with additional yields of curry leaf (1.0-1.4 t ha^{-1}) and Red gram as inter crop was beneficial with net returns of ₹ 33,365 ha^{-1} $year^{-1}$ and B:C ratio of 1:2.4 at ANGRAU, Hyderabad. Custard apple inter cropped with *Stylasanthes hamata* as fodder component produced higher fruit yield (5.7 t ha^{-1}), net returns (₹42,500 ha^{-1}) with application of 120 kg N, 30 kg P_2O_5 per hectare. This system is useful where grazing animals has to be raised in semi-arid region.

The pruning studies in guava based agroforestry system at JNKVV, Jabalpur revealed that open condition recorded significantly higher grain yield (702.19 kg ha^{-1}), where as no pruning recorded the lowest yield (408.19 kg ha^{-1}) and the reduction in grain yield was 42% (due to shade). Among pruning intensities, heavy pruning *i.e.* 60 cm pruning of tertiary branches from all four sides (NS EW) recorded significantly higher grain yield (605 kg ha^{-1}). The percent reduction in grain yield under no pruning, light pruning, moderate pruning and heavy

pruning was 42, 30, 23 and 14%, respectively. Among different *kharif* crops, paddy recorded significantly higher grain yield (961 kg ha^{-1}).

At SK Nagar, the evaluation of 10 plus trees and 17 provenances of neem exhibited maximum height in SKN-3 and SKN-10 (8.30 m), whereas SKN 4 exhibited highest collar diameter (31.9 cm) after 138 months of plantation. Out of 17 neem provenances collected from different region of the state, provenance from Vasda recorded highest (7.8 m) height whereas the provenance from Bharuch exhibited highest collar diameter (29.5 cm). Aonla with pearlmillet – cowpea rotation gives higher yield and net returns. This agroforestry system also enriches the fertility status of the soil.

The evaluation of bamboo germplasm at PDKV, Nagpur revealed that maximum height (107.7 cm) was attained by *B. vulgaries* and maximum number of tiller 5 was attained by *B. multiplex*. In execution of transfer of Agroforestry technologies programme under TSP fund 190 tribal farmers from four tribal districts were selected and provided nursery material (poly bags, irrigation pipe, storage tank, seeds, etc.) bamboo working tools, Sprinkler sets for enhancing the productivity from the marginal and small farmlands belonging to tribes. In addition to this, twenty five tribal farmers were trained in designing eco-friendly bamboo tree guards and other valuable items for livelihood security.

After 6 years of plantation, poplar attained significantly more girth under agroforestry than sole poplar at Hisar. Among different spacing, significantly more girth was recorded at 5x4m and 10x2m spacing than paired row planting (18x2x2m). The crop performance studies in the above plantation revealed that green fodder yield of both sorghum and cowpea increased with increasing row spacing, however, the differences in yield between 5x4m and 10x2m spacing were not significant. Eucalyptus planted on a saline soil at 3x3m and 6x1.5m and 17x1x1m spacing recorded significantly more girth at 3x3m spacing than 6x1.5m and 17x1x1m spacing. The green biomass yield of *Dhaincha* grown for green manuring in the interspaces of above eucalyptus plantation was significantly higher in paired row (17x1x1 m) plantation than 3x3m and 6x1.5m spacing. In field bund poplar plantation studies poplar was found to affect the green fodder yield of sorghum up to 9m distance from the tree line.

Studies conducted on effect of *in situ* soil moisture conservation measures on growth of fruit tree species in sloppy and waste land, at MPKVV, Rahuri revealed that the survival percentage was more (87%) in treatment of plantation of fruit tree species in conventional pit with semi-circular basin method. The soil moisture percentage (16%), increment percentage in plant height (27) and collar diameter (23) were recorded maximum in plantation of fruit tree species on CCT method. Among the fruit tree species the maximum increment percentage in height (28) and collar diameter (23) were recorded in Ber fruit tree.

The ARS Fatehpur Shekhawati centre collected thirteen improved germplasm and 15 plus trees of *Prosopis cineraria* and 19 plus trees and 6 provenances of *Dalbergia sissoo* for evaluation. Studies on intercropping of rainfed kharif crops with *P. cineraria* and *Hardwickia binata* indicated that clusterbean varieties RGC936, RGC197, Pearlmillet variety (HHB 67) and moongbean variety SML 668 as most promising varieties with respect to gross return. The centre selected 80 farmers in Banswara district under TSP programme and distributed various inputs and organized training program for capacity building of farmers.

In agrisilvicultural system at OUAT, Bhubaneshwar, four intercrops *viz.* one fruit crop pineapple (*Ananus comosus*) and three medicinal crops ghee kuanri (*Aloe vera*), kalmegh (*Andrographis paniculata*) and mango ginger (*Curcuma amda*) were grown in the alleys (8.0 m wide) of two fast growing timber species (*Acacia mangium* and *Gmelina arborea*) at 625 trees ha^{-1}. Shade had absolutely no adverse effect on the growth and economic yield of pineapple and *Aloe vera*. Leaves/plant and weight/leave in *Aloe vera* in agroforestry system during dry months were more than in sole crops. Pineapple was the best suitable crop to be included 12^{th} year of tree plantation in agrisilvicultural system with mean net returns of ₹ 81395 and 65860 ha^{-1} $year^{-1}$ with B:C ratios 2.18 and 1.95 when intercropped with *Acacia mangium* and *Gmelina arborea*, respectively, as against a net return of ₹39950 with B:C ratio 1.58 when grown as a sole crop. Among the two tree species, the growth in terms of height and dbh was significantly greater in *Acacia mangium* (height 19.12 m and dbh 24.35 cm) than *Gmelina arborea* at 138 months after planting. *Acacia mangium* recorded highest volume increment of 16.53 m^3 ha^{-1} $year^{-1}$ in combination with pine apple.

The plantation of timber tree species *viz*; *A. mangium, D. sissoo* and *E. tereticornis* as pure and mixed at IGKVV, Raipur revealed that *E. tereticornis* and *D. sissoo* performed better as pure and with *A. mangium*, while *A. mangium* showed overall poor performance in either conditions. The yield of Rice were maximum 3.6 t ha^{-1} in open field crop which reduced less under sole *A. mangium* (29.2%) and more under sole *D. sissoo* (48%) plantation. The cultivation of four Wheat varieties *viz.* Sujata, G273, Ratan and Kanchan could not show significant variation 13.38 (Ratan) to 1.81 t ha^{-1} (Sujata).The litter fall of *D. sissoo* (100 g m^{-2}) and *A. mangium* (55g m^{-2}) was found to responsible for higher soil nutrient status under *D. sissoo* + *A. mangium*. In *Dendrocalamus strictus*, population of culms per clump was found 22.71 $clump^{-1}$, out of which 4.4 culms $clump^{-1}$ were removed every year in summer. These removed mature and dead culms produced 11.68 kg dry weight per clumps. The yield of Paddy and Wheat crops were recorded 10.82 and 6.51 q ha^{-1} respectively under Bamboo, which was 69 and 53% less respectively than sole crop. Production of Turmeric between clumps was 2.17 t ha^{-1}. At Ranchi, in provenance trial of Gamhar maximum height was recorded under Simdega provenance (3.41m) with annual increment of 0.72m, which was significantly superior over other provenance. Annual increase in height of different provenance of *Pongamia* was recorded maximum in Latehar (10.03cm) which was at par with Dhanbad (9.93cm) and Bijapur (9.05cm).

The centre BCKV, Jhargram focused on collection and maintenance of germplasm of *Gmelina arborea* and *Acacia auriculiformis*; Fruit-based agroforestry systems; Agri-silvicultural systems (on the basis of allotted MPTs); Tree Borne Oilseeds; Bamboo-based agroforestry system along with different extension activities. Presently centre has a large collection of germplasm of *Gmelina arborea* and *Acacia auriculiformis* (36 and 40 provenances respectively) which are being maintained and evaluated. The fruit-based agroforestry systems *viz.* Mango + *Gmelina arborea* – arable crops, Mango + *Eucalyptus tereticornis* – arable crops, Mahua + Aonla – arable crops, *Gmelina arborea* + Guava, *Gmelina arborea* + Sweet orange, *Acacia auriculiformis* + Guava, *Acacia auriculiformis* + Sweet orange, *Eucalyptus tereticornis* + Sweet orange, and *Eucalyptus tereticornis* + Guava have been found to be most suitable alternative land use systems that provide sufficient income in red and laterite zone of

West Bengal. Certain fruit based agroforestry technologies have been developed through on-station trial at RRS, Jhargram and transmitted to the farmers' field. An initiative has been taken this year as well by the centre to popularize the practice of agroforestry system in the districts of Paschim Medinipur, Purba Medinipur, 24 Parganas (N), Hoogly and Nadia. Mango-based agroforestry system like mango + paddy in *kharif* and *boro* seasons, mango + mustard, mango + lentil, mango + jute, mango + pointed gourd, guava + brinjal, guava + mustard, guava + chilli, guava + bitter gourd, guava + pumpkin and guava + silvi species (*Anthocephalus cadamba*) fruit-based agroforestry systems were evaluated in the farmers field provided gainful employment opportunities and generated appreciable income.

The PAU, Ludhiana centre studied the comparative performance of newly released wheat varieties under four year old poplar plantation, the grain yield of DBW 17 (4.41 t ha^{-1}) was higher than other wheat varieties (PBW 550, PBW 621 and PBW 502). In a silvi-horticulture trial, the effect of trees on fruits was observed with respect to growth and yield parameters of fruits and reduction of fruit yield due to shade of trees. The height, collar diameter and fruit weight of kinnow (1.52 t ha^{-1}) were higher under *Melia* than poplar. The fruit weight of guava (0.89 t ha^{-1}) was also higher under *Melia* than poplar. Carbon sequestration by seven year old *Populus deltoides*, *Eucalyptus tereticornis*, *Melia composita*, *Ailanthus excelsa* and *Toona ciliata* in agroforestry system was 54.9, 48.0, 43.3, 20.8 and 19.1 t ha^{-1}, respectively. After seven years of age, the removal of N and P was the highest by poplar (N: 839 kg ha^{-1}, P: 107 kg ha^{-1}) and the lowest by toon (N: 365 kg ha^{-1}, P: 30 kg ha^{-1}) among these tree species. Among the different treatments of fertilizers applied to clonal eucalypt, a significantly more height (17.9 m) and dbh (17.1 m) were produced with the application of N:P:K @ 30:20:20 g $plant^{-1}$ during first year which increased to 150:100:100 g $plant^{-1}$ during fifth year. A trial has been initiated to evaluate the influence of integrated nutrient management on growth of crops and trees under different spacing of poplar.

The GBPUAT, Pantnagar centre studied the effectiveness of tractor-operated augur for poplar plantation in saving time and money. Initial results indicated superior growth also in the pits made by tractor operated augur. The centre also worked on use of bio-degradable pots for nursery plants. Initial results have shown superior survival and growth of plants beside the fact that such technology will be pollution free.

Out of the three paddy varieties evaluated (Saryu-52, BPT-5204 and ND-359) at NDUAT, Faizabad under agri-silvicultural systems of different *Populus deltoides* clones, Sarjoo-52 variety had maximum average grain yield (2.01 t ha^{-1}), showing grain yield reduction form open condition by about 27.7% (Saryu-52). Across different lopping intensities (0, 25, 50, 75 and 100% lopping) in *Dalbergia sissoo* trees under silvipastoral system, the annual green fodder yield for three grasses (*Pennisetum purpureum*, *Brachiaria mutica* and *Panicum maximum*) was studied. *P. purpureum* grass had maximum green herbage yield (45.5 t ha^{-1} yr^{-1}) amongst grasses. There was a clear cut increase in herbage yield of all three grasses along increasing lopping intensities. In nutshell, to manage trees under silvipastoral system, it would be desirable to restrict lopping to a maximum 50% of the crown portion.

An intercropping trial was conducted on 5-year-old Litchi (var. China) orchard planted at 7x7 m spacing to identify the suitable and profitable intercrops at RAU Pusa. The results indicated that the production of fruits significantly increased

due to intercrops and it was maximum in association with turmeric (6.1 t ha^{-1}) followed by ginger (5.2 t ha^{-1}), colocassia (4.9 t ha^{-1}) and elephant foot yam (4.6 t ha^{-1}). On the other hand, reduction in yield of intercrops was 6.5-15.2 % for turmeric, 12.4-35.5 % for ginger, 9.8-27.8 % for colocassia and 22.5-31.6 % for elephant foot yam compared to the yield in open area. It was confirmed that litchi-based agri-horticultural systems were effective in bringing about improvement in the soil properties as reflected by the significant increase in organic carbon, available nitrogen and phosphorus.

Provenance evaluation trial on *Acacia mangium* after 11 years of tree age at Thrissur, showed marginal growth variation among provenances. Among the provenances Papua New Guinean provenances performed better in the humid high rain fall conditions of Kerala. The better performers include Balimo and Upper Aramia, Kuranda, Arufi village and Oriomo WP. With the primary objective of standardizing ideal planting densities for various end uses a planting density-cum-pruning trial on *Acacia mangium* was established during 2001 at the centre. Tree heights though significantly varied among planting densities, a leveling trend was observed with advancing age. However, dbh (12 to 20 cm) and mean tree volume (0.15 to 0.4 m^3) registered significant increase with decreasing planting density. Stand volume on the other hand, was considerably higher for closely spaced stands (5000 trees ha^{-1}; 743 m^3 ha^{-1}) indicating the central role of population density on stand volume production. High MAI in volume (74 m^3 ha^{-1} yr^{-1}) at the age of 10 years further highlight the fast growth potential of *Acacia mangium*.

In teak legume based agroforestry system, grain yield of soybean with teak was higher as compared to teak with other legumes at UAS, Dharwad. Teak growth was significantly higher with soybean as compared to with redgram. In a study on integration of perennial vegetables with teak, soybean grain yield was higher with teak + curryleaf / drumstick as compared to greengram with teak + curryleaf / drumstick. Growth of teak was significantly higher in teak + curryleaf + greengram / soybean as compared to in teak + drumstick + greengram / soybean. Among the perennial vegetables, drumstick growth and yield were higher than curry leaf. Net income was higher in teak + drumstick + soybean as compared to other treatment. Thus reflecting that the excess resources available in the initial stages of agroforestry system can be made used by blending additional components there by generating additional interim receipts. The University has established large nursery where in quality seedlings are raised. In the past 7 years 40 lakhs seedlings were raised and supplied free of cost. A model plantation of Pongamia, Jatropha, Simarouba, Neem, Calophyllum, Amoora, and Mahua is also established. The University also identified few vehicles for running with 10% Biodiesel blend. In addition stationary machines are also run with this biodiesel since past 3 years. The unit is a model for research / extension workers.

AICRP on Agroforestry, Kattupakkam conducted a palatability trial on four selected tree fodders based on the local availability and preference for intake in sheep and goats was conducted for 35 days with *Leuceana leucocephala, Inga dulce, Albizzia lebbeck* and *Glyricidia sepium*. Initially all the animals were adapted for each of the tree leaves by feeding them as sole for ten days. Each animal is housed individually and offered pre-weighed quantity of all the four tree leaves at the same time. The feeding behaviour and pattern was observed and ranking of palatability was given based on it. In sheep and goats, palatability of *Leuceana leucocephala, Inga dulce* were ranked first and

second. In goats, *Glyricidia sepium* is ranked third followed by *Albizzia lebbeck* in contrast to sheep where *Albizia lebbeck* is ranked third followed by *Glyricidia sepium.* A feeding trial was conducted to evaluate the Jatropha oil cake as a feed for sheep and goats. Raw Jatropha oil cake is observed to be unpalatable and rejected by sheep and goat when fed at 5% inclusion level in concentrate feed. To overcome this, raw oil cake is treated with 2% calcium hydroxide solution and included at 5% level in concentrate feed. Calcium chloride treated oil cake is found palatable in sheep and goats as indicated by normal dry matter intake of concentrate feed. In another experiment, the possibility of complete replacement of concentrate feed (100g) in grazing animals (8-10 hrs grazing day^{-1}) with *Leuceana leucocephala* and *Inga dulce* was studied through feeding in weaned kids for 90 days. The average daily gain in concentrate feed group, *Leuceana leucocephala* and *Inga dulce* groups is 48.14 g, 50.55 g and 47.77 g, respectively. It was concluded that concentrate feed could be replaced by tree leaves without change in the growth rate of kids.

The UAS, Bangalore Identified 14 elite clones in Simarouba and established Clonal seed orchard**.** The clonal seed orchard of tamarind was established comprising of 27 clones/selections from different sources. Tamarind selections, Hosakote-15 and GKVK-17 recorded higher cumulative yield and grafted seedlings are produced in large scale and supplied to the farmers. The forage crops, CO-3, *Stylosanthus hamata* and Guinea grass and food crops, Fingermillet and sorghum performed better and recorded higher yield under Simarouba, Neem and Pongamia based agroforestry system.

Under *Melia dubia* trees of 2 years and 6 months age, nine intercrops were raised to study the compatibility of the intercrops with the tree component at TNAU, Mettupalaym. The results showed that owing to the age and height growth of *Melia dubia*, the canopy was rather dense which resulted in reduction of growth and yield of the intercrops to the tune ranging from 20 – 37% over the previous year. The Litter fall studies showed that litter fall was higher during the dry period irrespective of the tree species and among the different tree species, Simarouba recorded the maximum litter fall (1210 kg ha^{-1}) than Eucalyptus (1004 kg ha^{-1}) and Silver oak (815 kg ha^{-1}). Simarouba registered the maximum nutrient contents of 0.65% N, 0.34% P and 1.47% K. The annual litter production was higher in Simarouba (4.125 t ha^{-1} yr^{-1}) and lower in Eucalyptus (3.399 t ha^{-1} yr^{-1}).

Among ten bamboo species evaluated at Dapoli, overall high growth parameters *viz.*, height, number of culms/clump was reported by *Bambusa arudinacea* followed by *Bambusa nutans*. Under cashew based Horti-silviclture system, Asana (*Bridelia retusa*) recorded maximum significantly higher height of 4.75 cm. whereas Annatto (*Bixa orellana*) showed maximum significantly higher dbh of 11.61 cm. In the experiment of mango based horti- agricultural system, ground nut intercropped in mango recorded higher pod yield (1.30 t ha^{-1}) which was closely followed by finger millet.

Major activities of AICRP on AF during the year

Three Decades of AICRP on Agroforestry

All India Coordinated Research Project on Agroforestry, initiated by ICAR in 1983, has completed 30 years. NRCAF celebrated the Thirty Years of Agroforestry Network as a part of Silver Jubilee celebration. The, project has contributed remarkably in the field of agroforestry research in India. It is one of the largest AICRPs in the ICAR with 37 coordinating centres located throughout the country. During last thirty years large

number of technologies have been developed and identified by the coordinating centres of the project which has been demonstrated in famer's field and disseminated through trainings.

Annual Workshop of AICRP on Agroforestry organized at CSKHPKV, Palampur on 25th-27st May, 2013

Dr. S K Sharma, Vice Chancellor, CSKHPKVV, Palampur while inaugurating the three days Annual Workshop of the AICRP on Agroforestry emphasized that importance of agroforestry to meet the present challenges of climate change and provide livelihood opportunities to rural population is increasing. He mentioned that agroforestry is providing valuable fodder for livestock and helping in resource conservation particularly in the hilly and semi-arid region. Dr. S K Dhyani, Project Coordinator and Director, NRC for Agroforestry highlighted the research achievements of the project and thrust areas for the XIIth Plan. He informed that the AICRP on Agroforestry was initiated in 1983 and at present it has 37 coordinating centres located in 25 SAUs, 11 ICAR Institutes and one ICFRE Institute. The recommendations of the project regarding crop diversification through agroforestry have been implemented by eight states. Five bulletins complied by PC Unit, Jhansi; SKUAS&T, Srinagar; PAU, Ludhiana; AAU, Jorhat and ANGRAU, Hyderabad were released on the occasion.

Dignitaries releasing publication during workshop

Dr. B Mohan Kumar, ADG (Agroforestry), ICAR in his address invited the researchers to quantify agroforestry contribution for environmental services and its potential for control of non-point source pollution.

Dr. B Gangwar, Director, PDFSR, Modipuram while delivering the plenary lecture invited for establishing linkages between the two projects for developing farming system models for small and marginal farmers.

Dr. V P Singh, Regional Representative for South Asia of World Agroforestry Centre in his address emphasized that the second green revolution is not possible without having trees on the farm.

A view of Poster exhibition

Dr. R P Awasthi, Former VC, YSPUH&F, Solan and former chairman of the QRT, Dr. C L Acharaya, Ex Director, IISS, Bhopal, Dr. S P Sharma, Director Research, CSKHPKV, Palampur, Dr K S Dadhwal, Ex i/c Director, CSWCR&TI, Dehradun, Dr. A Arunachalam, PS and OSD, ICAR chaired different sessions of the Workshop and participated in the discussion.

The presentations of the coordinating centres were divided into five sessions namely; Himalayan, Indo-gangetic; Humid & Sub humid; Arid & semi arid and Tropical zones. The major recommendations emerging from the discussion include emphasis on tree improvement and production of quality planting material, value addition and post harvest technology, economic analysis and quantification of environmental services of the agroforestry systems. During the workshop the research achievements of each centre was reviewed using performance indicators and technical program finalized. AICRPAF at PAU, Ludhiana bagged the best presentation award. During the meeting there were 8 technical sessions in addition to field visits to the experimental area, Tea Husbandry and Organic Farming Unit of the University. A poster exhibition depicting agroforestry technologies developed by coordinating centres of the project for different agro-climatic zones was also organized. Scientists and Officers from NRC for Agroforestry and all the Coordinating centres attended the workshop.

Work Plan of AICRP on Agroforestry for Bali Island, Sunderban, West Bengal

The Project Coordinator participated in a meeting chaired by Secretary DARE and DG, ICAR for the development of Sunderbans in West Bengal. The AICRP on Agroforestry prepared a workplan for the region based on suitable tree species and technologies which can be transferred to the tribal population of Bali Island in Sunderbans for providing livelihood, food and nutritional security to them. The workplan focused on transfer of technology for Homestead/Bari-system; Boundary Plantation of multipurpose trees (preferably fruit trees) on field bunds of rainfed paddy lands in the undulating terraces and Agrihorticulture system and capacity building of tribal population for nursery raising and value addition.

Organization of Satellite Seminar and Plantation Drives

The coordinating centres of AICRP on Agroforestry organized satellite seminar and special plantation drives involving school children as pre congress activities related to Third World Congress on Agroforestry.

National Consultation Meet on Agroforestry

A one day National Consultation Meet on Agroforestry Research and Development in India was organized at New Delhi on 19th November, 2013. The meet was attended by the officials from Central Government Ministries, State Departments and organizations such as National Advisory Council (NAC), Planning Commission, National Rainfed Agriculture Authority, Ministry of Agriculture, Ministry of Environment and Forests, Ministry of Rural Development (Land Use and Planning), World Agroforestry Centre, BAIF, ICFRE, ICAR Institutes, representatives from WIMCO, ITC, NABARD, Tree Grower's Association and progressive farmers. The Meet was organized as precursor for showcasing Indian perspective for Agroforestry R & D and development at Global level during forthcoming WCA2014. The outcome of the meeting was identification of critical gaps and implementing constraints in Agroforestry Development and how to overcome them. This was a part of initiatives for evolving a framework for a National Agroforestry Policy.

4. AWARDS AND RECOGNITIONS

NAAS Fellowship

Dr. S K Dhyani, Director has been elected as a Fellow of National Academy of Agricultural Sciences (NAAS), New Delhi. The Fellowship was presented during the 20th Annual General Body Meeting of NAAS on 5th June, 2013 organized at the B. P. Pal Auditorium, IARI, Pusa, New Delhi.

Dr. Ramesh Singh, Sr. Scientist was awarded best paper presentation award for the paper entitled"Impact of Watershed Interventions on Runoff, Soil Loss and Water Availability in Drought Prone Bundelkhand Region"authored by Singh, Ramesh, Tewari, R K, Dhyani, SK and Sharma, HC in "47th Annual Convention of Indian Society of Agricultural Engineers (ISAE) and International Symposium on Bio Energy-Challenges and Opportunities" during 28th-30th January, 2013 held at Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad (A. P.).

Dr. R P Dwivedi, Pr. Scientist was awarded best paper presentation award for the paper entitled "Participatory Agroforestry based Ber budding Programme for Sustainable Rural Livelihood" in National Seminar on "Social Dimension of Extension Education in Holistic Development of Rural Livelihood" during 26th-27th April, 2013 organized by the Indian Society of Extension Education, IARI, New Delhi, ICAR, CBGAPG College, Bakshika Talab, Lucknow (U.P.).

Best Poster Award-1st was conferred to paper *"Krishivaniki adharit jalagam kriyaon dwara Bundelkhand kshetra me kam varsha ki stithi me bhi sukhe ka nivaran"* authored by Singh, Ramesh, Tewari, R K, Dhyani, S K, Dwivedi, R P, Rizvi, R H, Sharma, Babloo, Singh, R, Singh, Rajendra, Singh, Shishupal, Bajpai, C K, Karmakar, P S and Saxena, Abhisek. Sept. 20 during Hindi Saptah: 13th-21st September, 2013 at NRCAF, Jhansi.

5. CONSULTANCY SERVICES

Investigation on Carbondioxide Sequestration at M/s JSW Steel Ltd. through Green Belt Development

JSW Steel Ltd. is one of the premier steel producer in India with a production capacity of 10 million tons of steel per annum at it's Vijayanagar Plant in the Bellery district of Northern Karnataka. It is the largest steel plant in India at a *single location*. Significant efforts were taken in the recent past for reduction in CO_2 emission through improvements in energy efficiencyat JSW Steel Limited. Even with many of the new state-of-the-art facilities, the CO_2 emission from VijayanagarPlant is about 22- 25 MT of CO_2 per annum. In this scenario, the management of JSW Steel Limited has taken a policy initiative to take up a major R & D Programme on "*Carbon Dioxide Capture and Sequestration*". The main initiative aimed at quantifying the CO_2 sequestered through green belt development activities in the Plant (Vijayanagar Works) through quantitative modeling and suggesting plantation options for future land usage with a view to maximize CO_2 sequestration using the terrestrial sequestration approach.

JSW Steel Ltd. requested National Research Centre for Agroforestry (NRCAF), Jhansi (UP) to actualize this process. In this study detailed investigations were carried out on the impact of pro-active measures taken by JSW Steel Ltd. in CO_2 sequestration through green belt development within the steel plant premises and it's various residential colonies at Vidyanagar, V. V. Nagar and Shankar Guda.

In the recent past researchers in Europe have tried to develop a standard methodology for carbon sequestration potential for different plant species. The most significant development is the CO_2FIX model which is a comprehensive simulation modeling tool developed through joint funding from the European Commission (EC), Dutch Government and the Mexican National Council of Science & Technology under the Carbon Sequestration in Forested Landscapes (CASFOR II) Project. Scientists from the National Research Centre for Agroforestry, Jhansi have extensively used and parameterized CO_2 FIX model for Indian conditions to simulate carbon sequestered under tree based systems. Accordingly, the carbon sequestered under various existing greenbelt configurations at JSW Steel Ltd. was assessed using CO_2 FIX modeling simulations.

The carbon sequestration potential of existing green belt (block plantations) in 4MT, 7MT, 10MT and township areas of JSW campus was estimated to the tune of 2.65, 1.63, 3.01 and 3.71 tons C ha^{-1} yr^{-1} (or converting into CO_2 equivalent of 9.71, 5.97, 11.03 and 13.60 tons CO_2 ha^{-1} yr^{-1}, respectively).

The carbon sequestration potential of existing avenue/road-side plantations in 4MT, Main-Gate, VV Nagar, Shankarguda and Vidhya Nagar areas of JSW campus was estimated to the tune of 1.28, 0.61, 0.24, 0.15 and 0.89 tons C ha^{-1} yr^{-1} (or converting into carbon dioxide equivalent of 4.69, 2.23, 0.88, 0.55 and 3.26 tons CO_2 ha^{-1} yr^{-1}, respectively).

When results of all the nine study areas of JSW plant and residential campuses were put together, the overall carbon sequestration potential of existing plantations varied from 0.15 to 3.71 tons C ha^{-1} yr^{-1}. The simulation results of this study also seems reasonably acceptable in the light of the reported values of carbon sequestration potential of many tree species (namely *Syzyium cumini, Gmlina*

arborea, Tectona grandis, Acacia auriculiformis, Dalbergia latifolia, Terminalia chibula and *Hardwickia binata* with tree densities varying from 157 to 1112 trees ha^{-1}) planted in Hosakaote Research Station of Bangalore Research Circle (Central Karnataka Zone) ranging from 0.14 to 3.50 tons C ha^{-1} yr^{-1}. Moreover, the results of this study are comparable with the other published studies in India as well as in other parts of the world.

Evaluation of Preparatory Phase of Watershed Projects under IWMP Scheme

State Level Nodal Agency (Integrated Watershed Management Programme), Govt. of Uttar Pradesh, Lucknow has nominated National Research Centre for agroforestry (ICAR), Jhansi as independent agency for evaluation of Preparatory Phase of watershed projects under IWMP Scheme in eleven districts of U. P. other than Jhansi. The Centre has evaluated 39 IWMPs during the year 2012-13 in the districts of Lalitpur, Mahoba, Hamirpur, Banda, Agra, Mathura, Firozabad, Mainpuri, Bijnor, Rampur and Sambhal. In the post evaluation meeting held on 13th March, 2013 at Lucknow, Principal Secretary (LDWR), Govt. of U.P. and member Secretary, SLNA (IWMP), appreciated quantity and quality of evaluation by the Centre. Further, in light of recommendations suggested in evaluation reports, SLNA (IWMP), Govt. of U.P. organized one day Workshop of All PIAs (IWMP) of Bundelkhand region at Jhansi on dated 23rd May, 2013 and invited the Centre for discussion and presentation. Scientists from the Centre participated in the workshop and presented a paper titled "Useful technologies and participatory process for natural resource conservation on watershed basis". Various compatible technologies *viz.* (1) Rainwater harvesting and recycling on watershed basis for Bundelkhand region, (2) Cost effective design of rainwater harvesting structures (RWHS), (3) Prevention of Seepage through rainwater harvesting structures, (4) Aonla based horti-pastoral system in red soil of Bundelkhand region using contour staggered trenches, (5) Concept of drought proofing of Bundelkhand region and (6) Participatory process for watershed development were highlighted. The experiences of IWMP evaluation in various districts were also shared. The suggestions were given for effective implementation and assured success of programme.

6. ONGOING RESEARCH PROJECTS (2013-14)

Project code	Title of project/sub project	Duration	Project leader	Associates
Systems Research: Programme Leader : Dr. Anil Kumar				
AF01.17	Analysis of Eucalyptus based agroforestry for crop- lands in Jhansi	2003-2014	Dr. A K Handa	Dr. Ram Newaj, Dr. Badre Alam, Dr. Anil Kumar, Dr. Ajit & Dr. Ramesh Singh
AF02.12	Effect of irrigation on performance of aonla under agroforestry systems	2005-2015	Dr. R K Tewari	Dr. Ramesh Singh
AF02.14	Nutrient management in ber based agri-horti system	2010-2019	Dr. Sudhir Kumar	Dr. Anil Kumar, Dr. Rajendra Prasad & Dr. Inder Dev
AF03.9	Initiation of pruning and its intensity on productivity of *Albizia procera*	2006-2020	Dr. Inder Dev	Dr. K B Sridhar
Observational Trial	Development of bamboo based agroforestry systems in six agroclimatic zones	2007-2014	Dr. Inder Dev	Dr. K B Sridhar
Natural Resource & Environment Management: Programme Leader : Dr. Ram Newaj				
AF01.16	Evaluation of shade tolerance of crop species for agroforestry systems	2007-2014	Dr. Badre Alam	Dr. Ram Newaj
AF01.24	Studies on arbuscularmycorrhizal fungi of important MPT's	2008-2016	Dr. Anil Kumar	Dr. Rajendra Prasad
AF01.25	Development of soil quality index for assessing soil health of different agroforestry systems	2008-2015	Dr. Rajendra Prasad	Dr. Ram Newaj & Dr. Ramesh Singh
AF 05.6	Model watershed project on natural resource management through agroforestry interventions at Garhkundar, Tikamgarh, M.P. **Project Leader: Dr. S K Dhyani**	2005-2016	Dr. R K Tewari	Dr. Ramesh Singh, Dr. R P Dwivedi & Dr. R H Rizvi
AF 05.11	Multi-Source Inventory Methods for Quantifying Carbon Stocks through Generalized Volume/ Biomass Equations for Prominent Agroforestry Species in India	2011-2017	Dr. Ajit	Dr. A K Handa & Dr. R H Rizvi

Project code	Title of project/ sub project	Duration	Project leader	Associates
NICRA	National Initiative on Climate Resilient Agriculture **Dr. S K Dhyani, Director & Programme Leader** **Lead Instt.: CRIDA, Hyderabad**	2011-2017	Dr. Ram Newaj	Dr. Rajendra Prasad, Dr. A K Handa, Dr. Badre Alam, Dr. Ajit & Dr. R H Rizvi
New Project	Agroforestry based conservation agriculture for sustainable landuse and improved productivity	2013-2018	Dr. Inder Dev	Dr. R K Tewari, Dr. Ramesh Singh & Dr. K B Sridhar
MoRD, New Delhi	Model watershed for sustaining agricultural productivity and improved livelihoods. a) Domagor-Pahuj b) Parasai-Sindh **Lead Instt.: ICRISAT, Hyderabad** **Project Coordinator: Dr. SK Dhyani**	2009-2015 2011-2016	Dr. Ramesh Singh Dr. Ramesh Singh	Dr. R K Tewari & Dr. R H Rizvi Dr. R K Tewari, Dr. Inder Dev, Dr. K B Sridhar, Dr. R H Rizvi & Dr. R P Dwivedi
Inter Institutional project	Evaluation of aonla based horti-pasture system under different soil & water conservation practices in Central India **Lead Instt.: IGFRI, Jhansi**	2007-2014	Dr. Sunil Kumar	Dr. Ramesh Singh, Dr. Sunil Tiwari, Head, IGFRI & Dr. A K Shukla
Observational trial	Weed dynamics studies in different agroforestry systems	2012-2014	Dr. Inder Dev	---
AF 04: Tree Improvement, Post-Harvest and Value Addition (Programme Leader: Dr. A K Handa)				
AF01.22	Studies for augmenting pistillate flowers with exogenous application of growth regulators and chemicals in *Jatropha curcas*	2007-2014	Dr. Badre Alam	Dr. Sudhir Kumar
AF01.23	Comparative studies on seedling and clonal plants of *Pongamia pinnata* with special reference to their adaptability to rainfed dry agroclimate	2007-2015	Dr. Badre Alam	Dr. A K Handa & Dr. S Vimala Devi
AF 04.1b	Exploration, evaluation and conservation of germplasm of *Acacia nilotica*	2002-2014	Dr. S Vimala Devi	Dr. Badre Alam

Project code	Title of project/ sub project	Duration	Project leader	Associates
AF 04.5	Genetics and breeding of *Jatropha* species	2004-2014	Dr. S Vimala Devi	Dr. Sudhir Kumar & Sh. K Rajrajan
AF 04.6	Age- age correlation model for juvenile selection of trees in agroforestry	2004-2014	Dr. R H Rizvi	Dr. Ajit & Dr. K B Sridhar
AF 04.9	Assessment of candidate genes for oil biosynthesis in *P. pinnata* using eco-tilling approach	2012-2015	Dr. S Vimala Devi	Dr. A K Handa, Sh. K Rajrajan & Dr. Sudhir Kumar
AF 05.10	Lac based agroforestry in Bundelkhand region: Introduction and evaluation	2008-2015	Dr. K B Sridhar	Dr. Sudhir Kumar, Dr. Rajendra Prasad, Sh. Rajendra Singh, Dr. S Ghosal & Dr. Md. Monobrullah, IINRG.
NOVOD Board Project	National network on integrated development of Jatropha and Karanj	2005-2014	Dr. S Vimala Devi	Dr. Sudhir Kumar & Sh. K Rajrajan
ICAR, IINR&G Ranchi.	Harvest and post-harvest processing and value addition of natural resins, gums and gum resins	2008-2014	Dr. Rajendra Prasad	Dr. AK Handa, Dr. Ajit, Dr. Ramesh Singh & Dr. Badre Alam
AF 05: HRD, Technology Transfer & Refinement (Programme Leader: Dr. R K Tewari)				

7. PUBLICATIONS

(A) Research Journals

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(B) Technical Journals

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8. IMPORTANT MEETINGS / ACTIVITIES

ICAR-Industry & Agricultural Education Day

NRCAF organized ICAR-Industry & Agricultural Education Day on 28th February, 2013. Hundred participants including graduation and post-graduation students along with faculty member from Bipin Bihari Post Graduate College, Jhansi, SRF, RA, M.Sc. dissertation students and Ph.D. Scholars participated in the function. All scientific, technical, administrative and SSS staff of the Centre actively participated in the event. Lectures on Agroforestry Based Industries and Opportunities in Agricultural Research and Education for students were delivered. Possibilities of promoting agri-based and forestry-based enterprises in Bundelkhand region were also discussed.

Silver Jubilee Function of NRCAF & Observation of National Agroforestry Day

National Research Centre for Agroforestry (NRCAF), Jhansi celebrated its Silver Jubilee of establishment and observed National Agroforestry Day on 8th May, 2013. Dr. D N Tewari, Former Member, Planning Commission, Govt. of India and Ex-DG, ICFRE was the Chief Guest. An exhibition of agroforestry technologies was also organized on the occasion. Achievements of last 25

Years were displayed on the occasion. Employees of the Centre, guests, progressive farmers, research scholars, students and officers of line departments participated in the two-day function. On this occasion, an Indoor Sport's Complex was also inaugurated by the Chief Guest.

A brain storming session on the topic "Agroforestry Research and Development: Challenges and Opportunities in India" was organized as a part of the Silver Jubilee Celebrations. During the session Partnership, marketing strategies, linkages were the important issues highlighted.

National Consultation Meet on Agroforestry

A one day National Consultation Meet on "Agroforestry Research and Development in India" was organized at NASC Complex,

New Delhi on 19th November, 2013 by the Natural Resource Management Division, Indian Council of Agricultural Research and National Research Centre for Agroforestry, Jhansi. The meeting was inaugurated by Hon'ble Dr. S Ayyappan, Secretary, DARE & DG, ICAR, New Delhi and Dr. A K Sikka, DDG (NRM), ICAR briefed the gathering about the objectives of this meet. The meeting was organized in two sessions. Session-I was chaired by Dr. D N Tewari while Session-II Chaired by Dr. Gurbachan Singh, Chairman, ASRB, New Delhi.

Institute Management Committee

The 17th IMC meeting was held on 7th June, 2013 at NRCAF Jhansi under the chairmanship of Dr. S K Dhyani, Director, NRCAF, Jhansi. Dr. Ram Newaj, Pr. Scientist presented brief research achievements of NICRA project and Dr. R H Rizvi, Sr. Scientist presented salient features of agroforestry mapping in India. Thereafter, the agenda items were placed and discussed in the meeting.

IVth Quinquennial Review Team (QRT)

The Director General, ICAR, New Delhi vide letter No. 16-7/2011-IA.II dated 4th May, 2012 has constituted the IVth Quinquennial Review Team (QRT) of National Research Centre for Agroforestry, Jhansi (NRCAF) and All India Coordinated Research Project on Agroforestry (AICRP on AF) to review the work of NRCAF and the Centers of AICRP on AF located in different Agro-ecological Zones of the country for the period from 1st January, 2007 to 31st December, 2011. **The final review covered the period up to March 31, 2013.** Dr. D N Tiwari, Former Member Planning Commission & DG, ICFRE is the Chairman with five member team. Arrangement and coordination for the QRT review work of NRCAF and AICRP on AF was done through presentations at six places and visit of the centres. The team finalized its recommendations and the Chairman, QRT submitted the report to the D.G., ICAR on 12th June, 2013.

Research Advisory Committee

16th Research Advisory Committee meeting was held on 18th & 19th October, 2013 at the Centre. The chairman and all members of RAC, Programme Leaders and Scientists were participated in the meeting. The chairman and members of RAC committee also visited the Parasai- Sindh watershed and had discussions with farmers and watershed committee and watershed team.

Institute Research Council

Institute Research Council (IRC) meeting was held on 2nd & 3rd July, 2013. All the Scientists of the Centre participated in the meeting and presented the progress and significant findings of their projects as well as new research proposals.

Farm Innovators Day

NRCAF organized Farm Innovators Day on 16th November, 2013 in Parasai- Sindh Watershed. Two farmers Shri Lakhan Singh Yadav, vill. Kharak, Datia and Shri Bala Ram Yadav, vill. Chhatpur, Jhansi were facilitated on the occasion for adopting *Tectona grandis* based agroforestry system on large scale. On the eve health camp was also organized for watershed dwellers to active over all integrated development in watershed development projects. A team of doctors from different specialization *viz*. Pediatrics, surgery, gynecology and pathology from different reputed hospitals of the country examined about 400 farmers, farmwomen and children from all three villages of watershed. The medical unit of IGFRI was also a part of the health camp. Medicines worth rupees ten thousand were also distributed especially to the malnourished women and children. The people suffering from chronic diseases were advised to visit specialized government hospitals including Dr. Ram Manohar Lohia Hospital, New Delhi. It was observed by the doctors that most of the children were suffering from deficiency of different kinds of vitamins.

Republic Day and Independence Day

Republic Day (26th January, 2013) and Independence Day (15th August, 2013), respectively were celebrated at NRCAF, Jhansi. Flag hoisting ceremony was observed on both the occasions. Cultural programmes, sport events were organized for the staff along with their family members on the occasions.

9. PARTICIPATION IN WORKSHOP/COORDINATION/ TRAINING/MEETINGS/SYMPOSIA

- Dr. S K Dhyani, Director and Dr. R K Tewari, Pr. Scientist participated in RFD Meeting of Directors and Nodal Officers of the RSCs of NRM Division under the Chairmanship of DDG (NRM) on 11th January, 2013 for discussion of draft RFD (2013-14) organized by ICAR held at New Delhi.
- Dr. A K Handa, Pr. Scientist presented an invited paper on "Agroforestry for Sustainable Agriculture" in the International Conference on "Increasing Agricultural Productivity and Sustainability in India: The Future We Want" organized by National Institute of Advanced Studies, Bangalore and M S Swaminathan Research Foundation, Chennai on 8th & 9th January, 2013 held at Bangalore (Karnataka).
- Dr. S Vimala Devi, Sr. Scientist participated in Refresher Course on "Agricultural Research Management" during 7th to 19th January, 2013 held at NAARM, Hyderabad (A. P.).
- Dr. Ramesh Singh, Sr. Scientist (Land and Water Management Engg.) participated in the 47th Annual Convention of Indian Society of Agricultural Engineers (ISAE) and International Symposium on "Bio Energy- Challenges and Opportunities" during 28th to 30th January, 2013 held at Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad (A. P.).
- Dr. R H Rizvi, Sr. Scientist attended workshop on "GIS Applications for Natural Resource Management" and presented paper on "Harnessing Geospatial Technologies for Agroforestry Development in India" during 20th to 23rd February, 2013 held at NAARM, Hyderabad (A. P.).
- Dr. R K Tewari, Pr. Scientist participated in the training programme on "Rainfed and Arid Horticulture (Fruits & Vegetables) for Horticulture Officers of Bundelkhand Region of U.P." and delivered a lecture on "Agrihorticulture". The training was organized by Zonal Project Directorate IV, ICAR in collaboration with NARA from 13th to 15th March, 2013 held at Gramodaya Vishva Vidhyalaya, Chitrakoot (U.P.).
- Dr. R P Dwivedi, Pr. Scientist participated and presented a paper in the National Seminar on "Social Dimension of Extension Education in Holistic Development of Rural Livelihood" from 26th to 27th April, 2013 organized by the Indian Society of Extension Education, IARI, New Delhi held at CBGAPG College, Bakshi ka Talab, Lucknow (U.P.).
- Dr. Sudhir Kumar, Pr. Scientist attended Annual Review Meeting of NOVOD Board Funded Project on Jatropha and Karanja during 16th to 19th April, 2013 held at NOVOD Board, Gurgaon (H.R.).
- Dr. S K Dhyani, Director & Project Coordinator; Dr. A K Handa, Dr. Sudhir Kumar, Dr. Inder Dev, Pr. Scientists; Dr. R H Rizvi, Sr. Scientist and Sh. S B Sharma, AF & AO participated in the Annual Workshop of All India Coordinated Research Project on Agroforestry from 25th to 27th May, 2013 organized by the Centre at CSK HPKV, Palampur (H. P.).

- Dr. R K Tewari, Pr. Scientist and Dr. Ramesh Singh, Sr. Scientist attended Workshop organized for Watershed Development Team under Integrated Watershed Management Programme (IWMP) on 23rd May, 2013 at IGFRI, Jhansi. The Workshop was organized by Department of Land Development and Water Resources, Govt. of Uttar Pradesh. Dr. Ramesh Singh presented a paper entitled "Useful Technologies and Participatory Process for Natural Resource Conservation on Watershed Basis". The workshop was attended by all Project Implementing Agencies (PIAs) of Uttar Pradesh under IWMP.
- Dr. Asha Ram, Scientist attended Three Months Professional Attachment Training during 20th May to 19th August, 2013 at IGFRI, Jhansi.
- Dr. Ramesh Singh, Sr. Scientist attended and presented paper in National Seminar on "Technological Interventions for Sustainable Hill Development" during 17th to 19th June, 2013 held at college of Technology, GBPUA&T Pantnagar (Uttrakhand).
- Dr. Rajendra Prasad, Dr. Ajit, Pr. Scientists and Dr. Badre Alam, Sr. Scientist participated in the Annual Review Meeting of NICRA from 17th to 19th June, 2013 held at IARI, New Delhi.
- Dr. Anil Kumar, Pr. Scientist attended training programme on 'Ethics and Values' from 24th to 28th June, 2013 held at Centre for Disaster Management, NIAR, LBSNAA, Missouri (Uttrakhand).
- Dr. K B Sridhar, Scientist participated in Seminar cum filed visit on "Reliability and Economics of Biomass Gassifier, Operated with Bamboo Feed Stock, connected to Mini Power Generator" on 5th June, 2013 held at New Delhi.
- Dr. K B Sridhar, Scientist participated in one week Management Training Programme on "Consultancy Project Management" during 1st to 7th August, 2013 held at NAARM, Hyderabad (A. P.).
- Dr. Ramesh Singh, Sr. Scientist (Soil and Water Conservation Engineering) attended and presented research paper in All India Seminar on "Recent Advances in Watershed Development Programme (RAWDEP)" during 5th & 6th September, 2013 organized by Institution of Engineers, Ahmednagar Local Centre, Maharashtra at Padamashri Dr. Vitthalrao Vikhe Patil College of Engineering, Ahmednagar.
- Dr. K B Sridhar, Scientist participated in International Asia – Pacific workshop on Forest Hydrology during 23rd to 25th September, 2013 held at FRI, Dehradun (Uttrakhand).
- Dr. Badre Alam, Pr. Scientist participated in a National Workshop on "Building Awareness about the Need and Nature of National Fund for Basic Strategic and Frontier Application Research in Agriculture (NFBSFARM)" during 6th to 7th September, 2013 held at NDRI, Karnal (H.R.).
- Dr. Ajit, Pr. Scientist participated in the "Partner's Meet and 4th Installation-cum- Training Workshop for SAS-Nodal-Officers" during 17th &18th September, 2013 held at IASRI, New Delhi.
- Dr. A K Handa, Pr. Scientist delivered invited lecture on "Agroforestry Role in Integrated Farming System Approach" for Scientists from KVKs of Zone III on 18th September, 2013 organized by Zonal Project Coordinated III at Guwahati (Assam).

- Dr. Ramesh Singh, Sr. Scientist (Land and Water Management Engg.) and Dr. K B Sridhar, Scientist attended "Asia Pacific Workshop on Forest Hydrology: Water and Forest-Beyond Traditional Forest Hydrology" during 23rd to 25th September, 2013 organized by FRI, Dehradun, APAFRI, Malaysia and KFRI, Korea held at FRI, Dehradun (Uttrakhand).
- Dr. Ramesh Singh, Sr. Scientist (Land and Water Management Engg.) delivered lectures on "Integrated Watershed Interventions for Climate Resilient Agriculture in Semi-Arid Tropics-A Case Study of Garhkundar-Dabar watershed" on the request of IIT, BHU, Varanasi, on 21st September, 2013 held at Rajeev Gandhi South Campus, Barkachha, BHU, Varanasi. The talk was attended by all the students and faculties of RGSC, Barkachha, BHU, Varanasi (U.P.).
- Sh. Chavan Sangram Bhanudas, Scientist participated in 21 Days Summer School on "Agroforestry as a Strategy for Adaptation and Mitigation of Climate Change in Rainfed Areas" from 4th to 24th September, 2013 held at CRIDA, Hyderabad (A.P.)
- Dr. Asha Ram, Scientist attended 21 Days Winter School on "Quality seed production and seed standards in forage crops and range grasses: Challenges, advances and Innovation" during 11th September to 1st October, 2013 held at IGFRI, Jhansi (U.P.).
- Dr. Rajendra Prasad, Pr. Scientist & PI), Sh. Rajendra Sngh, ACTO and Dr. V D Tripathi (R. A.) attended 5th Coordination Committee Meeting of the Network Project on "Harvesting, Processing and Value Addition of Natural Resins and Gums" during 8th to 9th October, 2013 held at JNKVV, Jabalpur (M. P.).
- Dr. Ajit and Dr. Badre Alam, Pr. Scientists attended 4th National Research Conference on Climate Change during 26th & 27th October, 2013 held at IIT, Chennai (T.N.).
- Dr. K B Sridhar, Scientist participated in International Short Course on "Ecosystem Services and Integrated Watershed Management" during 6th to 15th November, 2013held at ICRISAT, Hyderabad (A. P.).
- Dr. R K Tewari, Pr. Scientist & Nodal Officer (RFD) and Dr. Rajeev Tiwari, Chief Tech. Officer participated in the RFD Meeting of NRM Division on 18th November, 2013 held at NASC, New Delhi.
- Dr. S K Dhyani, Director; Dr. R K Tewari, Dr. A K Handa, Dr. Inder Dev, Pr. Scientists and Dr. Rajeev Tiwari, Chief Tech. Officer participated in the "National Consultation Meet on Agroforestry" organized by NRM Division and NRCAF on 19th November, 2013 held at NASC, New Delhi.
- Dr. Mahendra Singh, Sr. Scientist participated in the MDP Workshop on PME on Agricultural Research during 19th to 23rd November, 2013 held at NAARM, Hyderabad (A. P.).
- Dr. K B Sridhar, Scientist participated and presented paper in National Seminar on "Recent Advances in Research on Beneficial Insects: Honey bee, Lac Culture, Tussser and Sericulture" during 27th to 30th November, 2013 held at IINRG, Ranchi (B.R.).
- Dr. Ajit, Pr. Scientist participated and presented paper in XVII National Conference of Agricultural Research

Statisticians during 27th to 28th November, 2013 held at NDRI, Karnal (Haryana).

- Dr. R P Dwivedi, Pr. Scientist (Agricultural Extension) participated in the International conference on Extension educational strategies for sustainable agricultural development-a global perspective during 5th to 8th December, 2013 held at University of Agricultural Sciences, Bangalore (Kanataka).
- Sh. Birendra Singh Tomar, Assistant attended Central Joint Staff Council Meeting during 15th & 16th December,2013 held at NASC, Complex, New Delhi. The meeting was chaired by DG, ICAR & Secretary, DARE, New Delhi.
- Dr. Ramesh Singh, Sr. Scientist (Soil & Water Conservation Engg.) delivered lecture on "Impact of Integrated Watershed Development Interventions on Hydrology and Eco-system services in drought prone Bundelkhand region of Central India" on 30th December, 2013 at Deptt. of Civil Engineering, Indian Institute of Technology, Banaras Hindu University, Varanasi (U.P.).

10. WOMEN IN AGRICULTURE

As per the ICAR guidelines NRCAF continued to emphasize on harnessing women power in agriculture to encourage gender equity. Even at the Centre, regular meetings of Women Cell is organized under the Chairmanship of Director. Gender equality and congenial environment in the office was appreciated by all the members. The Centre has a number of Women research scholars, research fellows, students in addition to its women staff.

In Domagor Pahuj watershed total 26 women self-help groups (WSHGs) were formed and their accounts were opened in the bank. Total saving of WSHGs is ₹ 2,60,020 and inter loaning amount is ₹ 81,500. They are mainly involved in goat rearing and vegetable cultivation.

Fodder cultivation in Domagor-Pahuj watershed

Vegetable cultivation by women in Domagor-Pahuj watershed

A human health camp was organized on 16th November, 2013 in Parasai-Sindh watershed. A team of three lady doctors from reputed national hospitals conducted health check-up of about 400 people of watershed. It was observed by the doctors that most of the children need care as they were malnourished.

Besides welfare, gender issues were taken care during construction of rainwater harvesting structures and other watershed interventions in Parasai-Sindh watershed. Women were employed on priority on equal wages at par with male to enthuse economic empowerment.

Human Health Camp in Parasai-Sindh watershed

Women get wages on priority basis

11. राजभाषा गतिविधियाँ

हिन्दी सप्ताह

राष्ट्रीय कृषिवानिकी अनुसंधान केन्द्र, झाँसी में दिनांक 13-21 सितम्बर, 2013 के दौरान हिन्दी सप्ताह मनाया गया। दिनांक 13 सितम्बर, 2013 को हिन्दी सप्ताह का शुभारम्भ किया गया। डा. शंकर शरण तिवारी, पूर्व विभागाध्यक्ष (हिन्दी), नेहरू महाविद्यालय, ललितपुर इस कार्यक्रम के मुख्य अतिथि थे। प्रभारी अधिकारी (राजभाषा) ने हिन्दी सप्ताह की व्यापक रूप-रेखा एवं कार्यक्रमों की जानकारी प्रस्तुत की। कार्यक्रम में माननीय कृषि मंत्री, भारत सरकार का हिन्दी दिवस पर संदेश तथा महानिदेशक, भारतीय कृषि अनुसंधान परिषद्, नई दिल्ली का सरकारी कामकाज में राजभाषा का अधिक से अधिक कार्य करने की अपील पढ़ी गई। डा. एस. के. ध्यानी ने अपने उद्बोधन में कहा कि भारत सरकार के गजट में इस केन्द्र का नाम ''क'' क्षेत्र में है, इसलिए केन्द्र में सभी को अपना प्रशासनिक कार्य शत प्रतिशत हिन्दी में करना है तथा उन्होंने केन्द्र पर राजभाषा में किये जा रहे कार्यों की सराहना की, विशेषतयः बुन्देलखण्ड के भूमि संरक्षण अधिकारियों, स्वयं सहायता समूहों के प्रतिनिधियों एवं किसानों के लिए विषयवस्तु एवं प्रशिक्षण पूर्णतया हिन्दी माध्यम से आयोजित करने की चर्चा की। सप्ताह के दौरान विभिन्न प्रतियोगिताओं का आयोजन किया गया। इन प्रतियोगिताओं में केन्द्र के वैज्ञानिकों, अधिकारियों, कर्मचारियों, शोध अध्येता, शोध छात्र एवं छात्राओं ने भाग लिया।

समापन समारोह के मुख्य अतिथि श्री तेजी लाल मिश्र, सेवानिवृत्त राजभाषा अधिकारी, उत्तर मध्य रेलवे, झाँसी रहे। इस अवसर पर मुख्य अतिथि महोदय द्वारा प्रतियोगिता में विजयी प्रतिभागियों को पुरस्कार वितरित किये गये। कार्यक्रम में वार्षिक राजभाषा पत्रिका ''कृषिवानिकी आलोक-2013'' सप्तम अंक का विमोचन भी मुख्य अतिथि महोदय द्वारा किया गया।

हिन्दी कार्यशालायें

केन्द्र पर वर्ष 2013 में 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। कार्यशाला में केन्द्र के समस्त वैज्ञानिकों, अधिकारियों एवं कर्मचारियों ने भाग लिया। वर्ष 2013 के दौरान आयोजित कार्यशालाओं का विवरण निम्नवत है :

दिनांक	विषय	वक्ता
23 मार्च, 2013	अनुवाद : परिचय और महत्व	श्री शामगणपति ढमढेरे, सेवानिवृत्त तकनीकी अधिकारी (पुस्तकालय)
18 अप्रैल, 2013	महिला सशक्तिकरण के अन्तर्गत कार्यक्षेत्र में महिलाओं के साथ व्यवहार एवं राजभाषा क्रियान्वयन में महिलाओं का योगदान	डा. (श्रीमती) एस. बिमाला देवी, वरिष्ठ वैज्ञानिक एवं अध्यक्ष, महिला प्रकोष्ठ
13 सितम्बर, 2013	हिन्दी भाषा का उद्भव, विकास एवं विशेषतायें	डा. शंकर शरण तिवारी
30 दिसम्बर, 2013	वित्तीय प्रबन्धन एवं लेखा पद्धति	श्री श्याम बाबू शर्मा, सहायक वित्त एवं लेखाधिकारी

राजभाषा कार्यान्वयन समिति की बैठकें

केन्द्र में वर्ष 2013 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-विमर्ष किया गया और सर्वसम्मत से निर्णय लिया गया। बैठकों की अध्यक्षता करते हुए केन्द्र निदेशक द्वारा केन्द्र के सभी वैज्ञानिकों, अधिकारियों एवं कर्मचारियों से धारा 3(3), पत्राचार एवं फाइलों पर टिप्पणियाँ हिन्दी में लिखने के लिए अपील किया गया।

12. VISITORS

- Hon'ble Dr. D N Tiwari, Former Member, Planning Commission & DG, ICFRE, Allahabad (U.P.).
- Dr. V P Singh, Regional Representative for South Asia, WAC, New Delhi.
- Dr. B. Mohan Kumar, ADG (AF & Agron.), NRM Division, ICAR, New Delhi.
- Dr. Brahma Singh, Advisor, Nauni Foundation, Chennai (T. N.).
- Dr. S D Kashyap, Dean, Dr. Y.S. P. U. of Horti. & Forestry, Solan (H.P.).
- Dr. D K Das, Former Head, IARI, Pusa, New Delhi.
- Dr. V K Gupta, Rtd. Pr. Scientist (NRCAF), Bangalore (Karnataka).
- Dr. Bhairam Singh, Dy. Director (Hort.), Jhansi (U.P.).
- Dr. P K Ghosh, Director, IGFRI, Jhansi (U.P.).
- Dr. P S Pathak, Ex. ADG (AF), ICAR, New Delhi.
- Dr. U C Sharma, Ex. Nat. Coordinator (NATP), Jammu (J&K).
- Dr. S N Pandey, Project Coordinator, Taragram, Jhansi (U.P.).
- Dr. Sushil Kumar, Principal Scientist, DWSR, Jabalpur (M.P.).

Field Visit of RAC

Parasai Field Visit of QRT Chairman

13. PERSONNEL

Dr. S K Dhyani, Director

Scientific

1. Dr. Anil Kumar, Pr. Scientist (Plant Pathology)
2. Dr. R K Tewari, Pr. Scientist (Horticulture)
3. Dr. Ram Newaj, Pr. Scientist (Agronomy)
4. Dr. Rajendra Prasad, Pr. Scientist (Soil Science)
5. Dr. Sudhir Kumar, Pr. Scientist (Horticulture)
6. Dr. A K Handa, Pr. Scientist (Forestry/ Agroforestry)
7. Dr. Ajit, Pr. Scientist (Agriculture Statistics)
8. Dr. R P Dwivedi, Pr. Scientist (Agriculture Extension)
9. Dr. Inder Dev, Pr. Scientist (Agronomy)
10. Dr. Badre Alam, Pr. Scientist (Plant Physiology)
11. Dr. (Er.) Ramesh Singh, Sr. Scientist (SWE)
12. Dr. R H Rizvi, Sr. Scientist (Computer Application)
13. Dr. S Vimala Devi, Sr. Scientist (Plant Breeding)
14. Dr. Mahendra Singh, Sr. Scientist (Agriculture Economics)
15. Dr. K B Sridhar, Scientist (Forestry)
16. Sh. K Rajarajan, Scientist (Genetics & Plant Breeding)
17. Sh. Chavan Sangram Bhanudas, Scientist (Forestry)
18. Dr. Asha Ram, Scientist (Agronomy)

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, Assit. Chief Technical Officer
5. Sh. Sunil Kumar, Assit. Chief Technical Officer
6. Sh. Rajendra Singh, Assit. Chief Technical Officer
7. Smt. Uma, Assit. Chief Technical Officer
8. Sh. Rajesh Srivastava, Sr. Technical Officer (Art & Photo)
9. Sh. R K Singh, Sr. Technical Officer
10. Sh. Prabhu Dayal, Technical Officer
11. Sh. S P Singh Yadav, Technical Officer
12. Sh. Ram Bahadur, Technical Officer
13. Km. Shelja Tamrkar, Technical Assistant
14. Sh. Het Ram, (T-3), Driver
15. Sh. Kashi Ram, (T-3), Driver
16. Sh. Prince, (T-2), Mechanic

Administrative

1. Sh. S B Sharma, A F& A O
2. Sh. Dalbir Singh Rawat, AAO
3. Sh. A K Chaturvedi, Personal Secretary
4. Sh. Hoob Lal, Personal Assistant
5. Sh. Om Prakash, Personal Assistant
6. Sh. K P Sharma, Assistant
7. Sh. Mahendra Kumar, Assistant
8. Sh. Birendra Singh Tomar, Assistant
9. Sh. Jai Janardan Singh, Assistant

10. Sh. Deepak Vij, Stenographer (Grade-III)
11. Sh. Tridev Chaturvedi, Stenographer (Grade-III)
12. Sh. Vir Singh Pal, Sr. Clerk
13. Smt. Kaushalya Devi, Jr. Clerk

Skilled Supporting Staff

1. Sh. Attar Singh
2. Sh. Tulsi Das
3. Sh. Ram Singh
4. Sh. Jagdish Singh
5. Sh. Ram Din
6. Sh. Pramod Kumar
7. Sh. Munna Lal

14. WORLD CONGRESS ON AGROFORESTRY 2014 - TREES FOR LIFE: ACCELERATING THE IMPACT OF AGROFORESTRY

The 3rd World Congress on Agroforestry (WCA 2014) was organized during 10th to 14thFebruary at Delhi. The Congress was jointly organized by the World Agroforestry Centre (ICRAF), the Indian Council of Agricultural Research, the Indian Society of Agroforestry and Global Initiatives. Earlier, the second Congress was held at Nairobi (Kenya) in 2009 and the first at Orlando, Florida, USA, in 2004. The main theme of the Congress was "Trees for life: Accelerating the impact of Agroforestry".

The main aim of the Congress was to expand global agroforestry, share the current status of knowledge and practices of agroforestry, consolidate its research base, build support for agroforestry within governments, companies, academia, NGOs and media and increase the engagement of private sector.

The World Congress was inaugurated by the Hon'ble President of India, Shri Pranab Mukherjee at Vigyan Bhavan in New Delhi on February 10, 2014. The President termed agroforestry as a promising sector which is emerging as a major domain in environmentally sustainable food production systems. Agroforestry system produces food, fuel and fibre; contributes to food and nutritional security; sustains livelihoods; helps in preventing deforestation; increases biodiversity; protects water resources, and reduces erosion. He pointed out that carbon sequestration of agroforestry farms is a low-hanging fruit for climate change mitigation, justifying greater investment in it. He also said that Agroforestry is also an important alternative to meet the target of increasing the vegetation cover to 33 % from the present level of less than 25 %, The President highlighted the research work being conducted by ICAR on agroforestry through its All India Coordinated Research Project (AICRP) on Agroforestry and National Research Centre for Agroforestry (NRCAF). The President mentioned about the National Agroforestry Policy which was approved by the Cabinet on February 6th, 2014.

Shri Sharad Pawar, Union Minister of Agriculture and Food Processing Industries, in his address said that Agroforestry has been a way of life in India for centuries and it has the potential to address issues such as employment generation, livelihood, resource conservation and optimization of farm productivity. A global 'agroforestry

transformation' is required to mobilize resources to overcome the constraints that impede its widespread application. The Indian Council of Agricultural Research and World Agroforestry Centre, Nairobi along with other partners are poised to foster such an agroforestry transformation, which will promote an "evergreen revolution" in agriculture and natural resource management arena, especially in the developing countries. Shri Pawar released special issue of the 'Indian Farming' (ICAR) and the 'Indian Journal of Agroforestry' and presented first copy to the Hon'ble President of India.

Dr. M. Veerappa Moily, Union Minister of Environment and Forests highlighted the important role of trees in the Indian sub-continent since centuries by providing food, fuel, fibre, fruit and timber. He said that Indian farmers are growing trees on farm lands as a dynamic system of agricultural sustainability for enhancing profitability and productivity. He hoped that the National Agroforestry Policy will pave way for new era of agroforestry in the country.

Dr. Anthony J. Simons, Director General, World Agroforestry Centre elaborated upon the theme of WCA-2014, Trees for Life-Accelerating the Impact of Agroforestry. He said that organization of WCA in this part of world is important as it feeds more population than other parts but has less number of trees in comparison. Dr. Simons said that agroforestry strives for green society rather than green economy.

Earlier, Dr. S. Ayyappan, Secretary, DARE and DG, ICAR welcomed the dignitaries and delegates and hoped that this conference would deliberate on road map for the agroforestry for the next couple of decades. He said that the Congress will achieve its goal to accelerate the financial, environmental and social impacts of agroforestry on the development.

Dr. A K Sikka, Deputy Director General (NRM), ICAR proposed the vote of thanks. About 1100 participants, including about 500 foreign participants from more than 80 countries, representing researchers, policymakers, and major businesses with concerns for sustainable development, NGOs, farmers and youth groups participated in this World Congress.

On the last day, Dr. Anthony J.Simons, DG, World Agroforestry Centre, Nairobi, Kenya, presented the draft Congress declaration entitled "The New Delhi Declaration on Agroforestry" at the plenary session. Draft is based on the observations, deliberations, recommendations, discussions and affirmations of about 1,100 global delegates and abstracts, posters and papers presented at the congress and lays emphasis on practice of agroforestry for the coming 5 years and beyond, and to fully harness the vital contribution that trees make to human well-being.Further, the declaration calls for the various groups to work closely together to accelerate the impact of agroforestry.

Shri Salman Khurshid, Minister of External Affairs, Government of India delivered valedictory address on the concluding day of World Congress on Agroforestry. While appreciating the efforts of World Agroforestry Centre and Indian Council of Agricultural Research for organizing this event of global importance,

he urged to domesticate fruit and medicinal plants in the homestead for nutritional security. He said that this is historical event with reference to Indian context as today we are looking beyond success of green revolution to sustain the food production. In the era of climate change, trees can do a lot of rescue work for us due to their innate ability to sequester carbon from atmosphere.

India could effectively showcase the diversity in the agroforestry practices adopted throughout the length and breadth of this vast country through the oral and poster presentations during the Congress. About 1100 abstracts covering diverse regions, disciplines, species and components related to agroforestry were submitted at the Congress and the maximum number was from India. One oral, twenty five posters and six blogs were contributed by NRCAF. In addition there were more than one hundred posters displayed by the scientists from AICRP on Agroforestry network.

In order to harness the strength of electronic and social media in land-use practices like Agroforestry, Blog posts were organized for the WCA-2014. Forty seven blog posts from 19 countries were submitted to the Congress website, out of which maximum were from India. These blog posts received a total of 23,991 online voters and 2,262 comments. The blog post on "Agroforestry: Attracting youth to farming

and transforming rural India" contributed by N. P. Chaudhary, a young farmer from Uttar Pradesh was adjudged the best and bagged juryblog award. In addition, four out of five prize winning blog posts were from India.

As part of Pre-Congress activities events like National Agroforestry Day (May 8th), plantations in different parts of the country by school children, farmers and others; satellite seminars, brain storming session, consultation meet, programs on television and radio and children painting and essay competition were organized.

National Agroforestry Day on 8th May, 2013 was celebrated at National Research Centre for Agroforestry, Jhansi. On the eve a number of events including plantation program were organized. Invited guests and experts and eminent scientists in the field, scientists of the Centre, representative from state departments, KVK, Heads from IGFRI and CSWCR&TI Centre, farmers and NGO participated. An exhibition of agroforestry technologies through exhibits, posters and materials was also organized on the occasion.

Four post Congress visits to demonstrate rich diversity in agroforestry in the countrywere also organized for the delegate's one each to Agra (Uttar Pradesh) for silvipasture systems and ravine agroforestry systems, Yamuna Nagar (Haryana) for commercial and industrial agroforestry, Jaipur (Rajasthan) for arid and semi-arid agroforestry systems and Kodaguru (Karnataka) for coffee based agroforestry systems. There was overwhelming response from the delegates for Congress visits.

15. MISCELLANEOUS

New Scientist / Staff

- Dr. Mahendra Singh, Sr. Scientist (Agril. Economics)
- Shri Chavan Sangram Bhanudas, Scientist (Forestry)
- Dr. Asha Ram, Scientist (Agronomy)

Promotion

- Dr. Badre Alam, Sr. Scientist (Pl. Physiology) promoted to Pr. Scientist from 7th August, 2012 under the provision of Career Advancement Scheme.
- Sh. R K Singh, Tech. Officer promoted to Sr. Tech. Officer w.e.f. 19th June, 2013.
- Sh. Om Prakesh, Stenographer (Gr. III) promoted to Personal Assistant w.e.f. 7th December, 2013.
- Sh. Kashi Ram, Driver (T-2) promoted to Driver (T- 3) w.e.f. 18th September, 2012.

PME cell

Under the Chairmanship of Dr. S K Dhyani, Director three meetings (22nd March, 14th May & 7th August, 2013) of Prioritization, Monitoring and Evaluation (PME) cell were held and attended by all the Scientist of the Centre.

Institute Joint Staff Council

Institute Joint Staff Council (IJSC) meetings were held under the Chairmanship of Director Dr. S K Dhyani. Various issues related to welfare of the staff were discussed.

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 2012-13 of the Centre during 2nd to 9th September, 2013.

Zonal Sports meet at Bikaner

A contingent of 22 persons participated in ICAR Zonal Tournament-2013 at Bikaner, held during 27th February to 2nd March, 2013 organized by National Research Centre for Camel, Bikaner, (Rajasthan). Mr. Attar Singh won the cycle race in a record time of 9.34 minutes. Mr. Rajesh Srivastava got 4th position in chess.

Obituary

Sh. Kamata Prasad, Skilled Supporting Staff of the Centre passed away on 16th March, 2013. The Centre condones untimely death of late Kamata Prasad and pay homage.

ANNEXURE-I

QUINQUENNIAL REVIEW TEAM

(01/01/2007 to 31/03/2013)

S. No.	Name	S. No.	Name
1	Dr. D N Tiwari, **(Chairman)** Former Member Planning Commission & DG, ICFRE, 18-A, Auckland Road, Civil Lines, Allahabad (U. P.)	2	Dr. R N Misra, IFS, Member Former PCCF Chhattisgarh, 64, Anand Nagar, Raipur (Chhattisgarh)
3	Dr. S R Arya, (Member) Ex. DDG (ICFRE), Arya Sadan, Surya Vihar, Khalili , Shimla (H.P.)	4	Dr. J P Mishra, (Member) Dean, College of Hort. & Forestry, N.D. University of Agriculture & Technology, Faizabad (U.P.)
5	Dr. S S Raju, (Member) Pr. Scientist (Economics), National Centre for Agricultural Economics & Policy Research (NCAEP), New Delhi	6	Dr. A K Handa, Pr. Scientist & Member Secretary NRC for Agroforestry, Jhansi (U.P.)

ANNEXURE-II

Research Advisory Committee

S. No.	Name	S. No.	Name
1	Dr. V P Singh **(Chairman)**, Regional Representative for South Asia, World Agroforestry Centre, New Delhi.	2	Dr. B Mohan Kumar, (Member), ADG (AF & Agron.), NRM Division, ICAR, New Delhi.
3	Dr. S D Kashyap, (Member), Dean, Dr. Y.S. Parmar Univ. of Horti. & Forestry, Solan (H.P.).	3	Dr. D K Das, (Member), Former Head, IARI, Pusa, New Delhi.
5	Prof. S B Nahatkar, (Member), Division of Agriculture Economics, J.N.K.V., Jabalpur (M.P.).	6	Prof. Brahma Singh, (Member), Advisor, Nauni Foundation, Chennai (T.N.)
7	Dr. V K Gupta (Member), Rtd. Pr. Scientist (NRCAF), Bangalore (Karnataka).	8	Dr. S K Dhyani, Director (Member) NRCAF, Jhansi (U.P.)
9	Dr. Anil Kumar, Pr. Scientist & Member Secretary, NRCAF, Jhansi (U.P.)		

ANNEXURE- III

Institute Management Committee

S. No.	Name	S. No.	Name
1	Dr. S K Dhyani, **(Chairman)** Director, NRCAF, Jhansi (U.P.)	2	Sh. K N Gupta Fin. & Accounts Officer, IIPR, Kanpur (U.P.)
3	Dr. S N Pandey, Project Coordinator, Development Alternatives, Taragram Orchha -Tikamgarh (M.P.)	4	Dr. G P Juyal, Head, (H &T), CSWCRTI, Dehradaun (Uttrakhand)
5	Mr. Pyare Lal, Chief Executive, Pragati Biotechnologies, Clonal Research and Production Centre, Village Semi, P.O. Khajurla Jalandhar (Punjab)	6	Dr. Rajendra Prasad, Pr. Scientist(Soil Science), NRC for Agroforestry, Jhansi (U. P.)
7	Dr. R K Tewari, Pr. Scientist (Horticulture), NRC for Agroforestry , Jhansi (U.P.)	8	Director Agriculture, Government of U.P., Krishi Bhawan, Lucknow (U.P.)
9	Dr. D R Malviya, Pr. Scientist, IGFRI, Jhansi (U.P.)	10	Deputy Director (Horticulture), Government Garden, Narayan Bag, Jhansi (U.P.)
11	Dr. B Mohan Kumar, ADG (AF & Agron.), NRM Division, ICAR, New Delhi.	12	Dr. Inder Dev, Pr. Scientist, H.O. & Member Secretary, NRC for Agroforestry, Jhansi (U.P.)

ANNEXURE- IV

Institute Joint Staff Council

Chairman : Dr. S K Dhyani (Director)		
Staff Side		**Office Side**
Category	***Name and Designation of the Govt. Servant***	***Name and Designation of the Govt. servant***
Technical	Sh. Kashi Ram, Driver, Tech. Asstt. - **Secretary**	Sh. D S Rawat, AAO - **Member Secretary**
	Sh, Ram Bahadur, Tech. Officer - Member	Sh. S B Sharma, AF&AO - Member
Administration	Sh, Birendra Singh, Assistant - Member, **CJSC**	Sh. A K Chaturvedi, Personal Secretary - Member
	Sh. Tridev Chaturvedi, Stenographer (Gr.-III) - Member	Dr. Anil Kumar, Pr. Scientist - Member
Supporting	Sh. Attar Singh, SSS- Member	Dr. Rajendra Prasad, Pr. Scientist - Member
	Sh. Ram Singh, SSS- Member	Dr. Inder Dev, Pr. Scientist - Member
		Dr. S Vimala Devi, Sr. Scientist - Member
		Smt. Uma, Asst. Chief Tech. Officer - Member

ANNEXURE- V

Women Cell

S. No.	Name	S. No.	Name
1	Dr. S Vimala Devi, Sr. Scientist - **Chairperson**	2	Smt. Uma, Asst. Chief Tech. Officer- Member
3	Km. Shelja Tamrkar, Tech. Assistant - Member	4	Smt. Kaushalya Devi, Jr. Clerk - Member
5	Smt. Sadhna Pandey, Sr. Scientist, IGFRI, Jhansi - Member	6	Dr. Inder Dev, Pr. Scientist & H O - Member
7	Sh. D S Rawat, AAO - Member	8	Sh. Kashi Ram, Sec. IJSC - Member

NOTES

NOTES

Bambusa vulgaris

Dendrocalamus strictus

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भाकृअनुप
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