भाकृअनुप
ICAR

कृषिवानिकी
AGROFORESTRY
वार्षिक प्रतिवेदन
ANNUAL REPORT
2018-19

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केकृवाअनुसं
CAFRI

भा.कृ.अनु.प.-केन्द्रीय कृषिवानिकी अनुसंधान संस्थान
झाँसी-284 003 (उ.प्र.) भारत

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

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PREFACE

Agroforestry has been a way of life in India and its role in improving livelihood is widely acclaimed today. Because of its role in carbon sequestration potential, it is one of the vital agricultural practice in mitigating climate change. It is matter of great satisfaction to present the Annual Report of ICAR-Central Agroforestry Research Institute, Jhansi for the period 2018-19. The Institute conduct basic, strategic and applied research on agroforestry. Agroforestry has the potential to achieve sustainability in agriculture, while optimizing its productivity and mitigating climate change impact. Agroforestry research outputs based on the objectives and activities for 2018 under 20 institutionally funded and 09 externally funded projects were planned in accordance with the suggestions by Research Advisory Committee (RAC) and workshops of All India Coordinated Research on Agroforestry (AICRPAF). Under ICAR-ICRAF work plan, ICRAF-Odisha staff and officials from AgriFose2030 (Sweden) and ICRAF, New Delhi visited the Institute.

The Institute is working on three aspects under NICRA project *viz.*, assessment of carbon sequestration potential of agroforestry systems in different agro-climatic regions through simulation model (CO2Fix model), mapping of agroforestry area using GIS and Remote Sensing technique and study on thermotolerance. The assessment of carbon sequestration potential (CSP) has been completed in 51 districts covering 16 states (Uttar Pradesh, Gujarat, Bihar, West Bengal, Rajasthan, Punjab, Haryana, Himachal Pradesh, Maharashtra, Tamil Nadu, Andhra Pradesh, Karnataka, Madhya Pradesh, Chhattisgarh, Orissa and Telangana). The average number of trees on farmer's field was found as 18.44 trees per hectare in these states. The net carbon sequestered in agroforestry systems existing on farmer's field under different states has been found as 10.18 t C ha^{-1} from baseline over simulated period of 30-years. The carbon sequestration potential (CSP) of agroforestry systems is 0.33 t C ha^{-1} yr^{-1} and total CSP has been found as 6.056 million tones C in these states.

The soil organic carbon (SOC) in agroforestry system existing on farmer's field in different states (Rajasthan, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Telangana) was higher than pure crop. The SOC in agroforestry systems under these states varied from 53.47 to 100.13 t C ha^{-1} in 0-90 cm soil depth.

The plantation drive was carried out by scientists of ICAR-CAFRI Jhansi in the selected MGMG villages. The scientists also interacted and created awareness about agroforestry among the farmers through farm visit, group discussions, workshop etc. ICAR-CAFRI, Jhansi organized thirty three batches of three days' training on (a) Livelihood security through agroforestry and organic farming and (b) Natural resource management and development of watershed through agroforestry for farmers and field functionaries of Bundelkhand region under *Pradhan Mantri Krishi Sinchai Yojna*-Watershed Development, State Level Nodal Agency, Govt. of U.P., Lucknow. Approximately 1250 farmers and field functionaries from different districts of Uttar Pradesh were trained during the year 2018.

I express my gratitude to Dr. Trilochan Mohapatra, Hon'ble Secretary, DARE and Director General, ICAR, New Delhi for his constant guidance, encouragement and overwhelming support. I am very much pleased to thank Dr. K Alagusundaram, Deputy Director General (NRM), ICAR, New Delhi for his constant direction and motivation. My special acknowledgements to Dr. S Bhaskar, ADG (Agron. AF/CC), Dr. S K Chaudhari, ADG (S&WM), NRM Division, ICAR, New Delhi and to all the staff members of NRM Division for continuous support. I appreciate the efforts made by the PME Cell and Editors in compiling and timely publication of the report. I am thankful to the Director, ICAR-IGFRI, Jhansi for continuous support in sharing the infrastructure and facilities from time to time.

(Anil Kumar)
Director (A)

June, 2019

कार्यकारी सारांश

भा.कृ.अनु.प.–केन्द्रीय कृषिवानिकी अनुसंधान संस्थान में किये जा रहे अनुसंधान का कार्यकारी सारांश निम्नलिखित है:

बेर आधारित कृषि उद्यानिकी पद्धति में बेर के वृक्षों की छटाई की गयी। सामग्री तथा फलों पर गुठली का वजन, गूदा/गुठली अनुपात, घुलनशील कुल ठोस (टी.एस.एस.) तथा प्रति पौधे फलों की संख्या को छोड़कर अन्य लक्षणों पर उपचारों का सकारात्मक प्रभाव पड़ा। अध्ययन में पता चला है कि ज्यादातर लक्षणों में टी 1 (100% आरडीएफ के साथ बेर) ने अपनी श्रेष्ठता दिखाई है। इस प्रणाली के तहत, रबी, 2017 में बोई गई जौ की कटाई की गई और परिक्षणों से पता चला कि उपचार टी 10 (शुद्ध फसल) और टी 6 (बेर 75% आर डी एफ + वैम + उर्द– जौ) के साथ 2395 और 2362 किलोग्राम / हेक्टेयर की उच्चतम बीज उपज दर्ज की गई जो कि अन्य उपचारों की तुलना में काफी अधिक था। उर्द को खरीफ, 2018 में उगाया गया और अवलोकन से पता चला कि उपचार टी 10 (शुद्ध फसल) और टी 6 (बेर 75% आरडीएफ + वैम + उर्द – जौ) के साथ 391 और 376 किलोग्राम / हेक्टेयर की उच्चतम बीज उपज दर्ज की गई जोकि अन्य उपचार की तुलना में काफी अधिक थी ।

अनार + नींबू के प्रयोग को 50x40 सेमी के अंतर पर अनार के पौधों के बीच में नींबू घास (कृष्णा) लगाकर योजना बनाई और क्रियान्वित की गई। प्रयोग को सीआरबीडी में अनार (वी1– गणेश और वी 2– भागवा), उर्वरक के चार स्तरों (टी 1– वर्मी–कम्पोस्ट 30 किग्रा / पौधा, टी 2– कम्पोस्ट खाद 30 किलोग्राम / पौधा, टी 3 – टी 1 $\pm$ टी 2 / पौधा) के साथ तैयार किया गया था। टी4– शुद्ध नींबू घास के नियंत्रण (टी 5) के साथ रासायनिक उर्वरकों प्रति पौधों की अनुशंसित खुराक। जुलाई–अगस्त 2018 के दौरान अधिक वृद्धि के कारण, नींबू घास के टसकों के बीच से एक टसक को हटाकर 100x80 सेमी. में बदल दिया गया। अनार, नींबू घास पर्ण और तेल की पैदावार में वृद्धि और फलों की पैदावार दर्ज की गई। अनार में, ऊँचाई 1.93 मीटर (टी 3 वी 2) से 2.76 मीटर (टी 4 वी 1), कॉलर का व्यास 5.48 सेमी (टी 2 वी 2) से 7.77 सेमी (टी 1 वी 1) तक, पूर्व–पश्चिम 1.03 मीटर (टी 2 वी 2) से 1.54 मीटर (टी 4 वी 1) तक फैला हुआ है। उत्तर–दक्षिण में 1.02 मीटर (टी 2 वी 2) से लेकर 1.56 मीटर (टी 4 वी 1) तक फैला हुआ है। हालाँकि, फलों की पैदावार 4.33 (टी 1 वी 2) से 6.34 (टी 2 वी 1) तक थी। ताजा वजन तेल / हेक्टेयर के आधार पर नींबूघास की दो कटों से संचयी उपज 8.16 (टी 2 वी 2) से 15.39 (टी 5), टन / हेक्टेयर हरी पत्तियों वाले तेल 64.69 टी 3 वी 2 से 173.48 (टी 5) किग्रा प्रति हे. पायी गयी।

सतत् भूमि उपयोग एवं बेहतर उत्पादकता के लिए कृषिवानिकी आधारित संरक्षण खेती में तीन प्रयोग शामिल किये गये जैसे–बेल आधारित कृषिवानिकी, सागौन आधारित कृषिवानिकी तथा बेल एवं सागौन आधारित कृषिवानिकी। इस प्रयोग में 4 मुख्य भूखण्ड उपचार जैसे न्यूनतम जुताई – उर्द – सरसों (सी एस–1), न्यूनतम जुताई – मूँग–जौ (सी एस–2), पारम्परिक जुताई – उर्द–सरसों (सी एस–1) तथा पारम्परिक जुताई – मूँग–जौ (सी एस–2)। इसके अलावा इस प्रयोग में 03 उपभूखण्ड उपचार जैसे–फसल अवशेष संयोजन, बिना फसल अवशेष संयोजन एवं सूबबूल (के–636) अवशेष संयोजन के साथ विभाजित भूखण्ड डिजाइन में लगाये गये।

रबी 2017–18 के दौरान बेल आधारित संरक्षण कृषि (सी ए) प्रणाली में, सरसों की बीज उपज पारंपरिक जुताई (सीटी) में 815.4 किलोग्राम / हेक्टेयर तक न्यूनतम जुताई (एमटी) के तहत 806.3 किलोग्राम / हेक्टेयर से भिन्न थी। जौ की अनाज की पैदावार 1406.6 किग्रा / हेक्टेयर (सीटी) और 1393.5 किग्रा / हेक्टेयर (एमटी) से हुई जो गैर–महत्वपूर्ण थे। खरीफ 2018 के दौरान, उर्द की बीज उपज 335.0 किलोग्राम / हेक्टेयर (एमटी) में और 342.0 किलोग्राम / हेक्टेयर (सीटी) में दर्ज की गई। एमटी प्लॉटों में मूंग की बीज उपज 379.3 किलोग्राम / हेक्टेयर और सीटी प्लॉटों में 387.5 किलोग्राम / हेक्टेयर थी।

सागौन आधारित सी ए प्रणाली में, रबी 2017–18 के दौरान, सरसों की बीज उपज 720.5 किलोग्राम /हेक्टेयर (एमटी) और 726.9 किलोग्राम / हेक्टेयर (सीटी) से भिन्न पाई गई। जौ की अनाज की पैदावार एमटी में 1242.7 किलोग्राम/ हेक्टेयर और सीटी मुख्य भूखंड प्रणाली में 1257.6 किलोग्राम/हेक्टेयर दर्ज की गई। खरीफ, 2018 के दौरान, सीटी में प्लॉट्स में उर्द की बीज की पैदावार 312.6 किलोग्राम/हेक्टेयर से लेकर एमटी प्लॉट्स में 315.8

किलोग्राम/हेक्टेयर तक थी, हालांकि गैर–महत्वपूर्ण। हालांकि गैर–महत्वपूर्ण मूँग की बीज उपज 365.0 किलोग्राम/हेक्टेयर (एम टी) और 375.0 किलोग्राम/हेक्टेयर (सी टी) में दर्ज की गई, ।

रबी 2017–18 के दौरान बेल–सागौन आधारित सीए प्रणाली में, सरसों की बीज उपज सीटी भूखण्डों में 787.8 किलोग्राम/हेक्टेयर और एमटी भूखण्डों में 778.9 किलोग्राम/हेक्टेयर दर्ज की गई। इसके अलावा, जौ की अनाज की पैदावार सीटी में 1316.8 किलोग्राम/हेक्टेयर से बढ़कर एमटी में 1327.3 किलोग्राम/हेक्टेयर तक हो गई। खरीफ 2018 के दौरान, एमटी में 277.3 किलोग्राम/हेक्टेयर से लेकर सीटी में 282.7 किलोग्राम/हेक्टेयर तक उर्द के बीज की उपज पाई गई। इसी तरह, एमटी में ग्रीनग्राम की बीज उपज 390.0 किलोग्राम/हेक्टेयर से लेकर 396.0 किलोग्राम/हेक्टेयर सीटी तक थी, हालांकि गैर–महत्वपूर्ण थे। अवशेष उपचारों के बीच, फसल अवशेषों ने लगभग सभी प्रयोगों में अन्य उपचारों की तुलना में बेहतर प्रदर्शन किया था।

इसके अलावा, सागौन और बेल दोनों के विकास मानकों (वृक्षोच्च व्यास और ऊँचाई) को गैर–महत्वपूर्ण पाया गया, हालांकि, अधिकतम ऊँचाई और बेल की वृक्षोच्च व्यास में क्रमशः 2.5 मी. और 47.69 मिमी. दर्ज किया गया। हालांकि, सागौन के मामले में संबंधित मूल्य 4.18 मीटर और 57.16 मिमी. थे।

कृषिवानिकी आधारित समन्वित कृषि प्रणाली में अमरुद की जीवितता लगभग 99% है और कॉलर व्यास की रेंज 1.0 से 5.0 सेमी तक है। अमरूद का अधिकांश पौधा रोपण के एक वर्ष के बाद ही फलित होने लगा।

रबी, 2017–18 के दौरान, मटर 0.9 हेक्टेयर क्षेत्र में उगाया गया था। रबी मक्का को 0.10 हेक्टेयर में लगाया गया था और इसका प्रदर्शन काफी उत्कृष्ट था तथा इससे लगभग 3500 हरे भुट्टे का उत्पादन प्राप्त हुआ। हरे भुट्टे से कुल आय ₹ 1700 प्राप्त हुई। गर्मियों के दौरान, भिण्डी, कद्दू और लौकी को मक्का के साथ 0.25 हेक्टेयर में उगाया गया और इससे ₹ 9540 की शुद्ध आय 1.54 के B: C अनुपात के साथ प्राप्त हुयी।

पोंगामिया पिन्नाटा के क्लोनल पौधों और रोपों में भिन्न प्रतिक्रियाएं उनके अनुकूलन क्षमता के संदर्भ में देखी गई हैं। क्लोनल पौधों ने शुष्क गर्म मौसम के दौरान बेहतर शारीरिक दक्षता बनाए रखी, जो अंकुरित पौधों की तुलना में बेहतर अनुकूली क्षमता का संकेत देता है।

नीम और सफेद सिरिस के थर्मोटोलेरेंस गतिकी की एक प्रवृत्ति को अस्थायी और मौसमी पैमाने पर देखा गया है और इसे CTD और CCI जैसे थर्मोटोलेरेंस इंडेक्स के लिए और पुष्टि की आवश्यकता है।

यमुनानगर जिले में चिनार के वृक्षारोपण से कार्बन उत्सर्जन के लिए मूल्य का अनुमान कृषि और पौधा रोपण के विभिन्न आयु के क्षेत्र के आधार पर लगाया गया था। यह अध्ययन क्षेत्र में किए गए क्षेत्र सर्वेक्षण के आधार पर क्रमशः 3, 4, 5, 6 और 7 वर्ष पुराने वृक्षारोपण के लिए 5, 10, 20, 30 और 35% के रूप में लिया गया था। कुल कार्बन स्टॉक और कार्बन डाइ आक्साइड पॉपलर से अनुक्रमित यमुनानगर में कुल पॉपलर प्लांटेशन के लिए लगभग 1.36 मिलियन टन और 4.99 मिलियन टन कार्बन डाइ आक्साइड इ. होगा। कुल मूल्य जीवन चक्र के 7 साल के दौरान ₹ 1663 मिलियन का और एक वर्ष में ₹ 238 मिलियन के अनुसार जिले में चिनार के रोपण के लिए कार्बन का अनुमान लगाया गया था। तात्पर्य यह है कि चिनार के वृक्षारोपण द्वारा कार्बन के संदर्भ में पारिस्थितिक तंत्र सेवाओं (विनियमन) का भुगतान पर्याप्त है और यह किसानों को बड़े स्तर पर कृषि को अपनाने के लिए प्रोत्साहित करता है।

गोंद एवं रॉल परियोजना के अंतर्गत झाँसी स्थित केन्द्रीय कृषिवानिकी अनुसन्धान संस्थान का मुख्य उद्देश्य गोंद एवं रॉल उत्पादित करने वाले वृक्ष आधारित कृषिवानिकी मॉडल विकसित करना तथा साथ–साथ तकनीक प्रसार करके लोगों को जीविकोपार्जन की सुरक्षा प्रदान करना है। इस वर्ष भी केन्द्र के प्रक्षेत्र एवं किसानों के खेत पर पहले से विकसित गोंद उत्पादक कृषिवानिकी मॉडल का रख–रखाव किया गया तथा इसके साथ–साथ वृक्षों की बढ़वार, इनसे होने वाले गोंद का उत्पादन एवं अन्तः फसलों (सरसों एवं मूँग) की उपज पर आंकड़े एकत्र किए गए। *अकेशिया सेनेगल* (कुमट) पर किए गए कुल बायोमास अध्ययन (भूमि के नीचे एवं ऊपर) से पता चला कि तीन वर्ष पुराने कुमट के वृक्ष में कुल 27.36 किलोग्राम बायोमास संरक्षित हुआ एवं अन्तः सतही (जड़) तथा सतह के ऊपर (तने) के बायोमास का अनुपात 0.139 प्राप्त हुआ। जड़ों की कैटायन एक्स्चेंज कैपेसिटी (CEC) पर किए गए अध्ययन से यह ज्ञात (cation exchange capacity) हुआ कि कुमट की ताजा जड़ों की कैटायन एक्स्चेंज कैपेसिटी गेहूं की जड़ों की कैटायन एक्स्चेंज कैपेसिटी की तुलना में अधिक थी, जो पेड़ के राइजोस्फियर (rhizosphere) क्षेत्र में पोषक

तत्वों के लिए प्रतिस्पर्धा उत्पन्न कर देते हैं। कुमट के वृक्ष से 16.52–37.63 ग्राम जबकि *अकेशिया निलोटिका* (बबूल) से 3.64–28.3 ग्राम प्राकृतिक गोंद उत्पादित हुआ। *एनोजीसस पेंडुला* (करधई) में गोंद उत्प्रेरक (एथेफोन) की सहायता से गोंद उत्पादन की तकनीक का मानकीकरण किया गया। टीकमगढ़ (दो गाँव) तथा झाँसी जिले (एक गाँव) के आदिवासी बाहुल्य क्षेत्र का सर्वेक्षण किया एवं गोंद के दोहन और उनके उपयोग पर स्वदेशी पारम्परिक ज्ञान (indigenous traditional knowledge) की जानकारी एकत्रित की गई। वर्ष 2018 की वर्षा ऋतु में संस्थान के प्रक्षेत्र पर कुमट एवं करोंदा आधारित चार सजीव बाड़ (bio-fence) के मॉडल विकसित किए गए, जिनमें कुमट एवं करोंदा के पौधों को एक अथवा दो पंक्तियों में रोपित किया गया है। इसके अतिरिक्त चयनित गाँव में किसानों को अपने खेतों पर कृषिवानिकी अपनाने हेतु प्रेरित किया गया। किसानों को अपने खेत पर रोपित करने हेतु कुमट के 3000 एवं फल उत्पादित करने वाले लगभग 1000 पौधे वितरित किए गए। ग्राम परासई में एक किसान ने कुमट एवं करोंदा आधारित सजीव बाड़ को अपने खेत की मेड़ पर लगाया है।

17–राज्यों (कर्नाटक, ओडिशा, बिहार, आंध्र प्रदेश, महाराष्ट्र, हिमाचल प्रदेश, तमिलनाडु, मध्य प्रदेश, उत्तर प्रदेश, पंजाब, हरियाणा, पश्चिम बंगाल, छत्तीसगढ़) में कार्बन सीक्वेस्ट्रेशन पोटेंशियल (CSP) की मात्रा को पूरा किया गया है। राजस्थान, गुजरात, तेलंगाना और झारखंड 58 जिलों को कवर करते हैं। इन राज्यों में प्रति वर्ष 0.11 से 0.82 टन कार्बन प्रति हेक्टेयर के बीच किसानों के क्षेत्र में मौजूद एग्रोफोरेस्ट्री प्रणाली में कार्बन सीक्वेस्ट्रेशन क्षमता पाई गई। एग्रोफोरेस्ट्री प्रणाली की अधिकतम सीएसपी महाराष्ट्र में पाई गई तथा इसके बाद क्रमशः आंध्र प्रदेश और हिमाचल प्रदेश का स्थान है।

कार्बन सीक्वेस्ट्रेशन पोटेंशिअल (CSP) का आकलन आंध्र प्रदेश के दो जिलों (पूर्वी गोदावरी और विजयनगरम) में किया गया था। आंध्र प्रदेश के दो जिलों (पूर्वी गोदावरी और विजयनगरम) में किसानों के खेतों में विद्यमान एग्रोफोरेस्ट्री के तहत वृक्षों का घनत्व 44.22 से 47.32 /हेक्टेयर तक है। इन जिलों में, तेजी से बढ़ने वाले पेड़ मध्यम बढ़ने वाले पेड़ों की तुलना में अधिक हैं। धीमी गति से बढ़ने वाले पेड़ों की आबादी बहुत कम है। कुल मिलाकर, विभिन्न राज्यों में कृषि व्यवसाय प्रणाली में वृक्षों की आबादी लगभग 17.8 पेड़ / हेक्टेयर है। पेड़ का अधिकतम घनत्व (41 पेड़ / हेक्टेयर) महाराष्ट्र में दर्ज किया गया है, इसके बाद आंध्र प्रदेश और हिमाचल प्रदेश का स्थान है।

12 कृषि–जलवायु क्षेत्र में एग्रोफोरेस्ट्री क्षेत्र का मानचित्रण पहले ही पूरा हो चुका है। 12 क्षेत्र में एग्रोफोरेस्ट्री के तहत कुल क्षेत्रफल 23.25 मिलियन हेक्टेयर था जो कुल भौगोलिक क्षेत्र (267.66 मिलियन हेक्टेयर) था। रिपोर्ट के तहत वर्ष के दौरान, कृषि–जलवायु क्षेत्र (11) में मानचित्रण किया गया था। जोन 11 में एग्रोफोरेस्ट्री क्षेत्र कुल भौगोलिक क्षेत्र 20.21 मिलियन हेक्टेयर का 2.36 मिलियन हेक्टेयर है।

रोपाई के बड़े पैमाने पर उत्पादन के लिए बंबूसा वल्गारिस में विकसित क्लोनल प्रसार तकनीक और क्लोनल मदर गार्डन की स्थापना की। चुनिंदा औद्योगिक पेड़ों में मिनी कटिंग प्रोटोकॉल के इंडोर और आउटडोर मानकीकरण को अंजाम दिया गया। *यूकेलिप्टस टेरिटोरिकिस, कैसुरीना जंघुहियाना, मेलिया डबिया* और *पॉपुलस डेल्टॉइड्स* के लिए मानकीकृत प्रसार प्रोटोकॉल। किसानों को पौधे लगाने के लिए विभिन्न पेड़ों के बीज वितरित किए गए। मध्य भारत के बुंदेलखंड क्षेत्र में पहली बार *मेलिया डुबिया, कैसुरीना जंगुनिना* और *संतालुम एल्बम* वृक्षारोपण को बढ़ावा दिया।

पोंगामिया पिन्नाटा की फूलों की फेनोलॉजी ने संकेत दिया कि फूल को पार–परागण के लिए अनुकूलित किया गया था। एंथेसिस 0800 और 1000 घंटे के बीच था, जिसमें अधिकतम 0800 से 0830 घंटे के बीच थी। पराग का अंकुरण पूरे दिन देखा गया था लेकिन परागण (96.15%) के समय अधिकतम पराग का अंकुरण हुआ था और 1200 घंटे (92.21%) तक जारी रहा था और 1200 घंटे के बाद अंकुरण प्रतिशत कम हो गया था। स्टिग्मा एंथेसिस के बाद आठ घंटे के लिए ग्रहणशील थी। कुल 13 विभिन्न फूलों के आगंतुकों को दर्ज किया गया है।

भारत–गंगा क्षेत्र में, पंजाब, हरियाणा, पश्चिमी उत्तर प्रदेश, उत्तराखंड और बिहार में चिनार प्रजाति आधारित कृषि व्यवसाय प्रणाली प्रचलित हैं। कुछ नमूना जिलों के तहत क्षेत्र के मानचित्रण और आकलन का चयन पंजाब, हरियाणा, उत्तर प्रदेश, उत्तराखंड और बिहार से किया गया जहां पोपलर प्रमुख है। जिला स्तर के लिए, LISS-4 डेटा का उपयोग करके पॉपलर क्षेत्र की मैपिंग की गई है। रूपनगर और होशियारपुर जिलों में कुल कृषि आधारित कृषि क्षेत्र में पॉपलर आधारित एग्रोफोरेस्ट्री सिस्टम का 50% से अधिक हिस्सा है। हरियाणा के यमुनानगर जिले में, पोपलर क्षेत्र का अनुमान 12169.66 हेक्टेयर (9.71%) था। यह चिनार क्षेत्र जिले के कुल कृषि व्यवसाय क्षेत्र का लगभग 74.7% है। पश्चिमी उत्तर प्रदेश में, पोपलर क्षेत्र सहारनपुर जिले (25911.23 हेक्टेयर) में

प्रदेश में, पोपलर क्षेत्र सहारनपुर जिले (25911.23 हेक्टेयर) में अधिकतम पाया गया, जो 7.17% बिजनौर जिले (12840.53 हेक्टेयर) के बाद है। राज्य स्तर पर चिनार की मैपिंग सेंटिनल –2 ए डेटा के साथ भी ऊपर वर्णित पद्धति का उपयोग करके की गई थी। पोपलर प्रजाति के अंतर्गत अनुमानित क्षेत्र को 81% की सटीकता के साथ 0.276 मिलियन हेक्टेयर (5.63%) पाया गया। इसी प्रकार, हरियाणा राज्य में पोपलर प्रजाति के तहत क्षेत्र का अनुमान लगाया गया था, जो 85.2% की सटीकता के साथ 0.205 मिलियन हेक्टेयर (4.66%) तक आता है। हरियाणा के यमुनानगर जिले के मामले में, जहां पोपलर आधारित एग्रोफोरेस्ट्री बहुत प्रमुख है, घनत्व 540 से 1560 पेड़ों / हेक्टेयर तक भिन्न होता है। डीबीएच 13. 96–22.71 सेमी की सीमा में पाया गया था। अनुमानित तना और उपरी बायोमास क्रमशः 103.05–213.48 किग्रा/वृक्ष और 118.55–268.67 किग्रा / वृक्ष के रूप में निकलते हैं।

रोपाई के दो साल बाद सागौन और महागौनी के जीवित रहने को अर्ध–शुष्क परिस्थितियों में सिल्विपैस्ट्रल सिस्टम में क्रमशः 91 और 82% देखा गया। रोपण के दो साल बाद, सागौन और महागौनी की अधिकतम ऊँचाई और स्कन्ध व्यास सागौऩ महागोनी. चराई. समोच्च कंपित खाइयों वाले उपचार में दर्ज किए गए थे। चारागाह की दूसरी कट सितंबर, 2018 में ली गई थी। यह पाया गया था कि घास (*सेन्क्रस सिलियेरिस*) और *एस सेब्राना* की ऊँचाई क्रमशः 127 सेमी से 152 सेमी और 80 सेमी और 102 सेमी. के बीच है। *सेन्क्रस सिलियेरिस* और *एस सेब्राना* के अन्य विकास मापदंडों में भी इसी तरह के रुझान देखे गए। अलग–अलग उपचारों में मिट्टी की नमी की गतिशीलता का 15 दिनों के अंतराल पर अध्ययन किया गया और यह पाया गया कि उच्चतम मिट्टी की नमी की मात्रा टी$_7$–चारा + सागौन + महागोनी + कन्टूर स्टेगर्ड ट्रैन्च में दर्ज की गई। पहली बरसात के बाद, समोच्च कंपित खाइयों (सीएसटी) और अर्धचन्द्राकार थालों (एचएमबी) ने क्रमशः 38. 30 टी / हेक्टेयर और 7.644 टी / हेक्टेयर की दर से मिट्टी के तलछट को फंसाया। दूसरी वर्षा ऋतु के लिए संबंधित मान 15.25 और 3.19 टन प्रति है. थे।

ग्रीष्म ऋतु में *हार्डविकिया बिन्नाटा* आधारित कृषिवानिकी प्रणाली में सूक्ष्म जड़ों की जैवभार (75–90) सेमी. मिट्टी की गहराई में 21.5 ग्राम प्रति मी.^{2} तथा (45–60) सेमी. गहराई में 89 ग्राम प्रति मी.^{2} पेड़ों से 0.5 मीटर दूरी पर पायी गई। इसी तरह पेड़ों से 3.0 मीटर की दूरी पर सूक्ष्म जड़ों की जैवभार 8.8 ग्राम प्रति मी.^{2}, (75–90) सेमी. मिट्टी की गहराई में तथा 50 ग्राम प्रति मी.^{2} (30–45) सेमी. गहराई में दर्ज की गई। आँवला आधारित कृषिवानिकी प्रणाली में सूक्ष्म जड़ों की जैवभार, 1.57 ग्राम प्रति मी.^{2} (75–90) सेमी. गहराई में तथा 15.4 ग्राम प्रति मी.^{2} (30–45) सेमी. गहराई में पेड़ों से 0.5 मीटर की दूरी पर पर पाई गई। इसी प्रकार 3.0 मीटर की दूरी पर यह 0.3 ग्राम प्रति मी.^{2} (15–30) सेमी. गहराई से लेकर 5.6 ग्राम प्रति मी.^{2} (30–45) सेमी. गहराई में मिली।

शरद ऋतु में *हार्डविकिया बिन्नाटा* आधारित कृषिवानिकी प्रणाली में पेड़ों से 0.5 मीटर की दूरी पर, सूक्ष्म जड़ों की जैवभार (60–75) सेमी. गहराई में 30.8 ग्राम प्रति मी.^{2} से 110 ग्राम प्रति मी.^{2} (15–30) सेमी. गहराई में पाई गई। पेड़ों से 3.0 मीटर की दूरी पर यह 34.8 ग्राम प्रति मी.^{2} (45–60) सेमी. गहराई से लेकर 93.75 ग्राम प्रति मी.^{2}, (15–30) सेमी. गहराई में दर्ज की गई। जबकि आँवला आधारित कृषिवानिकी प्रणाली में सूक्ष्म जड़ों की जैवभार 0.5 मीटर की दूरी पर, 0.48 ग्राम प्रति मी.^{2} (60–75) सेमी. मिट्टी की गहराई में तथा 47.7 ग्राम प्रति मी.^{2}, (30–45) सेमी. गहराई में पाई गई। पेड़ों से 3.0 मीटर की दूरी पर, यह 0.33 ग्राम प्रति मी.^{2}, (30–45) सेमी. गहराई तााि 38.17 ग्राम प्रति मी.^{2}, (15–30) सेमी. गहराई में पाई गई। दोनों कृषिवानिकी प्रणाली में सूक्ष्म जड़ों की जैवभार मिट्टी की (0–45) सेमी. ऊपरी सतह पर (50–60) प्रतिशत दर्ज की गई।

EXECUTIVE SUMMARY

The executive summary of the research and development activities carried out at ICAR-Central Agroforestry Research Institute during 2018 is presented here under:

In ber based agri-horti system, different characters (plant growth, pruned material and fruit) of ber were significantly influenced except canopy spread, stone weight, pulp/stone ratio and TSS. In most of the cases treatment T_1 (Ber with 100% RDF) showed its superiority but was found at par with the treatments T_7 (Ber with 75% RDF + *Trichoderma)* and T_8 (Ber with 75% RDF + *Trichoderma* + Blackgram – Barley). Under the system, barley sown in *rabi,* 2017 and which was harvested during March, 2018. The treatments T_{10} (pure crop) and T_6 (Ber with 75% RDF + VAM + Blackgram – Barley) recorded highest seed yield of 2395 and 2362 kg/ha and was significantly higher as compared to other treatments. It was found that the treatments T_{10} (pure crop) and T_6 (Ber with 75% RDF + VAM + Blackgram - Barley) recorded highest seed yield of 391 and 376 kg /ha and was significantly higher w.r.t. other treatments.

A experiment has been planned and executed in the field by planting lemongrass (var. Krishna) in between the pomegranate plants at the spacing of 50x40cm . The experiment was designed in CRBD with two cultivars of pomegranate (V_1- Ganesh & V_2- Bhagwa), four levels of fertilizer (T_1- Vermi-compost 30Kg/plant, T_2- FYM 30Kg/plant, T_3- T_1 + T_2/plant and T_4- Recommended doses of chemical fertilizers/ plant) along with control (T_5) of pure lemongrass. During July-August 2018 due to increase in tussock size, lemongrass spacing was converted into 100x80cm by removing one tussock from between the two tussocks. In pomegranate, height ranged from 1.93 m (T_3V_2) to 2.76 m (T_4V_1), collar diameter from 5.48 cm (T_2V_2) to 7.77 cm (T_1V_1), East-West spread from 1.03 m (T_2V_2) to 1.54 m (T_4V_1) and North-South spread ranged from 1.02 m (T_2V_2) to 1.56 m (T_4V_1). However, fruit yield was ranged from 4.33 (T_1V_2) to 6.34 (T_2V_1).The cumulative yield from two cuts of lemongrass yielded 8.16 (T_2V_2) to 15.39 (T_5) t/ha green leaves having oil 64.69 T_3V_2 to 173.48 (T_5) kg oil/ha on fresh weight basis.

The project entitled "Agroforestry based Conservation Agriculture for Sustainable Land use and Improved Productivity" consisted of three experiments *viz.* Bael based agroforestry system, Teak based agroforestry system and Bael + Teak based agroforestry system with 04 main plot treatments i.e., min. tillage-blackgram-mustard (CS-1); min. tillage-greengram-barley (CS-2); CT-blackgram-mustard (CS-1) and CT-greengram-barley (CS-2) and 03 subplot treatments (with crop residue; without crop residue and with Leucaena (K-636) residue and are being conducted in split plot design.

In Bael based conservation agriculture (CA) system, during *rabi* 2017-18, the seed yield of mustard varied from 806.3 kg /ha under minimum tillage (MT) to 815.4 kg /ha in conventional tillage (CT). The grain yield of barley ranged from 1406.6 kg /ha (CT) and 1393.5 kg /ha (MT) though were non-significant. During *kharif* 2018, the seed yield of blackgram was recorded as 335.0 kg /ha (MT) and 342.0 kg /ha (CT). The seed yield of greengram was recorded as 379.3 kg /ha in MT plots and 387.5 kg /ha in CT plots.

In Teak based CA system, during *rabi* 2017-18, the seed yield of mustard varied from 720.5 kg /ha (MT) and 726.9 kg /ha (CT). The grain yield of barley recorded 1242.7 kg /ha in MT and 1257.6 kg /ha in CT main plot system. During *kharif,* 2018, the seed yield of blackgram varied from 312.6 kg /ha in MT to 315.8 kg /ha in CT plots, though non-significant. Seed yield of greengram was recorded as 365.0 kg /ha (MT) and 375.0 kg /ha (CT), though non-significant.

In Bael + Teak based CA system, during *rabi* 2017-18, the seed yield of mustard recorded 787.8 kg /ha in CT plots and 778.9 kg /ha in MT plots.

Further, the grain yield of barley ranged from 1316.8 kg /ha in CT to 1327.3 kg /ha in MT main plot treatments. During *kharif* 2018, the seed yield of blackgram varied from 277.3 kg /ha in MT to 282.7 kg /ha in CT. Similarly, seed yield of greengram ranged from 390.0 kg /ha in MT to 396.0 kg /ha in CT though were non-significant. Among the residue treatments, crop residue retention had performed better as compared to other treatments in all of the experiments.

Further, the growth parameters (DBH and height) of both teak and bael were found to be non-significant though, maximum height and DBH of bael recorded 2.54 m and 47.69 mm, respectively. However, in case of teak, the corresponding values were 4.18 m and 57.16 mm.

In Agroforestry based Integrated Farming System (AF-IFS) survival in guava was found 99% and collar diameter ranged from 1.0 to 5.0 cm. Most of the guava plants started bearing after a year of planting and during this year fruit yield varied from 1.0 to 8.0 kg per plant with 5 to 20 fruits per plant. There were 45 papaya plants (var. Pusa dwarf) under fruiting and they yielded about 10 to 15 kg fruit per plant. Survival in mango and teak was reduced after a year of plantation and efforts are being made to refill the gap through in-situ grafting of mango. Most of the plants died due to heavy rain during 2018. Gap filling of papaya plants was done after making raised bed with var. Arka Surya and Arka Prabhat in month of September, 2018.

During *rabi,* 2017-18, pea was grown in 0.9 ha area, in which the yield of green pod was very poor. Winter maize was also tried in 0.10 has area and performance of winter maize was excellent and it produced about 3500 green cobs, which were sold in ₹ 17500 @ ₹ 5/cob. During summer, bhindi, pumpkin and bottle gourd were grown as intercrop with maize in 0.25 ha and it gave ₹ 9540 as net income with B:C ratio of 1.54.

Differential responses in clonal plants and seedlings of *Pongamia pinnata* in field have been observed with reference to their adaptability. Clonal plants maintained better physiological efficiency during dry hot season indicating its better adaptive potential than seedling plants.

A trend of thermotolerance dynamics of *Azadirachta indica* (Neem) and *Albizia procera* (Safed siras) has been observed in temporal and seasonal scale and it requires further confirmation for thermotolerance indices like CTD and CCI.

The value for carbon sequestered by poplar plantations in Yamunanagar district was estimated on the basis of area under agroforestry and different age of poplar plantations. This was taken as 5, 10, 20, 30 and 35% for 3, 4, 5, 6 and 7 years old plantations, respectively on the basis of field survey conducted in the study area. The total carbon stock and CO_2 sequestered from poplar would be about 1.36 million t and 4.99 million t CO_2 e for total poplar plantation in Yamunanagar. The total value of ₹ 1663 million was estimated for carbon sequestered by poplar plantation in the district during 7 year of life cycle and ₹ 238 million in a year. It implies that the payment of ecosystem services (regulating) in terms of carbon sequestered by poplar plantation is substantial and it encourages farmers to adoption agroforestry in big way.

At ICAR-CAFRI, Jhansi, the main aim of ICAR Network Project "Harvesting, Processing and Value Addition of Natural Resins and Gums" is to develop agroforestry models including gum- and resin-yielding trees for livelihood security and horizontal dissemination of technologies. During year under report, maintained and managed agroforestry models established at research farm and recorded data on growth of tree, gum exudation and yield of intercrops (mustard and moong). Total biomass study (above- and below-ground) revealed that three years old *Acacia senegal* accumulates 27.36 kg biomass per tree with root: shoot ratio of 0.139. The observations on cation exchange capacity (CEC) of roots revealed that the fresh root CEC of *A. senegal* was more than that of wheat (intercrop), which poses strong competition for nutrient cations in tree rhizosphere zone. Natural gum exudation from *A. senegal* ranged from 16.52-37.63 g/tree whereas, *Acacia nilotica* ranged from 3.64-28.3 g/tree. Gum tapping techniques with use of gum inducer (ethephon) in *Anogeissus pendula* was standardized. The ITK information on gum tapping and their uses was

collected by surveying tribal dominated areas in Tikamgarh (two villages) and Jhansi districts (one village). During the rainy season of 2018, four bio-fence models were developed at Institute research farm, wherein *A. senegal* along with *Carissa carandas* were planted in single and double rows. Besides, frequent visits were made to villages to motivate the farmers for planting agroforestry models on their farms. About 3000 seedlings of *A. senegal* (gum-arabic) and 1000 seedling of fruit plants were distributed to farmers for planting on their fields.

Quantification of Carbon Sequestration potential (CSP) in agroforestry system has been completed in 17-States (Karnataka, Odisha, Bihar, Andhra Pradesh, Maharashtra, Himachal Pradesh, Tamil Nadu. Madhya Pradesh, Uttar Pradesh, Punjab, Haryana, West Bengal, Chhattisgarh, Rajasthan, Gujarat, Telangana and Jharkhand) covering 58 districts. Carbon Sequestration potential in agroforestry system existing on farmers' field varied from 0.11 to 0.82 tons C per hectare per year in these states. The maximum CSP of agroforestry system is observed in Maharashtra followed by Andhra Pradesh and Himachal Pradesh.

The assessment of carbon sequestration potential (CSP) was undertaken in two districts (East Godavari and Vizianagaram) of Andhra Pradesh. Tree density under agroforestry existing on farmers' fields in two districts of Andhra Pradesh (East Godavari and Vizianagaram) varied from 44.22 to 47.32 tree /ha. In these districts, fast growing trees are more than medium growing trees. Overall, the tree population in agroforestry system in different states is about 17.8 trees /ha. The maximum tree density (41 trees/ha) was recorded in Maharashtra followed by Andhra Pradesh and Himachal Pradesh.

Mapping of agroforestry area in 12 agro-climatic Zone has already been completed. Total area under agroforestry in 12 zone was estimated to be 23.25 million ha of total geographical area (267.66 million ha). During year under report, mapping was done in agro-climatic zone (11). Agroforestry area in zone 11 is 2.36 million ha of total geographical area 20.21 million ha.

Developed clonal propagation techniques in *Bambusa vulgaris* for mass production of seedlings and established Clonal Mother Garden. Indoor and outdoor Standardization of mini cutting protocol in selected industrial trees was carried out. Standardized propagation protocol for *Eucalyptus tereticornis, Casuarina junghuhniana, Melia dubia and Populus deltoids.* Seedlings of different trees were distributed to farmers for planting. Promoted *Melia dubia, Casuarina jungunina* and *Santalum album* plantations for the first time in Bundelkhand region of Central India.

Flowering phenology of *Pongamia pinnata* indicated that the flower appeared to be adapted for cross-pollination. Anthesis was between 0800 and 1000 h, with a peak between 0800 to 0830 h. Pollen germination was noticed throughout the day but maximum pollen germination was at the time of anthesis (96.15%) and continued up to 1200 h (92.21%) and after 1200hr germination percentage was reduced. Stigma was receptive for eight hours after anthesis. A total of 13 different flower visitors have been recorded.

In Indo-Gangetic region, Poplar species based agroforestry systems are prevalent in Punjab, Haryana, western Uttar Pradesh, Uttarakhand and Bihar. Mapping and estimation of area under some sample districts were selected from Punjab, Haryana, Uttar Pradesh, Uttarakhand and Bihar where Poplar is dominant. For district level, mapping of Poplar area has been done using LISS-4 data. Poplar based agroforestry systems accounted for more than 50% of total agroforestry area in Rupnagar and Hoshiarpur districts. In Yamunanagar district of Haryana, Poplar area was estimated to be 12169.66 ha (9.71%). This poplar area accounted for about 74.7% of total agroforestry area in the district. In western Uttar Pradesh, Poplar area was found maximum in Saharanpur district (25911.23 ha), which is 7.17% followed by Bijnor district (12840.53 ha). Poplar mapping at state level was also done with Sentinel-2A data using the methodology described above. Estimated area under Poplar species was found to be 0.276 million ha (5.63%) with a reasonably good accuracy of 81%. Similarly, area under Poplar

species in Haryana state was estimated, which come out to be 0.205 million ha (4.66%) with an accuracy of 85.2%. In case of Yamunanagar district of Haryana, where Poplar based agroforestry is very predominant, density varies from 540 to 1560 trees /ha. DBH was found in the range of 13.96-22.71 cm. Estimated stem and aboveground biomass come out to be 103.05-213.48 kg/tree and 118.55–268.67 kg/tree, respectively.

The survival of the teak and mahagoni after two year of transplanting were observed to be 91 and 82%, respectively in silvipastoral system in semi-arid conditions. After two year of planting, maximum height and collar diameter of teak and mahagoni were recorded in treatment having teak+ mahagoni+ pasture+ contour staggered trenches. Second cut of pasture was taken in September, 2018. It was found that height of *Cenchrus ciliaris* and *S. seabrana* varied between 127 cm to 152 cm and 80 cm and 102 cm, respectively. Similar trends were observed in other growth parameters of *C. ciliaris* and *S. seabrana*. Soil moisture dynamics in different treatments were studied at 15 days interval and it was found that highest soil moisture content was recorded in T7- Teak + Mahagoni + Pasture + Contour Staggered Trenches (CST). After first rainy season, the contour staggered trenches (CST) and half-moon basin (HMB) trapped soil sediments at the rate of 38.30 t/ha and 7.644 t/ha, respectively. The corresponding values for second rainy season were 15.25 and 3.19 t /ha.

In *Hardwickia binata* based AFS, during summer season, the fine root biomass (FRB) varied from 21. 5 g/m^2 in 75-90 cm soil depth to 89 g/m^2 in 45-60 cm at 0.5 m distance from tree base. Similarly, at 3m distance from tree base, it varied from 8.8 g/m^2 at 75-90 cm depth to 50 g/m^2 at 30-45 cm depth. In aonla based AFS, FRB varied from 1.57 g/m^2 at 75-90 cm depth to 15.4 g/m^2 at 30-45 cm depth at 0.5 m distance from tree base. Contrary to this, at 3m distance from tree base, FRB ranged from 0.3 g/m^2 at 15-30 cm depth to 5.6 g/m^2 at 30-45 cm depth.

During winter season, in *Hardwickia binata* based AFS, at 0.5 m distance from tree base, FRB varied from 30.8 g/m^2 at 60-75 cm depth to 110 g/m^2 at 15-30 cm soil depth. At 3m distance from tree base, FRB ranged from 34.8 g/m^2 at 45-60 cm depth to 93.75 g/m^2 at 15-30 cm depth. However, in aonla based AFS, FRB showed 0.48 g/m^2 at 60-75 cm depth to 47.7 g/m^2 at 30-45 cm depth at a distance of 0.5 m from tree base. At 3m distance, it varied from 0.33 g/m^2 at 30-45 cm depth to 38.17 g/m^2 at 15-30 cm depth, respectively. There were around 50-60% of the fine root biomass, which belongs to 0-45 cm soil depth in both the agroforestry system studied.

CHAPTER 1 GENERAL

Mission

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

Vision

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

Mandate

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

Academic

Institute has been recognized by the Bundelkhand University as a study Institute to conduct Ph.D. programme. The Institute conducts M.Sc. dissertation and Ph.D. Thesis work in Agroforestry, Horticulture, Environmental Sciences, Plant Protection, Soil Science, Biotechnology and Soil & Water Conservation from different recognized Universities. Institute is contributing to education through UG teaching under collaborate programme with Rani Laxmibai Central Agriculture University, Jhansi.

Library

Library is an integral part of the institute. The Institute's Library is well furnished and equipped with LAN facilities. Library operations are automated using Koha Library Management Software. The library has 4549 books including Hindi books and subscribes 15 Indian Journals. On request references were supplied to the researchers on individual basis as well as through CERA (Consortium for E-Resources in Agriculture) servers through e-mail as well as soft/hard copies. Library also provided Services like Borrowing Facility, Reference Service and Inter Library Loan.

Agriculture Knowledge Management Unit

The entire network administration of computers, internet and website management is looked after by the Agriculture Knowledge Management Unit (AKMU). NKN connectivity of 100 Mbps have been commissioned from 1st January, 2019 at CAFRI, Jhansi. New web server based Ubuntu LINUX has been installed for hosting Institute's web site (www.cafri.res.in).

Research Farm and facilities

The Institutes possess now 284 acres land (after makeup of 69.48 acres land found excess in the 100 acres initially transferred from ICAR-IGFRI, Jhansi). Out of this about 30 acres land earmarked and handed over for the establishment of Maharani Laxmi Bai Central Agricultural University, Jhansi. Now Institute is having about 254 acres land only. Major area is rocky and degraded land which was gradually developed. About 85% 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 to hard pan (3-5 m below ground). Cultivation is totally dependent on rainfall and operation of canal. During *kharif* season major area was put under green manuring to improve the soil health. During *rabi* 2018-19 low water requirement crops were sown in concluded projects and general area. Details of cropped area and production during *rabi* and *kharif* are given in table.

Organizational Setup

DIRECTOR & PROJECT COORDINATOR

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

Research Programmes

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

Service Sections

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

Network Systems

- AICRPAF

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

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

ICFRE Institute : IFGTB, Coimbatore

- IPR Management
- NICRA
- HPVA of IINRG

Season / Crop & Variety	Area (ha)	Production (Qtls)
***Rabi* 2017-18 (received in 2018-19)**		
Wheat HUW-234/ DBW17	4.20	82.99
Barley BHS400/RD2552	5.70	33.66
Gram Jaki 9218	2.85	13.74
Mustard RH749	5.50	19.58
Lentil DPL62/ Mallika	0.40	0.53
Pea Arkel/IPF4-9	1.40	1.98
Maize (sweet corn) (IFS)	0.20	0.47 +532 green cobs
Pumpkin(IFS)	-	1.745
Bottle gourd(IFS)	-	0.655
Bhindi (IFS)	-	1.28
Straw	-	143.50
***Kharif* 2018-19**		
Dhaincha	4.80	0.48 + green manuring
Urd Azad-3/IPU2-43	6.30	16.70
Moong Sweta/IPM2-3	6.30	5.35 + green manuring
Cowpea Gomati	1.40	green manuring
Maize	0.20	127 green cobs
Fruits crops 2018-19		
Aonla	-	75.72
Bael	-	12.60
Guava	-	15.2
Lemon	-	0.69
Karonda	-	0.105

During *rabi* 2018-19 about 17.35 ha area have been sown which include 7.95 ha experimental and 9.40 ha general cropping in concluded agroforestry projects. Crop wise area sown in *rabi* season is given below;

Crop	Sown Area		Total
***Rabi* 2018-19**	**Experimental**	**General**	
Wheat HUW-234/ HD2967	2.20	1.55	3.75
Barley BHS400/DWRB92	2.50	4.30	6.80
Gram Jaki 9218	0.25	1.80	2.05
Mustard RH749/RH406	1.80	1.60	3.40
Lentil DPL62	-	0.15	0.15
Pea Arkel	1.20	-	1.20
Total	**7.95**	**9.40**	**17.35**

During the year a revenue to the tune of ₹ 6.47 lakhs have been generated from Central Research Farm. The Central Research Farm facilitated with most improved farm machineries and implements for mechanized farm operations. During the year 2018 one four wheeled Reaper-Binder machine,

one four wheeled Water Tanker cap.4500 litres, one Multi Crop Thresher and two Electronic Balances (cap.50kg & 300kg), one brush cutter were added in farm facilities. A mini workshop equipped with welding plants, drill machine, car washer, grinder etc. besides other tools for repair and maintenance of farm machineries is available at the Institute. Irrigation facilities was strengthen adding 100 Nos. HDPE irrigation pipes (90mm) besides extending 520 mtres (40/50mm) pipelines to newly planted to experiments.

Laboratories and other facilities

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

MIS/FMS

Five management modules *viz*., financial, project (project and scheme code generation), stores (indent creation), human resource (training information, applying leaves) and payroll (information related to transfer and joining of employees) have been supported through MIS/FMS.

Budget (2018-19)

(₹ in Lakhs)

S. No.	Head	Budget	Expenditure
1.	**ICAR-CAFRI, Jhansi**		
	a. Capital (grant for creation of Capital Assets)	60.47	60.45
	b. Establishment Expenses (Grant in Aid-Salaries)	874.59	874.57
	c. Grant in Aid-General. Pension Benefits	48.00	47.03
	d. General	215.64	213.97
	Total	**1198.70**	**1196.02**
	Plan Schemes		
2.	All India Coordinated Research Project on Agroforestry (AICRAF)	1566.92	1566.32
3.	Harvest and post-harvest processing and value addition of natural resins, gums and gum resins (HPVA; ICAR, New Delhi)	16.00	15.83
4.	Assessment of carbon sequestration potential of agroforestry systems (NICRA, ICAR, New Delhi)	34.78	31.16
5.	IP&TM	4.50	3.86
6.	**Externally Funded Projects**		
	Mapping and Estimation of Area under Poplar based Agroforestry Systems in Indo-Gangetic Plains of India (ICAR- ICRAF Workplan)	7.64	7.34
	Doubling farmers' income in Bundelkhand, UP (ICRISAT)	32.51	1.82
	Establishment of Teak and Aonla based Agroforestry System in Datia district on agricultural land (Consultancy project of Bundelkhand Agro)	4.81	0.38
	Establishment of Hi Tech Nursery for the Production of Quality Planting Material (U.P. Agroforestry Mission)	28.01	5.83
	National Mission for Sustaining the Himalayan Ecosystems (NMSHE- Taskforce 6 for Himalayan Agriculture) (DST)	14.96	5.86
	Development of Nursery of TBOs for Quality Planting Material Production (NMOOP MM-III)	5.80	5.76
	Studies on Pollination Dynamics, Pod yield and oil content in *Pongamia pinnata* (SERB-DST)	13.04	5.19

Resource Generation	Target	Achievement
	19.70	**22.19**
Expenditure as incurred on Swachhata Action Plan	---	6.74
SC SP Fund		
Capital	1.37	1.37
General	20.00	18.80

CHAPTER

2 RESEARCH ACHIEVEMENTS

2.1: System Research Programme

NRMACAFRISIL201000200085

Nutrient management in ber based agri-horticulture system

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

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

The observation recorded on fruits during 2017-2018 (plant age 7.5 years) is presented in Table 1. It is evident from the data that all the fruit characters were influenced significantly except stone weight, pulp/stone ratio and TSS. Maximum average fruit weight (20.08 g) was found significantly higher in treatment T_1, where as it was minimum (16.36 g) in treatment T_9. Average bigger size fruits were harvested in treatment T_3 (3.23 cm x 3.21 cm) followed by T_8 (3.22 cm x 3.20 cm). Fruit volume ranged from 16.88 cc in treatment T_9 to 20.34 cc in treatment T_1 and found significant. Likewise, pulp weight was recorded more in treatment T_1 (19.11 g) and it was less in T_9 (15.66 g) and found significant between the treatments. Stone weight, pulp/stone ratio and Total Soluble Solids (TSS) were found non-significant but recorded more in T_8 (1.13 g), T_9 (22.48) and T_8 (19.80^{0}B), respectively. As far as number of fruits plant^{-1} is concerned, it was significantly higher in treatment T_7 (2675.53) and lowest in treatment T_4 (1671.11). Fruit yield was significantly more in treatment T_1 (53.17 kg/plant) and found at par with treatments T_8 (51.17 kg / plant).

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

Treat	Weight (g)	Size (cm)		Volume (cc)	Pulp wt (g)	Stone wt (g)	Pulp/ stone ratio	TSS ^{0}B	No. of fruit / plant	Yield (kg/pl.)
		L	W							
T_1	20.08	3.12	3.09	20.34	19.11	0.97	20.22	19.47	2668.17	53.17
T_2	18.12	3.06	3.06	18.46	17.15	0.97	17.97	17.03	2021.53	36.64
T_3	18.45	3.23	3.21	18.65	17.47	0.98	18.19	18.44	1946.28	35.80
T_4	16.89	3.07	3.07	17.24	15.80	1.09	14.82	17.89	1671.11	28.40
T_5	18.83	3.17	3.19	19.17	17.86	0.97	19.09	17.84	2043.13	38.32
T_6	16.90	3.05	3.08	17.03	16.02	0.88	18.21	19.47	2429.56	40.75
T_7	16.65	3.11	3.11	17.21	15.71	0.94	17.14	18.33	2675.53	44.50

T_8	19.48	3.22	3.20	19.93	18.35	1.13	16.40	19.80	2632.93	51.17
T_9	16.36	3.08	3.06	16.88	15.66	0.70	22.48	17.01	2078.44	33.80
CD $_{(0.05)}$	1.91	0.12	0.11	2.08	1.86	NS	NS	NS	487.76	7.87

T_1: Ber (100%RDF), T_2: Ber (100%RDF) + Black gram-Barley, T_3: Ber (75%RDF), T_4: Ber (75%RDF) + Black gram-Barley, T_5: Ber (75%RDF) + VAM, T_6: Ber (75%RDF) + VAM + Black gram-Barley, T_7: Ber (75%RDF) + *Trichoderma*, T_8: Ber (75%RDF) + *Trichoderma* + Black gram-Barley and T_9: Ber (75%RDF) + VAM + *Trichoderma* + Black gram-Barley

The plants were pruned in the month of May, 2018 (VIIIth year after planting) and the pruned material ranged from 17.53 kg to 26.52 kg/pl on fresh weight basis, and 10.26 to 16.33 kg pl^{-1} on dry weight basis. In both the cases treatments were found significant (Table 2). After pruning cent percent survival was observed in the field. The plant growth observations recorded in the month of December, 2018 are also presented in Table 2. The data reveals significantly maximum collar diameter in treatment T_1 (13.57 cm) which was at par with treatment T_2, T_3, T_5, T_6 and T_7. Minimum collar diameter was recorded in treatment T_4 (10.24 cm). Canopy spread was found non-significant but observed more in treatment T_7 (5.13 m) for East-West direction and in treatment T_8 (5.38 m) for North-South direction.

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

Treatment	Pruned Material (kg/ pl)		Collar diameter (cm)	Canopy Spread (m)	
	Fresh	Dry		EW	NS
T_1	26.52	16.33	13.57	4.69	4.89
T_2	20.29	12.06	12.36	4.61	4.70
T_3	19.90	12.08	12.34	4.90	4.56
T_4	17.53	10.26	10.24	4.27	4.39
T_5	24.73	15.17	12.38	4.70	4.77
T_6	19.29	11.91	12.54	4.81	4.77
T_7	22.66	13.62	12.21	5.13	5.22
T_8	23.63	14.25	11.83	5.10	5.38
T_9	20.75	12.54	11.47	4.64	4.62
CD $_{(0.05)}$	5.15	3.16	1.66	NS	NS

Ber pruning

New flush after pruning

Ber based agrihorti system

Barley (BHS 400 C/S) was sown (@ 100 kg ha^{-1}) on November 16 & 30, 2017 during *rabi* season on residual fertility under rainfed condition and harvested between 19 to 22nd March 2018. Barley recorded seed yield in the range of 709 to 975 kg ha^{-1} and corresponding straw yield was recorded in the range of 2251 to 2395 kg ha^{-1} in different treatments. The treatments T_{10} (pure crop) and T_6 (Ber (75% RDF) + VAM + Black gram - Barley) recorded highest seed yield of 2395 and 2362 kg ha^{-1} and were significantly higher as compared to other treatments. Similar trend was observed in corresponding straw yield (Table 3). Data indicated that treatments T_{10} and T_6 also recorded significantly higher number of grains spike^{-1}.

Table 3: Yield and yield contributing characters of barley during *rabi*, 2017-18

Treat	Tillers (per m^2)	Plant height (cm)	Biomass at harvest (DW g/m^2)	Grains/ spike	Seed yield (kg/ ha)	Straw yield (kg/ ha)
T_2	238.4	67.8	924	37.2	2251	2453
T_4	242.6	69.4	937	35.1	2345	2551
T_6	234.9	71.2	921	39.5	2362	2570
T_8	245.4	70.5	933	38.6	2231	2416
T_9	231.3	73.9	928	38.5	2245	2442
T_{10}	245.4	70.4	947	41.2	2395	2612
CV (%)	18.4	18.7	19.2	18.5	18.4	17.5
CD $_{(0.05)}$	NS	NS	NS	6.3	152	230

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

During *kharif* 2018, black gram (urd) variety Azad-3 was sown on July 06, 2018 (15 kg ha^{-1}) with recommended dose of nutrients (20:60:30 kg NPK ha^{-1}). Data presented in Table 4 indicated that plant population, plant height and biomass accumulation were observed to be non-significant, however number of pods plant^{-1} and seeds pod^{-1} were significantly influenced by different treatments. The seed yield varied in the range of 335 to 391 kg ha^{-1} and were significantly higher as compared to other treatments. The treatments T_{10} (pure crop) and T_6 (Ber (75% RDF) + VAM + Black gram - Barley) recorded highest seed yield of 391 and 376 kg ha^{-1} and was significantly higher w.r.t. other treatments. Similar trend was observed for corresponding straw yield. During *rabi* 2018 barley (var. BHS-400 C/S) was sown on December 07 & 08, 2018 at the seed rate of 100 kg ha^{-1} on residual fertility under rain-fed condition and the production is awaited.

Table 4: Yield and yield contributing characters of black gram during *kharif*, 2018

Treatment	Plant population (m^{-2})	Plant height (cm)	Biomass (DW g m^{-2})	Seeds pod^{-1}	Pods plant^{-1}	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_2	21.4	38.7	128.3	4.65	9.03	343	755
T_4	22.2	36.9	130.4	4.72	8.48	335	735
T_6	20.9	37.5	126.5	4.87	10.07	376	825
T_8	21.5	39.2	128.7	4.68	8.72	342	751
T_9	23.3	42.1	130.8	4.69	8.76	341	759
T_{10}	18.2	38.5	136.2	4.92	10.43	391	851
CV (%)	18.07	17.92	18.74	17.56	18.15	17.85	18.54
CD (0.05)	NS	NS	NS	0.09	1.6	27.5	62

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

Ber + Barley

Ber + Black gram

NRMACAFRISIL201600100099

Performance of Pomegranate integrated with Lemongrass under organic Regime

(Sudhir Kumar, Rajendra Prasad and Veeresh Kumar)

An experiment was laid out during July 2016 after the approval of IRC 2016 in an established pomegranate orchard planted at 5x3m spacing during February 2013. The experiment was designed in CRBD with two cultivars of pomegranate (V_1- Ganesh & V_2- Bhagwa), four levels of fertilizer (T_1- Vermi-compost 30Kg/pl, T_2- FYM 30Kg/pl, T_3- T_1 + T_2/pl and T_4- recommended doses of chemical fertilizers/pl) along with control (T_5) of pure lemongrass. The experiment was replicated thrice and each treatment is having four plants of each cultivars. During July-August 2016, Krishna variety of lemongrass, procured from CIMAP Lucknow, was planted in between the pomegranate plants at the spacing of 50x40cm in a plot size of 60sqm with the area covered in plant basins. During July-August 2018, due to increase in tussock size, lemongrass spacing converted to 100x80cm by removing one tussock from between the two tussocks. Since, every plant basin is covering 1.0sqm area and not planted lemongrass in such area therefore the net plot size is 56sqm.

The observations recorded on growth & fruit yield of pomegranate and oil yield of lemongrass on fresh weight basis are presented in Table 5. The data revealed that mean height ranged from 1.93 m (T_3V_2) to 2.76 m (T_4V_1), collar diameter from 5.48 cm (T_2V_2) to 7.77 cm (T_1V_1), East-West spread from 1.03 m (T_2V_2) to 1.54 m (T_4V_1) and North-South spread ranged from 1.02 m (T_2V_2) to 1.56 m (T_4V_1). However, fruit yield ranged from 4.33 (T_1V_2) to 6.34 (T_2V_1). Reduction in plant height and canopy spread over previous year is due to pruning in the month of May-June 2018. In general, cv Ganesh is having vigorous growth in comparison to cv Bhagwa and also yielding higher than the cv Bhagwa except treatment T_4V_2 where cv. Bhagwa yielded more. The cumulative fresh yield from two cuts (May & October) of lemongrass, yielded 8.16 (T_2V_2) to 15.39 (T_5) t/ha green leaves and 64.69 to 173.48 kg oil/ha on fresh weight basis in treatment T_3V_2 and T_5, respectively.

Table 5: Effect of treatments on growth & yield of Pomegranate and fresh leaves & oil yield of Lemongrass (Lg) on green basis during 2018

Treat	Ht (m)	CD (cm)	EW (m)	NS (m)	Ft. yield (kg/pl)	Lg Fresh (t/ha)	Oil on green basis kg/ha
T_1V_1	2.45	7.77	1.39	1.41	5.30	12.26	63.92
T_1V_2	2.20	6.14	1.26	1.24	4.33	8.30	46.07
T_2V_1	2.75	7.72	1.42	1.43	6.34	8.84	50.21
T_2V_2	1.94	5.48	1.03	1.02	4.67	8.16	50.09
T_3V_1	2.33	6.65	1.30	1.35	5.52	8.74	45.72

T_3V_2	1.93	5.84	1.14	1.19	5.04	12.66	64.69
T_4V_1	2.76	7.30	1.54	1.56	4.74	-	-
T_4V_2	2.07	6.24	1.27	1.26	5.49	-	-
T_5 (Lg pure)	-	-	-	-	-	15.39	173.48

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

NRMACAFRISIL201600200100

Structural and functional analysis of short rotation tree based Agroforestry system

(Naresh Kumar, A K Handa, Asha Ram, Inder Dev, Dhiraj Kumar, Kamini (ICAR-IGFRI, Jhansi) and Mahendra Singh)

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

The growth data of tree species was recorded and through destructive method the carbon stock in different parts of *Anthocephalus cadamba, Melia dubia* and *Leuucaena leucocephala* was calculated during 2018. During the blackgram *(kharif)* and wheat *(rabi)* crops were grown as intercrop and tree-crop interactions were studied.

Height and collar diameter of tree species

Height and dbh data presented in Table 6 showed that at 4 x 5m spacing, the average height and dbh of *Anthocephalus cadamba, Melia dubia* and *Leuucaena leucocephala* were 3.96 m and 57.64 mm, 7.81 m and 110.27 mm, and 5.23 m and 53.15 mm, respectively when intercrop was taken under these species. Whereas, when these tree species were grown as pure plantations, their height and dbh were 3.17 m and 43.94 mm (cadamba), 7.37 m and 121.26 mm (melia) and 5.66 m and 66.56 mm (leucaena) (Table 6).

Table 6: Average height and dbh of Cadamba, Melia and Leucaena at 4 x 5 m spacing

Tree species	Height (m)	DBH (mm)	Height (m)	Collar dia.(mm)
	With crop (AF)		Pure plantation	
Cadamba	3.96	57.64	3.17	43.94
Melia	7.81	110.27	7.37	121.26
Leucaena	5.23	53.15	5.66	66.56

When intercrop was taken under *Cadamba, Melia* and *Leuucaena* planted at 8 x 2.5m spacing, their average height and dbh were 3.1 m and 40.81 mm, 6.01 m and 83.40 mm and 6.12 m and 89.93 mm, respectively. However, when these tree species were grown as pure plantation the respective values of height and dbh were 3.97 m and 56.71 mm, 6.12 m and 89.93 mm and 4.44 m and 45.59 mm (Table 7). Due to heavy rains and water logging conditions for longer duration, some mortality was occurred and gap filling was carried out.

Table 7: Average height and dbh of Cadamba, Melia and Leucaena at 8 x 2.5 m spacing

Tree species	Height (m)	DBH (mm)	Height (m)	Collar dia.(mm)
	With crop (AF)		Pure plantation	
Cadamba	3.10	40.81	3.97	56.71
Melia	6.01	83.40	6.12	89.93
Leucaena	6.12	89.93	4.44	45.59

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

The growth data of tree species were taken before uprooting trees. Excavation was done by manual digging and up-rooting and by using high pressure water to detach soil from roots. Prior to excavation the area around the tree was watered thoroughly to soften the ground and make it possible to excavate without damaging the tree roots and also to extract entire root system.

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

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

Data presented in Table 8 showed that in *A. cadamba,* dry biomass and carbon stock were found to be 13.64 and 6.82 kg/plant. Among different parts of the tree, stem contributed maximum to biomass (6.03 kg/tree) and carbon stock (44.13%). Above ground plant parts contributed 76.39% share in total carbon stock whereas below ground parts resulted 23.61% share (Table 9). In *Melia dubia,* dry biomass and carbon stock were found to be 84 and 42 kg/plant, respectively. Carbon stock in leaves, stem, branches and primary root were found to be 5.40, 23.46, 8.28 and 1.89 kg/plant, respectively. The secondary, tertiary, quaternary and fibrous roots collectively contributed 2.97 kg carbon stock per tree which is 7.07% of total carbon stock. The maximum carbon stock share i.e. 55.86% was found in the stem (Table 10). Above ground plant parts contributed 88.43% share in total carbon stock whereas below ground parts formed 11.57% share (Table 11). In *L. leucocephala,* dry biomass, carbon stock was found to be 25.39 and 12.69 kg/plant. The maximum carbon stock (7 kg/plant) and % share of total carbon stock (55.16%) was found in stem (Table 12). Above ground plant parts contributed 88.66% share in total carbon stock whereas below ground parts formed 11.34%

Table 8:Biomass and carbon stock in *Anthocephaus cadamba*

S.N.	Part	Dry biomass kg/ plant	Carbon stock kg/ plant	% share of total carbon stock
1.	Leaves	2.14	1.07	15.69
2.	Stem	6.03	3.01	44.13
3.	Branches	2.26	1.13	16.57
4.	Primary root	1.41	0.71	10.41
5.	Secondary, Tertiary, Quaternary and Fibrous roots	1.80	0.90	13.20
	Total	**13.64**	**6.82**	**100**

Table 9: Share of above ground and below ground parts in carbon stock in *Anthocephaus cadamba*

S.N.	Part	Dry biomass kg/ plant	Carbon stock kg/ plant	% share of total carbon stock
1.	Above ground	10.43	5.21	76.39
2.	Below Ground	3.21	1.61	23.61
	Total	**13.63**	**6.82**	**100**

Table 10: Biomass and carbon stock in *Melia dubia*

S.N.	Part	Dry biomass kg/ plant	Carbon stock kg/ plant	% share of total carbon stock
1.	Leaves	10.80	5.40	12.86
2.	Stem	46.93	23.46	55.86
3.	Branches	16.56	8.28	19.71
4.	Primary root	3.78	1.89	4.50
5.	Secondary, Tertiary, Quaternary and Fibrous roots	5.94	2.97	7.07
	Total	**84.00**	**42.00**	**100**

Table 11: Share of above ground and below ground parts in carbon stock in *M. dubia*

S.N.	Part	Dry biomass kg/ plant	Carbon stock kg/ plant	% share of total carbon stock
1.	Above ground	74.29	37.14	88.43
2.	Below Ground	9.72	4.86	11.57
	Total	**84.00**	**42.00**	**100.00**

Table 12: Biomass and carbon stock in *L. leucocephala*

S.N.	Part	Dry biomass kg/ plant	Carbon stock kg/ plant	% share of total carbon stock
1.	Leaves	3.70	1.85	14.58
2.	Stem	14.01	7.00	55.16
3.	Branches	4.81	2.40	18.91
4.	Primary root	1.55	0.78	6.15
5.	Secondary, Tertiary, Quaternary and Fibrous roots	1.32	0.66	5.20
	Total	**25.39**	**12.69**	**100**

Table 13: Share of above ground and below ground parts in carbon stock in *L. leucocephala*

S.N.	Part	Dry biomass kg/ plant	Carbon stock kg/ plant	% share of total carbon stock
1.	Above ground	22.52	11.26	88.66
2.	Below Ground	2.87	1.44	11.34
	Total	**25.39**	**12.69**	**100**

Tree-crop interactions

It was observed that the yield of wheat as well as blackgram crop was minimum at 1 m distance (i.e. nearest to the tree row) from the plants of all the tree species. Further, it was also observed that yield level increased with the increase in distance from tree row (Fig. 1 & 2; Table 14 & 15).

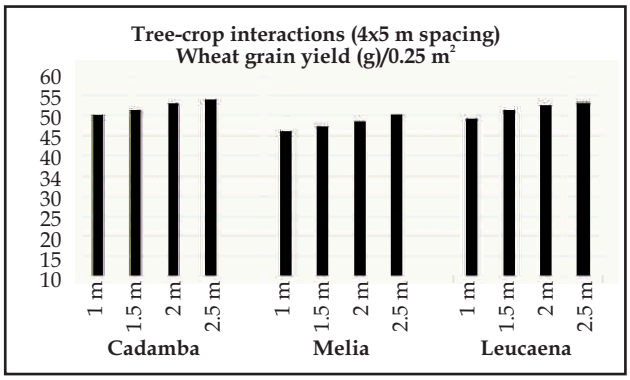

Fig.1: Yield of wheat crop at different distance from the tree species planted at 4 x 5 m spacing

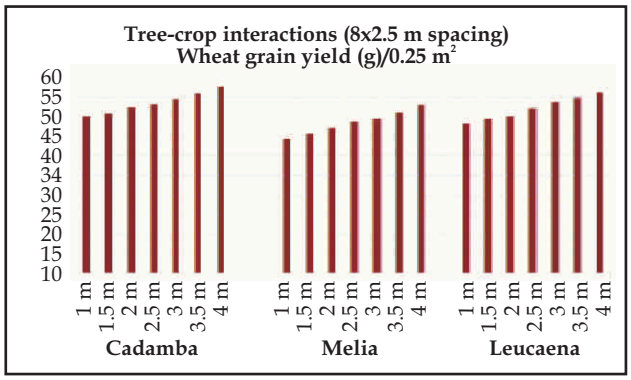

Fig.2: Yield of wheat crop at different distance from the tree species planted at 8 x 2.5 m spacing

Table 14: Yield of blackgram crop at different distance from the tree species planted at 4 x 5 m spacing

Distance from tree row	Yield per plant (g)		
	A. cadamba	*M. dubia*	*L. leucocephala*
1 m	3.20	3.15	3.30
1.5 m	3.25	3.17	3.36
2.0 m	3.33	3.24	3.41
2.5 m	3.40	3.25	3.46
Average	3.29	3.20	3.38
Control		3.75	

Table 15:. Yield of blackgram crop at different distance from the tree species planted at 8 x 2.5 m spacing

Distance from tree row	Yield per plant (g)		
	A. cadamba	*M. dubia*	*L. leucocephala*
1 m	3.21	3.10	3.31
1.5 m	3.26	3.19	3.35
2.0 m	3.35	3.25	3.39
2.5 m	3.38	3.30	3.45
3.0 m	3.45	3.35	3.49
3.5 m	3.48	3.38	3.51
4.0 m	3.52	3.46	3.60
Average	3.38	3.29	3.44
Control		3.75	

NRMACAFRISIL201600300101

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

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

Soil biodiversity play an important role in decomposition of organic materials, nutrient release and maintains physico-chemical properties of the soil. Agroforestry systems have the potential to maintain higher levels of biodiversity and greater biomass than lower diversity crop. The study was conducted at Central Agroforestry Research Institute, Jhansi during 2016-19 in Ber, Aonla, Bamboo and

Shisham based Agro-Forestry Systems (AFS) and mono-cropping systems. The sampling period was divided into pre-monsoon, monsoon and post-monsoon. The diversity of soil fauna was estimated and correlated with soil organic matter (SOM) (%), soil organic carbon (SOC) (%), dehydrogenase enzyme activity and Glomulin content (µg/gram of soil).

During pre-monsoon season, bacteria stains and *Pseudomonas* (cfu) were abundant in Shisham AF ($4.1 X10^6$ per g of soil and $51.0 X 10^4$ per gram of soil, respectively), while fungal stains and Actinomycetes were abundant in Bamboo AF ($8.0 X10^4$ per gram of soil and $10.0 X10^6$ per gram of soil, respectively). Meso, macro and mega fauna was comparatively high in Aonla and Shisham AFS, respectively. Per cent of SOC (0.86) and SOM (1.63) and dehydrogenase enzyme activity (1.01) was highest in Aonla AFS, whereas glomulin content was more in Ber AFS (546.5 µg/gram of soil) (Table 16).

Table 16: Soil fauna activity during pre-monsoon season

Pre-monsoon	Aonla AF	Ber AF	Shisham AF	Bamboo AF	Agriculture
Bacteria strains ($X10^6$ per g of soil)	3.7	2.8	4.1	3.1	2.7
Fungi strains ($X10^4$ per gram of soil)	4.1	6.8	6.2	8.0	3.0
Actinomycetes (cfu) ($X10^6$ per gram of soil)	8.5	7.7	6.4	10	7.2
Pseudomonas(cfu) ($X 10^4$ per gram of soil)	38.5	46.6	51	43.3	28.5
Acari	11.33	6.66	9.66	3.33	0.66
Collembola	2.33	3.33	3.33	2.33	0.66
Isopods	6.66	2.33	3.33	4.66	0.66
Centipeds	0.00	0.00	0.00	0.00	0.00
Millipedes	0.00	0.00	0.00	0.00	0.00
Earthworms	0.00	0.00	0.00	0.00	0.00
Spider	0.00	0.33	1.33	1.33	0.00
Ants	8.66	5.33	13.66	3.33	2.33
Coleoptera	3.66	2.00	1.66	1.33	1.66
Diptera	1.32	2.33	0.66	0.33	0.33
others	2.33	1.33	2.00	1.33	0.33
SOC (%)	0.86	0.64	0.77	0.61	0.31
SOM (%)	1.63	1.48	1.32	1.10	1.04
Dehydrogenase activity	1.01	0.80	0.75	1.0	0.85
Glomalin (µg/gram of soil)	386.50	546.5	375.8	269.81	305.5

In monsoon season, Shisham AFS was rich in bacterial strains ($7.5 X10^6$ per g of soil), meso, macro and mega fauna, whereas Ber AFS was abundant with fungal stains and actinomycetes ($10.6 X10^4$ per gram of soil and $14.7 X10^6$ per gram of soil, respectively), SOC (1.49 %) and SOM (2.57 %), dehydrogenase enzyme activity (2.6) and glomulin content (812.88 µg/gram of soil). *Pseudomonas* (cfu) was abundant in Bamboo AFS Table 17.

Table 17: Soil fauna activity during monsoon season

Monsoon	Aonla AF	Ber AF	Shisham AF	Bamboo AF	Mung	Blackgram
Bacteria strains (X10^6 per g of soil)	5.5	4.5	7.5	3.5	3	4
Fungi strains (X10^4 per gram of soil)	8.9	10.6	9.1	8.9	5.5	5.6
Actinomycetes (cfu) (X10^6 per gram of soil)	13.5	14.7	12.8	12.4	10.8	12.3
Pseudomonas(cfu) (X 10^4 per gram of soil)	65.9	76.8	68	83.4	43.2	48.9
Acari	15.33	9.00	17.66	4.66	2.33	3
Collembola	9.66	7.66	11.33	4.66	1.33	3.33
Isopods	1.33	0.66	1.00	2.33	0.00	0.66
Centipeds	1.33	0.00	1.66	1.33	0.33	0
Millipedes	1.66	0.66	1.33	0.66	0.00	0.33
Earthworms	1.33	1.66	3.33	1.33	0.66	1
Spider	2.66	0.66	2.00	2.33	1.33	0.00
Ants	4.66	9.00	15.33	2.33	4.66	2.33
Coleoptera	2.66	1.66	2.66	1.66	3.33	4.00
Diptera	3.00	2.66	1.66	2.00	1.33	2.33
Others	1.33	3.33	3.66	2.66	1.00	0.66
SOC (%)	0.95	1.49	1.37	0.95	0.98	0.59
SOM (%)	2.37	2.57	1.68	1.63	1.05	1.02
Dehydrogenase activity	1.88	2.6	1.22	1.00	1.05	1.07
Glomalin (µg/gram of soil)	481.81	812.88	572.34	304.22	215.96	162.89

During post-monsoon season, fungal stains, actinomycetes and *Pseudomonas* (8.0 X10^4 per gram of soil and 6.8 X10^6 per gram of soil, and 65.0 X 10^4 per gram of soil, respectively) were abundant in Bamboo AFS, whereas bacterial strains (5.1 X10^6 per g of soil), meso, macro and mega fauna was highest in Shisham AFS. SOC (1.46%) and SOM (2.52%), dehydrogenase enzyme activity (3.57) and glomulin content (908.22 µg/gram of soil) were highest in Ber AFS (Table 18).

Table 18: Soil fauna activity during post-monsoon season

Post-monsoon	Aonla AF	Ber AF	Shisham AF	Bamboo AF	Mustard	Barely	Mustard +barley
Bacteria strains (X10^6 per g of soil)	4.7	3.8	5.1	3.1	4.7	5.6	5.0
Fungi strains (X10^4 per gram of soil)	4.1	6.8	6.2	8.0	3.0	4.5	4
Actinomycetes (cfu) (X10^6 per gram of soil)	6.4	5.7	4.4	6.8	5.2	6.5	5.5
Pseudomonas(cfu) (X 10^4 per gram of soil)	58.5	65.6	58	65	38.5	67.5	56.5
Acari	19.33	11.33	26.66	8.00	3.66	4.33	4.66
Collembola	12.66	9.00	17.33	6.99	2.66	3.66	3.66
Isopods	7.66	2.66	2.33	3.33	0.33	1	0.66
Centipeds	0.00	0.00	0.00	0.00	0.00	0	0.33
Millipedes	0.00	0.00	0.00	0.00	0.00	0	0
Earthworms	0.00	0.00	1.00	0.00	0.00	0	0
Spider	1.66	1.33	2.66	2.66	0.66	1.33	0.66
Ants	10.33	7.00	9.66	5.00	6.33	2.33	4.33

Coleoptera	1.66	1.66	1.66	1.66	1.66	2.66	2.33
Diptera	1.66	5.66	3.66	1.33	0.33	0.66	1.33
others	2.00	2.00	2.00	1.33	0.33	2.33	2
SOC (%)	1.02	1.46	0.90	0.52	0.40	0.40	0.62
SOM (%)	1.76	2.52	1.55	0.89	0.68	0.69	1.07
Dehydrogenase activity	2.19	3.57	2.90	1.95	1.64	1.08	1.01
Glomalin (µg/gram of soil)	571.81	908.22	642.34	354.22	232.89	315.96	205.89

Overall, bacterial strains, meso, macro and mega fauna were abundant in shisham AFS throughout the year. During pre and post-monsoon, fungal stains and actinomycetes were abundant in Bamboo AFS, while in the monsoon it was highest in Ber AFS. SOC and SOM, dehydrogenase enzyme activity and glomulin content were highest also in Ber AFS except in the pre-monsoon season. AFS supported one or the other soil fauna activity compared to agriculture system.

CHAPTER

2 RESEARCH ACHIEVEMENTS

2.2: Natural Resource & Environment Management Programme

NRMACAFRISIL201100200088

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

(R H Rizvi and A K Handa)

Biomass Models for *Leuceana leucocephala*

Fifteen Subabul trees were harvested and data on diameter at breast height (DBH), stem, branch and leaf biomass was recorded for these trees. DBH of these trees ranged from 2.87 to 7.64 cm, stem weight from 1.10 to 14.90 kg/tree, branch weight from 0.10 to 3.30 kg/tree. This data was used for developing biomass models for stem and branch on the basis of DBH.

Non-linear models of the form $B = a.D^b$ and $B = a + b_1D + b_2D^2$ were fitted, where B- biomass (kg/tree) and D- diam. at breast height (cm). In case of stem biomass, model $B = 0.172\ D^{2.2045}$ ($R^2 = 0.929$) and in case of branch biomass, model $B = -2.6473 + 0.9658\ D - 0.0298\ D^2$ ($R^2 = 0.798$) were found good fit. These fitted models may be used for estimating stem and branch biomass of *L. leucocephala* but needs to be validated. Carbon stock was also estimated, which come out to be 1.72 kg/tree in stem biomass and 0.39 kg/tree in branch biomass in *L. leucocephala* trees.

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Agroforestry based conservation agriculture for sustainable land use and improved productivity

(Inder Dev, Asha Ram, Ramesh Singh, Dhiraj Kumar, , K B Sridhar, Naresh Kumar, Veeresh Kumar, Mahendra Singh and Lal Chand)

The project on the "Agroforestry based conservation agriculture for sustainable landuse and improved productivity" was initiated during July, 2014 with 03 experiments viz., Bael based Agroforestry system; Teak based Agroforestry system and Bael + Teak based Agroforestry system with 04 main plot treatments *i.e.,* min. tillage-blackgram-mustard (CS-1); min. tillage-greengram barley (CS-2); CT-blackgram-mustard (CS-1) and CT-greengram-barley (CS-2) and 03 subplot treatments (with crop residue; without crop residue and with leucaena residue) are being conducted in split plot design.

Experimental results

During *rabi* 2017-18, mustard (RH 749) and barley (BHS-400); and in *Kharif,* 2018 greengram (IPM 2-3) and blackgram (IPU 2-43) were sown as per the treatment details in all the three experiments, and the results of which are presented here as under:

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

In bael based CA system, during *rabi,* 2017-18, the seed yield of mustard varied significantly among tillage treatments (Fig. 3). The seed yield varied from 806.3 kg / ha under minimum tillage (MT) to 815.4 kg / ha under conventional tillage system (CT). The highest seed yield (836.0 kg/ha) was recorded in crop residue treatment followed by leucaena added treatment (820.5 kg/ha). However, seed yield in crop residue and leucaena added treatment remained statistically at par and significantly higher over the no residue treatment.

The grain yields of barley ranged from 1393.5 kg/ha (minimum tillage) to 1406.6 kg/ha (conventional tillage) though observed non-significant (Fig. 4). The addition of crop residue increased the seed yield of barley by 6.81% over no residue treatment and in leucaena residue treatment the increase was 4.60%.

In *kharif* season of the year 2018, the seed yield of blackgram was recorded 342.0 kg /ha in CT plot which was slightly higher than MT plot (335.0 kg /ha) though difference was non-significant (Fig. 5). The residue addition brought significant changes in seed yield of blackgram, it increased from 347.5 kg /ha (control) to 360.0 kg /ha (crop residue addition). The difference between yields of crop residue added plot and leucaena residue added plot were found statistically at par.

Similarly, no significant differences were observed in seed yields of greengram in both the tillage treatments. The seed yield of greengram ranged from 379.3 kg / ha in MT plot to 387.5 kg / ha in CT plot (Fig. 6). Addition of crop residue recorded with highest seed yield (402.8 kg / ha) followed by leucaena residue addition (388.5 kg /ha) and least yield was recorded in control (359.0 kg / ha).

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

In teak based conservation agriculture system, during *rabi*2017-18, the seed yield of mustard varied from 720.5 kg / ha in MT plot to 726.9 kg / ha in CT plot (Fig. 3). The residue addition has significantly increased the seed yield of mustard. The seed yield recorded 7.15 % increase with crop residue addition and 5.26 % increase with leucaena residue addition over control. However, both the residue added treatments remained statistically at par with each other.

The grain yield of barley was not influenced by tillage treatments in teak based conservation agriculture system. The grain yield ranged from 1242.7 kg / ha in MT to 1257.6 kg / ha in CT main plot treatment (Fig. 4). In sub plot treatments, crop residue (1280.7 kg / ha) and leucaena residue addition (1268.2 kg / ha) have increased the grain yield of barley substantially over control (1201.5 kg / ha).

Data presented in Fig. 5 showed that tillage treatment did not bring significant change in seed yield of blackgram. It varied from 312.6 kg /ha in MT to 315.8 kg / ha in CT plots. Among residue addition, the seed yield was recorded as 294.0 kg /ha (in control) to 318.1 kg /ha (in leucaena residue addition) and 330.1 kg /ha (crop residue addition). Between the tillage treatments, seed yield of greengram varied from 365.0 kg /ha (MT main plot) to 375.0 kg /ha (in CT plots) though were non-significant (Fig. 6). Addition of crop residue increased the seed yield (383.5 kg /ha) significantly over control (350.5 kg /ha) however remained at par with leucaena residue plot (376.0 kg /ha).

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

During *rabi* 2017-18, no significant effect of tillage treatments was observed on seed yield of mustard. However, the yield was recorded slightly higher (787.8 kg /ha) in CT plots than MT plot (778.9 kg / ha) (Fig. 3). The residue addition has significantly increased the seed yield of mustard over control. Residue addition showed an increase of 7.70% of seed yield (in crop residue addition) 6.12 % (in leucaena residue addition) sub-plots over control, respectively.

The grain yield of barley ranged from 1316.8 kg / ha in CT to 1327.3 kg / ha in MT plots (Fig. 4). The residue addition led to substantial increase in yield of barley and it increased from 1285.6 kg / ha (in control) to 1332.5 kg / ha (leucaena residue added plot) and to 1348.0 kg / ha (crop residue added plot).

The seed yield of blackgram was observed statistically at par in both the tillage treatments. It ranged from 277.3 kg /ha in MT to 282.7 kg /ha in CT (Fig. 5). The residue addition had influenced seed yield of blackgram significantly. The highest seed yield was recorded in crop residue added plot (298.5 kg /ha) followed by leucaena residue added plot (286.0 kg /ha) and minimum in control (255.5 kg /ha). However, both the residue treatments remained statistically at par.

The performance trend of greengram under varying tillage and residue incorporation were found as observed in blackgram. It varied from 390.0 kg / ha in MT to 396.0 kg / ha in CT though were non-significant (Fig. 6). Among the residue treatments, the seed yield of greengram increased upto 12.0% (in crop residue addition) and 8.84% (in leucaena residue addition) over no residue addition.

Growth parameters of bael and teak in different CA based AFS

The statistical analysis of growth parameters (DBH and Height) of bael and teak recorded no significant differences between and among the systems for DBH and height of both the tree species. In bael maximum height and DBH was recorded 2.54 m & 47.69 mm, respectively and the corresponding values for teak were 4.18 m and 57.16 mm (Table 19).

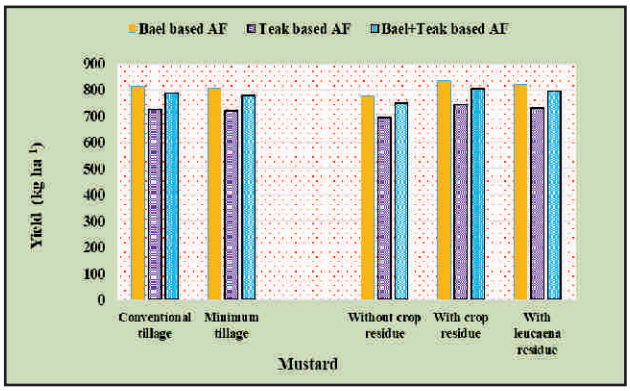

Fig. 3. Seed yield of mustard as influenced by tillage practices under bael, teak and bael+teak based agroforestry system

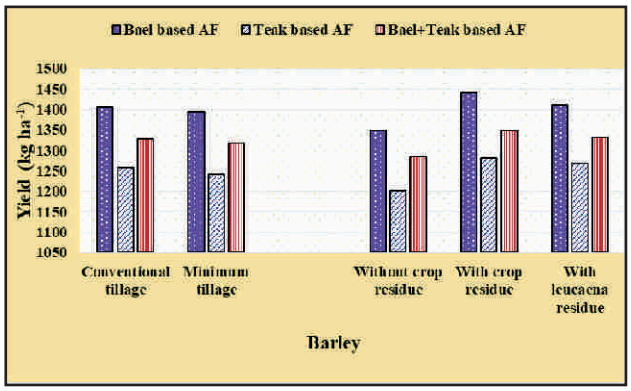

Fig. 4: Grain yield of barley as influenced by tillage practices under bael, teak and bael+teak based agroforestry system

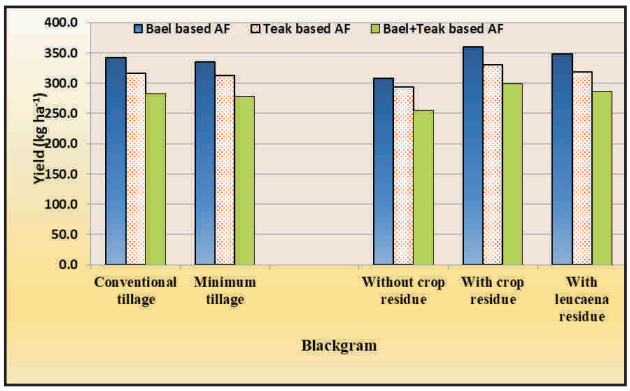

Fig. 5: Seed yield of blackgram as influenced by tillage practices under bael, teak and bael+teak based agroforestry system

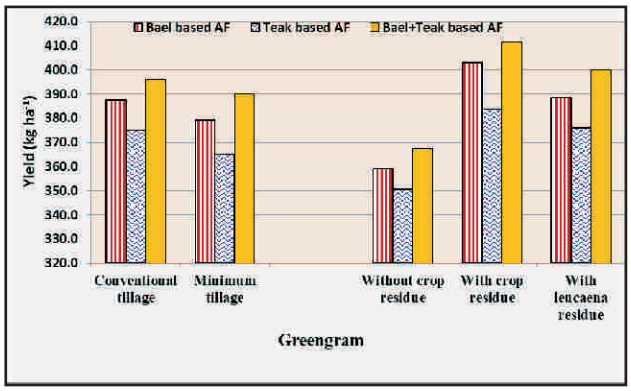

Fig. 6: Seed yield of greengram as influenced by tillage practices under bael, teak and bael+teak based agroforestry system

Table 19: Growth parameters of bael and teak in different agroforestry based CA systems

Treatment	Bael		Teak	
	DBH (mm)	Height (m)	DBH (mm)	Height (m)
Main				
CT-Blackgram-Mustard	45.41	2.17	51.53	4.02
CT-Greengram-Barley	41.88	2.12	53.28	4.00
MT- Blackgram-Mustard	42.25	2.54	52.55	3.96
MT- Greengram-Barley	47.69	2.43	57.16	4.18
SEm±	1.48	0.10	1.40	0.09
LSD (P= 0.05)	NS	NS	NS	NS

Sub				
Without crop residue	44.46	2.31	53.32	3.98
With crop residue	42.62	2.20	56.23	4.08
With Leucaena residue	45.85	2.44	51.35	4.06
SEm±	1.51	0.10	1.74	0.11
LSD (P= 0.05)	NS	NS	NS	NS
Main x Sub				
SEm±	3.02	0.20	3.47	0.21
LSD (P= 0.05)	NS	NS	NS	NS

Efficacy of different insecticides against Teak Skeletonizer, *Eutectonama chaeralis* Walker

The teak suffers more from insectpest and disease.More than 187 insect species have been found feeding on the living teak tree in India.Among the various insect-pest infesting teak plants, the most important are teak defoliator, *Hyblaeapuera* Cramer and teak skeletonizer, *Eutectonamaturalis* Walker.

The study was conducted at ICAR-Central Agroforestry Research Institute, Jhansi in teak based agroforestry systemto assess the efficacy of different insecticides against teak skeletonizer. Efficacy of four insecticides were evaluated viz.,T_1-Lambda Cyhalothrin(1ml/lt), T_2-Profenophos (2ml/lt),T_3-Emamectin benzoate(0.6gm/lt), T4-DDVP (2ml/lt)andT_5-Control.Observations wererecorded both before spraying and after spraying (two, five and ten days).

The studies on efficacy of insecticides revealed that the pre-treatment populationof the teak skeletonizer ranged from 30 to 46. The lowest population was recorded in T_1-Lambda Cyhalothrin at two, and seven Days After Spray (DAS) was 13.33 and 7.55, respectively followed by T_3-Emamectin benzoate at two (16.98), and seven (9.15) DAS. The highest teak skeletonizer population was observed in control.

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Agroforestry based Integrated Farming System for small and marginal farmers in semi-arid region

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

Agroforestry based Integrated Farming System (AF-IFS) was initiated during November 2016. The enterprises proposed for AF-IFS model and land allotted for each enterprises is given in Table 20. Survival in guava is about 99% and collar diameter ranges from 1.0 to 5.0 cm. Most of the Guava plant started bearing fruits after a year of planting and during this year fruit yield varied from 1.0 to 8.0 kg per plant with 5 to 20 fruits per plant. There were 45 papaya plant (var. Pusa dwarf) under fruiting and they yielded about 10 to 15 kg fruit per plant. Most of the plants were died due to heavy rain during 2018. Gap filling of papaya plants was done after making raised bed with var. Arka Surya and Arka Prabhat in month of September, 2018.

Survival in mango is reduced after a year of plantation and efforts are being made to refill the gap through *in-situ* grafting. Survival in teak was also reduced because of heavy rain during 2018. Moringa planted on road side as well as on field boundary is under fruiting and it may give some additional income in very short period. During rabi, 2017, pea was grown in 0.9 ha area, in which the yield of green pod was very poor. Winter maize was also tried in 0.10 has area and performance of winter maize was excellent and it produced about 3500 green cobs, which was sold in Rs. 17500 @Rs.5/cob. Since cost of cultivation for green pea was more that's why the net income was less than the input cost. The benefit: cost ratio of winter crop was very poor (Table 21). During summer, bhindi, pumpkin and bottle gourd was grown as intercrop with maize in 0.25 ha and it gave Rs.9540 as net income with B:C ratio of 1.54 (Table 21). It indicates that growing

of vegetable is profitable but it needs lot of labour. Similarly in rainy season also, bhindi, pumpkin and bottle gourd intercropped with maize (sweet corn) and this system also yielded good amount of vegetable with net income of Rs.11200 (Table 21). During August 2018, 3000 fingerlings were introduced in pond but all were lost due to overflow of pond after very heavy rain. In end of rainy season, the pond was auctioned Rs.12000 for fish farming. The goat keeping and poultry could not initiated due to paucity of funds in third phase.

Bhindi, pumpkin and bottle gourd intercropped with maize

Table 20: Agroforestry based IFS model for 1.83 ha land

Enterprise	Area (ha)
1. Agroforestry	1.15
i Fruit based	0.65
ii Vegetable based	0.52
iii Crop based	0.25
2. Poultry 0.03	
3. Fishery 0.22	
4. Goat keeping	0.075
5 Composting	0.01
Total	**1.83**

Moringa on field boundary

Table 21: Crop production and economic analysis of agroforestry based IFS model for the year 2017-18

Season	Area (ha)	Crop	Production (kg)	Cost of cultivation (₹)	Gross income (₹)	Net income (₹)	B:C ratio
Winter	0.9	Pea (green pod)	177	21000	30639	9639	0.45
(*Rabi*)		Grain	198				
	0.1	Maize	3500 cobs				
		Maize (Grain)	47				
Summer	0.25	Bhindi + maize	316	6200	15340	9540	1.53
(*Zaid*)		Bottle gourd + maize	60				
		Pumpkin + maize	250				
		Maize	1500 cobs				

Rainy (*Kharif*)	0.25	Bhindi + maize	214	5000	16210	11210	2.24
		Bottle gourd + maize	30				
		Pumpkin + maize	20				
		Maize (sweet corn)	2500 cobs				
	0.22	Fish		4000	12000	12000	3.00
Total	1.72			36200	74189	41989	1.15

NRMACAFRISIL201600500103

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

(Ramesh Singh and Dhiraj Kumar)

Monitoring of runoff and soil loss was done at five locations in Garhkundar-Dabar watershed (treated), however, untreated watershed was gauged for the same at the outlet. Datalogger based automatic stage level recorders were installed at six sites, including control watershed during 2018. Besides this, manual and self-recording rain gauges were also installed in the watershed to measure the rainfall. Total 1090.5 mm rainfall, 24.3% excess than normal, was received and it was spread over in 44 rainy days.

It was observed that the runoff from the treated watershed was 17.2% of total recorded rainfall during the year which is 41.7% lower than untreated watershed. Soil loss from treated and untreated was also recorded and it was 71% lower in case of treated over untreated watershed.

All open shallow dug wells in treated (116 nos.) and untreated (42 nos.) watershed were monitored monthly for water level. During the month of October average water column was 5.3 m which is 29.6% higher than the average water column of open wells situated in untreated watershed.

NRMACAFRISIL201600700104

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

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

The project on "Relevance of soil and water conservation measures in enhancing productivity and sustainability of silvipastoral system in semi-arid conditions " was initiated in *Kharif* season of 2016 with seven treatments comprising of T1- Sole Pasture; T2-Sole Teak (*Tectona grandis*); T3-Sole Mahagoni (*Swietenia mahagoni*); T4-Teak+Mahogoni+Pasture; T5-Teak +Mahogoni+ Pasture+ Half-Moon Basin (HMB); T6 Teak + Mahagoni + Pasture + Vegetative Hedge (VH); T7-Teak + Mahagoni + Pasture + Contour Staggered Trenches (CST). The experiment was laid out in Randomized Block Design and replicated thrice.

Experimental Results

The survival of the teak and mahagoni after two year of transplanting were observed to be 91 and 82%, respectively. After two year of planting, maximum height and collar diameter of teak and mahagoni were recorded in treatment having teak+ mahagoni+ pasture+ contour staggered trenches (Table 22). Second cut of pasture was taken in September, 2018. It was found that height of *C. ciliaris* and *S. seabrana* varied between 127 to 152 cm and 80 and 102 cm, respectively (Table 23). Similar trends were observed in other growth parameters of *C. ciliaris* and *S. seabrana*. Soil moisture dynamics in different treatments were studied at 15 days interval and it was found that highest soil moisture content was recorded in T7- Teak+Mahagoni+ Pasture + Contour Staggered Trenches (CST). After first rainy season, the contour staggered trenches (CST) and half-moon basin (HMB) trapped soil sediments at the rate of 38.30 t / ha and 7.644 t / ha, respectively. The corresponding values for second rainy season were 15.25 and 3.19 t / ha (Fig. 7).

Table 22: Height and collar diameter of Teak and Mahagoni at initial stage and after two year of planting

Treatment	Teak					Mahagoni			
	Height (cm)		Collar Diameter (mm)		DBH	Height (cm)		Collar Diameter (mm)	
	Initial	After Two Year	Initial	After Two Year	After Two Year	Initial	After Two Year	Initial	After Two Year
T1-Sole pasture	-	-	-		-	-		-	-
T2-Sole Teak	34.79	301.5	3.84	64.50	38.26	-		-	-
T3-Sole Mahagoni	-	-	-		-	31.88	158.0	6.87	38.26
T4- T+M +P	29.83	315.0	6.86	66.15	39.25	31.33	168.0	8.26	40.21
T5- T+M +P +VH	34.03	325.0	6.88	66.23	40.50	32.94	165.0	7.55	39.56
T6- T+M +P +HMB	30.22	330.0	5.88	68.23	42.50	25.44	175.5	5.79	42.50
T7- T+M +P +CST	28.24	352.0	6.88	71.21	44.24	32.11	184.6	7.80	44.67

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

Table 23: Growth parameters and biomass yield of *Cenchrus ciliaris*

Treatments	Height (cm)	No. of tiller/ tussock	Tussock Diameter (cm)	Grass yield (g) (Fresh weight/tussock)
T1-Sole pasture	137.8	121.3	38.2	1186.7
T2-Sole Teak	-	-	-	-
T3-Sole Mahagoni	-	-	-	-
T4- T+M +P	135.0	111.8	36.5	1154.4
T5- T+M +P +VH	134.5	112.5	38.1	1215.6
T6- T+M +P +HMB	137.8	126.4	38.8	1270.0
T7- T+M +P +CST	143.5	132.2	41.9	1376.7
SEm±	1.5	3.1	0.9	48.9
LSD (P=0.05)	4.9	10.2	2.9	159.3

Table 24: Growth parameters and biomass yield of *Stylasanthus seabrana*

Ttreatments	Height (cm)	No. of Primary branch/ plant	No. of Secondary branch /plant	Grass yield (g) (Fresh weight/ plant)
T1-Sole pasture	98.0	8.33	15.2	270.0
T2-Sole Teak	-	-	-	-
T3-Sole Mahagoni	-	-	-	-
T4- T+M +P	95.6	8.72	15.3	259.3
T5- T+M +P +VH	98.0	8.34	17.4	271.3
T6- T+M +P +HMB	94.8	8.28	15.2	281.7
T7- T+M +P +CST	99.1	9.70	18.2	301.7
SEm±	1.4	0.41	0.9	6.0
LSD (P=0.05)	NS	1.35	2.8	19.6

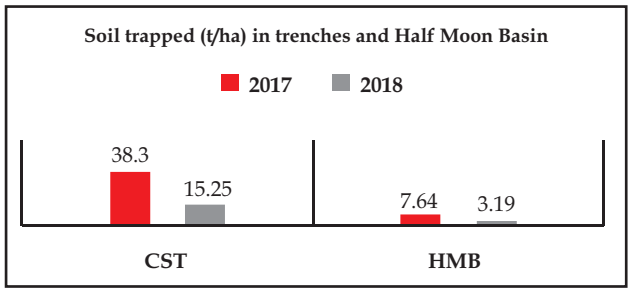


Fig. 7: Soil trapped in trenches and Half Moon Basin during 2017 and 2018

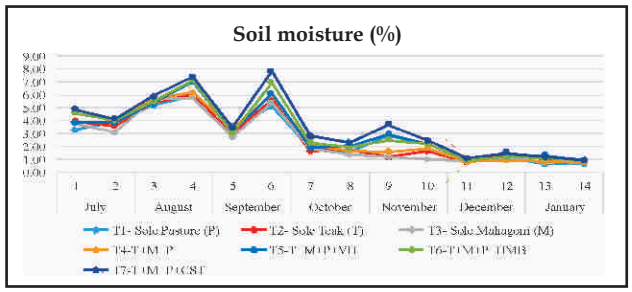


Fig. 8: Soil moisture dynamics in different treatments

Collection of runoff water

Removal of divers from guaging stations after rainy season

Soil moisture study

NRMACAFRISIL201600800105

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

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

The present study was initiated during 2016-17. The spacing in Aonla and *Hardwickia binata* was 10x10 m and 10x5 m, respectively. The Aonla were planted in the year 1996 and *Hardwickia binata* in the year 1991. The crop cycle in Aonla based AFS was greengram-mustard and in *Hardwickia binata*, blackgram-wheat. Horizontal stratified sampling was done from six distances 0.5m, 1.0m, 1.5m, 2.0m, 2.5m and 3.0 m. Similarly, in vertical stratified sampling, soil samples were collected from six depths i.e., 0-15cm, 15-30 cm, 30-45 cm, 45-60cm, 60-75 cm and 75-90 cm, respectively.

The grain yield of wheat (Fig. 9) in *Hardwickia binata* based AFS during *rabi* 2017-18 varied from 205.2 g/m^2 at 0.5 m horizontal distance from tree base to 236.8 g/m^2 at 3.0 m distance. Similarly, the seed yield of mustard in aonla based AFS varied from 84.87 g/m^2 at 0.5 m distance from tree base to 108.81 g/m^2 at 3.0 m distance from tree base.

Fig. 10, depicts the seed yield of greengram and blackgram during *kharif* 2018 in aonla and

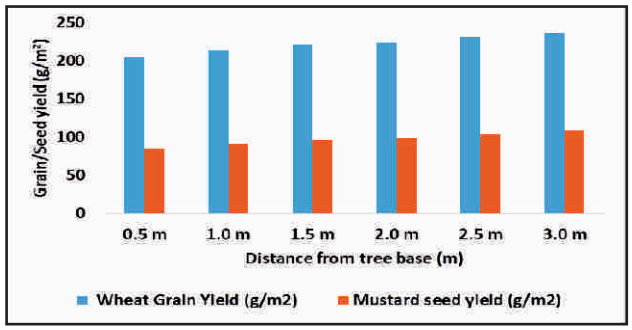


Fig. 9: The grain and seed yield of wheat and mustard (g/m^2) as influenced by horizontal distance in *Hardwickia binata* and aonla based agroforestry system

Hardwickia binata based AFS respectively. The data showed that seed yield of greengram ranged from 60.14 g/m^2 at 0.5 m distance from tree base to 79.64 g/m^2 at 3.0 m distance from tree base. On the other hand, seed yield of blackgram varied from 57.52 g/m^2 at 0.5 m distance to 74.55 g/m^2 at 3.0 m distance from tree base.

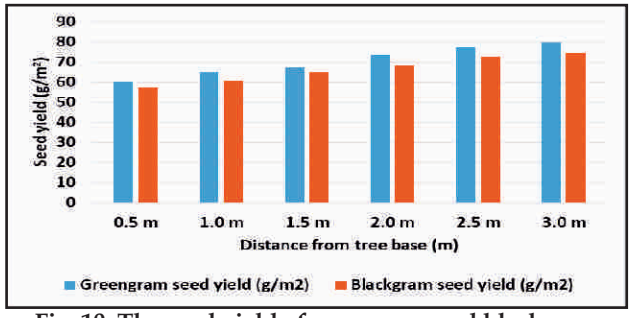


Fig. 10: The seed yield of greengram and blackgram (g/m^2) as influenced by horizontal distance in *Hardwickia binata* and aonla based agroforestry system

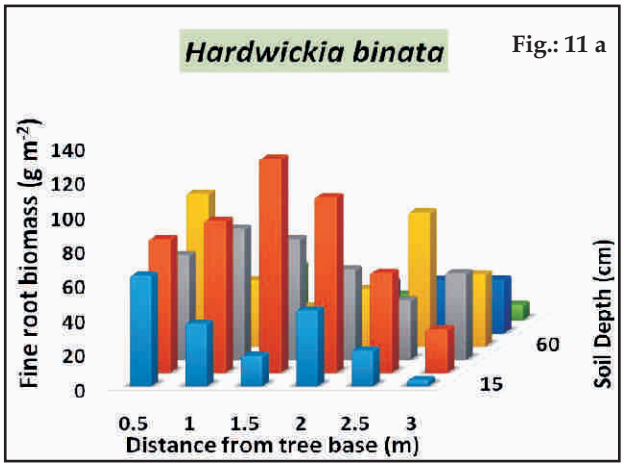
In *Hardwickia binata* based agroforestry system, 27 years old having a density of 200 trees/ha, it was found that during summer season the fine root length varies from 133.34 cm in 0-15 cm soil depth at a distance of 0.5 m from tree base to 14.20 cm in 75-90 cm soil depth at a distance of 3 m from tree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

While, during winter months, the fine root length varied from 234 cm at 0-15 cm soil depth at 0.5 m distance from tree base to 49 cm at 60-75 cm depth at 0.5 m distance from tree base. Similarly, it varied from 211 cm at 3 m distance from tree base in 15-30 cm depth to 80 cm at 30-45 cm depth. The FRLD varied from 0.245 cm/cm^3 at 0.5 m distance from tree base at 0-15 cm depth to 0.052 cm/cm^3 at 60-75 cm depth at 0.5 m distance. However, at 3m distance from tree base, it ranged from 0.22 cm/cm^3 at 15-30 cm depth to 0.084 cm/cm^3 at 30-45 cm depth.

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

During winter months, the root length varied from 160 cm in 15-30 cm depth at 0.5 m distance from tree base to 17.3 cm at 60-75 cm depth. Similarly, fine root length ranges from 106 cm at 15-30 cm depth at 3m distance from tree base to 13.6 cm at 30-45 cm depth. The fine root length density (FRLD) ranged from 0.168 cm/cm3 at 15-30 cm depth at 0.5 m distance from tree base to 0.018 cm at 60-75 cm depth. Similarly, FRLD varied from 0.111 cm/cm3 at 15-30 cm depth at 3m distance from tree base to 0.014 cm/cm^3 at 30-45 cm depth, respectively.

In *Hardwickia binata* based AFS (Fig. 11a), during summer season, the fine root biomass (FRB) varied from 21.5 g/m^2 in 75-90 cm soil depth to 89 g/m^2 in 45-60 cm at 0.5 m distance from tree base. Similarly, at 3m distance from tree base, it varied from 8.8 g/m^2 at 75-90 cm depth to 50.0 g/m^2 at 30-45 cm depth. In aonla based AFS (Fig. 11b), FRB varied from 1.57 g/m^2 at 75-90 cm depth to 15.4 g/m^2 at 30-45 cm depth at 0.5 m distance from tree base. Contrary to this, at 3m distance from tree base, FRB ranged from 0.3 g/m^2 at 15-30 cm depth to 5.6 g/m^2 at 30-45 cm depth.



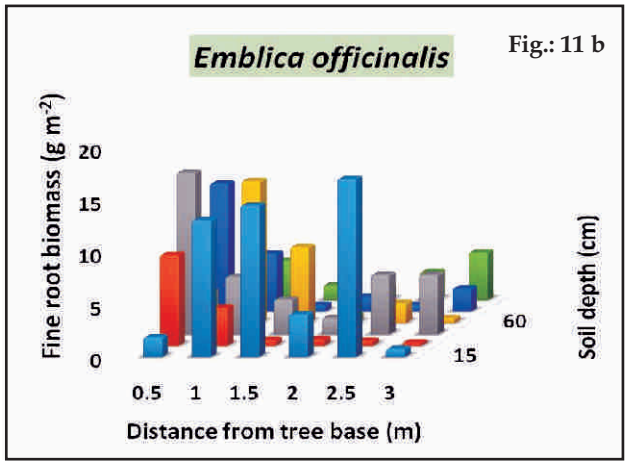
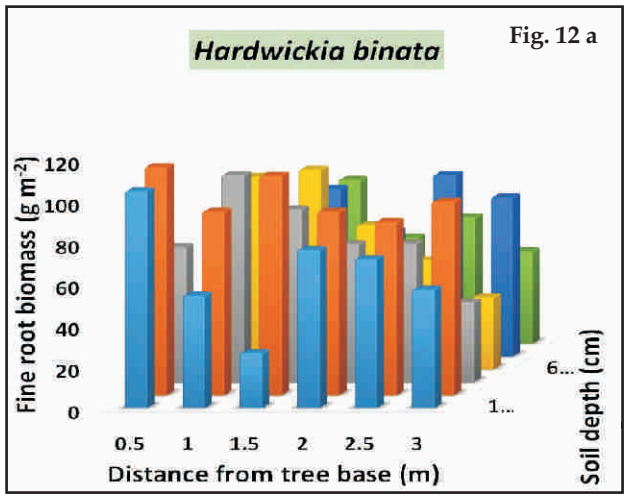


Fig. 11: Horizontal and vertical distribution of fine root biomass (g/m^2) of *Hardwickia binata* and *Emblica officinalis* based AFS [Summer]

During winter season, in *Hardwickia binata* based AFS (Fig. 12 a), at 0.5 m distance from tree base, FRB varied from 30.8 g/m^2 at 60-75 cm depth to 110 g/m^2 at 15-30 cm soil depth. At 3m distance from tree base, FRB ranged from 34.8 g/m^2 at 45-60 cm depth to 93.75 g/m^2 at 15-30 cm depth. However, in aonla based AFS (Figure 12 b), FRB showed 0.48 g/m^2 at 60-75 cm depth to 47.7 g/m^2 at 30-45 cm depth at a distance of 0.5 m from tree base. At 3m distance, it varied from 0.33 g/m^2 at 30-45 cm depth to 38.17 g/m^2 at 15-30 cm depth respectively. There are around 50-60% of the fine root biomass belongs to 0-45 cm soil depth in both the agroforestry system studied.



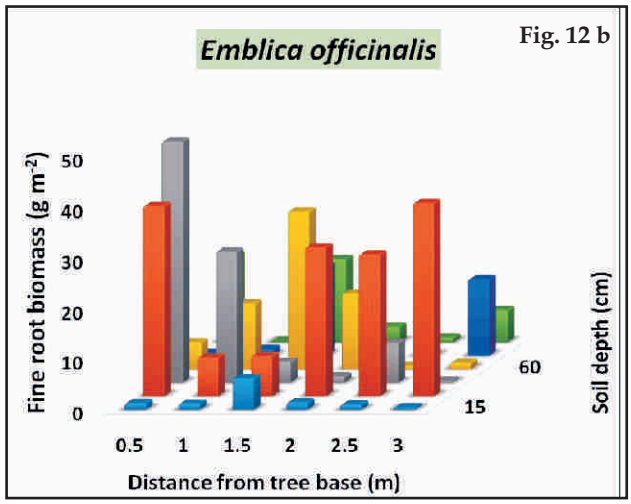


Fig. 12: Horizontal and vertical distribution of fine root biomass (g/m^2) of *Hardwickia binata* and *Emblica officinalis* based AFS [Winter]

CHAPTER

2 RESEARCH ACHIEVEMENTS

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

NRMACAFRISIL200700400071

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

(Badre Alam and A K Handa)

Intrinsic physiological efficiency to cope with dry hot summer climate was observed relatively better in clonal plants than in seedlings of *Pongamia pinnata* in field. Better physiological responses of clonal plants to deal with hot summer climate have been reflected in important physiological indicators namely in the rate of CO_2 assimilation (P_N max), thylakoid electron transport rate (ETR) and quantum yield of photosystem-2 (Figs. 13 & 14). The maintained flow of thylakoid electron transport in clonal plants during peak summer is corroborated with its relatively higher $P_N$max than seedlings.

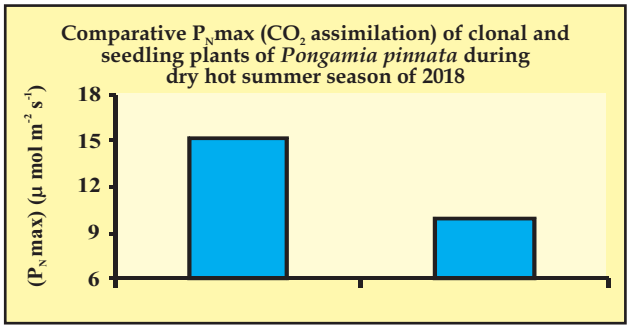


Fig.13: Maximum rate of CO_2 assimilation (P_N max) of clonal and seedling plants of *Pongamia pinnata* under dry hot summer season

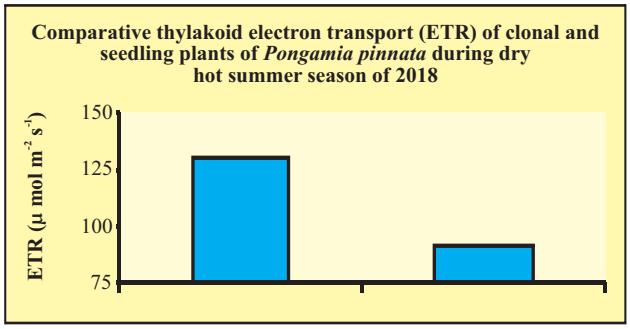


Fig. 14: Thylakoid electron transport rate (ETR) of clonal and seedling plants of *Pongamia pinnata* under dry hot summer season

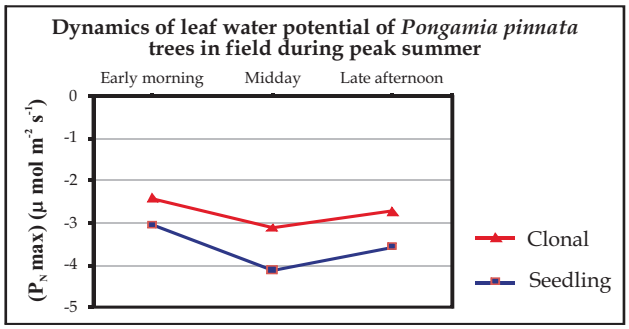


Fig. 15: Diurnal leaf water potential of clonal and seedling plants of *Pongamia pinnata* under dry hot summer season

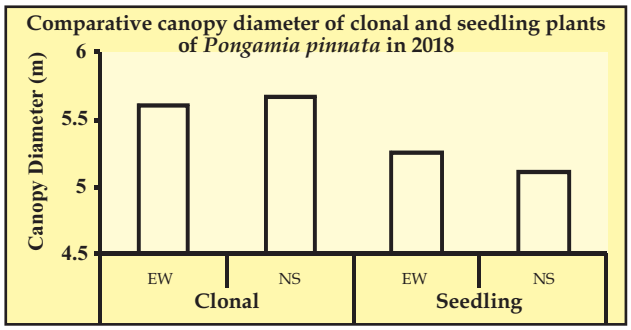


Fig. 16: Canopy diameter of clonal and seedling plants of *Pongamia pinnata* in east-west and north-south directions

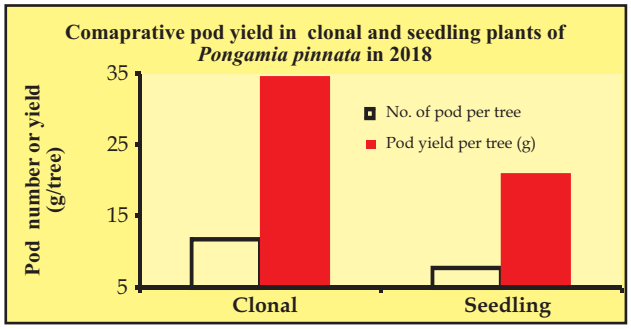


Fig. 17: Number of pods and pod weight per plant in clonal and seedling plants of *Pongamia pinnata*

NRMACAFRISIL201500100092

Evaluation and characterization of different Leucaena germplasm at ICAR-CAFRI

(K Rajarajan, A K Handa, A K Singh (IGFRI) & Maneet Rana (IGFRI))

Evaluation and characterization of leucaena germplasm was initiated in the year, 2015. The aim of the study is to estimate the genetic variability of different leucaena species and genotypes, identification of superior genotypes

for fodder values and fuel wood properties. Subabul accessions belonging to five different species *viz*., *Leucaena diversifolia, L. shannoni, L. lanceolata, L.collinsii*, *L. leucocephala* and a hybrid (*L. shannoni* X *L. leucocephala*) were planted at ICAR-CAFRI, experimental field during August, 2006. The seedlings were planted at spacing of 3m X 3m with three replication. During 2018-19 the fuel wood properties of different leucaena species were assessed. The traits *viz.* moisture content, bulk density, basic density, volatile matter, lignin content, fixed carbon, AB extractives, calorific value and ash content were studied.

The mean performance of ten leucaena en in genotypes for fuelwood properties are given in Table 25. Further, principle component analysis (PCA) was performed for fuel wood properties and results revealed that, traits like moisture content, bulk density, bulk specific density, volatile matter and calorific value are the major contributors for its variability. Hence, selection of genotypes based on these traits would be useful for improvement of fuel wood properties of *L. leucocephala*. The genotypes S-14 and S-24 were found to be most diversified for fuel wood properties and these genotypes would be used as potential donors for future hybridization programme.

Table 25: Mean performance of ten leucaena genotypes for fuel wood properties

Species/Genotypes	MC %	BD (kg/m^3)	BSD (kg/m^3)	VLM %	LC %	FC %	ABE %	CFV	ASH %
L. diversifolia 46/87	37.8	44.89	475.13	3.6	32.5	92.95	3.8	4328	3.45
L. diversifolia 49/37	32.9	41.45	374.71	3.7	35.2	92.74	4.2	4307	3.56
L. collinsii 58/88	34.7	43.29	531.31	3.2	37.8	89.46	6.1	4408	3.34
L. collinsii 15/83	36.6	45.17	476.88	3.6	32.5	95.26	5.8	4226	1.14
L. leucocephala S7	32.2	46.05	520.98	4.0	33.1	89.6	6.4	4397	6.4
L. leucocephala S23	37.6	45.73	616.96	3.6	36.2	92.4	3.6	4632	4.0
L. leucocephala S11	39.5	46.63	525.67	3.3	32.7	84.1	4.4	4589	1.26
L. leucocephala Conn	40.1	51.36	587.82	3.6	31.9	91.3	4.6	4492	5.1
L. leucocephala S14	31.2	46	431.81	1.9	36.6	96.84	5.1	4531	1.26
L. leucocephala S24	35.3	49.56	634.89	5.5	32.5	88.8	3.8	4658	3.38
Min	31.2	41.45	374.71	1.9	31.9	84.1	3.6	4226	1.14
Max	40.1	51.36	634.89	5.5	37.8	96.84	6.4	4658	6.4
Average	35.79	46.013	517.616	3.6	34.1	91.345	4.78	4456.8	3.289

MC- moisture content, BD- bulk density, BSD-basic density, VLM- volatile matter, LC- lignin content, FC- fixed carbon, ABE- AB derivatives, CFV- calorific value and ASH-ash content

NRMACAFRISIL201600900107

TBOs based agroforestry models

(K B Sridhar and Inder Dev)

To demonstrate and promote TBO based agroforestry model, an experiment was laid out at the experimental farm of ICAR-CAFRI, Jhansi. Trees selected for the study include *Pongamia pinnata, Simaruba glauca* and *Azadirachta indica*. Development of irregular flowers were observed in *Pongamia pinnata*.

The average height and collar diameter of seedlings was found highest in *Pongamia pinnata* (2.15 m and 47.68 mm) followed by *Azadirachta indica* (2.10 cm and 44.29 mm) (Table 26). The castor crop was completely damaged due to flash floods during September 2018. The castor crop was unable to tolerate water stagnation for 15 – 20 days.

Table 26:The growth performance of seedlings

Species	Avg height (m)	Avg collar diameter (mm)	Maximum height (m)	Maximum Collar diameter(mm)
Azadirachta indica	2.10	44.29	2.35	52.26
Pongamia pinnata	2.15	47.68	3.00	48.65
Simaruba glauca	1.08	29.87	1.10	31.65

NRMACAFRISIL20160010108

Mass propagation of Industrial trees Viz. *Eucalyptus tereticornis, Casuarina junghuniana, Melia dubia* and *Populus deltoides* using mini and micro clonal techniques

(K B Sridhar and Lal Chand)

Clonal Mother Garden (indoor and outdoor) of selected industrial trees has been established. Standardized mini cutting protocol of selected industrial trees *viz. Eucalyptus tereticornis, Casuarina junghuniana, Melia dubia* and *Populus deltoids* (Table 27). Mass production of clonal seedlings was carried out for distribution to farmers. These clones were cut back from the base to obtain new shoots. The obtained shoots were used to further multiplication of the clones. The clonal material of *Melia dubia* was exchanged with Forest Department, Rai Bareilly, Uttar Pradesh and is performing better. The *Casuarina junjuniana* seedlings were distributed for farmers for plating in their fields. The seedlings showed 80 percent survival.

Table 27: Details of clonal mother garden established outdoor collected from different places

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

NRMACAFRISIL201801100114

Functional genomics for early drought tolerance in *Pongamia pinnata* genotypes

(K Rajarajan, A Radhakrishnan, K B Sridhar and Lal Chand)

Functional genomics for early drought tolerance of *Pongamia pinnata* genotypes was initiated in the year 2018. The aim of the study is to assess an array of Pongamia genotypes for drought tolerance and understanding of biochemical, physiological and molecular responses of Pongamia genotypes for drought stress. This study comprised of twenty genotypes collected from different states and planted at CAFRI, experimental field. During the proposed year, nursery preparation was made and seedlings to be raised during March, 2019 as summer for initial screening of genotypes for drought tolerance through physiological and biochemical characterization.

Evaluation of Bael (*Aegle marmelos* (L.) Corr.) Varieties under Semi-Arid Conditions of Bundelkhand

(Lal Chand, Sudhir Kumar, Asha Ram and Anil Kumar)

A varietal evaluation block of Bael [*Aegle marmelos*

(L.) Correa] was established during July-August, 2018 at Central Research Farm of ICAR-CAFRI, Jhansi, with the objective to evaluate six bael varieties (CISH-B-1, CISH-B-2, NB-5, NB-9, Kagzi Etawah and Goma Yashi) under edaphoclimatic conditions of Bundelkhand and find out suitable variety for Bundelkhand region. The block was established in randomized block design with three replication and three plant per replication at a spacing of 6 m x 6m. The initial plant survival was recorded from 90 to 100 percent among different varieties.

CHAPTER

2 RESEARCH ACHIEVEMENTS

2.4. HRD, Technology Transfer & Refinement Programme

NRMACAFRISIL201500200093

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

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

The data were collected from targeted villages. In village Dabar, about 68% required fuelwood is collected from adjacent forest areas and 32% from own fields. The available tree species are Babul, Butea and Ber. The consumption of fuelwood is 7 Kg/day during rainy, 8 Kg/day during winter and 5 Kg/day during summer season. Cow and buffalo dung cakes are also used @ 6-8 Kg/day. There are about 15-20 LPG connections in village. Only 75% women do the collection of fuel wood.

In village Rautiana 97% of required fuel wood is collected from adjacent forest areas and 3% from own fields. The available tree species are Butea, Neem, Subabul and Dhaunkara. The consumption of fuel wood is 7 Kg/day during rainy 9 Kg/day during winter and 6 Kg/day during summer season. It is found that the collection of fuel wood is being performed mostly by women (90%). Cow and buffalo dung cake is another important fuel being used for cooking. The amount is 7 to 8 kg/day.

In village Kundar 85% of required fuel wood is collected from adjacent forest areas and 15% from own field. The available tree species are Butea, Neem, Subabul and Dhaunkara. The consumption of fuelwood is 6 Kg/day during rainy, 8 Kg/day during winter and 5 Kg/day during summer season. It is found that the collection of fuel wood is being performed mostly by women (80%). Cow and buffalo dung cake is another important fuel being used for cooking. The amount is 6 to 8 kg/days per requirement.

In village Sakuli, about 71% required fuel wood is collected from adjacent forest areas and 29% from own field. The available tree species are Butea, Neem, Kardhai, Babul, Chirol and Akola. The consumption of fuelwood is 7 Kg/day during rainy, 9 Kg/day during winter and 5 Kg/day during summer season. Cow & Buffalo dung is also used @ 6-7 Kg/day. There are about 30-35 LPG connections in Sakuli. Only 55% women do the collection of fuel wood.

About 93% required fuel wood is collected from adjacent forest areas and 7% from own fields in village Shivrampur. The available tree species are Butea, Kardhai and Besaram. The consumption of fuelwood is 9 Kg/day during rainy, 12-14 Kg/day during winter and 7 Kg/day during summer season. Cow and buffalo dung is also used @ 6-7 Kg/day. Average family size is 8 members in Shivrampur. Anna Pratha (stray animal) is major constraint in adoption of agroforestry.

NRMACAFRISIL201500300094

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

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

The primary data on height and diameter at breast height (DBH) for various age of poplar trees was collected from selected farmers' field in study area. Geographic information system (GIS) and remote sensing techniques were used for estimation of area under poplar based agroforestry system.

The biomass of poplar trees was estimated using allometric equation: $W=25.21-6.5D+0.7D^2-0.006D^3$, where; D is the diameter at breast height (dbh; cm); W is the dry stem wood biomass (kg) applied by Rizvi, et al., (2011). The total dry biomass was computed from dry stem wood biomass by assuming it to be 51% of the total biomass. The carbon storage in total biomass computed as: C=0.455*B; where, C is the carbon storage; and B is the dry biomass. The total ar

carbon assimilation by biomass of poplar trees as CO_2 was computed as: C*3.67; where C is the total carbon storage. Data from three to seven years old trees were estimated.

Value for carbon sequestered by Poplar in Yamunanagar district of Haryana

The value for carbon sequestered by poplar plantations in Yamunanagar district was estimated on the basis of area under agroforestry and different age of poplar plantations. This was taken as 5, 10, 20, 30 and 35 per cent for 3, 4, 5, 6 and 7 years old plantations, respectively on the basis of field survey conducted in the study area. The total carbon stock and CO_2 sequestered from poplar would be about 1.36 million t and 4.99 million t CO_2 e for total poplar plantation in Yamunanagar. The total value of ₹ 1663 million was estimated for carbon sequestered by poplar plantation in the district during 7 year of life cycle and Rs. 238 million in a year. It implies that the payment of ecosystem services (regulating) in terms of carbon sequestered by poplar plantation is substantial and encourage to farmers to adopt agroforestry in a big way (Table 28).

Table 28: Total estimated quantity and value of carbon stock and sequestration by poplar in Yamunanagar, Haryana

Age of poplar trees (year)	Share in area by age of poplar trees (%)	Estimated area by age of poplar trees (ha)	Total carbon stock (t/ha)	Total carbon (C) stock (t)	Total CO_2 sequestered (t CO_2 e)	Total value of CO_2 sequestered @Rs. 333/tCO_2 e
3	5	1205	33	0.04	0.15	48.60
4	10	2411	42	0.10	0.37	123.75
5	20	4822	52	0.25	0.92	306.44
6	30	7233	57	0.41	1.51	503.85
7	35	8438	66	0.56	2.04	680.60
Total	100	24109	250	1.36	4.99	1663.24

Source: Authors' estimate based on data from field survey

Consultancy Services

Establishment of Teak and Aonla Based agroforestry systems in Datia district of Madhya Pradesh.

Funding Agency: Bundelkhand Agro Pvt. Limited, Datia (Madhya Pradesh)

The field survey was conducted during August, 2018. The team surveyed the site demarcated for plantation. The agency is carrying out demarcation and fencing work. The soil samples were collected from different places and soil analysis is under process.

Kisan Gosthi, Farmers' Visits, Training and Exhibitions

The Institute organized a number of Farmers' activities for transfer of technologies related to agroforestry and increase the awareness for speedy adoption of agroforestry during 2018. These are as follow:

Farmers' Workshop

A Farmers' Workshop entitled "Bundelkhand Main Bans Ke Kheti Ke Sambhavna" was organized in collaboration with World Agroforestry Centre, South Asia Regional Office, New Delhi, ISAF, Jhansi and ICAR-CAFRI, Jhansi on 8th May, 2018. About 120 farmers from U.P. & M.P. participated in the workshop. Three progressive farmers were honoured for adopting Bamboo based Agroforestry system and setting example for other farmers in the Bundelkhand region.

Farmers' Training

ICAR-CAFRI, Jhansi organized thirty three batches of three days' training on **(a) Livelihood Security through Agroforestry and organic farming and (b) Natural Resource Management and development of watershed through agroforestry** for farmers and field functionaries of Bundelkhand region under ***Pradhan Mantri Krishi Sinchai Yojna***-Watershed Development, State Level Nodal Agency, Govt. of U.P., Lucknow. Approximately 1250 farmers and Regional Workers from Hamirpur, Jalaun, Lalitpur and Jhansi districts were trained during January to December, 2018. These farmers were exposed to different agroforestry intervention including field visits to on-farm agroforestry intervention in Parasai-Sindh watershed of Jhansi district.

Ber Pruning and Ber Budding Training

Institute organized three days' "ber pruning" training during 15th -17th May, 2018 at village-Hastinapur, Block-Babina, District-Jhansi (U.P.). In this training programme 20 farmers learned the skills of ber pruning.

Institute also organized three days' "ber budding" training during 23rd - 25th July, 2018 at village-Hastinapur, Block-Babina, Ganeshgarh, District-Jhansi (U.P.) and Village- Shivrampur, Dabar District-Tikamgarh (M.). In this training programme 86 farmers learned the skills of budding.

Vanmahotsava

Two Van mahotsava programme were organized *i.e.* on 06th July, 2018 village-Ishagarh, block-Babina, district-Jhansi and on 24th August,2018 in the Institute. In village-Ishagarh 26 farmers and in Institute all the staff members were participated in the programme.

Women Farmers' Day

Institute organized Women Farmers' Day on 15th October, 2018. During the function lectures were delivered by the Scientists of the Institute. About 35 women farmers from village Parbai, Karari and Rund Karari participated in the programme.

Kisan Diwas

Kisan Diwas was organized on 23rd December, 2018 in collaboration with ICAR-IISWC Regional Centre Datia at Village-Hastinapur, Block-

Baragaon, District-Jhansi (U.P.) on the occasion of Birth day of Former Prime Minister Late Sh. Chaudhary Charan Singh. The programme was attended by the farmers.

MERA GAON-MERA GARAUV (MGMG)

The plantation drive was carried out by Scientists of ICAR-CAFRI Jhansi in the selected MGMG villages. The scientists also interacted and created awareness about Agroforestry among the farmers. Interface meetings were organized with the farmers of MGMG villages during 2018. Total 7563 plants were distributed to the farmers till December, 2018. The list of clusters (5) and villages (16) are as below:

1. Hastinapur cluster (3 villages- Hastinapur, Karari, Rund Karari) U.P.
2. Domagor cluster (3 villages-Domagor, Dhikoli, Nayakhera) U.P.
3. Ganeshgarh cluster (3 villages- Ganeshgarh, Devgarh, Ramgarh) U.P.
4. Parasai cluster (3 villages- Parasai, Chhatpur, Bachhauni) U.P.
5. Garhkundar cluster (4 villages- Garhkundar, Dabar, Sakuli, Shivrampur) M.P.

Exhibitions

ICAR-Central Agroforestry Research Institute, Jhansi participated in following different exhibitions during the year-2018 and showcased the technology developed by the Institute through exhibitions:

Date	Programme	Places
27 February, 2018	Unnati Krishi Mela	IGFRI, Jhansi (U.P.)
16-18 March, 2018	Krishi Unnati Mela	IARI, New Delhi,
5-6 March, 2018	Rajya Stariya Kisan Mela	NDUAT, Kumarganj, Faizabad (U.P.)
8 May, 2018	Kisan Mela and Krishak Karyashala	ICAR-CAFRI, Jhansi (U.P.)
24 August, 2018	Van Mahotsav day	ICAR-CAFRI, Jhansi (U.P.)
10 October,2018	Mandliya Rabi Utpadakta Gosthi (Divisional Rabi Productivity Gosthi)	Bundelkhand University Auditorium, Jhansi (U.P.)
26-28 October, 2018	Krishi Kumbh (International Sammelan)	ICAR-IISR, Lucknow (U.P.)
01 November, 2018	Krishi Takniki Pradarshani evam Kisan Mela	ICAR-IGFRI, Jhansi (U.P.)
05 December,2018	Vishwa Mrada Diwas evam Krishak Karyashala (World Soil Day and Farmers' Workshop)	ICAR-CAFRI, Jhansi (U.P.)
23 December, 2018	Kisan Diwas on the occasion of Birth day of Former Prime Minister Late Sh Chaudhary Charan Singh. The programme was organized in collaboration with ICAR-IISWC Regional Centre Datia (M.P.).	ICAR-CAFRI, Jhansi at Village-Hastinapur Block-Baragaon, District-Jhansi (U.P.)

Visits

A number of students and Govt./NGOs officers from different parts of the country, Officials from Forest Department, FTI, Kanpur (U.P.) and State department official of different parts of the country and Bundelkhand region visited the Institute and demonstration sites. During the year a number of farmers from M.P., U.P. and Rajasthan visited the Institute as per the following details:

S. No.	Date	Districts	Number of Farmers
1	06.03.2018	Damoh (M.P.)	16
2	09.03.2018	Shahdol (M.P.)	18
3	25.08.2018	Chhatarpur (M.P.)	08
4	29.08.2018	Raisen (M.P.)	30
5	06.09.2018	ICRAF Odisha	06
6	19.09.2018	Jaipur (Rajasthan)	50
7	19.09.2018	Guna (M.P.)	17
8	27.09.2018	Tikamgarh (M.P.)	07
9	04.10.2018	Guna (M.P.)	32
10	19.12.2018	Damoh (M.P.)	21
11	21.12.2018	Kanpur Dehat (U.P.)	25
12	22.12.2018	Datia (M.P.)	45
Total			275

CHAPTER 2

RESEARCH ACHIEVEMENTS

2.5: Externally Funded Projects

Network Project

NRMACAFRISOP200800100075

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

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

ICAR-CAFRI Mandate:"*Development of agroforestry models including gum- and resin-yielding trees for livelihood security and horizontal dissemination of technologies*"

The main objective of the project is to develop agroforestry models including gum- and resin-yielding trees for livelihood security and horizontal dissemination of technologies. For conducting research at ICAR-CAFRI, Jhansi, the major themes are i) growth and productivity of gum-yielding tree-based agroforestry models, ii) demonstration and development of gum-yielding tree-based agroforestry models on farmers' fields, and iii) indigenous traditional knowledge (ITK) on gum and resin tapping, applications and post harvest value addition. During the year, recorded growth and productivity data from established gum-yielding tree-based agroforestry models, motivated farmers to plant agroforestry models on their farm, and surveyed tribal areas in Sakrar (district Jhansi) and Tikamgarh districts of Uttar Pradesh and Madhya Pradesh, respectively for ITK information on gum tapping and uses. Studies on root distribution pattern in three year old *Acacia senegal* plant was also conducted. Apart from this, Cation Exchange Capacity (CEC) in roots of understory crop *i.e.Triticum aestivum* and *Acacia senegal* was assessed in agri-horti-silviculture model established at research farm of the institute.

A. GROWTH AND PRODUCTIVITY OF AGROFORESTRY MODELS

A.1. Agroforestry models on-farm

Data on survival and tree growth in different agroforestry models established at central research farm of ICAR-CAFRI, Jhansi are presented in Table 29.

Table 29: Growth and survival of trees in agroforestry models at ICAR-CAFRI, Jhansi

Agroforestry models	GBH (cm)	Height (cm)	Canopy diameter (m^2)	Survival (%)	Pruned biomass (kg/tree)
Agri-horti-silviculture (field no. 25)					
Acacia senegal	39.6	570.0	17.8	92.6	4.1
Citrus limon	22.8	405.6	12.8	83.3	3.1
Aegle marmelos	36.1	541.2	15.3	82.1	3.5
Carissa carandas	2.5 (CD)	178.4	01.5	93.5	--
Horti-silviculture I (field no. 20)					
*Acacia nilotica***	22.8	374.7	07.3	57.1	--
Terminalia arjuna	29.5	503.0	08.7	100.0	3.2
Acacia senegal (at boundary)	36.4	569.4	13.3	90.0	6.8
Horti-silviculture II (field no. 20)					
Acacia nilotica	83.5	930.4	94.9	85.7	--
Terminalia arjuna	26.1	422.3	06.0	100.0	15.1
Acacia senegal (at boundary)	24.7	405.0	09.2	80.0	6.0

Block plantation					
Acacia senegal	22.3	466.5	11.1	100.0	--
Agri-silviculture (field no. 40 & 41) - 6 years old					
Acacia senegal					
10 m × 10 m	26.2	389.9	6.4	94.7	6.3
10 m × 5 m	20.7	313.9	5.1	85.7	4.9
5 m × 5 m	22.8	360.7	5.3	89.8	5.2
Acacia nilotica					
10 m × 10 m	30.6	444.9	5.4	76.2	5.7
10 m × 5 m	24.5	398.5	5.5	82.6	5.3
5 m × 5 m	27.4	435.6	6.2	91.5	5.4

** Plantation in July 2014*

In agri-horti-silviculture model (field no. 25), maximum GBH (cm), plant height (cm) and canopy diameter (m^2) were recorded in *A. senegal* (kumat), followed by *Aegle marmelos* (bael), *Citrus limon* (lemon) and *Carissa carandas* (karonda). Since, casualty replacement was done during 2017-18; hence, maximum survival (%) was recorded in *C. carandas*, followed by *A. senegal*, *C. limon* and *A. marmelos* (Table 29). In this model, fruit yields were recorded from 13 plants of *C. limon*, 19 plants of *A. marmelos* and 14 plants of *C. carandas* (Fig.18).

A total of 47.5 kg lemon, 10.5 kg karonda and 250 kg bael fruits were harvested. The average weight of bael variety CISH B1 was 0.77 kg and variety CISH B2 was 1.63 kg. During *rabi* season of 2017-18, mustard (variety RH 749) was cultivated and during *kharif* season of year 2018, moong (variety Sweta) was cultivated as intercrop. This year i.e. 2018-19 (*rabi* season), wheat (variety HD 2967) has been sown. During 2018-19, natural oozing of gum (average 34.14 g/tree) from *A. senegal* was recorded.

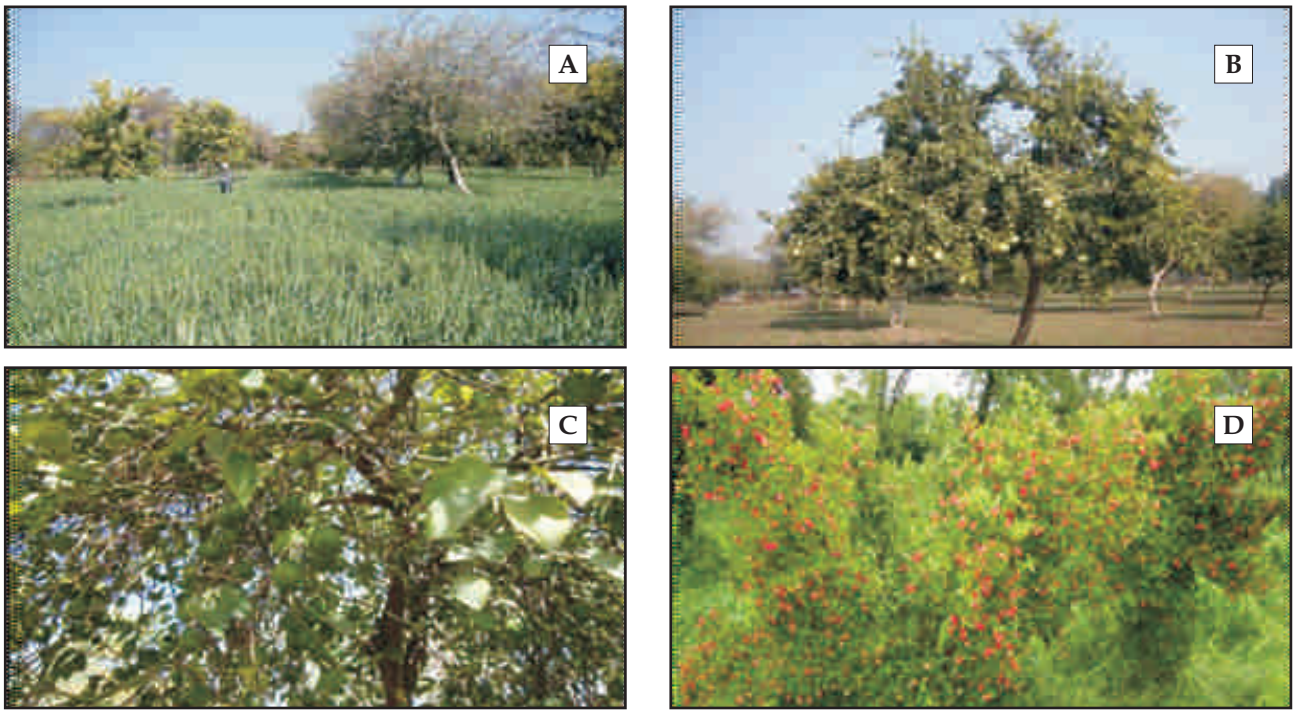


***Plate 1:Acacia senegal* based agri-horti-silvi model at research farm of CAFRI (A. Intercrop- wheat, B. *Aegle marmelos*, C. *Citrus limon*, and D. *Carissa carandas*)**

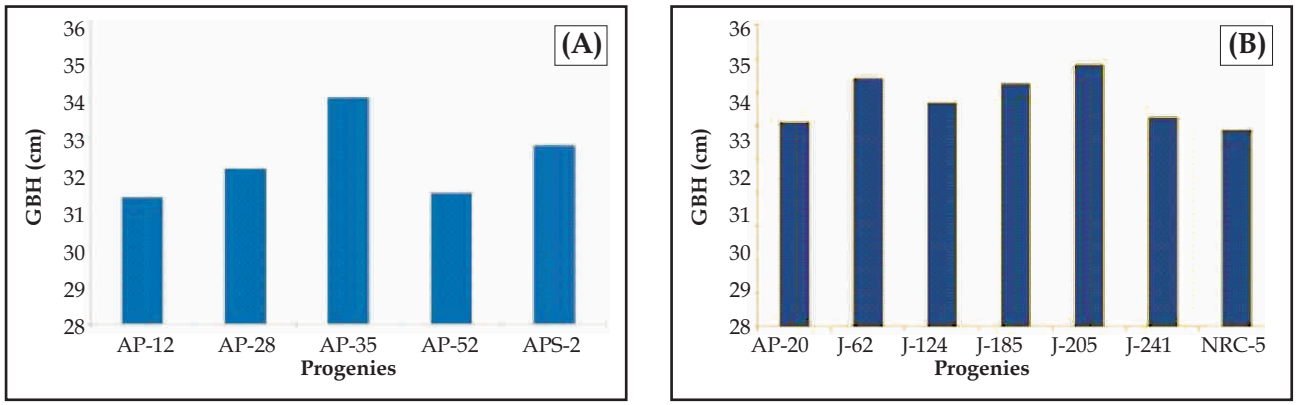


Fig. 18: GBH (cm) of different progenies of *Anogeissus pendula* after 24 years (A) and 23 years of plantation (B)

In horti-silviculture model I (field no. 20), *Terminalia arjuna* (arjun) showed maximum survival (100%), followed by *A. senegal* and *Acacia nilotica* (babool). Growth parameters i.e. GBH (cm), plant height (cm) and canopy spread (m^2) were maximum in *A. senegal*. In horti-silviculture model II (field number 20), *T. arjuna* showed maximum survival (100%), followed by *A. nilotica* (85.7%) and *A. senegal* (80%). Highest GBH (cm), plant height (cm) and canopy diameter (m^2) were recorded in *A. nilotica*. Survival of *A. senegal* in block plantation on rocky site was found to be 100% and plants attained mean height of 466.5 cm with GBH of 22.3 cm.

In agri-silviculture model (field no. 40 & 41) wherein *A. senegal* and *A. nilotica* were planted in three different spacings; maximum survival was recorded by *A. senegal* planted in 10 m × 10 m spacing and least in *A. nilotica* planted in 10 m × 10 m spacing. After six years of plantation, higher GBH (cm) and plant height (cm) were recorded in *A. nilotica* than *A. senegal* in all spacings.

During summer season (2018), natural exudation of gum in different fields of *A. senegal* were observed (Table 30). Gum yield ranged from 1.43 – 86.59 g/tree in field number 25 (average: 34.14 g from 18 trees), 3.67 – 355.51 g/tree in field number 40 & 41 (average: 37.63 g from 39 trees), 1.54 – 88.89 g/tree in old gum garden (average: 26.13 g from 48 trees), 1.74 – 76.68 g/tree in new gum garden (average: 16.52 g from 14 trees) and 13.60 – 30.76 g/tree (average: 22.18 g from 2 trees) in block plantation at rocky area. Maximum number of gum tears per tree (15) was recorded in field number 40 & 41 while minimum (1) in all the fields.

Table 30: Descriptive statistics of gum yield from *Acacia senegal* tree (natural exudation)

Particulars	Field no. 25			Field no. 40 & 41			Old gum garden			New gum garden			Block plantation		
	GBH (cm)	Total gum tears/ tree	Gum yield (g/tree)	GBH (cm)	Total gum tears/ tree	Gum yield (g/tree)	CD (cm)	Total gum tears/ tree	Gum yield (g/tree)	CD (cm)	Total gum tears/ tree	Gum yield (g/tree)	CD (cm)	Total gum tears/ tree	Gum yield (g/tree)
Count	7.00	18.00	7.00	39.00	112.00	39.00	48.00	119.00	48.00	14;00	22.00	14.00	2.00	7.00	2.00
Mean	35.14	2.57	34.14	18.54	2.87	37.63	53.64	2.48	26.13	46.67	1.57	16.52	16.00	3.50	22.18
Range	35.00	5.00	85.16	30.00	14.00	351.84	49.66	5.00	87.35	19.74	2.00	74.94	8.00	1.00	17.16
Minimum	22.00	1.00	1.43	2.00	1.00	3.67	24.49	1.00	1.54	32.59	1.00	1.74	12.00	3.00	13.60
Maximum	57.00	6.00	86.59	32.00	15.00	355.51	74.15	6.00	88.89	52.33	3.00	76.68	20.00	4.00	30.76
SD	5.57	0.81	13.34	1.38	0.39	10.23	1.89	0.21	3.56	2.18	0.20	5.61	4.00	0.50	8.58

Similarly, natural exudation of gum in different fields of *A. nilotica* was also observed (Table 31) and the gum yield ranged from 10.01 – 52.28 g/tree in field number 20 (average: 28.63 g from 4 trees) and 2.45 – 4.82 g/tree in field number 40 & 41 (average: 3.64 g from 2 trees).

Table 31: Descriptive statistics of gum yield from *Acacia nilotica* trees (natural exudation)

Particulars	Field no. 20			Field no. 40 & 41		
	GBH (cm)	Total gum tears/tree	Gum yield (g/tree)	GBH (cm)	Total gum tears/tree	Gum yield (g/tree)
Count	4.00	29.00	4.00	2.00	3.00	2.00
Mean	84.25	7.25	28.63	37.00	1.50	3.64
Range	61.00	12.00	42.27	2.00	1.00	2.37
Minimum	40.00	3.00	10.01	36.00	1.00	2.45
Maximum	101.00	15.00	52.28	38.00	2.00	4.82
SD	8.21	2.72	9.49	1.00	0.50	1.19

During *rabi* season of 2017-18, mustard (variety RH 749) was sown in agri-horti-silviculture model (field no. 25) and the recommended package of practices was followed. Plant growth and yield attributes of mustard were measured at three different distances *viz*., 1.0, 2.5 and 4.5 m from the stem base of *A. senegal*, *A. marmelos* and *C. limon*. Results revealed that tree species significantly affected the seed yield of mustard. Its maximum value was recorded under *C. limon*, followed by *A. marmelos* and *A. senegal* (Table 4). Irrespective of plant species, distance from the tree trunk significantly affected all studied parameters, except plant height. Maximum plant population, seed yield and above ground biomass were recorded at 4.5 m distance from the stem base and their minimum values were recorded at 1.0 m distance. The interaction between tree species and distances had no significant effect on studied growth parameters of mustard.

Table 32: Growth and yield attributes of mustard (variety RH 749) in agri-horti-silviculture model (2017-18)

Growth parameters	Distance (m)	Tree species			Mean
		A. senegal	*C. limon*	*A. marmelos*	
Plant population/m^2	1.0	9.50	10.00	9.00	9.50
	2.5	12.00	12.00	12.00	12.00
	4.5	14.00	14.50	15.00	14.50
	Mean	**11.80**	**12.20**	**12.00**	
Plant height (cm)	1.0	59.80	51.80	60.50	57.40
	2.5	57.70	61.40	60.10	59.70
	4.5	55.90	64.60	59.90	60.10
	Mean	**57.80**	**59.30**	**60.20**	
Grain yield (g/m^2)	1.0	36.58	84.34	72.75	64.56
	2.5	59.30	89.25	89.36	79.30
	4.5	66.92	105.94	114.57	95.81
	Mean	54.27	93.18	92.23	
Above ground biomass (g/m^2)	1.0	153.42	260.66	337.26	250.45
	2.5	203.09	300.75	395.64	299.83
	4.5	220.71	549.07	670.43	480.07
	Mean	**192.40**	**370.16**	**467.78**	
	$LSD_{0.05}$				

	Tree species	Distance	Interaction
Plant population	NS	1.9	NS
Plant height	NS	NS	NS
Seed yield	21.27	21.27	NS
Above ground biomass	NS	31.26	NS

During *kharif* season of 2018, moong (variety Sweta) was sown in agri-horti-silviculture model (field number 25) and the recommended package of practices was followed. Planted tree species did not affect plant population, plant height and seed yield. Maximum above ground biomass was recorded under *C. limon* which was statistically at par with *A. marmelos* (Table 33). On the other hand, distance from tree trunk significantly affected all the recorded parameters, except height of moong plants. Plant population, seed yield and above ground biomass were found to be increasing with increase in the distance from tree trunk *i.e.* their maximum values were recorded at 4.5 m distance and minimum at 1.0 m distance. The interaction effect of tree species and distances were not significant for all the recorded parameters, except plant population which was maximum at 4.5 m under *A. senegal*.

Table 33: Growth and yield attributes of moong (variety Sweta) in agri-horti-silviculture model (2018)

Growth parameters	Distance (m)	Tree species			Mean
		A. senegal	*C. limon*	*A. marmelos*	
Plant population/m^2	1.0	12.00	14.00	14.50	13.50
	2.5	16.50	16.50	18.00	17.00
	4.5	27.00	19.50	19.50	22.00
	Mean	**18.50**	**16.70**	**17.30**	
Plant height (cm)	1.0	50.60	49.60	45.00	48.40
	2.5	49.30	50.80	52.90	51.00
	4.5	51.90	52.00	52.50	52.10
	Mean	**50.60**	**50.80**	**50.10**	
Seed yield (g/m^2)	1.0	42.72	44.87	39.58	42.39
	2.5	46.68	49.43	50.80	48.97
	4.5	49.35	50.27	55.03	51.55
	Mean	**42.25**	**48.19**	**48.47**	
Above ground biomass (g/m^2)	1.0	131.56	175.91	163.34	156.94
	2.5	159.58	188.61	203.89	184.03
	4.5	194.41	220.95	214.19	209.85
	Mean	**161.85**	**195.16**	**193.80**	
	$LSD_{0.05}$				

	Tree species	Distance	Interaction
Plant population	NS	1.5	2.6
Plant height	NS	NS	NS
Seed yield	NS	3.52	NS
Above ground biomass	9.68	9.68	NS

Gum garden

Gum garden of *A. senegal* was developed in July, 2014 at central research farm of ICAR-CAFRI, Jhansi which was further extended during 2015. A total of 353 plants of *A. senegal* and *Butea monosperma* (palas) were planted at 3 m × 3 m spacing in the garden. The annual growth and survival data are given in Table 34. Survival percentage was higher in *A. senegal* than *B. monosperma* in both the fields. The planted saplings of *B. monosperma* showed very poor performance. *A. senegal*, planted in new gum garden i.e. during 2015, attained good girth and showing relatively higher survival (%) than the seedlings planted during 2014. Out of 190 plants of *A. senegal* in old gum garden (2014 plantation), 48 plants yielded *gum-arabic*. Similarly, out of 257 *A. senegal* planted in new gum garden (2015 plantation), on 14 plants natural exudation of *gum-arabic* was observed.

Table 34: Growth parameters of *Acacia senegal* and *Butea monosperma* in gum gardens

Tree species	GBH (cm)	Height (cm)	Canopy diameter (m^2)	Survival (%)	Pruned biomass (kg/tree)
Gum garden part-I (Planted in July, 2014)					
Acacia senegal	15.50	321.90	3.12	73.70	3.99
Butea monosperma	1.08 (CD)	42.50	--	20.00	--
Gum garden part-II (Planted in July, 2015)					
Acacia senegal	31.30	251.20	2.49	90.7	2.32
Butea monosperma	0.92 (CD)	50.7	--	52.1	--

Growth of *Anogeissus pendula*

The growth of existing plantations of *Anogeissus pendula* (progeny trial), which is now being used for standardizing gum tapping techniques, was monitored during 2018-19. The plantation (September, 1994) is consisting of tissue culture raised progenies of five plus trees of *A. pendula* (kardhai), planted in randomized block design with four replications. Each progeny had 25 plants in a plot. Net plot size was 15 m × 10 m with the spacing of 3 m × 2 m. Very slow growth was observed during 2018-19. On an average, the recorded GBH of AP-12, AP-52, AP S-2, AP-28 and AP-35 progenies were 31.38, 31.48, 32.76, 32.13 and 34.03 cm, respectively. The maximum GBH was recorded in AP-35 progeny and minimum in AP-12 (Fig. 18A).

Growth of trees was also recorded in experimental field wherein seven progenies of *A. pendula* (plus tree trial) raised through tissue culture were planted in August 1995 along with local check in randomized block design in four replications having plot size of 15 m × 10 m with a spacing of 3 m × 2 m. Plus trees were selected from plants of Haryana (Bandwari) and Rajasthan (Jodhpur and Udaipur) based on fast growth. Very slow growth in terms of GBH was reported during 2018-19. The GBH of AP-20, J-241, J-124, J-205, NRC-5, J-185 and J-62 progenies were 30.40, 31.14, 33.34, 39.07, 29.35, 36.19 and 36.92 cm, respectively (Fig. 18B). Maximum GBH was recorded in J-205 progeny and minimum in NRC-5.

Growth of another plantation consisting of *A. pendula* and *Anogeissus latifolia* (dhawra) was also monitored (field number 34 & 35). This plantation was established in 1990 which is now being used as agroforestry models for tapping gum and raising intercrops. The trees were planted at 5 m × 5 m spacing. The recorded growth increment was very negligible after 28 years. The better survival was recorded in *A. pendula* (87.5%) while, better GBH, canopy spread and height was recorded in *A. latifolia* (Table 35).

Table 35: Growth of *Anogeissus pendula* and *Anogeissus latifolia* after 28 years

Gum yielding tree species	GBH (cm)	Height (cm)	Canopy (m^2)	Survival (%)
Anogeissus pendula	42.0	737.7	23.6	87.5
Anogeissus latifolia	44.5	773.7	25.7	82.4

A2. Agroforestry models on farmers' fields

After nine years of planting, *A. senegal* recorded relatively more survival (57%) than *A. nilotica* (50%) at Garhkundar watershed area. At the farm of Shri Thakur Das, among planted species, maximum growth and survival was exhibited by *A. nilotica*, followed by *Psidium guajava* (guava) and *C. carandas*. In this field, many plants have been damaged by mechanized operations with tractor, as the farmer did not pay attention. On the farm of Shri Himmat, maximum growth was recorded in *Emblica officinalis* (aonla); however, survival percentage was recorded comparatively higher in *A. senegal*. At the farm of Shri Ghanshyam, *A. senegal* planted during 2012 showed poor performance in terms of growth; however, survival percentage was comparatively higher than the values recorded from other two fields. In general, at Garhkundar watershed area, *A. senegal* recorded relatively more survival (59.5%) than *A. nilotica* (50%). At village Ambabai, 37% survival of *A. senegal* with average height of 270.1 cm and average collar diameter of 7.6 cm was observed. Natural exudation of gum from *A. senegal* was observed during 2018 at farm of Shri Himmat (Table 36).

Table 36: Growth of trees in agroforestry models at garhkundar watershed (9 years old) and village Ambabai (6 years old)

Plant species	GBH (cm)	Height (cm)	Canopy (m^2)	Survival (%)
Shri Thakur Das				
Acacia nilotica	32.0	551.0	10.7	50.0
Psidium guajava	21.5	425.5	12.0	10.5
Carissa carandas	0.9 (CD)	137.0	0.6	12.5
Shri Himmat				
Acacia senegal	32.0	396.2	4.2	57.0
Emblica officinalis	53.4	514.3	22.5	54.0
Carrisa carandas	3.7 (CD)	143.0	0.3	1.8
Shri Ghanshyam				
Acacia senegal (boundary) (Planted in 2012)	2.3	152.0	--	59.5
Shri Mani Ram (Village Ambabai)				
Acacia senegal	7.6 (CD)	270.1	5.0	37.0

B. DEMONSTRATION AND DEVELOPMENT OF GUM YIELDING TREE-BASED AGROFORESTRY MODELS

B1. At institute research farm

During rainy season of 2018, four bio-fence models were developed at the institute research farm, wherein *A. senegal* along with *C. carandas* were planted in single and double rows. Bio-fence model-1 aimed to optimize distance apart trees consists of single row plantation of *A. senegal* + *C. carandas* alternated in three distances i.e. 1.0, 1.5 and 2.0 m apart on field boundaries. After six months of planting, survival of *A. senegal* and *C. carandas* was 67.4 and 87.0%, respectively (Table 37).

Bio-fence model-2 aimed to assess effectiveness of double row planting consists of *A. senegal* as outer row and *C. carandas* as inner row on field bunds. Distance between two rows was 1.0 m and within the row, plant to plant distance was 2.0 m. The planting of both species in two rows was done in staggered manner. After six months of planting, 32.1 and 64.2% survival of *A. senegal* and *C. carandas*, respectively were observed (Table 37).

Bio-fence model-3 aimed to assess the effectiveness of double row planting of *A. senegal* at different spacement. This model was planted on three sides of field boundary of a well-established *E. officinalis* orchard. Plant to plant distance was kept uniform at 1.5 m in both the tree rows, while the distance between two rows varied at all three sides of the field i.e. 1.0, 1.5 and 2.0 m. Planting was done in staggered manner in two rows. After six months of planting, 63.6, 84.1 and 72.0% survival in 1.0, 1.5 and 2.0 m distance, respectively were recorded in outer row. Similarly, 76.2, 65.9 and 80.0% survival in 1.0, 1.5 and 2.0 m distance, respectively were recorded in inner row (Table 37).

The bio-fence model-4 consists of two rows of *A. senegal* (inner and outer) kept at 1.5 m apart wherein plant to plant distance was also 1.5 m. This model was planted along two sides of a well-established *Punica granatum* (pomegranate) orchard. Planting was done in staggered manner in two rows. After six months of planting, 65.2 and 68.6% were recorded from inner and outer rows, respectively (Table 37).

Table 37: Plant growth and their survival in different bio-fence models at institute research farm (after six months of planting).

Bio-fence models	CD (mm)	Height (cm)	Canopy (m^2)	Survival (%)
Model-1 (Single row)				
Acacia senegal	6.72	44.3	0.04	67.4
Carissa carandas	3.52	14.7	0.01	87.0
Model-2 (Double row)				
Acacia senegal	4.23	36.0	0.01	32.1
Carissa carandas	4.79	15.3	0.01	64.2
Model-3 (Double row)				
Acacia senegal (outer row) 1.0 m	7.76	54.9	0.07	63.6
Acacia senegal (outer row) 1.5 m	7.13	46.1	0.05	84.1
Acacia senegal (outer row) 2.0 m	5.64	51.4	0.04	72.0
Acacia senegal (inner row) 1.0 m	9.39	67.7	0.13	76.2
Acacia senegal (inner row) 1.5 m	7.78	50.0	0.04	65.9
Acacia senegal (inner row) 2.0 m	5.72	50.6	0.04	80.0
Model-4 (Double row)				
Acacia senegal (outer row)	5.76	40.1	0.02	65.2
Acacia senegal (inner row)	6.78	45.2	0.05	68.6

B2. At farmer's fields

To motivate farmers and disseminate technology related to the development of gum-yielding tree-based agroforestry models on farmers' fields, regular field visits were conducted in villages to prepare socioeconomic profile of villagers and assess their preferences for species, type and pattern of planting etc. During rainy season of 2018, a total of 3925 seedlings, consisting of 3005 *A. senegal*, 570 *C. carandas*, 245 *C. limon*, 80 *Dendrocalamus strictus* (bamboo) and 25 *P. guajava* were distributed and planted at different locations (Table 38). 1000 seedlings of *A. senegal* were provided to army station at Talbehat (Uttar Pradesh). After six months of planting, the survival percentage of *A. senegal* varied from 49.7-80.0%, *C. carandas* from 60.0-75.0%, *C. limon* from 40.0-78.0%, *D. strictus* from 40.0-46.0% and *P. guajava* recorded 80.0% at different locations.

Table38: Distribution of gum-yielding and horticultural plants in different villages during 2018-19

Village	*A. senegal* (kumat)		*C. carandas* (karaunda)		*C. limon* (lemon)		*D. strictus* (bamboo)		*P. guajava* (guava)	
	No. of plants	Survival (%)	No. of plants	Survival (%)	No. of plants	Survival (%)	No. of plants	Survival (%)	No. of plants	Survival (%)
Indragarh (Datia)	300	80.0	-	-	-	-	-	-	-	-
Army station (Talbehat)	1000	**	-	-	-	-	-	-	-	-
Kotkhera	100	68.0	-	-	5	40.0	50	46.0	-	-
Gadhkundar	350	49.7	30	60.0	-	-	20	45.0	-	-
Binwara (GKD)	250	72.0	20	75.0	100	78.0	-	-	-	-
Dhikoli	30	66.7	10	70.0	10	50.0	10	40.0	-	-
Parasai	400	72.5	310	74.2	130	52.3	-	-	25	80.0
CAFRI campus	575	67.3	200	74.5	-		-		-	-
Total	3005		570		245		80		25	

** Not assessed

Survival of *A. senegal* and fruit plant species (*C. limon*, *P. guajava* and *P. granatum*), distributed and planted in the fields of 14 farmers of village Parasai during rainy season of 2017 was also recorded. After 1.5 years of planting, the survival of *A. senegal* ranged from 80-90%, 55.0-80.0% in *C. limon*, 60.0-80.0% in *P. guajava* and 59.1% in *P. granatum* (Table 39).

Table 39: Survival (%) of gum-yielding and horticultural plant species planted at Parasai during rainy season of 2017

Farmer's name	Plant species							
	A. senegal		*C. limon*		*P. guajava*		*P. granatum*	
	No. of plants	Survival (%)	No. of plants	Survival (%)	No. of plants	Survival (%)	No. of plants	Survival (%)
Shri Arjun Yadav	400	80.0	--	--	--	--	--	--
Shri Sukhnandan	350	82.9	5	80.0	5	60.0	--	--
Shri Rajveer Yadav	300	88.3	--	--	--	--	--	--
Shri Bisunnath	250	84.0	50	82.0	--	--	--	--
Shri Mahendra	150	90.0	--	--	--	--	--	--
Shri Komal Singh	250	84.0	50	84.0	55	80.0	22	59.1
Shri Bantoo	100	82.0	--	--	--	--	--	--
Shri Prema	100	81.0	--	--	5	60.0	--	--
Shri Jahar Singh	50	86.0	--	--	--	--	--	--

Shri Ashok	150	88.7	5	60.0	--	--	--	--
Shri Vinod	100	88.0	--	--	--	--	--	--
Shri Sushil	--	--	5	60.0	--	--	--	--
Shri Mathura Prasad	--	--	15	66.7	15	60.0	--	--
Shri Narendra Yadav	--	--	20	55.0	20	60.0	--	--

During rainy season of 2017-18, a bio-fence model consisting of single row of *A. senegal* (150 plants) and *C. carandas* (80 plants) was established at Shri Komal Singh Yadav's field (0.6 ha) in village Parasai. One *C. carandas* was planted in between two *A. senegal* plant at three sides of the field. Plant to plant distance was 1 m i.e. each *A. senegal* was planted 2 m apart, similarly one *C. carandas* was planted 2 m apart from another *carandas*. Inside the field, 10 *C. limon* were planted. After 1.5 years of plantation, 84.0% survival of *A. senegal* and 50.0-59.1% survival of horticulture plant species have been recorded.

C. ITK ON GUM AND RESIN'S TAPPING, APPLICATIONS AND POST HARVEST VALUE ADDITION

Surveys for collecting information on ITK of tapping gums and resins, post harvest value addition and their uses from tribal villages were continued during 2018-19. A village of Sakrar (district Jhansi), Uttar Pradesh and two villages of Tikamgarh, Madhya Pradesh dominantly inhabited by Saharia tribes were selected (Plate 2). For survey, close liaison was maintained with the officers of State Forest Department in Tikamgarh district. A purposely prepared questionnaire was used for collecting information from tribal peoples. The details of villages surveyed for ITK are given in Table 40. The main occupation of tribal people of Sakrar (district Jhansi) was agricultural wages, as most of the families were land-less labourers. In Tikamgarh district, the tribal families were also involved in cultivating agricultural crops on the land allotted to them on *patta* basis. Tribes of district Tikamgarh were also involved in collection of NTFPs. In both the districts, seasonal migration for earning livelihood was a common practice (Table 41). Major NTFPs collected by Saharia are listed in Table 42.

Plate 2: Interaction with Saharia tribes during survey for collecting ITK information on gums and resins in district Tikamgarh

Table 40: Tribal villages surveyed for ITK on gum tapping and uses

District	Forest range	Beat	Village	Number of tribal families	No. of respondents	GPS coordinate
Sakrar, Jhansi	Jhansi	-	Rautiyana	1000	35	25°20'30" NL 78°52'18" EL
Tikamgarh	Tikamgarh	Bilgaayn	Bilgaayn	65	25	24°52'26" NL 78°51'32" EL
		Paniyara Kheda (Vangraam)	Paniyara Khera	25	20	24°52'49" NL 78°54'28" EL

Table 41: Occupations of tribal peoples in surveyed districts

Districts	Main occupation	Secondary occupation
Sakrar, Jhansi	Marginal farmers and land-less agricultural labourers	Seasonal migration to Jhansi, Agra and Morena for potato and wheat harvesting, and Delhi as construction workers
Tikamgarh	Marginal farmers, cultivate crops on patta land	Livestock, seasonal migration to Jhansi, Delhi, Agra and Morena

Table 42: List of gum and other non timber forest produces (NTFPs) in surveyed districts

Districts	Trees tapped for gum	Other NTFPs
Sakrar, Jhansi	*Butea monosperma* (kamarkas)	*Cyperus scariosus* (naagarmotha)
Tikamgarh	*Boswellia serrata* (salai gum) *Butea monosperma* (kamarkas)	Flowers of *Madhuca indica* (mahua) Leaves of Diospyros melanoxylon (tendu) for bidi making *C. scariosus* (localy known as gondra) Basket making

Indigenous tapping techniques for gums

Tribes of Sakrar (district Jhansi) generally tap *B. mosnosperma* for collection of kamarkas. For tapping kamarkas, first they remove the dead bark from tree and then make cuts or incisions on the stem with the help of "bill hook". After 3-4 days of knotching, they visit the tree and collect kamarkas. While, in district Tikamgarh, the tribes generally tap *Boswellia serrata* (salai) for salai gum. They generally peel off the bark (2-3 inches) from the stem and make a ring along the tree girth, and after 4-5 days, collect salai gum. For peeling the stem bark, they use *"Khurpi"* and for gum collection, they use a special tool called *"Gaantri"* (Plate4). On an average, they collect approximately 1 kg salai gum from a single tree. Normally, they start peeling off tree bark at men's height and slowly move upwards as the season of gum exudation progresses from September to April. They peel off tree bark 20-25 times in a season.

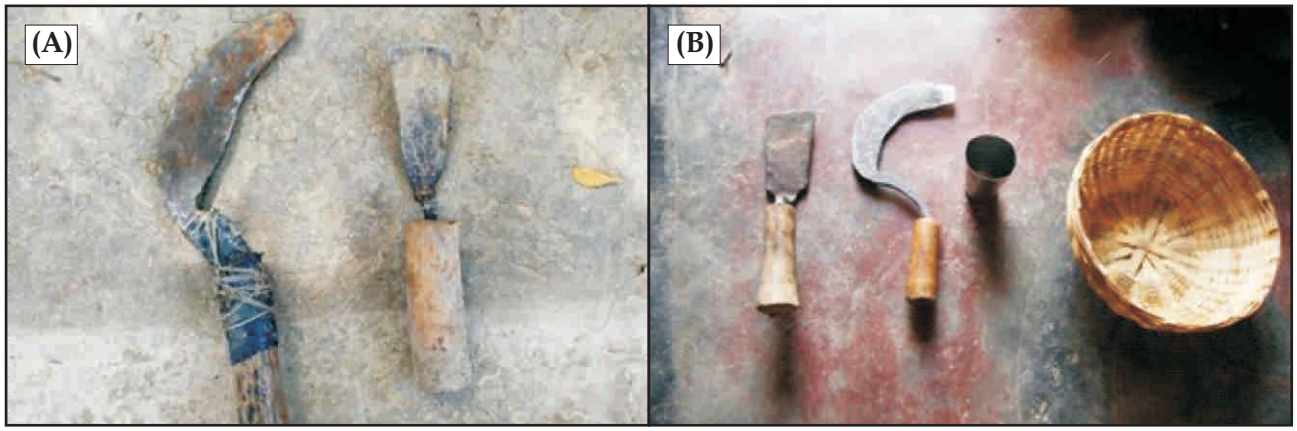


Plate 3: Tools used by Saharia tribes of Sakrar (A) and Tikamgarh (B) for tapping and collection of kamarkas and salai gum

Constraints faced by tribes of surveyed areas

The tribes of Sakrar (district Jhansi) tap only *B. monosperma* since long time. Now they are facing crisis of employment, as plants of *B. monosperma* are disappearing; hence, they compelled to move long distances from their native villages for collection of kamarkas. Most of them are land-less labourers; hence, migrate to nearby areas of Jhansi, Agra, Morena and Delhi for earning wages particularly in harvesting season of wheat and potato, and for construction works.

The tribes of district Tikamgarh tap *B. monosperma* for kamarkas and *B. serrata* for salai gum. Collection of other NTFPs such as flowers of *Madhuca indica,*leaves of *Diospyros melanoxylon* (tendu) for bidi making, *Cyperus scariosus* (naagarmotha or gondra), etc. is made from nearby forests. In district Tikamgarh, poor rainfall is the main constraint which affected exudation of kamarkas and salai gum during last years. The villagers informed that during good monsoon year, tree secrets good amount of gum and thus they get more income. The moisture stress also affected the collection of other NTFPs (medicinal herbs etc.), as there is no growth and regeneration of ground vegetation. In search of livelihood, most of the members of almost all the families migrated to Uttar Pradesh, Delhi and Rajasthan.

Value addition of gums and other NTFPs

The tribes of surveyed villages sell collected produce to the local trader or vendor in their original form i.e. without any post harvest value addition process. The main reason for selling produce in their original form is lack of skills and knowledge, and compulsion to meet their both ends meal. The local trader in Sakrar have post harvest value addition unit (Plate 5), where kamarkas cleaned by removing bark and other impurities with electric operated machines and thereafter, grading is done. For storage of salai gum, traders make small balls from the *salai ras* and apply *selkhadi* (chalk powder). For segregating and grading of tree gums, the local traders employ specific trained labourers, who have been doing this job for years. The tribes of village Paniyara Khera, district Tikamgarh use *M. indica* (mahua) flowers to make three different edible dishes, namely *Lataa* (in rainy season), *Dubri* (in summer season) and *Murka* (in winter season). For making *Lataa* and *Murka*, they use mahua flower and add roasted chickpea, sesame seeds and coconut powder, and prepare in ghee; and for making *Dubri*, they use mahua flower and add wheat flour, chickpea flour, coconut powder and water; and prepare in clay pots (utensils). These dishes develop immunity in body. The tribes of Tikamgarh use kamarkas to control dysentery and juice of Butea's roots to control eye infection.

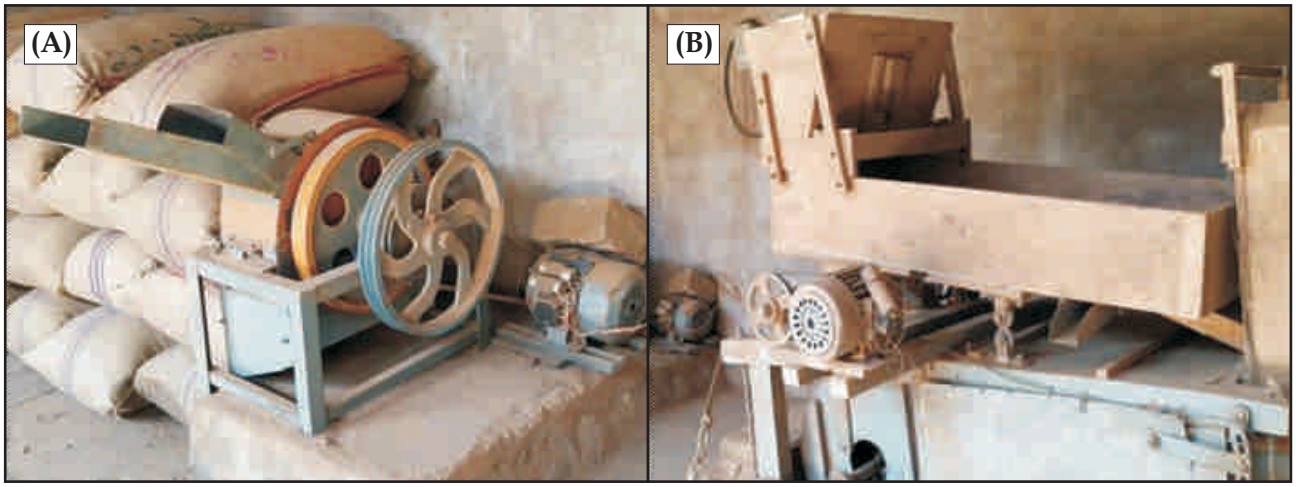


Plate 4 : Electric operated post harvest value addition unit for kamarkas at Sakrar (Jhansi).
A: De-sheller and B: Grader

Marketing of gums and other NTFPs

The tribes of Sakrar (district Jhansi) sell kamarkas @ Rs. 150-200/ kg to local trader, and tribes of village Bilgaayn and Paniyara Khera (district Tikamgarh) sell kamarkas @ Rs. 100-150/- and salai gum @ Rs. 150/- to the traders. The tribes of Sakrar generally go to Sakrar city for selling kamarkas, while villagers of Tikamgarh sell their produce to local vendors in village itself at low prices. The villagers of Sakrar have advantage of nearby trading centre in the city for selling their produce, hence get good price of their produce (Table 43). In surveyed villages of Tikamgarh, the traders run collection centre of NTFPs in the villages wherein tribes may sell their produce. The price

of produce is decided by the trader, not by the collectors. The tribal peoples are bound to sell their produce at the prices fix by the trader and hence generally get exploited. Moreover, tribal peoples generally prefer to get wheat grain in return of collected gum. The traders give them approximately 6-7 kg wheat in return of 1 kg kamarkas.

Table 43: List of NTFPs and their prices in surveyed areas of Jhansi and Tikamgarh

District	Forest produce	Price (Rs. Per kg)
Sakrar	Kamarkas	150 to 200
	Naagarmotha	10
Tikamgarh	Kamarkas	100 to 150
	Salai gum	150
	Basket (small size)	20 to 50/- piece
	Basket (big size)	100 to 150/- piece
	Soopa	120-150/-
	Mahua flower	70/- kg
	Tendu patta	250 per 100 bundles of 50 leaves each
	Naagarmotha or gondra	8-10/- kg

D. Standardization of gum tapping techniques

D1. Effect of ethephon application on gum yield from *Anogeissus pendula*

Earlier studies suggest that natural exudation of gum (known as *gum ghatti*) is negligible in *A. pendula*, which could be enhanced by the application of ethephon (gum inducer hormone). Therefore, a study was carried out during October, 2017 to assess the effect of application of different concentrations of ethephon on gum exudation. For the purpose, well established 22 years old plantation of *A. pendula* at research farm of CAFRI was taken into consideration. The plantation comprised of seven accessions of tissue culture raised progenies of *A. pendula* (AP-20, J-62, J-124, J-185, J-205, J-241 and NRC-5). The healthy trees were selected for the study and categorized in four different girth classes (20-30, 30-40, 40-50 and 50-60 cm girth). In the study, ethephon was used at four different concentrations i.e. 10, 20, 30 and 40%. Thus, the study consisted of 16 treatment combinations and each treatment was replicated three times (48 trees). 4 ml dose of different concentrations of ethephon was injected in selected trees. Results revealed that maximum gum yield was recorded with 40% ethephon which was significantly different from others (Table 44). Minimum gum yield was recorded with 10% ethephon and it was at par with the gum yield recorded from 20% ethephon. On the other hand, among girth classes, maximum gum yield was recorded from 50-60 cm girth class trees which was found statistically at par with the gum yield collected from 40-50 cm girth class. Two-way interaction between girth classes and concentrations of ethephon was found statistically significant. Maximum gum yield was recorded from 50-60 cm girth class when injected with highest concentration of the ethephon i.e. 40%. Thus, results clearly suggest that gum exudation from *A. pendula* increases with the increase in the concentration of ethephon as well as with girth class. Over all, irrespective of girth class and ethephon dose, the quantum of gum yield was low in *A. pendula*.

Table 44: Effect of ethephon application on gum yield from different accessions of *Anogeissus pendula* (2017)

Concentrations of ethephon (%)	Girth class (cm) 20-30	30-40	40-50	50-60	Mean
10	4.48	6.87	7.10	7.38	6.46
20	4.70	7.01	7.57	9.43	7.18
30	4.97	12.77	13.06	13.96	11.19
40	5.10	13.50	16.14	16.32	12.76
Mean	4.81	10.04	10.97	11.77	
	Girth	Concentration	Interaction		
$LSD_{0.05}$	1.42	1.42	2.85		

E. STUDIES ON ROOT DISTRIBUTION PATTERN AND ABOVE- & BELOW-GROUND BIOMASS IN *ACACIA SENEGAL*

Studies on root distribution pattern and above- & below-ground biomass in *A. senegal* was initiated in October, 2018. A three-years old *A. senegal* plant raised in new gum garden at institute farm was selected for the study. The marked plant was harvested close to the ground level with the help of a diesel-operated power-saw, and separated into main bole, branches and foliage (Plate 6 and 7). The main bole and branches were cut into 1.0 m long pieces. The fresh weights of these components were recorded immediately. After taking observations i.e. diameter (mm) of upper and lower ends of each section, length (cm) and weight (kg), sub-samples were left to dry at room temperature, thereafter these were dried in an oven at 80 °C to get constant weight.

For determining root biomass of *A. senegal*, roots of selected tree was excavated manually. Prior to excavation, rooting zone was moistened with water, and sufficient care was taken to reduce the damage to the fine roots. Whole root system was dug-out, and entire root system was divided into 30 cm long sections. From each section, primary, secondary and tertiary (fine roots having <2 mm size) roots were separated. Observations on diameter (mm), length (cm) and weight (kg) were taken.

The harvested tree attained 360 cm plant height, 18.5 cm GBH, 6.38 m^2 canopy spread and 34.7 m^3 canopy volume. In shoot portion, 24 primary, 85 secondary and 193 tertiary branches were recorded. The total fresh biomass of above-ground portion was 24.02 kg. The study recorded 9.20 kg fresh weight of main stem, 6.62 kg primary branches, 3.87 kg secondary branches, 2.25 kg tertiary branches and 2.08 kg foliage (Table 45). On the other hand, total depth of root system was recorded up to 270 cm with 3.34 kg total fresh weight. Below-ground root bound soil volume was 17.3 m^3. In entire root system, 25 primary, 64 secondary and 748 feeder roots were recorded. The study recorded 1.58 kg main root, 1.14 kg primary roots, 0.46 kg secondary roots and 0.16 kg feeder roots. Root to shoot ratio, on the basis of total above- and below-ground fresh biomass, was recorded 0.139.

Table 45: Fresh biomass of three year old *Acacia senegal* tree, raised at CAFRI research farm

Parameters		Main stem/ root	Primary branch/ root	Secondary branch/ root	Tertiary branch/ feeder root	Foliage
Above-ground	Numbers	-	24	85	193	-
	Biomass (kg)	9.20	6.62	3.87	2.25	2.08
Below-ground	Numbers	-	25	64	748 (<2 mm)	-
	Biomass (kg)	1.58	1.14	0.46	0.16	-

Root Cation Exchange Capacity (CEC): Cation exchange capacity (CEC) in roots of wheat plant grown in agri-horti-silviculture model was assessed. Fresh root samples of wheat were collected from three different distances *viz*., 1.0, 2.0 and 4.0 m from *A. senegal* stem base, after one month of sowing and at maturity. The fresh root samples from *A. senegal* was also taken. For estimating fresh root CEC, the roots were separated from plants, cut into 1 cm long bits and washed with distilled water. Surface of root samples were saturated by immersing in 0.01 N HCl for 5 minutes. Extra chloride ions adhered to root surface were removed by intermittent shaking in distilled water. Thereafter, roots were stirred in 1.0 N KCl solution and drop in pH was noted, and then titrated with 0.01 N KOH solution to bring back the pH up to 7.0. The fresh root CEC was calculated by using below-mentioned formula and expressed as meq/100 g of roots.

CEC of roots = $Y \times 0.01 \times 100 / X$

Where, X = weight of roots used; Y = volume of KOH solution used.

Results revealed that fresh root CEC of wheat was comparatively higher after one month of sowing than the value recorded at the time of maturity (Table 46). Initially, the root CEC of wheat increased up to 2.0 m distance from the tree and then declined. However, at maturity the root CEC remained almost similar up to 4.0 m distance. The fresh root CEC of *A. senegal* remained higher than the wheat, except at 2.0 m distance from the tree. After estimating dry root CEC of wheat and *A. senegal*, a more reliable parameter, the competitive uptake of cations by crop and tree components will be evaluated.

Table 46: Fresh root CEC (meq/100 g) of wheat and *Acacia senegal* in agri-horti-silviculture model at institute farm

Distance (m) from *A. senegal* stem base	Cation exchange capacity in wheat's root		Root CEC of *A. senegal* (roots collected from <1.0 m distance from tree base)
	One month after sowing	At the time of maturity	
1.0	3.900	2.279	3.906
2.0	4.100	2.548	
4.0	2.156	2.444	

Plate 5: Studies on root distribution pattern and biomass/carbon stock in three-years old *Acacia Senegal*

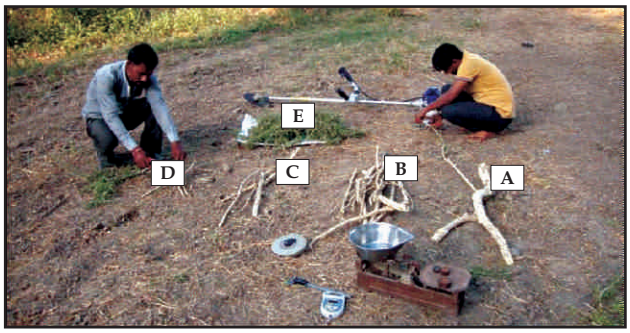


Plate 6: Sectioning of shoot of *Acacia senegal* plant into main stem (A), primary branches (B), secondary branches (C), tertiary branches (D) and foliage (E)

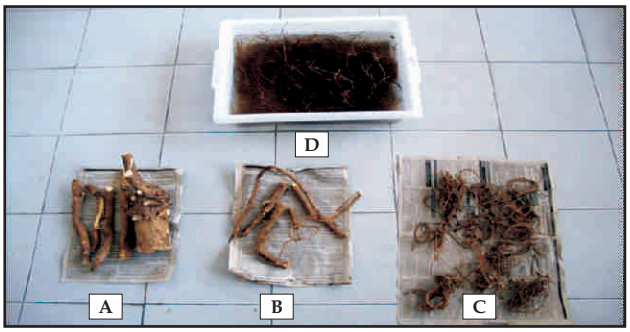


Plate 7: Sectioning of root system of *Acacia senegal* into main root (A), primary roots (B), secondary roots (C) and fine/feeder roots (D)

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

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

During the year under report, the assessment of carbon sequestration potential (CSP) was undertaken in two districts (East Godavari and Vizianagaram) of Andhra Pradesh. The general description of study area, major crops and their productivity and dominant tree species in total tree population is given in Table 47. Tree species and their population varied from one district to another district within the state. Similarly, crops and their productivity are also varied between the districts in the same state. The dominant tree species in East Godavari is *Casuarina equisetifolia, Cocos nucifera, Eucalyptus species* and *Anacardium occidentale.* In case of Vizianagaram, most dominant tree species are *Casuarina equisetifolia, Areca catechu, Cocos nucifera* and *Eucalyptus* species.

Tectona grandis based agroforestry system

Table 47: General description of study area

State	District	Location and Soil Type	Dominant crop (Productivity in t DM/ha)	Dominant Trees (Contribution in per cent)
Andhra Pradesh	East Godavari	17° 19'N 82° 2'E, Alluvial (clay loamy), red soil, sandy loams and sand.	*Oryza sativa* (3.83), *Saccharum officinarum* (88.38), *Zea mays* (2.95), *Sesamum indicum* (0.25), *Vigna radiata* (0.37), *Vigna mungo* (0.27)	*Casuarina equisetifolia* (31.69) *Cocos nucifera* (22.61) *Eucalyptus spp.* (13) *Elaeis guineensis* (12.96) *Anacardium occidentale* (12.27) *Mangifera indica* (2.59) *Tamarindus indica* (1.91) *Tectona grandis* (1.57)
	Vizia-nagaram	18° 6' N 83° 23' E, Red sandy loams, red sandy clay, red loamy sandy soil.	*Oryza sativa* (3.77), *Saccharum officinarum* (62.82), *Zea mays* (5.24), *Sesamum indicum* (0.21)	*Casuarina equisetifolia* (23.67) *Areca catechu* (18.01) *Cocos nucifera* (14.26) *Eucalyptus spp.* (13.19) *Anacardium occidentale* (11.33) *Elaeis guineensis* (7.83) *Mangifera indica* (6.45)

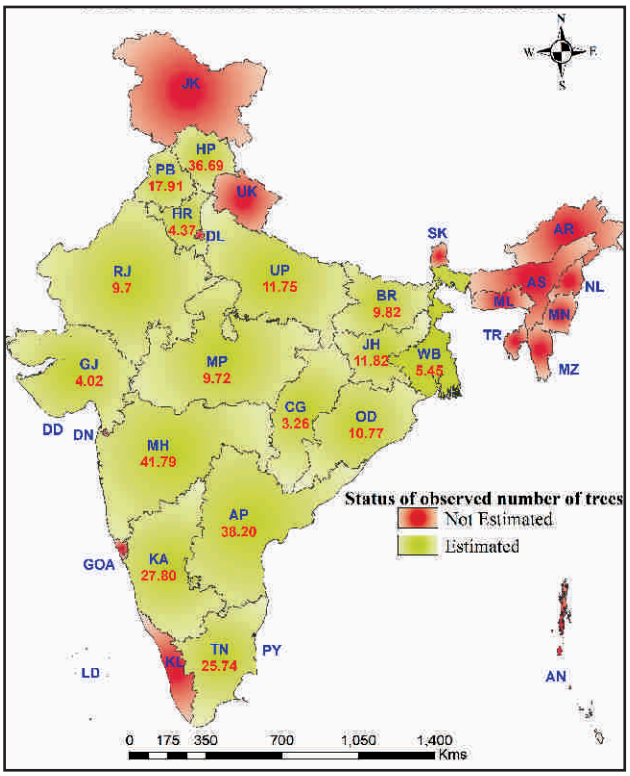
Tree density under agroforestry existing on farmer's field in two districts of Andhra Pradesh (East Godavari and Vizianagaram) varied from 44.22 to 47.32 tree/ha. In these districts, fast growing trees are more than medium growing trees. The population of slow growing trees are very less. Overall, the tree population in agroforestry system in different states is about 17.8 trees/ha. The maximum tree density (41 trees/ha) is recorded in Maharashtra followed by Andhra Pradesh and Himachal Pradesh.

The composition of tree species at country level indicates that the population of medium growing trees are more (9.12 tree /ha) as compare to fast growing trees (6.40 tree /ha). The population of slow growing trees at country level is 2.24 tree /ha.

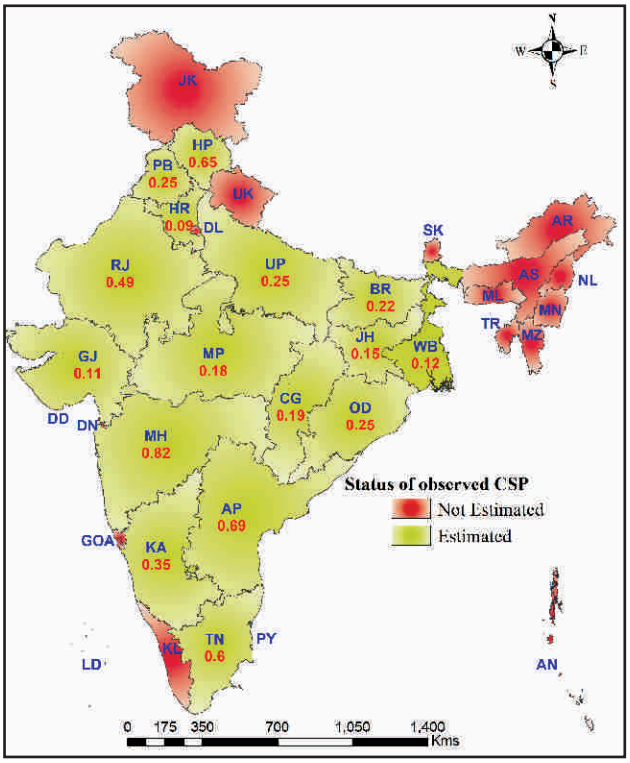
Quantification of Carbon Sequestration Potential (CSP) in agroforestry system has been completed in 17-States (Karnataka, Odisha, Bihar, Andhra Pradesh, Maharashtra, Himachal Pradesh, Tamil Nadu. Madhya Pradesh, Uttar Pradesh, Punjab, Haryana, West Bengal, Chhattisgarh, Rajasthan, Gujarat, Telangana and Jharkhand) covering 58 districts. Carbon Sequestration potential in agroforestry system existing on farmer's field varied from 0.11 to 0.82 tons C per hectare per year in these states. The maximum CSP of agroforestry system is observed in Maharashtra followed by Andhra Pradesh and Himachal Pradesh.

During 2018, the Carbon Sequestration potential was studied in two districts (East Godavari and Vizianagaram) of Andhra Pradesh. Tree biomass in baseline varied from 3.12 to 3.15 t DM /ha and total carbon stock available under baseline is 13.77 to 13.85 t C /ha in these two districts. Carbon sequestration potential of these two districts varied from 0.68 to 0.89 t C /ha/yr (Table 48).

Coconut based agroforestry system



Observed number of trees/ha in different states



Observed carbon sequestration potential (CSP) Mg C/ha/yr in different states

Table 48: Biomass, carbon and carbon sequestration potential of agroforestry system existing on farmer's field in two districts of Andhra Pradesh

Parameter			East Godavari (44.24 trees/ha)	Vizianagaram (47.37 trees/ha)
Tree Biomass (above and below ground) in Mg DM / ha	Baseline	Biomass	3.15	3.12
	Simulated		54.24	44.07
Total biomass (tree+ crop) in Mg DM / ha	Baseline		4.41	4.63
	Simulated		55.31	45.26
Soil carbon (Mg C / ha)	Baseline	Carbon	11.72	11.70
	Simulated		14.26	12.59
Biomass carbon (Mg C / ha)	Baseline		2.06	2.15
	Simulated		26.49	21.67
Total carbon (biomass + soil) (Mg C / ha)	Baseline		13.77	13.85
	Simulated		40.75	34.25
Net carbon sequestered in agroforestry systems over the simulated period of thirty years (Mg C / ha)		Carbon sequestered	26.98	20.40
Estimated annual carbon sequestration potential of agroforestry system (Mg C / hayr^{-1})			0.89	0.68

Soil organic carbon under agroforestry system existing on farmers' field in different states varied from 46.59 to 104.84 tons per hectare in 0-90 cm soil depth. It indicates that soil organic carbon is biggest carbon pool (Fig.19 & 20).

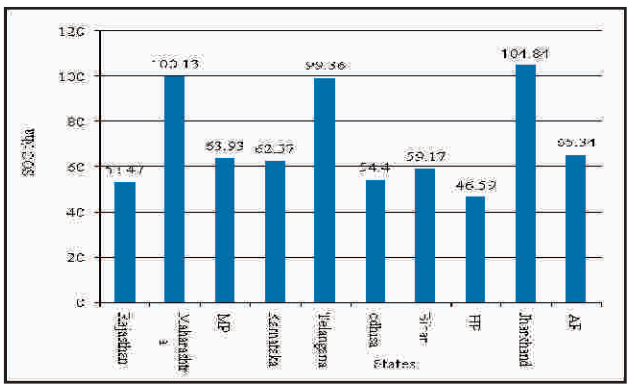


Fig.19: Soil organic carbon in agroforestry on farmer's field (0-90 cm soil depth)

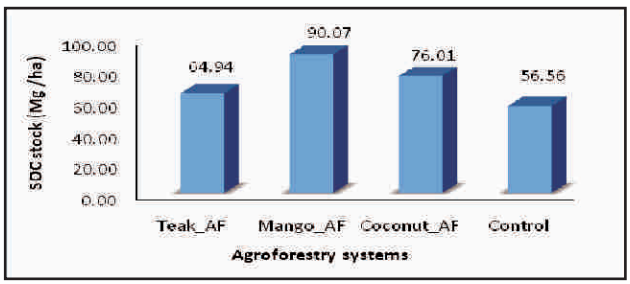
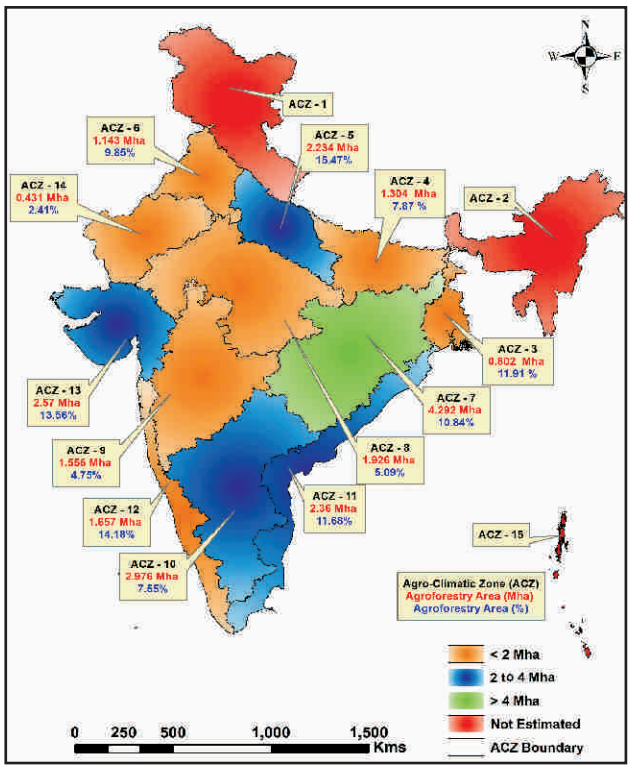


Fig. 20: SOC stock (Mg /ha) in East Godavari and Vizianagaram districts of Andhra Pradesh

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

Mapping of agroforestry area in 12 agro-climatic Zone has already been completed. Land use and



Agroforestry area in Agro-Climatic Zones of India

land cover analysis (LULC) for 12 agro-climatic zone is given in Table 49. The total area under agroforestry in 12 zone was estimated to be 23.25 million ha of total geographical area (267.66 million ha). During year under report, mapping was done in agro-climatic zone 11 (Table 50). The methodology used for mapping of agroforestry area is shown in Fig. 21. Highest agroforestry area was found in Cuddalore district (16.88%) followed by West Godawari district (16.33%). Out of nine districts, only three districts have less than 10 percent agroforestry area. Total agroforestry area in these nine district was estimated to be 686332.11 ha, which is 11.68 per cent of their geographical area. In this agro-climatic zone, the agroforestry area was extrapolated to be 2.36 million ha. Land Use Land Cover map of zone 11 is given in Fig. 21 & 22.

Table 49: Land use and land cover (LULC) analysis of different agro-climatic region

ACR No.	Agro-climatic zones	Geographical Area (M ha)	Agroforestry Area (M ha)	Agroforestry Area (%)
3	Lower Gangetic Plains Region	6.73	0.80	11.91
4	Middle Gangetic Plains Region	16.57	1.30	7.87
5	Upper Gangetic Plains Region	14.44	2.23	15.47
6	Trans Gangetic Plains Region	11.60	1.14	9.85
7	Eastern Plateau & Hill Regions	39.59	4.29	10.84
8	Central Plateau & Hill Regions	37.84	1.93	5.09
9	Western Plateau & Hill Regions	32.74	1.56	4.75
10	Southern Plateau & Hill Regions	39.41	2.98	7.55
11	East Coast Plains & Hill Regions	20.21	2.36	11.68
12	West Coast Plains & Hill Regions	11.68	1.66	14.18
13	Gujarat Plains & Hill Regions	18.98	2.57	13.56
14	Western Dry Regions	17.87	0.43	2.41
		267.67	**23.25**	**8.68**

Table 50: Estimated area under agroforestry in selected districts of agro-climatic zone-11

District (s)	Geographical Area (ha)	Agroforestry Area (ha)	Agroforestry Area (%)
W. Godawari	772678.80	126156.00	16.33
Vizianagaram	616864.95	71220.07	11.55
Prakasham	1761690.83	176253.90	10.00
Puri	349670.41	32387.97	9.26
Jajpur	291540.98	21613.98	7.41
Shivganga	410159.08	53417.97	13.02
Tiruannamalai	619210.5	78717.32	12.71
Cuddalore	371827.96	62751.39	16.88
Tiruneveli	681940.9	63813.51	9.36
Total	5875584.41	686332.11	11.68

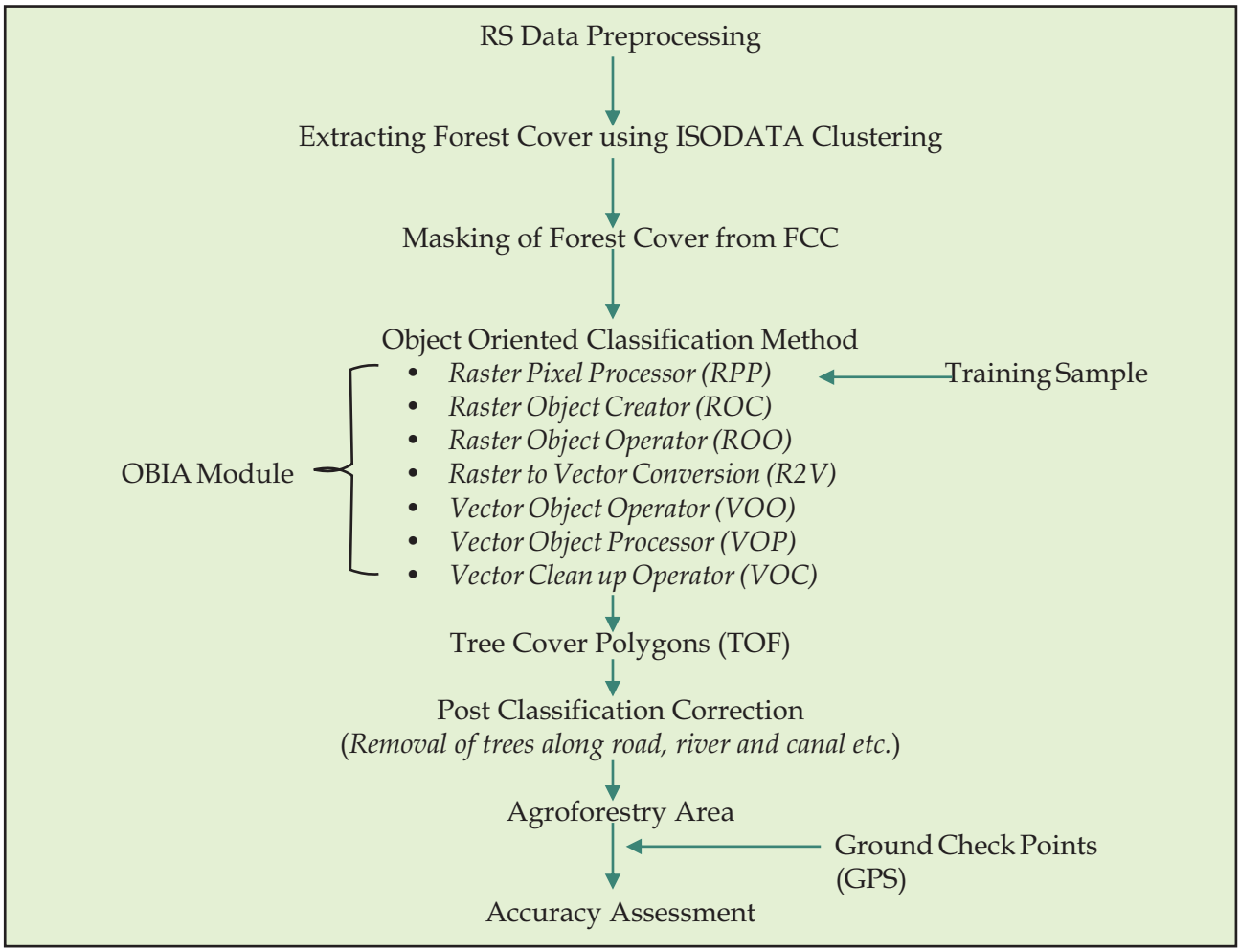


Fig. 21: Methodology used for mapping of Agroforestry area

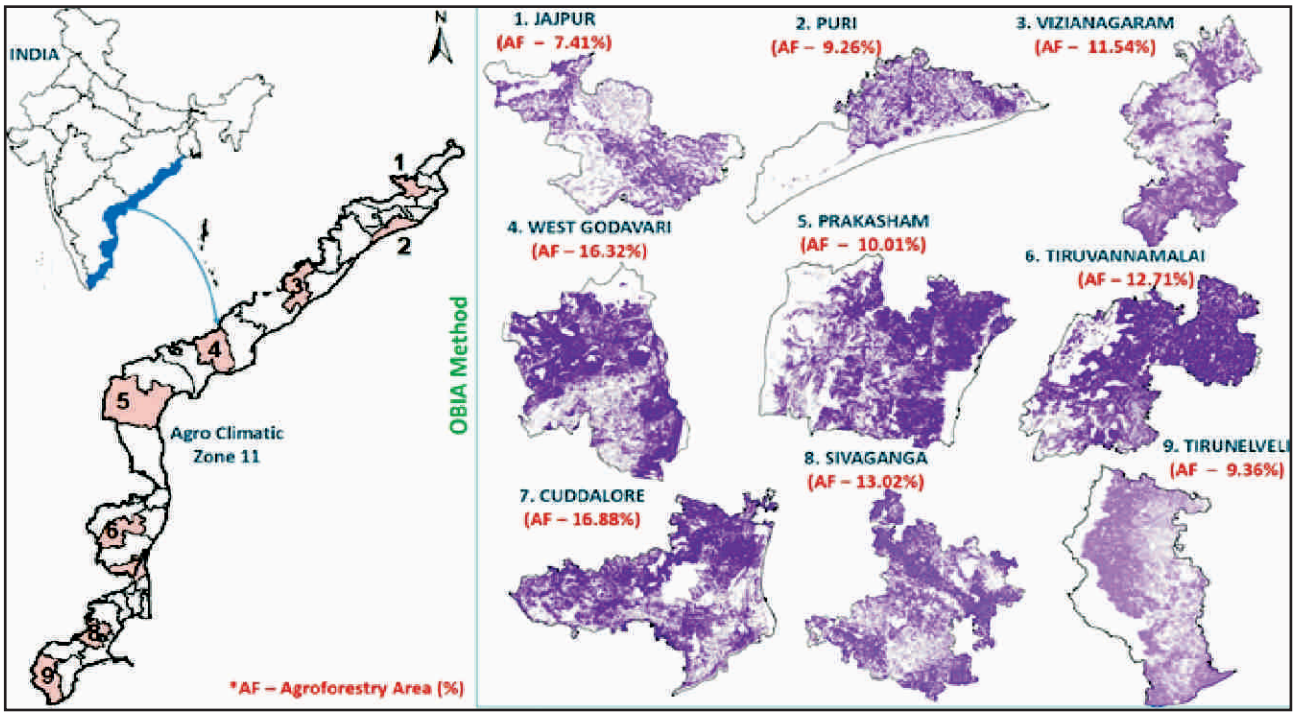


Fig. 22: Land Use Land Cover map of zone 11

III- Studies on thermotolerance in MPTs of agroforestry importance

Conspicuous impact of elevated temperature was observed on *Albizia procera* (safed siris) and *Azadirachta indica* (neem) by growing the seedlings in polybags under elevated temperature inside a temperature gradient tunnel (TGT) and under ambient condition outside the TGT. This has been depicted that there are dynamics in the trend of responses of the tree seedlings in response to elevated temperature and in ambient conditions. Effects of elevated temperature on the leaf physiological status have been critically studied in terms of the thermotolerance indices namely Canopy Temperature Depression (CTD) and leaf chlorophyll content index (CCI). Differential responses in leaf physiological functions have been observed in the capacity of the leaves for coping with the elevated temperature by altering the CTD. Remarkable effects of elevated temperature on the leaf physiological status have been observed for managing the leaf temperature for maintaining its physiological functions which is highly noteworthy. As an adaptive response, it has been noted that there were temporal changes in canopy temperature depression (CTD) in both the tree species under ambient and elevated temperature (Fig.23 & 24). Comparative responses of the seedlings through CTD and CCI require further confirmation for their thermotolerance properties (Fig.25 & 26).

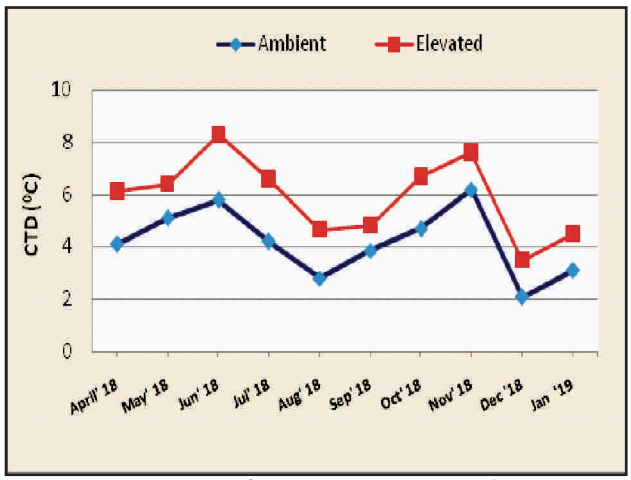


Fig. 23: Dynamics of canopy temperature depression (CTD) of safed siras (*Albizia procera*) under ambient and elevated temperature

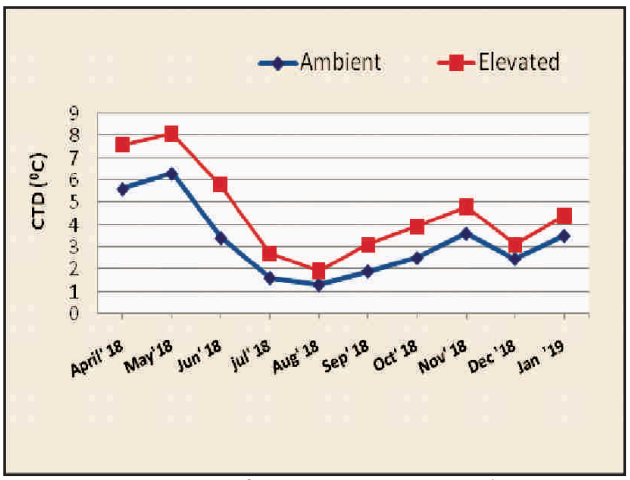


Fig. 24: Dynamics of canopy temperature depression (CTD) ofneem (*Azadirachta indica*) under ambient and elevated temperature

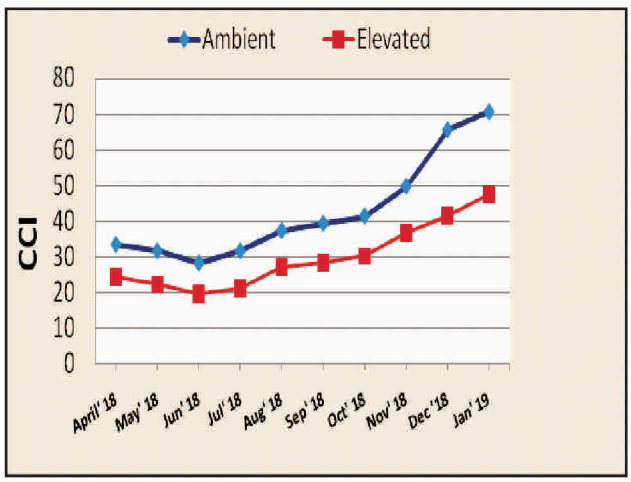


Fig. 25: Dynamics of temporal changes in leaf chlorophyll content index (CCI) of safed siras (*Albizia procera*) under ambient and elevated temperature

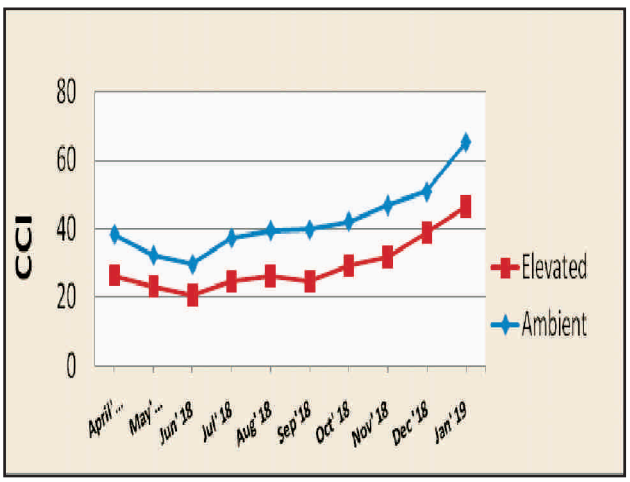


Fig. 26: Dynamics of temporal changes in leaf chlorophyll content index (CCI) of neem (*Azadirachta indica*) under ambient and elevated temperature

NMOOP MM-III Project

(K B Sridhar, Naresh Kumar, Lal Chand & K Rajarajan)

NRMACAFRISOL201601100110

Development of Nursery of TBOs for Quality Planting Material Production

The primary objective of the project was to develop nursery of TBOs. The TBOs selected for the production is presented in Table 51.

Table 51: TBOS – Selected for propagation and seed source identified

Neem (*Azadirachta indica*)	ICAR- CAFRI, Jhansi, Uttar Pradesh
Karanj (*Pongamia pinnata*)	ICAR CAFRI, Jhansi, Uttar Pradesh
	AICRPAF, Raipur, Chhattisgarh
	CRIDA, Hyderabad, Telangana
Mahua (*Madhuca longifolia*)	ICAR- CAFRI, Jhansi, Uttar Pradesh
Olive (*Olea europaea*)	Center of Excellence, Olive, ROCL, Bassi, Jaipur, Rajasthan
Jojoba (*Simmondsia chinensis*)	Center of Excellence, Jojoba, Jodhpur, Rajasthan
Paradise tree (*Simaruba glauca*)	TNAU Coimbatore, ICAR-CAFRI, Jhansi

Standardization of vegetative propagation protocol for *Azadiractha indica*, *Simarouba glauca*, *Madhuca longifolia* and *Pongamia pinnata*

Table 52: Different type of propagation methods standardized in TBOs

S.No.	Species	Propagation method	Source
1	*Pongamia pinnata*	Seeds/hardwood and Semi hardwood cuttings/ Shoot Tips/ Grafting	ICAR- CAFRI, Jhansi, AICRPAF, Chhatisgarh
2	*Simaruba glauca*	Seeds/ hardwood and Semi hardwood cuttings Cuttings/ Shoot Tips	Tamil Nadu, ICAR-CAFRI
3	*Azadiractha indica*	Seeds/ hardwood and Semi hardwood cuttings Cuttings/ Shoot Tips/	ICAR- CAFRI, Jhansi
4	*Madhuca longifolia*	Seeds/ hardwood and Semi hardwood cuttings Cuttings/ Shoot Tips	ICAR- CAFRI, Jhansi
5	*Olea europea*	Shoot tips	Centre of excellence, Olive, Bassi, Jaipur
6	*Simmondsia chinensis*	Seeds	ICAR-CAZRI, Jodhpur

Vegetative propagation protocol for *Populus deltioides*, *Eucalyptus tereticronis Casuarina junjuniana* and *Melia dubia* were standardized using minicuts.For *Populus deltioides*, *Eucalyptus tereticronis* and *Casuarina junjuniana* IBA 6000 ppm was found best and for *Melia dubia* IBA 1000 ppm was found best. The indoor clonal hedges were established. This technique offers propagules with high uniformity and low topophysis effects. Established clonal mother hedge Garden of *Populus deltioides*, *Eucalyptus tereticornis Casuarina junjuniana* and *Melia dubia* using minicuts. Supplying regularly clonal planting material of Eucalyptus to farmers for boundary plantation and biodrainage. Other short rotation trees *Gmelina arborea*, *Switenia mahogany* is being multiplied for distribution.

Timber	Short Rotation Trees (4-5 years)	Multipurpose trees
Teak (*Tectona grandis*)	*Eucalyptus tereticornis*	*Acacia Senegal* (Gum/ Live fence)
Shisham (*Dalbergia sissoo*)	*Melia dubia*	*Pongamia pinnata* (Shade/ Biofuel)
Mahagony (*Switenia mahagony*)	*Casuarina junjuniana*	*Simaruba glauca* Shade/ biofuel
Bamboo species	*Anthocephalus kadamba*	*Moringa oleifera* (Fodder/food)
Gamhar (*Gmelina arborea*)		*Hardwickia binata*

Pongamia pinnata

Clonal propagation was carried out using top cuts and semi hardwood cuttings. The identified accessions of *Pongamia pinnata* viz NRC 21 which was found promising was multiplied vegetatively. The seed propagated *Pongamia pinnata* seedlings were cleft grafted to obtain improved quality planting material. Clonal hedge garden was established from stumps, tops, hard wood cuttings of seedlings obtained from different sources. The seedlings were distributed to farmers for planting. Improved and quality seeds of *Pongamia pinnata* were procured from AICRPAF, Raipur, Chhattisgarh and were raised. The quality seedlings were further distributed to farmers for planting. Few grafted plants were further planted in the Institute campus as avenue tree as well as for seed collection.

Olea europea

The olive plantation was established in the experimental farm and the plants showed 60 percent survival. The seedlings were distributed to selected farmers and are performing better in the field. The flowering was noticed in the distributed plants. There exists all opportunity to promote olive plantations on large scale in Bundelkhand region of Central India.

Simaruba glauca

The wildlings of *Simaruba glauca* were recovered from the established plantation and the seedlings showed 70% survival.

Azadirachta indica

Semi hardwood, hardwood and top cuttings were used as planting material for propagation in *Azadirachta indica.* The cuttings showed good response initially but showed mortality in the later stages. However the survival percentage was found about 70% survival.

Simmondsia chinensis

The seeds of Jojuba were procured from Jojoba growing farmer from Sri Ganga Nagar, Rajasthan. The seeds were then subjected to cold water treatment over night. The seeds were sown directly in polythene bags. The seeds took nearly 15 days to germinate. Overall the seeds showed 70 percent germination. The same seedlings will be distributed to farmers for planting.

Madhuca longifolia

The wildlings were recovered from the established plantation and the seedlings showed 50 percent survivability and are ready for planting.

SERB- DST Project

NRMACAFRISOL201700100111

Studies on Pollination Dynamics, Pod yield and Oil content in *Pongamia pinnata*

(Veeresh Kumar)

Millettia pinnata is a species of family Leguminosae, which has unique floral architecture. Bisexual, zygomorphic flowers have one large standard petal, two light-purple wing petals and two white keel petals. Floral morphometry and biology was studied at ICAR-Central Agroforestry Research Institute, Jhansi.

Flowering was commenced in the first week of May and lasted until the first week of June. The anthesis within an inflorescence followed acropetal succession. Individual flowers measured 12.30±0.32 x 4.16±0.18 mm (Mean±SD). The standard petal was large and measured 12.47±0.84 x 5.59±0.60 mm. The two wing petals measured 10.29±0.28 x 3.19±0.24 mm. Two keel petals measured 9.90±0.13 x 3.11±0.12 mm.

Studied flowering phenology of *Pongamia pinnata* indicated that the flower appeared to be adapted for cross-pollination. Anthesis was between 0800 and 1000 h, with a peak between 0800 to 0830 h. Pollen germination was noticed throughout the day but maximum pollen germination was at the time of anthesis (96.15%) and continued up to 1200 h (92.21%), later germination percentage was reduced. Stigma was receptive for eight hours after anthesis. A total of 13 different flower visitors have been recorded.

ICAR- ICRAF Work Plan

NRMACAFRISOL201800100112

Mapping and Estimation of Area under Poplar based Agroforestry Systems in Indo- Gangetic Plains of India

(RH Rizvi, AK Handa and KB Sridhar)

Field survey has been conducted in Ludhiana, Shahid Bhagat Singh Nagar, Rupnagar and Hoshiarpur districts of Punjab, Karnal, Kurukshetra and Yamunanagar districts of Haryana during Aug. 2018; Bagpat, Bijnor, Shamli and Muzaffarnagar districts of Uttar Pradesh; and Udham Singh Nagar district of Uttarakhand during Oct. 2018. Growth and GPS data on Poplar (*Populus deltoides*) plantations from these districts have been collected. Some tracks of Poplar plantations were also taken through GPS. LISS IV images of selected districts from Punjab, Haryana, Uttar Pradesh and Uttarakhand states have been layer satacked, mosaicked and analyzed using ERDAS Imagine 2015. Agroforestry area has been mapped and estimated in these districts by applying object oriented classification techniques. From the agroforestry area, Poplar area was identified and mapped with the help of field check points taken through GPS (Figs. 27 to 30).

Poplar area was recorded highest in Hoshiarpur district (10573.13 ha) followed by Rupnagar district (5495.20 ha), but in terms of percent highest area was found in Rupnagar district i.e. 4.09% (Table 53). Poplar based agroforestry systems accounted for more than 50% of total agroforestry area in Rupnagar and Hoshiarpur districts. In Yamunanagar district of Haryana, Poplar area was estimated to be 12169.66 ha (9.71%). This poplar area accounted for about 74.7% of total agroforestry area in the district. In case of Kurukshetra and Karnal districts of Haryana, estimated Poplar area was found to be 2581.73 and 2317.34 ha, respectively. This area is about 32.3 and 30.3% of the total agroforestry area in these districts (Table 53).

From western Uttar Pradesh, five districts namely, Baghpat, Bijnor, Muzaffarnagar, Shamli and Saharanpur districts were selected for mapping Poplar species. Poplar area was found maximum in Saharanpur district (25911.23 ha), which is 7.17% followed by Bijnor district (12840.53 ha). In terms of total agroforestry area, Saharanpur district has highest Poplar area of 64.9% (Table 53). Poplar mapping at state level was also done with Sentinel-2A data using the methodology described above. Estimated area under Poplar species was found to be 0.276 million ha (5.63%) with a reasonably good accuracy of 81%. Similarly, area under Poplar species in Haryana state was estimated, which come out to be 0.205 million ha (4.66%) with an accuracy of 85.2%.

Table 53: Estimated agroforestry and Poplar area in selected districts by remote sensing

State	Districts	Agroforestry Area (ha)	Poplar Area (ha)	%
PUNJAB	Rupnagar	9567.3	5495.2	57.44
	Nawashahr	5501	534.00	9.71
	Ludhiana	11691.85	3698.67	31.63
	Hoshiarpur	19600.38	10573.13	53.94
HARYANA	Yamunanagar	16292.88	12169.66	74.69
	Karnal	7641.09	2317.34	30.33
	Kurushetra	7997.87	2581.73	32.28
UTTAR PRADESH	Baghpat	8207.69	2838.44	34.58
	Muzaffarnagar	18872.77	6791.21	35.98
	Bijnor	28929.28	12840.53	44.39
	Saharanpur	39936.31	25911.23	64.88
	Shamli	8140.96	3779.38	46.42

Data on diameter at breast height (DBH), tree spacing and system type was recorded during field survey. Stem and aboveground biomass has been computed from available biomass equations. Poplar plantations of different densities were found with minimum 200 trees/ ha in Ludhiana to maximum 1905 trees /ha in Hoshiarpur district. Average DBH also varied from minimum 9.54 cm to maximum 24.76 cm. Estimated stem biomass in Hoshiarpur was in the range of 80.57-245.18 kg/tree and aboveground biomass was in the range of 89.64 - 313.86 kg / tree. Per tree biomass was converted to per ha biomass by multiplying it with tree density (Table 54).

In case of Yamunanagar district of Haryana, where Poplar based agroforestry is very predominant, density varies from 540 to 1560 trees /ha. DBH was found in the range of 13.96-22.71 cm. Estimated stem and aboveground biomass come out to be 103.05-213.48 kg/tree and 118.55–268.67 kg/tree, respectively. On ha basis, stem and aboveground biomass were estimated to be 41.526-160.964 t/ha and 44.164-185.175 t/ha, respectively. In Kurukshetra district, stem and aboveground biomass was estimated to be 87.45-202.68 t/ha and 104.03-239.77 t/ha, respectively (Table 54).

Table 54: Stem and aboveground biomass of Poplar trees in some selected districts

Parameter	Ludhiana	Hoshiarpur	Rupnagar	Yamunanagar	Kurukchetra
DBH (cm)	10.21 - 22.68	12.42 - 24.76	14.70 - 20.46	13.96 - 22.71	13.41- 21.99
Trees density (trees/ ha)	200 - 1550	494 - 1905	667 - 1333	540 - 1560	476 - 2500
Stem biomass (kg/ tree)	60.13 - 206.52	80.57 - 245.18	106.95 - 180.56	103.05 - 213.48	92.75 - 202.01
Aboveground biomass (kg/ tree)	64.52 - 258.52	89.64 - 313.86	123.84 - 222.55	118.55 - 268.67	105.72 - 252.17
Stem biomass (t/ha)	28.36 - 223.74	39.80 - 241.73	98.04 - 170.07	41.526 - 160.964	87.448 - 202.685
Aboveground biomass (t/ha)	34.00 - 279.91	44.28 - 286.07	117.69 - 209.68	44.164 - 185.175	104.033 - 239.767

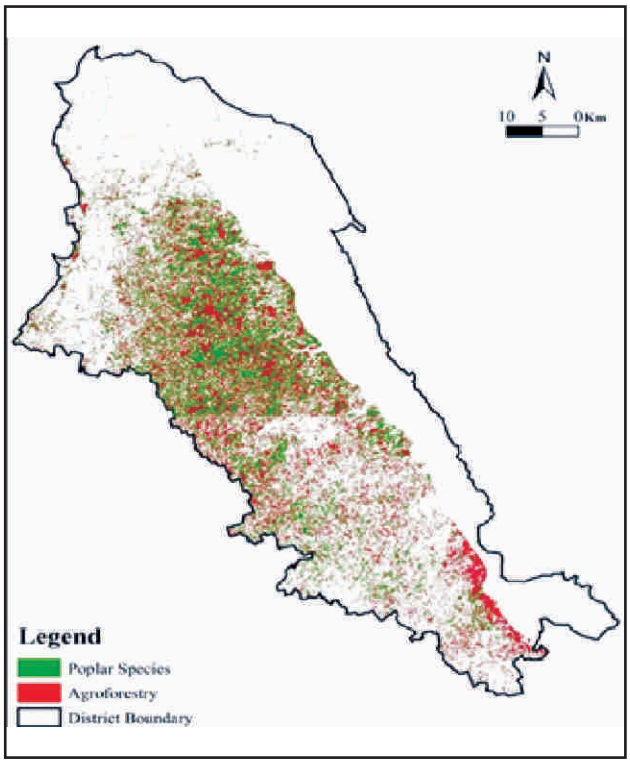


Fig. 27: Poplar area in Hoshiarpur district

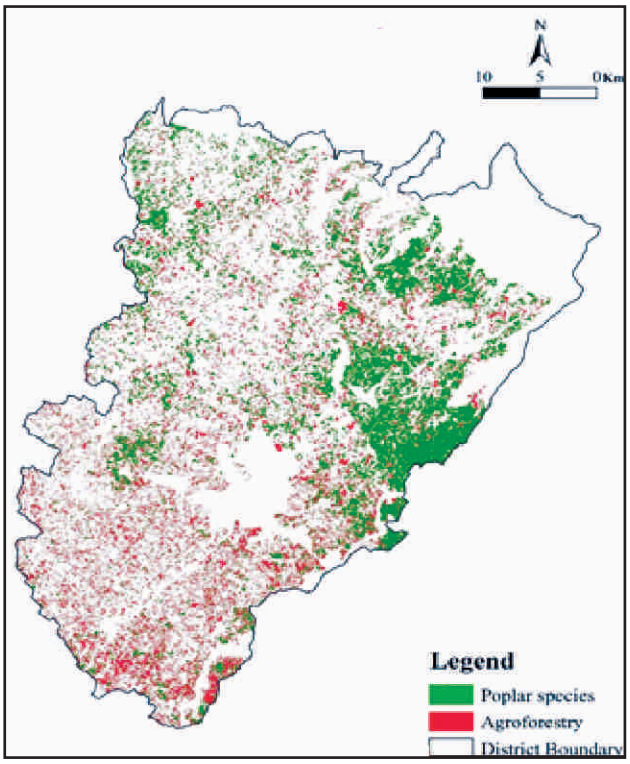


Fig. 28: Poplar area in Yamunanagar district

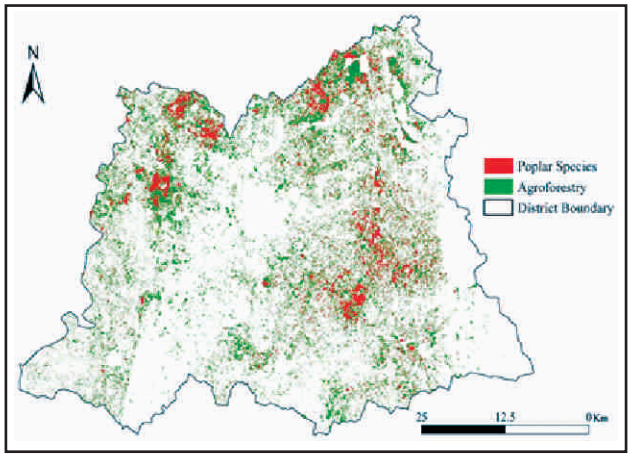


Fig. 29: Poplar area in Muzaffarnagar district

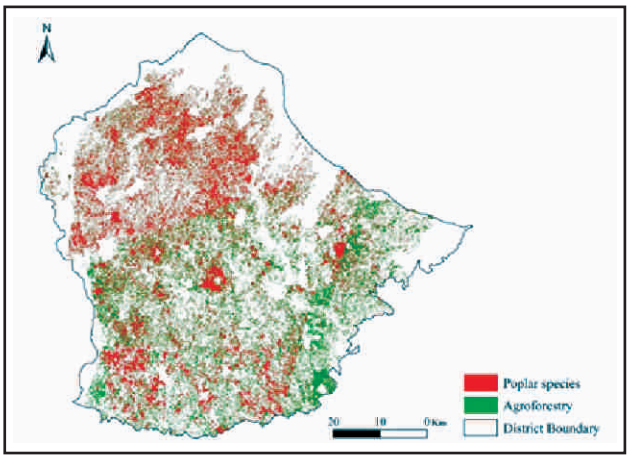


Fig. 30: Poplar area in Bijnor district

ICRISAT, Hyderabad

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

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

Background

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

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

Runoff and groundwater recharge

To improve the situation of water resources, three *nallah* plugs (small checkdam), nine checkdams, one haveli (traditional rainwater harvesting structure), one community pond and one farm pond were constructed by 2015. Runoff and soil loss were gauged at 11 locations including field scale monitoring. Total rainfall during the year was 1120.9 mm, 27.8% excess over normal rainfall (877 mm), spread over in 41 rainy days. Nine runoff events were recorded and total runoff recorded at the out was 13.9% of annual recorded rainfall which is 27.6% lower than control (Fig. 31).

All the open shallow dug wells (388 Nos.), which are only means of irrigation in the watershed were monitored for water table on monthly interval. The average water column during the year was 4.9 m.

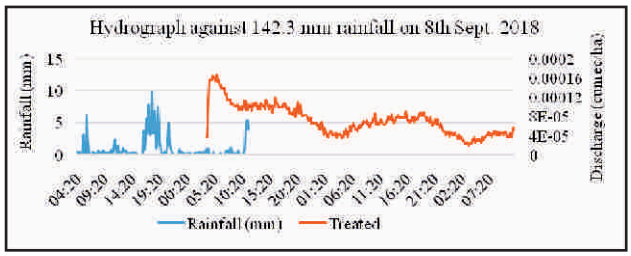


Fig.31: Hydrograph recorded at outlet in treated area

Development of Agroforestry Interventions

To bring more area under permanent vegetal cover, 100, 380 and 400 seedlings of lemon, karonda and *A. senegal*, respectively, were planted by 7 farmers at the field boundaries. Survival of lemon and karonda was 82 and 86%, respectively by the end of December 2018.

Productivity enhancement (as per farmer practice)

The major crops grown by the farmers of Parasai-Sindh watershed during 2018 were groundnut, greengram and blackgram (*kharif*) and wheat, chickpea and mustard (*rabi*). In order to substantiate the crop productivity enhancement samples were taken from upper, middle and lower reaches of each village. 72 samples {3(lower, middle and upper reaches) x 3(villages) x 8 (replications)} were taken for groundnut and wheat. 27 {3(lower, middle and upper reaches) x 3(villages) x 3 (replications)}samples were taken for assessment of each crop of greengram, blackgram, chickpea and mustard. Each unit of sample was harvested from an area of 3m x 3m. The productivity levels recorded are presented in Table 55. The productivity of wheat, mustard and chickpea was 65.8, 35.2 and 34.2%, respectively, higher in treated watershed as compared to base line data(Table 55).

Table 55: Productivity of different crops in Parasai-Sindh watershed

Rabi 2017-18		*Kharif* 2018	
Crop	**Productivity (kg/ha)**	**Crop**	**Productivity (kg/ha)**
Wheat	2735	Groundnut	1192
Chickpea	1037	Blackgram	223
Mustard	1227	Greengram	259

Capacity building of watershed dwellers

Farmers of the villages Parasai, Chhatpur and Bachhauni were motivated to adopt agroforestry practices at their field. Capacity building programme were organized to farmers and farm women using exposure visit to research farm of CAFRI and IGFRI, Jhansi. Farmers and farm women from watershed villages participated in Kisan Mela and Gosthi organized by CAFRI and IGFRI Jhansi and also made awareness by showcasing the technologies and products of agroforestry and allied activities. The various extension tools and methods from socio-economic viewpoints were applied *i.e.* Interacted in-person, Interface meeting and Focused Group Discussion (FGD) with 375 farmers. The farmers have shown keen interest in watershed based agroforestry intervention.

Agroforestry Mission U.P. Government

Establishment of Hi-Tech Nursery for the Production of Quality Planting Material

(Lal Chand, Naresh Kumar and K B Sridhar)

The main objective of this project is to establish a Hi-Tech nursery for supply of quality planting material with the capacity of production of one lakh plants. Nursery activities were carried during FY 2018-19 are establishment of mother blocks, installation of drip irrigation system in mother blocks, digging of bore-well for irrigation purpose in nursery area, procurement of small nursery tools and production of planting material. The main emphasis was on production of QPM of guava, teak, *Acacia senegal* and other priority species.

Collection of fruit crop germplasm

Collection of different fruit varieties were carried out from various institutes viz., CHES, Godhra, Gujarat: jamun (Goma Priyanka), khirni (Thar Rituraj), tamarind (Goma Prateek) and bael (Goma Yashi); from IIHR, Bengaluru: guava (Arka Rashmi, Arka Mridula and Arka Kiran), fig (Poona and Deana), custard apple (Balanagar and Arka Sahan), mango (Arka Uday) and sapota (Cricket Ball); from CISH, Lukhnow: mango (Amrapali, Mallika, Ambika, Arunika, Langra, Chausa and Dashehari), bael (NB-5, CISH-B-1, NB-9 and CISH-B-2); from Center of Excellence for Citrus, Kota: Sweet Orange (Jaffa and Blood Red), Mandarin (Kinnow, Nagpur, Nagpur Seedless, Clementine and Daisy); Central Citrus Research Institute, Nagpur: Acid lime (NRCC-Acidlime-7, NRCC-Acidlime-8, Vikram, Pramalini, Sai Sharbati and Balaji), Sweet Orange (Mosambi) and from IARI, New Delhi: Sweet Orange (Pusa Sharad and Pusa Round), Acid lime (Pusa Abhinav and Pusa Udit).

Jack fruit germplasm collection: Three varieties (EC963455, EC963456 and EC963457) were introduced from Tropical Horticulture Center, Nawalpur, Nepal with the help of ICRAF, maintained in isolation, and facilitated post entry quarantine conducted by NBPGR. Two varieties (NSP and Sidhiappa) were brought from GKVK, Bangaluru, one variety (Sidhu) from IIHR, Bengaluru and one (Manipur Local) from Manipur.

Fruit Tree Mother Block

A fruit tree mother block was established during February-March, 2018 at Central Research Farm of ICAR-CAFRI, Jhansi, which was further extended in July, 2018. A total of 190 plants of different fruit varieties were planted on raised bed at 6 m x 6 m spacing. This was established with the objective to ensure availability of good quality scion source for raising true to type and quality planting material.

Plantation in Fruit Tree Mother Block

Fruit Tree Mother Block

Collection of rootstocks

Rootstock is an integral part in fruit production which impart tolerance to scion variety from various biotic and abiotic factors and also improve fruit quality and yield of scion variety. Thus mother plant of rootstock is essentially required in fruit nursery for seedling raising. In citrus, mother plants of following rootstocks have been procured from Center of Excellence (Indo-Israel Project), Mangiana, Sirsa (Haryana):

1. Alemow (*Citrus macrophylla* Wester)
2. Cleopatra mandarin (*Citrus reshni* Hort. ex Tan.)
3. Kharna Khatta (*Citrus karna* Raf.)
4. Rangpur Lime (*Citrus x limonia*)
5. Sour orange (*Citrus x aurantium*)
6. Volkameriana (*Citrus volkameriana*)
7. Pectinifera (*Citrus × depressa)*

CHAPTER

3 AICRP ON AGROFORESTRY

A. Research Achievements

At Srinagar centre, eight sources of *Ulmus villosa* (Elm) were collected from different regions of Kashmir valley and planted (Boundary plantation) at Shalimar Campus of the University. At the end of 10th growing season (January-2018), the material collected from Pulwama out classed all other material in respect of height (18.80 m) and DBH (28.50 cm). Elm source from Pulwama exhibited a greater advantage in the leaf fodder to overall yield 17.2 kg/tree. Apricot based agroforestry system completing four growing seasons at Benhama, Ganderbal revealed a good potential for the stakeholder with maximum height of 3.10 m and collar diameter of 5.07 cm in combination with orchard grass. Among four types of grasses, orchard grass performed exceptionally well with 28 t/ha of green fodder yield. An arboretum of different multiple purpose tree species has been established at Benhama, Ganderbal. Till date about 24 different multipurpose tree species were planted in the arboretum for ex-situ conservation. Five thousand plants of MPTS raised by the centre were distributed among farmers through different KVKs and among the tribal farmers during the year.

Studies conducted by Solan centre showed that supplementation of normal feed with *Grewia optiva* leaves to crossbred dairy cows increased the milk yield (+1.09 kg/ animal/ day), milk fat (+0.636%), solid fat (+0.31%), total solids (+0.89%) and milk protein (+0.111%) over control group. Supplementation of normal feed with *Bauhinia variegata* leaves to crossbred dairy cows increased the milk yield (+0.52 kg/ animal/day), milk fat (+0.49%), solid not fat (+0.44%), total solids (+1.03%) and milk protein (+0.13%) over control group. Application of Jeevamrut @1000 litre /ha (organic input) to maize crop raised under *Grewia optiva* based agroforestry system increased the maize crop yield by 1.69 q /ha over recommended doses of fertilizer *i.e.* NPK @150 kg /ha N, 75 kg /ha P, 40 kg/ha K. Tree species of Mid-hill Himalayan ecosystem *viz.*, *Acacia catechu, Albizia chinensis, Bauhinia variegata, C. australis, F. roxburghii, G. optiva L. leucocephala, M. composita M. serrata, Olea glandulifera O. oojeinensia, Pittosporum floribundum, Quercus glauca, leucotrichophora* and *S. tetrasperma* were evaluated for their nutritional, anti-nutritional properties. Regression equations were also developed for predicting their leaf and branch biomass production (kg/tree/year) and calorific values (Kcal / kg/tree). The best fodder trees of Mid-hill Himalayan ecosystems in summer season are: *M. serrata* > *P. floribundum* >*B. variegata* > *C. australis* > *M. composita* whereas, in winter season, *G. optiva* was the best fodder species followed by *L. leucocephala* > *P. floribundum* > *O. oojeinensis* >*A. catechu, etc.*

D&D exercise conducted in Kangra and Palam-Valley sub-regions of Kangra district by Palampur centre revealed that in both the sub-regions, farmer have retained traditional agri-silviculture agroforestry system with fodder, timber and fuelwood trees mainly concentrated on boundary of the agricultural fields. Out of 42 species of trees classified on the basis of their uses, it was observed that 17 horticulture species (40%), 9 fodder species (21%), 7 timber species (17%), 4 fuel wood species (9%), 2 medicinal species (5%), 2 multi-purpose trees species (5%) and one species for religious purposes were present. Under Tree Improvement work, HP 5(b)71 seed source of *Toona ciliata* germplasm and sources AS3, AS5 of *Sapindus mukorossi* germplasm are best performing in the field in terms of different growth parameters. Under Horti-medicinal plant based agroforestry system, maximum yield 16.02 t/ha of Lemon grass was obtained with the application of 10t vermi-compost. Three (one day) agroforestry training programmes were organized by the centre under TSP for 150 tribal farmers which included 114 women from Kinnaur, Chamba and Kangra districts of the state. About 5.5 ha farmers' land / degraded *ghasnis* have been

developed under Silvi-pasture and Horti-pasture systems through people participation approach by the centre.

Under component Interactions in Mango based Agroforestry System in the Sub-tropics of Jammu and Kashmir by Jammu centre, performance of different intercrops *viz., Zingiber officinale, Andrographis paniculata, Stevia rebaudiana* and *Curcuma longa* was studied in mango based agroforestry system. The economic evaluation showed marked variation in the yield of different intercrops under the canopy of mango trees. In the year 2015, maximum value of B:C ratio (1.80) was recorded in turmeric, whereas, minimum in stevia (0.62). In the year 2016, being an on year, there was a high yield in mango which led to increase in B:C ratio. Highest B:C ratio of 3.13 was recorded in kalmegh. Lower B:C value of stevia indicated its unsuitability of intercropping in old orchards of mango under sub-tropical conditions of Jammu. The study on diagnostic survey and appraisal of agroforestry systems in Jammu district of Jammu and Kashmir was carried out to identify the existing agroforestry systems in the Jammu district and estimate the economic returns of agroforestry systems. Two major agroforestry systems were identified in the study area, agri-silvicultural system and agro-silvopastoral system contributing 23% and 77%, respectively. Average income from agri-silvicultural system was ₹ 1,64,833/ha whereas from agro-silvopastoral system was ₹ 1,81,820/ha. The TSP activities were carried in the villages *viz;* Naneter and Palai in Block Sumb of Samba district of Jammu and Kashmir during the year 2017-18. After consultation with the farm families, necessary inputs like hybrid maize seed was distributed during *Kharif*, 2017 for improving the productivity. Multi-nutrient mineral blocks were also distributed to the beneficiaries to improve the animal health and productivity.

Under *Gmelina arborea* tree improvement at Kahikuchi, seed source from Byrnihat (AAU 15 & AAU 16) and Silchar (AAU 17 & AAU 18) registered 16.93, 17.00, 14.67 and 16.18 m height after 16 year of plantation, whereas, AAU 18 (Silchar), recorded the highest timber volume of 0.8614 m^3 /tree, biomass of 943.18 Mg /ha and above ground C stock of 471.59 Mg /ha. In *Acacia mangium* based system, the maximum plant height (13.81 m) and DBH (29.92 cm) were observed in 5 m x 6 m spacing and 5 m x 5 m with intercrops, respectively. However, the maximum canopy diameter (8.75m), timber volume (207.12 m^3 /ha), tree biomass (334.5 Mg/ha) and above ground carbon stock (167.25 Mg/ha) was recorded in sole tree at 5 m x 4 m spacing. The maximum fodder yield of Hybrid Napier (48.20 t/ha) was obtained in sole fodder followed by tree spaced at 5 m x 6 m (45.19 t/ha), 5 m x 5 m (40.16 t/ha) and 5 m x 4 m (38.50 t/ha), respectively. In Jackfruit based system, tree height (7.79 m), DBH (27.93 cm), canopy diameter (3.80 m), timber volume (28.125 m^3/ha), tree biomass (86.249 Mg/ha) and above ground C stock (43.12 Mg /ha) of jackfruit was recorded in intercrop plot which was superior in comparison to sole tree.

Under tree improvement work at Ludhiana, a multi-locational trial for evaluation of 15 clones of poplar (5 from Pantnagar, 3 from HAU and 7 from PAU) was established at PAU Ludhiana and Bathinda in January 2014. After 4-year growth, the highest DBH (15.07 cm) and height (15.74 m) was attained in case of Pantnagar clone PP9-25 and PAU clone No. 10, respectively. Centre initiated a multi-locational trial of *Melia composita* in 2010. After 8 year age, the height of progeny 1 was the highest (15.82 m) followed by progeny 5 and 19 (15.32 m). The DBH was also maximum that of progeny 1 (26.13 cm) followed by progeny 19 (22.65 cm) and 7 (22.29 cm) at Bathinda. In a trial on performance of poplar and intercrops under different spacing (5 x 3 m, 7 x 3 m paired at 2.5 m, 8 x 2.5 m and 4 x 3 m), among sixteen wheat varieties, the grain yield of wheat varieties PBW 343 (4.41 t/ha), PBW 725 (4.11 t/ha), PBW 723 (3.98 t/ha), and PBW 677 (3.88 t/ha) was significantly higher than other varieties. Seven potato varieties *viz*; Kufri Jyoti, Kufri Pukhraj, Chipsona 3, Kufri Badshah, Chipsona 1, Khyatee and Pushkar were sown under 5-year-old poplar plantations, spaced at 8 x 2.5 m. The mean total yield was maximum in Khyatee (19.9 t/ha) and statistically at par with

Kufri jyoti (19.0 t/ha), and K. Badshah (18.0 t/ha). Among six wheat cultivars *viz;* HD 2967, WH 1105, PBW 677, HD 3086, PBW 725 and PBW 658 intercropped with 4 year old *Melia* plantation (7 m x 3 m paired at 2.5m), the highest grain yield was obtained from PBW 725 (4.18 t/ha) being at par with PBW 677 (4.13 t/ha). Effect of bio-fertilizer on growth of eucalyptus was studied and treatment combinations of 6 biofertilizer (Control, Consortium, PSB, Azotobacter of IARI, PAU Mycorrhizae, IARI Mycorrhizae) and 3 inorganic nutrient levels (N75 P100, N100 P75, N100 P100 % of recommended) were applied to eucalyptus. The DBH and height after two-year growth were highest with application of consortium (8.68 cm and 11.92 m, respectively). These were maximum at the 100% application of inorganic nutrients (8.72 cm and 12.35 m, respectively). Ludhiana centre conducted trial on effect of sewage sludge on tree growth and the average dbh and the height after five-year of growth was highest in case of eucalyptus (17.26 cm and 22.59 m, respectively). Last year Ludhiana centre produced about one lakh twenty-five thousand plants of poplar, clonal eucalyptus, clonal shisham, neem, M*elia* spp. and other important MPTS of the region and out of this one lakh poplar plants were produced for the State Forest Department for the distribution to farmers.

Higher grain yield of mustard was achieved with variety NDR-8501 (1.37 t/ha) as compared to Kranti (1.28 t/ha) and Varuna (0.96 t/ha) under *Dalbergia sissoo* based agrisilviculture system with paddy-mustard sequence at Faizabad centre. The variety Narendra Urd-1 showed significantly higher grain yield (0.84 t/ha) as compared to Pant Urd-35 (0.78 t/ha) and Pant Urd-19 (0.75 t/ha) under *Casuarina equisetifolia* based agrisilviculture system. Amongst four different agroforestry systems at Faizabad, the maximum total carbon in the system (Vegetation+soil pool) was found under *C. equisetifolia - P. guajava* based agri-silvihorticulture system followed by *C. equisetifolia* based agri-silviculture system. Net carbon accumulation and the uptake of NPK were also found higher under this system.

Bacterial diversity in three *Dalbergia sissoo* provenances have been analysed by Pantnagar centre. The soil microbial enzyme activity, metagenomic bacterial diversity and physico-chemical properties indicated significant variation in phosphorous solubilizing bacteria. The centre used biochar as growing media for clonal eucalyptus propagation. The results indicated higher rooting per cent, root length, shoot length and plant height of mini-cutting of *Eucalyptus* under perlite + pine needle biochar (50:50) followed by rice husk biochar growing media. Pantnagar centre was awarded a patent: "A Novel Hybrid Renewable Fuel Blends of Karanja Oil Ethanol for Compression Ignition Engine". Pantnagar centre supplied more than ten thousand saplings during the year.

Three varieties of turmeric *viz;* Rajendra Sonia, NDH-92 and Rajendra Sonali were grown in the interspaces of Aonla orchard at the age of 12 to 16 years at Pusa centre. Under 16 year old orchard, reduction in yield of turmeric was maximum with Rajendra Sonali (53.7 %) and minimum with NDH-92 (30.5 %) when compared to the yield in open area. The average turmeric yield data of five year (2013-2017) indicated that NDH-92 gave the maximum yield (18.51 Mg /ha). Turmeric yield and light intensity under canopies of Aonla orchard showed highly significant and positive relationship (r^2 = 0.802** to 0.864**). The average yield data of four years indicated that the production of fruits (16.01-16.17 Mg /ha) increased by 24 to 26 % due to intercrops. By and large, Aonla+NDH-92 system is the most profitable on the basis of Land Equivalent Ratio (2.06), Aonla Equivalent Weight (27.17 Mg /ha) and B:C ratio (4.15).

Growth, biomass, volume and carbon storage along an age series in kadamb plantations was assessed. The annual increment of *Kadamb* trees reached its maximum point or the interaction between MAI (Mean annual increment) and PAI (Periodic annual increment) at the age of 10 year. Volume of the tree increased with the age and varied from 66.0 (8 year old) to 116.5 m^3 /ha (12 year old). Carbon stock in stem varied between 16.83 and 29.71 Mg /ha from 8 to 12 year plantation age showing the removal of 61.8 –

109.0 Mg /ha CO_2 from the atmosphere. This study recommends *Kadamb* planting as a viable option for sustainable production and carbon mitigation. Yield of sesame crop was adversely affected under higher density three year old *Bombax* (Semal) plantations (666 – 1000 tree /ha). Sesame yield varied from 4.75 (5x2m tree spacing) to 5.40 q /ha (5x5m tree spacing). Height, girth at breast height (GBH) and crown diameter of tree varied from 2.53 to 3.34 m, 14.28 to 25.02 cm, and 1.56 to 2.60 m, respectively. Semal plantations of different spacings intercropped with sesame were found to have average light intensity varying from 375×100 lux (58.8%) to 462×100 lux (73.4%).

Among the silvipasture systems evaluated at Bhubaneswar centre, the maximum green forage yield was obtained from guinea (21.6 t/ha) with *Acaia mangium* from three cuttings followed by thin napier with *A. mangium* (20.7t/ha). All the three grasses recorded yield recovery above 86% as compared to sole crops. The highest net return of ₹ 17400 /ha/ yr and B:C ratio of 2.16 was obtained from guinea grass in association with *A. mangium* followed by thin napier with *A. mangium* with net return of ₹ 16050/ha/ yr and B:C ratio 2.07. In fruit based agri-silvi-horticultural system during second year of experimentation arhar was the most suitable crop with net returns of ₹ 36,920, ₹ 32,920 and ₹ 18,520/ha /year when intercropped with mango + eucalyptus, jackfruit + eucalyptus and cashew + eucalyptus having B:C ratios of 2.48, 2.32 and 1.74, respectively. Cowpea is the next best intercrop which recorded net return of ₹ 8,000, ₹ 5,500 and ₹ 4,720 /ha /year with B:C ratios 1.32, 1.22 and 1.19 when intercropped with mango + eucalyptus, jackfruit + eucalyptus and cashew + eucalyptus, respectively as against a net return of ₹ 12540 /ha and B:C ratio 1.50 when grown as sole .

In guava with arrow root system, the highest guava fruit of 25.50 q /ha, fresh arrowroot yield of 56.35 q /ha, net return ₹ 52,272 /ha and B:C ratio 1.97 was recorded with STD (100%) + FYM + bio-fertiliser followed by STD (100%) + FYM (24.36 q /ha and 53.72 q /ha, net return of ₹ 47,406/-/ha and B:C ratio 1.88) and STD (75%) + FYM + bio-fertiliser (23.84 q /ha and 51.40 q /ha, net return of ₹ 44,440 /ha and B:C ratio 1.84), respectively. The *Gmelina arborea* entries of Durgaprasad village of Daspalla block at 30 months after planting recorded the highest plant height (2.71 m), dbh (14.46 cm) and crown spread (2.10 m). The lowest plant height of 1.83 m, dbh 9.89 cm and crown spread 1.24 m was found with Badakameti.

Under TSP programme at the centre, Twenty-five tribal families of Durgaprasad village of Daspalla block in Nayagarh district were benefitted. Total 16.0 ha of Mango and Cashew based Agroforestry system demonstrations were done with brinjal, cowpea, okra and blackgram as intercrops. During 4th year of plantation of fruit trees, brinjal was the most profitable intercrop with net returns of ₹ 59,000, ₹ 70,160 /ha/year with B:C ratios 2.40, and 2.67 when intercropped with mango and cashew, respectively, as against a net return of ₹ 48,750 /ha/year with B:C ratio 2.22 when grown as a sole crop.

Design and diagnostic survey was done among farmer of the Mauzas Ramnagar, Murabani, Asanmoni Binpur-I block), Sagunbasa (Binpur-II block) and Dulalpur, Krishnanagar, Antapati (Jhargram block) in West Bengal by Jhargram centre. The centre continued evaluation of germplasms of *Gmelina arborea*, *Acacia auriculiformis* from promising six and eight germplasms, respectively. The promising fruit-based agroforestry models identified for the region, i. *Eucalyptus tereticornis* + mango – based agroforestry system; ii. *Gmelina arborea* + mango – based agroforestry system and iii. *Gmelina arborea* + sweet orange – based agroforestry system. Impact of these agroforestry systems with crop combinations of arhar, cowpea-toria, greengram-toria were studied for soil quality, and economic benefits. Though all these systems are profitable, but fruit-based silvi-agroforestry system with cowpea-toria was with highest B:C ratio. Fruit-based silvi agroforestry system with arhar showed better soil health. Centre initiated Mango based agroforestry system in about 2.81 ha at farmers' field in Binpur-I block, Jhargram and boundary plantation with 100 *Gmelina* saplings at 5 x 5 m spacing under TSP.

The Ranchi centre is working on *Gmelina arborea* under tree improvement work and the maximum plant height (2.53 m) was recorded in Latehar provenance, which is significantly superior over other provenances. In silvipasture system, it was observed that the average maximum plant height of *Gmelina* was 6.97m with forage crop (hybrid napier) and the growth of *Gmelina* was faster than teak in most of the treatments. The maximum yield of forage was recorded in pure hybrid napier (135 q /ha) which is 68% more yield than the lowest yield of sudan grass (92 q /ha). After nine yea` of tree plantation and forage cultivation under silvi-pasture system, the maximum organic carbon content (0.53%) and nitrogen content (242 kg /ha) were recorded in combination with Gmelina+sudan treatment and it was significantly superior over other treatments. This system is useful for utilization of degraded land to meet the requirement of fodder besides additional incomes.

Under Tribal Sub Plan work at Ranchi, it has been observed that tribal families have shown interest in intercropping with tree plantations. The farmers have adopted the package of practices of the agricultural crops *viz.*, ginger, onion, pea, tomato, reddish, cabbage, cucumber, bean, mustard and pulses and horticultural crops *viz;* mango, papaya, litchi etc. and tree crop like Gamhar, Teak, Bakain. The soil status of the farmers' field has improved after the cultivation/agroforestry practices. Besides this, the socio-economic status of the tribal farmers has increased with better livelihood.

Ailanthus excelsa germplasm evaluation studies in rainfed condition at S K Nagar, revealed that Mithivavadi and Soneripura seed sources are the best performing in terms of major growth parameters *viz*; plant height (9.40 m) and collar diameter (24.8 cm) after seven years of plantation. Significant difference among the ten elite progenies of neem along with a local check was observed for growth parameter in the multi locational co-ordinated trial after thirteen year of plantation. Progeny No 110 gave significantly highest plant height (7.90 m) and collar diameter (26.05 cm). Three medicinal plant species *i.e.* Kalmegh, Ashwagandha and Isabgol were intercropped in *Ailanthus excelsa* (Ardusa) plantation. Significantly highest Ardusa plant height (64.94 cm) was observed under Ardusa + Kalmegh followed by Ardusa + Ashwagandha and Ardusa + Isabgol. Two mycorrhizal cultures *i.e. Acaulospora scrobiculata* and *Rhizophagus intraradices* were tested in three crops namely ardusa, simarouba and neem in pots. The treatment of *Acaulospora scrobiculata* significantly increased the plant height (46.90 cm) of ardusa over control. The combined treatment of *Acaulospora scrobiculata* + *Rhizophagus intraradices* fungi gave significantly highest plant height (55.74 cm), collar diameter (2.52 cm) and shoot fresh weight (27.90 cm) in *Simarouba* over control and similarly the treatment of *Acaulospora scrobiculata* + *Rhizophagus intraradices* gave significantly higher root fresh weight (14.60 cm) of neem over control. The centre produced 8000 seedlings of different MPTs and medicinal tree species in the nursery for distribution to the farmer. Tribal Sub Plan was implemented in Vagdadi and Gavra villages of Banaskantha district comprising of 60 farmers. The tribal farmers have adopted different agroforestry systems *viz;* boundary plantation, horti-pastoral systems, vadi project etc. under TSP. Major activities implemented under TSP were supply of improved seeds of various intercrops (castor, moongbean, clusterbean, oat, barley and mustard), fertilizer, castor cake, insecticides (Chlorophyriphos), fungicide (COC), polythene sheet (Tadpatri) and hand tools to the selected farmers of Vagdadi and Gavra villages.

Survey work was conducted by Fatehpur Shekhawati centre in different district of Rajasthan for selection of Candidate Plus Trees (CPT's) of *Prosopis cineraria* and status of *P. cineraria* in the state. Twenty CPT's of *P. cineraria* were selected from Sikar (10) and Jhujhunu (10) district and seed were sown in nursery for further evaluation. The density of *P. cineraria* in Laxmangarh Tehsil and Fatehpur Tehsil of Sikar district recorded 45-50 trees/ha and 30-35 ease in

trees/ha, respectively. In rainfed condition, experiment under 21 year old *P. cineraria* based agri-silvi-culture system recorded highest yield (7.20 q/ha) in clusterbean variety RGC 1066 and lowest (2.80 q/ha) in Moth bean variety RMO 435. Significant variation were seen between crop varieties in comparison to control (without tree). It is also found that in the *P. cineraria* based agri-silviculture system percent yield increase over control (without tree) and ranges from 3.0% (mothbean) to 30.5% (clusterbean). Under rainfed condition experiment under 16 year old *H. binata* based agri-silviculture system showed decreasing trend in crop yields in comparison to control. The per cent decrease in yield of crops ranges from 5.0% (Moongbean) to 40.0% (Pearl millet). In silvipasture systems, maximum green fodder yield of *C. ciliaris* recorded with *P. cineraria* tree 255 q /ha followed by *Tecomella undulata* 220 q /ha, *A. indica* 155 q /ha and *H. binata* 135 q /ha.

In a spacing and variety evaluation trial in poplar based system at Hisar centre, height and dbh varied non significantly irrespective of spacing (3×3, 4×3, 5×3, 6×3, 7×3, 8×3 m) in poplar after one year of transplantation. Grain yield of wheat was significantly influenced both by variety and spacing. Among different spacings with respect to different wheat varieties, the maximum grain yield (4.85 t/ha) was recorded in wheat variety WH-1105 followed by variety HD-2967 (4.48 t/ha) in wider spacing (8×3m) of poplar. On an average, the highest per cent decrease in grain yield over control was recorded in wheat variety WH-711 (7.48%) under 3×3 m spacing. The rate of decrease in straw yield was comparatively lower than grain yield under different spacings of poplar. The fodder yield of berseem exhibited non-significant variation under different spacings of poplar after one year of transplantation. However, maximum fodder yield of berseem was found under 8×3 m spacing. In agri-silvi-horticulture system, at the age of seven years a significant increase in basal diameter and dbh of clonal (HC-2045) eucalypts was recorded. An average increase in height of 1.3 m also recorded. In the current growing session; maximum CAI (2.7) was observed for basal diameter in eucalypts followed by dbh (diameter at breast height) which indicated that trees achieved sufficient biomass during 7th year of growth.

In three year old poplar planted at 5×3 m spacing, maximum grain (4.92 t/ha) and straw (5.51 t/ha) yield was recorded in WH-1105 being statistically at par with HD-2967 but significantly higher than WH-711. Recommended dose of fertilizer + additional dose of N (10, 20 and 30%) significantly increased the grain as well as straw yield over recommended dose of fertilizer in all the varieties of wheat. Progenies of 18 CPTs of *Melia composita* exhibited significant variability w.r.t. growth character in the field. The plus tree progeny MCB2 from Haryana exhibited highest diameter at breast height followed by MCPAU2 and MCS6 from Punjab and Himachal Pradesh, respectively. Sixty eight clones of poplar from PAU, Ludhiana; GBPUA&T, Pantnagar and WIMCO has been raised in nursery and 14 clones from University of Horticulture & Forestry, Nauni, Solan have been observed for growth performance in field as multi-location trial. In a coordinated trial of shisham with eight clones, the significant variability for growth traits was observed among the clones. After 18 months of transplantation, the plant height differed significantly and ranged from 3.4 to 4.3 m with the general mean of 3.7 m. The highest basal diameter (3.4 cm) was observed in clone PS-38 closely followed by L-5 and L-1 and lowest (2.0 cm) in PS-54.

Nagpur centre focused on bamboo cultivation and its value additions. The centre has collected germplasm of twenty bamboo species where as being evaluated for variety of value added products. Bamboo species *Dendrocalmus stockssi, Bambusa arundinacea, Bambusa tulda, Bambusa balcoa* have been found better for cultivation in hot and dry agro-climatic conditions in the Vidarbha region. Centre has organised two workshop in collaboration with Maharashtra Bamboo Development Board and Bamboo Society of India - i) Bamboo harvesting, processing and value addition ii) Bamboo

nursery and Management of Plantations and developed Hi-tech nursery complex for production of quality planting material of medicinally useful trees for afforestation in the region. Seventy thousand saplings were raised for massive afforestation programme of Maharashtra state.

In provenance trial of babul, (*Acacia nilotica*) at Jabalpur centre, among 30 provenances collected from MP (17), Maharashtra (07), UP (02), Bihar (01), Chhattisgarh (02), and Punjab (1), at the age of 6½ year, Firojpur (Punjab) provenance recorded significantly higher plant height (4.76 m) and collar diameter (7.4 cm), MAI (2.82 m), CAI (1.16 m), whereas Shyampur, Sehore (M.P.) provenance recorded significantly lower plant height (1.49 m) and collar diameter (2.5 cm). In provenance trial of Shisham (*Dalbergia sissoo*) among seven provenances collected from Jhansi (02), Faizabad (01), Nagpur (01), Raipur (1), Samastipur, Bihar (1) and Jabalpur (01)], at the age of 7½ year, provenance received from NRC Jhansi recorded higher plant height (7.08 m) and collar diameter (11.5 cm) and dbh (9.3 cm). Under 19 year old agri-silvi-culture system (*D. sissoo*+Paddy-Mustard/Gram/Wheat rotation) where 4 pruning treatments (*viz;* no pruning, 25%, 50% and 75% pruning) and one open were carried out in main plot and three crop rotation [*viz;* T1- Early paddy (Danteshwari) - Mustard], [T2- Medium paddy (MTU-1010) - Gram], [T3- Late paddy (Kranti) - Wheat] in sub plot. Significantly maximum grain yield of paddy was recorded under open condition (15.03 q /ha) which was at par with 75% pruning (13.57 q /ha) and 50% pruning (12.61 q /ha). No pruning recorded significantly lowest grain yield (9.72 q/ha) at par with 25% pruning (9.82 q /ha).

Under On-farm trial, Jackfruit+chili based agroforestry practice gave higher monetary return (₹ 3,08,000/ha/year) as compared to growing of only fruit crop (₹ 1,88,000/ha /year) and vegetables crop *i.e.* chili (₹ 2,00,000/ha/ year). Jack fruit+tomato based agroforestry practice gave higher monetary return (₹ 2,46,000/ha/ year) as compared to growing of only fruit crop (₹ 1,88,000/ha/year) and vegetables crop *i.e.* tomato (₹ 1,25,000/ha /year). The B: C ratio of horti-vegetable was more as compared to growing of fruit crop alone or vegetables alone. In another farmer's field trial, agri-horticulture system (Aonla + Wheat) was more profitable (₹ 52,750 /ha) as compared to wheat alone (₹ 37,720 /ha). The B: C ratio of agri-horticulture system was more (2.63) as compared to growing of crop alone (2.35).

In provenance trial of *Acacia nilotica* var. *indica*, a progeny of RHRAN-1 recorded significantly highest plant height (12.09 m), collar diameter (32.19 cm), dbh (27.49 cm) and bole height (2.81 m) at the age of seventh year at Rahuri centre. During seventh year of second coppice, the differences among the treatments were statistically significant for all the character studied. The entry SRY-16 (Yashwant) recorded significantly highest plant height (12.10 m) and collar diameter (11.56 cm) and dbh (9.33 cm). Among the coppice of different eucalyptus clones, SRY-6 recorded significantly highest number of coppice (2.43). In agri-horticulture system of different fruit tree species with inter crop under irrigated condition, sole Anola recorded maximum plant height (2.67 m). The highest collar diameter was recorded in Tamarind + Aonla treatment (23.80 cm). Anola in sole cropping system registered highest branches per plant (3.47), east-west spread (2.21 m), north-south spread (2.46 cm). Treatment sole chickpea - sole soybean recorded the highest grain and straw yield of gram (22.11 and 27.86 q/ha) and highest grain and straw yield of soybean (19.42 and 23.32 q /ha). The highest soil organic carbon (0.57%) was observed in custard apple (sole). Under TSP programme 50 agricultural equipments *viz*., Cycle hoe, Vaibhav sickle, Maize shellar, Krishida hani and 1,00,000 sets of BxN hybrid Phule Gunwant were distributed to the tribal farmer of Nimoni, Palipada, Nijampur, Kasare and Karanjali villages of Nandurbar district.

Among the eleven Neem germplasm lines (received from CAFRI, Jhansi) planted during 2004 as Multi-location trial at Hyderabad, Line 106 (90%) recorded highest survival. Among the

test material, line 117 recorded a mean plant height of (7.8 m) followed by Line 118 (7.7 m). In Pongamia, 29 lines were tested and SRJ-3, SRJ-37, NGSR-13, and NGSR-14 registered highest survival of 100 per cent even after 13 year of establishment. The entries showed wide variability in respect of plant height and DBH. The entry SRJ-39 recorded highest plant height of 7.70 m followed by SRJ-43 (7.30 m), SRJ-45(7.20 m). In respect of DBH, the entry NGSR 27 recorded highest DBH of 66 cm followed by SRJ-39 (66 cm), SRJ- 38 (56 cm) and SRJ- 43 (55 cm). A total of 50 segregating lines of Gowri and Kaali were collected from UAS, Bangalore. All the lines have started flowering and fruiting after 6 year. Data on plant height, girth and fruit yield was recorded. Among the entries, RJS-34 recorded highest seed yield of 18.50 q/ha with plant height (5.1 m) and girth (40 cms). In *Melia dubia* (1 year old) based agroforestry system, different millets and pulses were tested. The data reveals that among millets higher grain and straw yield was recorded in pearl millet (8.76, 10.23 q/ha) followed by finger millet (7.75, 8.47 q /ha), foxtail millet (5.92, 6.46 q/ha). Among the pulses, higher grain yield was recorded with black gram (4.10 q/ha), cowpea (3.30 q/ha) and green gram (2.30 q/ha). The yields realized in intercropping is similar when compared to sole crop treatments. Significant higher net returns were realized with black gram intercropping (₹ 13,040/ha) with B: C ratio of 2.30 as compared to green gram and cowpea system. In case of millets, intercropping with pearl millet has produced higher net returns (₹ 7,764 /ha with B:C ratio 1.52 when compared to finger millet and foxtail millet.

In soil analysis blackgram as inter crop recorded higher organic carbon content (0.67%) which was at par with greengram and cowpea (0.64%). In custard apple based hortipasture system, 3 grasses *Cenchrus ciliaris*, *Panicum maximum* and *Hedge lucerne* were tested. The application of 100% RDF + 10 t FYM has produced significantly higher fruit yield (43.00 q /ha) followed by 100% RDF + 10 t Poultry manure (40.80 q /ha). Dry and herbage yield was significantly higher with *Cenchrus ciliaris* (12.2 t/ha) followed by *Panicum maximum* (8.0 t/ha), while the protein content was higher with *Hedge lucerne* (14%) followed by *Cenchrus ciliaris* (8.5%). Among the nutrient management practices, significant higher forage yield was attained with application of 100% RDF + 10 t FYM /ha (8.3 t/ha) which was at par with application of 100% RDF + 10 t Poultry manure (8.0 t/ha).

In the response of AM fungi in Subabul and Pongamia, seedlings were transplanted in the main field. While transplanting added the pot mixture and observed the seedlings survival. Survival in Pongamia is 100% and subabul is 0%. The height and girth recorded in Pongamia seedlings after 8 months of age was 0.41 m and 2.1 cm, respectively. There was no much variation in growth attributes due to various Arbusculor Mycorhhizae fungi when compared to control. In pearl millet intercropped in *Melia dubia* based agri-silvi system, different gas emissions like CO_2, N_2O were estimated. The significantly lowest CO_2 gas emission was observed with control and it was significantly lower (12.81 kg/ha/day) at all stages. The highest CO_2 emission was recorded with Sole crop of Pearl millet without trees with application of 80-40-30 N, P and K kg /ha.

Dharwad centre is working on Tamarind as one of the mandate tree species and hence collected 14 germplasms for evaluation. Among them, NTI-14 and SMG-13 were superior and were vegetatively propagated for large scale demonstration under farmer fields. Clonal orchards with these materials were also developed and multiplied. The centre is also having two collections of *Simarouba gluaca viz.*, Kali and Gouri which are being evaluated under different density levels. The growth and yield of Simarouba was higher in 5 x 5 m spacing. In a study on different density levels of *Melia dubia* based agroforestry system, dbh was significantly higher in 4 x 4 m spacing as compared to other spacings, tested. Among various collections of *Pongamia pinnata,* the maximum seed yield was observed in RAK-90 (3.13 kg/plant). Among seven fodder tree species evaluated under agroforestry systems, biomass was significantly higher in *Moringa olifera* (19.79 q/ha) and

Glyricidia sepium (17.27 q /ha) as compared to other fodder tree species.

The biomass and carbon sequestration of natural stand and different timber tree species grown with sapota based agroforestry systems were estimated. Among the tree species, significantly higher biomass and carbon sequestration were recorded in *Anogeissus latifolia* as compared to other tree species. In sapota based agroforestry system, biomass and carbon sequestration was significantly higher when sapota grown with *Lagestroemia lanceolata* as compared to other agroforestry systems.

A Biofuel Information and Demonstration Centre with the funding from Karnataka State Bio-energy Development Board, Government of Karnataka is in operation with an objective to cater various needs of the region. The centre established 'Biofuel Park' in an area of 40 acres to develop appropriate technology and environmental friendly farmer oriented bio-fuel production. Large scale clonal orchard of important bio-fuel tree species was also developed. During the year, 2000 kg of neem and 4477 kg of Pongamia seeds were procured by the centre and 2496 kg pongamia seeds were crushed to extract 900 lit of Pongamia oil. During the year, 306 lit of bio-diesel and 5962 kg of cake and 25 lit of biphenyl were also produced.

Ceiba pentandra (Kapok) and *Melia dubia* are the mandate tree species for Mettupalayam centre for tree improvement programmes. In kapok of the 14 clonal progenies evaluated for the past 10 year, 2 clonal progenies *viz.* Arachalur (MTPCP 8) and Paramakudi (MTPCP 30) were shortlisted based on their growth, yield and drought tolerant traits. Arachalur progeny (MTPCP 8) yielded the maximum pod yield of 1,14,124 pods /ha and the floss yield was 570 kg /ha. Owing to good biometric growth and pod yield traits of Arachalur (MTPCP 18), multi-location trial of the progeny was carried out during 2107-18. Rooted stem cuttings of Arachalur progeny (MTPCP 18) were provided to farmer covering an area of 18 acres. Two drought tolerant and high yielding progenies *viz.* Arachalur (MTPCP 18) and Paramakudi (MTPCP 37) were identified for establishment of organized Kapok plantations in rainfed areas as well as for promotion of the species as boundary plantations in agroforestry systems.

The centre has collected 20 progenies of *Melia dubia* from different parts of Tamil Nadu and Karnataka in coordination with the Department of Tree Breeding of the Institute. Thalamalai progeny (MD 1) and Kallar (MD 5) were observed to be promising in growth traits at 30 months after planting. In the Integrated tree fodder trial with *Casuarina junghuhniana* as the main crop (3 x 1.5 m spacing) along with 4 major tree fodder species (*Gliricidia sepium, Leucaena leucocephala, Sesbania grandiflora* and *Melia dubia*) in TNPL unit II, Mondipatti, Trichy district, T3 (Main crop +*Melia dubia*) recorded the minimum GBH of 34.62 cm at 48 MAP while control (T5) recorded the maximum GBH of 44.65 cm and the same trend was also observed at 54 MAP. Maximum green fodder yield was recorded in T2 (Main crop + *Leucaena leucocephala*) followed by T1 (Main crop + *Gliricidia sepium*). At rotation age of *C. junjghuhniana*, the best compatibility was observed in *C. junghuhniana* + *Leucaena leucocephala* with regard to main crop growth as well as green fodder yield.

Tree fodder model comprising of 19 major tree species (*Morus alba, Leucaena leucocephala, Leucaena diverifolia, Gliricidia sepium, Sesbania grandiflora, Holoptelia integrifolia, Thespesia populnea, Melia dubia, Albizia lebbek, Dalbergia sissoo, Inga dulce, Moringa oleifera, Ficus religiosa, Terminalia arjuna, Bauhinia purpurea, Neolamarkia cadamba, Hibiscus tiliaceus, Peterocarpus marupium* and *Pterocarpus santalinus*) was established as hedges. Maximum green fodder yield of 690.4 t/ha was recorded in *Dalbergia sissoo* followed by *Leucaena leucocephala* (617.3 t/ha). Under performance evaluation of silvipasture and hortipasture based Integrated Farming System, subabul recorded highest plant height followed by kadamba in silvipsature system and in hortipasture system, the height of moringa was higher followed by aonla. At 2 year of age, subabul recorded 4.27 kg green fodder per tree while Agathi recorded a yield of 3.8 kg of green

fodder per tree. Moringa recorded a pod yield of 216 pods per tree resulting in an income of ` 1080 per tree. Centre supplied more than fifty thousand seedlings of different species to farmer and forest department and generated about ` 3.30 lakhs in addition to ₹ 4.55 lakhs through sale of seeds/seedlings/ramets of industrial agroforestry tree species. Nine on-farm demonstration trials were established during the year by the centre.

Among thirty teak accessions from South India evaluated at Thrissur centre, the better ones were from Nedumkayam-1, Nedumkayam-2, Cherupuzha and Nellikutha-5. All these best performers were from Nilambur region. In *Acacia mangium*, the provenances like Kuranda, Arufi village and Upper Aramia showed better performance and hence will be screened for further tree improvement programme. They are also advocated as seed source for future planting programmes.

In Multitier home garden model, the coconut palms and MPTs are in their fifth year of growth. Coconut and cocoa have started bearing. Nutmeg seedlings were planted in the centre of every four coconut trees. The vegetables and spices such as cowpea, brinjal, amaranthus, cucurbits, turmeric and ginger were raised as intercrops. Model of multitier silvopature systems including hybrid napier grass, mulberry, calliandra, desmanthus and stylosanthes were also integrated in between the coconut trees. Hedgerow planting of calliandra and mulberry was done in the interspaces of coconut at a close spacing of 45 to 60 cm. Pruning at 1 m height and at interval of 2 months during rainy season and 3 months during summer season ensures higher forage yield and quality. Annual fresh fodder yield of 60 - 70 t/ha from second year onwards was obtained. About thirty five saplings of teak, mahogony, ailanthus, rose wood, neem, sandal, gmelina and other miscellaneous species were produced and distributed to the farmer.

Dapoli centre collected and conserved fifteen endangered tree species from Sahyadri hilly tract of Western India. The centre developed *Melia dubia* based medicinal agroforestry system in Konkan region of Maharashtra and *Acacia mangium, Termenelia tomentosa*, *Moringa* spp. on bunds of farmers' field. Under silvi-pasture system protein bank was established by planting various grasses under mango based system by cut and carry method. Centre contributed in five crore mega tree plantation program of Maharashtra State by supplying plants and playing active role in plantation. During the year four ton of vermi-compost was produced by recycling of agroforestry residues. Under TSP programme improved male goat breed was supplied to tribal farmer for enrichment of local breed of goat in Tribal areas.

Database creation of agroforestry models in Western zone of Tamil Nadu by Kattupakkam centre revealed that, nearly 55.63% of the farmer were having coconut garden with understorey Bajra napier hybrid grass. Fodder sorghum Co 31 undertorey *Cocus nucifera* gave a yield of 22.23 t/harvest/ha and Fodder cowpea Co (FC) 8 in *Psidium guajava* based pasture system gave yield of 5.33 t/ha in degraded waste lands. Fodder sorghum Co 31 had a CP, DCP and TDN of 7.9, 5.52 and 69.74% on dry matter basis, and Fodder cowpea Co (FC) 8 had a CP, DCP and TDN of 18.25, 12.76 and 72.20%, respectably on dry matter basis. At 48 hour rumen *in vitro degradation,* fodder sorghum Co 31 revealed *in vitro* true digestibility of dry matter (IVTDDM) of 62.89% and microbial biomass of 10.12% and fodder cowpea Co (FC) 8 had *in vitro* true digestibility of dry matter (IVTDDM) of 65.16% and microbial biomass of 11.28%. Crop residue based compost enriched with *Gliricidia sepium* green biomass at 3:1, 3:2 and 3:3 ratios were superior over compost with only crop residue, in terms of nitrogen, phosphorus and potassium.

The Bangalore centre has developed the transferable technologies for *Melia dubia* based agroforestry system for bund, boundary and block plantation; perennial tree based agroforestry systems for sustainable fodder production; agroforestry based integrated farming systems for small and marginal farmers; precision maize cultivation in Tamarind orchard and aerobic rice cultivation in mango orchard.

These technologies help in sustaining production, profitability and soil health besides sustaining the livelihood security of the farmers by providing nutritious food, fodder, fuel, income, employment generation *etc.* In addition, this centre is giving much importance on improvement of mandate trees (Simarouba and Tamarind), identification of existing agroforestry systems through tree survey in southern districts of Karnataka. During the year, tree survey was conducted in Bangalore rural district of south Karnataka. The survey showed that bund, boundary planting and block plantations are the common agroforestry systems in arable lands. In bund and boundary planting system, pongamia, coconut, melia, sesbania, jackfruit, teak, albizia, silveroak, tamarind, neem, ficus, casurina, arecanut and terminalia were common. Arecanut, teak, silveroak, melia, guava, mango and sapota are the common trees planted in the block plantations.

Tribal sub plan was implemented in Hebbala village (130 families), Hunsur Taluk, Mysore District. The major activities implemented were construction of farm pond; distribution of sprayers and tarpaulins; trainings on improved cultivation practices for agroforestry trees, agricultural crops, fruits & vegetables and distribution of seedlings of *Melia dubia, Mangifera indica, Syzygium cumini,* Tamarind, Cherry and *Cocus nucifera*.

In D & D survey conducted by Ponnampet centre, important agroforestry practices found in the area were plantation crops in combination with trees, boundary planting, bund planting, scattered trees and home gardens. Among the different agroforestry practices scattered trees in coffee plantation (plantation crops in combination with trees) was found to be the highest (36%) followed by home gardens (25%). Information on tree domestication revealed that more number of native species with more of conservation values were preferred for domestication as compared to exotics and commercial species. The centre has produced around 16 Kg of *Garcinia gummigutta* extract and generated a receipt worth of ₹ 13,600. Under TSP programme tribal communities in the Virajpet taluk were supported through different schemes such as provision of chicks to have poultry birds to ensure supply of animal proteins. Training programme on kitchen garden and mushroom cultivation were organised and important vegetable seeds and mushroom spawns were distributed to tribal beneficiaries. In order to enhance the tribal income, piglets were distributed to tribal beneficiaries. It is prudent to mention that some of the tribal community member produced piglets and each piglets were sold at ₹ 3000. Honey produced from the bee boxes supplied to the tribal beneficiaries resulted in production around 30 Kg of honey which were sold at the rate of ₹ 500/- per kg. Majority of the tribal hamlets were not having electricity and students who were studying in the hamlets were provided solar lamps.

ANNUAL GROUP MEETING

The Annual Group Meeting of All India Coordinated Research Project on Agroforestry was organized at Birsa Agricultural University, Ranchi from 28-30 July, 2018 with inauguration by Dr. Parvinder Kaushal, Hon'ble Vice Chancellor of the University. In his inaugural speech Dr. Kaushal stressed upon transfer of proven technology to the farmer field and impact assessment of these technologies. He emphasized the need for integrating livelihood options in the agroforestry models. Dr. S. Bhaskar, ADG (Agron./AF and CC),NRM Division, ICAR, New Delhi highlighted the future thrust areas and asked all the centres to ensure economic security of the farmer and to identify most important technologies for He

further dissemination. He urged the centres to compile the information on work done on bamboo under the project to showcase our strength on bamboo research and submit projects under National Bamboo Mission. Dr. Anil Kumar, Project Coordinator and Director, ICAR-Central Agroforestry Research Institute, Jhansi presented the Co ordinator Report and the brief summary of the research achievements of the project for the year. Dr. Javed Rizvi, Regional Director of World Agroforestry Centre, South Asia programme highlighted the achievements and future programmes under ICAR -ICRAF workplan for the year. In the beginning, Dr. D. N. Singh, Director of Research of the host University welcomed the dignitaries and delegates and highlighted the significant achievements of the university. During the occasion four publications on agroforestry published by coordinating centre were released by the dignitaries. During the meeting there were nine technical sessions including inaugural and valedictory sessions and field visit to the experimental area of the Project at BAU, Ranchi. There was an invited talk on Role of Information and Communication technology (ICT) in Agroforestry by Dr. Manoj Khare, from Centre for Development of Advanced Computing, Pune. The best presentation award was presented to coordinating centre CCSHAU, Hisar and BSKVV, Dapoli.

CHAPTER 4 AWARDS AND RECOGNITIONS

- Dr. Dhiraj Kumar received "Young Scientist Award-2018" by The Society of Tropical Agriculture. This award was conferred during "7th International Conference on Agriculture, Horticulture and Plant Sciences" held during 28th -29th June, 2018 at Shimla (H.P.).

- Dr. Dhiraj Kumar was awarded 'Best Research Paper Presentation Award' for the paper entitled "Distribution of fine roots of well-established *Phyllanthus emblica* (Aonla) based agroforestry system in Bundelkhand region of Central India" during "7th International Conference on Agriculture, Horticulture and Plant Sciences" held during 28th -29th June, 2018 at Shimla (H.P.).
- Dr. Badre Alam, Principal Scientist awarded 'Best Worker Award' for outstanding contribution in the Science and Institution development during 30th Institute Foundation Day (8th May, 2018).
- Dr. Badre Alam, Principal Scientist received Best Research Paper Publication Award in 2018 during Institute Foundation Day (8th May, 2018) for the research paper by Badre Alam et al. entitled "Different genotypes of *Dalbergia sissoo* trees modified microclimate dynamics differently on understory crop cowpea (*Vigna unguiculata)* as assessed through ecophysiological and spectral traits in agroforestry system" published in *Agricultural and Forest Meteorology*, 249: 138-148.

- Dr. Mahendra Singh, Dr. K B Sridhar, Dr. Dhiraj Kumar, Dr. R P Dwivedi, Dr. Inder Dev, Dr. R K Tewari and Dr. O P Chaturvedi received Best Popular Article Award (English) for the article entitled "Agroforestry for doubling farmers' income: a proven technology for trans-gangetic plains zone of India" published in Indian Farming, January issue, 2018. This honour was conferred at the function of 30th Foundation Day Celebration on 8th May, 2018.
- Dr. Sudhir Kumar Honoured with Best Worker (Field Operation) award during 30th Foundation Day of ICAR-CAFRI on 8th May 2018.
- Sh. B Singh, awarded 'Best Worker Award' in the technical category during Institute Foundation Day (8th May, 2018).
- Sh. J J Singh, Assistant awarded 'Best Worker Award' in the administrative category during Institute Foundation Day (8th May, 2018).
- Dr. Naresh Kumar, Dr. Asha Ram, Dr. Inder Dev, Dr. A. K. Handa and Dr. Anil Kumar awarded Best poster Award (3rd Prize) in Poster Competition. Bans ka Samvardhan Poster presented in Poster competition in Hindi Saptah during 14th -20th September, 2018.

- Dr. Sudhir Kumar bagged Ist prize in "Sulekh evam Imla" pratiyogita during "Hindi Saptah (14th -20th September 2018)" held on 18th September, 2018 at ICAR-CAFRI, Jhansi.
- Dr. Sudhir Kumar bagged IInd prize in "Shodh Patra Poster" pratiyogita during "Hindi Saptah (14th -20th September, 2018)" held on 20th September, 2018 at CAFRI, Jhansi.
- Dr. R P Dwivedi received EE Fellow Award of Society of Extension Education, Agra by Hon'ble Agri Minister, Govt. of Sikkim, at Gangtok during 9th National Extension Congress-2018 on "Climate Smart Agricultural Technologies: Innovations and Interventions" during 15th -17th November,

- Dr. Naresh Kumar awarded Emerging Scientist Award -2018 by the Agricultural Technology Development Society (ATDS), Ghaziabad (UP) for his outstanding contribution and recognition in the field of Conference on "Advances in Agricultural, Biological and Applied Sciences for Sustainable Future (ABAS-2018) during 20th - 22nd October,2018 held at Sardar Patel Auditorium, Swami Vivekanand Subharti University, Meerut (U.P.)
- Dr. Veeresh Kumar awarded "Fulbright-Nehru Post-Doctoral Fellow" from United States-India Educational Foundation (USIEF) during 2019-20.
- Best Oral Presentation award awarded to Dr. Veeresh Kumar (Co –author) for the paper authored by Sanjay Kumar, Tejveer Singh, Veeresh Kumar, Maharishi Tomar of the paper "Plant pollinator interaction to enhance berseem (Tifolium alexandrium L.) seed yield". Paper presented in the National Symposium on "Forage and livestock based Technological innovations for doubling farmers' income" 13th to 14th December, 2018 held at University of Agricultural Sciences, Dharwad.
- Dr. Asha Ram, Dr. Inder Dev, Dr. Ramesh Singh, Dr. Naresh Kumar and Dr. Dhiraj Kumar awarded Best Poster Award during RMSI National Symposium at UAS Dharwad. Poster presented on "Initial impact of soil and water conservation measures on biomass potential in silvipastoral system" in technical session on "Maximizing forage production from arable and non-arable land and agroforestry" at National symposium on 'Forage and livestock based technological innovations for doubling farmers' income' held at UAS Dharwad during 13th-14th December, 2018.

CHAPTER

5 ON GOING PROJECTS (2018-19)

Sl.	Project Code	Title of the Project	Leader	Associates
(A)	**SYSTEM RESEARCH PROGRAMME**			
1	NRMACAFRISIL 201000200085	Nutrient management in ber based agri-horti. system	**Sudhir Kumar**	Anil Kumar, Rajendra Prasad, Inder Dev & Veeresh Kumar*
2	NRMACAFRISIL 201600100099	Performance of pomegranate integrated with lemon grass under organic regime	**Sudhir Kumar**	Rajendra Prasad & Veeresh Kumar*
3	NRMACAFRISIL 201600200100	Structural and functional analysis of short rotation tree based agroforestry system	**Naresh Kumar**	A K Handa, Asha Ram, Inder Dev, Dhiraj Kumar, Kamini (ICAR-IGFRI, Jhansi) & Mahendra Singh
4	NRMACAFRISIL 201600300101	Studies on soil biodiversity & nutrient dynamics in different agroforestry & mono-cropping system	**Veeresh Kumar***	Anil Kumar, Dhiraj Kumar, Naresh Kumar, Mahendra Singh & N. Manjunath (ICAR-IGFRI, Jhansi)
(B)	**NATURAL RESOURCE & ENVIRONMENT MANAGEMENT PROGRAMME**			
1	NRMACAFRISIL 200800200078	Studies on arbuscular mycorrhizal fungi of important MPT's	**Anil Kumar**	Rajendra Prasad & Naresh Kumar
2	NRMACAFRISIL 201100200088	Multi-source inventory methods for quantifying carbon stocks through generalized volume/ biomass equations for prominent agroforestry species in India	**R H Rizvi**	A K Handa
3	NRMACAFRISIL 201300100091	Agroforestry based conservation agriculture for sustainable landuse	**Inder Dev**	Asha Ram, Ramesh Singh, Dhiraj Kumar, K B Sridhar, Naresh Kumar, Veeresh Kumar*, Mahendra Singh & Lal Chand

4	NRMACAFRISIL 201600400102	Agroforestry based Integrated Farming System for small and marginal farmers in semi-arid region	**Ram Newaj**	Asha Ram, Sudhir Kumar, Naresh Kumar, Ramesh Singh, Dhiraj Kumar, Veeresh Kumar* & Mahendra Singh
5	NRMACAFRISIL 201600500103	Impact of watershed and agroforestry interventions on hydrology and nutrient loss at Garhkundar-Dabar watershed in Bundelkhand region of Central India	**Ramesh Singh**	Dhiraj Kumar
6	NRMACAFRISIL 2016007104	Relevance of soil and water conservation measures in enhancing productivity and sustainability of silvipastoral system in semi-arid conditions	**Asha Ram**	Ramesh Singh, Naresh Kumar, Dhiraj Kumar & Inder Dev
7	NRMACAFRISIL 2016008105	Horizontal and vertical distribution of fine roots of tree and nutrients content in well-established Aonla and *Hardwickia binata* based agroforestry system	**Dhiraj Kumar**	Ram Newaj, Rajendra Prasad & Asha Ram
8	NRMACAFRISIL 2016008106	Effect of Abuscular mychorizal inoculation on productivity of agroforestry systems	**Anil Kumar**	Sudhir Kumar, Naresh Kumar, Dhiraj Kumar & Inder Dev
(C)	**TREE IMPROVEMENT, POST-HARVEST & VALUE ADDITION PROGRAMME**			
1	NRMACAFRISIL 200700400071	Comparative studies on seedling and clonal plants of *Pongamia pinnata* with special reference to their adaptability to rainfed dry agroclimate	**Badre Alam**	A K Handa
2	NRMACAFRISIL 201500100092	Evaluation and characterisation of different Leucaena germplasm at CAFRI	**K Rajarajan**	A K Handa, A K Singh, (IGFRI) & Maneet Rana (IGFRI)
3	NRMACAFRISIL 2016009107	TBOs based agroforestry models	**K B Sridhar**	Inder Dev
4	NRMACAFRISIL 20160010108	Mass propagation of Industrial trees viz. *Eucalyptus tereticornis, Casuarina junghuhniana Miq. Melia dubia* and *Populus deltoides* using micro and mini clonal cuttings	**K B Sridhar**	Lal Chand

5	NRMACAFRISIL 201701100112	Integrated development of Jatropha and Karanj	**Naresh Kumar**	Lal Chand
6	NRMACAFRISIL 201801100114	Functional genomics for early drought tolerance in *Pongamia pinnata* genotypes	**K Rajarajan**	A Radhakrishnan, K B Sridhar & Lal Chand
(D) HRD, TECHNOLOGY TRANSFER & REFINEMENT PROGRAMME				
1	NRMACAFRISIL 201500200093	Socio-economic, energetic and environmental impact assessment of watershed and agroforestry interventions at Garhkundar-Dabar watershed in Tikamgarh district of Madhya Pradesh	**R P Dwivedi**	R K Tewari, Ramesh Singh, R H Rizvi & Mahendra Singh
2	NRMACAFRISIL 201500300094	Economic evaluation of poplar and eucalyptus based agroforestry systems prevalent in Indo-Gangatic Plains, India	**Mahendra Singh**	R P Dwivedi, Inder Dev, R H Rizvi, K B Sridhar & Dhiraj Kumar
PROJECTS CONCLUDED DURING IRC-2018				
1	NRMACAFRISIL 200700100068	Evaluation of shade tolerance of crop species for agroforestry systems	**Badre Alam**	Ram Newaj
2	NRMACAFRISIL 200400100054	Genetics and breeding of Jatropha species	**Naresh Kumar**	K. Rajarajan

EXTERNALLY FUNDED PROJECTS

Sl.	Project Code	Title of the Project	Leader	Associates	Funding Agency
1	NRMACAFRISOP 200800100075	Harvest and post-harvest processing and value addition of natural resins, gums and gum resins	**Rajendra Prasad**	A K Handa, Ramesh Singh & Badre Alam	ICAR, IINR&G Ranchi
2	NRMACAFRISOL 201500700096	National mission for sustaining the himalayan ecosystems (NMSHE-taskforce 6 for Himalayan Agriculture)	**A K Handa**	Inder Dev, Badre Alam, Mahendra Singh & Asha Ram	DST, New Delhi
3	NRMACAFRISOL 20110030087	Assessment of carbon sequestration potential of agroforestry systems (NICRA)	**Ram Newaj**	Rajendra Prasad, A K Handa, Badre Alam & R H Rizvi	ICAR Network Project
4	NRMACAFRISOL 201601100110	Development of nursery of TBOs for quality planting material production	**K B Sridhar**	Naresh Kumar, Lal Chand & K Rajarajan	NMOOP MM-III Project

5	NRMACAFRISOL 201700100111	Studies on pollination dynamics, pod yield and oil content in *Pongamia pinnata*	**Veeresh Kumar***		SERB- DST Project
6	NRMACAFRISOL 201800100112	Mapping and estimation of area under poplar based agroforestry systems in Indo-Gangetic Plains of India	**R H Rizvi**	A K Handa & K B Sridhar	ICAR-ICRAF Work Plan

INTER INSTITUTIONAL AND INTERNATIONAL COLLABORATIVE PROJECT

Sl.	Project Code	Title of the Project	Leader	Associates	Funding Agency
1	----	Water requirement of grass based inter-cropping system in semi-arid area	J B Singh, IGFRI, Jhansi	**Ramesh Singh,** Mahendra Prasad, Amit Kumar & Singh- IGFRI, Jhansi	Inter-Insti-tutional (IGFRI-Jhansi)
2	NRMACAFRISOP 201100100085	Enhancing groundwater recharge and water use efficiency in SAT region through watershed interventions-Parasai-Sindh Watershed, Jhansi	**Ramesh Singh**	R K Tewari, Inder Dev, R H Rizvi , R P Dwivedi, K B Sridhar, Dhiraj Kumar & Mahender Singh	ICRISAT, Hyderabad
3	----	Farmer FIRST programme (FFP): Scaling up and integration of fodder technologies in existing farming system for sustainable livestock productivity in Bundelkhand	Purshottam Sharma	Sunil Seth, S K Mahanta, Harsh Vardhan Singh, Mukesh Choudhary & R P Dwivedi	Inter-Insti-tutional (IGFRI-Jhansi)
4	---	Studies on pollination dynamics in berseem	Sanjay Kumar	Tejveer Singh & **Veeresh Kumar***	Inter-Insti-tutional (IGFRI-Jhansi)

• Associated upto 12th February, 2019

CHAPTER 6 PUBLICATIONS

(A) Research Journals

Alam, B, Singh, R, Chaturvedi, M, Newaj, R and Chaturvedi, O P (2018). Determination of critical low light limit and adaptive physiological and biochemical traits regulating growth and yield of mustard (*Brassica juncea* Coss.). *Physiology and Molecular Biology of Plants,* 24(5):985-992.

Alam, B, Singh, R, Uthappa, A R, Chaturvedi, M, Singh, A K, Newaj, R, Handa, A K and Chaturvedi, O P (2018). Different genotypes of *Dalbergia sissoo* trees modified microclimate dynamics differently on understory crop cowpea (*Vigna unguiculata)* as assessed through ecophysiological and spectral traits in agroforestry system. *Agricultural and Forest Meteorology,* 249: 138-148.

Anuragi, Hirdayesh, Srijan, Ambati and Jain, Bharat Taindu (2018). RNA-guided multiplex genome engineering using *cas9* nucleases for crop improvement: A review. *Indian Journal of Agricultural Sciences,* 88(12): 1811-17.

Asha Ram, Kumar, Dinesh, Shivay, Y S, Anand, Anjali, Singh, Nain and Dev, Inder (2018). Effect of sulphur on growth, productivity and economics of wheat (*Triticum aestivum*) and residual soil fertility under aerobic rice (*Oryza sativa*)–wheat cropping system in Inceptisols. *Indian Journal of Agronomy,* 63(3):271-277.

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Dev, Inder, Radotra, Sudesh, Ram, Asha, Singh, J P, Deb, D, Roy, M M, Srivastava, M, Kumar, Pardeep, Ahmad, Suheel and Chaurasia, R S (2018). Species richness, productivity and quality assessment of grassland resources in hill agroecosystem of western Himalaya. *Indian Journal of Animal Sciences,* 88 (10): 1167–1175.

Dev, Inder, Asha Ram, Ahlawat, S P, Palsaniya, D R, Newaj, Ram, Tewari, R K, Singh, Ramesh, Sridhar, K B, Dwivedi, R P, Srivastava, M, Chaturvedi, O P, Kumar, R V and Yadav, R S, (2017). Bamboo (*Dendrocalamus strictus*) + sesame (*Sesamum indicum*) based agroforestry model: A sustainable livelihood option for farmers of semi-arid region. *Indian Journal of Agricultural Sciences,* 87 (11): 1528-34.

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Kumar, N, Kamini, Ram, A, Handa, A K, Dev, I, Chand, L, Shukla, A and Kumar, D (2019). Allelopathic impact of *Anthocephalus cadamba* (Roxb.) Miq. and *Melia dubia* Cav. on *Triticum aestivum* L.: Bioassay study. *Journal of Pharmacognosy and Phytochemistry.* 8(1): 1265-1269.

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CHAPTER 7 IMPORTANT MEETINGS /ACTIVITIES

Research Advisory Committee

20th RAC meeting of ICAR-CAFRI was held on 12th March, 2018 under the chairmanship of Dr. Tej Partap, Former Vice-Chancellor, Sher-E-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar; Dr. S. Bhaskar, ADG(A, AF/CC), NRM Division, ICAR, New Delhi; Dr. M. A. Shankar, Ex. Director of Research, University of Agricultural Science, Bangalore; Dr. P. Kaushal, Vice-Chancellor, BAU, Ranchi; Dr. V. K. Mishra, Ex-Dean, College of Horticulture & Forestry, Solan and Dr. Anil Kumar, Director (A), CAFRI, Jhansi (Members of RAC) participated in the RAC meeting. The Committee interacted with the Scientists and reviewed the ATR of previous RAC.

30th Foundation Day

ICAR- CAFRI, Jhansi celebrated its 30th Foundation Day on 8th May, 2018. Dr. Alka Bhargava, Joint Secretary, National Agroforestry & Bamboo Mission (NABM), Department of Agriculture and Cooperation, Ministry of Agriculture and Farmers Welfare, Govt. of India, Krishi Bhawan, New Delhi was the Chief Guest of the function. Dr. Bhargava in her foundation day lecture highlighted the development of small & marginal farmers by transferring the agricultural and agroforestry technologies at their field. Guest of Honour Dr. A K Mishra, Director, ICAR-IGFRI, Jhansi appreciated the contributions made by the Institute.

Certification of Trees outside Forests (TOF): Agroforestry

A workshop on "Stakeholder consultation on trees outside forests certification standard" under chairmanship of Dr. Devendra Pandey held on 16th May, 2018 at ICAR-CAFRI, Jhansi.

International Yoga Day

International Yoga Day was organized on 21st June, 2018 at the Institute and staff members participated in the different activities.

Institute Research Council

Institute Research Council (IRC) meeting was held on 26th & 30th June, 2018. All the Scientists of the Institute participated in the meeting and presented the progress and significant findings of their projects.

Vigilance Awareness Week

Vigilance Awareness Week was organized from 31st October to 5th November, 2018. During this week, slogan competition conducted and lectures were delivered. Oath was taken by all staff members to discourage act of corruption in India.

Institute Management Committee

The 19th IMC meeting was held on 27th November, 2018 at ICAR-CAFRI, Jhansi under the chairmanship of Dr. Anil Kumar, Director, ICAR- CAFRI, Jhansi. Chairman IMC appraised to the house about the Human Research Development, Education, nomination of Scientists, Technical and Administrative staff to Training/Workshop organized by the different scientific organization for their exposure and to update their knowledge. The Chairman also appraised about the training imparted to the farmers sponsored by the State Govt. After the discussion, the Committee confirmed the proceedings of 18th IMC. The Committee, thereafter, discussed the new proposals.

World Soil Day

World Soil Day cum Farmers' workshop on 05th December, 2018 was organized. The chief guest of the programme was Smt. M. Arun Mozhi, IAS, Joint Magistrate, Jhansi. On the occasion, an exhibition on importance of soil health cards was organized and agroforestry technologies were

also demonstrated. The programme was attended by 265 participants of which 110 farmers from 7 districts of Bundelkhand (Jhansi, Jalaun, Lalitpur, Mahoba, Hamirpur, Banda and Chitrakut), 55 students of RLBCAU, Jhansi and staff members of ICAR-CAFRI, Jhansi, NGOs people, ICAR institutes and state line departments.

Death Anniversary of Bharat Ratna Late Sh. Atal Bihari Vajpayee Ji

The ICAR-Central Agroforestry Research Institute, Jhansi (U.P) observed the death anniversary (16th September, 2018) of Bharat Ratna late Sh. Atal Bihari Vajpayee Ji. On this occasion, Director (I/c) briefed the staffs of the Institute about late Sh. Atal Bihari Vajpayee Ji and it was followed by giving tribute to him by reciting the poems composed by him.

Commemorating 150th birth anniversary of Mahatma Gandhi from 2nd October, 2018 to 2nd October, 2019

A quiz programme on Gandhi Ji was organized by the ICAR-CAFRI, Jhansi on 14th November, 2018 in the Institute. All staff members participated in the programme. A field demonstration on "Farm waste management through composting" was organized by the ICAR-CAFRI, Jhansi on 01st December, 2018 at the Institute farm.

Republic Day and Independence Day

Republic Day (26th January, 2018) and Independence Day (15th August, 2018) were celebrated at ICAR-CAFRI, Jhansi. Flag hoisting ceremony was observed on both the occasions. Cultural programmes and sport events were organized for the staff along with their family members on the occasions.

CHAPTER

8 PARTICIPATION IN WORKSHOP/ COORDINATION/MEETINGS/SYMPOSIA

Duration	Event	Venue	Participants
8th January 2018	Institute Management Committee meeting	ICAR-IIFSR, Modipuram, Meerut (UP)	Dr. A K Handa
13th January, 2018	Consultative meet Network for Certification and Conservation of Forests		Dr. A K Handa
22nd January, 2018	Meeting of progress of Sub Mission on Agroforestry under National Mission on sustainable Agriculture	NASC Complex, New Delhi	Dr. A K Handa
15th & 16th February, 2018	Second Meeting of Expert Committee to increase Tree outside Forest by MoEF & CC	New Delhi	Dr. A K Handa
20th February, 2018	Delivered a lecture on PPV&FRA	KVK, Datia	Dr. K Rajarajan
6th -8th March, 2018	EU-India Conference on Advanced Biofuels	New Delhi	Dr. K. B. Sridhar
8th & 9th March, 2018	Third Meeting of Expert Committee to increase Tree outside Forest by MoEF & CC	New Delhi	Dr. A K Handa
25th -26th March, 2018	International Conference on "Environmental, Educational and Biological Research for Human Welfare"	BHU, Varanasi (UP)	Dr. Naresh Kumar & Sh. Lal Chand
27th-29th March 2018	International workshop on Technological Innovation and Management for Sustainable Development	ITM University, Sithouli, Gwalior (MP)	Dr. Badre Alam
16th April, 2018	Seminar on Recent Development in Bamboo sector and road ahead	New Delhi	Dr. A K Handa
25th-26th April, 2018	National Conference on Agriculture for Kharif Campaign, 2018, organized by DAC&FW, Ministry of Agriculture and Farmers Welfare, New Delhi as Subject Matter specialist for Agroforestry	Vigyan Bhawan, New Delhi	Dr. A K Handa
27th-29th April, 2018	International Agroforestry Conference on "Promotion of Agroforestry for Rural Income Generation, Climate Change Mitigation and Adaptation"	Kathmandu (Nepal)	Dr. Anil Kumar & Dr. R H Rizvi

2nd May, 2018	Inception Workshop of Joint collaborative project with ICRAF- ICAR	Bhubaneshwar (Odisha)	Dr. A K Handa
14th-15th May, 2018	Invited Speaker a National Conference on Agroforestry	KAU, Thrissur (KA)	Dr. A K Handa
28th-29th June, 2018	7th International Conference on "Agriculture, Horticulture and Plant Sciences" organized by the Society of Tropical Agriculture, New Delhi	Shimla (HP)	Dr. Dhiraj Kumar
28th-30th July, 2018	Annual Group Meeting of AICRP-Agroforestry	Birsa Agriculture University, Ranchi (Jharkhand)	Dr. Anil Kumar, Dr. Ram Newaj, Dr. Sudhir Kumar, Dr. A K Handa, Dr. R P Dwivedi, Dr. Mahendra Singh, Dr. Naresh Kumar, Dr. Asha Ram, Dr. C K Bajpai & Sh. S B Sharma
13th September, 2018	First meeting of State Level technical Committee of UP State Agroforestry Mission	Lucknow (UP)	Dr. A K Handa
18th-19th September, 2018	National Conference on Agriculture for Rabi campaign 2018 as Subject Matter specialist for Agroforestry, organized by DAC&FW, Ministry of Agriculture and Farmers Welfare, New Delhi	NASC Complex, New Delhi	Dr. A K Handa
11th-12th October, 2018	National workshop on productivity enhancement and post-harvest management of Bamboo	Indore (MP)	Dr. K B Sridhar
16th October, 2018	World Food Day Function along with Agri-startup & Entrepreneurship Conclave	NASC Complex, Pusa, New Delhi	Dr. R P Dwivedi
20th-22nd October, 2018	2nd International Conference on "Advances in Agricultural, Biological and Applied Sciences for Sustainable Future (ABAS-2018)	Sardar Patel Auditorium, Swami Vivekanand Subharti University, Meerut (U.P.)	Dr. Naresh Kumar
26th-28th October, 2018	Krishi Kumbh Exhibition and International conference	ICAR-IISR, Lucknow(UP)	Dr. R P Dwivedi

15th-17th November, 2018	9th NEE Congress-2018 Climate smart agricultural technologies: Innovations and interventions Organized by Society of Extension Education, Agra, CAU, Imphal, ICAR-RC for NEH Region, Umiam, Meghalaya and ICAR-NRC for Orchid, Pakyong, Sikkim.	Pakyong (Sikkim)	Dr. R P Dwivedi & Dr. Mahendra Singh
16th-18th November, 2018	39th Annual Conference & National Symposium on Plant and Soil Health Management: New Challenges and Opportunities	ICAR-IIPR, Kanpur (UP)	Dr. Sudhir Kumar
26th-28th October, 2018	Krishi Kumbh Exhibition and International conference	ICAR-IISR Lucknow (UP)	Dr R P Dwivedi, Dr. Mahendra Singh & Dr. K B Sridhar
27th November, 2018	Multi-stake holder consultation on harnessing potential of trees outside forest to meet India's NDC Commitment, organized by TERI	New Delhi	Dr. A K Handa
2nd-5th December, 2018	4th International Plant Physiology Congress-2018	Lucknow (UP)	Dr. Badre Alam
4th-5th December, 2018	Nodal Officer's Workshop on KRISHI	NASC, New Delhi	Dr. R H Rizvi
5th- 7th December, 2018	National Symposium on "Entomology 2018: Advances and Challenges"	PJTSAU, Hyderabad (Telangana)	Dr. Veeresh Kumar
13th-14th December, 2018	National symposium on 'Forage and livestock based technological innovations for doubling farmers' income'	UAS, Dharwad (KA)	Dr. Inder Dev, Dr. Naresh Kumar & Dr. Asha Ram
27th December, 2018	First meeting of the committee to include agroforestry under Prime Minister Crop Insurance Scheme	Krishi Bhavan, New Delhi	Dr. A K Handa
16th-19th January, 2019	Biennial workshop of AICRP on DA	UAS, Bangalore (KA)	Dr. A K Handa
28th January, 2019	XXXIXth PGRC meeting	ICAR-NBPGR, New Delhi	Dr. K Rajarajan
4th-5th February, 2019	XXV meeting of Regional committee VI of ICAR	AAU, Anand (Gujarat)	Dr A K Handa

11th-14th February, 2019	13th International Conference on "Development of Drylands Converting Dryland Areas from Grey into Green"	Jodhpur, India	Dr. Ram Newaj Dr. Dhiraj Kumar
18th February, 2019	Second Meeting of State Level Standing Technical Committee for UP Agroforestry Mission	Lucknow (U.P.)	Dr. A K Handa
18th-20th February, 2019	International Workshop on "Earth Observations for Agricultural Monitoring" jointly organized by ISPRS & ISRS	IARI, New Delhi	Dr. R H Rizvi
20th-23rd February, 2019	XIV Agricultural Science Congress	NASC Complex, New Delhi	Dr. Rajendra Prasad, Dr. Sudhir Kumar, Dr. Mahendra Singh & Dr. K Rajarajan
6th March, 2019	National Consultation on Application of IT in Agricultural Research	NASC, New Delhi	Dr. R H Rizvi

CHAPTER 9 TRAINING AND CAPACITY BUILDING

A. Participation in Trainings

Duration	Event	Venue	Participants
21st -23rd March, 2018	Training programme on "Quality Seed Production in Forage Crops"	ICAR-IGFRI, Jhansi (UP)	Dr. K Rajarajan, Scientist & Dr. C K Bajpai, Chief Technical Officer
27th -31th August, 2018	International Training on "Introduction Course in Meta-Analysis"	World Agroforestry Centre (ICRAF), Bogor, Indonesia	Dr. Asha Ram, Dr. Dhiraj Kumar & Dr. Veeresh Kumar (Scientists)
05th-10th September, 2018	SAARC Regional Training on " Integrated Nutrient Management for Improving Soil Health and Crop Productivity"	ICAR-IISS, Bhopal (MP)	Dr. Dhiraj Kumar, Scientist
14th-20th September, 2018	Capacity building and skill upgradation programme on "Farm Management"	ICAR-IIFSR, Modipuram, Meerut (U.P.)	Sh. Sunil Kumar, Chief Technical Officer
11th September - 1st October, 2018	Winter school on Maintenance breeding and assured quality seed production in dual purpose crops and grasses	ICAR-Indian Grassland and Fodder Research Institute, Jhansi (UP)	Dr. Veeresh Kumar, Scientist
26th-28th September, 2018	Training on "Administrative & Financial Rules"	ICAR-IIPR, Kanpur (UP)	Sh. S B Sharma, AF&AO Sh. Birendra Singh, AAO & Sh. Jai Janardan Singh, Assistant
24th-29th September, 2018	Training programme entitled "Innovative practices in extension research and evaluation"	ICAR-NAARM, Hyderabad (Telangana)	Dr. R P Dwivedi, Pr. Scientist
14th November, 2018 - 14th February, 2019	Three months Professional Attachment Training (PAT) as a part of Foundation Course for Agriculture Research Services (FOCARS-108)	ICAR-Indian Grassland and Fodder Research Institute (IGFRI), Jhansi, UP	Mr. Hirdayesh Anuragi

16th November 2018 - 14th February, 2019	Three months Professional Attachment Training (PAT) as a part of Foundation Course for Agriculture Research Services (FOCARS-108)	ICAR-National Institute of Abiotic Stress Management, Baramati, Pune (MH)	Mr. Sukumar Taria
19th-25th February, 2019	Automobile Maintenance, Road Safety and Behavioral Skills	ICAR-CIAE, Bhopal (M P)	Sh. Kashi Ram, Sr. Technical Assistant (Driver)

B. Trainings organized for Various Categories of Employees

Event	Duration	Venue	Participants
NIL	NIL	NIL	NIL

C HRD funds Allocation and Utilization

(₹ in Lakh)

Year	Allocation	Utilization
2018-2019	1.28	1.28

CHAPTER

10 राजभाषा गतिविधियाँ

हिन्दी सप्ताह

दिनाँक 14 सितम्बर, 2018 को हिन्दी सप्ताह (14–20 सितम्बर, 2018) का शुभारम्भ आई.सी.ए.आर. कुलगीत से किया गया। हिन्दी सप्ताह के अवसर पर हिन्दी को बढ़ावा देने के लिए माननीय केन्द्रीय कृषि मंत्री, भारत सरकार का संदेश एवं भारतीय कृषि अनुसंधान परिषद, नई दिल्ली के महानिदेशक डा. त्रिलोचन महापात्रा जी की अपील को पढ़कर उपस्थित सभी लोगों को अवगत कराया गया। इस अवसर पर संस्थान के वैज्ञानिकों, अधिकारियों एवं कर्मचारियों ने हिन्दी को बढ़ावा देने के लिए अपने विचार व्यक्त किये।

डॉ. अनिल कुमार, निदेशक (कार्यवाहक) ने सभी वैज्ञानिकों एवं अधिकारियों से अपील की कि हिन्दी में अधिक से अधिक पुस्तकें, तकनीकी बुलेटिनों तथा प्रसार बुलेटिनों का प्रकाशन किया जाए जिससे किसान भाई आपके अनुसंधान को पढ़कर उसका भरपूर लाभ उठा सकें। कार्यक्रम की अध्यक्षता करते हुए निदेशक, डॉ. अनिल कुमार ने अपने उद्‌बोधन में कहा कि भारत सरकार के गजट में इस संस्थान का नाम ''क'' क्षेत्र में है, इसलिए हम लोगों को अपना प्रशासनिक कार्य शत–प्रतिशत हिन्दी में करना है। उन्होंने समस्त वैज्ञानिकों, अधिकारियों से अपील की कि हिन्दी में पत्राचार को बढ़ाने में अपना सहयोग प्रदान करें जिससे राजभाषा विभाग द्वारा दिये गये लक्ष्यों को पूरा किया जा सके। दिनाँक 14 सितम्बर, 2018 को सप्ताह के उद्‌घाटन के साथ ही दूसरे सत्र में हिन्दी कार्यशाला का आयोजन भी किया गया।

हिन्दी कार्यशालायें

संस्थान में वर्ष 2018 के दौरान चार हिन्दी कार्यशालाओं का आयोजन किया गया। इन कार्यशालाओं के आयोजन का मुख्य उद्‌देश्य हिन्दी में सरकारी काम–काज करने में अधिकारियों एवं कर्मचारियों को होने वाली झिझक को दूर करना था। हिन्दी कार्यशालाओं का विवरण निम्न प्रकार है:

दिनाँक 23 मार्च, 2018 (जनवरी–मार्च, 2018)

कार्यशाला के मुख्य वक्ता संस्थान के वरिष्ठ वैज्ञानिक (वानिकी), डा. नरेश कमार थे। उन्होंने अपना व्याख्यान ''बाँस प्रजातियों में विविधता एवं उनकी उपयोगिता'' पर दिया। उन्होंने कार्यशाला के दौरान देश में प्रचलित बाँस आधारित कृषिवानिकी पद्धतियों के बारे में अवगत कराया। चर्चा के दौरान वक्ता द्वारा बाँस के विभिन्न उपयोगों के बारे में भी अवगत कराया गया। वक्ता द्वारा हिन्दी शोध–पत्र लेखन में आने वाली सामान्य समस्याओं पर भी चर्चा की गई। उन्होंने बताया कि परिषद के हिन्दी विभाग द्वारा कृषि से सम्बन्धित तकनीकी शब्दों की शब्दावली तैयार की गई है जो कि परिषद की बेवसाइट पर उपलब्ध है। उन्होंने यह भी बताया कि हिन्दी भाषा में अंग्रेजी से इतर एक शब्द के अनेक समानार्थी शब्द मौजूद है जिन्हें शोध–पत्र लेखन के दौरान सरल सामान्य भाषा के रूप में प्रयोग किया जा सकता है।

दिनाँक 29 जून, 2018 (अप्रैल–जून, 2018)

कार्यशाला के मुख्य वक्ता संस्थान के प्रधान वैज्ञानिक डा. आर.एच. रिजवी थे उनका व्याख्यान ''अंतर्राष्ट्रीय कृषिवानिकी सम्मेलन : एक अनुभव''–विषय पर आधारित था। यह सम्मेलन 27–29 अप्रैल, 2018 की अवधि में काठमाण्डू, नेपाल में सम्पन्न हुआ था। उन्होंने अपने व्याख्यान में नेपाल में प्रचलित कृषिवानिकी पद्धतियों के बारे में अपने अनुभवों से अवगत कराया। चर्चा के दौरान शोध–पत्र एवं प्रसार बुलेटिन लेखन में प्रचलित शब्दावली, जोकि जन–सामान्य की समझ के लिए सरल हो, ऐसे सरल शब्दों के प्रयोग पर बल दिया गया। कार्यशाला में संस्थान के अन्य वैज्ञानिकों द्वारा संस्थान के संदर्भ में कृषिवानिकी की विभिन्न पहलुओं पर गहन चर्चा की गयी और यह चर्चा पूरी तरह से हिन्दी में संपन्न हुई।

दिनाँक 14 सितम्बर, 2018 (जुलाई–सितम्बर, 2018)

जुलाई–सितम्बर 2018, समाप्त तिमाही अवधि की कार्यशाला दिनाँक 14.9.2018 को डा. अनिल कुमार, कार्यवाहक निदेशक की अध्यक्षता में सम्पन्न हुई। कार्यशाला के मुख्य वक्ता संस्थान के मुख्य तकनीकी अधिकारी डा. चन्द्रेश कुमार बाजपेयी थे। व्याख्यान ''भारतवर्ष में हिंदी भाषा की वर्तमान

स्थिति'' विषय पर आधारित था। चर्चा के दौरान शोध–पत्र एवं प्रसार बुलेटिन लेखन में प्रचलित शब्दावली, जोकि जन–सामान्य की समझ के लिए सरल हो, ऐसे सरल शब्दों के प्रयोग पर बल दिया गया। कार्यशाला में संस्थान के अन्य वैज्ञानिकों द्वारा संस्थान के संदर्भ में कृषिवानिकी की विभिन्न पहलुओं पर गहन चर्चा की गयी और यह चर्चा पूरी तरह से हिन्दी में संपन्न हुई।

दिनाँक 03 अक्टूबर, 2018 (अक्टूबर–दिसम्बर, 2018)

अक्टूबर–दिसम्बर 2018, समाप्त तिमाही अवधि की कार्यशाला दिनाँक 03.10.2018 को सम्पन्न हुई। कार्यशाला के मुख्य वक्ता संस्थान के वैज्ञानिक डा. धीरज कुमार, डा. वीरेश कुमार तथा डा. आशाराम थे। व्याख्यान ''मेटा एनालाईसिसः एक परिचय'' (इण्डोनेशिया में आयोजित वैज्ञानिक प्रशिक्षण के संदर्भ में) विषय पर आधारित था। चर्चा के दौरान शोध–पत्र एवं प्रसार बुलेटिन लेखन में प्रचलित शब्दावली, जोकि जन–सामान्य की समझ के लिए सरल हो, ऐसे सरल शब्दों के प्रयोग पर बल दिया गया। कार्यशाला में संस्थान के अन्य वैज्ञानिकों द्वारा संस्थान के संदर्भ में कृषिवानिकी की विभिन्न पहलुओं पर गहन चर्चा की गयी और यह चर्चा पूरी तरह से हिन्दी में संपन्न हुई।

राजभाषा कार्यान्वयन समिति

दिनाँक 13 सितम्बर, 2018 को संस्थान की राजभाषा कार्यान्वयन समिति की बैठक संस्थान कार्यवाहक निदेशक डा. अनिल कुमार की अध्यक्षता में सम्पन्न हुई, जिसमें राजभाषा कार्यान्वयन समिति के सदस्य उपस्थित थे। बैठक में सर्वसम्मति से निर्णय लिया गया कि संस्थान में 14–20 सितम्बर, 2018 के मध्य हिन्दी सप्ताह का आयोजन किया जाय तथा हिन्दी को बढ़ावा देने के लिए विभिन्न प्रतियोगिताओं का आयोजन किया जाये। प्रतियोगिताओं को सफल बनाने हेतु निदेशक महोदय द्वारा प्रत्येक प्रतियोगिता के लिए अलग–अलग निर्णायक मण्डल का गठन किया गया। प्रतिभागियों को प्रोत्साहित करने हेतु प्रत्येक प्रतियोगिता के लिए प्रथम, द्वितीय एवं तृतीय पुरस्कारों का भी प्रावधान रखा गया।

CHAPTER 11 SWACHH BHARAT ABHIYAN

Swachh Bharat Abhiyan

Various awareness programmes of cleanliness were started from 15th September, 2018. Cleanliness drive programmes have been initiated in the Institute campus as well as in different villages.

Swachchhata Hi Seva (SHS)

On 02 October, 2018 all staff members of the Institute cleaned picnic site of Pahuj Dam. Plastic and other non-degradable waste was collected and disposed-off. All staff members gathered at the conference hall and offered flowers to Mahatma Gandhi to celebrate his 149th Birth Anniversary. On this occasion, Swachchhata Karmi (7 numbers) of the Institute were given personal protective equipment, *viz.*gloves, face mask and appron.

Swachhta Pakhwada -16-31, December, 2018

The staff members were engaged in cleaning of offices, corridors and premises. Later, Swachhta activity was carried out near ATIC building on 17.12.2018.

The Cleanliness Programme was conducted within campuses including residential colonies on 18.12.2018. Staff members (25) participated in the Programme.

In the presence of the Director and staff members the cleanliness and sanitation activities were conducted in the Hastinapur village and in the surroundings of Institute sports complex on 19.12.18.

Programme was preceded by the Director and the activity plan was briefed by the scientist on 20.12.18. The utilization of organic wastes through composting was explained by scientist. The cleaning activity was also done in the Director quarter surrounds. Staff members participated in the programme.

On 21.12.18 Dr. Ramesh Singh explained about recycling of waste water and efficient water utilization strategies for kitchen gardening. Staff members (30) participated in the programme.

On 22.12.2018 a Farmer's Workshop was organized and created awareness to the farmers regarding utilization of farm waste. Institute Scientist explained about the safe disposal of all kinds of wastes. Staff members of the Institute participated in the programme.

Kisan Diwas and Swacchata Pakhwad was jointly organized by the ICAR-CAFRI, Jhansi and ICAR-IISWC regional centre, Datia at Hastinapur village on 23.12.2018. The programme was conducted to created awareness to the farmers regarding recycling and efficient utilization of farm waste. Scientists also emphasized on the adaptation of Agroforestry systems and its role in Doubling Farmer Income. All categories of farmers including youths and farm women were participated (42) in the programme.

The Swachhta Pakhwada activities were organized on 24.12.2018 in Village Simardha, Ward No. 21, Jhansi. Staff of the Institute visited the village and did door to door canvassing for cleanliness. Staff, village women, youth and children participated in the activities. Safe disposal of waste water and composting was emphasized. Villagers were shown keen interest to learn about re-use of waste water and organic waste.

The Swachhta Pakhwada activities were organized on 25.12.2018. On National Highway in front of Pahuj Dam, Jhansi. Students of

RLBCAU, Jhansi residing in Institute campus and staff of the Institute campaigned for Swacchhta Pakhwada and motivated road passers for Swacchhta. Non decomposable plastic rags were removed and road side cleaning was done.

The Swachhta Pakhwada activities were organized on 26.12.2018. A quiz competition was organized in accordance with scheduled activities as suggested by ICAR Headquarter. The event was organized in Institute Conference Hall. Staff members participated in the event. Four groups were constituted and questions were coined. Chandan Group scored highest mark. List of questions is given below-

- Swachh Bharat Abhiyan started on whose birthday?
- When was Swachh Bharat Abhiyan started?
- What is the tag line of Swachh Bharat Abhiyan?
- What is the Logo of Swachh Bharat Abhiyan?
- Prime Minister of India, Sh. Narendra Modi while launching SBM asked people to donate minimum how many hours every year for Swachhta?
- Date of World Toilet Day?
- What is primary goal of Swachh Bharat Abhiyan?
- Name the disease caused by contaminated drinking water?
- Name the cleanest Country in the World?
- Name the award given by Indian Govt. to cities and villages for cleanliness?
- Name the cleanest village of India?

Swachhta Pakhwada activity was organized in village Karari, Jhansi on 27.12.18. Staff of the Institute visited the village and conducted door to door survey to assess the status of waste management. Every farm family was found using farm waste into compost pit, dung, ash and sweepings were being taken to compost pit. However, polythene bags and small packings are not being properly disposed off, hence, it is choking drainages and polluting environment. Villagers were urged to segregate plastic from waste and collect them in closed container so that they can be sold in bulk for recycling. Use of cloth bag in market was emphasized to discourage the use of plastic carry bags.

Swachhta Pakhwada activity was organized in village Boorha on 28.12.18 to create awareness among villagers regarding the use of waste water. Villagers informed that they should channelizing household waste water to their kitchen garden where invariably they grow papaya, chili, elephant foot yam etc. Every village has drainage channel along the road and many households drain waste water in these channels. Drainage channel on village boundary opens into agricultural fields. The villagers were urged to separate non-decomposable plastic

waste before it reaches to the drainage channel or compost pit. Keeping in view water scarcity it was emphasized that channel should be constructed around the well and hand pump. Excess water from channel should be safely disposed off through pipe to the nearest kitchen garden or agricultural field.

On 29.12.2018 staff of ICAR-CAFRI, Jhansi visited village Bhojala for creating awareness in rural masses. Composting technique was explained to villagers. Benefits of using compost in agriculture and horticulture was discussed. Farmers showed keen interest in learning composting technique and they were eager to adopt the technology. About 40 villagers, village women and staff participated.

On 30.12.18, a press release is issued by chairman, Swachhta Pakhwada for wide circulation of events and popularizing of abhiyan amongst masses through print media. The events were widely published through newspaper.

To mark the closing of the pakhwada a function was organized in ICAR- CAFRI, Jhansi on 31.12.2018. where in Dr. A R Sharma, Director (Research), RLBCAU, Jhansi was chief guest. The function was presided over by Director of the Institute. Scientist of the event presented event report of Swachhata Pakhwada. Dr. Sharma urged gathering to continue the spirit of Swachhata throughout the 150th birth anniversary celebration of Rashtrapita Mahatma Gandhi who championed cleanliness drive in India for better health and hygiene. Speaking on the occasion Dr. Anil Kumar appreciated the efforts of the Institute during swachhata abhiyan and insisted that every staff must contribute in awakening masses for cleanliness. All staff members of the institute participated in the activities. The Programme ended with vote of thanks to the chair and participants.

CHAPTER

12 DISTINGUISHED VISITORS

- Dr. Tej Partap, Former Vice-Chancellor, Sher-E-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar (J & K).
- Dr. Javed Rizvi, Regional Director, South Asia Progarmme, ICRAF, New Delhi.
- Dr. S Bhaskar, ADG (A/AF & CC), NRM Division, ICAR, New Delhi.
- Dr. P Kaushal, Vice-Chancellor, B A U, Ranchi (Jharkhand).
- Dr. Alexander, Board of Trusty, ICRAF, Nairobi (Kenya).
- Dr. Ravi Prabhu, DDG, ICRAF, Nairobi (Kenya).
- Sh. Vijay Sharma, IAS, Former Secretary, Ministry of Environment, Forest and Climate Change & Member, Board of Trusty, ICRAF, Nairobi (Kenya).
- Dr. M A Shankar, Ex. Director of Research, University of Agricultural Science, Bangalore (K.A.).
- Dr. V K Mishra, Ex-Dean, College of Forestry, YSPUHF, Solan (H.P.).
- Dr. Alka Bhargava, Joint Secretary, National Agroforestry & Bamboo Mission (NABM), Department of Agriculture and Cooperation, Ministry of Agriculture and Farmers Welfare, Govt. of India, Krishi Bhawan, New Delhi.
- Smt. M Arun Mozhi, *IAS,* Joint Magistrate, Jhansi.
- Dr. Ben Boxer, DDG, Corporate Services, ICRAF, Narobi (Kenya).
- Dr. Shiv Kumar Dhyani, Sr. Agroforestry Specialist, ICRAF, New Delhi.
- Ms. Linda Pernilla Hansson, Sweden.
- Mr. Hakan Gunnar Marstorp, Sweden.
- Ms. Johanna Maria Wetterlind, Sweden.
- Mr. Ivar Hemming Christian Virgin, Sweden.
- Dr. Anil Kumar, Director (Education), Rani Laxmi Bai Central Agricultural University, Jhansi,
- Dr. R S Yadav, Head, Indian Institute of Soil and Water Conservation, Regional Centre, Datia
- Dr. Rajesh Kanwar, Scientist, ICRISAT, Hyderabad.

CHAPTER 13 PERSONNEL

Dr. Anil Kumar, Director (A)			
Scientific			
1.	Dr. R K Tewari	Pr. Scientist (Horticulture/Fruit Science)	
2.	Dr. Ram Newaj	Pr. Scientist (Agronomy)	
3.	Dr. Rajendra Prasad	Pr. Scientist (Soil Science)	
4.	Dr. Sudhir Kumar	Pr. Scientist (Horticulture/Fruit Science)	
5.	Dr. A K Handa	Pr. Scientist (Forestry/ Agroforestry)	
6.	Dr. R P Dwivedi	Pr. Scientist (Agriculture Extension)	
7.	Dr. Inder Dev	Pr. Scientist (Agronomy)	
8.	Dr. Badre Alam	Pr. Scientist (Plant Physiology)	
9.	Dr. (Er.) Ramesh Singh	Pr. Scientist (SWC Engs.)	
10.	Dr. R H Rizvi	Pr. Scientist (Computer Application)	
11.	Dr. Mahendra Singh	Pr. Scientist (Agriculture Economics)	
12.	Dr. Naresh Kumar	Sr. Scientist (Agroforestry)	
13.	Dr. K Rajarajan	Scientist (Genetics & Plant Breeding)	
14.	Dr. K B Sridhar	Scientist (Forestry)	
15.	Sh. S B Chavan	Scientist (Forestry)	
16.	Dr. Asha Ram	Scientist (Agronomy)	
17.	Sh. A R Uthappa	Scientist (Forestry)	(on Study Leave)
18.	Dr. Dhiraj Kumar	Scientist (Soil Science)	
19.	Sh. Lal Chand	Scientist (Fruit Science)	
20.	Sh. Hirdayesh Anuragi	Scientist (Genetics & Plant Breeding)	
21.	Sh. Sukumar Taria	Scientist (Plant Physiology)	
Technical			
1.	Sh. B Singh	Chief Technical Officer (Farm Manager)	
2.	Dr. Rajeev Tiwari	Chief Technical Officer	
3.	Dr. C K Bajpai	Chief Technical Officer	
4.	Dr. A Datta	Chief Technical Officer	
5.	Sh. Sunil Kumar	Chief Technical Officer	
6.	Sh. Rajendra Singh	Chief Technical Officer	

7. Sh. Rajesh Srivastava	Assit. Chief Technical Officer (Art & Photo)	
8. Sh. R K Singh	Sr. Technical Officer	
9. Sh. S P Singh	Sr. Technical Officer	
10. Sh. Ram Bahadur	Sr. Technical Officer	
11. Sh. Ajay Kumar Pandey	Technical Officer	(on Study Leave)
12. Smt. Shelja Tamrkar	Sr. Technical Assistant (Library)	
13. Sh. Het Ram	Sr. Technical Assistant (Driver)	
14. Sh. Kashi Ram	Sr. Technical Assistant (Driver)	
15. Sh. Prince	Technical Assistant, Mechanic	
Administration		
1. Sh. J L Sharma	A O	
2. Sh. Birendra Singh	AAO	
3. Sh. S B Sharma	A F & A O	
4. Sh. A K Chaturvedi	Private Secretary	
5. Sh. Hoob Lal	Personal Assistant	
6. Sh. Om Prakash	Personal Assistant	
7. Sh. Mahendra Kumar	Assistant	
8. Sh. Jai Janardan Singh	Assistant	
9. Sh. Deepak Vij	Stenographer (Grade-III)	
10. Sh. Tridev Chaturvedi	Stenographer (Grade-III)	
11. Sh. Vir Singh Pal	Sr. Clerk	
12. Smt. Kaushalya Devi	Jr. Clerk	
Skilled Supporting Staff		
1. Sh. Attar Singh		
2. Sh. Ram Singh		
3. Sh. Jagdish Singh		
4. Sh. Ram Din		
5. Sh. Pramod Kumar		
6. Sh. Munna Lal		

CHAPTER

14 MISCELLANEOUS

New Staff

1. Sh. Hirdayesh Anuragi, Scientist (Genetics & Plant Breeding) joined the Institute on 6th October, 2018.
2. Sh. Sukumar Taria, Scientist (Plant Physiology) joined the Institute on 8th October, 2018.

Promotion

Sh. Birendra Singh, Assistant promoted to the post of AAO through Limited Departmental Competitive Examination, w.e.f. 16th January, 2019.

Institute Joint Staff Council

New IJSC has been constituted for the period of 06/04/2019 to 05/04/2022.

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 2017-18 of the Institute.

Zonal Sports Meet

A contingent of 39 players from ICAR-CAFRI, Jhansi participated in ICAR Zonal Tournament-2018 at ICAR-IGFRI, Jhansi held during 05th to 8th October, 2018 which was organized by ICAR-IGFRI, Jhansi. ICAR-CAFRI secured 3rd position in the cycle race (Sh. Atar Singh).

Inter-zonal Sports Meet

Sh. J. L. Sharma, AO as a CDM and Sh. Atar Singh, SSS in Cycle race participated in the Inter-Zonal Sports Meet during 25th to 28th February, 2019 held at ICAR-Indian Veterinary Research Institute (ICAR-IVRI), Izatnagar - Bareilly (UP).

Ph. D. Degree

Dr. K Rajarajan, Scientist awarded Ph.D. degree programme in the field of Genetics and Plant Breeding during 2018 from Tamil Nadu Agricultural University, Coimbatore.

Transfer

Dr. Veeresh Kumar, Scientist (Entomology) has been transferred to ICAR- National Bureau of Agricultural Insect Resources, Bengaluru (Karnataka) on 12th February, 2019.

ANNEXURE-I

RESEARCH ADVISORY COMMITTEE

Dr. K Gurumurthi, Chairman
Ex. Director, IFGTB
62/4, Leela Apartments
Ponnayarjapuram
Coimbatore - 641 001 (TN)

Dr. S K Dhyani
Senior Agroforestry Expert
World Agroforestry Centre (ICRAF),
Regional Office for South Asia,
C- Block, NASC Complex, DPS Marg
New Delhi - 110 012

Dr. A K Mandal
Ex. Director, TFRI
Srikrishna Apartment, New Area,
Morabadi, Balihar Road,
Ranchi - 834 008 (Jharkhand)

Dr. S Bhaskar
Assistant Director General
(Agron./ AF & CC)
NRM Division, ICAR,
Krishi Anushandhan Bhawan-II,
New Delhi- 110 012

Sh. Ashok Rajput
Village- Nandsiya, Mooth,
Post- Karjanva, Jhansi (U.P.)

Dr. Inder Dev
Pr. Scientist & Member Secretary,
ICAR- CAFRI,
Jhansi (U.P.)

Dr. R K Patnaik
Ex. Dean, CoF, OUAT, Bhubaneshwar
Flat Number 303, Gopal Residency
Kalpana Road, B.J.B. Nagar
Bhubaneswar - 751 014 (Odisha)

Dr. S D Bhardwaj
Ex- Dean,COF, YSPUHF, Solan
House No. 33, Scientist Colony,
P.O. Shamti,
Solan - 173 212 (H.P.)

Dr. B N Patel
Principal and Dean,
ASPEE College of Horticulture and Forestry,
Navsari Agricultural University,
Navsari - 396 450 (Gujarat)

Dr. R C Dhiman
General Manager
WIMCO Seedling Limited,
R&D Centre,
Bagwala, Kashipur Road,
Rudrapur - 263 153 (Uttrakhand)

Sh. Pradeep Saravgi
House No. 165, Purani Nazai
Jhansi(U.P.)

ANNEXURE-II

INSTITUTE JOINT STAFF COUNCIL

Chairman : Dr. Anil Kumar, Director (A)				
Category	**Staff Side**		**Office Side**	
Administration	Sh, Birendra Singh AAO	Member, CJSC	Dr. R. K. Tewari Pr. Scientist	Member
	Sh. Tridev Chaturvedi Stenographer	Secretary IJSC	Dr. Rajendra Prasad Pr. Scientist	Member
Technical	Smt. Shelja Tamrkar Sr. Technical Assistant	Member Pr. Scientist	Dr. Inder Dev	Member
	Sh. Kashi Ram Tech. Asstt. (Driver)	Member	Dr. C K Bajpai CTO	Member
Supporting	Sh. Attar Singh SSS	Member	Sh. J L Sharma A.O. & H.O.	Member Secretary
	Sh. Ram Singh SSS	Member	Sh. S B Sharma AF&AO	Member

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