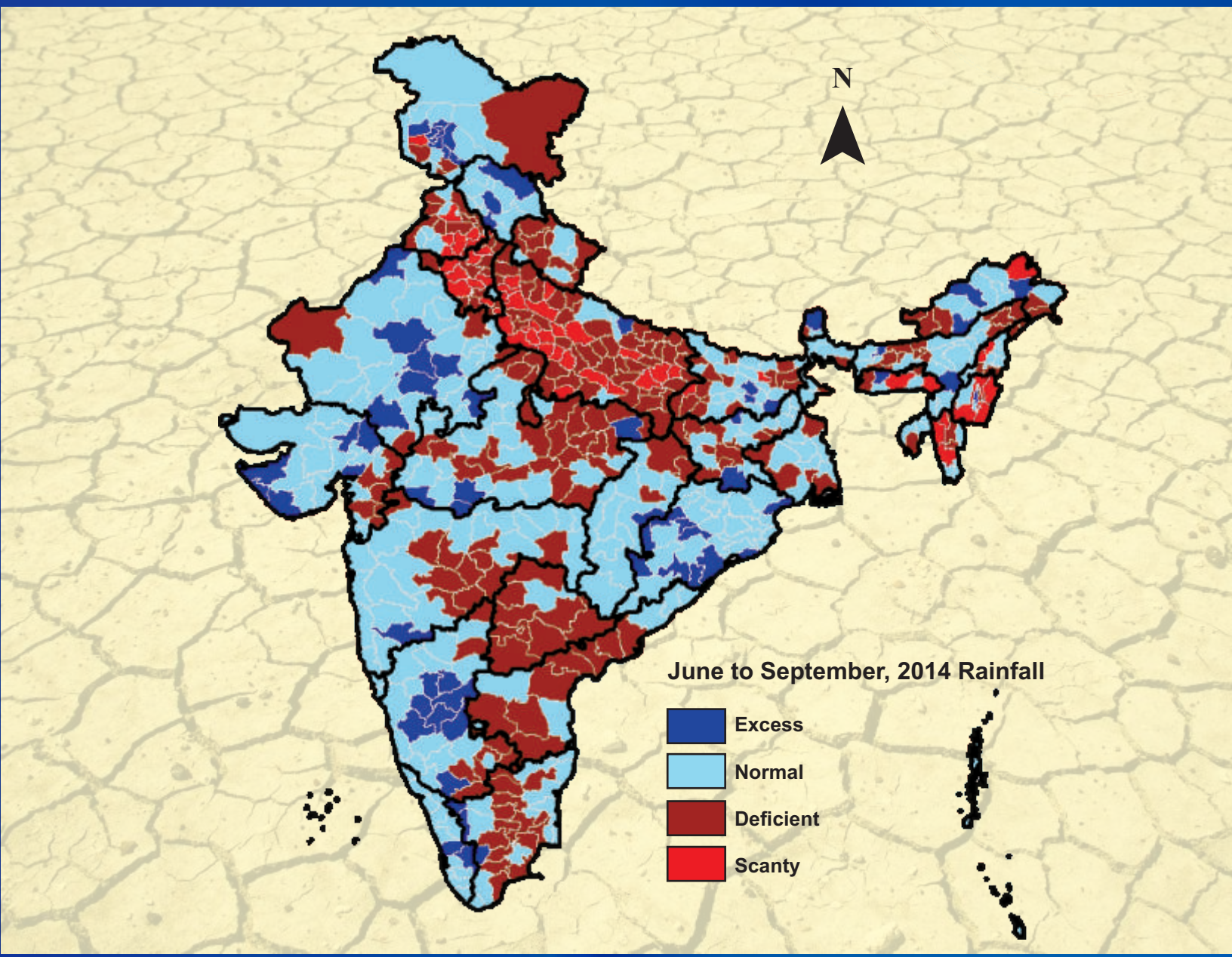
ICAR-CRIDA

वार्षिक प्रतिवेदन

Annual Report 2014 - 15



केंद्रीय बारानी कृषि अनुसंधान संस्थान, संतोषनगर, हैदराबाद

Central Research Institute for Dryland Agriculture

Santoshnagar, Hyderabad - 500 059

May, 2015

Citation : ICAR-CRIDA (2015), Annual Report 2014-15, Central Research Institute for Dryland Agirculture, Hyderabad, India. p 190

Published by
Ch. Srinivasa Rao, Director, CRIDA

Editorial Committee
Ch. Srinivasa Rao
K. Srinivas
C. A. Rama Rao
B. Bapuji Rao
M. Prabhakar
G. Nirmala
K. A. Gopinath
Manoranjan Kumar
V. Visha Kumari

Hindi
K. L. Sharma
S. R. Yadav
G. Prabhakar

Photography and Art
K. Surender Rao
K. V. G. K. Murthy

Cover Page
Map showing district-wise June to September rainfall status in deficit rainfall year 2014

Designed and Printed at :
Heritage Print Services Pvt. Ltd.
IDA Uppal, Hyderabad. Ph : 040 - 27201927
heritageprintsadmn@gmail.com

वार्षिक प्रतिवेदन
Annual Report 2014 - 15

केंद्रीय बारानी कृषि अनुसंधान संस्थान, संतोषनगर, हैदराबाद
Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad - 500 059

Preface

The year 2014-15 has been a most challenging one for agriculture in the country. Rains affected farming in larger parts of the country, when they were absent in the beginning of the agricultural year as well as when they hit the ready-to-harvest crops towards the end of the year. Both kharif and rabi crops were affected. The institute, with the kind of mandate given to address, was in the thick of the things in devising ways and means of dealing with such erratic developments in the behavior of rainfall. The institute played a proactive role in developing contingency plans for a range of situations for most of the districts in the country, and more importantly in initiating steps towards implementing the plans. The institute prepared a compensatory rabi production plan in view of the effects of a deficit monsoon. Apart from this, there was considerable progress in different research activities going on at the institute and its three network projects viz., the All India Coordinated Research Project for Dryland Agriculture (AICRPDA), All India Coordinated Research Project on Agrometeorology (AICRPAM), and the National Initiative on Climate Resilient Agriculture (NICRA). This annual report presents a synthesis of the work done during 2014-15.

A new methodology was proposed for watershed planning based on land use and proposed in-situ conservation measures and existing storage available within watershed. A water application software (WAS) that included standard mathematical models and standard protocols for the design of different on-farm irrigation systems, including surface irrigation as well as pressurized irrigation in structured form with different options was developed. Efforts were made in watershed evaluation as well as application of remote sensing and GIS based approaches in assessing rainfall variability and weather induced crop damage. Appropriate *in situ* soil and water conservation measures were identified for selected regions.

Minimum tillage was found to lead to significantly higher soil organic carbon stock and microbial biomass compared to conventional tillage. Lower soil and nutrient losses were observed in zero tillage as compared to conventional and reduced tillage. In a pigeonpea-castor rotation, soil organic carbon was higher with zero tillage over conventional and reduced tillage and with 30 cm high residue retention over 10 cm and no residue retention. Raised bed/permanent bed planter was refined by adjusting the bottom of the bed maker, and driving mechanism for accurate seed and fertilizer placement. Carbon footprint, considering GHG emissions from operation use and input use, was 23% and 9% lower with zero tillage and reduced tillage respectively over conventional tillage.

Field phenotyping of maize genotypes was carried out and drought tolerant genotypes were identified. Intercropping systems involving hybrids of maize and sorghum were found superior to those of local varieties with yield advantage. Inoculation with thermo-tolerant bacteria was found to reduce ASI in maize. Genotypes of maize with higher transpiration efficiency were identified. Genotypes of pongamia with better growth parameters and pest resistance were identified. Supplementation with vitamin E, selenium and zinc was found to impart better adaptive capacity in sheep towards heat stress.

An exercise on prediction of pest scenarios of *Spodoptera litura* on peanut using life table approach indicated that temperature and CO_2 are vital in influencing the growth and life table parameters of S. litura and that pest incidence is likely to be higher under climate scenarios of the future. Pest specific decision tree models were developed for predicting severity based on weather index computed from significant weather variables for pest categories of low, medium and high severity. Ingen – a software calculator for computing number of insect generations was developed.

Micro-level agromet advisories were issued by 25 AICRPAM-NICRA centers based on block-level weather forecast provided by IMD. Weather indices required for designing weather insurance products for groundnut were developed by analyzing long-term yield and weather conditions at three locations viz., Bangalore, Anand and Ludhiana. Weather Cock 14 - a weather analysis software was developed.

Interaction meetings with stakeholders were organized by AICRPDA centres for disseminating the rainfed agricultural technologies appropriate to the agro-ecosystems. Information on the technologies that can be scaled out through NMSA was shared with DAC in an interaction meeting. Fifteen farm implements developed by CRIDA were commercialized by granting license to five private industries of Maharashtra for large scale production. The institute also took lead in assessing the damage inflicted on crop and livestock production by drought during the beginning of the year and by the Hudud cyclone in northern Andhra Pradesh during September. Technology interventions with climate focus, implemented in 100 NICRA KVKs during kharif season under four modules, i.e. natural resource management, crop production, livestock and fisheries and institutional interventions gave promising results. The Krishi Vigyan Kendra conducted 134 on farm trials of 14 technologies, 123 front line demonstrations, and 63 need based and skill oriented training programmes on various aspects of improved technologies, and several extension activities for farmers of Ranga Reddy district.

The work and contributions of the institute were well recognized as reflected in a number of scientists of the institute receiving awards from various professional bodies and fora. The AICRPAM received the ICAR - Chaudhary Devi Lal Outstanding All India Coordinated Research Project Award - 2013 for outstanding work on climatic variability and development of real-time contingency plans. Many of CRIDA's scientists were admitted as Fellows/Members of professional societies/bodies. The institute's work was published in a number of peer reviewed international and national journals, books, bulletins, etc. The institute was granted License of Quality Management Certification under the Quality Management System in accordance with IS/ISO 9001:2008 during the year.

I am privileged to present this annual report for the first time after taking over as Director, CRIDA. I would like to place on record my gratefulness to all my predecessors who built CRIDA and its reputation over the years. I thank ICAR and other stakeholders for their support in delivering our contributions towards making rainfed agriculture more sustainable. I appreciate the efforts of the editorial team in bringing out this elegantly prepared annual report in time.

May, 2015

(Ch. Srinivasa Rao)

Contents

कार्यकारी सारांश

संसाधन लक्षण

- हयातनगर अनुसंधान प्रक्षेत्र में वर्ष के दौरान सूखे की परिस्थितियां थी यहाँ वार्षिक वर्षा 435 मि.मी थी, जो 703.5 मि.मी की साधारण वर्षा की तुलना में 38 प्रतिशत कम थी एवं मानसून वर्षा 249.8 मि.मी. थी जो साधारण वर्षा की तुलना में 49 प्रतिशत कम थी। इस वर्ष 2.5 मि. मी. से अधिक वर्षा वाले दिनों की संख्या् 38 थी जोकि सामान्य तौर पर 48 दिनों के लगभग होती है।
- कृषि सांख्यिकी का जिला डेटाबेस एक डेटाबेस प्रबंधन प्रणाली का विकास किया गया एवं इसे ऑनलाइन उपलब्ध कराने के लिए वेब परिचालन योग्य बनाया गया। स्थिति एवं प्रवृत्ति को समझने के लिए उपयोगकर्ता डेटा को डाउनलोड कर, बार चार्ट, लाइन डायग्राम, पाई डायग्राम आदि बना सकते हैं एवं इसे इमेज फाइल के रूप में भी सुरक्षित रख सकते हैं।
- ज्वार, बाजरा, मक्का, अरहर, चना, मूंगफली, सूरजमुखी, सोयाबीन, राई व सरसों एवं कपास जैसी फसलों से उत्पादन लाभ के लिए उच्चतम क्षमतावाले जिलों की पहचान की गई।
- संबंधित परावैद्युतांको (dielectric constants) से मृदा नमी को आकलन करने के लिए लोएओ मॉडल(Loew model) एवं टॉप्पस मॉडल (Topps model) का सफलतापूर्वक प्रयोग किया गया एवं इन्हें क्रमश: निम्न एवं उच्च मृदा नमी प्रतिशत के आकलन के लिए अनुकूल पाया गया।

जलवायु परिवर्तन

- जलवायु परिवर्तन के प्रति अनुकूलन (Adaptation) पर किए गए अध्ययन से पता चला कि जलवायु परिवर्तन की परिस्थितियों में स्थानीय किस्म की तुलना में चावल की स्वर्णा किस्म ने बेहतर उत्पादन दिया।
- जलवायु विविधता एवं परिवर्तन के प्रति किसानों द्वारा अपनाए गए अनुकूलन उपायों में रोपण की तिथियां एवं फसल पद्धत्तियों में परिवर्तन प्रमुख थे। उसके बाद पशुधन में विविधीकरण आदि शामिल हैं।

वर्षाजल प्रबंधन

- प्राप्त वर्षा की मात्रा एवं शुष्क दौर से संबंधित दो विषम वर्षों के दौरान पॉलिमर(Polymer) का उपयोग कर मक्का के खेत में किए गए प्रयोगों के परिणामों ने स्पष्ट किया कि 25 किलोग्राम प्रति हेक्टेवयर पॉलियाक्रिलामाइड पॉलिमर (Polyacrylamide polymer) के उपयोग से फसल वृद्धि, उत्पादन में बढ़ोतरी एवं कम अवधि के शुष्क दौरों के प्रभावी प्रबंधन द्वारा वर्षाजल उपयोग क्षमता में वृद्धि हुई। लेकिन जब लगातार शुष्क दौरों सहित प्राप्त की गई वर्षा की मात्रा अपेक्षाकृत कम थी तो पालिमर का प्रभाव नहीं था।
- चार प्रबंधन विकल्पों के लिए सीडब्ल्यूपीएफ (फसल जल उत्पादन कार्य) का विकास किया गया एवं गुणांक के निर्धारण(R^2) में 0.88 एवं 0.97 के बीच की भिन्नता पाई गई।
- मक्का के प्रयोगिक आंकड़ों का उपयोग कर एफएओ और अक्वाक्राप मॉड़ल (FAO & Aqua Crop model) के निष्पादन का मूल्यांकन किया गया। मांपे गए (Measured) एवं अनुकरित (Simulated) अनाज उत्पादन डेटा तथा जल उत्पादकता के बीच (क्रमश R^2=0.93 एवं 0.85) अच्छा ताल–मेल देखा गया। जैविक मापे गए एवं मॉड़ल अनुकरित अनाज उत्पादन डेटा एवं जल उत्पादकता (क्रमशरू R^2= 0.99 तथा 0.85) की दक्षता भी सराहनीय रही जोकि स्वीकार्य सीमा में थी।
- भूमि उपयोग एवं प्रस्तावित स्व–स्थाने नमी संरक्षण उपायों तथा जलसंग्रहण में उपलब्ध भंड़ारण क्षमता पर आधारित जलसंग्रहण योजना के लिए नई कार्यप्रणाली का प्रस्ताव किया गया। यह कार्यप्रणाली विभिन्न भूमि उपयोगों के अंतर्गत स्व–स्थाने नमी संरक्षण पद्धत्तियों के द्वारा नमी उपलब्धता को ध्यान में रखकर अपवाह उपलब्धता के आधार पर विभिन्न भंड़ारण संरचनाओं (Storage structures) की आवश्यकताओं की पहचान में सहायता करती है।
- रबी क्षेत्र के लिए प्रमुख रूप में पहचाने गए 421 जिलों में, 112 जिलों में तीव्र से अति तीव्र भूमिजल रीचार्ज

की संभावनाएं हैं। इन 112 जिलों में, 32 जिले उत्तर प्रदेश में हैं, हरियाणा एवं पंजाब हरेक में 11 जिले, बिहार एवं महाराष्ट्र हरेक में 9 जिले, तेलंगाना में 7 जिले एवं अन्य कर्नाटक, मध्य प्रदेश एवं तमिलनाडु में फैले हैं। अन्य 133 जिलों में वर्तमान मानसून के दौरान भूमिजल रीचार्ज की संभावनाएं कम हैं एवं वे उत्तर प्रदेश (19 जिले), मध्यप्रदेश (121 जिले), गुजरात (18 जिले), राजस्थान (16 जिले), महाराष्ट्र (12 जिले), आंध्र प्रदेश (7 जिले) में फैले हुए हैं। शेष 198 जिलों में भूमिजल रीचार्ज की संभावनाएं मध्यम से साधारण स्तर की है।

- मानक गणितीय मॉड़लों (Standard Mathematical Models) एवं विभिन्न प्रक्षेत्र पर सिंचाई प्रणाली की अभिकल्पना के मानक प्रोटोकॉल (Standard protocol), विभिन्न विकल्पों सहित धरातल सिंचाई, एवं दबाव सिंचाई को ध्यान में रखकर, एक जल प्रयोग संबंधी सॉफ्टवेअर का विकास किया गया। मानक अभिकल्पना की आवश्यकताएं जैसेकि प्रवाह वेग, पंप का चयन, पाइप नेटवर्क, पाइप की विशिष्टताएं, चैनल का आकार, विभिन्न प्रत्यागमन काल (Return period) आदि जल प्रयोग सॉफ्टवेअर के प्रमुख लक्षण हैं।
- चयनित किए गए विभिन्न स्व–स्थाने मृदा एवं जल संरक्षण हस्तिक्षेपों में, चयनित किए गए अन्य हस्तक्षेपों की तुलना में अदिलाबाद जिले के लिए हस्तक्षेप जैसेकि पत्थर के बांध (क्षेत्र का 43 प्रतिशत), कंटूर बांध (क्षेत्र का 21 प्रतिशत), कंटूर पट्टियां (क्षेत्र का 14 प्रतिशत) एवं छोटे गर्त(क्षेत्र का 14 प्रतिशत) अधिक उपयुक्त थे।
- अमिस्तापुर सूक्ष्म–जलसंग्रहण के लगभग 80 प्रतिशत से मृदा हानि 1.5 टन प्रति हेक्टेयर प्रति वर्ष से कम थी। 15 प्रतिशत क्षेत्र में मृदा हानि 1.5 से 5 टन प्रति हेक्टेयर प्रति वर्ष थी, 3.5 प्रतिशत क्षेत्र में 5 से 10 टन प्रति हेक्टेतयर प्रति वर्ष– से अधिक थी एवं शेष 1.5 प्रतिशत क्षेत्र में 10 से 27 टन प्रति हेक्टेयर प्रति वर्ष थी। असमतल भूमि में, जो 450 से 510 मीटर अधिक एमएसएल(MSL) एवं 480 से 525 मीटर एमएसएल(MSL) ऊंचाई एवं 9.3 से 19.0 डिग्री की ढलानों पर स्थित है, मृदा अपरदन हानि तीव्र गति से देखी गई है।

फसल एवं फसल प्रणालियां

- प्रजनन पदार्थों(Breeding material) के उत्पादन के लिए कुल 35 नए संकर किस्म (cross varities) बनाने का प्रयास किया गया एवं चार संकरों को मक्का में सूखा सहिष्णुता के लिए क्युटीएल (QTL) विश्लेषण हेतु मानचित्रण जनसंख्या के विकास के लिए एफ3/एफ4 संतति तक अग्रेषित किया गया।
- अर्ध–मात्रात्मक आरटी–पीसीआर विश्लेषण ने एबीए दबाव से जीनों के SnRK2 परिवार की विभेदक अनुक्रिया को स्पष्ट किया। बहु अजैविक दबाव सहिष्णुता में शामिल PgLEW1 जीन से ट्रांसजेनिक तंबाकू पौधों का उत्पादन किया गया।
- निम्न, मध्यम एवं तीव्र भीषणता के नाशीजीव वर्गों के अनुमान के लिए महत्वपूर्ण मौसम परिवर्तियों (Weather variables) से किए गए मौसम सूचकांक की गणना के आधार पर तीव्रता अनुमान के लिए नाशीजीव विशेष निर्णय ट्री (Pest specific decision tree) का विकास किया गया। सांख्यकीय समीकरणों द्वारा ज्ञात निश्चित गुणांक माहूं (R^2=0.74), जैसिड (0.67), थ्रिप्सी (0.83) एवं श्वेत मक्षी (0.54) नाशीजीवों के लिए काफी महत्वपूर्ण थे।
- महाराष्ट्र के लिए मौसम की तुलना में फसल नाशीजीव तीव्रता की भौगोलिक सूचना प्रणाली पर स्टेण्डलोन (Standalone) प्रयोग का विकास किया गया। नाशीजीव आपतन के साप्ताहिक स्थानीय उपस्थिति का उपयोग जिला एवं तहसील स्तर के विभिन्न प्राचलों के लिए किया गया।
- मक्का एवं ज्वार की संकरयुक्त अंतरसस्ययन प्रणालियों ने स्थानीय किस्मों की तुलना में 30 से 40 प्रतिशत का अधिक उत्पादन लाभ दिया एवं सभी अंतरसस्ययन प्रणालियों के एलईआर (LER) एकल फसल प्रणाली से करीब 23 प्रतिशत श्रेष्ठ पाए गए।
- केवल उर्वरक या अहाता खाद के प्रयोग की तुलना में नाइट्रोजन, फासफोरस, पोटाश + पीएसबी की सिफारिश की गई मात्रा के प्रयोग से प्रोटीन (12.83 प्रतिशत) एवं जिंक (4.66 मिलि ग्राम प्रति 100 ग्राम) की मात्राओं में वृद्धि हुई।
- मक्का बीज के इंड़ोफाइटिस ने आणविक के साथ–साथ जैव–रसायन विविधता दर्शाई, लेकिन यह प्रदर्शन पादपरोगजनकों (37 प्रतिशत विलग) की तुलना में केवल दो पीजीपी जांचों यानि अमोनिया(सभी विलग) एवं एनटोगोनिस्म के लिए थे। मूंगफली के विलगों ने विभिन्नं पीजीपी जांचों के साथ–साथ अजैविक दबावों(सूखा एवं तापमान लवणता) के प्रति सहीष्णुता के भिन्न स्तरों को दर्शाया।

- जीवाणु टीकाकरण ने पर्यावरण वृद्धि चैंबर में तापमान दबाव परिस्थितियों के अंतर्गत मक्का की प्रोटीन अभिव्यक्ति प्रोफाइल को प्रभावित किया। प्रक्षेत्रीय परिस्थितियों के अंतर्गत, टीकाकरण रहित नियंत्रण की तुलना में तापमान सहीष्णु जीवाणु से टीकाकरण ने एएसआई (ASI) को कम किया। बोवाई की विभिन्न तिथियों के अंतर्गत जीवाणु स्ट्रेन एनआईसी (NIC) से उपचार ने अधिकतम अनाज उत्पादन दिया।
- देसी माइक्रोप्लोरा से ऐजोटोबैक्ट्र एसपी.19 के जीएफपी (टेट्रासाइक्लिनप्रतिरोधीजीन से) अंकित स्ट्रेन की अनुकूलता एवं ज्वार की जड़ों में क्लोरिन बनाए रखने की योग्यता, जैव टीकाकरण क्षमतावाले केंड़ीडेट स्ट्रेनों को पोषक प्रबंधन एवं पादप वृद्धि के लिए तैयार करती हैं।

मृदा स्वास्थ्य एवं पोषक प्रबंधन

- न्यूनतम कर्षण (449 किलोग्राम प्रति हेक्टेयर) की तुलना में पारंपरिक कर्षण से उड़द का महत्वपूर्ण रूप से बेहतर उत्पादन (540 किलोग्राम प्रति हेक्टेंयर) दर्ज किया गया। फसल कटाई के समय 60 सेंटीमीटर की ऊंचाई तक अवशेषों को बनाए रखने से महत्वपूर्ण रूप से बेहतर उड़द उत्पादन (567 किलोग्राम प्रति हेक्टेयर) प्राप्त हुआ इसके बाद नियंत्रण (406 किलोग्राम प्रति हेक्टेयर) की तुलना में 35 सेंटीमीटर तक अवशेषों को बनाए रखने से 512 किलोग्राम प्रति हेक्टे्यर उत्पादन हुआ।
- 18 वर्षों के प्रक्षेत्रीय प्रयोगों के बाद, पारंपरिक कर्षण से मृदा जैविक कार्बन भंड़ार (12.3 Mg/हेक्टेयर) एवं एमबीसी मात्रा (295 µg प्रति ग्राम मृदा) की तुलना में न्यूनतम कर्षण से महत्वपूर्ण रूप से बेहतर मृदा जैविक कार्बन भंड़ार (13.6 Mg/हेक्टे यर) एवं एमबीसी मात्रा(334 µg प्रति ग्राम मृदा) दर्ज किए गए।
- अन्य उपचारों की तुलना में बोवाई के 25 एवं 55 दिनों पर सिफारिश की गई नाइट्रोजन, फासफोरस, पोटाश की मात्रा. 0.5 प्रतिशत पानी में घुलनशील उर्वरकों का पर्ण छिड़काव. 0.5 प्रतिशत ZnSO4 + 20 ग्राम प्रति हेक्टेरयर के सोड़ियम सेलेनाइट के प्रयोग से मक्का भूसी का अधिकतम उत्पादन प्राप्त हुआ।
- क्रमश: कम एवं शून्य कर्षण की तुलना में पारंपरिक कर्षण से 17 एवं 38 प्रतिशत अधिक अरहर उत्पादन दर्ज किया गया। पारंपरिक एवं कम कर्षण की तुलना में शून्य कर्षण में मृदा एवं पोषक तत्वों की हानि कम देखी गई।
- विभिन्न नमी संरक्षण उपचारों में, साधारण बोवाई एवं तालाब गाद (Tank silt) के प्रयोग की तुलना में संरक्षण कूंड़ बनाने से 21 एवं 12 प्रतिशत अधिक अरंड़ उत्पादन प्राप्त हुआ। अहाता खाद . यूरिआ द्वारा 50 प्रतिशत नाइट्रोजन, करंज खली, नीम की खली लेप वाली यूरिआ एवं एकल यूरिआ की तुलना में वीटेक्स् लेप युक्त यूरिआ से क्रमश: 34,25,19 एवं 52 प्रतिशत अधिक अरंड़ उत्पादन दर्ज किया गया।
- क्रीडा बायोचर किल्न को प्रक्षेत्र पर लगाया गया ताकि विभिन्न लोडिंग दरों एवं आंशिक दहन अवधियों(Partial combustion periods) पर ग्लेरिसिड़िया एवं ल्युडकेना टहनियों के परिवर्तन की दक्षता का अध्ययन किया जा सके। 39.0 एवं 38.0 किलोग्राम प्रति किल्न की लोडिंग दर पर 32.0 एवं 21.0 प्रतिशत अधिकतम परिवर्तन दक्षता एवं ग्लेरिसिड़िया एवं ल्युकेना टहनियों के लिए क्रमश: 27.0 एवं 30.0 मिनटों की आंशिक दहन अवधि दर्ज की गई।

भूमि उपयोग विविधीकरण

- अमरूद में समेकित पोषक प्रबंधन में सिफारिश किए गए उर्वरक पीएसबी के प्रयोग से प्रति पौधा(72.13 किलोग्राम) अधिकतम उत्पादन प्राप्त हुआ। उसके बाद सिफारिश किए गए उर्वरक ट्राइकोडेरमा(50.05 किलोग्राम) एवं सिफारिश किए गए उर्वरक ऐजोटोबेक्टर (34.63 किलोग्राम) का स्थान रहा। सीताफल में, अन्य उपचारों की तुलना में, सिफारिश किए गए उर्वरक के साथ ऐजोस्पीरीलम के प्रयोग से फलों की अधिकतम संख्या (56) एवं उत्पादन प्रति पेड़(12 किलोग्राम) प्राप्त हुए।
- 2010 एवं 2013 के साधारण वर्षा वाले वर्षों के दौरान अनुपचारित नियंत्रणों की तुलना में पोषकों के जैविक एवं/या अजैविक स्रोतों से विभिन्न सूक्ष्मजीवों के मृदा निवेशन से अमरूद, सीताफल, आम एवं सिट्रस की फिनोलॉजिकल अवस्थाओं (Phenlogical events) पर लाभकारी प्रभाव पड़ा। जबकि, 2011,2012 एवं 2014 के कम एवं असमान वर्षा वितरण वाले वर्षों के अंतर्गत यह प्रभाव सीमित थे।
- एक प्रक्षेत्र जांच में, किसानों की प्रक्रिया(केवल ड्रिप सिंचाई) की तुलना में ड्रिप सिंचाई के साथ प्लासटिक पलवार (Plastic mulch) से अधिक टमाटर उत्पादन (3.7

किलोग्राम प्रति पौधा) प्राप्त हुआ। काली प्लांस्टिक की पलवार .50 प्रतिशत सिंचाई से 49.6 किलोग्राम प्रति हेक्टेयर–मि.मी. की अधिकतम जल उपयोग दक्षता उपलब्ध की गई।

- आंध्र प्रदेश से करीब 144 पोंगामिया प्राप्तियों का संग्रह किया गया एवं इन्हे एनबीपीजीआर, दिल्ली में क्रायो–संरक्षित (Cryo-preserved) किया गया।
- 9 वर्षों के मूल्यांकन अध्ययनों के आधार पर, अगेतेपन, उगाऊ प्राचलों एवं नाशीजीव प्रतिरोधिता के आधार पर निम्न पोंगामिया जीनरूपों को पंजीकरण या बड़े पैमाने पर रोपण के लिए सिफारिश किया गया राष्ट्रीय जांच–1 से टीएनएमपी–2, टीएनएमपी–4 एवं टीएनएमपी–1 संतति जाचं से परिग्रहण–14, परिग्रहण–13 एवं परिग्रहण–10 क्षेत्रीय जांच से टीएनएमपी–23, टीएनएमपी–6 एवं टीएनएमपी–3 ।

पशुधन प्रबंधन

- 1–1.5 हेक्टेमयर भूमि वाले किसानों को पशुधन का व्यवसाय अपना कर प्रक्षेत्र विविधिकरण से करीब 25–50 प्रतिशत लाभ प्राप्त हुआ।
- विटामिन E, Se एवं Zn संपूरक के प्रयोग से भेड़ों में तापमान दबाव को अपनाने की शक्ति प्राप्त हुई। पॉलिहरबल (Polyherbal) के प्राकृतिक उत्पादों के उपयोग से मिथेन उत्सर्जन में 17.35 प्रतिशत तक की कमी आई एवं यह पशुधन द्वारा मिथेन प्रशमन की एक अनुकूलता के रूप में सिद्ध हुई।

ऊर्जा प्रबंधन

- हयातनगर अनुसंधान प्रक्षेत्र–निक्रा परिसर पर मक्का के खेत में संशोधित हारवेस्टर (Modified harvester) की क्षमता की जांच की गई। छोटे ट्रेक्टर से जुड़े हारवेस्टर की तुलना में यह 50 प्रतिशत अधिक क्षमतायुक्त पाया गया। 85 प्रतिशत परिवहन क्षमता के साथ करीब 90 प्रतिशत डंठलों की कटाई उचित रूप से की गई। जबकि, इस अभिकल्पना को अंतिम रूप देने में कुछ और लंबी अवधि की जांचों की आवश्यकता है।
- उचित जगह पर बीज एवं उर्वरकों के प्रतिस्थापन के लिए बेड़ मेकर (Bed maker) के निचले हिस्सों एवं इसकी ड्राविंग मेकानिजम में समायोजन के द्वारा रेस्ड बेड(Raised bed) परमानेंट बेड़ प्लांगटर(Permanent bed planter) को सुधारा गया। इसे हयातनगर अनुसंधान प्रक्षेत्र पर चना,अरंड़, मक्का, कपास एवं ज्वार की फसलों के लिए जांचा गया। यह देखा गया कि समतल भूमि पर पारंपरिक बीज ड्रिल से फसल उगाई की तुलना में सभी मामलों में रेस्ड बेड़ प्लांटर (Raised bed planter) से उगाई गई फसलों की अंकुरण प्रतिशतता 15–22 प्रतिशत अधिक थी।
- खरीफ मक्का की बोवाई से पूर्व शुन्य कर्षण प्लॉट में 51 प्रतिशत का अधिकतम फसल अवशेष पृष्ठ छादन (Crop residue cover) दर्ज किया गया जबकि आरंभ में छादन 90 प्रतिशत था (मक्का अवशेष डंठल का उत्पादन 3187 किलोग्राम प्रति हेक्टेयर (शुष्क) एवं नमी 69 प्रतिशत थी। बॉयोमास का शीर्ण (Shredding) करने पर 5–10 सेंटीमीटर ऊंचाई वाली टूंटी फसल (Stubbles) को छोड़, कटे हुए बायोमॉस टुकड़ों की लंबाई लगभग 20 से 25 सेंटीमीटर थी जबकि आरंभ में फसल के डंठलों की औसत ऊंचाई 125 सेंटीमीटर थी।
- पारंपरिक माप एवं इमेज विश्लेष्ण तकनीकी का उपयोग कर मांपे गए (measured) बीज की लंबाई एवं चौड़ाई में अच्छा सहसंबंध पाया गया। संकर 1 (एच1), संकर 2 (एच2) तथा संकर 3 (एच3) में क्रमश: 0.889, 0.932 एवं 0.914 बीज की लंबाई के लिए समाश्रयण गुणांक (Regression Coefficients) तथा 0.919, 0.924 तथा 0.945 समाश्रयण गुणांक बीज की चौड़ाई के लिए पाए गए।
- 3.3 किलोमीटर प्रति घंटा आगे की गति पर चलाए गए न्युमेटिक सीड़ मीटरिंग मेकानिजम पर, 3.5 एमएम सेल व्यास एवं 4kPa नकारात्मक दबाव उत्पन्न हुआ। इससे सेल में बीज सुचारू रूप से गिरे एवं इन जांच परिस्थितियों में बहु बीज पिकअप्सन कम होने के कारण सूचकांक परिशुद्धता (Precision index) (3.58) के मामले में संतोषजनक परिणाम दिखाई दिए।

सामाजिक–आर्थिक अध्ययन एवं प्रौद्योगिकी हस्तांतरण

- बहु–उद्देशीय लीनिअर प्रोग्रामिंग मॉडल का उपयोग कर मृदा अपरदन एवं प्रक्षेत्र आय के बीच के संबंधों के अध्य्यन ने स्पष्ट किया कि सस्याक्रम में परिवर्तन एवं संसाधनों के इष्टतम उपयोग के कारण प्रतिफलों में वृद्धि एवं वार्षिक मृदा हानि में 14.5 टन प्रति प्रक्षेत्र से 8 टन प्रति प्रक्षेत्र की कमी आई। रास्टर केलकुलेटर

एवं मिश्रित संधारणीयता सूचक जैसे उपकरणों का उपयोग कर तेलंगाना के नलगोंड़ा एवं रंगारेड्डी जिलों में स्थित जलसंग्रहणों के मूल्यांकन ने स्पोष्ट किया कि जलसंग्रहण परियोजनाएं सकारात्मक थी लेकिन कृषि पर इनका प्रभाव न्यूनतम था क्योंकि डीपीएपी परियोजनाएं कुछ क्षेत्रों में संधारणीय थी पर अन्य में विफल रही। विफलता के कारण परियोजना अवधि के बाद असंधारणीय (Unsustainable) गतिविधियां, जलसंग्रहण क्षेत्र में निर्माण कार्यों की अधिकता एवं भूमि उपयोग में परिवर्तन थे।

- जलवायु विविधता एवं परिवर्तन पर किए गए अध्ययनों पर अनंतपुर, अकोला, सोलापुर एवं बीजापुर जैसे चार केंद्रों के परिणामों की तुलना की गई। इन केंद्रों के रूझान स्पष्ट करते हैं कि जलवायु विविधता एवं परिवर्तन पर अधिकांश किसानों का तात्पर्य (Perception) है दीर्घकालिक शुष्क दौर, तापमान में वृद्धि इसके बाद वर्षा होने में देरी एवं कम वर्षा। जलवायु विविधता एवं परिवर्तन पर किसानों द्वारा अपनाई जाने वाली प्रमुख अनुकूलताएं हैं फसल रोपण तिथियों में परिवर्तन, विभिन्न सस्यक्रम पद्धत्तियों को अपनाना एवं पशुपालन व्यवसाय अपनाना।

- सूखे के प्रति अतिसंवेदनशीलता पर अध्यायन से यह ज्ञात हुआ कि कुछ पुरूष किसान भी जलवायु परिवर्तन रूझानों से प्रभावित हैं, लेकिन कुछ भिन्न तरीकों से, कुछ पुरूष किसानों के पास कृषि के अलावा कोई अन्य जीवीकोपार्जन का साधन नहीं है, इसके अतिरिक्तक कौशलता की भी कमी महसूस की गई। इन पहलुओं को जीविकोपार्जन अतिसंवेदनशीलता के रूप में संप्रत्यायीकृत किया गया क्योंकि कुछ पुरूष किसान कुछ ही कौशल जानते हैं और वे कृषि के अलावा कोई अन्य कार्य नहीं कर सकते हैं। कुछ पुरूष किसानों का साधारणतया यह मानना है कि पानी की समस्या का मुख्य कारण पानी की उपलब्धता नहीं बल्कि इसका सही प्रबंधन न होना है। पुरूष किसान समेकित कृषि प्रणाली, ड्रिप सिंचाई एवं अलग–अलग समय पर बोवाई को प्रमुख अनुकूलन उपाय मानते हैं। दूसरी तरफ, महिला किसान बोरवेल सिंचाई, मूंगफली के बदले वैकल्पिक फसल ज्वार, अरंड़, अरहर की खेती एवं लकड़ियों के लिए जंगलों पर आधारित न होना जलवायु परिवर्तन के विरूद्ध प्रमुख अनुकूलन मानती हैं।

राष्ट्रीय जलवायु समुत्थान कृषि पहल

- भारतीय मौसम विभाग द्वारा प्रदान किए गए ब्लॉक स्तरीय मौसम पूर्वानुमानों पर आधारित 25 अखिल भारतीय समन्वित कृषि–मौसमविज्ञान अनुसंधान परियोजना(एक्रीपाम)– राष्ट्रीय जलवायु समुत्थाान कृषि पहल(निक्रा) केंद्रों द्वारा सूक्ष्म स्तरिय कृषि–मौसमविज्ञान सलाहें जारी की गई। 100 एडब्ल्यूएस (AWS) द्वारा एकत्रित सही समय के मौसम आंकड़ों का उपयोग कर आकाशीय अंतर्वेशित (Spatially interpolated) दैनिक मौसम मानचित्र तैयार किए गए।

- लंबी अवधि के उत्पादन एवं तीन स्थानों यानि बंगलूरू, आनंद एवं लूधियाना पर मौसम परिस्थितियों के विश्लेषणों के आधार पर मूंगफली के लिए मौसम बीमा उत्पादों की अभिकल्पना के लिए आवश्यक मौसम सूचकों का विकास किया गया।

- स्पेसबार्न आंकड़ों का उपयोग कर ओलावृष्टि से प्रभावित महाराष्ट्र के पूणे डिविजन(सोलापुर एवं पूणे जिले के कुछ भागों) में क्षति के क्षेत्रफल का अंदाजा एवं तीव्रता का मूल्यांकन किया गया। ओलावृष्टि से पूर्व एवं बाद के नार्मलाइस्ड डिफरेंस वेजिटेशन इंडेक्सी(NDVI) में अंतर का उपयोग कर क्षति का मानचित्र एवं मूल्यांकन किया गया। विभिन्न फसलों के अंतर्गत कुल क्षतिग्रस्त क्षेत्र लगभग 20770 हेक्टेयर था। वर्गीकृत उपग्रह चित्र में अंगूर, पपीता, अनाज एवं गन्ना के क्षतिग्रस्तग क्षेत्रों की पहचान की गई।

- भारत में कृषि अतिसंवेदनशीलता का मूल्यांकन करने के लिए उपग्रह आधारित वनस्पति सूचकांक की विविधताओं का उपयोग किया गया। NOAA&AVHRR और MODIS&TERRA (1982–2012) के आंकड़ों पर आधारित अधिकतम एनडीवीआई की सीवी(CV) एवं फसल उगाऊ काल की अवधि में विविधताओं संबंधी लगाए गए अनुमानों ने सूचित किया कि जलवायु परिवर्तन से 12 राज्यों के 122 जिलों में फैला 110 लाख हेक्टेयर क्षेत्रफल अतिसंवेदनशील है। यह अनुमान लगाया गया कि शुष्क, अर्ध–शुष्क तथा शुष्क उप–आर्द्र जैव–जलवायु में स्थित निवल बोए गए क्षेत्र के 46.3 लाख हेक्टेयर पर की जाने वाली कृषि प्रतिकूल रूप से प्रभावित होगी।

- जलवायु परिवर्तन से अरहर के उत्पादनों की

अतिसंवेदनशीलता के विश्लेषणों ने स्पष्ट किया कि 2031–50 के दौरान औसत उत्पादन स्तरों में करीब 76 किलोग्राम प्रति हेक्टेयर की कमी होगी, जोकि वर्तमान उत्पादन स्तरों का करीब 10 प्रतिशत है।

- विभिन्न मौसमों में किए गए अनुसंधान में मक्का के जीनरूपों के क्षेत्रीय समलक्षणों एवं सूखा सहीष्णु जीनरूपों की पहचान की गई। बाजरा की दबावग्रस्त cDNA लाइब्रेरियों से जल की कमी, अधिक तापमान एवं लवण दबावग्रस्ति एक्सप्रेस्ड सीक्वेंस टेगों(Tags) की पहचान की गई। रूपांतरण के लिए यूएसपी, एलईडब्ल्यू 1 एवं सीडीपीके से पादप व्यंगजक रोग वाहकों (Plant expression vectors) का निर्माण किया गया।
- पादप समलक्षणी सुविधा (Plant Phenotyping facility) से प्राप्त उच्च संवेश–प्रवाह आरजीबी डिजिटल इमेजरीस से सार लक्षणों(Extracting features) के लिए एमएटीएलएबी (MATLAB) में एक सॉफ्वेअर उपकरण का विकास किया गया।
- जल दबाव के दौरान कौन सा जीन नियामक प्रतिक्रिया व्यक्त करती है एवं क्या फाइलोजेनेटिक रूप से समान जल दबाव से समान प्रतिक्रिया होती है या नहीं? इन सबका पता लगाने के लिए मक्का के जल दबावग्रसित एवं नियंत्रण पौधों की संपूर्ण जिनोम माइक्रोएर्रे (Whole Genome Microarray) की गई। 4500 जीनों के व्यांजक पर आंकड़े एवं मक्का के जिनोम में अनुलेखन कारक (Transcription factors) प्राप्त किए गए एवं उनकी व्यजक पद्धत्ति (Expression pattern) की पहचान की गई।
- सिंचित एवं सूखा दबावग्रस्त परिस्थितियों में बायोमॉस संग्रहण, बीज उत्पादन एवं फसल कटाई सूचक के लिए तीन अरहर जीनरूपों जैसेकि जीटी–1, एकेपी–1 एवं सूखा दबाव के अंतर्गत पीआरजी–158 का मूल्यांकित किया गया। पीआरजी–158 ने बेहतर जल उपयोग दक्षता दर्शाई।
- बेहतर वाष्पोस्तर्जन (Transpiration) के लिए मक्का के जीनरूपों के परीक्षण ने स्पष्ट किया कि जेड़32–87, जेड़6–34, जेड़59–9,डीटीएल–2 एवं आरजेआर–288 जीनरूपों ने बेहतर स्टोमी घनत्व सहित बेहतर स्टोमी चालकता, अधिक जल का वाष्पोस्तर्जन एवं अधिक बायोमॉस का उत्पादन इत्यादि गुण दर्शाए जिसके परिणामस्वरूप बेहतर वाष्पोस्तर्जन (Transpiration) क्षमता प्राप्त हुई।
- कुल कार्बोहाइड्रेटों एवं क्रूड रेशा मात्रा के लिए अरहर की नौ किस्मों का विश्लेषण किया गया। जीनरूप एकेपी–1, एल–201 एवं डब्ल्यू की आरजी में बेहतर कुल कार्बोहाइड्रेट तथा पीजी–25, जीटी–1, एल–201 एवं पीटी–002 में बेहतर क्रूड़ रेशा मात्रा पाई गई।
- कर्षण एवं अवशेष प्रयोग से लंबी अवधि के परिणामों ने स्पष्ट किया कि न्यूतनतम कर्षण के अंतर्गत 6 टन ज्वार अवशेष के प्रयोग से बेहतर लोबिया अनाज उत्पादन, मृदाजल अंतरसस्यन दन दर एवं कम मृदा संहनन (Compaction) अनुभव किए गए।
- अरहर–अरंड़ घूर्णन(Rotation) में विभिन्न कर्षण एवं फसल अवशेष प्रबंधन प्रक्रियाओं की तुलना ने स्पष्ट किया कि पारंपरिक एवं कम कर्षण की तुलना में शून्य कर्षण में अधिक मृदा जैविक कार्बन की मात्रा दर्ज की गई। इसके अतिरिक्त 30 एवं 10 सेंटीमीटर कर ऊंचाई पर फसल अवशेष रखने से नियंत्रण की अपेक्षा अधिक जैविक कार्बन की मात्रा अनुभव की गई। पारंपरिक कर्षण की तुलना में कार्बन पदचिह्न, प्रचालन उपयोग एवं निवेश उपयोग से जीएचजी उत्सर्जनों को देखते हुए शून्य कर्षण एवं कम कर्षण में क्रमश: 23 एवं 9 प्रतिशत कम उत्सर्जन देखा गया।
- मध्य प्रदेश के रीवा मे तेरह वर्षों की लंबी अवधि के पोषक प्रबंधन प्रयोग से चावल प्रणाली में कार्बन की सक्रीयता के लिए किए गए मृदा नमूनों के विश्लेषण ने स्पष्ट किया कि कंपोस्ट से डाली गई 100 प्रतिशत नाइट्रोजन में अधिक मृदा जैविक कार्बनपृथक्करण हुआ।
- लोबिया एवं चना हरेक की दो किस्मों के जड़ एवं प्ररोह के जैव–रसायन विश्लेषण ने स्पष्ट किया कि प्ररोह की तुलना में जड़ों में (विशेषकर लिग्निन) अधिक रेशा के अंश पाए गए।
- जैविक, अजैविक एवं समेकित फसल प्रबंधन प्रणालियों के अंतर्गत सूरजमुखी एवं उड़द के निष्पादन के तुलनात्मक मूल्यांकन में, जैविक एवं अजैविक प्रबंधन की तुलना में समेकित प्रबंधन में सूरजमुखी एवं मूंगबीन का अधिक उत्पादन हुआ।
- वृक्षों में जलवायु दबाव अनुकूलन प्रक्रियाओं के रूप में अधिकतम फसल वृद्धि के लिए जड़ प्रणाली के पुनरभिमुखीकरण के उद्देश्यू से मृदा में सूक्ष्मजीवीय गतिविधि में सुधार एवं मृदा में सीमित नमी का प्रभावी उपयोग किया गया।

- 10 वर्ष पुराने रोपणों (Plantation) में जीएचजी उत्सृर्जनों के मांप ने स्पष्ट किया कि जेट्रोफा में अधिक उत्सर्जन है, इसके बाद सीमारूबा एवं पोंगामिया का स्थान रहा। साधारणतया, जीएचजी का उत्सर्जन ठण्ड़ के मौसम की तुलना में वर्षा के मौसम में अधिक होता है। जेट्रोफा में, धरातल कुल शुष्क बायोमॉस, भूमिगत कुल शुष्क बायोमॉस एवं कुल बायोमॉस से संबंध स्थापित करने और भिन्न्ता दर्शाने में कोल्लार डायमीटर (Collar diameter) उपयुक्त पाया गया एवं इससे बायोमॉस का आकलन किया जा सकता है।
- मूंगफली माहूँ, अरहर रोमिल इल्ली, मक्का माहूँ एवं मूंगफली थ्रिप्स (Thrips) (स्किरेटोथ्रिप्सक एवं केलिलिओथ्रिप्सह) (Scirtothrips and Caliothrips) जैसे कीट नाशीजीवों के विकास पर तापमान के प्रभाव का अध्ययन किया गया। जीवन सारणी दृष्टिकोण का उपयोग कर मूंगफली की फसल में स्पोसडोप्टेरा लिटुरा फेब (*Spodoptera litura Fab*) के नाशीजीव परिप्रेक्ष्य के अनुमानों पर किए गए अध्ययनों ने स्पष्ट किया कि स्पोयडोप्टेपरा लिटुरा (*Spodoptera litura*) की वृद्धि एवं जीवन सारणी प्राचलों को तापमान एवं कार्बन डाईआक्साइड काफी प्रभावित करते हैं। भविष्य मे जलवायु परिस्थितियों के अंतर्गत नाशीजीव का आपतन अधिक हो सकता है।
- स्केलेरोटियम रॉल्फ्सिल पर उत्थित कार्बन डाइआक्साइड के प्रभाव पर किए गए अध्ययनों ने स्पष्ट किया कि स्केवलोरोशिआ के बायोमॉस या आकार पर 550 पीपीएम कार्बन डाइआक्साइड का कोई प्रभाव नहीं था।
- छोटे पशुओं की वृद्धि पर चराई की पद्धत्ति के प्रभाव के विश्लेषण से पता चला कि चराई भूमियों में उचित मात्रा में चारा की अनुपलब्धता एवं उसके बाद तापमान दबाव के कारण वर्ष के जून से नवंबर में अधिक एवं मार्च से मई के दौरान कम औसत दैनिक वृद्धि एवं भार वृद्धि थी। ग्रीष्म की तुलना में वर्षा के मौसम के दौरान रक्त् में ग्लूकोस, कोलेस्ट्राल, ट्रिग्ला इसेरिडस एवं कुल प्रोटीन महत्वपूर्ण रूप से अधिक थे। ग्रीष्म के दौरान क्रियाटिना एवं रक्त यूरिआ नाइट्रोजन की अधिकता दर्शाती है कि पशु दबावग्रस्त हैं। दक्क्नी किस्मो की तुलना में नेल्लूरि संकर अधिक जलवायु समुत्थाान थे एवं मादा की तुलना में नर काफी समुत्थान थे।
- आंध्र प्रदेश के बाढ़ग्रस्त क्षेत्र के ज्ञान की आवश्यकताओं के विश्लेषण ने स्पष्ट किया कि दबाव(बाढ़) सहीष्णु किस्मों पर किसानों ने सूचना दी, उसके बाद बाढ़ परिस्थितियों के दौरान नाशीजीव एवं रोगों के प्रबंधन की सूचना की आवश्यकता जताई जबकि क्षेत्र स्तरीय प्रसार अधिकारियों ने आकस्मिक फसल योजनाओं से संबंधित सूचना पर अधिक महत्व दिया।
- चार मांपदंड़ों जैसेकि प्राकृतिक संसाधन प्रबंधन, फसल उत्पादन, पशुधन एवं मात्स्यिकी के अंतर्गत खरीफ के दौरान 100 निक्रा कृषि विज्ञान केंद्रों में मुख्यत: जलवायु पर जोर डालते हुए प्रौद्योगिकी हस्तक्षेपों (Interventions) का कार्यान्वयन किया गया तथा संस्थागत हस्तक्षेपों ने आशाजनक परिणाम दिए। निक्रा द्वारा अपनाए गए गांवों में जलवायु समुत्थान प्रक्रियाओं एवं प्रौद्योगिकियों को अपनाने के लिए चयनित किसानों को चतुर किसान (Smart Farmer) प्रमाणपत्रों से पुरस्कृत किया गया। विभिन्नं क्षेत्रों के 30 चुने गए कृषि विज्ञान केंद्रों पर चलाए जा रहे जलवायु समुत्थुन एवं प्रौद्योगिकी पर वीडियो प्रलेखन तैयार किया गया। विभिन्न मापदंड़ों के अंतर्गत निक्रा गांवों में उनासी प्रशिक्षण कार्यक्रमों का आयोजन किया गया।
- फसल, पशुधन, पोल्ट्री एवं मात्स्यिकी क्षेत्रों में मौसम प्रतिकूलताओं से जूझने के लिए आठ जिला स्तरीय आकस्मिक योजनाओं को तैयार किया गया।

कृषि विज्ञान केंद्र

- रंगा रेड्डी जिले के किसानों के लिए बेहतर प्रौद्योगिकी के विभिन्न पहलुओं एवं कई प्रसार गतिविधियों पर कृषि विज्ञान केंद्र द्वारा 14 प्रौद्योगिकियों पर 134 प्रक्षेत्र जांच (On farm trail), 123 अग्रिम पंक्ति प्रदर्शन, 63 आवश्यकता आधारित एवं कौशलोन्मुख प्रशिक्षण कार्यक्रमों का आयोजन किया गया। निक्रा परियोजना के अंतर्गत, रंगा रेड्डी जिले में पुडूर मंड़ल के कंड्लापल्लीग, मिर्जापुर एवं येल्लंकीपल्ली गांवों में भू–जल स्तरों की मॉनीटरी, छाया नर्सरी के अंतर्गत प्रो–ट्रेस (Pro&trays) में अच्छे पौधों का उत्पादन, बैंगन में प्लास्टिक पलवार एवं बेहतर चारा उत्पादन गतिविधियों का आयोजन किया गया। कृषि विज्ञान केंद्र ने 2,92,270/- रुपए का राजस्वा अर्जित किया।

मानव संसाधन विकास

- वर्ष के दौरान, 3 वैज्ञानिकों ने देश मे आयोजित ही प्रशिक्षण कार्यक्रमों में भाग लिया एवं 2 वैज्ञानिकों ने विदेश में प्रशिक्षण/कार्यशाला/बैठकों में भाग लिया। संस्थान में पचीस स्नातकों एवं स्नातकोत्तर विद्यार्थियों ने अपनी परियोजनाएं/अनुसंधान कार्य पूरा किया।

पुरस्कार एवं मान्यताएं

- अखिल भारतीय समन्वित कृषि–मौसमविज्ञान अनुसंधान परियोजना को जलवायु विविधता एवं सही समय की आकस्मिक योजनाओं के विकास पर उत्कृष्ट कार्य के लिए चौधरी देवी लाल उत्कृष्ट अखिल भारतीय समन्वित अनुसंधान परियोजना 2013 से पुरस्कृत किया गया। संस्थान के कई वैज्ञानिकों को राष्ट्रीय अकादमियों/ व्यावसायिक सोसाइटियों जैसेकि राष्ट्रीय कृषि विज्ञान अकादमी, भारतीय सस्य विज्ञान सोसाइटी एवं कृषि–प्रसार, कंप्यूटर प्रयोग तथा कृषि इंजीनियरिंग सोसाइटी आदि से संबंधित सोसाइटियों के अध्येतावृत्ति से पुरस्कार प्राप्त हुए। कई वैज्ञानिकों को अनुसंधान, प्रौद्योगिकी हस्तांतरण एवं संचार आदि में योगदान के लिए पुरस्कार प्राप्त हुए।

संपर्क एवं सहयोग

- संस्थान पणधारियों एवं संगठनों(राष्ट्रीय एवं अंतर्राष्ट्रीय) से नए संपर्क एवं सहयोग स्थापित कर तथा अपने तकनीकी कार्यक्रमों को और अधिक प्रभावी रूप से कार्यान्वित करने के लिए पुराने संपर्कों के नवीकरण द्वारा मजबूत रिश्ते बनाकर लागू कर रहा है।

प्रकाशन

- अभिजात समीक्षा पत्रिकाओं में बानवे अनुसंधान लेख प्रकाशित हुए। वैज्ञानिकों का योगदान कई पुस्तकों, बुलेटिनों, पुस्तक के अध्याोयों एवं लोकप्रिया लेखों के रूप में प्रकट हुआ। वेदर कॉक 14 – मौसम विश्लोषण सॉफ्टवेअर एवं इनजेन – कीट निर्माण केलकुलेटर सॉफ्टवेअर का विकास कर विमोचित किया गया। आनलाइन ओपन सोर्स आधारित विषयपरक मानचित्रों का निर्माण उपकरण (http://www-crida-in/onlinemap-html), ओपन सोर्स आधारित क्रीड़ा डिजिटल संग्रह (http://www-eprints&crida-in), एवं आनलाइन प्रश्नक आधारित आकस्मिक योजना पुनरूप्राप्ति प्रणाली (http://www-crida-in:82/CFCP/) इत्यादि का विकास किया गया।

आईएसओ प्रमाणन

संस्थान को 21 अगस्त 2014 से 20 अगस्त 2017 की अवधि के लिए आईएस/आईएसओ 9001:2008 के अनुसार गुणता प्रबंधन प्रणाली के अंतर्गत गुणता प्रमाणन का लाइसेन्स प्रदान किया गया।

Executive Summary

Resource characterization

- Drought conditions prevailed during the year at Hayathnagar Research Farm where the annual rainfall was 435.5 mm, 38% lower than the normal rainfall of 703.5 mm, and monsoon season rainfall was 249.8 mm, 49% lower than the normal. There were 38 days with rainfall >2.5 mm compared to normal of 48 rainy days.
- 'District Database of Agricultural Statistics - A database management system' was developed and web enabled to make available online. Users can download data or generate bar chart, line diagram, pie diagram, etc. from the data to understand status or trends and the same can be saved as an image file.
- Districts with high potential for yield gains were identified for crops viz., rice, sorghum, pearlmillet, maize, pigeonpea, chickpea, groundnut, sunflower, soybean, rapeseed & mustard and cotton.
- Loew model and Topps model was successfully applied to derive soil moisture from respective dielectric constants and was found to estimate the lower and higher soil moisture percentage, respectively.

Climate change

- A study on adaptation to climate change showed that change of variety (Swarna) in rice would give better yields compared to the local variety in a climate change scenario.
- The major adaptation measures followed by farmers towards climate variability and change include change in planting dates and cropping pattern followed by diversification to livestock

Rainwater management

- The results of maize field experiments with polymer conducted during two contrasting years with respect to amount of rainfall received and length of dry spells clearly indicated that the application of 25 kg/ha polyacrylamide polymer would enhance crop growth, yield and rain water use efficiency by effectively managing short dry spells. But their effect may not be significant if the amount of rainfall received is considerably low with prolonged dry spells.
- The CWPF (crop water production function) for four management options were developed and the coefficient of determination was found to vary between 0.88 and 0.97.
- The FAO-AquaCrop model performance was evaluated using the experimental data of maize. Good agreement was observed between measured and simulated grain yield and water productivity with R^2 of 0.93 and 0.86 respectively. The model simulated grain yield and water productivity with an efficiency of 0.99 and 0.85 respectively which are within the acceptable limits.
- A new methodology was proposed for watershed planning based on land use and proposed *in-situ* conservation measures and existing storage available within watershed. The methodology helps identify the requirement of on-stream storage structures within the watershed based on runoff available after accounting for *in-situ* conservation methods in various landuses.
- Out of 421 districts indentified to be dominant for rabi areas, 112 districts had extremely low to very low ground water recharge prospects. Among these 112 districts, 32 districts are in Uttar Pradesh, 11 districts each in Haryana and Punjab, 9 districts each in Bihar and Maharashtra, 7 districts in Telangana and others are spread in Karnataka, Madhya Pradesh and Tamilnadu. Another 133 districts had the low prospects for ground water recharge during the current monsoon and are spread in Uttar Pradesh (19

districts), Madhya Pradesh (121districts), Gujarat (18 districts), Rajasthan (16 districts), Maharashtra (12 districts), AP (7 districts). The remaining198 districts had the possibility of medium to normal ground water recharge prospects.

- A water application software (WAS) that included the standard mathematical models and standard protocols for the design of different on-farm irrigation system, including surface irrigation as well as pressurized irrigation in structured form with different options was developed. The standard design requirement such as flow velocity, pump selection, pipe network, pipe specification, channel dimensions, irrigation water requirement at different return period etc. are the major features of WAS.
- Among different *in-situ* soil and water conservation interventions selected, the interventions like stone bunds (43% of area), contour bunds (21% of area), contour strips (14% of area) and small pits (14% of area) were more suitable for Adilabad District compared to other interventions selected.
- The soil loss from 80% of the Amistapur micro-watershed was below 1.5 t ha^{-1} y^{-1}. The soil loss from 15% area ranged from 1.5 to 5 t ha^{-1} y^{-1}, 3.5% area ranged from more than 5 to 10 t ha^{-1} y^{-1} and remaining 1.5% area ranged from more than 10 to 27 t ha^{-1} y^{-1}. Severe erosion was noted in regions with highly undulated topography with a steep rise in elevations from 450 to 510 m above MSL and 480 to 525 m above MSL and with slopes ranged from 9.3 to 19.0 degrees.

Crops and cropping systems

- A total of 35 new crosses were attempted for generation of breeding materials and four crosses were advanced to F3 / F4 generation for development of mapping population for QTL analysis for drought tolerance in maize.
- Semi-quantitative RT-PCR analysis revealed differential response of SnRK2 family of genes to ABA stress. Transgenic tobacco plants with PgLEW1 gene involved in multiple abiotic stress tolerance were generated.
- Pest specific decision tree models were developed for predicting severity based on weather index computed from significant weather variables for pest categories of low, medium and high severity. Goodness of fit statistics indicated higher coefficients of determination for aphids (R^2 = 0.74), jassids (0.67), thrips (0.83) and whitefly (0.54).
- Developed a standalone application on GIS for crop pest severity vis-à-vis weather for Maharashtra using weekly spatial overlays of pest incidence over different weather parameters for district and tehsil level.
- Intercropping systems involving hybrids of maize and sorghum were found superior to those of local varieties with an yield advanatageof 30-40% and LER of all intercropping systems were superior to sole systems by about 23%.
- Application of recommended NPK + PSB enhanced the protein (12.83%) and Zn contents (4.66 mg/100 g) in maize grain compared to application of fertilizers or farmyard manure alone.
- Endophytes from maize seed exhibited molecular as well as biochemical diversity, but exhibited only two PGP traits i.e. ammonia (all isolates) and antagonism against phytopathogens (37% isolates). Groundnut isolates exhibited various PGP traits as well as varying degree of tolerance to abiotic stresses (drought and heat salinity).
- Bacterial inoculation influenced the protein expression profile of maize under heat stress conditions in environmental growth chamber. Under field conditions, inoculation with thermotolerant bacteria reduced ASI as compared to uninoculated control. Treatment with bacterial strain NIC8 showed highest grain yield under different dates of sowing.

Soil and nutrient management

- Conventional tillage recorded significantly higher yield (540 kg/ha) of blackgram compared to minimum tillage (449 kg/ha). Residue retention at 60 cm height recorded significantly higher

blackgram yield (567 kg/ha) followed retention at 35 cm height (512 kg/ha) compared to control (406 kg/ha).

- After 18 years of field experimentation, minimum tillage recorded significantly higher soil organic carbon stock (13.6 Mg/ha) and MBC content (334 µg/g) compared to conventional tillage (12.3 Mg/ha and 295 µg/g, respectively). Similarly, application of gliricidia loppings and sorghum stover recorded significantly higher soil organic carbon stock and MBC contents compared to control.
- Application of recommended NPK + foliar spray of 0.5% water soluble fertilizer + 0.5% $ZnSO_4$ + 20 g/ha of sodium selenite at 25 and 55 DAS resulted in highest maize straw yield (4892 kg/ha) compared to other treatments.
- Conventional tillage recorded 17 and 38% higher pigeonpea yields as compared to reduced and zero tillage, respectively. Lower soil and nutrient losses were observed in zero tillage as compared to conventional and reduced tillage.
- Among different moisture conservation treatments, conservation furrow recorded 21 and 12% higher castor seed yield as compared to normal sowing and tank silt application. Vitex coated urea recorded 34, 25, 19 and 52% higher castor yields as compared to FYM + 50% N through urea, Karajin cake, neem cake coated urea, and urea alone respectively.
- CRIDA biochar kiln was used at farm level to study the conversion efficiency of Gliricidia and Leucaena twigs at different loading rates and partial combustion periods. The highest conversion efficiency of 32.0 and 21.0% was obtained at a loading rate of 39.0 and 38.0 kg/kiln and a partial combustion period of 27.0 and 30.0 minutes for Gliricidia and Leucaena twigs, respectively.

Land use diversification

- Integrated nutrient management in guava involving application of recommended fertilizers (RDF) + PSB gave highest yield per plant (72.13 kg) followed by RDF + Trichoderma (50.05 kg) and RDF + Azotobacter (34.63 kg). In custard apple, application of RDF along with Azospirilum gave the maximum number of fruits (56) and yield per tree (12 kg) compared to other treatments.
- Beneficial effects on the phenological events of guava, custard apple, mango and citrus were observed with the soil inoculation of different microbes with organic and / or inorganic sources of nutrients compared to untreated controls during normal rainfall years of 2010 and 2013. However, these effects were limited under less or erratic rainfall distribution years of 2011, 2012 and 2014.
- In an on-farm trial, plastic mulching coupled with drip irrigation gave higher tomato yield (3.7 kg/plant) compared to farmers' practice (drip irrigation alone). Maximum WUE of 49.6 kg/ha-mm was obtained with black plastic mulching + 50% irrigation.
- About 144 pongamia accessions were collected from Andhra Pradesh and have been cryo-preserved at NBPGR, Delhi.
- On the basis of 9 years of evaluation studies, depending on earliness, growth parameters and pest resistance the following pongamia genotypes are recommended for registration or for large scale plantations: TNMP-2, TNMP-4 and TNMP-1 from national trial-I; Acc-14, Acc-13 and Acc-10 from progeny trial, and TNMP- 23, TNMP- 6 and TNMP-3 from zonal trial.

Livestock management

- Farm diversification with livestock improved profitability by 25-50% for farmers having 1-1.5 ha of land
- Supplementation with vitamin E, Se & Zn was found to impart better adaptive capacity in sheep towards heat stress. Use of polyherbal preparations was found to reduce methane emission by up to 17.35% and thus found to be one of the methane mitigating strategies in livestock.

Energy management

- The modified harvester was tested for its efficacy in maize field at HRF-NICRA complex. It was found that the efficiency of the harvester was increased by 50 % when compared to the mini tractor mounted harvester. About 90 % stalks were cut properly with 85 % conveying efficiency. However, some more long term tests are needed to go further in finalizing the design.
- Raised bed/permanent bed planter was refined by adjusting the bottom of the bed maker and its driving mechanism for accurate seed and fertilizer placement. This was tested at HRF farm for redgram, castor, maize, cotton and sorghum crops. It wasobserved that, in all the cases the germination percentage of the crops grown with raised bed planter was 15-22 % higher than the crops grown with conventional seed drill on flat surface.
- The highest crop residue surface cover recorded under zero till plot was 51% before sowing of kharif maize where the soil surface coverage achieved with the machine was 90% at maize stalk production of 3187 kg/ha (dry basis) with 69% (wet basis) stalk moisture content. The length of shredded biomass pieces ranged from 20 to 25cm against the average stalk height of 125cm, leaving crop stubbles in the height range of 5 - 10 cm.
- Good correlation was found in length and width of seed measured using conventional measurement and image analysis technique and followed a linear relation with regression coefficients0.889, 0.932 and 0.914 for length and 0.919, 0.924 and 0.945 for width of seed for hybrid1(H1), hybrid2 (H2) and hybrid3 (H3) respectively.
- The pneumatic seed metering mechanism operated at 3.3 kmph forward speed, 3.5 mm cell diameter and 4 kPa negative pressure gave a highly satisfactory result in terms of the precision index (3.58), as the quality of seed feeding into cell is good and as well as low multiple seed pickups at these test conditions.

Socioeconomic aspects

- Study of trade of between soil erosion and farm income in a multi-objective linear programming model showed that changes in the cropping pattern and resource use through optimization led to increase in net returns and reduction in the annual soil loss from 14.5 to 8 t/farm.
- An evaluation of watersheds in Nalgonda and Rangareddy districts of Telangana by applying tools like raster calculator and composite sustainability index showed that watershed projects had a positive but marginal impact on agriculture as DPAP projects were sustainable in some locations and failed in others. Causes of failure were unsustainable activities, construction and land use change in watershed area during post-project phase.
- Results across four centers viz., Anantapur, Akola, Solapur and Bijapur were compared and trends across the centers show that the prominent farmers' perceptions towards climate variability and change are: prolonged dry spells, rise in temperatures followed by delayed and shorter rains. The important adaptation measures followed by farmers towards climate variability and change are: change in planting dates, cropping pattern followed by diversify to livestock.
- Vulnerability to drought from men group as indicated from cluster map showed that climate change had affected men too but in different ways which are mostly centered on livelihoods having fewer options in job areas other than agriculture due to skill poverty. These aspects had been conceptualized as Livelihood vulnerability (LV), as male farmers have been equipped with few skills and are unable to shift to other occupations other than farming. The general perception of male farmers is that water problem is so acute primarily due to poor management rather than availability of water itself.
- Integrated farming system, drip irrigation, and staggering sowing were the major adaptation measures as perceived by men farmers. On

the other hand, women farmers saw borewell irrigation, cultivation of sorghum, castor, pigeonpea as alternative crop to groundnut and dependence on non-forest timber produce as important to adaptation to climate change.

NICRA

- Micro-level agromet advisories were issued by 25 AICRPAM-NICRA centers based on block-level weather forecast provided by IMD. Real-time weather data from 100 AWS were used to generate spatially interpolated daily weather maps.
- Weather indices required for designing weather insurance products for groundnut were developed by analyzing long-term yield and weather conditions at three locations viz., Bangalore, Anand and Ludhiana.
- Extent and intensity of damage caused by hailstorms that struck Pune Division (Solapur and parts of Pune district) of Maharashtra were assessed using space borne data. Difference in Normalised Difference Vegetation Index (NDVI) before and after hailstorm was used to map and assess the damage. Total damaged area under different crops was estimated at 20779 ha. Damaged fields of grape, papaya, pomegranate and sugarcane were identified in the classified satellite image.
- Variations in satellite based vegetation index were used to assess agricultural vulnerability in India. CV of Max NDVI and variations in length-of-crop-growing-period (LGP) estimated from NDVI composites of NOAA-AVHRR and MODIS-TERRA (1982- 2012) indicated that 122 districts covering 110 million ha in 12 states are vulnerable to climate change and agriculture in 46.3 million ha of net sown area located in arid, semi-arid and dry sub-humid bio-climate would be adversely affected.
- An analysis of vulnerability of pigeonpea yields to climate change showed that the average yield levels during 2021-50 would be lower by about 76 kg/ha, which is about 10 per cent of current yield levels.
- Field phenotyping of maize genotypes was carried out over the seasons and drought tolerant genotypes were identified. Water-deficit, high temperature and salt (NaCl) stress induced expressed sequence tags (ESTs) were identified from stress induced cDNA libraries of pearl millet. Plant expression vectors with USP, LEW1 and CDPK genes were constructed for transformation.
- A software tool was developed in MATLAB for extracting features from high throughput RGB digital imageries acquired from plant phenotyping facility.
- Whole Genome Microarray of water stressed and control plants of maize was done to determine which genes regulate responses to water stress and also to determine if phylogenetically similar genes have similar responses to water stress. Data on the expression of 4500 genes and transcription factors in the maize genome was obtained and their expression pattern was determined.
- Three pigeon pea genotypes viz., GT-1, AKP-1 and PRG-158 were assessed for biomass accumulation, seed yield and harvest index under irrigated and drought stressed conditions. PRG-158 showed higher water use efficiency under drought stress.
- Screening of maize genotypes for higher transpiration efficiency (TE) showed that genotypes Z32-87, Z6-34, Z59-9, DTL-2 and RJR-288 with higher stomatal density had higher stomatal conductance, transpired more water and produced more biomass resulting in higher TE.
- Nine varieties of pigeon pea genotypes were analysed for total carbohydrates and crude fiber content. Genotypes AKP-1, AL-201 and WRG had higher total carbohydrates and PRG-25, GT-1, AL-201 and PT-002 had higher crude fiber content.
- Results of a long term experiment with tillage and residue application showed higher cowpea grain yield and soil infiltration rate, and lower soil compaction with application of 6 t/ha of sorghum residue under minimum tillage.

- A comparison of different tillage and crop residue management practices in pigeonpea-castor rotation showed higher soil organic carbon with zero tillage over conventional and reduced tillage, and with 30 cm high residue retention over 10 cm and no residue retention. Carbon footprint, considering GHG emissions from operation use and input use, was 23% and 9% lower with zero tillage and reduced tillage respectively over conventional tillage.
- Analysis of soil samples for carbon dynamics in rice system from thirteen year long term nutrient management experiment at Rewa in Madhya Pradesh indicated higher soil organic carbon sequestration with 100% N through compost.
- Biochemical analysis of root and shoot samples of two varieties each of cowpea and horsegram showed that roots had higher fibre fraction, especially lignin, compared to shoots.
- In a comparative evaluation of the performance of sunflower and green gram under organic, inorganic and integrated crop management systems, integrated management was found to give higher yield of sunflower and green gram compared to organic and inorganic management.
- Improving soil microbiological activity and to making use of limited moisture in the soil in order to reorient root systems for optimum crop growth were identified as climatic stress adaptatiom mechanisms in tree crops.
- Measurement of GHG emissions in 10 year old plantations showed higher emissions in Jatropha followed by Simarouba and Pongamia. In general, GHG emissions were higher in rainy season compared to winter season. In Jatropha, collar diameter was found to explain much of the variation in above ground total dry biomass, below ground total dry biomass and total dry biomass and can be used for estimating the biomass.
- Effect of temperature on development of insect pests was studied for groundnut aphid, pigeonpea hairy caterpillar, maize aphid, and groundnut thrips (Scirtothrips and Caliothrips). An exercise on prediction of pest scenarios of *Spodoptera litura Fab.* on peanut using life table approach indicated that temperature and CO_2 are vital in influencing the growth and life table parameters of *S. litura* and that pest incidence is likely to be higher under climate scenarios of the future.
- Studies on the effect of elevated CO_2 on *Sclerotium rolfsii* showed that exposure to 550 ppm CO_2 had no effect on biomass or size of sclerotia.
- Analysis of growth patterns of grazing small ruminants showed average daily gain and weight gain to be higher during June to November and lower during March to May period of the year due to non-availability of sufficient fodder in grazing lands and heat stress in the later period. Blood glucose, cholesterol, triglycerides and total protein were significantly higher during rainy season compared to summer. Creatinine and blood urea nitrogen were higher during summer indicating that the animals were under stress. Nellore cross was more climate resilient than Deccani and males were more resilient than females.
- Analysis of knowledge requirements of farmers in a flood prone area in Andhra Pradesh showed that while farmers expressed information on stress (flood) tolerant varieties, followed by need for information to manage pests and diseases during flood conditions as most felt needs while field level extensional personnel expressed need for information on contingency crop planning as the foremost need.
- Technology interventions with climate focus, implemented in 100 NICRA KVKs during kharif season under four modules, i.e. natural resource management, crop production, livestock and fisheries and institutional interventions gave promising results. Smart farmer certificates were awarded to selected farmers following climate resilient practices and technologies in the NICRA adopted villages. Video documentation of climate resilient practices and technologies in action was undertaken at 30 identified KVKs across different zones. Seventy nine training programmes were conducted in NICRA villages under different modules.

- Eighty district level contingency plans were prepared to meet weather aberrations in crop, livestock, poultry and fisheries sectors.

Krishi Vigyan Kendra

- The KVK conducted 134 on farm trials of 14 technologies, 123 front line demonstrations, 63 need based and skill oriented training programmes on various aspects of improved technologies, and several extension activities for farmers of Ranga Reddy district. Under the NICRA project, monitoring of ground water levels, production of quality seedlings in pro-trays under shade net nursery, plastic mulching in brinjal, improved fodder production activities were undertaken in Kandlapalli, Mirzapur and Yenkepalli villages in Pudur Mandal of Rangareddy district. The KVK generated a revenue of Rs. 2,92,270.

HRD

- During the year, 3 scientists underwent training within the country and 2 scientists attended trainings/workshops/meetings outside the country. Twenty five graduate and post graduate students carried out project/research work at CRIDA.

Awards and recognition

- AICRPAM was awarded the Chaudhary Devi Lal Outstanding All India Coordinated Research Project Award - 2013 for outstanding work on climatic variability and development of real-time contingency plans. Many of CRIDA's scientists received awards from National academies/ fellowships of professional societies such as National Academy of Agricultural Sciences (NAAS), Indian Society of Agronomy, Societies related to agricultural extension, computer applications, agricultural engineering, etc. Many scientists received awards for their contributions in research, technology transfer and communication, etc.

Linkages and collaboration

- The Institute continued to forge new linkages and collaborations with stakeholders and organizations (national and international) while renewing and strengthening old ones for more effective pursuit of its mandate.

Publications

- Ninety two research articles were published in peer reviewed journals. The contributions of scientists also appeared in the form of a number of books, bulletins, book chapters and popular articles. Weather Cock14 - weather analysis software and Ingen - insect generations calculator software were developed and released. Online Open source based thematic maps generation tool (http://www.crida.in/onlinemap.html), Open source based CRIDA digital repository (www.eprints-crida.in) and Online query based contingency planning retrieval system (http://www.crida.in:82/CFCP/) were developed.

ISO Certification

- The institute was granted License of Quality Management Certification under the Quality Management System in accordance with IS/ISO 9001:2008 for the period 21 August 2014 to 20 August 2017.

1 Introduction

Rainfed agriculture is predominant in arid, semi-arid and sub-humid regions of the country. These regions are home to about 81 per cent of rural poor in the country. The geographic and demographic dimensions of rainfed agriculture warrant a continued priority to rainfed agriculture in general and rainfed agriculture research and extension in particular. The impending effects of climate change will further add the dimension of urgency to rainfed agriculture as the problems of poverty, hunger and resource degradation are likely to be exacerbated if appropriate measures are not initiated. CRIDA continues to play an important role in developing appropriate technologies for improving the productivity of rainfed agriculture in a sustainable way.

1.1 Rainfed Farming - Historical

Rainfed agriculture constitutes a major part of Indian agriculture, necessitating a comprehensive approach and multi-disciplinary research for improving food and nutritional security while conserving and managing natural resources in the country. Food and Agriculture Organization (FAO) of the United Nations indicated the tremendous potential of rainfed agriculture which could feed the entire world by use of improved technology. The concern on the issues of rainfed areas has been expressed from time to time since the first Famine Commission and Royal Commission on Agriculture. However, it was not until 1923 that the first systematic and scientific approach to the problem of dry farming research was initiated. These were the earliest attempts made to improve the system and tackle the problems of rainfed areas (scarcity tracts) of erstwhile Bombay State. During 1933-35, the then Imperial (now Indian) Council of Agricultural Research (ICAR) initiated a broad-based dry farming research project at Solapur, Bijapur, Hagari, Raichur and Rohtak to formulate appropriate strategies. After independence, renewed efforts were made to improve stability and productivity of rainfed agriculture through efforts on developing appropriate Soil and Water Conservation practices.

1.2 CRIDA's Evolution

Recognizing the importance of rainfed agriculture, the ICAR gave a new impetus by launching the All India Coordinated Research Project for Dryland Agriculture (AICRPDA) in 1970, based at Hyderabad with 23 cooperating centres spread across the country. Pooling of expertise and leveraging the strengths of AICRPDA network eventually resulted in the establishment of Central Research Institute for Dryland Agriculture (CRIDA) at Hyderabad, on April 12, 1985 to provide leadership in basic and strategic research in dryland agriculture while continuing location-specific ORP's at AICRPDA centres. To further strengthen the activities in this field, the All India Coordinated Research Project on Agrometeorology (AICRPAM) was launched in 1983, also at CRIDA, Hyderabad, with 10 cooperating centres under different SAUs. Presently the strength of AICRPDA and AICRPAM is placed at 25 centres each.

1.3 Mandate

The mandate of CRIDA is:

- To conduct basic and applied research for improving the productivity of natural resources in drylands
- To develop techniques and systems for long-term conservation and efficient utilisation of dryland environmental resources
- To understand crop growth process and yield management more specifically under moisture-stress
- To carry out economic evaluation of technologies, to study the constraints, and to develop suitable resource base models for adoption
- To evolve appropriate extension, training and communication methodologies for accelerating transfer of technology

Following the recommendations of the Second Quinquennial Review Team in 1991 and the felt needs of the VIII Five Year Plan and beyond, the mandate of the Institute was redefined as follows which as on date is applicable.

- Undertake basic and applied researches that will contribute to the development of strategies for sustainable farming systems in the rainfed areas,
- Act as a repository of information on rainfed agriculture in the country,
- Provide leadership and co-ordinate network research with state agricultural universities for generating location-specific technologies for rainfed areas,
- Act as a centre for training in research methodologies in the fields basic to management of rainfed-farming systems,
- Collaborate with relevant national and international agencies in achieving the above objectives, and
- Provide consultancy.

1.4 Current thrust areas

Along with the key programme areas the Institute is also giving due importance to understand the nature of climate change and its potential impacts on the behaviour of rainfed crops, insect pests and microbes. Efforts are on to identify the potential options such as carbon sequestration for mitigating climate change. Another thrust area is how the livelihoods of the rainfed farmers can be improved through technological and institutional interventions. Drought mitigation continues to engage the resources of the Institute and efforts are being made to evolve transgenic crop varieties that are tolerant to drought. Renewed emphasis is now placed on on-farm water harvesting in view of increased extreme rainfall events and greater run off.

The following programmes have been identified to address the mandate:

Programme No.	**Programme title**	**Main components of sub-programmes**
I	Resource characterization	Rainfall and soil characteristics, length of growing season, land capability-based potential and constraints, climatic analysis, crop weather modelling, and geographic information system
II	Rainwater management	In situ moisture conservation, water harvesting and recycling, groundwater recharge studies, sustained management of surface and groundwater resources and efficient water-use strategies.
III	Crops and cropping systems	Efficient crops and cropping systems, crop diversification for sustained water use and productivity, germplasm enhancement/ evaluation and stress physiology
IV	Soil and nutrient management	Soil physical condition management - tillage, crusting, drainage, soil fertility care, integrated and micro-nutrient management and supply systems (chemical fertilizers and natural nutrient sources including micro-organisms), sustenance of soil quality and sustainable agriculture
V	Alternate land use systems	Efficient utilisation of different categories of lands through capability-based resource planning and generation of food, fodder and fuel. Promotion of tree borne oilseeds for non-arable lands.
VI	Energy management	Development of low-cost seeding and intercultural devices and low lift pumps for lifting water from ponds.
VII	Socio-economic aspects	Socio-economic and policy research studies, impact of research, constraints and feedback, transfer of technology
VIII	Training	Training of primary and secondary stakeholders and use of modern tools like ICT.

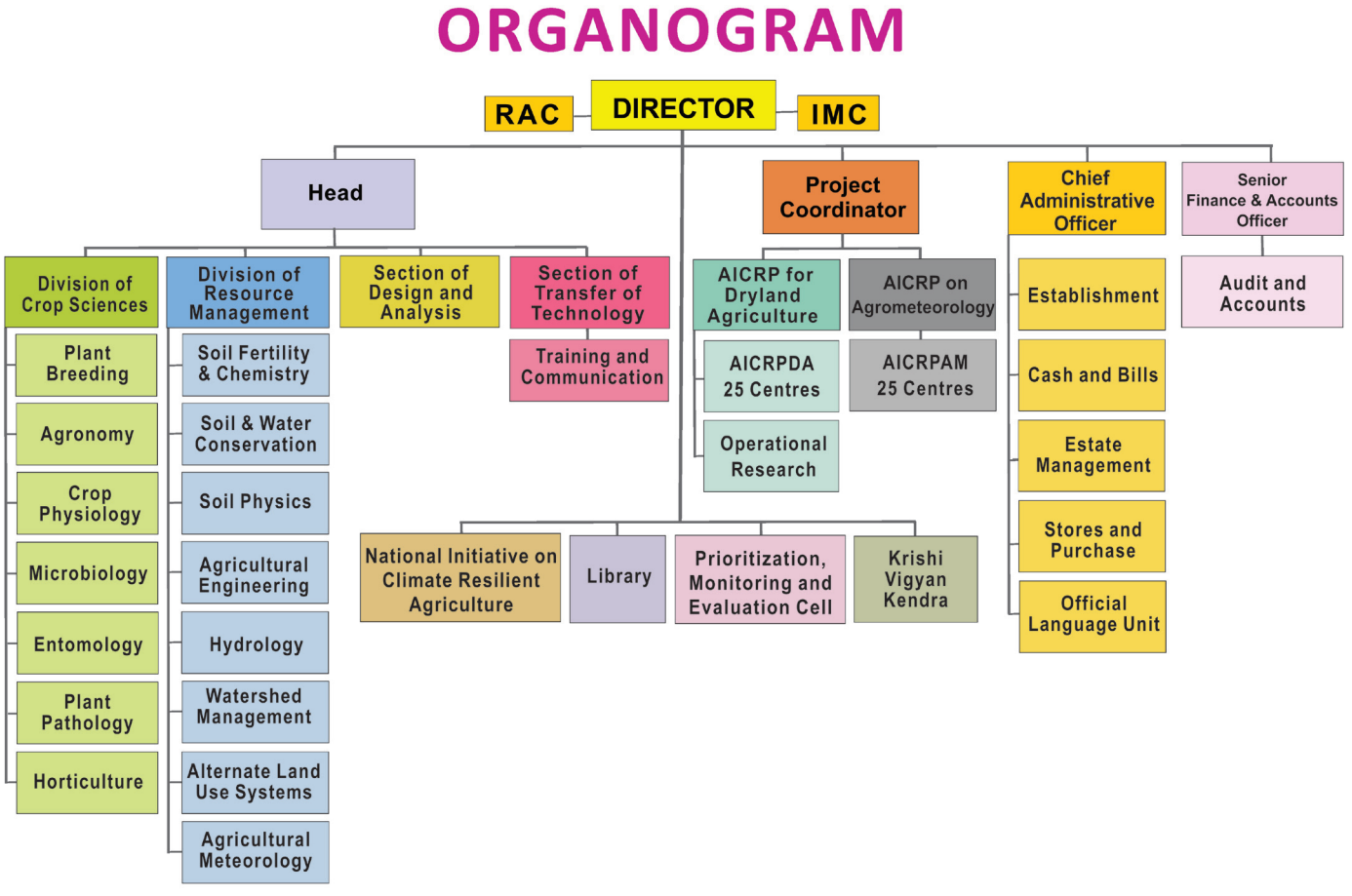
1.5 Organogram

The organizational setup of CRIDA is given below:

1.6. Past Achievements

Some of the accomplishments of the institute are as follows.

- Agroclimatic characterization and delineation of areas suitable for different crops/cropping systems in rainfed regions and assessment of drought probabilities
- Value added agrometeorological advisory services (www.cropweatheroutlook.in) and district-wise crop contingency strategies for monsoon aberrations
- Development, testing and commercialization of implements for timely agricultural operations such as planters, intercultural implements, herbicide applicators, low-lift portable pump sets for lifting water from farm ponds etc
- Release of two improved dual purpose horse gram varieties (CRIDA 18R and CRHG 04) for cultivation in peninsular India
- Transgenic sorghum for enhanced drought tolerance
- Identification and popularization of K-636 variety of Leucaena for industrial biomass production
- A large culture bank of agriculturally important microbes and microbial technologies for enhanced seed germination under high soil temperatures and alleviating zinc deficiency in soils
- Development of location specific in situ moisture conservation practices for diverse soil and climatic conditions
- Mapping areas with potential for rainwater harvesting in the country and standardization of farm pond technology
- Strategies for agricultural drought management in



dryland areas, contingency planning and required mid-season interventions

- Soil quality enhancement through residue recycling, conservation agriculture and biochar application
- Hyper-spectral remote sensing for detection of crop stress
- Agrotechnologies for maximizing yields in biofuel crops like jatropha and pongamia
- Easy-to-use software for drought monitoring, estimation of runoff potential in watersheds, agroclimate data analysis, tank silt recycling, and insect pest incidence in rice & cotton.
- Mapping of climatically vulnerable regions of the Country following the IPCC methodology of exposure, sensitivity and adaptive capacity
- Weather-based pest and disease forewarning systems for major crops
- Development of alternate land use systems involving agri-silvi, silvi-pastoral, agri-horti and horti-pastural systems with focus on marginal lands
- Upscalable models for enhancing livelihood security in rural areas through convergence of schemes at village level

1.7 Training, Consultancy and Contract Research Services

Based on its rich expertise and experience, CRIDA offers the following services:

- Planning, monitoring and evaluation of watershed development projects
- Drought management strategies for minimizing risk in rainfed crops
- Early warning systems for drought studies
- Production technology for rainfed crops
- Integrated pest and nutrient management in ranfed crops
- Production of quality biofertilizers, bio-pesticides and planting materials of multipurpose trees
- Application of modern tools like GIS, remote sensing etc for resource characterization and monitoring
- Dryland mechanization
- Agro-forestry, dryland horticulture and alternative land use systems
- Generation of crop-weather relationship data to support weather based crop insurance
- Contract services for analysis of soil, water, plant, organic manures and biofertilizers for quality assessment, and greenhouse gases quantification

Besides, CRIDA can also take up customized consultancies and contract research for the clients within its mandate

1.8 Road Map for Future Research

- Continue to address critical problems of rainfed agriculture through basic and strategic research using frontier tools
- Promote cost-effective water harvesting and recycling technologies for supplemental irrigation and drought-proofing of rainfed crops
- Application of biotechnological tools for inducing drought tolerance in rainfed crops and enhancing input use efficiency
- Rehabilitation of marginal and wastelands through crop diversification and alternate land use systems
- Development of agro-techniques including farming system modules for enhanced productivity and profitability in rainfed regions
- Design and development of efficient implements for small farm mechanization and their increased accessibility to small farmers through custom hiring centres
- Undertake action research to evolve innovations in technology dissemination and up-scaling for enhancing livelihood security
- Carry out impact assessment of technologies and suggest policy reforms for better technology adoption in rainfed agriculture

- Develop linkages and collaborate with national and international agencies in advancing rainfed agriculture

1.9 National Initiative on Climate Resilient Agriculture (NICRA)

CRIDA coordinates the national programme on climate change across the Country with the following two key objectives:

- Enhance the resilience of rainfed agriculture to climate change by developing adaptation and mitigation strategies in crop and livestock systems
- Develop climate smart villages in India by promoting practices that efficiently use weather, soil, water and energy resources

1.10 Infrastructure

CRIDA has a 9000 sq m spacious building located at Santoshnagar in the eastern corner of Hyderabad city. The Institute has excellent laboratories, guesthouse, trainees hostels, seminar halls, museum, auditorium and two well laid out research farms. Over the years, the Institute has built modern facilities for conducting research and training. A synoptic over-view of the facilities is provided below.

Laboratories: CRIDA has 15 well-equipped laboratories to support multi-disciplinary research on natural resource management and crop sciences. Laboratories of various disciplines such as Agronomy, Soil chemistry, Soil physics, Hydrology, Plant physiology, Microbiology, Plant breeding, Molecular biology, Agroforestry, Horticulture, Plant pathology, Entomology and Animal sciences are well equipped with state-of-the-art facilities. In addition, Central laboratory, Agrometeorology & Data bank, and GIS laboratories cater to the needs of research across the divisions. Dedicated laboratories for root study and estimation of green house gases were added during XI plan.

Soil physics: The laboratory, besides basic facilities, has instruments to measure physical properties of soil and special equipment such as particle size analyzer, modulus of rupture apparatus, time domain reflectometer, rainfall simulator, hysteresis apparatus, pressure plates and temperature data pads. The laboratory supports research and training in soil and water management, land degradation and resource mapping.

Soil chemistry: The laboratory is equipped with important instruments for estimating essential nutrients required for plant growth. It supports research activities on integrated nutrient management, soil quality assessment, organic matter dynamics, carbon sequestration etc.

Plant physiology: The laboratory has facilities to conduct research in stress physiology, plant nutrition, crop modelling and climate change. It is equipped with leaf area and transpiration measurement systems, osmometer, cold centrifuges, plant canopy analyzer and sapflow systems and portable photosynthesis analyser.

Agronomy: The laboratory is equipped with all basic instruments for soil and plant analyses, neutron moisture probes and root length measurement systems. It supports research activities in soil and water management and crop husbandry.

Microbiology: The laboratory is equipped with facilities to conduct research on agriculturally important micro-organisms including molecular characterization. Important equipments include phase contrast and stereo microscopes, gas chromatograph, vacuum concentrators, PCR and electrophoresis systems.

Plant molecular biology and tissue culture laboratory: The laboratory is well equipped with up-to-date facilities for carrying out research activities pertaining to molecular biology of abiotic stress tolerance in rainfed crops such as PCR machines, Gel documentation system, Gene gun, Southern, Western and Northern blotting for achieving their objectives. The plant tissue culture laboratory undertakes research on tree micropropagation.

Entomology: The Entomology laboratory is equipped with modern instruction facilities and equipments relating to insect rearing, bio-pesticide evaluation, testing of pesticides, studies on pest development and assessing the effect of climate change on insect life cycles.

Plant pathology: The laboratory is equipped with state-of-the-art facilities to pursue research in disease epidemiology in relation to weather, development of cost effective and eco-friendly disease management options, integrated disease management and plant growth promoting microbes.

Central laboratory: Besides the discipline-wise research facilities highlighted above, the Institute has a central laboratory, which has state-of-the-art instruments, Inductivity Coupled Plasma (ICP) spectrometer, atomic absorption spectrophotometer, auto analyser, CNS analyzer, HPLC and TOC analyzer. This laboratory not only supports research at CRIDA but also assists the entire research network on rainfed agriculture in the country and provides analytical services to institutions and individuals on payment.

Agrometeorology and databank: The Institute is the coordinating centre for research and training in agrometeorology since the VII Five Year Plan, and has built up excellent equipment support. The centre has automatic weather stations, line quantum sensors, Bowen's ratio apparatus, spectro radiometers and the relevant computer packages for processing historical weather data for agrometeorological planning. State-of-the-art facilities for quality checking, storing of the meteorological data of all the AICRPAM centres and other weather stations of the country are also available. It also maintains a website www.cropweatheroutlook.in providing agrometeorological information, current weather status and contingency crop plans to aid the rainfed farmers across the country.

Hydrology: CRIDA has established excellent infrastructure with GIS and GPS facilities for conducting hydrology experiments. Computer controlled rainfall simulator and large tilting flume have been installed, which are useful in conducting micro plot experiments under controlled conditions.

Agroforestry: Agroforestry laboratory has facilities for like soil and plant analysis, including fully automated kjeldahl nitrogen system, and equipment for estimation of aromatic oils and secondary metabolites in medicinal, aromatic and dye yielding plants.

Horticulture: A new laboratory has been established during X five year plan for analysis for soil, plant, fruit, leaf and other horticultural samples/products. There is also a cool chamber for storage of fruits and vegetables and their value added products.

Animal sciences: A new wing has been added in Animal Science in the X-plan covering both Animal Husbandry and Animal Nutrition for estimation of proximate principles, fibre fractions, in-vitro digestibility of feeds and fodders, de-worming & vaccination of livestock, metabolic studies with small ruminants, clinical biochemistry parameters like serum, proteins, cholesterol, calcium, magnesium, albumin, etc.

GIS: The GIS laboratory supports in–house digitization, mapping and analysis of watersheds, land use, land cover change analysis and mapping of soil erosion, drought incidence, and land degradation. The laboratory is also equipped with advanced software like ArcGIS (Ver.9.0.) with two add-on modules – ArcEngine and ArcPad, digital satellite data interpretation software - ERDAS Imagine (Ver.9.0.) with virtual and vector GIS add-on modules for analysis and a Trimble DGPS.

Transgenic glasshouse and green house: A transgenic glasshouse conforming to containment standards for evaluating transgenic crops is available in the Institute. Apart from this, the Institute has a net house and climate controlled glasshouse for conducting pot culture experiments.

Climate change study facilities: Six Open Top Chambers (OTCs) were set up to assess the impact of elevated CO_2 concentration on crops and soils. State-of-the-art Phenotyping Platform with automated non-destructive imaging based scan analysis of crop growth and development has been developed during XI plan to characterize genetic material with drought and other abiotic stress tolerances. A 7 ha research complex to study crop and soil response to elevated temperature, CO_2 and extreme rainfall events has been developed at Hayatnagar research farm.

Bio-resource centre: A bio-resource centre for production and sale of biological pesticides and biofertilizers was set up at Hayathnagar Research Farm (HRF).

Farmers' service laboratory: A research and farmer's service laboratory was set up at HRF to cater to the analytical needs of experiments at HRF as well as of the farmers.

Agriculture Knowledge Management Unit: Agriculture Knowledge Management Unit (AKMU) services are effectively used for IT infrastructure maintenance, e-mail, website, internet, file transfer, database development & maintenance, developing application software, building IT infrastructure and hosting video conferencing. CRIDA successfully runs all internet related services under National Knowledge Network (NKN) connectivity. CRIDA has 4th generation desktops computers, GPU workstations, Dell servers and GPU server with 4 teraflops speed. Video conferencing facility was successfully utilized to conduct 20 video conferences between headquarters and AICRP centres. Centralized uninterrupted power supply systems (80 + 80 KVA) was established in CRIDA premises. 20KVA UPS was established in Phenomics facility. Websites of CRIDA and NICRA are hosted on CRIDA servers and maintained and updated regularly.

Museum: The Institute maintains a Dryland Gallery where the history of dryland research and research achievements are highlighted through charts, photographs and models.

Conference and training facilities: The Institute has three air-conditioned conference halls with a seating capacity of 30, 100 and 20, besides a large auditorium for accommodating 250 persons.

Library: The Institute has a central library with a collection of over 8187 books and 4719 back volumes of periodicals. It subscribes to 132 Indian

and 21 International Journals, and is equipped with AGRICOLA, AGRIS, CROP – CD and SOIL – CD Databases. Scientists access the CD-ROM databases through LAN. The library extends online access of foreign journals through subscription of Agroforestry Abstracts (CAB International) and Science Direct (Elsevier) for more periodical literature to the Institute scientists. The ICAR under National Agricultural Innovation Project (NAIP) has established a Consortium for e-Resources in Agriculture (CeRA) to access 2000 + scholarly peer reviewed e-journals from the most renowned publishers in the disciplines of agricultural and related sciences. This online e-resource is available across 150+agricultural research institutes, project directorates, and SAU's under NARS. The library is also powered with SOUL software from INFLIBNET for in-house library management.

Institute Technology Management Unit (ITMU): The ITMU acts as a repository of Intellectual Properties (IPs) of CRIDA and facilitates all scientists in protecting and commercialization of their IPs. The ITMU plays a key role in drafting MoUs, MoAs, technology licencing, filing of patents, copy rights and conducting awareness programs on IPR issues. It also liaises between institute and ICAR in fostering public-private partnerships for knowledge generation and dissemination in the field of rainfed farming for the ultimate benefit of both inventor and end-user.

Research farms: The Institute has two well laid-out research farms at Hayathnagar (HRF, 280 ha) and

Gunegal (Gunegal Research Farm, GRF, 80 ha) about 15 and 45 km from the main campus, respectively. These farms represent the predominant agro-ecological settings of the rainfed regions of the country. The mean annual rainfall received at Hayathnagar is 750 mm and that at Gunegal is 690 mm. The research farms have well equipped infrastructure and facilities for supporting field experiments and demonstrations including weather stations, mist chambers, maintenance workshop, tractors and farm equipments and a fabrication facility for farm tools and implements. Advanced facilities for processing of research material and data analysis are also available.

Quarters: A total of 33 residential quarters (Type-A 12; Type-B 8; Type-C 4; Type-D 6; and Type-E 3) are located at the headquarters.

1.11 Financial Statement for 2014-15 as on 31 March, 2015 (Rupees in lakhs)

	CRIDA		AICRPDA		AICRPAM	
	Sanctioned	Utilized	Sanctioned	Utilized	Sanctioned	Utilized
Non-Plan	3774.00	3725.43	46.00	45.90	48.00	45.81
Plan	225.00	220.75	1745.00	1745.00	630.00	630.0
Total	3999.00	3946.18	1791.00	1790.90	678.00	675.81

1.12 Staff Position as on 31 March, 2015

Staff	Positions	
	Sanctioned	Filled
Scientific	67	63
Technical	80	55
Administrative	50	34
Supporting	55	28
TOTAL	252	180

2 Research Achievements

2.1 Resource characterization

2.1.1 Weather conditions at Hayathnagar Research Farm during the drought year 2014-15

The southwest monsoon set in at Hayathnagar Research Farm (HRF) Region by 15th June in the year 2014, slightly later than the normal onset. The total rainfall during the period April 2014 to March 2015 was 435.5 mm, very low compared to normal 703.5 mm. The total monsoon rainfall was 249 mm which was 49% less than normal. There were 38 rainy days with rainfall more than 2.5 mm during April 2014 to March 2015. Solar radiation at the station varied from a low of 2.41 MJ M^{-2} Day^{-1} to a high of 23.95 MJ M^{-2} Day^{-1}. The wind speed varied between 2.2 to 16 km h 1 and Potential evapotranspiration ranged from 0.8 to 8.9 mm. The highest maximum temperature recorded was 41.7°C on 25 May 2014 and the lowest minimum was 10.1°C on 12 January 2015. The weekly PET reached 50 mm during 24th week and then slowly came down to 22.1 mm during 35 SMW and then increased again. Very less rainfall was recorded during 24, 25, 26, 32 and 33 SMWs during the crop season.

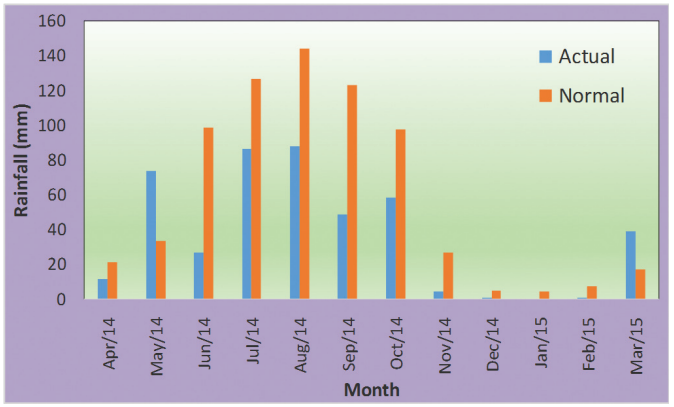


Fig. 2.1: Rainfall distribution during April 2014 to March 2015

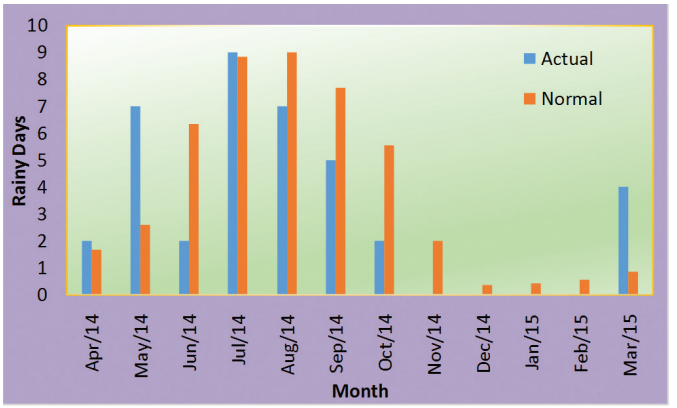


Fig. 2.2: Number of rainy days (> 2.5 mm) during April 2014 to March 2015

Table 2.1: Weekly meteorological parameters recorded at HRF during April 2014 to March 2015

Standard meteo-rological Week	Air Temperature (oC)		Relative Humidity (%)		Wind Speed (M/S)	Rainfall (mm)	Solar Radiation (MJ)	PET (mm)
	Max.	Min.	Morning	Evening				
14	38.3	21.9	75	14	5.7	4.3	20.3	42.7
15	36.5	22.9	77	21	5.6	0.8	17.8	37.8
16	36.8	23.7	72	22	5.9	0	19.2	40.8
17	39.1	24.9	72	20	4.9	5.8	17.6	38.3
18	37.2	23.5	87	26	7.0	25.8	20.3	42.7

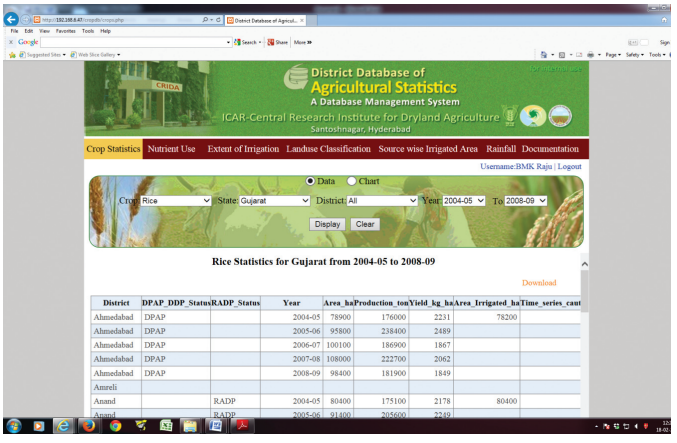
19	35.1	23.6	83	31	6.6	19	19.6	41.2
20	38.4	25.6	57	19	6.2	0.0	19.4	43.8
21	38.9	26.3	64	21	7.2	23.5	18.4	45.8
22	38.4	25.8	72	25	7.2	24.3	17.8	43.0
23	38.0	27.3	54	29	10.1	0	18.3	44.3
24	36.7	26.3	73	32	11.1	5.5	19.6	50.2
25	36.0	26.4	68	31	11.7	1.3	17.2	48.7
26	36.3	26.9	65	28	7.9	5.8	15.1	37.0
27	34.9	25.2	85	37	9.1	22.3	17.0	38.5
28	31.2	23.8	86	50	11.9	11.3	13.1	32.4
29	30.3	24.0	82	55	11.4	1.5	10.7	29.0
30	30.9	23.1	92	52	9.9	26.8	13.1	29.4
31	31.1	23.7	88	53	10.3	21.0	13.9	31.5
32	33.2	23.9	84	43	8.8	3.5	17.5	37.3
33	33.7	24.7	79	39	7.7	6.3	17.7	37.5
34	33.8	23.6	93	43	6.6	19.0	17.1	33.1
35	28.3	22.9	96	67	8.5	57.3	11.4	22.1
36	29.4	23.0	90	57	9.2	18.3	13.9	27.6
37	31.4	23.3	91	51	7.4	20.5	16.5	30.8
38	31.3	23.4	93	53	7	5.5	14.6	27.5
39	32.8	22.5	97	40	4.9	4.3	15.9	28.8
40	34.3	22.1	91	34	4.5	0	15.1	28.9
41	33.5	23.6	82	34	7.5	0.8	14.6	34.9
42	32.5	21.5	96	38	6.1	24.0	15.8	29.6
43	27.5	19.8	100	56	4.5	33.5	10.6	18.3
44	30.5	16.7	90	23	5.1	0	15.6	28.0
45	30.6	18.6	83	31	5.4	0	12.5	25.7
46	30.0	20.3	99	48	5.2	3.8	11.9	20.8
47	29.5	16.8	97	35	3.8	0	14.3	22
48	29.7	14.2	86	23	4.2	0	15.7	24.9
49	29.7	14.2	89	26	4.4	0	14.7	23.9
50	27.5	19.5	97	49	5.8	0.3	9.1	18.3
51	27.0	12.2	74	26	4.4	0	12.9	21.5
52	27.9	14.1	83	29	5.4	0	12.9	26.6
1	29.4	17.7	90	37	5.1	0	10.9	21.2

2	27.7	11.8	63	16	4.8	0	14.9	25.5
3	27.8	13.7	77	26	5.8	0	14.1	25.7
4	28.9	15.3	94	25	7.6	0	15.1	29.3
5	28.9	15.8	95	29	5.9	0	14.8	26.6
6	29.9	16.2	83	22	8.5	0	16.1	34.5
7	33.7	17.2	72	13	5.0	0	16.3	32.4
8	32.9	18.1	68	17	6.6	0	16.8	36.5
9	32.0	19.2	85	29	7.3	4.8	15.3	33.1
10	31.4	20.7	88	37	6.4	31.5	14.6	29.3
11	34.8	19.6	79	17	7.5	0	20.4	42.7
12	36.6	22.1	54	13	5.6	0	19.5	40.6
13	35.1	21.4	91	22	6.6	3.0	18.3	33.1

Rainfall is weekly total and other parameters are weekly means

2.1.2 Development of a database of rainfed districts

'District Database of Agricultural Statistics - A database Management System' was developed and web enabled to make available online. Users can now download data or generate bar chart, line diagram, pie diagram, etc. from the data to understand status or trends. The chart or diagram generated can be saved as an image file.



Screen shot of web enabled district database of agricultural statistics showing data retrieved

2.1.3 Unreaped yield potentials of major rainfed crops

Delineation of homogenous agro-climatic zones for crops viz., rice, sunflower and rapeseed & mustard and identifying crop-wise unreaped yield potential (yield gap) at district level

Identified major districts for crops viz., rice, sunflower and rapeseed & mustard. Homogeneous agro-climatic zones were delineated for each of these crops using multivariate cluster analysis. As the resources (that farmer has less choice) for raising the crop with in a cluster are more or less same, the district producing highest yield in a cluster may be regarded as potential target for the remaining districts in the cluster. Unreaped yield potential (yield gap) for district X was computed as the difference between potential yield (highest yield obtained with potential target district) in the cluster to which district X belongs to and yield of district X (for a given level of resources in the cluster).

Building yield efficiency index

In a given crop, yield of a district (for a given level of agro-climatic resources) was compared to the highest yield obtained (with potential target district) in the cluster to which the district belongs to.

In each crop, districts yielding at less than 50% potential ($Z_{ij} < 0.5$) were designated as high potential districts. Unreaped yield potential in these districts is at least 50%. Crop-wise districts with high potential were identified in crops viz., sorghum, pearlmillet, maize, pigeonpea, chickpea, groundnut, sunflower,

Table 2.2: List of districts with high unreaped yield potential in selected crops

Crop	Districts having high potential (efficiency < 0.5) for improving yield
Soybean	Chhatarpur (MP), Satna (MP), Jhabua (MP), Khargone (MP), Barwani (MP), Khandwa (MP), Chandrapur (MAH), Beed (MAH), Belgaum (KAR), Bidar (KAR), Dharwad (KAR)
Sunflower	- (No district was found have efficiency < 0.5)
Groundnut	Jhansi (UP), Khargone (MP), Barwani (MP), Nasik (MAH), Nalgonda (AP), Kurnool (AP), Anantapur (AP), Chittoor (AP), Belgaum (KAR), Bagalkot (KAR), Bijapur (KAR), Gulbarga (KAR), Raichur (KAR), Koppal (KAR), Gadag (KAR), Dharwad (KAR), Haveri (KAR), Bellary (KAR), Chitradurga (KAR), Davanagere (KAR), Tumkur (KAR), Kolar (KAR), Chamarajanagar (KAR)
Rapeseed & Mustard	Jaisalmer (RAJ), Pali (RAJ), Shahjahanpur (UP), Sitapur (UP), Barabanki (UP), Tikamgarh (MP), Chhatarpur (MP), Shahdol (MP)

soybean, rapeseed & mustard and cotton. Crop-wise list of districts with high unreaped yield potential were furnished for soybean, sunflower, groundnut and rapeseed & mustard in Table 2.2.

Crop-wise possible interventions in terms input use through fertiliser nutrients and use of HYV were suggested for districts with low yield efficiency with consideration of extent of input use in districts having high yield efficiency.

Overall yield efficiency index at district level

Overall yield efficiency of a district was computed as weighted average of crop-wise efficiencies, with share of area sown under a crop in the district as weight and was formulated as

Overall Yield Efficiency of j^{th} district is $Z_j=\Sigma_i W_{ij} Z_{ij}$

where W_{ij}=Proportion of area sown to i^{th} crop to total area sown in j^{th} district such that $\Sigma_i W_{ij}=1$ (for all j)

The resultant map showing overall yield efficiency at district level is given as Fig 2.3.

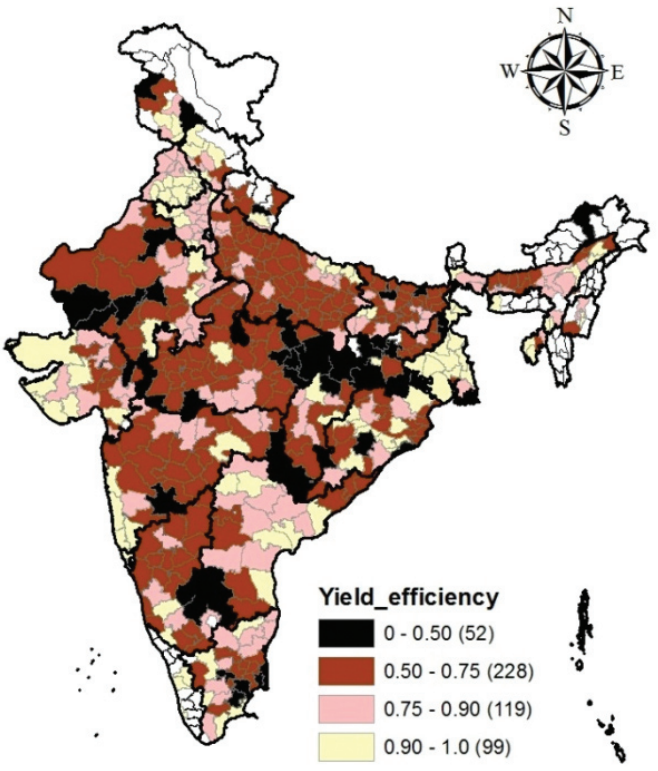


Fig. 2.3: Districts categorized based on yield efficiency

2.1.4 Spatial estimation of soil moisture using microwave remote sensing

Sensitivity of microwaves towards soil moisture is well understood and Microwave bands have proven particularly interesting for this purpose because the soil dielectric constant at these frequencies exhibits a noticeable dependence on the moisture content of the observed bodies, making a direct estimate of soil moisture possible. The present study is undertaken with the objective to utilize RISAT-1 satellite data for spatial estimation of soil moisture in the upper root zone. Ground truth data collection on soil moisture for the respective microwave data on particular date and time has been collected for proper validation and calibration of microwave data. Loew model and Topps model then successfully applied to derive soil moisture from respective dielectric constants. Loew and Topps model found to estimate the lower and higher soil moisture percentage respectively.

2.2 Climate change

2.2.1 Simulation modeling of crop growth and development in maize

Due to the complexity of agricultural systems and the multifaceted nature of climate change, crop models are frequently used to comprehend the influence of climate change on agriculture and to support in the development of adaptation strategies. The objective of simulation modeling is to develop a data base of maize growth and development from various publically available sources, run and evaluate the models for maize and exploring functional relationships between physiological processes and growth. Database of maize growth and development in irrigated and rainfed conditions was collected from various sources and tabulated including experimental crop data. Minimum data set of the maize was also collected that consisted of daily weather data where ever available, soil profile descriptions, management practices used and other relevant experimental data.

2.2.2 Assessment of impact of climate change on rice production in the eastern region of India using DSSAT (CERES) rice model

Varietal change has been studied in the rice crop as part of developing adaptation strategies under climate change scenarios for rice crop in Eastern region of India. Well calibrated cultivar coefficients developed by IIT, Kharagpur for the variety "Swarna" were used in this study. The DSSAT rice model was simulated by incorporating the cultivar coefficients along with Ensemble climate change scenarios generated by (CNRM-CM3, CSIRO-Mk3_5, ECHam5 and MIROC3.2) - MarkSim™ -DSSAT Gen for 2020, 2040 and 2080 at four locations viz. Faizabad, Kanpur, Raipur and Bhubaneswar with location specific management practices in Eastern region of India.

- Kanpur location is likely to get better yields in all projected years compared to the other three locations. But in Kanpur, year 2040 may yield better compared to 2020 and 2080. At Faizabad and Bhubaneswar yields are likely to increase in the year 2080 compared to the years 2020 and 2040. At Raipur, yield of rice is likely decrease gradually from 2020 to 2080. Soils as well as the likely weather change that are projected may be the reason for increase /decrease of yields in the in this region
- "Swarna" variety may be sown as alternate crop to the current cultivars used in the respective locations. Further, modifications of management practices would definitely improve the yields of rice in this region.

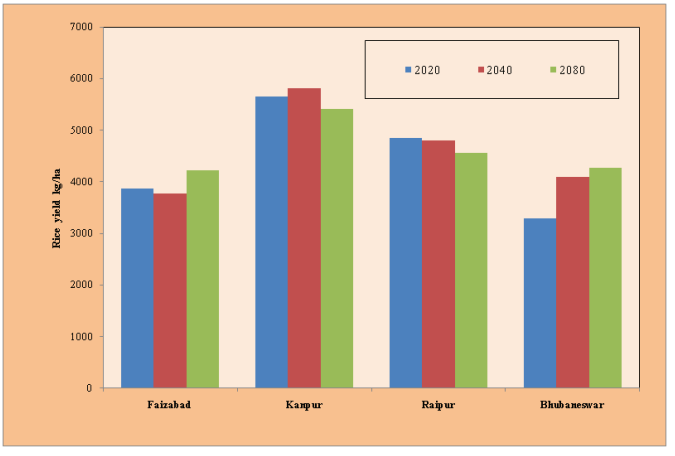


Fig. 2.4: Impact of climate change on rice yields in eastern region of India

2.2.3 Understanding farmer knowledge, attitude and adaptation strategies to climate variability and change in semi-arid regions of india

The study was conducted in the three different states viz., Andhra Pradesh, Karnataka and Maharashtra through AICRPDA centers (4 nos.) reflecting drought conditions in red and black soils. A sample of 240 farmers @60 from each center was selected randomly for data collection. Results across four centers viz., Anantapur, Akola, Solapur and Bijapur were compared and collated this year. Trends across the centers show that the chief farmers' perceptions towards climate variability and change are: prolonged dry spells, rise in temperatures followed by delayed and shorter rains. The chief adaptation measures followed by farmers towards climate variability and change are: change in planting dates, cropping pattern followed by diversify to livestock.

Barriers to climate change adaptation as expressed by farmers' are: lack of access to credit, lack of labour and lack of access to water. Measures that government should do regarding climate change are control pollution, afforestation and develop irrigation projects. Adaptation index value for Anantapur was highest among the centers which, indicates farmers are highly receptive and already adapting to climate change.

Across the four centers, majority of farmers agreed with the following attitude statements towards Climate change:

- Climate change is a serious problem.
- Climate change is affecting my farming.
- Average temperatures are increasing.
- Human activity is responsible for climate change.
- Climate change affects small and marginal farmers more.
- Rainfall patterns are changing.
- Climate change enhanced incidence of pests & diseases.
- Government should do more to help farmers adapt to climate change.
- Scientists/Govt. will solve the problem of climate change.

2.3 Rainwater management

2.3.1 Evaluation of polymers for improving water productivity in different crops grown on sandy soils in semi-arid region

The problem of inefficient use of rain and irrigation water by crops is most important on light textured soils of semi-arid and arid regions. Application of super absorbent polymers into the soil could be an effective way to increase water use efficiency in crops. Laboratory and field investigations have been conducted to study water retention and release characteristics of a cross linked polymer of polyacrylamide and potassium acrylate (PAM) and to evaluate its effect on yield and water productivity in tomato and maize grown on sandy loam soil under field conditions. Results of two year field experimentation on tomato showed that the spot application of PAM polymer at 25 kg/ha with alternate week irrigation not only produced the higher tomato yield but also increased the water productivity to 291 kg/ha-mm and thereby saved 180 ha-mm irrigation waters during a crop growth season.

Effect of row application of PAM polymer at 25-50 kg/ha on rainfed maize grown on sandy loam soil was studied during *kharif* seasons of 2013 and 2014. First Maize crop was sown on 10 June 2013. During this year, there was a 1st dry spell from 26 June to 10 July 2013. Due to this dry spell, wilting symptoms were observed in maize grown without application of polymer (control) on 2 July 2013. Whereas, in plots those treated with PAM (25 kg/ha), maize started wilting from 7 July 2013 onwards. These results clearly showed that the application of polymers at 25 kg/ha delayed the wilting of maize by 5-6 days during initial dry spell at early growth stage of maize. Application of PAM at 25 kg/ha maintained higher moisture retention in soil at different crop growth stages as compared to control treatment. Application of PAM at 25 kg/ha produced 16% higher maize yield as compared to control. But this beneficial effect of application of PAM polymer at 25 – 50 kg/ha on maize grown during *kharif* 2014 was not significant due to very prolonged dry spells and about 35% deficient rainfall received

in *kharif* 2014 as compared to normal year. Thus the results of maize field experiments with polymer conducted during two contrasting years with respect to amount of rainfall received and length of dry spells clearly indicated that the application of 25 kg/ha PAM polymer may enhance crop growth, yield and rain water use efficiency by effectively managing short term dry spells. But their effect may not be significant if the amount of rainfall received is considerably deficit with prolonged dry spells.

2.3.2 Assessment of rainwater productivity of maize (*zea mays*) through Aquacrop model under different supplemental irrigation strategies in semi arid alfisols

A field experiment was conducted at Gunegal Research Farm during 2014 for consecutive third year with maize crop (variety: Monsanto Dekalb 900 M Gold) sown on 5th July, 2014 under different supplemental irrigation treatments as main plots and mulching and fertilizer application as sub treatments in split plot design and plant growth parameters from sowing to maturity were measured for every 15days for AquaCrop model validation.

The total rainfall received during crop season was 249 mm, which was 68 % below the normal seasonal rainfall in *kharif* , 2014. There was a long dryspell for 30 days during vegetative stage and supplemental irrigation (20, 30, 40 and 50 mm for I1, I2, I3 and I4 respectively) through sprinklers, was given on 11August 2014. The highest grain yield (1.7 t/ha) and biomass (4 t/ha) was observed in 50 mm supplemental irrigation under mulch with 125% increase in N fertilizer level and there was no yield recorded in rainfed treatment due to long dry spells. The crop water production functions (CWPF) were developed by using regression analysis considering the yield and crop water use. The CWPF were developed for four management options of M0NF, M1NF, M0HF and M1HF (Fig. 2.5) and it was observed that, coefficient of determination ranged from 0.88 to 0.97. It was observed that the crop yield to supplemental irrigation with 40 mm and 50 mm was more than the other two irrigation levels over the rainfed under no mulch and normal fertilizer. The results indicated that the rainfed crop with mulching responded more with increased yield as compared to no mulch.

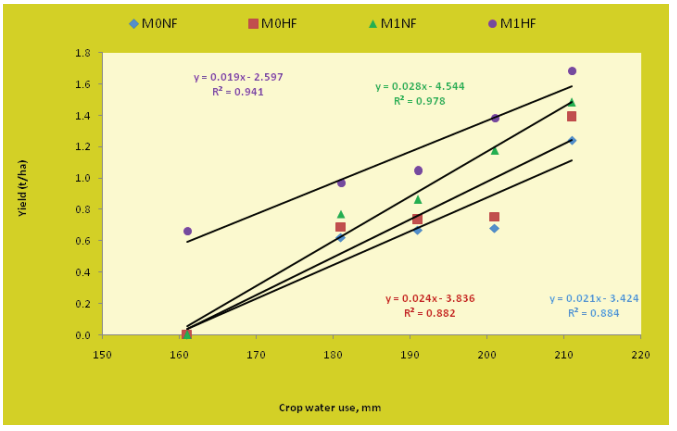


Fig. 2.5: Crop water production functions for maize under different crop management practices

AquaCrop model validation

The experimental datasets were used for validation of FAOs AquaCrop model to simulate grain yield, above ground biomass and water productivity. The model predicted well the grain yield and biomass yield and water productivity as compared to measured under drought situations also (Fig. 2.6). The model performance was evaluated with statistics using RMSE (root mean square error), MAE (mean absolute error) and model efficiency(E). There was a good agreement between measured and simulated grain yield and water productivity with R2 of 0.93 and 0.86 respectively. The model simulated grain yield and water productivity with an efficiency of 0.99 and 0.85 respectively which are within the acceptable limits.

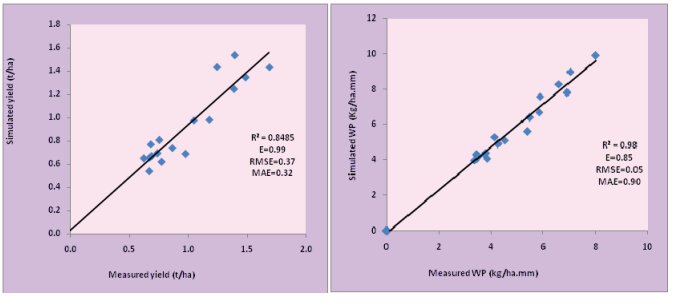


Fig. 2.6: Model validation and performance indicators

2.3.3 Impacts of meso-scale watershed development in Andhra Pradesh (India) and their implications for designing

This project aims to integrate environmental, economic, social and equity dimensions at meso levels (1500-10000 ha) to help ensure that WSD contributes positively to the sustainable livelihoods efforts. The project implemented in Prakasam and Anantapur dist of AP covering 2 HUNs (hydrological unit networks). A new methodology has been proposed for watershed planning based on land use and proposed in-situ conservation measures and existing storage available within watershed. The proposed method suggests the requirement of on-stream storage structures within the watershed based on runoff available after accounting for in-situ conservation methods in various land uses. Priority could be given to treating the agricultural lands and different stakeholders with in-situ conservation works rather than the on-stream works. Based on soil water balance method, an assessment was made for meeting the crop water requirements in *kharif* crops and for growing *rabi* crops in different soils with in study area with adoption of water conservation measures.

Groundwater recharge prospects

The rainfall distribution coupled with total rainfall greatly influence the ground water recharge during the monsoon period. Exact estimation of groundwater recharge would require considerable time and large quantities of data. On the other hand, qualitative estimation of groundwater recharge prospects was attempted by interpreting the rainfall received on a week to week basis for each district. For example, if scanty rainfall is received in more than 65% of weeks or deficit rainfall is received are more than 80% of weeks on cumulative basis, the recharge possibility is considered to be extremely low. Criteria followed for groundwater rechange prospects is given in Table 2.3.

Rainfall data furnished by IMD (www.imd.gov.in) during the current monsoon is utilized for the analysis purpose. Based on this criteria, the ground water recharge due to monsoon rainfall is extremely low to very low in about 197 districts (30% of total districts). About 57% of total districts had low to extremely low

Table 2.3: Criteria followed for groundwater rechange prospects

Percent of deficit rainfall weeks	Percent scanty rainfall weeks	Groundwater recharge prospects
80	65	Extremely low
70	50	Very Low
50	30	Low
30	10	Medium
10	0	Normal

prospects for groundwater recharge. About 37 districts (52% of total UP districts) out of these 197 districts are in Uttar Pradesh. Among the states of Punjab and Telengana, 75% (15 districts) and 80% (8 districts) of districts respectively have extremely low to very low prospects for groundwater recharge.

States of Rajasthan Karnataka, Maharashtra and Andhrapradesh had extremely low to very low ground water recharge prospects in about 6%(2 districts), 20% (6 districts), 25% (9 districts)and 15%(2 districts) respectively. States of Bihar, Jharkhand and Chhattisgarh had extremely low to very low ground water recharge prospects in about 29% (11 districts), 29% (7 districts), and 11% (2 districts) respectively.

Groundwater recharge in rabi cropped areas

Districts with significant area in during *rabi* season for different crops were identified. These districts cover 80% of *rabi* area under each crop. The crops considered for the study included Wheat, Chicken pea, Rice, Sorghum, Rapeseed & Mustard, Maize and Groundnut.

Out of 421 districts indentified to be dominant for *rabi* areas, 112 districts had extremely low to very low ground water recharge prospects. Among these 112 districts, 32 districits in Uttar Pradesh, 11 districts each in Haryana and Punjab, 9 districts each in Bihar and Maharashtra, 7 districits in Telengana and others are spread in Karnataka, Madhya Pradesh and Tamilnadu.

Another 133 districts had the low prospects for ground water recharge during the current monsoon and are

spread in Uttar Pradesh (19 districts),Madhya Prade sh(121districts),Gujarat(18 districts), Rajasthan(16 districts), Maharashtra(12 districts), AP (7 districts).198 districts had the possibility of medium to normal ground water recharge prospects.

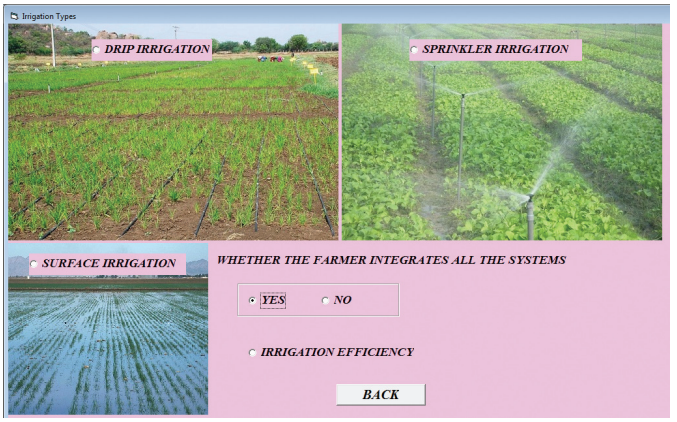
2.3.4 Water application system (WAS) software for efficient utilization of farm pond water

The project aims to provide a handy tool to design an irrigation system with respect to farm pond as a water source and would be helpful in increasing water use efficiency in rain-fed agriculture. The standard mathematical models and standard protocols for the design of different on-farm irrigation system, including surface irrigation as well as pressurized irrigation are utilized in developing the software in structured form with different options. The standard design requirement such as flow velocity, pump selection, pipe network, pipe specification, channel dimensions, irrigation water requirement at different return period etc. are the major feature of this software.

Different modules on various components of the software were coded in visual basic 6.0. Modules for three major types of irrigation namely drip, sprinkler and surface (border, check basin and furrow) are prepared. Climate data for 1960-2010 for 25 stations are collected. The PET and eventually daily design, irrigation requirement for 5,10,15 and 20 year return period were computed. These data are ensembles with crop and soil data to further design the irrigation system. In case of drip and sprinkler irrigation system, the output suggested the selection of drippier, sprinkler, pipe and pumping requirement based on the water source and crop to be grown. Based on soil characteristics and depth of root zone, the program suggests the length of the border and irrigation time in case of border irrigation; net irrigation requirement and operation time in case of check basin irrigation and average irrigation depth in case of furrow irrigation.

2.3.5 Watershed based soil and water conservation interventions prioritization in different rainfall zones

Dry land in India is experiencing more frequent water scarcity events usually in summer months as well as



Main window of WAS

in drought years. So, there is an urgent need for the planning and construction of suitable soil and water conservation measures for *insitu* water conservation and rainwater harvesting to meet the water requirements for agriculture, domestic use and groundwater recharge. This study attempts to examine the feasibility of GIS for location specific identification of suitable soil and water conservation interventions in different rainfall zones.

Prioritized in situ soil and water conservation interventions for district level planning

Thematic layers of slope, rainfall, soil and land use land cover were clipped for Adilabad, and Warangal Districts, intercepted using ARCGIS and selected criteria based on slope (%), permeability of the soil, runoff coefficient, land use land cover, soil type, soil depth, rainfall and rainy days was applied for finding suitable locations for different *insitu* soil and water conservation interventions like contour bench terraces, contour bunds, contour ridges, contour strips, small pits, semi-circular bunds etc in these two districts. Among the different *insitu* soil and water conservation interventions selected, the interventions like stone bunds (43% of area), contour bunds (21% of area), contour strips (14% of area) and small pits (14% of area) were more suitable for Adilabad District compared to other interventions selected (Fig. 2.7). Similar approach was adopted for prioritizing different *insitu* soil and water conservation interventions for Warangal District.

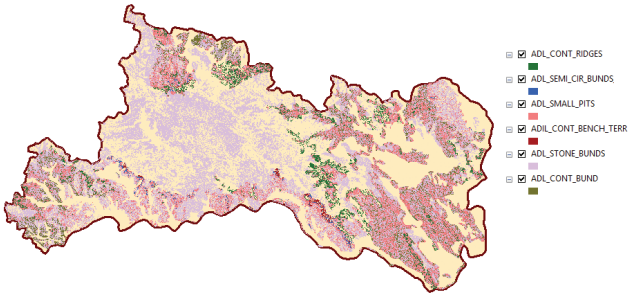


Fig. 2.7: In-situ soil and water conservation interventions suitable for Adilabad District

Soil erosion estimation using Revised Universal Soil Loss Equation (RUSLE)

A spatial soil erosion estimation model was developed for the Amistapur microwatershed using Revised Universal Soil Loss Equation (RUSLE) coupled with GIS. The slope was derived from digital elevation model generated using contours of SOI toposheet (1:25000). The different thematic layers of rainfall, soil, flow accumulation, land use land cover and slope were intersected in ARCGIS 10 and RUSLE was applied. The soil loss generated from the RUSLE model coupled with GIS showed that major portion of the area comes under slight erosion category (Fig. 2.8). The soil loss from 80% of the micro-watershed area was below 1.5 t ha^{-1} y^{-1}. The soil loss from 15% area ranged from 1.5 to 5 t ha^{-1} y^{-1}, 3.5% area ranged from more than 5 to 10 t ha^{-1} y^{-1} and remaining 1.5% area ranged from more than 10 to 27 t ha^{-1} y^{-1}. Severe erosion was noted in regions with highly undulated topography with a steep rise in elevations from 450 to 510 m above MSL and 480 to 525 m above MSL and with slopes ranged from 9.3 to 19.0 degrees. This methodology can be well adopted for the estimating soil erosion from microwatersheds or even from large catchments.

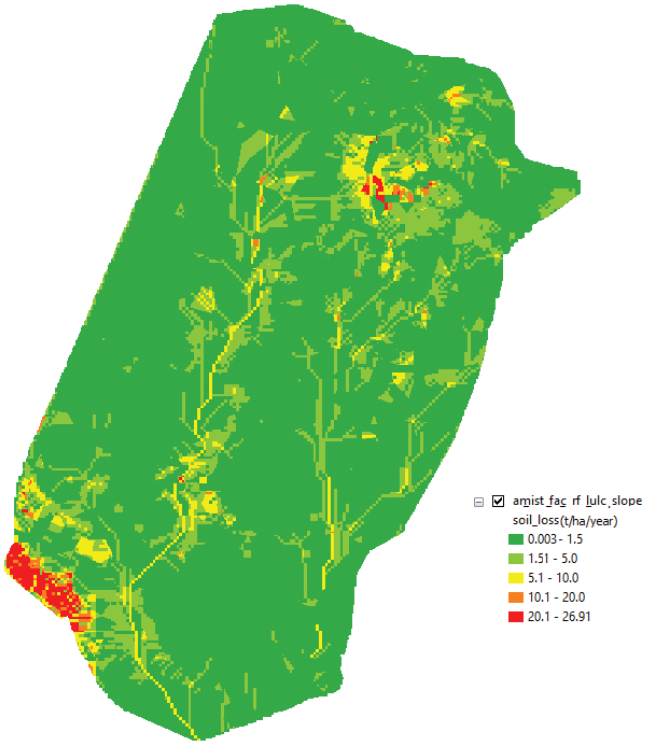


Fig. 2.8: Soil loss (t/ha/year) in the microwatershed

2.4 Crops and cropping systems

2.4.1 Evaluation of horsegram mutants in multi-locational AICRP trials

Horsegram is an important drought resistant dual purpose crop with nutritious seeds and forage. It is adaptable to poor soils and adverse climatic conditions which are unsuitable to many other crops. It is also grown as a contingency, green manure and cover crop. Mutation breeding programme was carried out at CRIDA to develop high grain and forage yielding horsegram cultivar with early maturity and tolerance to major diseases. A number of stable mutant lines were identified by selections in the advanced generations. These mutants were tested in multi-location trials to identify the promising material for release as variety and suitability of these genotypes for different regions of the country. During the year, nine horsegram entries consisting of two entries from CRIDA and CRHG-19 as check were evaluated at HRF. The seed yield per plot ranged from 522 (HG-8) to 1082 g (HG-1). HG-1 and HG-3 were the top ranking entries. Fodder yield per plot ranged from 452 (HG-7) to 2375 g (HG-3). HG-1and HG-3 were also tolerant to anthracnose. In FLDs, CRIDA varieties CRIDA-18R and CRHG-4 out yielded the local varieties. Breeder seed production of released varieties and seed multiplication of advanced lines CRHG-22 and CRHG-23 were carried out. Seed (700 kg) of CRIDA-18R, CRHG-4 and CRHG-19 was supplied to various research stations in South India and farmers of Telangana.

2.4.2 Genetic improvement in cluster bean for dryland agriculture

Cluster bean, popularly known as guar, is a hardy drought tolerant annual legume. It is one of the most important vegetable cum industrial crops grown for its tender vegetable pod and seed endospermic gum (30-35%). Because of its wide variety of uses and suitability to drought conditions, it could be an alternative crop for arid and semi-arid tracts of India. During the year, screening and evaluation of 100 germplasm accessions obtained from NBPGR Regional Station, Jodhpur was done to assess the variability and diversity in cluster bean germplasm. Among the 100 germplasm sown during *kharif* 2014, only 47 accessions germinated. Plant height ranged from 15 (IC-40691) to 76 cm (IC-40538). Number of branches per plant ranged from 4 (IC-40536 and IC-51533) to 35 (IC-113265). Number of pods per plant ranged from 8 (IC-51533) to 212 (IC-113251). Pod weight per plant ranged from 4 (IC-51533) to 55 g (IC-113251). Seeds per pod ranged from 5 (IC-51533) to 10 (IC -40538, IC-40633 and IC-40743). Seed yield per plant ranged from 2 (IC-51533) to 34 g (IC-113251). All the entries were susceptible to powdery mildew.

2.4.3 Development of mapping population and genetic enhancement for drought tolerance in maize

In recent years, the area under maize has expanded to different parts of the country including dry areas of central and southern India under rainfed conditions. It is essential to develop high yielding genotypes which can tolerate intermittent drought spell during the crop cycle. Genetic diversity in germplasm collection is a critical source to improve the yield under moisture stress. The evaluation of maize breeding materials for different drought related physiological traits for development of physiologically improved variety is tedious and time consuming process, which can be overcome through development of molecular markers for drought tolerance and using in marker assisted selection breeding. During *kharif* 2014, a set of 54 genotypes including 3 checks were evaluated both under well watered and water stressed condition in augmented block design at main campus CRIDA, Hyderabad. Data were recorded for various morphological and physiological traits for identifying drought tolerant genotypes for using in hybridization programme. Another set of 35 genotypes which were selected at field day of DMR summer nursery at Rajendranagar, Hyderabad in March, 2014 were also sown for seed multiplication and further evaluation in next crop season. Three F2 population developed by crossing between drought tolerant and susceptible genotypes were adavanced to F3 generation and one F3 into F4 population for development of mapping population. Another experiments was conducted at HRF with a set of 80 maize genotypes in augmented block design under rainfed condition, where a dry spell of 7 days was given which coincided with the anthesis-silking interval for selection of drought tolerant inbreds.

The materials evaluated showed high variation for various morpho-physiological traits. Some of the genotypes, identified for drought tolerance/ susceptibility for specific morpho-physiological traits (viz. RWC, transpiration efficiency, stomatal conductance) were used in crossing (Table 2.4) between contrasting parents, during *kharif*, 2014 for developing mapping population for drought tolerance in maize.

The materials evaluated at HRF also showed high variation for anthesis-silking interval, plant height, cob weight, 100-seed weight and grain yield/plant. Fifteen new crosses (SNJ-2011-70 / Z96-5, SNJ2011-37 / Z49-65, SNJ2011-37 / Z101-15, Harsha / Z49-65, Harsha / Z101-15, RJR-385 / PSRJ-13007, DTL4-1 / Z101-15, DTL-9 / Z49-65, DTL-9 / Z101-15, DTL-11 / Z49-65, DTL-11 / Z101-15, PSRJ-13247 / PSRJ-13007, Z59-11 / PSRJ-13007, Z96-5 / SNJ-2011-70, Z101-57 / SNJ-2011-70) were attempted among drought tolerant genotypes for generation of breeding materials with better tolerance to drought stresses. For development of mapping population for QTL analysis of drought tolerance, number of crosses were attempted involving drought tolerant and susceptible genotypes during *kharif* 2014. Three crosses (HKI-766 (O) / HKI-161, HKI-766 (O) / Z93-194 and HKI-766 (O) / Z40-19) which were attempted during *kharif* 2014 were advanced to F3 through single seed decent method and one cross (SNJ2011-17 / PSRJ 13154) to F4 generation.

Table 2.4: New crosses attempted during *kharif* 2014

Female	Male	Attributes
HKI-164-D4	18224	Susceptible x tolerant
HKI-164-D4	SNJ-2011-26	Low x high RWC
HKI-164-D4	18301	Low x high RWC
HKI-766(O)	SNJ-2011-26	Low x high TE and SC
HKI-766(O)	HKI-164-D4	Low x high TE and SC
HK1-164-7-4	Z32-87	Susceptible x tolerant
HKI-161	SNJ-2011-26	Low x high RWC
Z59-17	Z40-183	Susceptible x tolerant
PSRJ-13154	Z101-15	Susceptible x tolerant
PSRJ-13154	Z40-183	Susceptible x tolerant
RJR-132	SNJ-2011-26	L ow x high RWC
RJR-208	Z32-87	Susceptible x tolerant
RJR-385	SNJ-2011-26	Low x high TE and SC
SNJ-2011-17	Z101-15	Susceptible x tolerant
SNJ-2011-17	18224	Susceptible x tolerant
Z96-5	SNJ-2011-26	Low x high TE and SC
PSRJ13154	Z32-87	Susceptible x tolerant
RJR132	Z32-87	Low x high RWC
SNJ-2011-26	HKI-164-D4	High x low RWC
Z40-183	PSRJ-13154	Tolerant x susceptible

2.4.4 Candidate genes approach for enhanced drought tolerance and grain yield in drylands

Enhancing tolerance to climatic stresses is an important priority for stabilizing yields in drylands. Among the different classes of genes which are upregulated under various stresses such as drought, heat and salinity, transcriptional factors (TFs) are involved in signaling as well as activation of cascade of downstream genes resulting in tolerance. Two-week old sorghum seedlings were subjected to ABA stress by spraying with a solution of 100 µM ABA. The leaf samples were collected at different time intervals i.e. 0, 3, 6 and 24 h after stress imposition. Total RNA was isolated from all samples using TRIZOL reagent. The cDNA was synthesized using 5 µg of total RNA. Semi-quantitative RT-PCR experiments were conducted in triplicates and the expression levels of target genes were normalized by a sorghum housekeeping gene actin. The PCR was performed with an initial denaturation at 94^{0}C for 5 min, followed by 40 cycles 94^{0}C for 30 s, 60^{0}C for 30 s and 72^{0}C for 60 s and final extension at 72^{0}C for 5 min. The 1300 *PgLEW1* construct was transformed into *Agrobacterium tumefaciens* (LBA 4404) and the transformed *Agrobacterium tumefaciens* strain was used to develop transgenic tobacco plants with *LEW1*. The transformed tobacco plants were regenerated and hardened. Molecular characterization of the transgenics was carried out by PCR and RT-PCR analysis using *hpt*, *PgLEW1* gene specific primers. Semi-quantitative RT-PCR analysis of SnRK2 family of genes at different time intervals (0, 3, 6, 24 hrs) revealed differential gene expression (Fig. 2.9). All the SbSnRK2 genes were induced by ABA stress

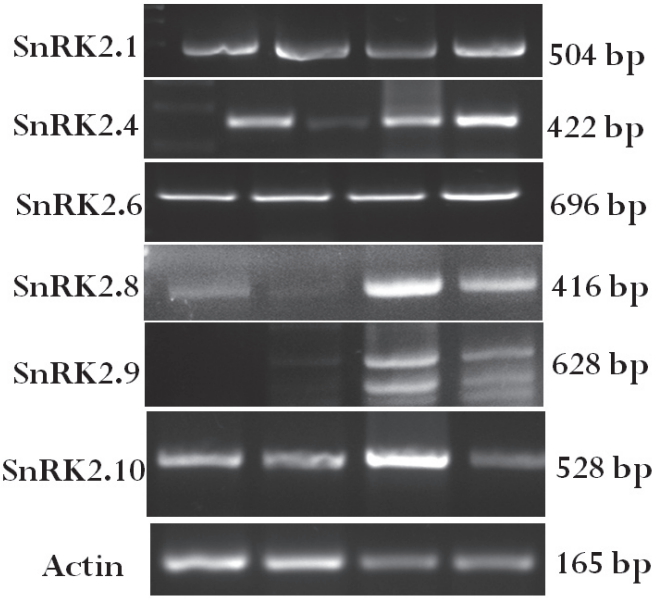


Fig. 2.9: Expression analysis of SnRK2 family of genes from sorghum under ABA stress

except SbSnRK2.9 which was weakly induced and SbSnRK2.2 was not induced by ABA application. The expression patterns of *SbSnRK2* genes revealed that the expression genes varied and may play important role in sorghum stress responses.

Functional validation of LEW1 from pearl millet

Tobacco *LEW1* transgenics were developed. PCR and RT-PCR analysis revealed amplification of 800bp and 822bp fragments confirming the integration and expression of *hpt* and *LEW1* genes (Fig. 2.10).

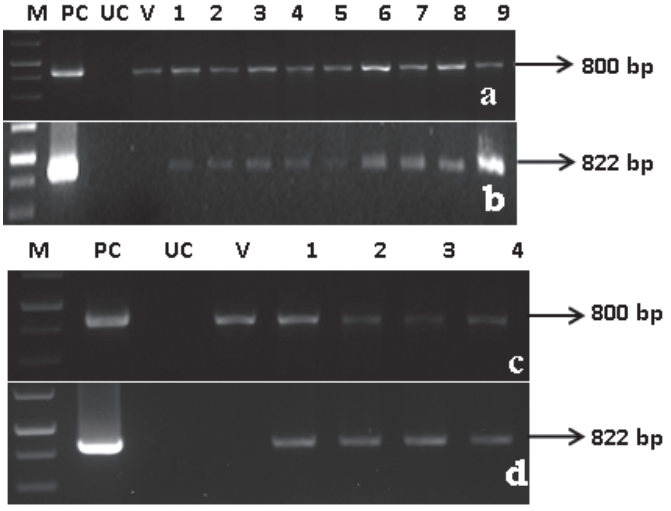


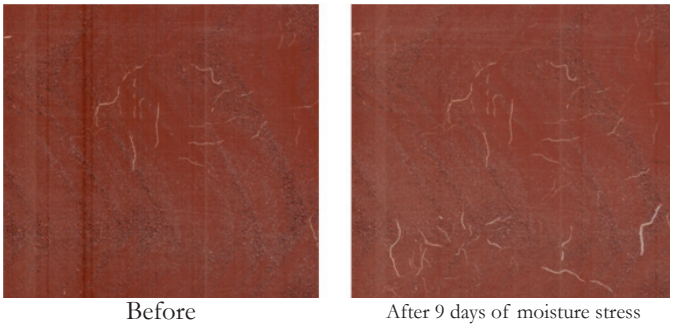
Fig. 2.10: PCR and RT-PCR analysis of *pgLEW1* transgenic tobacco lines. (a, c) using *hpt* gene specific primers. (b, d) using *LEW1* gene specific primers. Lanes M-1 kb DNA marker, PC- positive control, UC-untransformed control , V-1300 vector only Lanes 1-9 *pgLEW1* transgenics.

2.4.5 Molecular and physiological characterization of transgenics of greengram (*Vigna radiata* L.) for oxidative stress tolerance

Drought stress is single most important factor affecting crop growth and productivity under rainfed agriculture. Absence of sufficient and satisfactory level of genetic variability is the major hurdle in greengram improvement by conventional breeding. Present study is aimed at over-expression of *annexin Bj1* gene in greengram to enhance its abiotic stress tolerance. Generation advancement and molecular characterization of the putative transgenic events using PCR, RT-PCR was undertaken to establish integration and expression of the transgene. Five independent events of transgenic greengram material were advanced from T_2 to T_3 generation. Molecular characterization using PCR and RT-PCR with gene specific primers confirmed integration and expression of the transgene. Evaluation of confirmed transgenic material (T_3) for various physiological parameters and Southern analysis is underway.

2.4.6 Assessing the plant root adaptive plasticity in the stressed environments of moisture deficits and excess in rainfed agriculture: Maize

Of late, maize is popularly grown in a big way in dryland areas of India. It is necessary to understand the plant root adaptive plasticity to come back from the existing adverse situation, for the benefit of its survival even under excess or deficit soil moisture conditions. An experiment was carried out during 2014-15 on maize rooting traits under deficit soil moisture conditions in the open field condition with two drought tolerant maize lines and one drought susceptible maize line. The treatment of water stress was imposed to capture its effect on the root dynamics in the form of both non destructive digital root images in-situ using CI Root Scanner as well as root parameters from destructive sampling.



Effect of soil moisture stress on root growth of drought tolerant and drought susceptible maize lines (9 days of stress imposed)

This was compared with the respective maize lines under no moisture stress. The above picture illustrates the effect of moisture stress on root growth of drought tolerant and drought susceptible maize lines.

2.4.7 Pest models for prediction of sucking pest severity in cotton based on AICCIP historical data

The objective was to develop weather index based pest prediction models using correlation, regression and decision tree analysis of pest and weather data. Standard meteorological week-wise pest data for nine years from 2004-05 to 2012-13 was collected from All India Coordinated Cotton Improvement Project (AICCIP) for twelve centres, viz., Akola, Bhawanipatna, Coimbatore, Dharwad, Guntur, Junagadh, Khandwa, Nanded, Nandyal, Rahuri, Raichur and Surat. Weather data for the corresponding standard meteorological weeks (SMWs) was collected from IMD, AGROMET-CRIDA and the cotton growing centres. The weather variables viz., maximum temperature (MaxT, °C), minimum temperature (MinT, °C), morning relative humidity (RH1, %), evening relative humidity (RH2, %) and rainfall (RF, mm) were normalised using the formula given below. Secondly, SMW-wise averages were calculated for the normalised weather variables (Z_i's) and the pest count (P).

$$Z_i = \frac{X_i - X_{min}}{X_{max} - X_{min}}\delta + \frac{X_{max} - X_i}{X_{max} - X_{min}}(1-\delta)$$

Where, δ is unity when the variable is positively related to the pest severity and is zero otherwise; X_i, X_{min} and X_{max} are respectively, the non-normalised value, the minimum and the maximum of the weather variable in original units across centres and years.

Linear regression models were fitted using step-wise regression technique to the average weekly pest count (P), by taking Z_i's as explanatory variables to identify significant explanatory variables, for each pest. Correlation coefficients obtained were used as weights to compute an index for different pests as follows:

The weights were calculated as follows:

$$I_p = w_{1_p} \times Z_{1_p} + w_{2_p} \times Z_{2_p} + \ldots + w_{5_p} \times Z_{5_p}$$

$$w_{i_p} = \frac{r(P, Z_{i_p})}{r(P, Z_{1_p}) + r(P, Z_{2_p}) + \ldots + r(P, Z_{n_p})}$$

Where, $r(P, Z_{i_p})$ is the correlation coefficient between pest count, P and the ith significant normalised weather variables corresponding to the pest P.

A two splits-decision tree model that yielded three branches was fitted by taking P as a response variable and the index (I_p) as independent variable. Correlation and regression analysis of pest data with corresponding weather data for 36 weeks resulted in the estimation of weights for weather variables having significant relationship to develop pest-wise index values for decision tree analysis. Pest specific decision tree models were developed for predicting severity based on weather index computed from significant weather variables for pest categories of low, medium and high severity (Table 2.5). Goodness of fit statistics indicated higher coefficients of determination for aphids (R_2 = 0.74), jassids (0.67), thrips (0.83) and whitefly (0.54).

Table 2.5: Decision tree model estimates for Indices based on normalised weather variables for different pests

Pest	Index based on normalised weather variables*	Pest incidence predicted by decision tree#			R^2
		Low	Medium	High	
Aphid	I_a=0.45xZ_1+0.43xZ_2+0.12xZ_3	6.5 (0,0.34)	12.7 (0.34,0.45)	23.4 (0.45,1)	0.74
Jassid	I_j=0.36xZ_3+0.44xZ_4+0.20xZ_5	2.8 (0,0.40)	5.8 (0.39,0.47)	7.0 (0.47,1)	0.67
Thrips	I_t=0.26xZ_3+0.43xZ_4+0.31xZ_5	1.4 (0,0.32)	4.9 (0.32,0.42)	14.5 (0.42,1)	0.83
Whitefly	I_w=1.12xZ_2–0.12xZ_5	2.1 (0,0.48)	3.1 (0.70,1)	4.9 (0.48,0.7)	0.54

* I_a, I_j, I_t & I_w are indices for aphid, jassid, thrips and whitefly, respectively; # values in parentheses are lower and upper index values estimated by decision tree model

2.4.8 CROPSAP

Developed a standalone application on Geographical Information System for Crop Pest Severity vis-à-vis weather for Maharashtra: The DVD on GIS for crop pest severity vis-à-vis weather for Maharashtra was developed using weekly spatial overlays of pest incidence over different weather parameters such as temp (Max, Min and deviation from normal), RH, RF, SMI and MAI for district and tehsil level. The software retrieves the GIS maps for any given week in the past three years (5000 GIS maps) as selected by the user. These GIS maps are helpful in comparing current situation with the past situation for any given location while issuing the agro–advisories for pest and disease management. The software is with Visual Basics 6.0 as front end and Ms Access as back end. A web enable version of the GIS for pest severity was developed in 2014-15.

OPMAS : Collected daily weather data parameters viz. maximum temperature (°C), minimum temperature (°C), relative humidity (%) and rainfall (mm) from 26 districts across the country in cotton growing areas for developing relationships with pest severity.

2.4.9 Intercropping of various cereals

A need based intercropping experiment was conducted with main crops of maize (hybrid and local) and sorghum (hybrid and local) intercropped with pigeonpea, clusterbean (vegetable) and greengram in additive series. There was lot of moisture stress during entire cropping period from germination to harvest of all crops in all the phenological stages, and pigeonpea had the highest stress during its reproductive stages. The yields of cereal hybrids were more than cereal locals in all the treatments (both sole and intercropping) by about 30 to 40%. The yields of cereal main crops in intercropping systems were about 60 to 70% of cereal sole cropping systems. The yields of legume intercrops in intercropping systems were 55 to 65% of legume sole cropping systems. The intercropping systems were better than sole cropping systems by about 23% as seen by LERs (Table 2.6). The best income equivalent ratios (IERs) were obtained by clusterbean systems (Table 2.7). Since clusterbean had six multiple pickings it could perform better than other crops, as it took advantage of rain whenever it occurred.

Table 2.6: Land equivalent ratio (LER) of different intercropping systems

		MH	ML	SH	SL	Mean
	Sole	1.00	1.00	1.00	1.00	
MH + PP	1.00	1.23	1.21	1.18	1.14	1.19
MH + CB	1.00	1.28	1.27	1.25	1.26	1.27
MH + GG	1.00	1.27	1.27	1.21	1.19	1.23
Mean		1.26	1.25	1.21	1.19	1.23

Table 2.7: Income equivalent ratio (IER) of different intercropping systems

		MH	ML	SH	SL
	Sole	1.00	0.75	1.11	0.82
MH + PP	0.41	0.86	0.71	0.94	0.73
MH + CB	1.78	1.78	1.61	1.80	1.60
MH + GG	0.82	1.17	1.00	1.20	0.99

2.4.10 Biofortification for improved nutritional traits in selective dryland crops grown under rainfed conditions

In order to deliver enhanced nutrition within a food-based system, it is necessary to increase the nutritional value of the food. By enhancing nutrient dense crops, severe deficiencies can be eliminated in developing countries. Hence, one of the ways by which this goal can be achieved is through natural method, possibly with biofortification of food crops. A field experiment was carried out with the following 6 treatments: farmyard alone (FYM), FYM + PSB, FYM + PSB + citrate (FYM + PSB+C), PSB alone, 100% RDF + PSB (NPK+PSB), 100% RDF and no input (NC). Maize hybrid DHM 117 seed was biofortified with PSB-I at the time of sowing. The field experiment was conducted at HRF to study the absorption of essential minerals i.e., iron and zinc from soil to root, leaves and finally to the edible part of the maize crop. Protein content (%) of maize grain was higher in PSB treated crops. Mean protein content (%) showed an

increase in NPK + PSB treatment (12.8%) followed by FYM + PSB + citrate (12.5%), PSB alone (12.3%), FYM + PSB (12.1%) and NPK (12.0%). Zinc content (mg/100g) was found to be significantly higher in maize grain with NPK + PSB treatment (4.66 mg/100g) followed by FYM + PSB + C (4.53 mg/100 g) and FYM+PSB (4.50 mg/100g) compared to 100% RDF treatment (Table 2.8). Iron content in the maize grain also showed a significant increase in NPK + PSB treatment compared to other treatments.

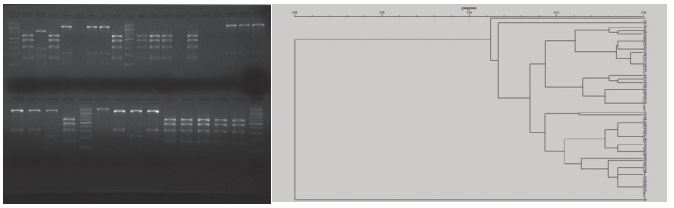
Table 2.8: Effect of different treatments on protein and zinc content of maize grain

Treatment	Protein (%)	Zn (mg/100 g)
FYM	11.55	4.53
FYM + PSB	12.05	4.50
FYM + PSB + citrate	12.46	4.54
PSB alone	12.30	3.25
100% NPK	12.02	3.05
100% NPK + PSB	12.83	4.66
No inputs	10.89	1.66

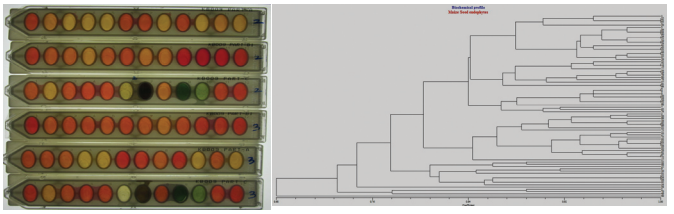
2.4.11 Endophytic microorganisms for management of drought in rainfed maize and groundnut

The endophytes might play an important role in combating plant stress through various mechanisms. These intimate interactions between endophytes and host plants need to be understood and exploited for agricultural benefits. Characterization of endophytic bacteria isolated from maize seeds (80), maize stem (120), groundnut stem (101), and groundnut roots (69) is in progress. Amplified ribosomal DNA restriction analysis (ARDRA) was used for molecular characterization of eighty endophytic bacteria isolated from 34 different maize genotypes. The biochemical diversity of the 80 endophytic bacteria was studied by Hi-Carbohydrate kit from HIMEDIA containing 35 different carbohydrate substrates.

Phylogenetic analysis based on restriction profiles of amplified 16SrDNA generated by using three enzymes (*Eco*RI, *Msp*I and *Hae*III) placed 80 endophytic isolates into 25 groups. The 16S rDNA sequencing analysis of representative isolates showed that majority of endophytes from maize seed belonged to genus *Bacillus*. However 6 isolates identified as *Staphylococcus*



ARDRA based phylogenetic diversity of maize seed endophytes



Biochemical diversity of maize seed endophytes (HiCarbo Kits)

Fig. 2.11: Phylogenetic and biochemical diversity of maize seed endophytes

spp. and one isolate as *Corenybacter* sp. Phylogenetic analysis based on utilization of carbon source placed 80 isolates in 65 groups indicating high biochemical diversity among different isolates (Fig. 2.11).

Eighty maize seed endophytes and 101 groundnut stem endophytes were characterized for PGP traits and abiotic stress tolerance *in vitro*. All maize seed endophytes axhibited ammonia production but none of the isolate found positive for production of siderophores, IAA and solubilization of P and Zn. However 37% isolates exhibited antagonism against minimum one fungal pathogen out of three tested (*R. solani, S. rolfsii, M. phaseolina*). Among 101 groundnut stem isolates, 32, 30 and 47% exhibited tolerance to high temperature (50oC), drought (20% PEG 6000) and salinity (10% NaCl). About 99, 14, 15, and 21% isolates were positive for ammonia, siderophore, Zn solubilization and P solubilization. Further 24, 24 and 48% isolates were antagonistic to S. rolfsii, *M. phaseolina, A. tenuissima, respectively* (Table 2.9).

2.4.12 Phenotyping of rainfed maize inoculated with heat tolerant PGPR for enhanced adaptation

Use of these microorganisms *per se* can alleviate stresses in crop plants thus opening a new and emerging application in agriculture. In the present project, role of abiotic stress tolerant microorganisms in helping

Table 2.9: Characterization of endophytes for abiotic stress tolerance and PGP traits

Abiotic stress tolerance	% of isolates positive	
	Maize (80)	Groundnut (101)
Temperature (50°C)	37	30
Salinity (NaCl-8%)	68	50
Drought (30% PEG-6000)	51	9
PGP traits		
Ammonia production	100	99
Siderophore	0	14
Antifungal activity	37	48
Zn-solubilisation	0	15
P-solubilisation	0	21

dryland crop (maize) to cope with abiotic stress (heat) is being studied. Maize plants (Bioseed-9681) treated with bacterial strain KB-82 were subjected to heat stress (44oC for 11 days) in an environmental plant growth chamber. After heat stress, the shoot proteins from the inoculated and uninoculated plants were extracted and subjected to 2D gel electrophoresis to study the difference in protein expression profile due to bacterial inoculation. Bacterial inoculation resulted in enhanced expression of some proteins where as expression of some proteins was reduced (Fig. 2.12). The results indicated the influence of bacterial inoculation on plant physiology under heat stress conditions. The selected spots will be identified by mass spectrometry.

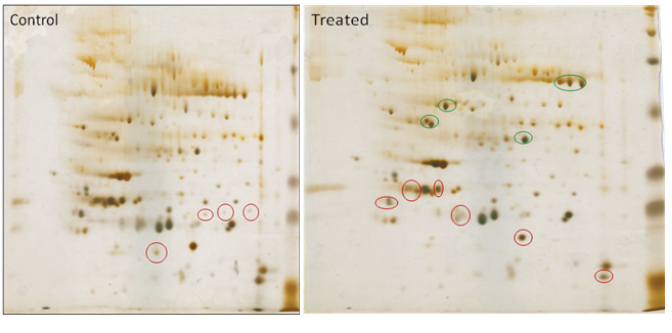


Fig. 2.12: 2D gel electrophoresis showing differential protein expession in control and bacteria treated maize under heat stress. Red circle represent down regulation and green circles represent upregulation in the bacteria treated maize.

Four bacterial isolates (NIC-8, NIC-16, NIC-17, NIC-23) were selected for field study based on their performance in pot experiments. A field experiment in *rabi* season with two dates of sowing (set I: 07.02.2014 and set II: 01.03.2014) was conducted to impose high temperature stress in set II during reproductive stage of maize cv. Bioseed 9681. For bacterial treatments, seeds were coated with carrier based bacterial formulation before sowing. The experiment was conducted as RBD maintaining three replications of each treatment (five treatments including un-inoculated control).

Inoculation of thermotolerant rhizobacteria in maize improved the shoot length and chlorophyll content over controls. Set II (sowing date 01.03.2014) recorded advancement of days to 50% tasseling, 50% anthesis and 50% silking by 2-3 days as compared to set I (sowing date 07.02.2014). Inoculated treatment showed less ASI as compared to uninoculated control; however the effect was more in Set I (Table 2.10). Significant reduction in grain yield was observed under set-II due to heat stress. Grain yield was positively influenced due to bacterial inoculation in both sets. Treatment with NIC8 showed highest grain yield under both the sets. The maximum temperature during reproductive stage in set I and Set II was 39°C and 40°C respectively. Events of storm and heavy rains were observed during flowering stage in both the sets.

Multinutrient (P, Zn and K) solubilizing bacteria

CRIDA strains ZnKPSB-1 and ZnKPSB-3 along with two commercial inoculants (PSBc and ZSBc) were evaluated for plant growth and nutrient uptake in maize under field conditions at GRF. Inoculation with multinutrient solubilizing bacteria had positive effect on plant growth as well as macro- and micro-nutrient uptake in the maize shoots. Treatment ZnKPSB-1 was found superior to all other treatments in terms of plant growth parameters and shoot macro and micronutrient levels (Table 2.11).

Field experiment with two dates of sowing for testing the effect of bacterial inoculation on maize (DHM 117) under heat stress

Table 2.10: Effect of sowing dates and bacterial inoculation on tasseling, anthesis and silking in maize

Set I DOS 7.02.2014	Days to 50% tas-seling	Days to 50% anthesis	Days to 50% silk-ing	ASI		Set II DOS 1.03.2014	Days to 50% tas-seling	Days to 50% anthesis	Days to 50% silking	ASI
Control	65.0	67.0	70.7	3.67		Control	62.3	64.3	68.0	3.7
NIC 8	64.3	66.3	67.7	1.33		NIC 8	62.0	63.7	66.3	2.7
NIC 16	64.7	66.7	69.3	2.67		NIC 16	62.0	64.0	66.7	2.7
NIC 17	64.7	67.3	69.0	1.67		NIC 17	62.3	64.3	67.3	3.0
NIC 23	65.0	67.0	68.7	1.67		NIC 23	63.7	65.7	68.3	2.7
CV%	1.15	1.11	0.67	31.49		CV%	2.24	2.04	2.09	15.74

Table 2.11: Effect of bacterial inoculation on nutrient content in maize shoot

Treatment	% N	% P	% K	% Na	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Control	0.290	0.154	1.340	0.05	228.9	83.1	24.2	17.5
ZnPSB-1	0.358	0.329	1.473	0.05	246.9	98.8	33.3	19.1
ZnPSB-3	0.371	0.351	1.646	0.04	194.4	98.2	38.1	15.5
PSB (c)	0.319	0.198	1.497	0.04	164.7	93.4	34.9	18.6
ZSB (c)	0.313	0.220	1.491	0.05	192.5	92.1	33.5	20.2
LSD	0.011	0.059	0.11	0.003	41.41	6.89	4.06	2.42

2.4.13 Application of microorganisms for nutrient management and plant growth promotion

Efficient consortium of *Bacillus, Pseudomonas, Azospirillum* and *Azotobacter* were selected from the pot studies and further evaluated on field for nutrient management and plant growth promotion of sorghum and pigeonpea. During *kharif* 2014, a field trial was conducted at GRF under rainfed conditions using sorghum cv. SPV-462 and pigeonpea cv. PRG-158 with three replications. Among seven treatments, sorghum grain yield of 2203 kg/ha was realized in the treatment Azb19+Asp20+P29 followed by Asp 20 with a grain yield of 2116 kg/ha and these treatments were significantly different from other treatments and control. In pigeonpea, Azb19+Asp20+B105 treatment resulted in seed yield 519 kg/ha followed by Asp32+Azb19+B105 yielding 506 kg/ha whereas in control the yield was only 468 kg/ha.

The shelf-life of consortia was studied in the laboratory after formulation by drawing samples at monthly interval for six months. The liquid formulation showed enhanced shelf-life as compared to lignite formulation. In all the cases, the initial population 5x1010 cfu/ml or g significantly dropped with the increase of storage time. However, the degree of reduction varied with the type of formulation (Fig. 2.13).

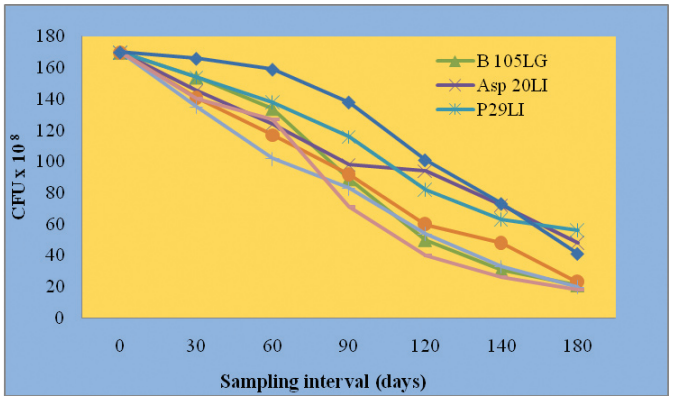


Fig. 2.13: Shelf-life of consortia of Bacillus, Azospirillum, Azotobacter and Pseudomonas in liquid and lignite formulations (LI: Liquid inoculant, LG: Lignite based bioinoculant formulation. B: Bacillus, Asp: Azospirillum, Azb: Azotobacter, P: Pseudomonas)

For monitoring introduced organism in the soil, selected promising strains of *Bacillus* sp.105, *Pseudomonas* sp. 29 and *Azotobacter* sp. 19 were tagged with GFP gene (in pHC 60 plasmid) using electroporation method. After transformation of GFP gene into plant growth promoting bacteria, colonization of sorghum and pigeonpea was studied. Samples were drawn at regular intervals to see the mobility of the organism in the plant. To visualize colonization and obtain qualitative data, confocal laser scanning microscopy (CLSM) was used. Fluorescing *Azotobacter* cells adhering to the root hairs as well as inside the root hairs (Fig. 2.14) could be seen under microscope revealing the ability of the strain to get into the plant system.

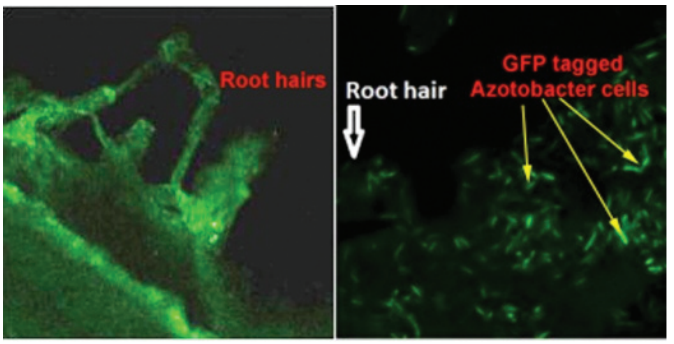


Fig . 2.14: Colonization of *Azotobacter* in the roots of sorghum

To understand the population dynamics, the GFP (with tetracycline resistance gene) tagged strain of *Azotobacter* sp. 19 was introduced into the rhizosphere as seed treatment in pots containing unsterile soil and samples were drawn for 14 days. The populations increased until 8th day after inoculation and thereafter there was marginal gradual reduction in the population (Fig. 2.15). The highest populations of the individual bioinoculants were recorded on 8th day and thereafter the populations started declining gradually. The spatial distribution and population dynamics of individual bioinoculants at various levels of sorghum roots provided the information regarding the development of the introduced bioinoculant in relationship to the host rhizosphere and rhizosphere competence. The compatibility with indigenous microflora, and the ability to colonize sorghum roots make the bioinoculants potential candidate strains for nutrient management and plant growth promotion.

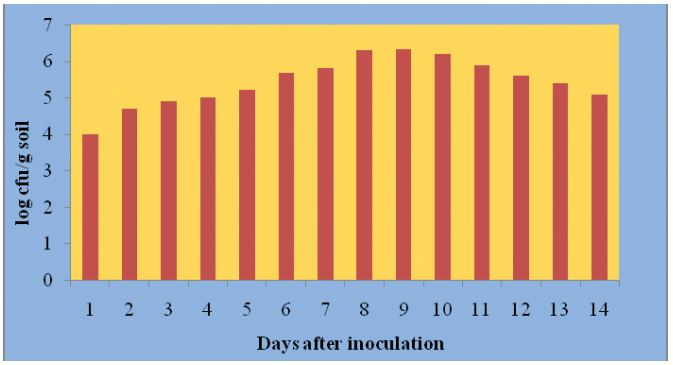


Fig. 2.15: Mean populations (log cfu) per gram of soil of *Azotobacter* 19 recovered from rhizosphere of sorghum

2.5 Soil and nutrient management

2.5.1 Conservation tillage farming strategies and crop residue management for soil health improvement and higher crop productivity in sorghum-blackgram system in rainfed Alfisol

In order to improve organic matter and overall quality of soils in semi-arid tropical Alfisols, it is important to focus on restorative soil management practices such as reduced tillage, crop residue retention and recycling and appropriate crop rotation incorporating legumes with cereals. Keeping in view this, a long-term experiment was initiated during 2013 with sorghum and black gram as test crops in yearly rotation at HRF. The experiment was laid out in a strip plot design with two tillages: conventional (CT) and reduced (RT) (treatments effective from 1998) and three residue retention treatments (started w.e.f 2013) viz; no residue application (S1), cutting at 35 cm height (1/3 rd height) (S2), and cutting at 60 cm height (S3); For blackgram crop, the residue retention treatments were as follows: no residue (S0), 50% of the residue retention (S1) (clearing of residue from alternate rows), and 100% retention (S2). During the current year, blackgram (T 9) was the test crop in rotation. Nitrogen @ 30 kg N/ ha and phosphorus @ 30 kg P2O5/ha were applied uniformly in all the plots. In order to control weeds, pre-emergence herbicide atrazine was sprayed. It was observed that blackgram yield varied from 323 to 578 kg/ha across the treatments (Table). Conventional tillage recorded (540 kg/ha) significantly higher yield (20%) compared to minimum tillage (449 kg/ ha) (Table 2.12). Blackgram yield significantly varied with residue retention treatments of previous crop (sorghum). Among the residue retention treatments, residue retention at 60 cm height recorded significantly higher blackgram yield (566.7 kg/ha) followed by S1 (retention at 35 cm height) (511.8 kg/ha) compared to control (405.6 kg/ha). The increase in yield with S2 treatment was 10.7 and 39.5% higher over control. Residue retention treatments of previous sorghum crop influenced black gram yield as well as biomass and consequently carbon inputs to the soil. When

Table 2.12: Long-term effect of conservation tillage and residue retention of previous crop on blackgram yield and carbon input

Tillage	Residue	Seed yield (kg/ha)	Black gram C input
Minimum tillage	S0: No residue application	332	0
	S1: Cutting at 35 cm height (1/3 rd height)	468	98.3
	S2: Cutting at 60 cm height	545	230.6
Conventional tillage	S0: No residue application	478	0
	S1: Cutting at 35 cm height (1/3 rd height)	554	117.1
	S2: Cutting at 60 cm height	587	241.2
CD (0.05)			-
Tillage		**	-
Residues*		**	-
T X R		*	-

*** Residue retention treatments were imposed only at the time of harvest of crop by manipulating the harvesting method.**

averaged over residue retention treatments, it was observed that conventional tillage practice contributed higher amount of C inputs (179.2 kg/ha) compared to minimum tillage (164.5 kg/ha). On an average, S2 treatment contributed 236 kg/ha equivalent carbon inputs followed by S1 (107.7 kg/ha) (Table 2.12).

2.5.2 Assessing soil quality key indicators for development of soil quality index using latest approaches under predominant management practices in rainfed agro-ecology

To ensure desired targets of productivity, it is of paramount importance to check soil degradation and improve soil quality through effective soil management practices such as conservation tillage, residue recycling and adequate amount of fertilization (to ensure higher below and above ground biomass) and to monitor changes in soil quality parameters and indicators periodically. A study was conducted to evaluate the long-term influence of tillage, crop residues and graded levels of N on MBC and soil organic carbon stock in sorghum-castor system in rainfed Alfisol. A field experiment comprising of tillage, [conventional (CT) and minimum (MT)], residues [2 t/ha dry sorghum stover (SS), 2 t/ha fresh gliricidia loppings (GL) and no residue (NR)] and nitrogen levels [0 (N_0), 30 (N_{30}), 60 (N_{60}) and 90 (N_{90}) kg N/ha] under sorghum and castor system was initiated in a strip split-split plot design at HRF during 1995. During the current year (2014), Castor was the test crop. Tillage, residues and N showed a significant influence on microbial biomass carbon (MBC) and the values varied from 170 to 490 mg/kg. Minimum tillage recorded higher MBC content (334 µg/g) compared to conventional tillage (295 µg/g) (Fig. 2.16). Surface application of residues also significantly influenced the soil MBC contents. Application of gliricidia loppings and sorghum stover recorded MBC contents of 403 and 326 ug/g which were significantly higher by 86 and 50% respectively. Application of N @ 30, 60 and 90 kg/ha increased MBC contents by 27, 43 and 46% respectively over no nitrogen application. Of all the treatment combinations, significantly higher MBC content was recorded with MTGLN90 (490.8 µg/g) followed by MTGLN60 (476.6 µg/g).

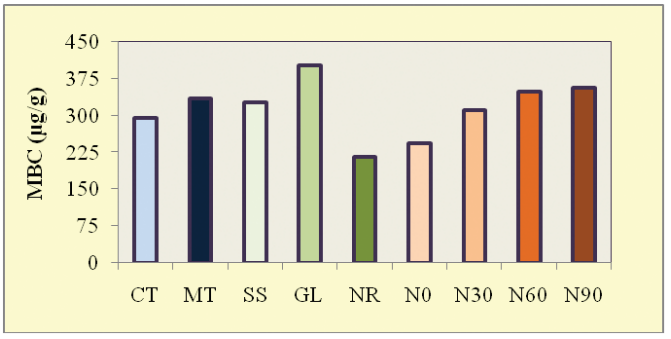


Fig. 2.16: Long-term effect of tillage, residues and N levels on microbial biomass carbon

After 18 years, it was observed that tillage, residues and N levels showed a significant influence on organic carbon stock. The soil organic carbon stock varied from 9.9 to 15.8 Mg/ha. Minimum tillage recorded significantly higher (13.6 Mg/ha) soil organic carbon stock (10% higher) compared to conventional tillage (12.3 Mg/ha). Application of sorghum stover and gliricidia loppings recorded organic C stock to the tune of 14 and 13.7 Mg/ha which was 26 and 23% higher respectively compared to control. Significantly higher organic C stock was observed with MTGLN90 (15.82 Mg/ha) (Fig. 2.17). The interactive effects between tillage and residues (TxR) and residues and N levels (RxN) were found to be significant.

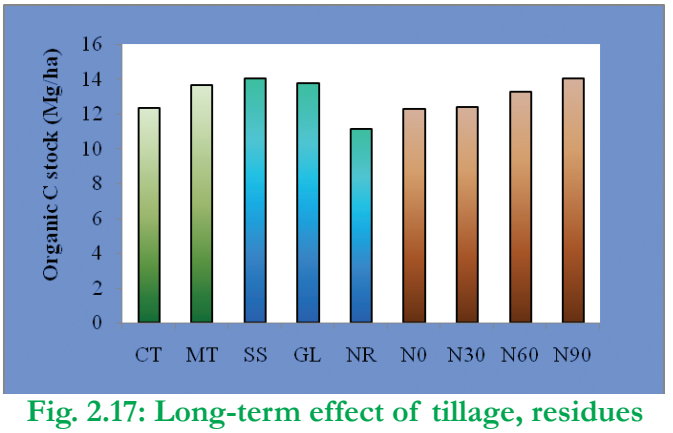


Fig. 2.17: Long-term effect of tillage, residues and N levels on organic C stock

A relationship between relative yield of sorghum and castor with soil organic carbon stock was developed (Fig. 2.18). It was observed that the relative sorghum grain and castor bean yield with carbon stock was found to be significant (R^2= 0.522 and 0.428 respectively).

$Y_{\text{Rel Sorghum Yld}} = 9.559\ x - 71.33$ (R2 = 0.522)

$Y_{\text{Rel Castor Yld}} = 8.449x\text{-}43.39$ (R2 = 0.522)

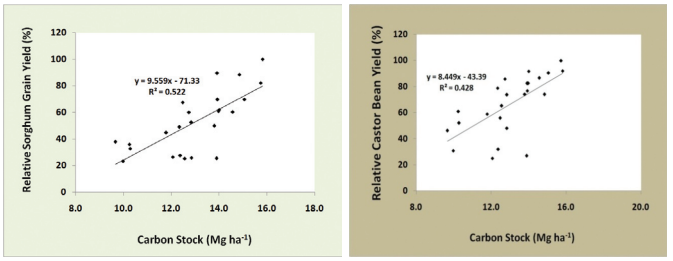


Fig. 2.18: Relationship between relative crop yield (sorghum and castor) with soil organic carbon stock after 18 years

2.5.3 Improving nutrient use efficiency through foliar supplementation in rained areas

In rainfed areas, due to lack of soil moisture, the crops are unable to utilize the applied nutrients efficiently resulting in low/decreased efficiency of the applied nutrients. Hence, efforts were made to study whether application of water soluble fertilizers through foliar sprays during the vegetative and reproductive stages can enhance the efficiency of applied nutrients and also to study whether foliar sprays of water soluble fertilizers, micro (zinc) and beneficial elements (selenium) can influence some of the plant physiological processes and in turn help minimize the yield reduction due to drought/insufficient soil moisture conditions in maize and sorghum. Maize cv. DHM 117 was raised during *kharif* 2014 at GRF in randomized block design with nine treatments and three replications. The treatments were: T1: recommended dose of fertilizer (90:45: 45 kg NPK/ha), T2: T1 without top dressing of 45 kg N/ha at 25 DAS + foliar spray of 0.5% water soluble fertilizer (19-19-19) + 0.5% ZnSO4 + 20 g/ha of sodium selenite at 25 and 55 DAS, T3: T1 + foliar spray of 0.5% water soluble fertilizer + 0.5% ZnSO4 + 20 g/ha of sodium selenite at 25 and 55 DAS, T4: T1 + foliar spray of 0.5% water soluble fertilizer + 0.5% ZnSO4 + 20g/ha of sodium selenite at 55 DAS only, T5: T1 + foliar spray of 0.5% water soluble fertilizer + 0.5% ZnSO4 + 20 g/ha of sodium selenite at 25 DAS only, T6: T1 + spraying of sodium selenite at 25 and 55 DAS, T7: T1 + foliar spray of 0.5% water soluble fertilizer at 25 and 55 DAS, T8: T7 + foliar spray of 0.5% ZnSO4 + 20 g/ha of sodium selenite at 25 and 55 DAS, T9: Absolute control (no fertilizers). Spraying of water soluble fertilizer plus micronutrient and beneficial nutrient at two intervals i.e. 30 and 60 DAS along with the recommended dose (T3 treatment) of fertilizer resulted in highest straw yield (4892 kg/ha) followed by T7 (4714 kg/ha) where only water soluble fertilizer was sprayed during 30 and 60 DAS along with the recommended dose of fertilizer even during the drought year where the rainfall was 50% less than the normal (Fig. 2.19). Further, the straw yield in treatment T2 was less than the treatment T1 indicating that the water soluble fertilizers through foliar sprays can be used only for supplementing the nutrients required by the plants but not as a replacement to soil application of conventional fertilizers.

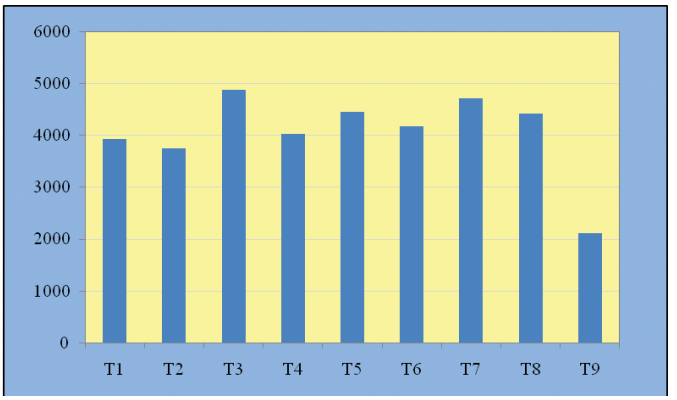


Fig. 2.19: Straw yield (kg/ha) of maize as influenced by different treatments

2.5.4 Impact of conservation agriculture practices on soil physical properties in maize-pigeonpea crop rotation under rainfed Alfisols

Development of economically viable tillage and nitrogen management strategies is important for conservation of natural resources and improvement in soil physical health, which in turn helps in increasing the productivity of crops. A long-term field experiment was initiated to develop sustainable tillage and nitrogen management strategies to improve the soil physical health of dryland farming systems (maize-pigeonpea crop rotation) and farm productivity and profitability. Maize (DHM-117) was grown during *kharif* 2014. The experiment involved three tillage practices viz. conventional tillage (summer ploughing + cultivator + disc harrow before sowing and no residue retention), reduced tillage (one time cultivator + disc harrow + residue retention (up to 30 cm stem height), and no tillage + residue retention (30 cm stem height) + direct sowing, and four nitrogen levels, viz. no nitrogen (N_0), 75% of the RDN (N_{75}), 100% of the RDN (N_{100}),

Conventional tillage | No tillage | Reduced tillage

Maize germination and plant stand in different treatments

and 125% of the RDN (N_{125}). The experiment was laid out in a split plot design with three replications. No significant difference was observed in seed yield among different tillage treatments but significant difference was observed among different nitrogen levels and the yield increased with successive addition of nitrogen levels as compared to the control. Similarly, no significant difference was observed in stover yield among the tillage treatments, although 3 to 5% more stover yield was observed in no tillage and reduced tillage as compared to conventional tillage. There were significant differences among different nitrogen levels. The mean straw yield was increased by 34, 52 and 59% in N75, N100 and N125 treatments, respectively over the control.

2.5.5 Potential role of conservation agriculture in resource conservation and carbon sequestration

A field experiment was initiated in 2009 at HRF to assess the potential role of conservation agriculture practices including all the three components like different tillage practices, quantity of residue and its management for efficient resource conservation, increase productivity and profitability of pigeon pea and castor system in rainfed Alfisols. In this year, castor was taken after pigeonpea with three tillage practices viz. conventional tillage (disc ploughing in off season, cultivator, disc harrow and sowing of crop), reduced tillage (ploughing once with cultivator and disc harrow), and zero tillage (direct sowing in residues) and different residue levels by harvesting at different heights (0, 10 and 30 cm) to increase the residue contribution to the field. The experiment was laid out in a split plot design with tillage treatments as main plots and harvesting heights as sub plots. The pigeon pea residues were killed by spraying contact herbicide (Paraquat). The rainfall during the year was very low resulting in low castor yields as compared to the average yields. Residue height of 30 cm recorded around 60% higher residue yield as compared to 0 cm residue height. Termites infested the flat residues whereas the standing residues were not infested. The residue cover was around 90% in all the treatments and was not significantly influenced by the tillage treatments or anchored residue heights. CT recorded 17 and 38% higher yields as compared to reduced and zero tillage, respectively. This was followed by reduced tillage. The pigeon pea yields increased with increase in residue harvesting heights; 10 cm harvest height recorded higher yields as compared to 0 and 30 cm harvest height (no residues). The yield decrease in zero tillage with residues was low as compared to zero tillage without residues. There were no runoff events due to low rainfall. Lower soil and nutrient losses were observed in zero tillage as compared to conventional and reduced tillage.

Termite infestation on flat pigeonpea residues

2.5.6 Management strategies for resource conservation and carbon sequestration in rainfed Alfisols

The conservation agriculture increases soil and moisture conservation but the yields of the crops are reduced. Hence implementing resource conservation technologies in line with CA principles increases the crop yield. Permanent raised bed is one of the options where sowing is done on raised beds and soil moisture can be conserved. The implements to form permanent beds and reuse it without tilling are not available. Hence an attempt was made to fabricate the implement. An experiment was laid out in a RBD with different treatments (conventional planting without residues, conventional tillage & formation of raised beds every year, conventional planting with conservation furrow, CA flat sowing, permanent raised bed reshaping every year with residues, CA + conservation furrows). An implement was fabricated this year and was tested. The maize crop could be sown on the raised beds. The growth of the crop was better in conservation furrows, and raised bed as compared to flat sowing without conservation furrows. Since the rains and rainfall intensity was lower this year, the stability of the beds was tested with rainfall simulator and was observed that the beds were stable and the height of beds were not reduced.

2.5.7 Influence of different natural nitrification inhibitors under different moisture conservation in castor-maize based cropping system

An experiment was conducted at GRF in castor-maize cropping system with different moisture conservation practices viz. control, conservation furrow, and tank silt application; and natural nitrification inhibitors like neem cake coated urea, Karanjin cake coated urea and vitex leaf coated urea. These were compared with urea and 50% nitrogen through FYM + 50% N through urea. This year castor crop was sown. Among the three moisture conservation treatments, conservation furrow recorded 21 and 12% higher castor seed yield as compared to normal sowing and tank silt application. All the natural nitrification inhibitors recorded higher castor yield as compared to urea and 50% nitrogen through FYM + 50% N through urea and control. Vitex coated urea recorded 34, 25, 19 and 52% higher yields as compared to FYM + 50% N through urea, Karajin cake, neem cake coated urea, and urea alone respectively. GHG fluxes were recorded in different treatments. It was observed that CO_2 fluxes were not influenced by moisture conservation methods. Karanj cake coated, and neem cake coated urea treatments did not reduce the CO_2 emissions but the CO_2 fluxes were lower in urea as well as vitex coated urea. In general, methane absorption was observed in all the treatments. Higher N_2O fluxes were observed immediately after fertilizer application. Among natural nitrification inhibitors, vitex cake coated urea recorded lower N_2O fluxes and this was followed by neem cake coated urea.

2.5.8 Effect of biochar amendment on soil properties and growth of pigeonpea

Use of slow pyrolysis to convert crop residues into biochar is gaining importance as a more effective means of utilization/disposal of crop residues. Use of biochar as soil amendment for improving soil quality as well as crop productivity in the rainfed farming systems may be ecologically promising. Studies are underway at CRIDA on the possibility of converting the agroforestry residues (*Leucaena* and *Gliricidia* twigs) into biochar using the CRIDA biochar kiln and use of biochar from crop residues as an amendment in rainfed systems. Biochar can be produced at scales ranging from large industrial facilities down to small individual farm level ones. Small facilities are less complicated than larger units. A protocol was developed to produce biochar through use of low cost biochar kiln at community level or at individual farmer's level.

Steps to be followed for biochar production from different residues with CRIDA biochar kiln are: 1. Create a central vent in the kiln with pole, 2. Load the kiln with freshly chopped and sundried residue with gentle shaking, 3. Mount the kiln on raised stones, 4. Bottom ingnition with dried grasses for 3-4 minutes (carbon neutral), 5. Blue exhaust (350- 450˚C) is the target end stage, 6. Close the top vent with metal lid to develop backward pressure, 7. Transfer the kiln to flat ground to prevent primary air ingression through bottom vents, 8. Seal the edges of the top lid and circumferential bottom edges of the kiln, 9. Allow to cool off by heat loss, 10. Remove seal and unload the biochar, 11. Cure the biochar , 12. Grind, sieve and store the biochar.

CRIDA biochar kiln was employed at farm level to study the conversion efficiency of *Gliricidia* and *Leucaena* twig residues at different loading rates and partial combustion periods. The highest conversion efficiency of 32.0 and 21.0% was obtained at a loading rate of 39.0 and 38.0 kg/kiln and a partial combustion period of 27.0 and 30.0 minutes for *Gliricidia* and *Leucaena* twigs, respectively. Order of nutrient recovery in different agroforestry biochars in terms of total N was *Leucaena* twig (20.9 %) < *Pongamia* shell (24.9 %) < *Eucalyptus* bark (28.5 %) < *Eucalyptus* twig (35.7 %) < *Gliricidia* twig (38.1 %); Total P was *Eucalyptus* bark (46.2 %) < *Leucaena* twig (51.8 %) < *Eucalyptus* twig (67.4 %) < *Gliricidia* twig (68.4 %) = *Pongamia* shell (68.4 %) and Total K was *Leucaena* twig (24.2 %) < *Pongamia* shell (29.1 %) < *Eucalyptus* twig (31.7 %) < *Gliricidia* twig (35.1 %) < *Eucalyptus* bark (35.7 %). Total carbon in biochar was 31.4, 43.0, 46.0, 48.0 and 62.2 % for *Eucalyptus* bark, *Gliricidia* twig, *Leucaena* twig, *Eucalyptus* twig and *Pongamia* shell, respectively.

Biochar from crop residues can play a major role in improving the resilience of soil towards climate change by way of higher soil moisture retention and improving soil quality for improving the crop performance in rainfed regions. A long-term experiment was initiated during 2010 with pigeonpea (PRG 158) as test crop at Hayatnagar Research Farm to investigate the effect of different biochars applied at different schedules (every and alternate year application) on pigeonpea (PRG 158) performance and soil quality. During fifth

Biochar from different agroforestry residues

year of the study, biochar plots marked for every year and alternate year application schedules were not amended. Residual biochar treatments were 0 t/ha + RDF, 3 t/ha + RDF and 6 t/ha + RDF for three biochar sources (castor, cotton and pigeonpea stalk biochar). Recommended dose of fertilizers (RDF) (20-50-0 kg N, P_2O_5, K_2O /ha) was applied uniformly in all the treatments except in control (without biochar and fertilizer). Broadcast method of biochar application was adopted for incorporation of biochar in surface soil. Biochar with native soil (carrier) mix was broadcast with the onset of southwest monsoon after primary soil preparation and incorporated to a depth of 10-15 cm using hand hoe. Incorporation can be done with implements such as hand hoes, spades, animal draft plows, harrows, disking, rotary hoes or chisel tillage depending on the size of field and scale of the farming operations. Soil moisture at field capacity (1/3 bars) and permanent wilting point (15 bars) was measured using pressure plate apparatus.

During 2014, sowing of pigeonpea (PRG 158) was delayed due to late onset of rains. Subsequently, the crop failed due to severe water stress. Soil analysis revealed that the soil available N ranged from 100 to 151 kg/ha; soil available P from 11.1 to 15.8 kg/ha; and soil available K from 130 to 330 kg/ha with treatments. Alternate year application of pigeonpea stalk biochar @ 6 t/ha with RDF resulted in higher soil available N of 151 kg/ha and soil available P of 15.8 kg/ha which was on par with every year application of pigeonpea stalk biochar @ 3 t/ha with RDF. In case of soil available K, every year application of castor stalk biochar @ 6 t/ha with RDF was superior with mean of 330 kg/ha. In the present study, biochar source and application schedules (every year and alternate year) influenced the soil organic carbon content. Results revealed that every year application of biochar had positive influence on soil organic carbon in the surface soil layer compared to alternate year biochar application and no biochar application. In every year biochar application schedule, the soil organic carbon content varied from 3.1 to 8.2 g/kg. Higher soil organic carbon content was observed under pigeonpea stalk biochar @ 6 t/ha with RDF (8.2 g/kg) followed by cotton stalk biochar @ 6 t/ha with RDF (7.1 g/kg). In case of alternate year application

Biochar incorporated into surface soil

schedule, soil organic carbon content varied from 3.0 to 5.1 g/kg with highest being recorded under alternate year application of pigeonpea stalk biochar @ 6 t/ha with RDF (5.1 g/kg). Soil organic carbon content was lowest under RDF alone (2.2 g/kg) and control (1.1 g/kg) compared to different biochar amended plots.

The cost of production of biochar from four different crop residues were calculated on the basis of cost of kiln, maintenance charge per kiln, family labour, crop residue load per kiln and its conversion efficiency into biochar. All aspects from on-farm crop residue preparation, handling and operation of the kiln, pounding, sieving and packing of biochar were considered for cost estimation. On an average, the production cost of one kg of biochar from maize, castor, cotton and pigeonpea stalk was Rs. 17.0, 14.0, 17.0 and 10.0, respectively. The cost of biochar production is affected by several factors viz. availability of family labour, quantity of on-farm availability of surplus crop residue, demand for biochar and weather conditions to run biochar kiln.

2.6 Alternate land use systems

2.6.1 Integrated nutrients and bio-inputs as components of horticultural crop production in dryland regions

In order to work out the suitability or other wise of bio-inputs in the traditional fruit growing regions, inorganic and organic sources of nutrients along with or without bio-inputs were applied to custard apple and guava at Gunegal Research Farm during 2010-14. Twenty-eight year old guava and custard

apple plantations were selected to work out efficient integrated nutrient management practices and bioinputs for optimum growth and fruit yields. Separate trials were initiated at on-farm and on station in custard apple, guava, citrus and mango. In a study on the effect of recommended doses of chemical fertilizers and bioinputs on branching pattern and fruit yield in guava cv Allahabad Safeda, application of 30 kg FYM+RDF was found to impart more secondaries and tertiaries yielding more number of fruits and yield per plant followed by 15 kg FYM+½ RDF. Combinations of all organic and bioinputs imparted significantly more number of tertiaries thereby increasing the fruit yields. The yields in general were drastically reduced during 2011, 2012 and 2014 due to continuous drought spell during sigmoid fruit growth stage when compared to 2010 and 2013 in which there was more than 840 mm rainfall. The no. of fruits and fruit weight/plant declined among different treatments during 2011 and 2012 and 2014 in which it rained less with dry spells when compared to 2010 and 2013. Fruit size was drastically reduced and many unmarketable small fruits dried up on the trees due to prolonged dry spell during the fruit development. Early flush, flowering and fruit set were observed with the soil inoculation of different microbes in the experimental orchard crops like guava, custard apple, mango and citrus when compared to untreated controls during normal rainfall years i.e. 2010 and 2013. However, their effects were limited under less or erratic rainfall distribution years during fruit development stages of 2011, 2012 and 2014.

In case of guava, the yields in all the treatments were drastically reduced due to less rainfall and acute drought situation during fruit development in 2014. Among all the years, the yield per tree and the no of fruits were higher during 2013 compared to other years irrespective of different treatments. Among the treatments in 2013 highest yield was recorded by the treatment RDF+AZOS (102.6 kg) followed by RDF+AZOT (87.3 kg) RDF (81.9 kg). During this year, RDF+PSB gave highest yield per plant (72.13 kg) followed by RDF+ TRICHO (50.05 kg), RDF +AZOT (34.63 kg) and lowest yield under control (11.2 kg).

During 2014 the soil samples were analyzed for macro- and micro-nutrients in guava and custard apple orchards, the results indicated that nitrogen ranged from very high to high in all the treatments including control. Phosphorus was in medium range in all the treatments. Micro nutrients were in the normal range. PSB or *Trichoderma* when combined with ½ RDF increased available phosphorus to a greater extent.

In custard apple, the yields in all the treatments were drastically reduced during 2014 due to less rainfall. Custard apple responded very well to the treatments during 2013. Number of fruits and yield per tree were significantly higher for all the treatments when compared to control. Among treatments, recommended dose of fertilizer along with *Azospirilum* (RDF +AZOS) gave the maximum number of fruits (56) and yield per tree (12 kg/tree). RDF +PSB contributed for 11.4 kg/tree with 57 fruits, followed by 100 kg FYM+AZOT with 10.6 kg/tree, 150 kg FYM with 9.3 kg/tree.

2.6.2 Developing supplemental irrigation schedules for sustainable vegetable production in dryland regions

An on-farm experiment was conducted to study the effect of drip irrigation and mulching on crop growth, yield and water use efficiency (WUE) in villages Darmanaguda of yacharam mandal, Kapapahad and kongarakalan villages of Ibrahimpatanam and also at GRF CRIDA. During *Kharif* 2013-14 experiments were conducted in tomato, brinjal, bhendi and chilli, and during early summer in ridge gourd, bitter gourd and cucumber. The treatments imposed were drip with black plastic mulching, drip alone, drip and black plastic mulching with 50% irrigation. In tomato, polythene mulching remarkably improved the plant biomass, earliness and registered 94.7% higher dry matter over unmulched control. Maximum fruit yield (3.7 kg/plant) was recorded with polythene mulch. Plastic mulches gave significant weed control, however, the highest weed reduction (89% over control) was observed with black polythene mulch. Maximum WUE of 49.6 kg/ha-mm was obtained with black plastic mulching + 50% irrigation.

Field view of bhendi crop response to plastic mulching and drip irrigation

Field view of plastic mulching and drip irrigation treatments in village Kapapahad

2.6.3 National network on integrated development of pongamia

Biofuels are prioritized by planning commission of India, and Pongamia is one of the promising species for the production of biofuels in wastelands. The candidate plus trees (CPTs) of pongamia were selected and seeds from CPTs were collected during 2004-05 in germplasm survey. The collected germplasm was then screened on the basis of nursery performance and oil content in seed, and promising accessions selected are being evaluated in progeny, zonal and national trials at HRF since 2005. Agro-techniques for raising successful plantation of pongamia sole plantation and under agroforestry conditions have been standardized.

In total, 144 accessions were collected during 2005-2014 & have been cryopreserved at NBPGR, which includes 2 collections from Rangareddy district during reporting period. Three germplasm evaluation trials (progeny, national network and zonal trial) were stablished in 2005. Different accessions taking top three positions in the trials in different years since 2010 indicated that the stabilization of yield has not yet reached in all the three trials (Tables 2.13, 2.14 and 2.15).

Table 2.13: Top three accessions in progeny trial since 2010

May-2010	May-2011	May-2012	May-2013	May-2014
Acc-22 (1.07)	Acc-33 (0.56)	Acc-13 (0.54)	Acc-16 (3.32)	Acc-14 (0.54)
Acc-16 (0.53)	Acc-16 (0.32)	Acc-8 (0.39)	Acc-13 (2.32)	Acc-13 (0.51)
Acc-11 (0.45)	Acc-23 (0.24)	Acc-14 (0.32)	Acc-7 (2.144)	Acc-10 (0.48)

Figures in parentheses are t/ha

Table 2.14: Top three accessions in national network trial since 2010

May-2010	May-2011	May-2012	May-2013	May-2014
RAK-22 (0.18)	RAK-22 (0.22)	RAK-22 (0.34)	TNMP-4 (2.03)	TNMP-2 (0.43)
RAK-103 (0.06)	RAK-103 (0.09)	TNMP-2 (0.12)	TNMP-1 (1.75)	TNMP-4 (0.42)
TNMP-4 (0.04)	TNMP-4 (0.05)	TNMP-4 (0.07)	RAK-22 (0.89)	TNMP-1 (0.42)

Figures in parentheses are t/ha

Table 2.15: Top three accessions in zonal trial since 2010

May-2010	May-2011	May-2012	May-2013	May-2014
Acc-14 (2.82)	Acc-30 (0.47)	TNMP-9 (0.56)	TNMP-9 (1.29)	TNMP-23 (0.60)
TNMP-23 (0.68)	Acc-14 (0.32)	TNMP-23 (0.23)	TNMP-6 (1.08)	TNMP-6 (0.45)
TNMP-6 (0.57)	TNMP-9 (0.19)	TNMP-20 (0.11)	TNMP-20 (0.91)	TNMP-3 (0.33)

Figures in parentheses are t/ha

Table 2.16: Recommended genotypes for registration

Name of TBOs	Name of trial	Recommended genotype(s)	Featuring remarks
Pongamia Trials	National trial-I	TNMP-2, TNMP-4 and TNMP-1	On the basis of earliness, growth parameters & pest resistance
	Progeny trial	Acc-14, Acc-13 and Acc-10	
	Zonal trial	TNMP- 23, TNMP- 6 and TNMP-3	

On the basis of 9 years of evaluation studies in progeny, national and zonal trials, depending on earliness, growth parameters & pest resistance the following genotypes are recommended for registration or for large scale plantations (Table 2.16).

A new national network trial was established in 2013 with 7 best elite accessions selected from across the locations of India. Year-wise performance is being observed on the basis of growth parameters, seed yield and oil content in kernel (Table 2.17)

The spacing trial established in 2004 continued during this year. No significant difference was noticed in seed yield of pongamia due to different spacings (5 m x 5 m, 6 m x 4 m, 6 m x 6 m and 8 m x 6 m). Average kernel yield in grafted plants at the end of 10th year (May 2014) ranged from 0.82 to 2.7 kg/plant; the average kernel yield of seedling originated plants ranged from 0.19 to 3.14 kg/plant. Observations on infestation of insect-pests and diseases are given below:

Infestation of insect-pests: Name of insect-pests - Leaf galls, leaf roller & stem borer; Nature of damage and parts affected- Leaf galls (production of green and polyploid galls with pedicel on leaves); Leaf roller (rolling and defoliation of leaves), Stem borer (affects the stem); Time of infestation- throughout the year; Effect on growth & yield- no effect on growth and yield; Control measures- none of the pongamia plants were damaged beyond economic threshold level, hence no control measures were taken.

Infestation of diseases: Name of the disease- Leaf spot; Nature of damage and parts affected- white patches on leaves; Time of infestation- October to December; Effect on growth & yield- no serious effect; Control measures – Nil

Table 2.17: Growth of different genotypes in national network trial-II

Genotype	Plant height (cm)	Collar diameter (cm)
CARI Port Blair 589037	77.6	1.6
RHRAK-47	81.0	1.3
RHRAK-50	78.0	1.967
CRIDA AC-16	91.0	2.333
CRIDA AC-13	90.3	2.333
Bijapur PT-01	93.0	1.667
Bijapur PT-02	89.0	1.467

Progeny trial

Zonal trial

National trial

2.7 Livestock management

2.7.1 Developing organic meat production system for promoting sustainable animal husbandry, enhancing income to producers and health benefits to consumers

Many consumers are seeking alternatives to conventionally produced meat. Organically produced meat is one such an alternative to conventionally produced meat and the demand for this 'organic meat' is sharply increasing day by day in both developed and developing countries. India need to tap this opportunity for promoting business prospects in Animal Husbandry sector. Hence, a project was undertaken to design model organic sheep meat production system and to study its viability and economics. Nine Deccani ewes and one ram and six Deccani lambs (two ram lambs and four ewe lambs) were reared and fed with organically produced green fodder and concentrate mixture. Fertility and lambing percent was recorded in ewes, whereas birth weight and live weight gain were recorded in offsprings. All the ewes conceived and 100% lambing rate was observed in organically fed ewes. Six ram lambs and 3 ewe lambs were added to the flock through lambing of organically reared sheep. A mean birth weight of 2.10±0.16 kg was observed in lambs with higher mean birth weight in males (2.3±0.18 kg) than females (1.8±0.27 kg).

2.7.2 Development of inventory of technologies for livestock production for counteracting seasonal stress in rainfed areas

In rainfed areas, livestock rearers face tremendous feed and fodder shortage which becomes acute during summer or drought years. Most of farmers keep local animals, which can survive in harsh

environment with low inputs where grazing is the dominant livestock production system in drylands. However, the performance of livestock gets affected by seasonality and climatic extremes which need to be addressed through low cost technologies. A study was undertaken to critically evaluate and document existing livestock production system in the rainfed areas and suggest suitable measures. Survey was carried out using pre-tested questionnaire in selected districts of Maharashtra and Karnataka (Solapur and Bijapur). Collection and analysis of feed samples from farmers' fields in selected districts was done to understand the production dynamics in dryland areas.

The survey work suggested that:

- Land holding pattern among livestock rearers indicate that most of them belong to small and marginal farmers.
- Average age of farming community engaged in livestock rearing is very high (>45 yrs) suggesting that youths are not finding it lucrative.
- About 20-25% of farm produce is used by livestock; however, more than 60% is sold outside by livestock rearing farmers.
- Large land holders are keeping large ruminants, while small land holders prefer small ruminants and large ruminants are acting as status symbol also.
- Backyard fodder production is gaining momentum by small farmers and about 5% of them are practicing it.
- In the selected areas of dryland region of Andhra Pradesh, Maharashtra and Karnataka, diversification using livestock improved livelihood option and profitability by 25-50% of the farmers having 1-1.5 ha land.
- In the areas with chronic dry spells, prefer small ruminants using agro-waste as major feeding resource.
- Health related analysis suggested special attention to small ruminants during monsoon season.
- Over 200 feed samples were collected and analyzed. Vit. E, Se and Zn were found to contribute better to adaptive capacity in sheep towards heat stress.

Farmers participating in the survey work in village Kaggod, Bijapur, Karnataka

Backyard fodder production in village Kaggod, Bijapur, Karnataka

Polyherbal preparations were evaluated to reduce greenhouse gas (GHG) emission from ruminants. All the polyherbal supplemented groups were significantly ($p<0.05$) efficient in reducing methane emission. In control group, methane emission (L/kg) of digestible dry matter intake (DDMI) was 66.25 litres. However, a significant reduction by 17.35% was recorded in Ruchamax supplemented group (54.75 L), 12.33% in AV/LMP/10 supplemented group (a coded herbal lean meat product) (58.21 L) and 8.33% in AV/AGP/10 (a coded natural growth promoter product) supplemented group (60.73 L).

An investigation was carried out to study the effect of sunshine duration on anti-oxidant enzymes and finding suitable nutrient supplement to combat the adverse effect, if any. Twenty four Deccani females were divided randomly into four groups of similar overall body weight viz., Control (C), T1: 3 ml of 10% zinc sulphate, T2: 1 ml of 0.1% selenium and T3: 60 mg Vitamin E daily and reared under semi-

intensive conditions at HRF. Superior body weight was achieved in supplemented groups than control which was explained by significantly ($p<0.05$) less rectal temperature, pulse rate and respiratory rate in supplemented groups. In SS-wise analysis (group-I: 120 to 160 h, group-II: 160 to 200 h and group-III; More than 200 h), performance of supplemented group of animals was superior to that of control animals in terms of all physical (20% vs 30% increase in body weight), physiological, biochemical and molecular parameters. Bio-molecular analysis using catalase (51% vs 150%) and lipid peroxidase enzymes (15% vs 30%) suggested superior adaption of supplemented sheep to environmental stress (Fig. 2.20). Hence, supplementing sheep with anti-oxidants can build up thermo-tolerance in small ruminants and may help in mitigating the seasonal stress.

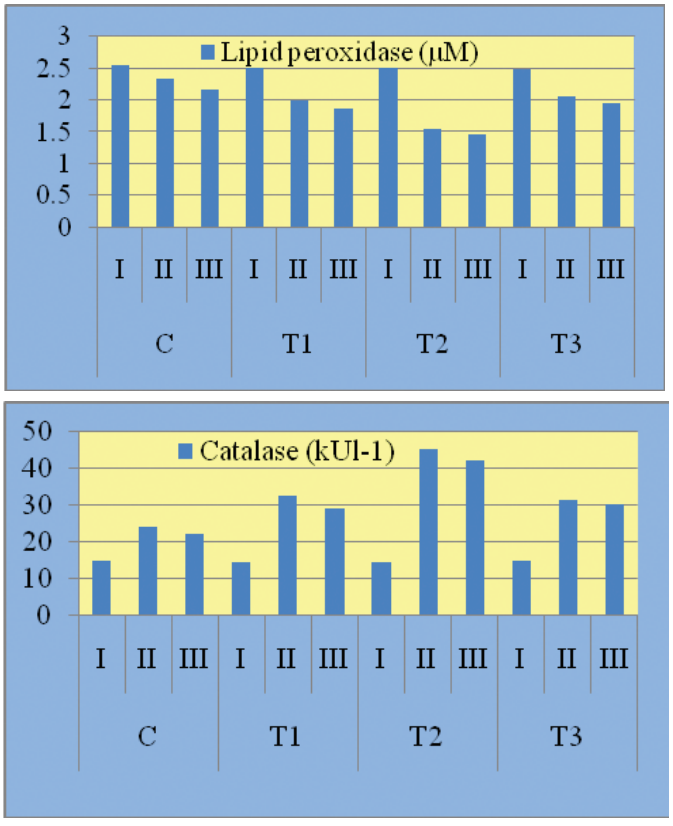


Fig. 2.20: Levels of anti-oxidative enzymes under different monthly sunshine classes in various groups of Deccani female sheep (n=24). C: Control; T1: 3 ml of 10% zinc sulphate, T2: 1 ml of 0.1% selenium and T3: 60 mg Vitamin E daily; I: 120 to 160 h, group-II: 160 to 200 h and group-III; More than 200 h

2.8 Energy management

2.8.1 Development of low to medium scale propelled harvesting equipment for sorghum and maize

The major objective of this project is to develop a self propelled or tractor mounted mini harvester for harvesting the Maize, Sorghum and other fodder crops considering the fact that the self propelled/ tractor operated low cost harvesters are much useful for small farm mechanization with a special focus on rainfed farming.

Parameters considered for the development of harvester:

Small farm holdings and low fabrication cost are the main parameters considered for the development of tractor mounted harvester. As the cost of large scale harvesters is a major hurdle for small and marginal farmers, a mini harvester which can cut the crop stalk and forms a windrow was designed and developed at CRIDA Research workshop.

Description

Since the earlier model of mini tractor mounted harvested could not perform well in the field, it was planned to mount the same harvester with modifications on 35 h.p. tractor. The hydraulic lifting mechanism was modified by connecting the front lifting attachment to the three point hitch links through rope and pulley system which improved the field movement of the harvester with easy lifting adjustability. It consists of two harvesting rows with a rotary cutting discs in each row which can cut the stalks as they enter into the cutting zone which was also modified for flexible feeding of stalks. A 3-tier conveying system carries the cut stalks towards a horizontal conveying belt to form the windrows in the field. Speed of the conveying mechanism is increased by 30 % for fast movement of the cut stems. The drive from the P.T.O shaft is transferred to the harvester gear box through a horizontal shaft fixed underneath the tractor. Power from the gear box is distributed to different moving parts of the harvester through the chain and sprocket mechanism.

Field test results

The modified harvester was tested for its efficacy in

Tractor front mounted harvester

Field testing of harvester

Maize field at HRF NICRA complex (Fig.). It is found that the efficiency of the harvester was increased by 50 % when compared to the mini tractor mounted harvester. About 90 % stalks were cut properly with 85 % conveying efficiency. However, some more long term tests are needed to go further in finalizing the design.

2.8.2. Development of raised/permanent bed planter

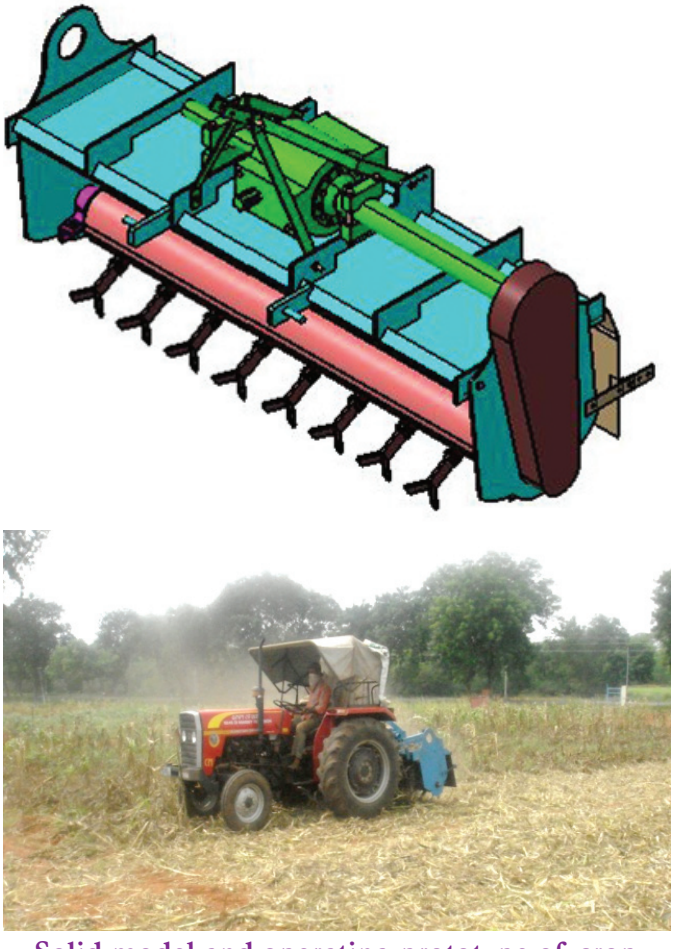
Raised bed/Permanent bed planter which was developed during last year was refined by adjusting the bottom of the bed maker and its driving mechanism for accurate seed and fertilizer placement (Fig). The same was tested at HRF farm for Redgram, Castor, Maize , Cotton and Sorghum crops. The beds with 100 cm width were made using the planter on which the seed and fertilizer was placed simultaneously for some treatments. The beds were initially made during the first pass and the seed and fertilizer were placed in another tractor pass for some treatments to test the germination percentage. Proper pre germination herbicides are used to control the weeds. How ever there was no significant difference on the part of germination percentage which was recorded around 75 % in cotton, 90 % in Redgram (Fig.), 85 % in sorghum, 88 % in Maize and 80 % in castor % during the last year. Top dressing was also done using the same implement using zero till shovels and by detaching the bed maker (Fig.). It is observed that, in all the cases the germination percentage of the crops grown with raised bed planter was 15-22 % higher than the crops grown with conventional seed drill on flat surface.

Tractor drawn Raised/permanent bed planter Red gram crop on raised beds

Top dressing on raised beds

2.8.3 Development of machinery for handling and utilization of crop residues of maize and cotton

The previous year developed crop stalk shredder was tested under field conditions to shred the maize stalk after cobs harvesting. The initial cutting blades rotor speed setting is 850 rpm, which found to be insufficient to shred the whole stalk into smaller length pieces. So, the rotor speed was increased to 1250 rpm for this year filed tests. The solid model diagram of shredder and operating proto type was given in fig and salient findings include : the highest crop residue surface cover recorded under zero till plot was 51% before sowing of *kharif* maize crop in 2014; the soil surface coverage achieved with the machine was 90% at maize stalk production of 3187 kg/ha(dry basis) with 69% (wb) stalk moisture content; and the shredded biomass pieces length ranged from 20 to 25cm against the average stalk height of 125cm, leaving crop stubbles in the height range of 5 - 10 cm.



Solid model and operating prototype of crop stalk shredder

2.8.4 Optimization of design parameters for development of a Precision Pneumatic Seed Planter

The majority of planting machines marketed in developed country belongs to this category. These seeders have a metering plate with holes on a predetermined radius and vacuum is applied to these metering holes by means of exhaust blower. As the plate / rotor rotate, the vacuum applied to the metering cells enables them to pick up seeds from the seed chamber. Precision vacuum seeders are more advantages over the mechanical seeders, better working quality, more precise seed rates with lower rate of seed damage, better control and adjustment broader spectrum of applicability. Hence, a precision pneumatic seed metering mechanism was developed and tested under laboratory simulated conditions for cotton and okra crops.

Key parts of developed precision pneumatic seed metering unit and functions

The newly developed seed metering unit consisted of two main parts (i) seed hopper (180x90x90 mm size) with a outlet tube (φ 27 mm) fixed at front lower portion to allow smooth flow of seeds into vacuum chamber of rotor and (ii) seed metering unit. The seed inlet for metering unit was positioned at the bottom of removable cover leading to vacuum portion of rotor. The main shield of pneumatic seed pick up device was made into circular shape (250 mm inner diameter with 70 mm in depth) fixed to square shaped 5 mm thick mild steel plate with pedestal bearing at the centre. A circular nylon roller of 248 mm diameter with a 100 mm uniform annular chamber off set much of the portion towards the periphery was fitted inside the shield. Shaft was fitted to the roller, which pass through centre of main shield, supported by pedestal bearing to provide required drive. A rectangular opening of 30x30 mm provided at lower portion of cover plate allows the seed to flow in to vacuum chamber of the rotor. A 20x10 mm slot is cut on outer side of the shield ring (horizontal axis with respect to positioning of mechanism) to which a 30 mm diameter pipe piece welded to connect with the blower through flexible duct pipe to create vacuum to pick up seed and a

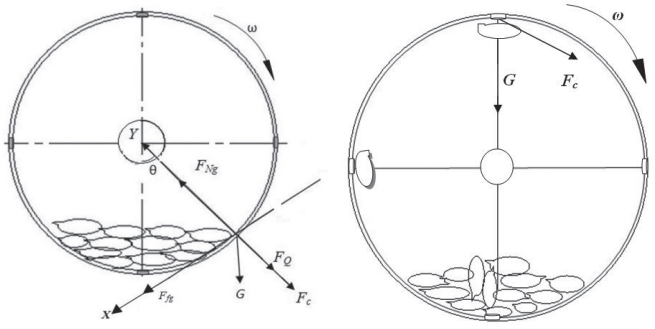
10x10mm notch (y axis) for vacuum release from chamber which aid in seed drop.

The seed rotor (248mm φ and 70mm thick) was fabricated from of a nylon block and have two functions. The rotor has a mini seed chamber and pick up and drop metered quantity of seeds with 4 equidistant cylindrical holes designed as for plant spacing. On the outer periphery of the seed rotor, a 10 mm wide and 10 mm deep slot was made to create vacuum in the chamber and holes were drilled axially over the slot. The diameter of the seed cell was optimized for different pressures and forward speeds of planter in operation. In this design due to good control over the vacuum, the seeds exposed to cells and move when the seed rotor starts to rotate and are released when the gravitational force of seed due to its mass exceeds the vacuum pressure in the chamber due to orifice provided at the top portion of shield.

The seeds are stirred as for the movement of the seed rotor, and then were picked up by the cell provided on the inner periphery of the seed rotor, held and transported under the influence of negative pressure up to top portion. At the top, the negative pressure drops suddenly in the chamber due to expose to atmosphere through orifice provided on the shield ring (which acts as cut off device), the seed falls down due to gravity into outlet port which was connected to the seed tube. The various forces acting on the seed while metering by rotor were diagrammatically depicted in Fig. 2.21.

Significant achievements

- Cotton seed geometrical properties such as length, width, projected area, sphericity were measured using flat bed scanner - MATLAB analysis software and compared with the results of conventional measurements. Good correlation was found in length and width of seed that measured using conventional measurement and image analysis technique and followed a linear relation with regression coefficients 0.889, 0.932 and 0.914 for length and 0.919, 0.924 and 0.945 for width of seed for hybrid1(H1), hybrid2(H2) and hybrid3(H3) respectively.



Pick up Stage

Immediately after release from cell

Fig. 2.21: Forces acting on the seed during metering by rotor

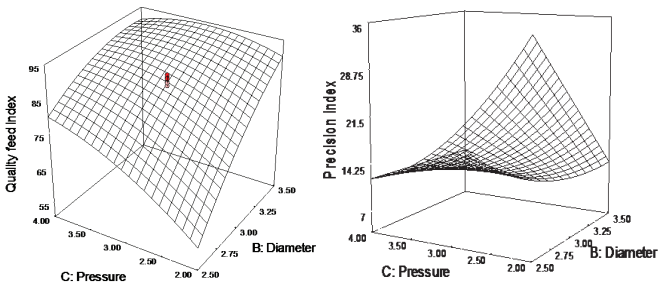
- In conventional method, the average lengths of cotton seeds were found to be 9.086, 9.197 and 8.263 mm, whereas in image analysis the same were 8.902, 9.038 and 8.095 mm for H1,H2 and H3 respectively. The mean reduction in length of cotton seed in image processing technique was found to be 2.07 percent.
- The angle of repose is 39.195, 35.363 and 38.569º for H1, H2 and H3 respectively at safe storage moisture content. The coefficient of static friction for the three varieties of cotton seeds against three material surfaces i.e mild steel, card board and nylon sheet surfaces are closer, indicating that the friction property is not affected very much by the hybrid.
- The pneumatic seed metering mechanism was tested setting boundary conditions for major variables; machine forward speed 1.5 - 5.5kmph, vacuum pressure 1.5 - 5.0 kPa and cell size 2 - 4mm. A rotatable central composite design (CCD) RSM (response surface method) was used and analyzed the data with design expert software.
- The results show that, the pneumatic seed metering mechanism operated at 3.3kmph forward speed, 3.5 mm cell diameter and 4 kPa negative pressure gave a highly satisfactory result in terms of the precision index (3.58), as the quality of seed feeding into cell is good and as well as low multiple seed pickups at these test conditions. The next best bet values for these variables are 4.5kmph, 3.5mm and 2.0 kPa respectively for rotor speed, cell size and air flow pressure with precision index 6.72. These results explained that,

the selection of boundary conditions in the design of pneumatic metering mechanism is good for independent variables and their step values.

- A polynomial function with transformed dependent variable (precision index) for more precise prediction was developed using replicated test results for the precision index model and found significant at 99 percent level.

$$\sqrt{I_{prc}} = 13.49 + 4.67D - 6.00S - 6.09P + 5.57SP + 4.38P^2$$

Where, D, S and P are the coded values for cell diameter in seed rotor, speed of rotor and negative pressure respectively. Graphical views of some response surfaces generated using polynomial functions are depicted in Fig. 2.22.



Quality of feed index constant) Precision index

Fig. 2.22: Quality of feed index and precision index as a function of cell diameter and vacuum pressure (rotor peripheral speed constant)

2.8.5 Energy use efficiency of conservation agricultural practices in pigeonpea - castor system

Energy use with different tillage operations and crop residue levels in pigeonpea and castor rotation were compared. Globally, energy analysis has been done to compare various variables. Similar comparative studies were done in conservation systems (minimum tillage, zero tillage) and conventional systems. However, the differential energy coefficients reported in the literature, can affect the conclusions derived from these studies when differences among treatments are less. Different tillage systems significantly influenced the energy inputs whereas residue levels did not differ significantly. Total energy inputs averaged across castor and pigeonpea was 8.5, 7.5 and 5.9 GJ ha^{-1} in conventional tillage (CT), reduced tillage (RT) and zero tillage (ZT), respectively. CT recorded 30 and 12% higher energy input over zero and reduced tillage, respectively. Higher energy input in CT was due to increased number and depth of tillage operations which accounted for higher machinery use and increased fossil fuel consumption. Besides fossil fuel consumption, intercultural operations and manual weeding also contributed to higher energy use in CT. Conventional tillage recorded 12% higher direct energy than indirect energy whereas, RT and ZT recorded 41 and 72% higher indirect energy than CT, respectively. The fossil fuel share in CT (34%) and RT (26%) was higher whereas in zero tillage it was only 16%. These values are lower as compared to other studies due to use of CRIDA precision planter which performed sowing, fertilizer application and spray of pre-emergence herbicide simultaneously in a single operation. The decrease in number of tillage operations saved 32 and 68% fossil fuel in RT and ZT, respectively as compared to CT. The share of fertilisers was highest in ZT (34%) but in CT and RT the fossil fuel share of energy was followed by fertilizers. Energy use of fossil fuel consumption and fertilizers were followed by insecticide application. Herbicides share was 10 and 13% in RT and ZT, respectively. The share of fertilizers and insecticides energy in different tillage systems was similar in all the treatments within the crop as in different studies. This was purposefully kept similar to study the influence of tillage systems and residue levels on the out- put of the crop. However, the higher fossil energy use in pigeonpea and manual labor use in castor was due to differential harvesting and threshing methods. But the detailed analysis revealed that major human energy is used in harvesting of castor. The challenging issue for the use of pluckers in castor harvesting is that the varieties available in castor do not mature at the same time hence the use of machine cuts the plant in the first round and may also pluck immature capsules leading to yield reduction by around 35–40%. Hence use of castor harvester may become reasonable on the condition of harvester or crop variety improvements. Renewable energy share to total energy input were 22, 14, and 10% in CT, RT and ZT, respectively. The higher renewable energy use in CT and RT is due to manual weeding and intercultural operations. Whereas,

in zero tillage herbicides were used for weed control. In both the crops when averaged across residue treatments, CT recorded higher non renewable energy as compared to ZT. This differential non renewable energy consumption in both the crops was due to use of fossil fuel for land preparation and sowing

Grain Energy Output (EOg) was directly related to the yield, hence the highest energy output was observed in the treatment with highest yield. It was significantly influenced by the crop, tillage practices, height of harvested residues and year. This variation in yield was due to difference in both quantity and distribution of rainfall in different years during the crop growth period. Averaged across years, tillage and residue level, castor recorded highest EOg than pigeonpea. This differential EOg in different crops is due to difference in the yield. Energy out- put was significantly ($P < 0.05$) influenced by tillage practices in both the crops. In pigeonpea and castor highest EOg was observed in CT (29.77 GJ ha−1, 50.69 GJ ha^{-1}, respectively), followed by RT (28.99 GJ ha^{-1}, 49.37 GJ ha^{-1}, respectively) and ZT (24.08 GJ ha^{-1}, 40.61 GJ ha^{-1}, respectively). CT and RT were on par with each other but were significantly higher than ZT in both the crops. Different residue heights have significant ($P < 0.05$) influence on EOg. Interaction between tillage and anchored residue height were non significant in pigeonpea but significant in castor. In castor 30 cm anchored residue (53.50 GJ ha^{-1}) had maximum EOg and was on par with 10 cm (51.71 GJ ha^{-1}) and 0 cm (46.84 GJ ha^{-1}) anchored residues in CT, 10 (51.12 GJ ha^{-1}) and 30 cm (50.95 GJ ha^{-1}) anchored residues in RT. But this was significantly superior to RT 0 cm and all anchored residue heights in ZT. 6 and 14% higher output was observed in ZT 10 cm anchored residue over ZT 0 and ZT 30 cm anchored residue. Furthermore, the energy output in 0 and 30 cm were statistically on par with each other.

Similar results were observed in total energy output (EOt), which included energy output of grain and crop residue harvested and removed from the field. Crop residue left over in the field was not included in calculation of total energy output since they were returned to the land at the end of crop season. Energy use efficiency (EUE) was influenced by different tillage treatments and anchored residue height in both pigeonpea and castor. Averaged over treatments castor recorded higher EUE (6.16 EUEg and 9.43 EUEt) as compared to pigeonpea (4.07 EUEg and 8.11 EUEt). ZT (4.34, 6.59 in pigeonpea and castor, respectively) and RT (4.17, 6.22 in pigeonpea and castor, respectively) recorded significantly higher EUEg than CT but in RT and ZT they were statistically similar in both the crops. Similar observations were recorded in EUEt. Irrespective of tillage treatments anchored residue heights influenced the EUE significantly in both the crops. In general, with increase in anchored residue height EUEg and EUEt also increased. Anchored residue height of 30 and 10 cm registered highest EUEg and EUEt and were on par with each other but they were statistically superior to 0 cm anchored residue. In pigeonpea no significant interaction was observed between tillage and residue heights in both EUEg and EUEt, but in castor the interaction was significant. In pigeonpea maximum EUEg was observed in ZT 10 cm anchored residue and this was significantly higher than all the residue heights and tillage treatments. In castor significant interaction in tillage and residue height was observed and it is of the order 10 cm anchored residue height in ZT>RT 30cm>ZT 0cm> RT 10cm>ZT30cm.

In general, Grain Net Energy gain (NEg), Total Net Energy gain (NEt), Grain Energy Productivity (EPg) and Total Energy Productiv- ity (EPt) was higher in castor. In both the crops NEg and NEt was significantly influenced by the tillage treatments. CT has higher NEg and NEt and was significantly superior to ZT in both the crops and RT in pigeonpea but in castor CT and RT were on par with each other. Different anchored residue height significantly influenced NEg and NEt in both the crops. Highest NEg and NEt was observed in 30 and 10 cm anchored residue and these were signifi- cantly higher than 0 cm in both the crops. In pigeonpea there was no significant interaction between tillage and residue height, whereas in castor significant interaction between tillage and residue height was observed. ZT 10 cm anchored residue recorded highest NEg and this was followed by ZT 30 cm. Castor recorded higher grain energy productivity (EPg) and total energy productivity (EPt) as compared

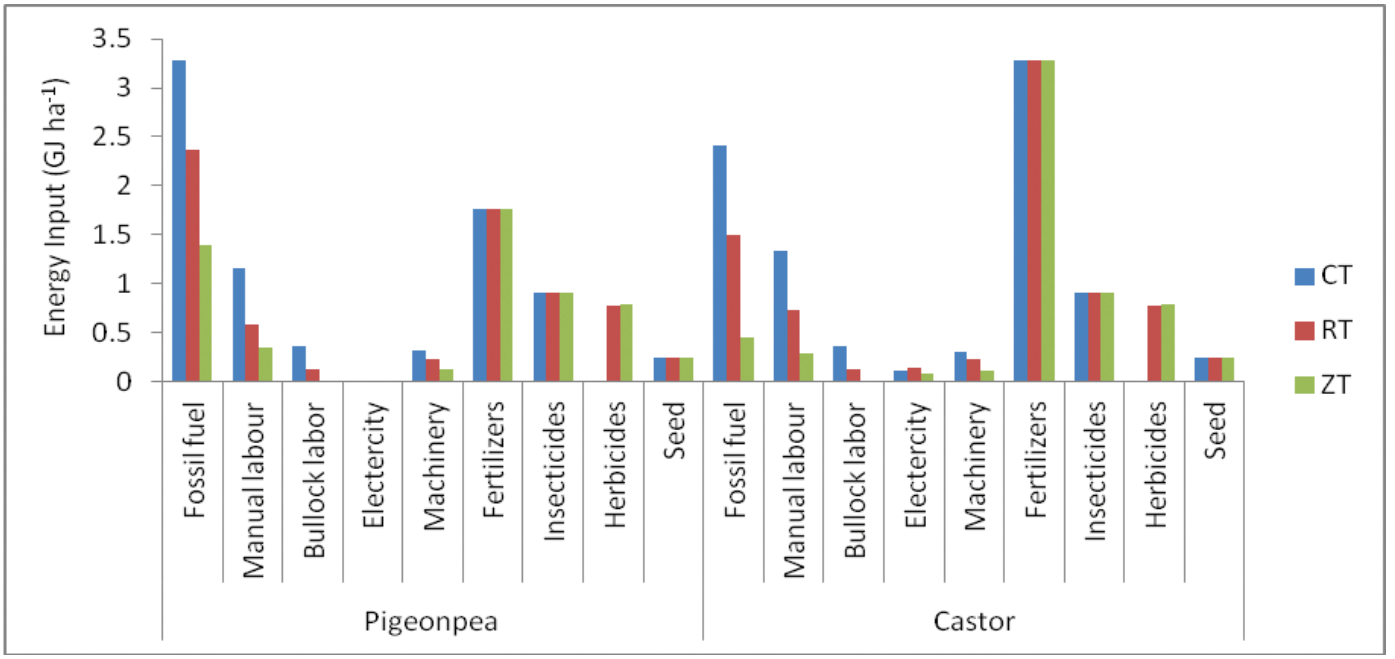


Fig. 2.23: Source-wise energy consumption (GJ ha-1) in different tillage treatments in pigeonpea-castor cropping systems (CT – Conventional Tillage, RT – Reduced Tillage, ZT – Zero Tillage)

to pigeonpea. In pigeonpea, RT (0.174 kg MJ−1) and ZT (0.167 kg MJ−1) have higher EPg than CT (0.148 kg MJ−1), but EPt was higher in ZT (0.621 kg MJ−1) followed by RT (0.581 kg MJ−1) and CT (0.496 kg MJ−1). While, in castor ZT has higher EPg and EPt over RT and CT. In both the crops EPg and EPt was significantly influenced by anchored residue heights. 10 and 30 cm anchored residue have higher EPg and EPt over 0 cm in both the crops. Significant interaction between tillage and anchored residues was not observed in pigeonpea unlike in castor. In castor ZT 10 cm recorded significantly higher EPg and EPt over other tillage and residue height.

2.9 Socioeconomic aspects

2.9.1 Economic implications of soil erosion: A farm level study

Soil erosion is one of the major environmental threats to sustainability of agriculture. Loss of top soil through erosion will affect the cropping pattern, farm productivity and income. The farm level implications of erosion for the Padmaram watershed located in Kondurgu mandal of Mahabubnagar district of Telangana were studied using the bio- economic model developed. Primary data on the farm management practices and the secondary data on land use and soil parameters of the untreated area of the watershed were used for the analysis. The input use and yield of major crops were higher at lower elevation in the watershed indicating a relatively better soil status. This also seemed to have induced farmers to invest more in terms of inputs and better soil management compared to those at the upper reach.

A spatial soil erosion estimation model was developed using GIS and was coupled with Revised Universal Soil Loss Equation (RUSLE). The soil loss from 60.0% of the watershed area was found to be below 3.0 t ha^{-1} y^{-1}. The soil loss from 27.5% area ranged from 3.1 to 4.5 t ha^{-1} y^{-1}, and remaining 12.5% area have soil loss more than 4.6 t ha^{-1} y^{-1}. By considering the soil loss in the upstream, midstream and downstream of the watershed, maximum mean annual soil loss was observed in the midstream area (3.54 t ha^{-1} y^{-1}) from crop land, where all the three major drains joined together. The lower mean annual soil loss was observed in the downstream and upstream (3 t ha^{-1} y^{-1}). Using the soil loss data obtained a multi-objective linear programming (MOLP) was done to arrive at a farm plan with two goals, one for maximizing net income and the other for minimizing the soil loss.

Data of a farmer possessing land in the three reaches of the watershed was used for the analysis considering a cropping pattern that included maize, paddy, cotton and chilly. By reorganizing the cropping pattern, the analysis revealed, the income could be increased by 14 per cent and soil loss decreased by about 36 per cent compared to the existing farm plan. The optimum crop plan did not include growing paddy in the middle reaches, which is more eroding. The trade-off between soil loss and farm income is depicted in fig. 2.24.

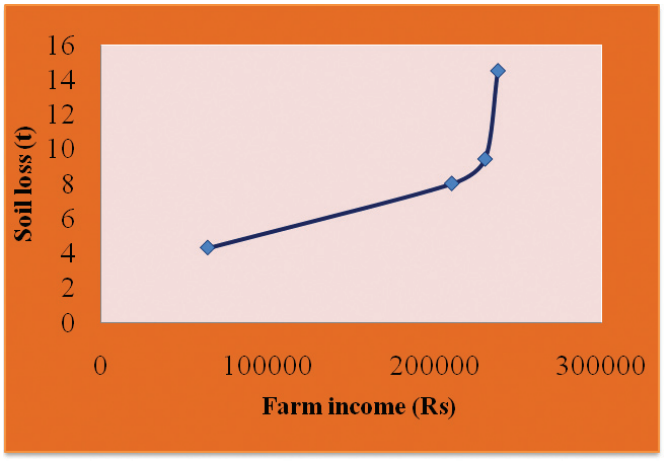


Fig. 2.24: Trade-off between farm income and soil loss

2.9.2 Assessment of sustainability of treated/ developed watersheds in rainfed agro-eco-sub regions of peninsular india using GIS and remote sensing

Watershed projects have been implemented as a strategy for soil and water conservation in rainfed agriculture by several agencies prior to implementation of 2008 Common Guidelines leading to variations in impact that are difficult to assess and compare across various scales and agro eco-regions in India. A procedure was developed to measure the impact of watershed development projects on agricultural sustainability in rainfed regions in India. The procedure would be automated into a Decision Support System that would be useful for Monitoring and Evaluation of Watershed Projects in India.

GIS and remote sensing tools and techniques were employed to develop a spatial methodology for measuring, analysing and mapping five aspect of agricultural sustainability namely, agricultural productivity, livelihood security, environmental protection, economic viability and social acceptability at three spatial levels viz., household, field and watershed. Fifty-one indicators were developed and scores were assigned from which six critical monitoring and six critical evaluation indicators were identified using PCA for assessing the impact of watershed projects. A spatial evaluation tool called Raster Calculator was developed and a Composite Sustainability Index was constructed to measure and compare agricultural sustainability at field- and watershed-level.

While the monitoring indicators namely, construction and maintenance of S & WC structures, adoption of soil moisture conservation measures, adoption of farm organic matter recycling, total crop production level, gross agricultural income level and improvement in availability of fodder, were found to be useful by the Project Implementing Agency to carry out mid-course corrections, implementation of these activities could ensure over 69% of agricultural sustainability. Six critical evaluation indicators viz., development of credit facility, Crop Diversity Index (No. of crops taken in unit area), soil organic carbon status, availability of gainful employment options, soil fertility status and improvement in availability of fodder could ensure over 80% of agricultural sustainability in reined region. These indicators could serve as signpost to facilitate evaluation of watershed projects by funding agencies thus stemming wasteful investment. During the year, eight watersheds located in Rangareddy and Nalgonda districts in Telangana were evaluated. Study of one treated and one untreated micro-watershed located in Pamana in Chevella mandal, Rangareddy district indicated that during 2013 over 10 ha of the 132 ha treated micro-watershed (TMW) was under Fairly Sustainable agricultural management.

Survey no 244, 248 and 261 in TMW were moderately to Fairly Sustainable during 2007- 2013. In untreated micro-watershed (UTMW) only one holding (survey no.220) was under sustainable agriculture indicating a marginal but positive impact of watershed program. Temporal evaluation of fields in both types of watersheds indicated that except in case of survey no. 244 that was found to be sustainable since 2006, most of the others were inconsistent in their performance. Table 2.18 indicates field -wise trend in agricultural sustainability in both types of watersheds.

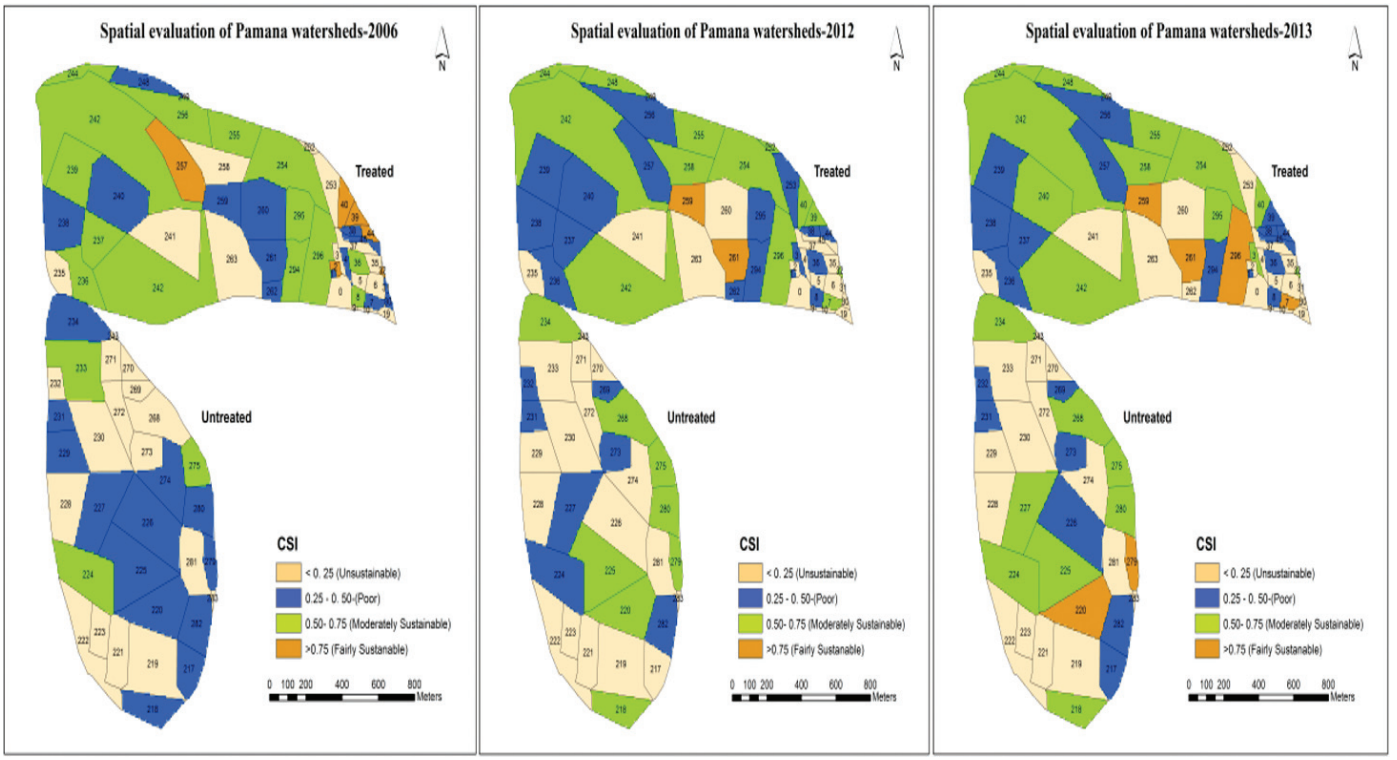


Fig. 2.25: Spatial evaluation of agricultural sustainability in Pamana (2006 - 2013)

Table 2.18: Temporal evaluation of Pamana watersheds (2006 -2013)

Pamana Field no.	Watershed Type	2006	2012	2013	Trend
259	Treated	PS	FS	FS	Inconsistent
220	Untreated	PS	MS	FS	Positive
261	Treated	PS	FS	FS	Positive
40	Treated	MS	MS	FS	Sustainable
279	Untreated	PS	MS	FS	Positive
244	Treated	MS	MS	FS	Sustainable
296	Treated	MS	MS	FS	Sustainable
248	Treated	PS	MS	MS	Positive

(US = Unsustainable (<0. 25); PS = Poorly Sustainable (0.25-0.50); MS = Moderate Sustainable (0.50-0.75); FS = fairly sustainable (>0.75))*

2.9.3 Understanding farmer knowledge, attitude and adaptation strategies to climate variability and change in semi-arid regions of india

The study was mainly aimed at identification of farmers' perceptions, attitudes and major farm-level adaptation measures followed by farmers' in coping with the perceived climatic variability and change in semi-arid regions of India. The study location constituted four AICRPDA centers, representative of red and black soils and prevalence of drought conditions, located in three different States viz., Andhra Pradesh, Karnataka and Maharashtra were purposively selected. A total of 240 farmers at the rate of 60 farmers from 2 villages of a mandal of each district under each AICRPDA center were selected randomly.

- Results across four centers viz., Anantapur, Akola, Solapur and Bijapur were compared and collated this year. Trends across the centers show that the chief farmers' perceptions towards climate variability and change are: prolonged dry spells, rise in temperatures followed by delayed and shorter rains. The chief adaptation measures followed by farmers towards climate variability and change are: change in planting dates, cropping pattern followed by diversification to livestock.
- Barriers to climate change adaptation as expressed by farmers' are: lack of access to credit, lack of labour and lack of access to water. Measures that government should do regarding climate change are control pollution, afforestation and develop irrigation projects. Adaptation index value for Anantapur was highest among the centers which, indicates farmers are highly receptive and already adapting to climate change.
- Across the four centers, majority of farmers agreed with the following attitude statements towards Climate change:
- Climate change is a serious problem.
- Climate change is affecting my farming.
- Average temperatures are increasing.
- Human activity is responsible for climate change.
- Climate change affects small and marginal farmers more.
- Rainfall patterns are changing.
- Climate change enhanced incidence of pests & diseases.
- Government should do more to help farmers adapt to climate change.
- Scientists/Govt. will solve the problem of climate change.

2.9.4 Assessment of KVK Ranga Reddy interventions on knowledge and adoption of farmers

The study aimed at assessment of impact of KVK technologies on knowledge, income levels, drudgery reduction and adoption of farmers in KVK adopted villages of CRIDA. KVK of Rangareddy district of Telangana state was purposively selected for the study. Three adopted villages in Pudur mandal viz., Mirzapur, Kandlapally and Yenkepally along with three non-adopted neighboring villages have been selected purposively. The total sample size of 240 farmers were selected randomly at the rate of 40 from each of adopted and non-adopted villages. Under the year of report an interview schedule for collection of data from farmers has been formulated and pretested and data collection is in progress.

2.9.5 A study on assessment of post training impact and effectiveness in the work environment

Access to various forms of knowledge improves the users' understanding on climate variability, impacts, adaptations and mitigation strategies with a range of available options and opportunities for effective decision making. This formed the crux of training curriculum on climate change variability and impacts for the training programmes conducted in CRIDA. A study is being carried out to know the potential impact of training in the work environment of an individual in the post training scenario to elicit the training effectiveness on the job situation using a structured questionnaire designed for the study.

- The structured questionnaire after pretesting is administered to 250 trainees for assessing the effectiveness of training programme in the area of climate change related training programmes in rainfed agriculture.
- Data receipt and analysis are in progress. The questionnaire measures the parameters like utility of training in on job situation, factors influencing the application of knowledge and skills learnt in the training, frequency of usage in organizational environment, areas of application, constraints in applying the skills learnt, participants opinion towards training outcome etc,.

2.9.6 Gender dimension of impacts of climate change: a participatory assessment of vulnerabilities and adaptations in agriculture

A vulnerability study to impacts of climate change was undertaken utilizing the concept mapping technique

in Anantapur District of Andhra Pradesh. Concept mapping is a methodology of participatory text analysis that directly involves respondents or their proxies in the coding of the text as defined by Jackson and Trochim, 2002. It is an effective methodology for aggregating of ideas into a logical sequence. The maps generated will act as precursor for building evaluation criteria for future analysis.

The study was conducted in Chumuluru and Chakrayapeta villages of Anantapur district of Andhra Pradesh where NICRA project is active and therefore, is purposively selected. The rationale behind the selection is that adequate awareness building on climate change impacts might have been carried out by the project officials in the village and also that farmers are aware of the changing climate variability in the form of decreasing rainfall and increasing temperatures. Concept mapping was conducted separately for men and women groups. Six key steps were followed such as brainstorming, card sorting, rating, point mapping, cluster mapping, labeling and conceptualization. In brainstorming session it was started with a focus question "How have the households being affected with under adverse weather conditions like drought?" Question being common to both men and women groups. In response to the prompt question men found to have given 24 statements ranging from education, livelihood, health, water problems, institutional problems etc., and women responded with 34 statement problems ranging from education, health, livelihood, adaptiveness and institutional problems.

- Vulnerability to drought as indicated by women group (Fig. 2.26) through point and cluster maps found to have many forms such as: Social Vulnerability (SV) which mainly focused on children's education and family health; livelihood concerns influenced by increasing debts, migration of family members for wages and work; Household Vulnerability (HHV) is looked at from the angle of food habits: members diet due to non availability of protein diet (non vegetarian food) and poor quality drinking water mainly due to presence of high percentage of fluoride content in deep layers of groundwater; Institutional Vulnerability (IV) which was found to be high among women who generally hesitate to share problems with their neighbours and the reason stated was existence of small and restricted networks and strong cultural norms like casteism that hinder their development; and also tend to have preferences to small families and less number of dependents likely to lead to small families and that might increase gender gaps in future; Some of the nonfarm focused activities (NF) were of concern to women who under difficult circumstances opt in for petty businesses like salt businesses and prefer to migrate to long distances to jobs other than agriculture.

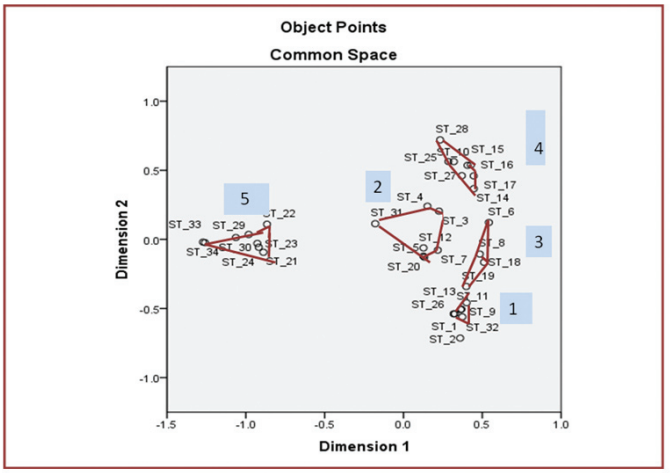


Fig. 2.26: Cluster map of vulnerability of women to climate change impacts

- Vulnerability to drought from men group as indicated from cluster map (Fig. 2.27) showed that climate change has affected men too but in different ways which are mostly centered on livelihoods having fewer options in job areas other than agriculture due to skill poverty. These aspects had been conceptualized as Livelihood vulnerability (LV), as male farmers have been equipped with few skills and are unable to shift to other occupations other than farming. Farming being the major livelihood in Anantapur district, farmers have high hopes on good rainfall; despite desire to cultivate commercial crops, horticulture crops etc but unable to do due to poor water management practices that causing major concern and termed as water management vulnerability. The general perception of male farmers is that

water problem is so acute primarily due to poor management rather than availability of water itself.

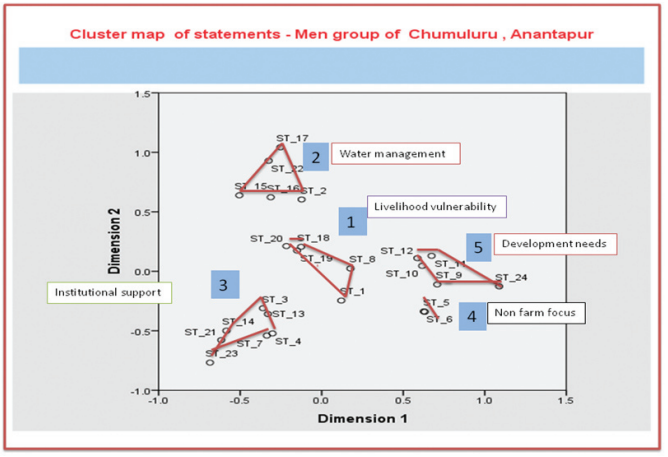


Fig. 2.27: Cluster map of vulnerability of men to climate change impacts

- There was significant agreement among key personnel of the village in rating vulnerability clusters in terms of importance and doability of each of the problem as mentioned by the women members indicating that women concerns need to be given equal importance as much as men's that need immediate action and design intervention measures so as to reduce impact of drought in rainfed areas.

Assessment of adaptation to climate change impacts using pair wise ranking technique

- Women farmers gave a different picture of the adaptation measures to climate change impact of drought in Anantapur district. Some of the measures are efforts to reduce fodder scarcity, application of FYM, enhancement of livestock population and avoid migration, drip Irrigation, purchase of water tanker, social and religious beliefs, sheep rearing, selling of fuel wood, dryland horticulture, bore well irrigation, sorghum cultivation as alternative crop, castor, pigeonpea as alternative crop to groundnut and Non forest timber produce. However the best four ranks were given to borewell irrigation, sorghum cultivation as alternative crop, castor, pigeonpea as alternative crop to groundnut and non forest timber produce.
- Adaptation measures reported by men were gap filling with short duration crops, sorghum, green gram as alternative crop to groundnut, sowing across slope, reduction of crop acreage, rearing of milch cattle, integrated farming system, purchase of fodder, support of government subsidy, drip irrigation, farm bunding, reduction of cost of production and staggering sowing. Out of these measures given out by men farmers, integrated farming system, drip irrigation, reduction of cost of production and staggering sowing received highest ranking.

3 National Initiative on Climate Resilient Agriculture (NICRA)

The project was initiated in 2010 to develop and promote climate resilient technologies in agriculture which will address vulnerable areas in India. The outputs of the scheme will help the districts and regions prone to extreme weather conditions like droughts, floods, frost, heat waves, etc. to cope with such extremes. Although the target area of the scheme are all climatically vulnerable regions of the country, more emphasis is placed on small and marginal farmers in rainfed, coastal and hill areas of the country. The specific objectives of the initiative are: to enhance the resilience of Indian agriculture covering crops, livestock and fisheries to climatic variability and climate change through development and application of improved production and risk management technologies; to demonstrate site specific technology packages on farmers' fields for adapting to current climate risks; and to enhance the capacity of scientists and other stakeholders in climate resilient agricultural research and its application. The project has four components: Strategic research on adaptation and mitigation, Technology demonstration to cope with current climate variability in 100 vulnerable districts, Capacity building and Sponsored/competitive grant research to fill critical gaps. Significant work was carried out during 2014-15 under the strategic research and technology demonstration components at CRIDA.

3.1 Strategic research

3.1.1 Sensitivity of Indian wheat yields to temperature: District level dynamics

Wheat yields in major wheat growing districts were found to be inversely related to minimum temperatures (T_n) especially during post-anthesis period. Correlations worked out between temperatures and wheat yields are shown in Fig. 3.1. Growing season maximum temperature (T_x) showed a negative association with yields over 162 districts (81.3% area) and of these wheat yields over 58 districts (35.5% area) showed a significantly negative association with T_x. Monthly T_x values correlated with wheat yields indicated that T_x of January and February had a significant negative association with 78 (43% area) and 54 (20% area) districts wheat yields, respectively. A significant and positive influence of seasonal T_x is noticed over a small area (7 districts and 2.6% area). This may be due to either cultivars being grown are less susceptible or prevalence of T_x lower than the cultivars' optimum. Of all the months, T_x of March showed a significant negative association over small area confined to western parts of the country, mainly in the state of Rajasthan, a region that experiences a relatively warm climate.

About 52% variance in year-to-year changes in wheat yields was explained by T_n. District wheat yields when correlated with seasonal T_n resulted in more area (42.7%) with more number (77) of districts showing significantly negative association compared to seasonal T_x (35.5% area with 58 districts). Wheat yields over 7.2% more geographical area are influenced by T_n compared to T_x. There is practically no area that exhibited a positive association between seasonal T_n and wheat yields. Among different months, T_n during February and January has considerable areas (79.2 and 86.7% area, respectively) showing negative association with district wheat yields. T_n of November and December could exert negative impact to a limited extent. Wheat yields from the more geographical area showing negative correlation with T_n in comparison with T_x is indicative of role of nighttime warming. A regression of district yields for the period 1980–2011 on temperature variables only for those districts where the correlations were negatively significant resulted in a mean yield decline of 204 kg ha^{-1} with 1°C rise in T_n. This is approximately 7% of Indian wheat yields. Exposure to continual T_n exceeding 12 °C for 6 days and terminal heat stress with T_x exceeding 34 °C for 7 days during post-anthesis period are the other thermal constraints found in achieving high productivity. It is suggested to consider inclusion of early maturing, high

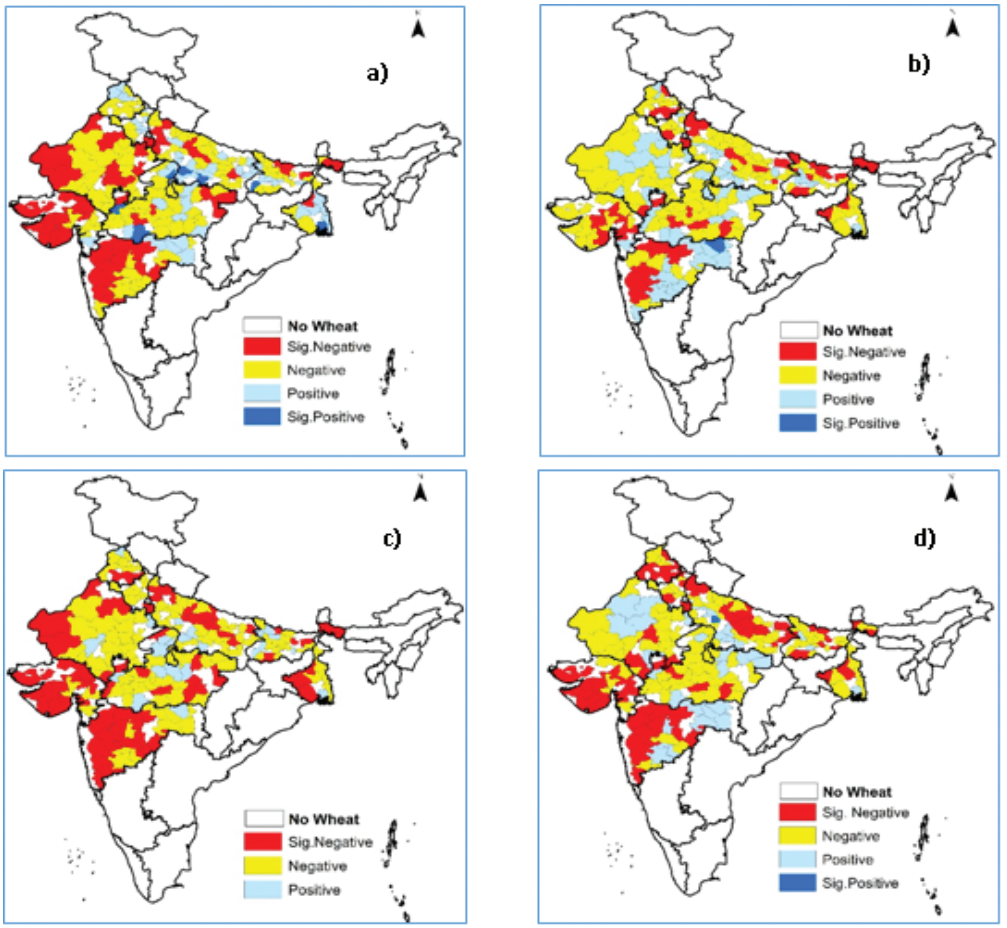


Fig. 3.1: Correlation between (a) seasonal Tx; (b) February Tx; (c) seasonal Tn; (d) February Tn and district wheat yields

yielding and heat tolerant wheat lines in the breeding program for Indian conditions. Thermally sensitive areas evolved from this study may be explored to identify such wheat lines for their adaptability to future climates.

3.1.2 Development of strategies for improved agromet advisories at micro level and their dissemination

Efforts are being made since 2011 to make the farmers aware of climatic information and to enrich them with knowledge on viable adaptation strategies. This is being done through selection of centres based on climatic vulnerability, establishment of Automatic Weather Stations (AWS) in the identified locations, data acquisition, management and dissemination, creation of a website to upload the scrutinized and quality checked data for research purpose and for real time weather data display, benchmark survey of selected villages to delineate hot spots for weather anomalies and map extremes, assessing crop weather responses using agro-climatic analysis and crop simulation modeling, appointment of Field Information Facilitators (FIFs) to monitor crop status and to aid in the design and issue of micro level agromet advisories, capacity building for developing the skills in issuing micro level agromet advisories and awareness programs to alert the farmers on climate variability/change. The achievements in 2014-15 were as follows

- Micro-level agromet advisories were issued by 25 AICRPAM-NICRA centers based on block-level weather forecast provided by IMD.
- Request for AWS data have come from 46 institutes during the year.
- The accuracy of data recorded by AWS at

different locations was determined by comparing the AWS data against the data recorded in manual meteorological observatories.

- Real-time weather data from 100 AWS were used to generate spatially interpolated daily weather maps using Arc GIS.
- Successful systems for dissemination of agromet advisory services were established in Bhubaneswar, Bijapur and Udaipur centers.
- Hailstorm damage was assessed and reported by AICRPAM-NICRA centers.

3.1.3 Development of weather index based insurance modules for selected crops and other agricultural sectors

Modules for weather based insurance for major crops and allied sectors are being developed since 2012. This year, weather indices required for designing weather insurance products for groundnut were developed by analyzing long-term yield and weather conditions at three locations viz., Bangalore, Anand and Ludhiana.

At Bangalore, higher rainfall during pod initiation to pod filling in DH 3-30 and Robut 33-1 and during pod initiation to pod formation in TMV-2, JL-24 and K-134 was found to be favourable for achieving higher pod yield in respective varieties. Rainfall less than 119, 109, 156, 138 and 122 mm during this critical stage resulted in lesser than optimum yield in these varieties. At Anand, rainfall during first seed to harvest was found to be critical for obtaining higher yield and rainfall lesser than 319, 469 and 174 mm during first seed to harvest stage of varieties Robut 33-1, GG-2 and Gaug-10, respectively resulted in below optimum yield. At Ludhiana, in M-13 variety, 334 mm rainfall during complete emergence to 50% flowering was found to be critical for higher pod yield and any decrease in rainfall during this stage resulted in below optimum pod yield.

The relation between water requirement satisfaction index (WRSI) and yield in respect of different varieties at three locations revealed that the WRSI required for optimum pod yield ranged from 64.7 to 93.3 percent across different crop varieties and centres. Yield showed a highly significant positive relationship with WRSI increasing by 33.8 kg/ha for one percent increase in WRSI (Fig. 3.2). Decline in pod yield with respect to the number of dry spells of different durations were also studied in different varieties at all the three centres (Table 3.1). At Bangalore (cv. DH 3-30) and Anand (cv. Robut 33-1) two dry spells of more than 15 and 20 days, respectively caused nearly 70 percent reduction in pod yield compared to no dry spell. At Ludhiana, M-13 variety could tolerate one dry spell of 15 days, but four such dry spells reduced the yield 90%.

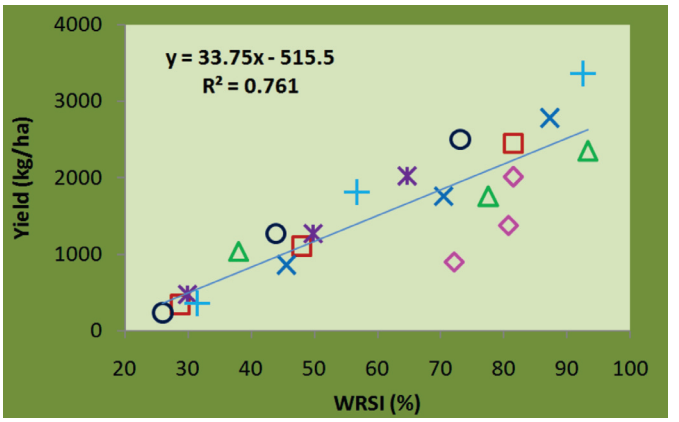


Fig. 3.2: Relation between WRSI and yield of different cultivars at three centres

Table 3.1: Thresholds of dry spells affecting yield of groundnut varieties DH 3-30 at Bangalore, Robut 33-1 at Anand and M-13 at Ludhiana

Centre	Variety	Dry spells		Yield reduction (%)
		Duration	Number	
Bangalore	DH 3-30	≥ 15 days	0	-
			1	38
			2	67
Anand	Robut 33-1	≥ 20 days	0	-
			1	37
			2	69
Ludhiana	M-13	≥ 15 days	1	-
			2	46
			4	89

3.1.4 Identification of extent and intensity of hailstorm damage using spaceborne data

During Feb-March, 2014, hailstorms struck central India and caused severe losses to several crops. A team of scientists from CRIDA conducted field surveys during 16-19 March, 2014 in Pune Division (Solapur and parts of Pune district) of Maharashtra to assess the damage. Extensive ground truth data was collected during the visit and the position details of damaged fields were collected using GPS with sub-meter accuracy. Landsat-8 satellite data of pre and post hailstorm periods (25 February and 13 March 2014, respectively) was used to map the hail streaks (Fig 3.3). High resolution LISS-IV data (Resourcesat-2, 11 February, 2014) was used to distinguish different crops within the hail streak, so as to assess extent of damage to different crops in the study area. Geometric and radiometric corrections were performed for satellite data by using standard procedures in ENVI 4.6 image processing software. Normalized Difference Vegetation Index (NDVI) is the most common vegetation index used in remote sensing. To detect changes in vegetation due to hailstorm damage, a ΔNDVI image was generated by subtracting the pre and post hailstorm NDVI images (Fig. 3.4). Wherever there was vegetation, the ΔNDVI showed an abrupt change (> 0.02), which was verified in the field during ground truthing as hailstorm damage. About six hailstorm damaged streaks were identified in the study area. Characters of each streak (perimeter, length, width and area) and the extent of area damaged by hail in each streak under different crops were calculated. The mean length and width of streaks was about 18 and 5 km, respectively. The maximum length of streak was about 33 km (Streak VI), width was 8 km (Streak V), perimeter was 76 km (Streak VI) and area was 36262 ha (Streak V). Total damaged area under different crops estimated from the data was about 20779 ha (Table 3.2). Using LISS IV data, crop classification was performed by the minimum distance classifier method. Grape was the major crop affected due to hailstorm in the study area (about 3122 ha). Damaged fields of papaya, pomegranate and sugarcane were also identified in the calssified image (Fig 3.5).

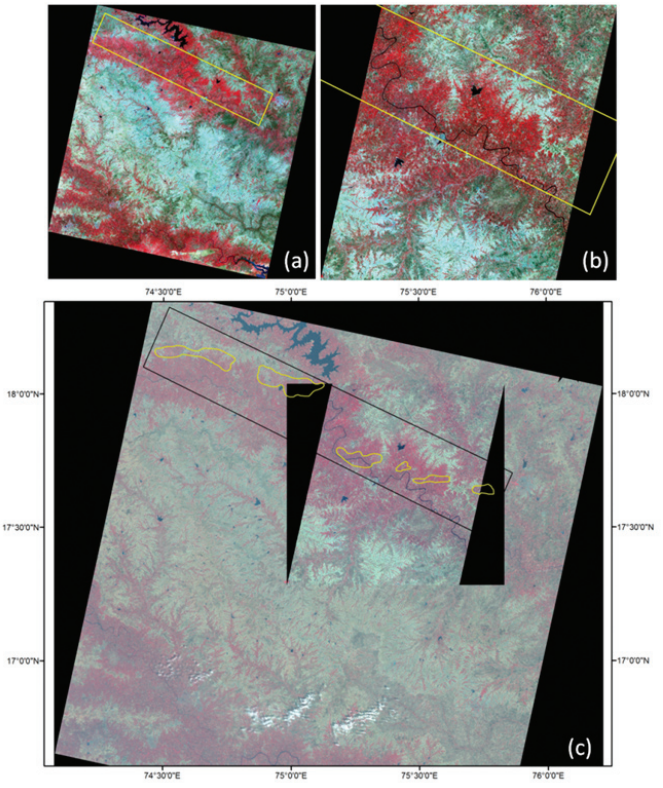


Fig. 3.3: False Color Composite (FCC) of the study area (shown in the rectangular box in the images), Landsat-8 (a), LISS-IV (b) and the overlaid image of Landsat and LISS-IV (c).

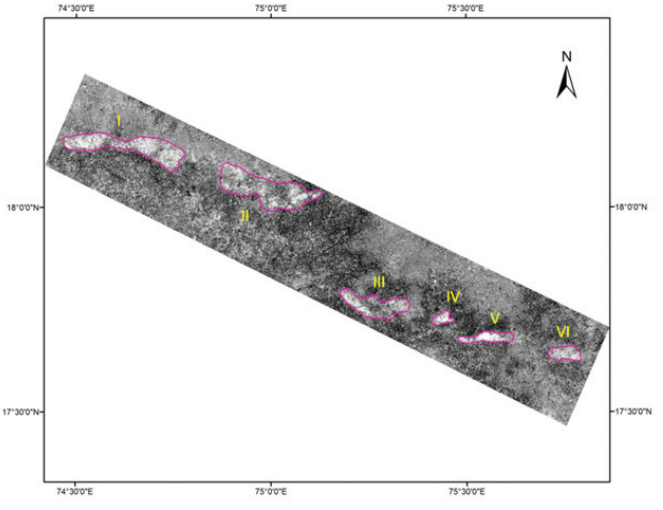


Fig. 3.4: NDVI difference of pre and post event showing different hailstorm streaks (I to VI) in the study area

Table 3.2: Area (ha) damaged by hailstorm under different streaks

Streak	Area under hail damage (ha)
Streak-I	1430
Streak-II	1846
Streak-III	791
Streak-IV	3108
Streak-V	6212
Streak-VI	7392
Total area	20779

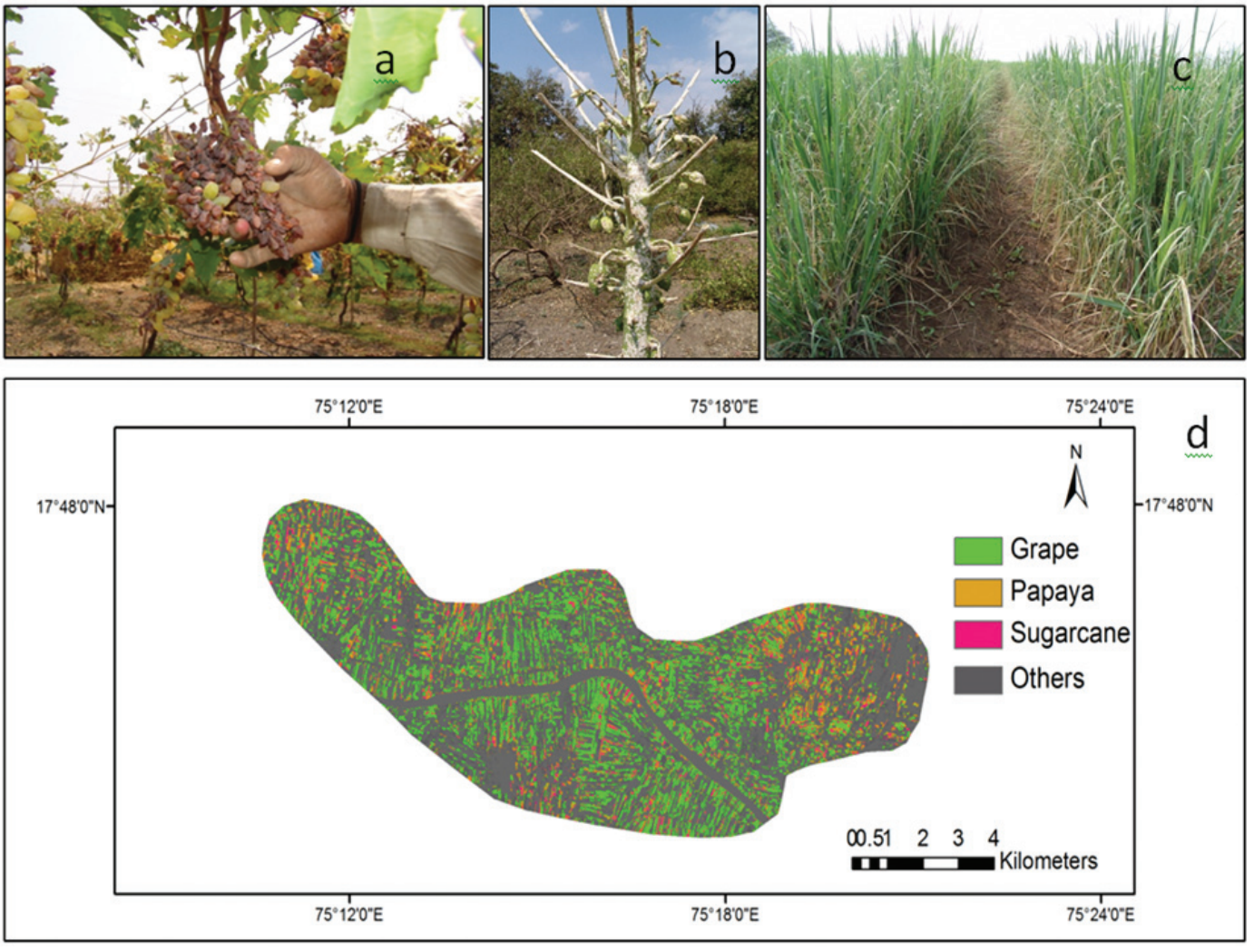


Fig. 3.5: Damaged fields of grape (a), papaya (b), sugarcane (c) and classified satellite data showing crops in the hailstrom affected site (Streak III)

3.1.5 Satellite–derived NDVI variations to assess agricultural vulnerability in rainfed regions due to climate change

Variations in satellite based vegetation index due to climate change were used to assess agricultural vulnerability in India. Time-series NDVI composites from NOAA-AVHRR and MODIS-TERRA since 1982 were analyzed to study variations in Max NDVI and in length-of-crop-growing-period (LGP) in various agro-eco-sub-regions (AESR) in order to develop typology of agricultural vulnerability essential to formulate adaptation and mitigation strategies. The basis for classifying agricultural vulnerability under various typologies were as follows: importance of agriculture in each vulnerable district based on actual area under agriculture, bio-climate of district based on Thornthwaite's moisture index, normal LGP in district based on water-balance model, LGP derived from NDVI estimated from AVHRR and MODIS datasets and prevalent major cropping systems in the vulnerable district.

Based on the criteria listed above, a composite typology of agricultural vulnerability to climate change was drawn for the country. It is clear that all types of cropping systems viz., cereals, oilseed, pulses and major cash crops viz., cotton, sugarcane, groundnut, etc., will be adversely affected by climate change. There has been a change in LGP in vulnerable districts as estimated from variations in NDVI from AVHRR and MODIS datasets (Fig. 3.6). MODIS dataset pertaining to last decade indicates an increase in LGP in arid regions, and no change in dry semi-arid northern and western parts of the country. However, the moist semi-arid and sub-humid region of Gangetic Plains, Central India and Southern Plateau region are experiencing a decline in LGP which will adversely impact cultivation of soybean and several pulses (Fig. 3.6).

Variations in upper-limit and lower-limit of LGP were compared with normal LGP estimated based on water-balance model. AVHRR dataset indicated decrease in upper-limit of LGP in 44 districts, increase in 70 districts and no change in 8 districts while MODIS indicated decrease in 4, increase in 65 and no-change in 53 districts. Decrease in lower-limit of LGP based on AVHRR was seen in 92 districts, increase in 28, and no change in 2 districts while MODIS indicated a decline in 53, increase in 60 and no change in 9 vulnerable districts (Fig. 3.7).

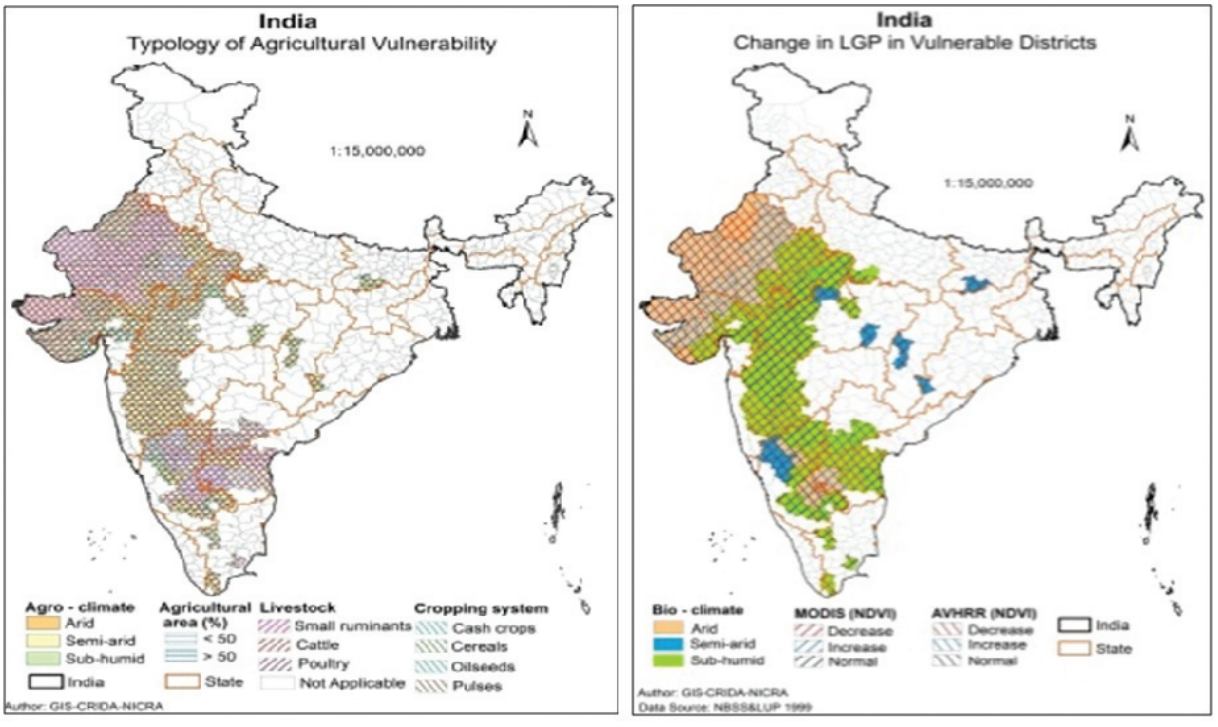


Fig. 3.6: Typology of agricultural vulnerability in India & change in LGP

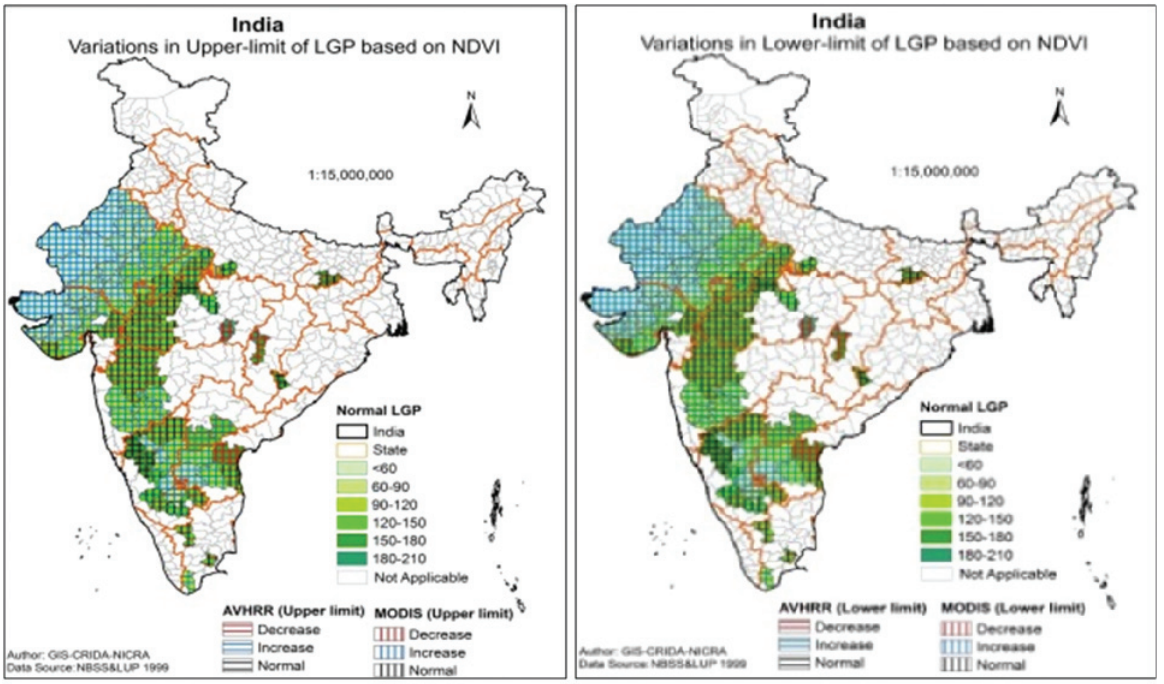


Fig. 3.7: Change in upper-limit & lower limit of LGP compared to normal LGP

3.1.6 Assessment of vulnerability and adaptation to climate change

Vulnerability refers to the propensity to be hit and harmed by an external shock. It is basically determined by the exposure of the entity to the shock, its sensitivity to such shock and its ability to withstand and moderate the shock. In the context of crop production, it can be argued that vulnerability of a crop can be considered as probable fall in productivity because of climate change characterized by the changes in temperature and rainfall after accounting for the technological change. In other words, the changing temperature and rainfall will have adverse effect on crop yields but the technological advances may have some moderating effect on such reduction and the net effect can be considered as vulnerability of the yield of a particular crop to climate change. With this background, the vulnerability of productivity of pigeonpea in India was analyzed applying a panel data regression framework using the district level time series data for the period 1971-2004 on pigeonpea yield, monthly average temperature and rainfall and number of rainy days (June to November) in India. The variability in monthly temperature and rainfall was included in the model in the form of coefficient of variation (CV). A time trend variable to capture the technological trend was also included and the cross section dummies in the panel data regression would capture the district specific effects. All the districts that have at least 10000 ha under pigeonpea were included in the analysis.

The model fitted was found to explain 72 per cent of variation in pigeonpea yields. The district specific effects were found to be significant in many districts. It was observed that average temperature during June and August were found to have a significant negative effect on productivity. The rainfall during August also affected the yields positively as did the interaction between temperature and rainfall during June and August. The technological trend as captured by the time trend variable was also found to be significant. A comparison of the average yield levels estimated using the fitted model for the baseline period 1960-1990 and for 2021-50 as obtained from PRECIS model for A1B scenarios revealed a possible fall in yield by about 76 kg/ha, which is about 10 per cent of current yield levels. Considering the current scenario of pulse production and protein consumption in India, there is a clear need to invest in developing and transferring technologies for enhancing productivity and the climate related issues are to be adequately considered in doing so.

3.1.7 Influence of climate variability on groundwater variability

Studies were initiated to ascertain the groundwater variability, recharge and discharge on year to year basis and as a function of rainfall. Longterm data on groundwater fluctuations was collected from state groundwater department. Mandal level rainfall was collected from bureau of economics. Preliminary analysis of the data for Makhtal mandal of Mahabubnagar district, Telangana, showed increase in recharge and discharge of ground water with increase in rainfall indicating that there is no carry over storage of ground water from year to year.

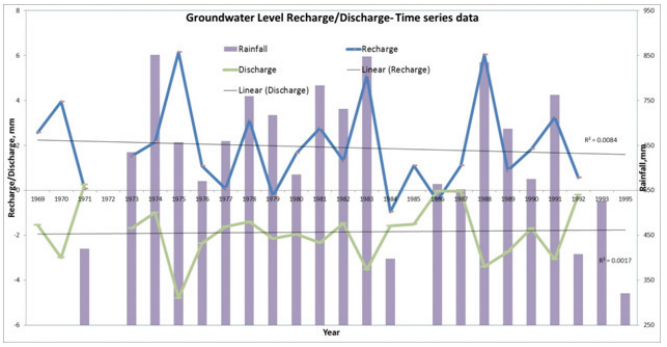


Fig. 3.8: Influence of rainfall on groundwater recharge and discharge

3.1.8 Phenotyping of rainfed crops (maize & pigeon pea) for enhanced tolerance to climatic stresses

Drought stress has a great impact on agricultural production. Improving drought resistance of maize can contribute to increasing maize yields and production. In *rabi* 2013-14, a field experiment was conducted for evaluating 9 different drought related physiological traits under irrigated and rainfed conditions in 16 genotypes of maize. Total rainfall received during crop growth period was 55.4 mm. A dry spell of 7 days coinciding with post anthesis stage occurred at 65 DAS. Further, 20 F1 crosses and their parents were evaluated using water relations viz., relative water content (RWC), leaf water potential (LWP) and osmotic potential (OP) under irrigated and rainfed conditions. Soil moisture content of 12% and 6% was recorded in control and stress plots respectively during the dry spell. Analysis of various physiological parameters at the stress point revealed a significant decline in leaf water relations, membrane stability and increase in metabolites, leaf and canopy temperature. Among the genotypes, 18242, 18506 and 18401 maintained higher water relations under stress. Genotype 18127 showed higher MSI and lower MDA content contributing to better membrane stability. N265 and N277 maintained higher photosynthesis and stomatal conductance under rainfed conditions. Genotype 18855 maintained higher stomatal conductance and also higher membrane stability. Of the 20 F1 lines evaluated, cross HKI164D4 x Z60-87 performed better in terms of RWC, while SNJ2011-26 x Z40-19 and RJR-363 x Z40-19 performed best for LWP and HKI164-D4 x Z93-194, HKI766(0) x Z93-194 performed better for OP.

In *kharif* 2014, a field experiment was conducted with 54 genotypes consisting of the 35 selected genotypes along with the 16 genotypes evaluated in *rabi* 2013-14. Total rainfall received during crop growth period was 222.4 mm. A dry spell of 5 days coinciding with vegetative stage occurred at 38 DAS. The genotypes were evaluated using 12 different morpho-physiological traits under irrigated and rainfed conditions. Parental polymorphism studies of 9 selected genotypes, which were used for making crosses using eighty SSR markers, were carried out. Soil moisture content of 14% and 7% was recorded in control and stress plots respectively during the dry spell. Analysis of various physiological parameters at the stress point revealed a significant decline in leaf water relations, ELWRC, photosynthesis related parameters, SPAD, total biomass and yield traits and increase in leaf and canopy temperatures. ELWRC of the maize genotypes revealed that NSJ211 and Z59-17 retained 81-82% of moisture while HKI-164-7-4,18301 and HKI-766(0) retained 70-68% of moisture (Fig. 3.9). Among the 35 genotypes, Z101-15, Z40-19, NSJ245, Z32-87, NSJ366, performed better for the above traits studied. Among the 16 genotypes, the genotypes 18224,18229,18261,18171 and 18242 showed better performance for the traits studied and were selected for further confirmation in the next season.

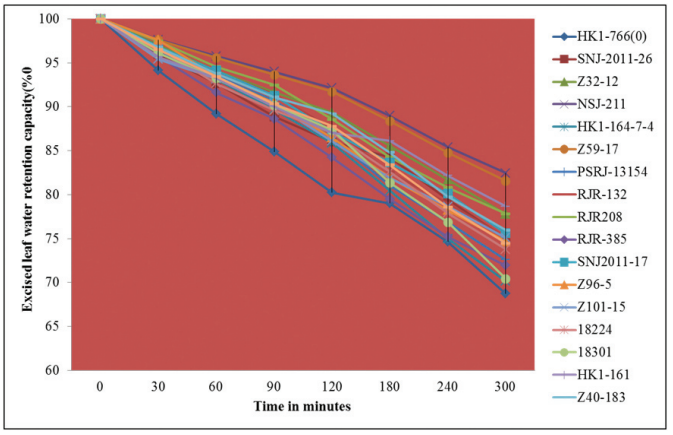


Fig. 3.9: Excised leaf water retention capacity among maize genotypes

Prospecting of genes for multiple stress tolerance

Universal stress protein (USP) gene from pearl millet was used for constructing the plant expression vector (Fig. 3.10). Transgenic tobacco plants harbouring USP gene were generated. Expressed sequence tags (ESTs) obtained from water-deficit, high temperature and salt (NaCl) stress-induced cDNA libraries were deposited in the EST database of NCBI (Table 3.3). Full- length sequence of CDPK has been deposited in GenBank with the accession number KJ923435. Plant expression cassette pCAMBIA1302-35S:*PgCDPK* was constructed and mobilized into *A. tumefaciens* strain LBA4404. For functional validation of CDPK gene, the gene construct pCAMBIA1302-35S:*PgCDPK* was transformed into tobacco plants through Agrobacterium mediated genetic transformation.

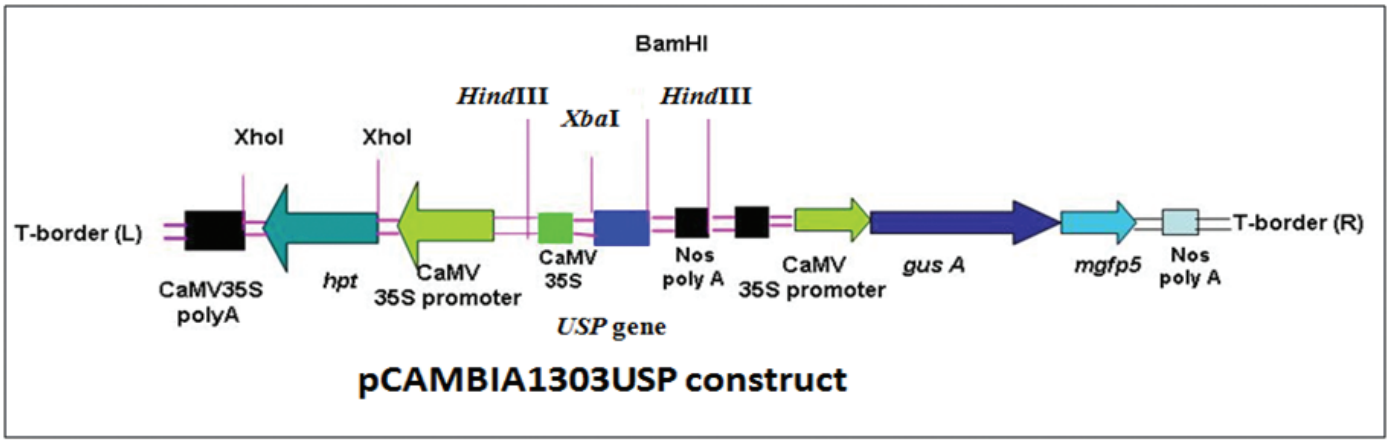
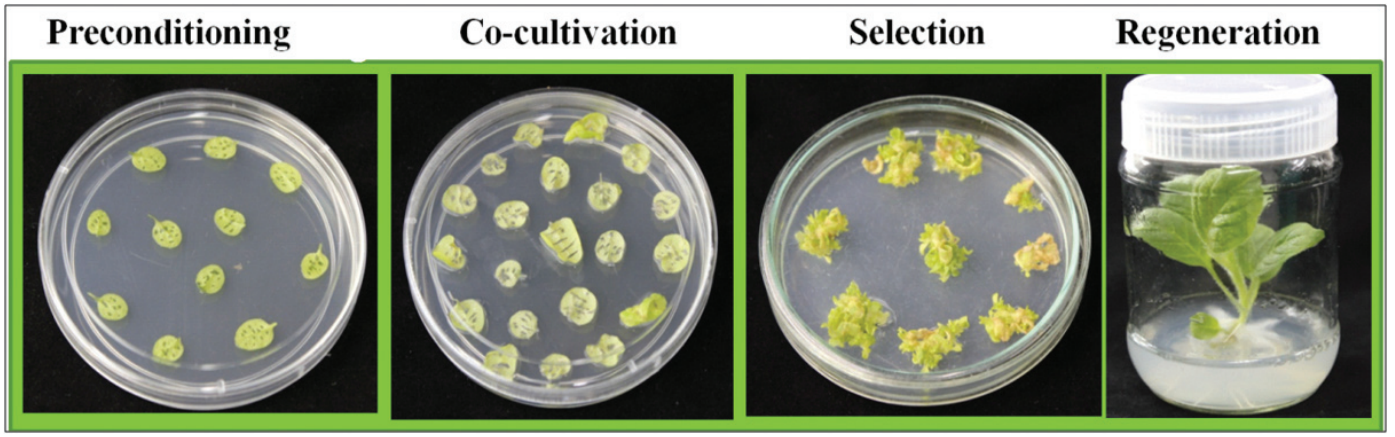


Fig. 3.10: Recombinant vector map of pCAMBIA1303USP

Table 3.3: P*ennisetum glaucum* cDNA libraries submitted to EST database of NCBI

Library name	Library ID	Accession numbers	Year
Pennisetum glaucum gradual water-deficit stress-induced cDNA library	LIBEST_028431	JZ681087 - JZ681229	2014
Pennisetum glaucum high temperature stress-induced cDNA library	LIBEST_028446	JZ705005 - JZ705123	2014
Pennisetum glaucum salt stress (NaCl) induced cDNA library	LIBEST_028447	JZ705124-JZ705239	2014



Agrobacterium mediated genetic transformation of pCAMBIA1302-35S:*PgCDPK* into tobacco

3.1.9 Developing image processing methodologies for analyzing high throughput plant phenotyping imageries

A large volume of data is generated by high throughput phenotyping platform during plant growth. This data is stored in a database system. High-throughput image analysis for automated phenotyping is used to extract several phenotypic parameters related to growth, yield and stress tolerance of plants.

A software tool was developed in MATLAB for extracting features from high throughput RGB digital imageries database, which are acquired from plant phenotyping facility. Plant photographs were taken from side view 0 degrees, side view 90 degrees and top view. 7500 RGB digital images were extracted and analyzed for plant features. Extracted plant features were quantified in terms of early ground cover. Healthy plants showed significantly higher early ground cover compared to stressed plants.

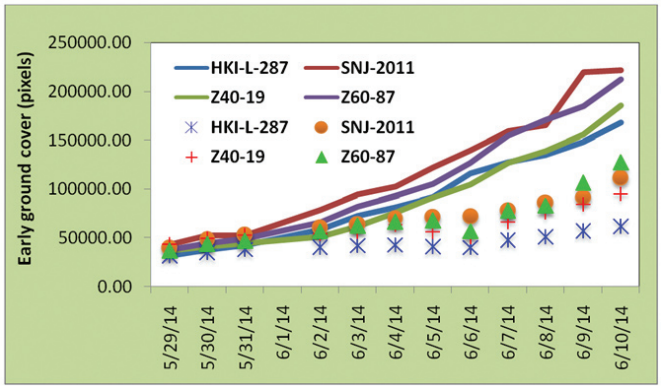


Fig. 3.11: Early groundcover in healthy (lines) and stressed (markers) plants

3.1.10 Physiological and metabolic indices for heat tolerance in maize

Heat is one of the important abiotic stresses which leads to significant loss in crop growth and productivity and is a function of intensity, duration and rate of increase in temperature. To characterize and choose the plant traits that best explain genetic variation for various morpho-physiological and biochemical traits under normal and heat stress conditions, 15 day old seedlings of maize genotypes NSJ 189 and NSJ 221 (heat tolerant) and PSRJ 13099 and RJR 270 (heat susceptible), were exposed to 48^{O}C temperature for three hours after having been sprayed with peroxide (1.2 mM), thiourea (20 mM) and putrescine (4 mM) 72 hrs prior to heat exposure. Foliar application of hydrogen peroxide (1.2 mM), thiourea (20 mM) and putrescine (4 mM) at early vegetative stage on four genotypes of maize resulted in variable reduction in the impact of heat stress by maintaining seedling growth, cell membrane stability, chlorophyll content, quantum yield and activity of SOD and peroxidase.

3.1.11 Computational genome analysis and in vivo validation of genes and transcription factors involved in abiotic stress in maize

Efforts are being made to develop a comprehensive database on maize genome and specifically on genes involved in abiotic stress, to computationally analyse and model WRKY, RBOH and MBF1c in maize genome and to validate the expression of WRKY, RBOH and MBF1c in maize genome under abiotic stress. The methodology adopted was to conduct

targeted genome wide computational analysis of genes and transcription factors involved in drought tolerance, dissection of key morphological traits involved in drought tolerance by high-throughput phonemics with specific reference to growth and development and elucidate the role of physiological, genetic and environmental interactions under drought stress.

Presence of WRKY family of genes in *Zea mays* genome was determined by mining for WRKY gene/ product in maize genome, every matching gene from the maize genome by query to search against the maize genome dataset was done. BLASTP – AtWRKY53 protein against the maize proteome and BLASTN – AtWRKY53 nucleotide query to maize nucleotide database. In addition, TBLASTN – AtWRKY53 was done wherein protein sequence was compared to maize nucleotide database translated on all six reading frames. BLAST (PSI-BLAST) search was done to increase the extent of the database search results. Open reading frames (ORFs) were performed with ORF Finder (Open Reading Frame Finder) in NCBI (http:// www.ncbi.nlm.nih.gov/gorf/). A multiple alignment analysis was performed with ClustalW (http:// bioinformatics. ubc.ca/resources/tools/ clustalx). Phylogenetic trees were constructed using the neighbour-joining (NJ) method and the pictures of phylogenetic trees were drawn with program MEGA4 (http://www.megasoftware.net/mega.html).

Exploring the phylogenetic relationship between WRKYs from *Arabidopsis thaliana* and *Zea mays* was done and the identified gene products from previous search were analysed for phylogenetic relationship, all identified maize WRKY proteins were aligned for local pairing using MAFFT tool the aligned sequences were transformed into a phylogenetic tree using the CLUSTALX software. Phylogenetic analysis of the maize sequences was done using MEGA-5 software. Python script generation was done to determine what are the genes or proteins that WRKY acts on as plant WRKY proteins recognize various W-box elements with a TGAC core that are present in promoters of many genes.

A detailed classification of the WRKY proteins was done for the maize genome. Homology modelling was done using templates from protein data bank and DNA docking with a matrix of homologous interface contacts was done (Fig. 3.12). A chromosome map of WRKY class of transcription factors in the maize genome was generated (Fig. 3.13).

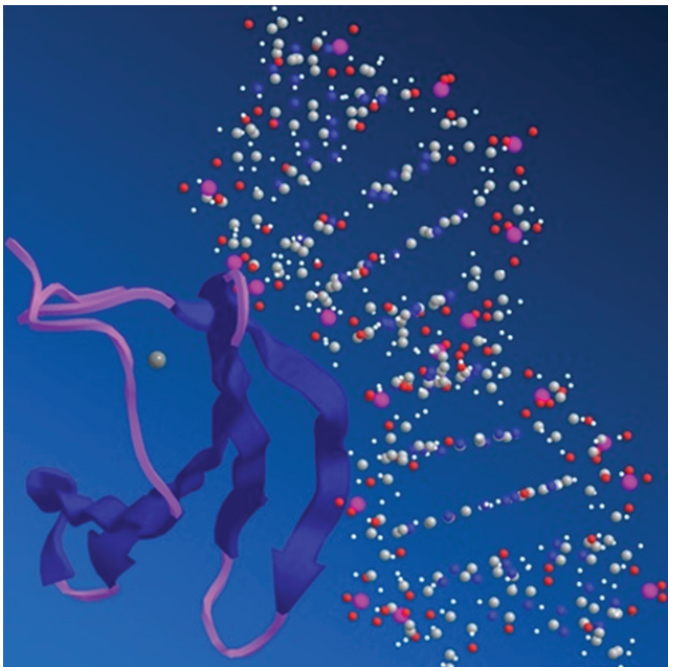


Fig. 3.12: WRKY protein and DNA docking model with a matrix of homologous interface

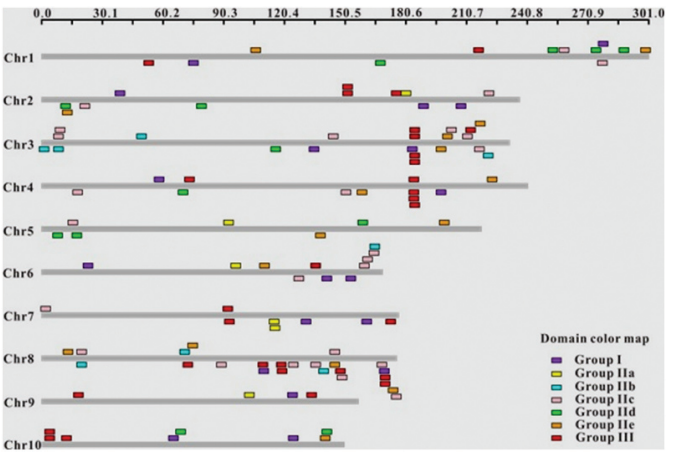


Fig. 3.13: Chromosome map of WRKY class of transcription factors in the maize genome

Whole Genome Microarray in water stressed and control plants of maize was initiated to determine which genes regulate responses to water stress and also determine if phylogenetically similar genes have similar responses to water stress. Data on the expression of

4500 genes and transcription factors in the maize genome was obtained and their expression pattern was determined. A Euler diagram was constructed (Fig. 3.14) based on the results wherein various genes and their expression overlaps were determined.

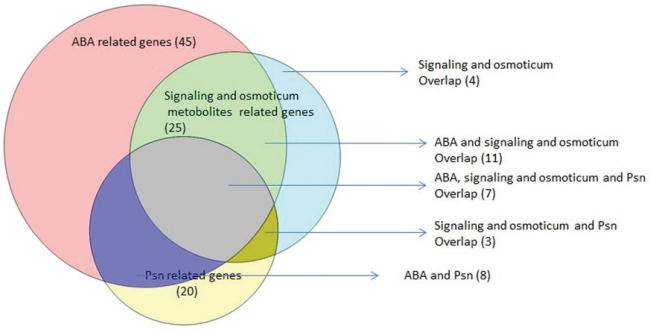


Fig. 3.14: Euler diagram based on the expression of various genes in maize under water stress

3.1.12 Genetic enhancement of pigeonpea germplasm for moisture stress tolerance

Terminal drought and heat stress coinciding with reproductive phase are serious problems in pigeonpea and cause considerable reduction in yield. Large scale screening of germplasm for moisture stress tolerance is needed to address the anticipated water scarcity in changing climatic conditions and to develop climate resilient varieties. To identify pigeonpea germplasm accessions with moisture stress tolerance, 169 pigeonpea germplasm accessions obtained from IIPR, Kanpur and NBPGR were evaluated along with check. Thirty selected germplasm accessions from previous studies of different maturity groups were evaluated in three replications under rainfed and irrigated conditions. Data on days to flower initiation, days to 50% flowering, days to pod initiation, days to 50% podding, SPAD, canopy temperature, plant height, number of primary branches, number of secondary branches, number of pods, pod weight, 100 seed weight, biomass yield and seed yield were recorded. Among the 169 germplasm accessions, days to 50% flowering ranged from 52 (AL-1757 and PUSA-2002-2) to 134 days (PSRJ-13115). Number of pods per plant ranged from 70 (C-11) to 685 (RJR -263). Pod weight per plant ranged from 21.33 (C-11 and RVK-280) to 221.33 g (RJR-263). Seed yield per plant ranged from 2.67 (AL-1778) to 149.67 g (TS-3). Test weight ranged from 5.04 (RJR-232) to 23.62 g (WRP-1).

In the replicated trial of 30 genotypes, the data on physiological parameters, yield and its contributing characters in both the treatments were compared to identify the moisture tolerant germplasm accessions. The number of pods per plant ranged from 78.17 (PAU-881) to 477.17 (GRG-815) in irrigated conditions and 71.33 (PAU-881) to 399 (RVK-274) in rainfed condition. Pod weight per plant in irrigated condition ranged from 27.83 (PAU-881) to 221.5 g (ICPL-1298) and in rainfed condition it ranged from 27.67 (PAU-881) to 194.83 g (ICPL-1298). Net photosynthetic rate ranged from 10.46 (AL-1702) to 29.23 (BAHAR) in irrigated condition and from 10.07 (GRG-815) to 23.90 (AL-1702) in rainfed condition. In irrigated condition water use efficiency ranged from 2.59 (GRG-815) to 5.21 (ASHA) and in rainfed condition it ranged from 4.13 (AL-1702) to 7.19 (BDN-2008-1).

3.1.13 Productivity of rainfed crops under enhanced carbon dioxide and its interaction with water deficit and elevated temperature

Elevated atmospheric CO_2 and warming of the earth's climate are beginning to affect different production systems including agriculture. Studies are being conducted to quantify the impact of increased atmospheric carbon dioxide concentration and its interaction with high temperature and moisture stress on productivity and quality of rainfed crops. Three pigeon pea genotypes viz., GT-1, AKP-1 and PRG-158 were assessed for biomass accumulation, seed yield and harvest index under irrigated and drought stressed conditions at flowering stage during *kharif* season. The crop, sown on 2-08-14 received 223 mm rainfall in 12 rainy days during the growth period. The irrigated plots were maintained stress free by providing irrigations during prolonged dry spells. The first spell of moisture deficit condition was imposed by withholding irrigation at flowering of first flush (41 DAS) and second spell at flowering of second flush (73 DAS).

Kharif 2014 was a drought season with prolonged rainless periods, few rainy days and low rainfall. Pigeonpea crop received 106 mm rainfall in 6 rainy days up to flowering of first flush (41 DAS). None of the first flush flowers turned into pods, even in irrigated

plots. The presented data is the yield recorded with flowering of second and third flush. The physiological and biochemical parameters were monitored during drought stress condition as well as 48 hrs after stress release and seed yield and yield components at harvest. With imposition of moisture deficit, the photosynthetic rate (A_{net}) of all the selected pigeon pea genotypes showed a decrease, ranging from 33% (PRG-158) to 43.3% (GT-1) over irrigated control. However A_{net} exhibited complete recovery once stress was relieved in PRG-158 and GT-1 while AKP-1 recovered only 80%. Among the three genotypes, PRG-158 recorded better WUE under drought stress condition as the reduction in transpiration rate (Tr) was much higher than A_{net} in this genotype.

Impact of drought stress on reproductive biomass was much higher than vegetative biomass. Among the three genotypes, the reduction of vegetative and reproductive components was less with AKP-1 followed by GT-1 and PRG-158. The reduction in total biomass with moisture deficit was 8%, 27% and 37% in AKP-1, GT-1 and PRG-158 respectively. The reduction in leaf biomass was high (38%) in PRG-158 whereas stem weight was maintained in AKP-1. The root biomass was affected by moisture deficit in all the three genotypes. Reduction in seed yield (11% to 50%) under moisture deficit condition was mainly due to reduction in pod number (17-44%) and seed number (11-46%). Moisture deficit also reduced the HI in these genotypes (3% to 21%). Among the three genotypes, AKP-1 a short-medium duration genotype with spreading growth habit and semi-determinate flowering pattern recorded significantly lower reduction in all the yield contributing characters such as pod number, pod weight, seed number, and seed yield and even higher 100 seed weight. This genotype also recorded the highest seed yield under moisture deficit condition as it could maintain higher pod and seed number than the other two genotypes.

3.1.14 Transpiration efficiency and water use variations in maize

Transpiration efficiency (TE), defined as biomass accumulation per unit water transpired, is the preferred measure for examining potential genetic variation in crop water use efficiency. Stomata control the movement of gases in and out of a leaf, make carbon dioxide available for photosynthesis, and control the loss of water from the leaf through transpiration. Gas exchange is regulated by controlling the aperture of the stomatal pore and the number of the stomata (density) that form on the epidermis. The density of the stomata determines the stomatal conductance to CO_2 and H_2O because gaseous diffusion is regulated through turgor-mediated variation in the aperture of stomatal pores.

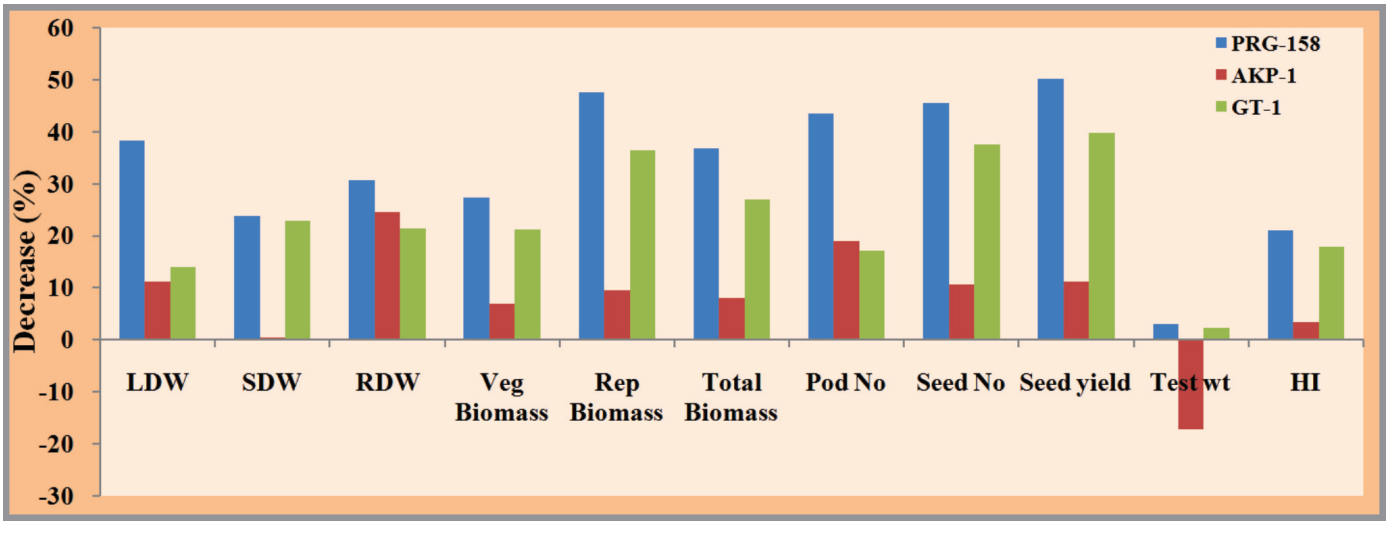
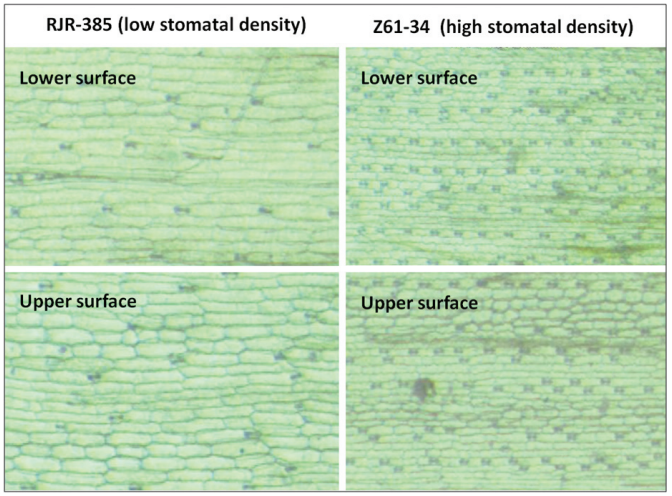


Fig. 3.15: Decrease (%) in leaf (LDW), stem (SDW), root (RDW), vegetative, reproductive and total biomass, seed yield and yield contributing characters and HI of pigeonpea genotypes with drought stress over irrigated control

One hundred maize genotypes from DMR, NBPGR, CIMMYT including two checks viz. Harsha and Varun, were evaluated to understand the variations in water use and transpiration efficiency at vegetative stage (from sowing to 40 DAS). Whole plant TE was determined by the gravimetric method. Plants were grown under well-watered condition. The middle part of fully mature leaf was selected from each genotype for counting the stomata number/mm^2 (density) on upper and lower surface of leaf. Genotypes Z32-87, Z6-34, Z59-9, DTL-2 and RJR-288 had higher number of stomata (average range: 111-130 stomata/mm2) while the genotypes RJR-42, RJR-385, HKI-1035-10 and Z96-5 had lower number of stomata (average range: 18-32 stomata/mm^2) on the lower surface of leaf. The genotypes with higher stomatal density had higher stomatal conductance, transpired more water and produced more biomass resulting in higher TE than genotypes with lower stomatal density.



Maize genotypes with low and high stomatal density

3.1.15 Effect of elevated atmospheric CO_2 concentration and high temperature on nutrient quality of dryland crops

Elevated CO_2 concentrations and temperatures under future climate change scenarios could impact food crop quality. There is a need to understand the effects of these factors on nutritional quality of food crops. As a first step, nutritional quality analysis was carried out in 9 pigeonpea genotypes grown under normal conditions to identify nutritionally superior genotypes that can subsequently be studied for effects of elevated CO_2. The 9 genotypes were analyzed for total carbohydrates and crude fiber content. Genotypes AKP-1, AL-201 and WRL had significantly higher (P>0.05) total carbohydrates ranging from 39.5 - 50 g/100 g (Fig. 3.16). Genotypes PRG-25, GT-1, AL-201and PT-002 had higher crude fiber content ranging from 8.69 - 8.71 g/100 g. Genotype WRL had the lowest crude fiber content among the 9 genotypes.

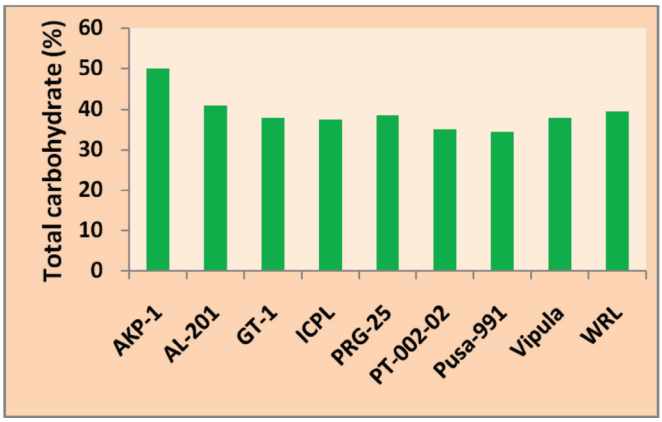


Fig. 3.16: Total carbohydrate content (g/100 g) of pigeonpea genotypes

3.1.16 Adaptation strategies through cropping systems at selected soil benchmark sites

At Varkhed watershed, during 2014, onset of monsoon was delayed by 27 days against normal onset (12th June) followed by dry spell from 3rd June to 1st July, in 2014. A seasonal rainfall (June-September) of 331 mm was received which was deficient by 401 mm compared to normal (732 mm). This affected *kharif* rainfed crops i.e. at vegetative and reproductive stages of soybean, greengram. The dry spell during 36 SMW to 41 SMW coincided with pod filling stage of soybean, late vegetative stage of pigeonpea and flowering stage of cotton. In general, crop yields were low. However, the yield of soybean with opening of conservation furrow at 35 DAS increased by 9.5% over farmer`s practice (no conservation furrow). Higher soybean yield with conservation furrow was recorded on very fine smectitic, calcareous Typic Haplusterts (824 kg/ha) as compared to fine smectitic, calcareous Typic Ustochrepts (785 kg/ha) and fine smectitic, calcareous Vertic Ustochrepts (731 kg/ha).

Vertic Haplusterts

Vertic Ustochrepts

Performance of soybean with conservation furrow in different soils

3.1.17 Quantitative assessment of potential positive impacts of long-term conservation agricultural practices on climatically resilient soil parameters in rainfed Alfisols

Soils in the rainfed regions suffer due to deterioration of soil quality resulting in low yield of crops. The anticipated climate change may further influence soil processes and functions and adversely affect the crop yield. Restorative management practices such as minimum tillage, surface residue application and stubble retention may help in providing resilience towards climate change by way of higher moisture retention, reducing soil temperature, influencing soil quality indicators and improving soil quality. An experiment with surface application of 4 levels of sorghum residues @ 0, 2, 4, 6 t ha^{-1} in combination with N (30 kg N ha^{-1} for cowpea and 60 kg N ha^{-1} for sorghum through urea) and uniform dose of 30 kg P_2O_5 ha^{-1} (through super phosphate) with minimum tillage, was initiated in 2005 at Hayathnagar research farm of CRIDA. The system adopted for this study was sorghum-cowpea with yearly rotation. In 2014, cowpea was grown as the test crop.

Cowpea grain yield varied from 208 to 537 kg ha^{-1} and was considerably low as a result of late sowings due to delayed monsoon and erratic low rainfall. Significantly higher cowpea yield (538 kg ha^{-1}) was observed with application of sorghum stover @ 6 t ha^{-1} followed by @ 4t ha^{-1} (328 kg ha^{-1}) and 2 t ha^{-1} (296 kg ha^{-1}) compared to control (208.7 kg ha^{-1}). The increase in yield due to application of sorghum stover @ 6, 4 and 2 t ha^{-1} was to the extent of 158%, 57% and 40% respectively over no residue application.

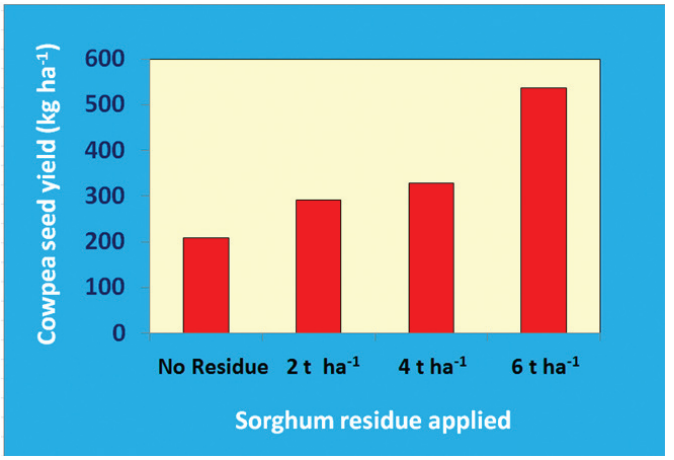


Fig. 3.17: Effect of graded levels of sorghum residue on yield of cowpea under minimum tillage

Penetration resistance or soil compaction measured with penetrometer at 21 DAS and after harvest of the crop showed that soil compaction was significantly lower with application of sorghum residue @ 6 t ha^{-1} at all the depths measured (0-10 cm). Water infiltration rate measured using double ring infiltrometer showed that the infiltration rate in these soils varied from 156 to 246.5 mm/hr. Application of sorghum residue at 6 t ha^{-1} significantly increased the infiltration rate by 58% over control. Increase in infiltration rate with 2 t and 4 t ha^{-1} was 21% and 27% respectively over control or no residue application.

3.1.18 Mitigation of climate change through conservation agriculture in rainfed regions of India

A study was initiated at HRF, CRIDA to assess the potential of conservation agriculture practices like different tillage practices, quantity of residue, and its management for increasing the productivity and profitability of pigeonpea and castor system in rainfed Alfisols and to assess the role of CA practices on mitigation of climate change through reducing GHG emissions and carbon sequestration. Pigeonpea and castor were grown with different tillage practices -conventional tillage (ploughing once with disc plough, cultivator, disc harrow and sowing), reduced tillage (ploughing once with cultivator and disc harrow), zero tillage (direct sowing in residues), and different residue levels achieved by managing the harvesting heights (0 cm, 10 cm and 30 cm).

At the end of four years, soil organic carbon with conventional tillage decreased in 0-7.5 cm,7.5 -15 cm depth as compared to initial carbon content whereas in reduced tillage decrease was observed only in surface layers (0-7.5 cm). In zero tillage, soil organic carbon increase was observed up to 15 cm depth as compared to initial. Zero tillage recorded higher organic carbon in all the depths as compared to CT and RT. Soil organic carbon was higher with 30 and 10 cm harvest height as compared to 0 cm harvest height. Algal growth was observed on the soil surface in zero tillage treatments and showed increase with each year. The species was identified as green and blue green algae. Fluxes of CO_2, N_2O and CH_4 were measured using a vented insulated non steady state closed chamber technique. In conventional tillage, immediately after tillage there was increase in CO_2 emissions for a period of four to five days but later it decreased. Similar increase in CO_2 emissions were observed in reduced tillage after land preparation with cultivator. CH_4 and N_2O fluxes were also influenced by the tillage and residue levels. CH_4 absorption was observed in conventional tillage but methane emission was observed in zero tillage. Higher N_2O fluxes were observed after fertilizer application. Cumulative seasonal N_2O fluxes were influenced by tillage and residue heights. N_2O fluxes in conventional and reduced tillage were on par with each other but these two treatments recorded 20% higher fluxes as compared to zero tillage. Higher CO_2 and N_2O fluxes were observed in 10 cm anchored residue height but CH_4 absorption was observed at 30 cm harvest height.

The carbon footprint of conservation agriculture and conventional tillage was estimated. Total carbon foot print (CF) from various practices like decomposition of crop residues, application of synthetic N fertilizers, field operations, and input (fertilizer, pesticides) production were estimated. Emission factors were used to estimate the total CF. On an average the contribution of direct N_2O emissions to total GHG emissions was 56 and 62% in castor and pigeonpea, respectively. The CF (considering GHG emissions from operation use and input use) was lower by 23 and 9% in ZT and RT over CT. Yield scaled and spatial CF was influenced by tillage and residue treatments. Reduced tillage with 10 cm anchored residue recorded lower yield scaled CF (0.90 kg CO_2 eq. kg^{-1}). Further, castor grown on pigeon pea residue recorded 20 percent higher GHG emissions over pigeon pea grown on castor residues. Fuel consumption in ZT was reduced by 58 and 81 percent as compared to CT in pigeon pea and castor, respectively. The results of the study indicate that, there is scope to reduce the CF by reducing one tillage operation (RT) with harvesting at 10 cm height with minimal impact on the crop yields.

Tillage implements and GHG fluxes

Field CO_2 emission, fuel consumption and fuel derived CO_2 emissions with different tillage implements were measured. GHG fluxes from soil were influenced by the type of the implement used for land preparation. Tractor drawn MB plough + disc harrow, rotavator and disc plough + disc harrow recorded higher CO_2 and N_2O fluxes as compared to cultivator. No tillage and bullock drawn plough recorded lower emissions as compared to tractor drawn implements as the depth of ploughing was more in tractor drawn implements. Methane absorption was observed in all the tillage treatments whereas in zero tillage, methane emissions were observed. Higher methane absorption was observed in tractor drawn MB plough +disc harrow, rotovator and disc plough + disc harrow as compared to bullock drawn harrow. Fuel consumption and fuel derived CO_2 emissions varied with the type of the implement and soil moisture content. Tractor drawn disc plough + disc harrow recorded highest fuel consumption (25.1 liters/ha) and fuel derived CO_2 emissions (89.63 kg CO_2/ha) closely followed by MB plough+ disc harrow. Rotavator and cultivator recorded lower fuel consumption and fuel derived CO_2.

3.1.19 Effect of conservation agriculture practices and balanced fertilization on productivity and nutrient use efficiency in maize (*Zea mays* L.)-horsegram (*Macrotyloma uniflorum* L.) cropping sequence in rainfed Alfisols

Conservation agriculture (CA) can play a major role in stabilizing production in rainfed regions by mitigating water and nutrient stress through adoption of reduced tillage, crop rotations and residue retention and also improve nutrient use efficiency.

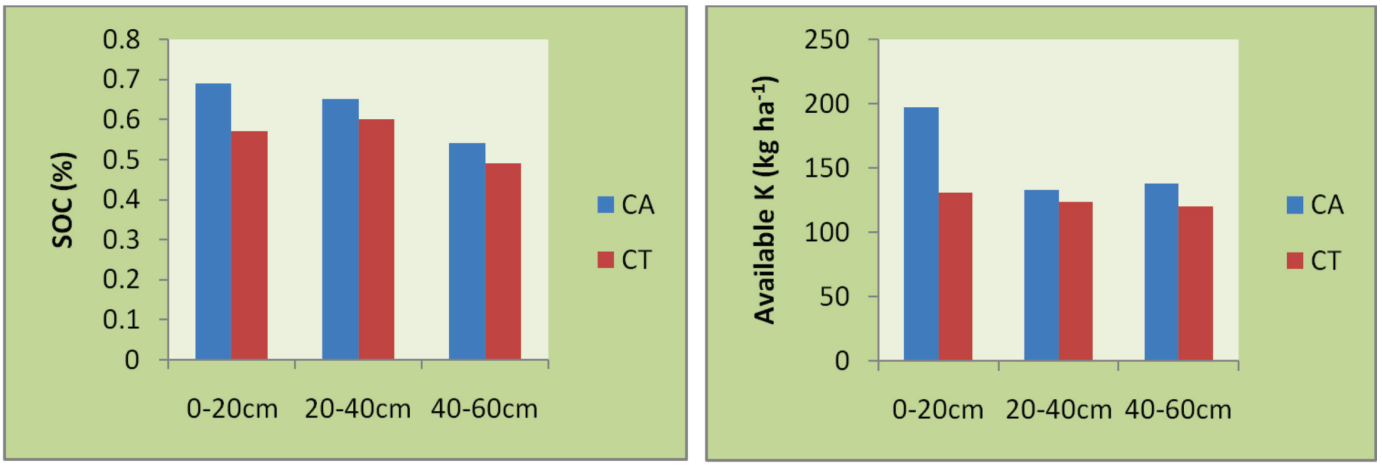


Fig. 3.18: Effect of CA on soil organic carbon and available K

A field experiment was started in 2012 on sandy loam soil of Gunegal research farm of CRIDA to study the effect of CA practices and balanced fertilization on performance of maize -horsegram cropping sequence, and the impact of CA on soil properties. In 2014-15, plant population was very low due to drought. Further, due to severe water stress during grain development and grain filling stage, there was no economic yield. Soil organic carbon (SOC) was improved by practicing CA (0.69%) compared to conventional practices (CT) (0.57%) (Fig. 3.18). There was a buildup of available K in all the depths due to CA practices.

3.1.20 Soil carbon sequestration strategies for improving soil health, productivity enhancement, enhancing nutrient use efficiency and reducing GHG emissions in rainfed production systems of India

Application of locally available organic manures along with chemical fertilizers is important for yield sustainability of rainfed crops as well as enhancing soil carbon status which is an important GHG mitigation strategy. Curtailing depletion and enriching SOC stock are essential to improve the use efficiency of nutrients, buffering agro-ecosystems in harsh climates, and stabilizing agronomic productivity. Profile soil samples up to the depth of 1 m were collected in the year 2011-12 from 10 ongoing long term experiments on integrated nutrient management under the aegis of All India Coordinated Research Project for Dryland Agriculture (AICRPDA) to identify better carbon sequestration strategies in different agro ecological regions of India and determine the critical carbon input requirement for zero change in carbon with locally identified organic resources under rainfed agriculture.

Soil samples were collected from ongoing long term experiments at Kovilpatti, Rajkot, Arjia and Rewa. Soil samples were analysed for pH, EC, macro and micro nutrients, carbon pools and enzyme activities. The thirteen year long term nutrient management experiment at Rewa in Madhya Pradesh assessed for carbon dynamics in rice system showed that microbial biomass carbon (MBC) was significantly higher in surface layer (0-20 cm) under 50% N (Urea) + 50% N (Compost) + Azotobacter treatment. The carbon (SOC) sequestration (Mg/ha) was higher in 100% N (Compost).

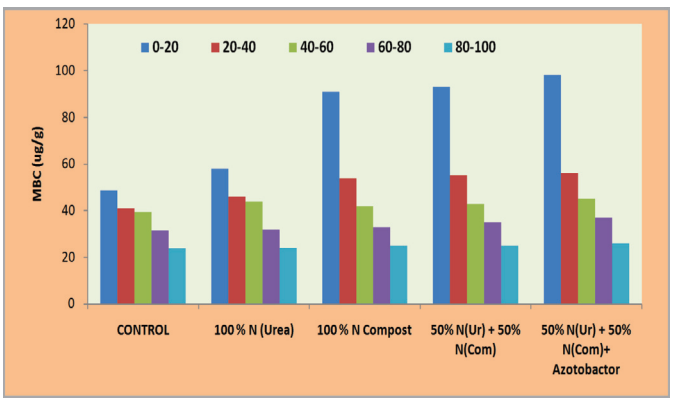


Fig. 3.19: MBC as influenced by 13 years long cropping and nutrient management in Rice based system (Rewa, Madhya Pradesh)

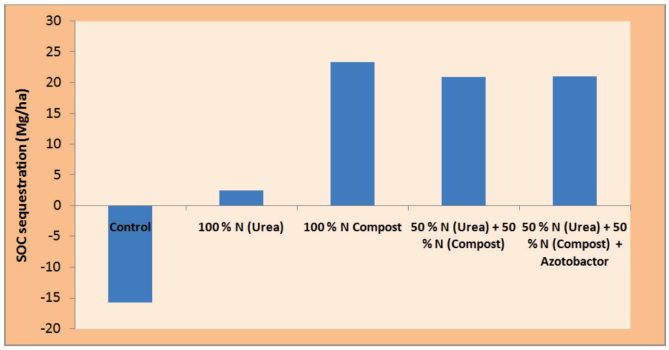


Fig. 3.20: Soil carbon sequestration (Mg/ha) after 13 years long term cropping and nutrient management in Rice (Rewa, Madhya Pradesh) based system

3.1.21 Role of plant roots in soil C sequestration

The study was initiated in 2011 to understand the role of plant roots in sequestering carbon in soil. In *kharif* 2014, two varieties each of cowpea (C 152 and APFC 10-1) and horse gram (CRIDA 18 R and CRHG 4) were grown in 100 L plastic containers filled with ~120 kg red sandy loam soil. Root systems of the plants were extracted by washing away the soil in the containers with a jet of water. Roots were extracted at two stages, maximum biomass stage (late flowering) and crop maturity. After washing away the soil, root and shoot portions were separated, dried and weighed.

Shoot:root ratios at maximum biomass stage were higher for horse gram compared to cowpea (Fig. 3.21). Roots of both the varieties of each of the crops had lower soluble fraction and higher fibre fraction, especially recalcitrant fraction - lignin, compared to shoots (Fig. 3.22), suggesting that roots may decompose more slowly in soil than shoots.

Cowpea varieties grown in containers

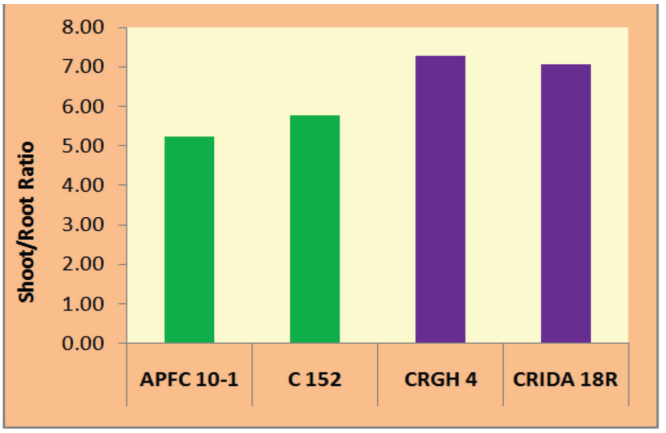


Fig. 3.21: Shoot: root ratios of cowpea and horse gram at maximum biomass stage

Fig. 3.22: Biochemical composition of roots and shoots of cowpea varieties

3.1.22 Potential of organic crop production as a climate change adaptation and mitigation strategy in rainfed agriculture

Organic agriculture is one of the fastest growing sectors of agricultural production, and is reported to have both climate change adaptation and mitigation potential particularly in rainfed agriculture. A field experiment was conducted during *kharif* 2014 at Gunegal research farm of CRIDA to evaluate the performance of sunflower, green gram and pigeonpea under organic, inorganic and integrated crop management systems. The experiment was laid out in a strip-plot design with three production systems and three crops. In the plots under organic management, farmyard manure was applied on N equivalent basis to all the three crops and the P requirement was supplemented through rock phosphate. In the plots under integrated management, 25% of recommended N was applied through farmyard

manure. The remaining 75% N and 100% P and K was applied through chemical fertilizers. The plots under inorganic management received recommended dose of chemical fertilizers.

In general, the performance of sunflower and green gram was poor across different treatments due to less rainfall (242 mm) during crop season with 4 dry spells of more than 10 days. Integrated management gave higher yield of sunflower and green gram compared to organic and inorganic management. The plots under organic management produced 7.2 and 7.3% lower seed yield of sunflower and green gram compared to integrated treatment, respectively (Fig 3.23). However, the yields of both sunflower and green gram were similar under inorganic and organic treatments. Pigeonpea crop failed due to low rainfall during October (50 mm) and November (19 mm) months and no rainfall during December.

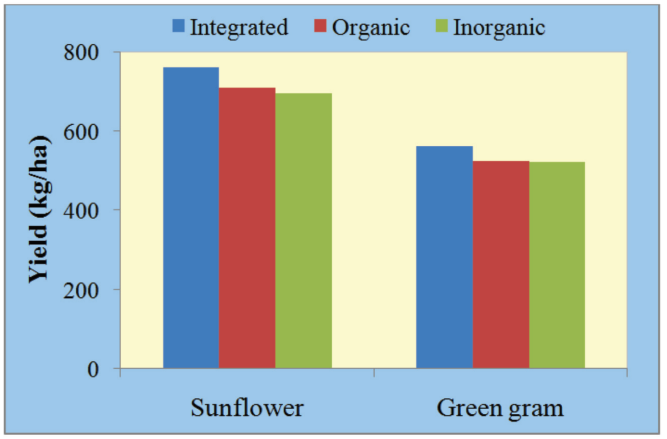


Fig . 3.23: Performance of green gram and sunflower under different production systems

3.1.23 Impact and scope for enhanced adaptation strategies for climate resilience in horticultural crops through improved management practices

One of the approaches for adaptation of tree crops for climate induced stress is how best we can make use of available moisture in the soil in order to reorient their root systems for optimum crop growth under less moisture availability situations. On farm trials were initiated in this direction in order to economize on supplemental irrigation water with different moisture deficit situations in citrus and mango. Available weather data from FRS, Sangareddy and Horticulture College and Research Institute, Anantharajupeta, Kodur were collected for different mango hybrids and cultivars. Attempts were made to correlate the yields in terms of number of fruits and fruit wt (kg/plant) with total rainfall during different sets of months where the active differentiation process might have been initiated, viz. 1. June-- August 2. July-- September 3. August-- October 4. June-- October. A rainfall of 171.5 mm during June, July and August produced maximum yields (307.1 kg/plant) in Neeleshan hybrid variety and a rainfall of 551.7 mm during the above months produced a yield of only 36.22 kg/plant.

Soil microbial activity for enhanced climate resilience

Improving soil microbiological activity is one of the adaptation strategies for climate change. Rhizosphere soil samples collected from guava, custard apple and mango under different nutrient treatments were analyzed for microbial counts by serial dilution method using specific media, Jenson's N free medium for *Azotobacter*, N free malate medium for *Azospirillum*, Pikovskaya's for P-solubilizing bacteria and specific medium for *Trichoderma*. In custard apple soil samples, treatment with 100 kg FYM showed highest azotobacter count followed closely by 50% CHEM+Azt and 100 kg FYM+Azt treatments. All the inoculated treatments had higher PSB counts as compared to respective uninoculated treatments. Treatments with chemical fertilizers (both 50% and 100% chemicals) showed lower PSB counts as compared to absolute control treatment. Treatments with 100% chemicals showed lower PSB counts as compared to 50% chemical treatments indicating the negative effect of higher chemical dose on PSB counts. Highest PSB count was observed in treatment with 30 kg FYM+PSB. All treatments showed higher *Trichoderma* counts as compared to absolute control. Highest counts were observed in treatments 200 kg FYM and 150 kg FYM+Tri. Similarly all the treatments showed higher *Azospirillum* counts as compared to absolute control with maximum counts in treatment 150 kg FYM+Azo followed by 50% CHEM+Azo and 100 kg FYM+Azo.

In Guava, except for 200 kg FYM, all the treatments under inoculation showed higher *Azotobacter* counts as compared to respective control treatments. However

Table 3.4: Allometric relationships ($Y= aCD^b$) developed by regression of various biomass variables on collar diameter (CD) in Jatropha

Tree parameter	a	b	R^2	F ratio significance
Leaves dry biomass (kg/plant)	0.194	0.715	0.954	144.78**
Stem dry biomass (kg/plant)	0.019	2.036	0.900	108.28**
Branches dry biomass (kg/plant)	0.015	2.063	0.907	116.95**
Above ground dry biomass (kg/plant)	0.091	1.725	0.976	565.8**
Below ground dry biomass (kg/plant)	0.138	1.158	0.932	191.78**
Total above and below ground dry biomass (kg/plant)	0.197	1.559	0.971	472.83**

** - Significant at 1% level

treatments with 50% and 100% chemical showed lower counts as compared to FYM treatments. Not much difference was observed in *Azotobacter* counts under different levels of FYM treatments. PSB counts in chemical treatments were low as compared to absolute control. However inoculation improved PSB counts in the presence of 100% chemical. *Trichoderma* and *Azospirillum* counts were higher in all the treatments as compared to absolute control. Highest *Trichoderma* count was observed in treatment with 100% CHEM+Tri followed by 150 kg FYM sole. Highest *Azospirillum* count was observed in treatment 30 kg FYM sole followed by 50% CHEM+Azo.

3.1.24 Role of bio-fuel crops in rural energy supply and GHG mitigation

Use of biofuels alternatively or in combination with fossil fuels has been gaining momentum as biofuels reduce GHG emissions and biofuel crops have the potential to sequester atmospheric CO_2. A study is in progress since 2011 to develop allometric equations and to quantify the C sequestration potential of biofuel crops in drylands. In the current year, recording of growth data, development of allometric equations in Jatropha and measurements of GHG emissions in 10 yr old plantations of Pongamia, Simarouba and Jatropha was done.

Allometric equation in Jatropha

A power function of the form Biomass = aX^b, where 'X' is a predictor (collar diameter), 'b' is a scaling exponent or allometric coefficient and 'a' is an intercept, was used to establish the relationship between collar diameter and biomass of eight year old Jatropha plantation grown on rainfed Alfisols.

Results of the regression relationship between the collar diameter and various biomass variables of Jatropha showed that collar diameter explained much of the variation in above ground total dry biomass, belowground total dry biomass as well as total dry biomass (above + below) and the relationships were found to be significant. Root biomass (dry) along with leaf, stem and branch also showed strong relationship with the collar diameter.

GHG Emissions

Pongamia, Jatropha and Simarouba plantations established in 2004 were selected for the study. The closed chamber (or enclosure) technique, which is the most widely used method of assessing surface-to-atmosphere GHG (CO_2, CH_4 and N_2O) fluxes in agroforestry systems, was followed. Soil-atmosphere exchange of greenhouse gases was determined periodically by collecting gas samples from the chambers and measuring the change in concentration of the gas with time during the period of linear concentration change. Initial results indicate that among the three biofuel species, Jatropha recorded highest values for GHG emissions followed by Simarouba and Pongamia. In general, the GHG emissions were higher in rainy season compared to winter season. Litter fall was recorded and found to be 2.25 t/ha/yr, 7.5 t/ha/yr and 11.2 t/ha/yr respectively in Jatropha, Pongamia and Simarouba plantations.

GHG measurement in Simarouba plantation

3.1.25 Prediction of pest scenarios of *Spodoptera litura* Fab. on peanut using life table approach

Studies were conducted to understand the direct effects of rising temperature and host –mediated effect of elevated CO_2 (eCO_2), on *Spodoptera litura* (Fabricius) (Noctuidae: Lepidoptera). This study involved i. the construction of life tables of *S. litura* reared on peanut *(Arachis hypogaea* L.) grown under 380 ppm ambient CO_2 (aCO_2) and 550 ppm elevated CO_2 (eCO_2,) at six constant temperatures viz., 20, 25, 27, 30, 33 and 35 °C ± 0.5°C ii. Estimation of threshold temperatures and thermal constants and iii. Prediction of the pest scenarios during near and distant future climate change periods. The mean development time (days) of each stage, egg, larva, pupa, pre-oviposition and total life span decreased with increase in temperature from 20 to 35°C. The thermal requirement of S. litura from egg to egg (within the range of 20°C to 35°C) was 538.50 DD in larvae fed with eCO_2 foliage as against 494.51 DD in larvae fed with aCO_2 foliage. Finite (λ) and intrinsic rates of increase (r_m), net reproductive rate (R_o), mean generation time (T) and doubling time (DT) of S. litura varied significantly with temperature and CO_2 and were found to have quadratic relationship with temperature.

The data on life table parameters were plotted against temperature and two non-linear models were developed for the two CO_2 conditions and used for predicting the pest scenarios based on PRECIS A1B emission scenario data at eleven peanut growing locations of the country during near future (NF) and distant future (DF) climate change periods. Results showed increased 'r_m' and 'λ' with variable 'R_o' and reduced 'T'. The results of per cent change in predicted life table parameters during NF and DF scenarios over baseline are depicted in Fig. 3.24. The per cent change in 'r_m'

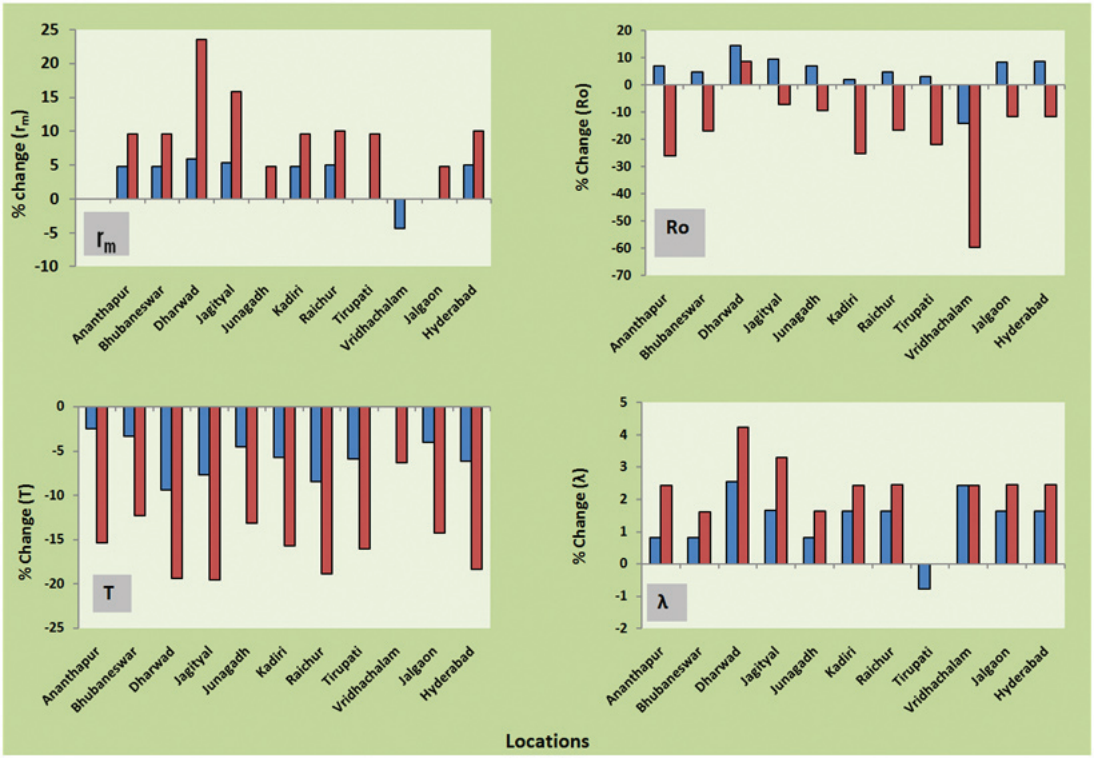


Fig. 3.24: Per cent change over baseline in pest scenarios during near and distant future climate change period

was higher at majority of the locations in both NF (up to 6%) and DF (up to 23%) scenarios. The 'R_o' is expected to increase moderately in NF (14%) and decrease in DF (-26-60 %) scenarios at all locations. Reduction of generation time 'T' is expected to be higher in DF (19%) than NF scenario (1-9%). At majority of locations, λ was expected to increase in both NF and DF periods. These results suggest that temperature and CO_2 are vital in influencing the growth and life table parameters of S. *litura* and that pest incidence is likely to be higher in the future.

3.1.26 Impact of elevated CO_2 on Aphids (*Aphis craccivora* Koch) on peanut

Experiments were conducted to quantify the impact of elevated CO_2 on Aphids *Aphis craccivora* Koch on peanut. The plants were grown under ambient (380 ppm - aCO_2) and elevated (550 ppm - eCO_2) CO_2 conditions in open top chambers (OTCs). Results indicated that the adults produced more number of off spring when fed on peanut leaves obtained from eCO_2 condition. The number of nymphs laid per female was significantly higher at eCO_2 than aCO_2. Fecundity was 33.3% higher under eCO_2 over aCO_2. Data were recorded on production of winged or alate forms of aphids under eCO_2 condition across five generations (Fig 3.25). Higher number of alate aphids was recorded under eCO_2 condition than the ambient and this was more evident during 3rd -5th generations.

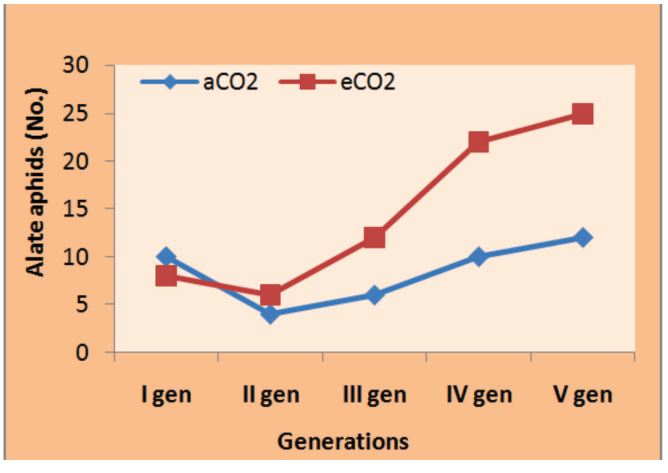


Fig. 3.25: Impact of eCO_2 on alate forms of *Aphis craccivora*

3.1.27 Studies on pest population dynamics

a) Effect of temperature on development of insect pests

Pigeonpea hairy caterpillar: The development of the hairy caterpillar *Euproctis subnotata* (Walker) was studied at seven constant temperatures, viz., 15, 18, 20, 25, 27, 30, 31 and 33±1°C. Developmental durations of egg, larva, pupa showed linear decreasing trend till 30°C and nonlinear response was observed at 31°C for total larval period. At 33°C egg hatching was not observed and development of larval stage ceased at IV instar. Developmental duration was longer at 15°C.

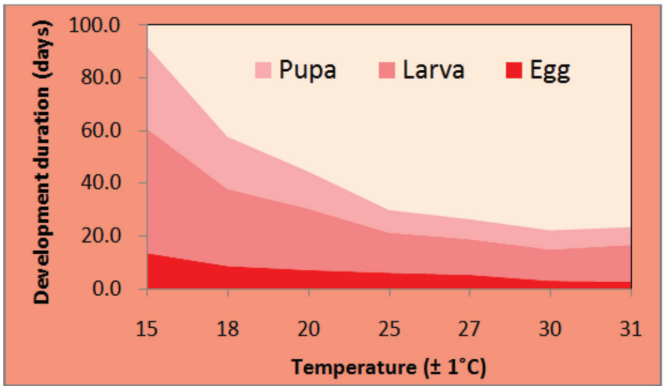


Fig. 3.26: Development duration of immature stages of hairy *caterpillar* at different constant temperatures

Maize aphid: The effect of temperature on the development, survival and fecundity of maize aphid *Rhopalosiphum maidis* (Fitch) was studied at eight constant temperatures 15, 18, 20, 25, 27, 30, 32 and 33±1°C on maize leaves. Total nymphal development showed a linear decreasing trend till 25°C and a nonlinear response was observed at 27°C. Longest developmental period was observed at 15°C (12.96 days) and shortest was observed at 30°C (5.1 days).

Groundnut thrips (*Scirtothrips dorsalis*): Thrips (*Scirtothrips dorsalis*) development on groundnut was studied at three different constant temperatures viz., 20, 25 and 30°C. Developmental duration decreased with increase in temperature for 1st instar, whereas for pre pupal, pupal and total nymphal periods non linear relation was observed at 30°C.

Groundnut thrips (*Caliothrips*): Thrips (*Caliothrips*) development on groundnut was studied at five different

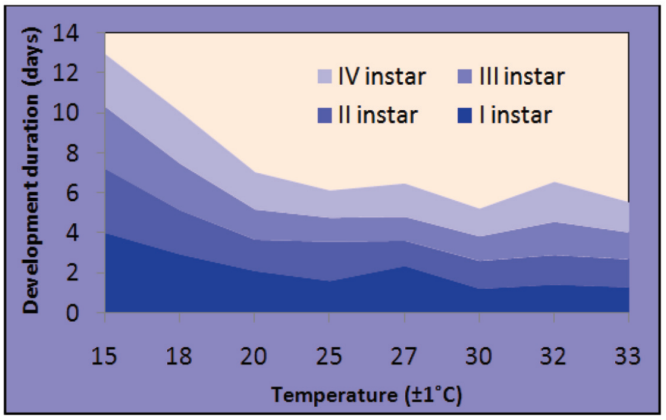


Fig. 3.27: Development duration of immature stages of maize aphid at different constant temperatures

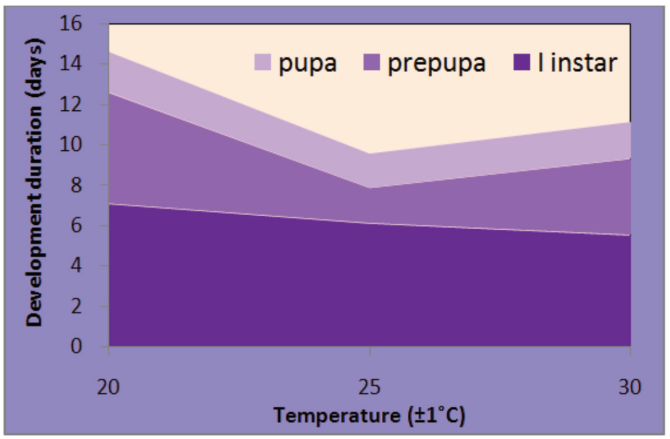


Fig. 3.28: Development duration of *Scirtothrips dorsalis* at different temperatures

constant temperatures viz., 20, 25, 27, 30 and 32°C. Developmental duration decreased with increase in temperature for 1st instar, whereas for pre pupal, pupal and total nymphal periods non linear relation was observed at 27°C.

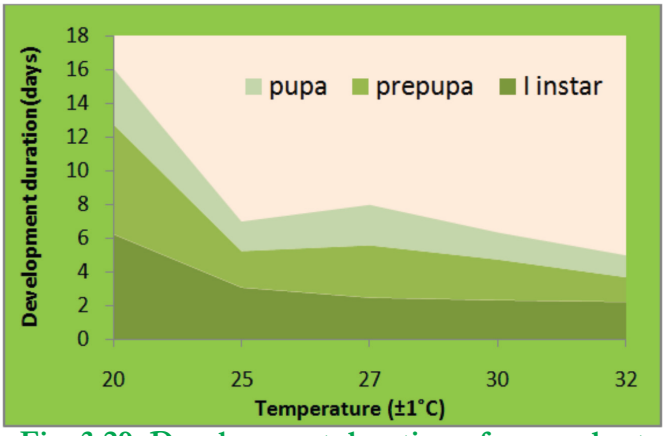


Fig. 3.29: Development duration of groundnut thrips (*Caliothrips*) at different constant temperatures

b) Field population dynamics of pigeonpea pod borer

Field incidence data of pod borer (*Helicoverpa armigera* Hubner) on pigeonpea varieties PRG 100 and BDN-2004-3 were collected during *kharif* 2014 at Hayathnagar research farm, CRIDA. The crop area was kept unsprayed throughout the season. The data on field incidence of pod borer was collected on 25 randomly selected plants at biweekly intervals from flower initiation to harvest. Peak pest incidence was observed at 47th standard week on PRG 100 variety.

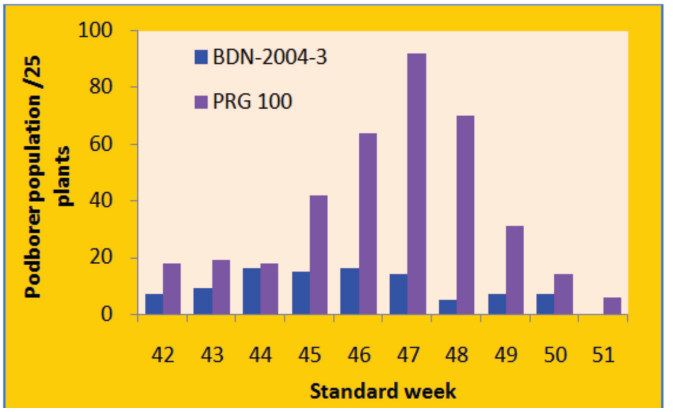


Fig. 3.30: Field incidence of pod borer on pigeonpea varieties PRG 100 and BDN-2004-3

3.1.28 Developmental durations of groundnut aphid and castor semilooper

Groundnut aphid *(Aphis craccivora)*

Staggered sowings of the groundnut varieties Narayani and K6 were taken up starting from July 2014 at fortnightly intervals at Hayathnagar research farm. Groundnut aphid (*Aphis craccivora*) adults were collected from these fields and maintained as stock culture. After passing through one complete generation, the freshly laid nymphs were collected and used for temperature studies. The nymphs were shifted to individual Petri dishes and maintained at five constant temperatures (15, 20, 25, 27 and 30±1°C) with 60±10% RH and 12:12 h photoperiod in environmental growth chambers. Fresh groundnut leaves were provided daily to the nymph. A visible exuvia was used as evidence of moulting in the nymph. Observations were recorded daily on survival and developmental time of each instar of nymph until the adult formation. Data were

also collected on fecundity of the adults developed at each temperature. The lower temperature threshold (T_{min}) and thermal constant (K) for the development of various nymphal stages of groundnut aphid were estimated from linear regression of Campbell model. The T_{min} values ranged from 3.3 to 7.5°C and the thermal constants ranged from 21.1 to 28.2 degree-days. The scatter plot of adult longevity at different constant temperatures revealed no significant effect of temperature on adult longevity (Fig. 3.31).

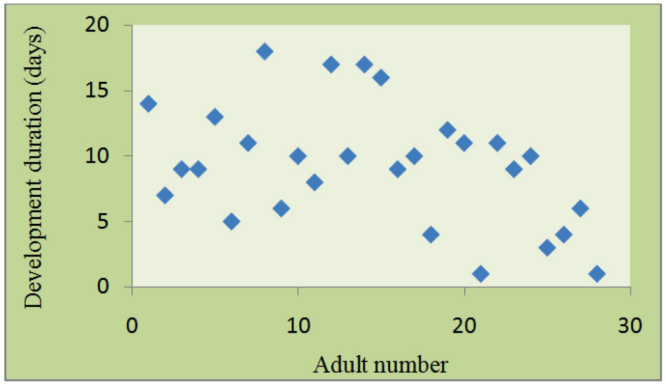


Fig. 3.31: Scatter plot of developmental duration (days) of adult aphid at 27°C

Castor semilooper *(Achaea janata)*

Experiments were carried out to study the effect of temperature on the growth and development of castor semilooper, *Achaea janata* at seven temperatures (18, 22, 25, 27, 32,34 and 36±1°C) in environmental growth chambers set at of 60±10% RH and 12:12 h photoperiod. The total number of eggs hatched at each temperature and duration of egg and larval development was observed at each temperature. Observations were recorded daily on the the survival and developmental time of each larval instar, pupa, until adult emerged. Results indicated that Campbell linear model was fitted in the linear temperature range of developmental rate of *A. janata*. The lower temperature thresholds for immature life stages ranged from 1.7 to 11.1°C, and the thermal constant values ranged from 25.6 to 59.7 degree-days. The toal growing degree days for *A. janata* from egg to pupal stage was about 534.

Table 3.5: Thermal constants and developmental thresholds for castor semilooper

	Larva	Pre Pupa	Pupa	Total pupa	Total DD
T min	7.27	5.37	13.96	12.98	-
Thermal constant (k)	261.10	53.33	136.05	182.48	632.96

3.1.29 Impact of climate change on plant pathogens

Effect of 550 ppm levels of CO_2 and temperature were studied on *Sclerotium rolfsii,* a devastating soil-borne plant pathogen infecting several field crops. Observations were recorded on variability in biomass, morphology and pathogenicity over 50 generations (G), at an interval of 10G. These studies were carried out in 250 ml flasks, inoculated with 5 active sclerotia and incubated for 15 days. The biomass was collected and dried in hot air oven until constant mass of the pathogen. Even after 50 generations, there was no significant change in drymass (Fig 3.32). Similarly the exposure to 550 ppm levels of CO_2 did not significantly alter the size of scelrotia, which ranged from 0.8 to 1 mm.

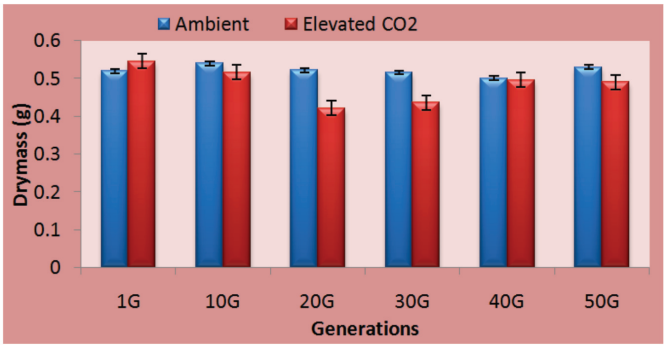


Fig. 3.32: Effect of CO_2 on drymass of *Sclerotium rolfsii* over generations

Pot studies were carried out to study the pathogenicity of *Sclerotium rolfsii* over generations from 1st to 50th G with an interval of 10G under ambient (380 ppm) and elevated CO_2 (550 ppm) conditions. Groundnut cv. Narayani was used for the experiment. Pots were filled with sterile soil and 3% redgram (leaf + stem) powder to serve as organic matter. Five sclerotia per seed were added and the seeds were sown to assess the rate of southern blight. Rate of sclerotial germination was checked, before the onset of the studies. Disease

progress was recorded over time. The infection started earlier in cultures exposed to elevated CO_2 i.e. by 3rd day itself whereas in control, the infection started by 6th day. However, by 12th day, disease progress became uniform across generations (Fig 3.33).

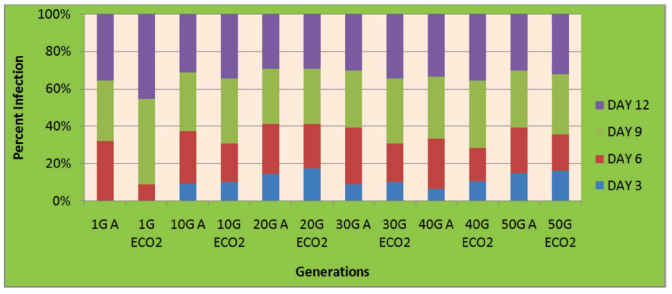


Fig. 3.33: Effect of CO_2 on pathogenicity of *Sclerotium rolfsii*

Similarly, effect of elevated CO_2 on pathogenicity of castor wilt pathogen *Fusarium oxysporum* f. sp. *ricinii* was studied. Castor seedlings were infected by root dip method with a concentration of 1x106 cfu/ml and sown in sterile soil and observed for the infectivity followed by disease development. The infectivity of the pathogen until 9 days after inoculation did not vary but thereafter the disease started progressing faster in culture exposed to elevated CO_2 as compared to control strain (Fig 3.34).

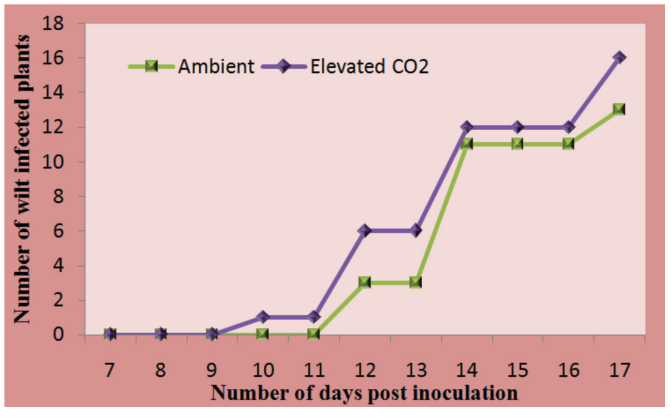


Fig. 3.34: Effect of CO_2 on pathogenicity of *Fusarium oxysporum* f. sp. *ricini*

3.1.30 Adaptive management of small ruminants under grazing conditions to climate change

Small ruminants play significant role in supporting the livelihood system of the poor people, especially in the marginalized rainfed areas. Climate related calamities have been increasing in the recent past causing severe fodder shortage, severely affecting the productivity in small ruminants. Experiments were conducted to identify the physiological indicators of stress in grazing small ruminants and to develop consolidated adaptation strategies under grazing conditions. In one experiment 24 grazing lambs (6 each Nellore and Deccani breed rams and ewes) were studied at HRF for live weight gain dynamics in relation to their blood metabolites (glucose, cholesterol, triglycerides, total protein, creatinine and urea) over a period of one year to assess the critical period for production in small ruminants. Live weight gain was recorded at fortnightly intervals. Five ml blood was collected from the jugular vein from all the animals and blood samples were brought to the laboratory in ice immediately after collection. Serum was separated by centrifugation and upper plasma layer was separated for biochemical assay and stored at –20^{0}C until assay.

Average daily gain (ADG) and weight gain were found to be higher from June to November and lower during March to May period of the year due to non-availability of sufficient fodder in grazing lands in addition to heat stress in the later period (Fig 3.35). Blood glucose, cholesterol, triglycerides and total protein were significantly higher during rainy season compared to summer. Higher creatinine and blood urea nitrogen during summer indicated that the animals were under stress. Among the breeds, Nellore cross was more resilient than Deccani, and among the sexes, female animals were less resilient to adverse climatic conditions as a result of additional stress caused by physiological activities related to production and reproduction.

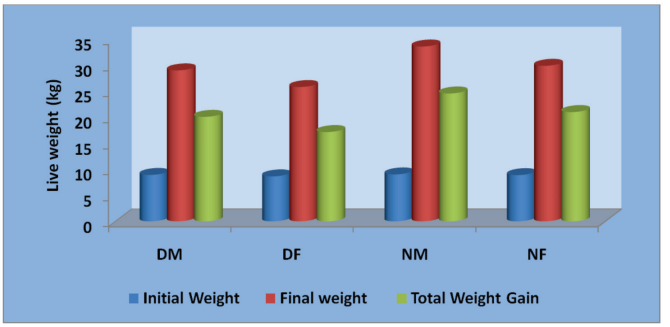


Fig. 3.35: Average weight gain in experimental grazing lambs during different periods of the year

In another experiment, 8-9 months old Deccani (20.8±4.32 kg) and Nellore (19.6±2.16kg) rams were studied to assess their heat tolerance. After two days of adaptation, animals were exposed in a climate chamber for a period of 7 days to heat stress followed by 2 days of thermo-neutral (stress free) conditions. Subsequently, the rams were removed from the climate chamber and were housed in an open-sided shed for 7 d, during which time they were exposed to natural ambient conditions. Physiological responses (Rectal temperature (RT), body temperature, respiration rate (RR) and panting score) of animals as recorded. Five ml blood was collected from the jugular vein from all the animals in lithium heparin coated vaccutainer for biochemical analysis. Blood samples were collected on days 2, 6 and 11. Serum was separated by centrifugation and upper plasma layer was separated for biochemical assay and stored at –20°C until assay for concentrations of glucose, total protein, cholesterol, creatine, etc, and cells for HSPs. Temperature and humidity data from data loggers were recorded daily and THI was calculated using average of hourly data as THI = T°F – [0.55 – (0.55 x RH/100)] x (T°F – 58)

The mean ambient temperature and RH ranged from 28.6-40.8°C and 75-50.1%, respectively in the climate chamber. The body temperature and rectal temperature of Deccani rams gradually increased as THI increased from 80.0 to 92.8 in the morning to noon and decreased towards the evening as THI decreased (83.5) (Fig 3.36). However, the increase in body and rectal temperature was relatively prominent on day one of exposure to stress and by 7th day most of the rams were able to acclimatize to climatic variability to some extent. This resulted in relatively lower increase in body and rectal temperature although THI increased towards the end of the experimental period. Respiration and pulse rates of rams also showed a similar trend. Open mouth panting with panting score of 3 was observed in rams when the mean ambient temperature increased to 40.8°C and THI was 92.8. Significant difference was observed in feed intake of rams during first 3 days of exposure but later on not much variation was observed. Concentration of blood glucose, cholesterol and total protein was higher on day 2 and lower on day 6, but not significantly different when compared to day 11, indicating that animals had become acclimatized to stress to some extent. Slightly higher creatinine and blood urea nitrogen were observed in rams during early phase of exposure.

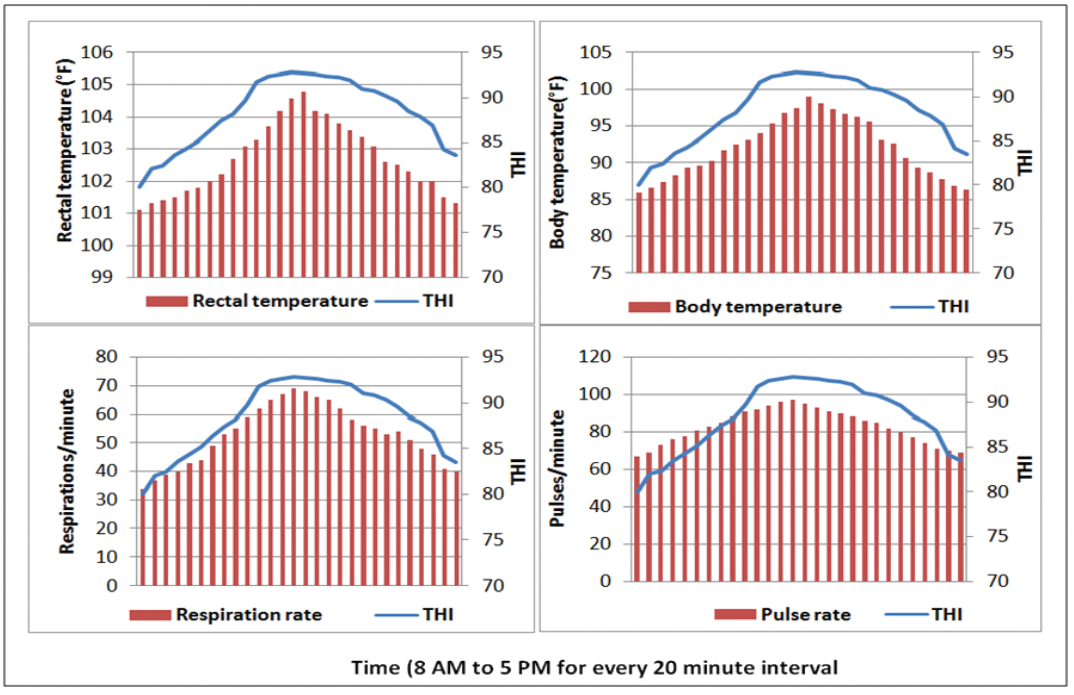


Fig. 3.36: Physiological alterations in Deccani ram lambs exposed to climatic variations (Temperature 28.6-40.8°C and RH 75-50.1%)

3.1.31 Morphological and biochemical profile and genetic studies on Ongole breed cattle

Livestock in arid and semi-arid environments of India face numerous challenges but heat stress and vulnerability to diseases are the major challenges that animals face for a longer period of the year. High ambient temperatures outside the thermo - neutral zone generally cause significant changes in physiological processes of cattle including feed intake, production and reproduction, however some of native Indian cattle breeds have adapted over the years to these weather aberrations and developed resilience and these breeds are likely to play a vital role in sustenance of livelihoods in rural areas in climate change scenario. Studies were undertaken to identify unique climate resilient traits in Ongole breed of cattle using tools like physical, biochemical, hormonal profile and genetic studies. Blood samples from Ongole cattle were collected and heparinized blood samples were processed for lymphocyte isolation using Histopaque. WBCs were isolated by centrifugation and washed in

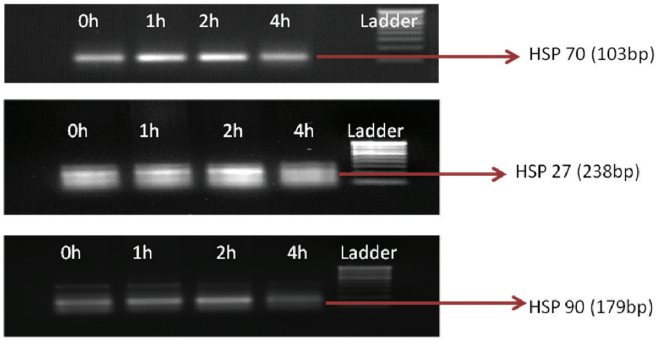


Fig. 3.37: HSP70, HSP 27 and HSP 90 expression at different time intervals at mRNA level

RPMI medium. Live cell count was determined using trypan blue dye. Cell count was adjusted to $5x10^6$/ ml . Cells were cultured in RPMI medium containing 10% FCS and streptomycin, at 45°C for 4h. Cells were processed at 1, 2, and 4 h for RNA and protein isolation. RNA was isolated using trizol method. Whole cell proteins were extracted under denaturing conditions.

Standardized protocol was used for gene expression studies and related to heat shock proteins (HSP 27, 70 and 90) at mRNA level (Fig 3.37) and also protein level (Fig 3.38). In vitro studies with isolated WBC at 45°C showed a gradual increase in expression of HSP 27, 70 and 90 at mRNA level during the first two hours followed by a decline at 4th hour which could be due to death/apoptosis of cells after 2 hrs of exposure to the temperature of 45°C. Expression of HSP 70 at protein level also showed a similar trend, reaching a maximum at 2 hours followed by a decrease at 4 h.

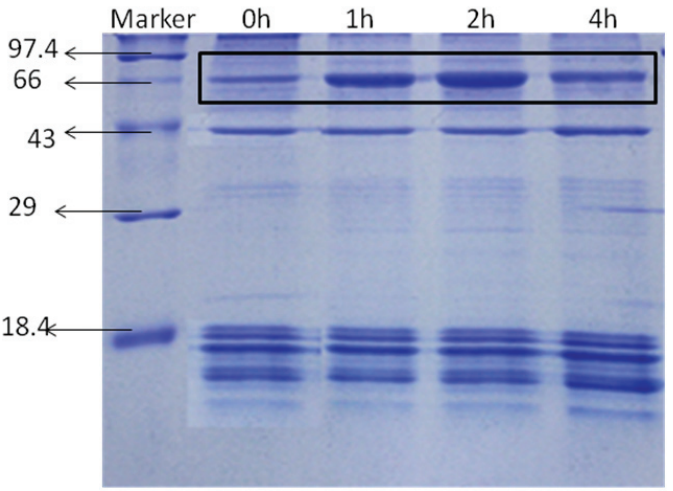


Fig. 3.38: HSP70 expression at different time intervals at protein level

3.1.32 Knowledge management for climate resilient agriculture

Tackling impacts of climate variability requires specific focus and attention addressing the knowledge needs of various stakeholders. Access to various forms of knowledge improves the users' understanding on climate variability, impacts, adaptations and mitigation strategies with a range of available options and opportunities for effective decision making.

An assessment is being done to analyze the knowledge needs and priorities of various stakeholders, i.e. farmers, field level extension professionals and researchers to manage climate variability. Preferential analysis of knowledge needs assessment was done using Likert 5 point scale methodology. A web based data collection format for collation of knowledge resources was prepared and pre testing is in progress. During 2014-15, data was collected from various stakeholders of Sirusuvada village in the flood prone district of Srikakulam in Andhra Pradesh. Analysis of knowledge requirements revealed a high need for information on stress (flood) tolerant varieties,

followed by need for information to manage pests and diseases during flood conditions. Among the preferred channel for IT based knowledge products, the farmers chose mobile based SMS services as the priority channel to receive the information services.

Focus group discussions with farmers

The group of field level extensional personnel from KVKs and line departments expressed a high need for information on contingency crop planning followed by advance weather information on mitigation/ adaptation strategies.

3.2 Technology demonstration

Technology Demonstration Component (TDC) under NICRA addresses demonstration of appropriate practices and technologies to enable farmers cope with current climatic variability. Demonstration of available location-specific technologies related to natural resource management, crop production, livestock and fisheries is the primary objective for enhancing adaptation gains and mitigation potential for building climate resilience. TDC is being implemented in a farmer participatory mode in 130 vulnerable districts of the country through 100 Krishi Vigyan Kendra's (KVKs), 23 research centres of AICRP on Dryland Agriculture and 7 TOT divisions of ICAR research institutes spread across the country. The following are the salient activities/achievements under the TDC component during 2014-15.

- Action plans for technology interventions with climate focus were prepared and implemented in 100 NICRA KVKs during *kharif* season under four modules, i.e. natural resource management, crop production, livestock and fisheries and institutional interventions.
- In view of the unfolding aberrant monsoon in *kharif*, a monsoon contingency action plan was prepared by 60 NICRA KVKs in states vulnerable to drought for implementation of contingency crop plan for late planting (after mid July) including crop - soil moisture - and nutrient management measures in standing crops experiencing dry spells.
- Interface meetings (ICAR - DAC - State Governments) for monsoon preparedness were organized in four states viz., Karnataka, Gujarat, Rajasthan and Bihar to sensitize the state and district level officials and road maps for implementation of district level contingency plans were prepared for each of the states in view of the aberrant monsoon. Issues of seed and input availability for implementation of district level contingency plans were discussed.
- In-situ soil moisture conservation practices in soybean in 80 ha covering 125 farmers in Takali village, Amravati gave 37 to 51% increase in yield under deficit rainfall conditions during *kharif* 2014. Strip cropping of soybean and pigoenpea (6:1) gave a yield of 15 q/ha of soybean. Short duration soybean variety (JS-93-05) gave a yield advantage of 22% over long duration variety. Contingency crops sesame (Madhuri) and sunflower (PKV 559) for delayed planting also proved effective.

Strip cropping at Amravati, Maharashtra

Sesame (Madhuri) at Amravati, Maharashtra

- Late sowing of short duration pigeonpea (BRG-2) gave a yield advantage of 23.5% and B:C ratio of 3.1 compared to 2.6 with the local variety in D. Naganhalli village, Tumkur, Karnataka. Aerobic rice (MAS 26) grown under water scarcity situation resulted in 14.4% yield gain over transplanted paddy and B:C ratio of 2.2 as against 1.9.

Pigeonpea BRG 2 at Tumkur, Karnataka

- Green and brown manuring with sesbania demonstrated to 36 farmers along with short duration varieties of rice (Lalat and Anjali) gave a yield advantage of 18 - 20% and B:C ratio of 1.49 to 1.67 over farmer's practice at Gunia village, Gumla, Jharkhand. Direct seeding of rice with Lalat variety gave a yield advantage of 14% with B:C ratio of 1.72. Contingency cropping of Niger (Birsa Niger-3) was demonstrated to 20 farmers with an average yield of 4.1 q/ha.

Niger at Gumla, Jharkhand

- Contingency cropping of basmati rice (Pusa-1509) in 20 ha area resulted in a yield advantage of 1 q/ha over transplanted paddy in Killi Nihal Singh village, Bathinda, Punjab. Green manuring with sesabania and soil test based nutrient use was demonstrated in 39 ha covering 60 farmers at Bandnshi Kalan village, Fatehgarh Sahib, Punjab.

Green manuring with sesabania at Fatehgarh sahib

- Contingency measures were implemented in rice, pigeonpea and blackgram in Lowkeshra village in East Singhbhum, Jharkhand. In rice, short duration and drought tolerant varieties (BVD-110 and Sahbhagi Dhan) were sown by direct seeding in uplands.

Drought tolerant variety Sahbhagi Dhan at East Singhbhum

- Contingency cropping with pearlmillet demonstrated in rice fallows in 30 ha area covering 115 farmers gave an average yield of 29 q/ha with HHB-67 and 32 q/ha with VBH-24 cultivar in Kukurha village of Buxar, Bihar.
- Smart Farmer Certificates were awarded to selected farmers following climate resilient practices and technologies in the NICRA adopted villages on ICAR Foundation Day - 16th July, 2014.

Distribution of Smart Farmer certificates

- Compensatory production plan for *rabi* 2014 was prepared for rainfed areas in drought affected states for implementation in view of the aberrant monsoon experienced during *kharif* 2014.
- *Kharif* programme of NICRA KVKs from Maharashtra, Andhra Pradesh, Telangana, Gujarat, Rajasthan, Jharkhand, Bihar and West Bengal was reviewed and Zonal Monitoring Committee reviewed the NICRA Technology Demonstration Component at 31 KVKs in different Zones.
- Video documentation of climate resilient practices and technologies in action was undertaken during *rabi* and *kharif* 2014 at 30 identified KVKs across different zones.
- In capacity building activities, 79 training programmes were conducted in NICRA villages under different modules of natural resource management, crop production, livestock and fisheries in Haryana, Punjab, Himachal Pradesh, Uttar Pradesh, Maharashtra, West Bengal, Odisha, Tamilnadu, Madhya Pradesh, Gujarat, Chhattisgarh, Karnataka, Bihar, Meghalaya, Jammu & Kashmir, Arunachal Pradesh, and Telangana.
- Zonal Monitoring Committee reviewed the NICRA Technology Demonstration Component at 16 KVKs in different Zones during the period March to October, 2014. Revenue generated from 58 custom hiring centers managed by Village Climate Risk Management Committees (VCRMCs) was Rs. 6,89,725 during 2014-15. The VCRMCs generated a total revenue of Rs.27,31,256.
- Brainstorming workshop on climate resilient villages (CRVs) was organized on 29 November, 2014. The aim of the workshop was to share the experiences on successful climate resilient practices among stakeholders implementing projects in agriculture addressing climate change. The workshop brought together different stakeholders working towards climate resilient agriculture for cross-fertilization of ideas, innovations, processes and delivery mechanisms and to evolve a broad framework for climate resilient villages. During the workshop, best NICRA KVK awards for the period 2011-14 were presented to NICRA implementing KVKs of Faridkot (Zone I), Gumla (Zone-II), West Garo Hills (Zone-III), Gonda (Zone-IV), Amaravati (Zone-V), Valsad (Zone-VI), Datia (Zone-VII) and Namakkal (Zone-VIII). Two publications on custom hiring equipment by CRIDA and Zonal Monitoring Committee report (Zone VI) were released.

Dr.Alok Sikka, DDG (NRM) inaugurating the brainstorming workshop

Best NICRA KVK awards

- An 8-day capacity development program for KVK staff was organized in four batches during 19-31 January, 2015 in which 205 participants including Program Coordinators, Subject Mater Specialists and Research Fellows from 100 NICRA-KVKs in eight Zonal Project Directorates (ZPDs) implementing Technology Demonstration Component (TDC) under the National Initiative on Climate Resilient Agriculture (NICRA) project participated.

Capacity development program for NICRA KVK scientists

3.3 District level contingency plans

Eighty district level contingency plans were prepared to meet weather aberrations in crop, livestock, poultry and fisheries sectors during 2014-15.

Nagaland (4): Wokha, Zunheboto, Mon, Tuensang

Meghalaya (11): East Garo Hills, East Khasi Hills, East Jaintia Hills, Ri Bhoi, West Garo Hills, West Khasi Hills, West Jaintia Hills, North Garo Hills, South Garo Hills, South West Garo Hills, South West Khasi Hills

Chhattisgarh (16): Dantewada, Dhamtari, Kanker, Korba, Mahasamund, Narayanpur, Bilaspur, Balod, Baloda Bazar, Balrampur, Bemetara, Gariyaband, Kondagaon, Mungeli, Sukma, Surajpur

Uttar Pradesh (39): Banda, Chitrakoot, Hamirpur, Jalaun, Jhansi, Lalitpur, Agra, Basti, Farukkabad, Hardoi, Kannauj, Kanpur-Dehet, Lucknow, Mahoba, Mathura, Rai-Bareily, Aligharh, Ambedkarnagar, Auraiya, Etah, Etawah, Fatehpur, Firozabad, Mainpuri, Kaushambi, Allahabad, Unnao, Shravasti, Sitapur, Pratapgarh, Lakhimpur Kheri, Barabanki, Shamli, Hathras, Amethi, Hapur, Kasganj, Shambhal, Kanpur Nagar

Uttarakhand (10): Bageshwar, Pauri Garhwal, Uttarkashi, Chamoli, Champawat, Tehri Garhwal, Dehradun, Nainital, Pithoragarh, Rudraprayag

4 Coordinated/Network Projects

4.1 All India Coordinated Research Project for Dryland Agriculture (AICRPDA)

The All India Coordinated Research Project for Dryland Agriculture has a network of 25 centers located across arid, semi-arid, sub-humid, humid and per-humid climates, and represent diverse bio-physical and socio-economic settings of the rainfed agro-ecologies of the country. The project has a mandate to generate location specific technologies through on station research focusing on rainwater management, cropping systems, nutrient management, energy management, evaluation of improved varieties, alternate land use and farming systems in rainfed rice, maize, sorghum, pearl millet, finger millet, cotton, groundnut and soybean based production systems. The resultant technologies are subsequently assessed on farmers' fields through 8 Operational Research Projects. The outreach programs like on-farm trials are also being undertaken. The salient research findings and activities of AICRPDA during 2014-15 are summarized below.

4.1.1 Salient achievements

4.1.1.1 Rainwater management

- At Varanasi, supplemental irrigation from harvested rainwater in farm pond at pod development stage of pea gave maximum seed yield of 1747 kg/ha, net monetary returns (NMR) of Rs. 18594/ha and B:C ratio of 2.14 as compared to no irrigation with 1345 kg/ha, Rs. 12000/ha and 1.81, respectively.
- Efficient utilization of harvested rainwater in *nadi* and with supplemental irrigation for higher water productivity was evaluated at Arjia in *rabi* crops (taramira, mustard and chickpea). The maximum yield was obtained in mustard (1678 kg/ha) with a WUE of 1.24 kg/ha-mm, NMR of Rs. 28837/ha and B: C ratio of 1.68.
- In a study at Bangalore on efficient utilization

Rainwater harvesting & supplemental irrigation in chickpea after fodder bajra

of harvested rainwater in farm pond for intensive and profitable crop production, the forage yield of giant bajra was significantly higher (43067 kg/ha) with RWUE of 245 kg/ha-mm compared to sweet sorghum (34765 kg/ha). Significantly higher chickpea seed yield (1067 kg/ha) was recorded as sequence to early sown giant bajra compared to Annigeri-1 (868 kg/ha). Higher system B:C ratio was obtained with giant bajra (2.61) followed by sweet sorghum (2.27) under fodder-chickpea double cropping system.

- Ridges and furrows system at Solapur gave maximum *rabi* sorghum grain yield of 874 kg/ha and fodder yield of 1665 kg/ha compared to cultivated fallow. The ridges and furrows, tied ridges and compartment bunding method of *in-situ* moisture conservation recorded 64, 34 and 29% more grain yield of *rabi* sorghum over cultivated fallow treatment, respectively.

4.1.1.2 Cropping systems

- In an assessment of different crops for contingency planning at Bijapur during Aridra Nakshatra (22nd June to 6th July) in medium deep black soils, pearl millet + pigeonpea (2:1) system was superior with maximum *rabi* sorghum equivalent yield of 5069 kg/ha with net monetary returns (NMR) of Rs. 66015/ha and RWUE of 22.73 kg/ha-mm. Among different crops sown during punarvsu (6th to 22nd July) pigeonpea gave highest *rabi* sorghum equivalent yield of 3853 kg/ha with NMR of Rs. 45949/ha and RWUE of 17.28 kg/ha-mm.
- In an evaluation of maize based double cropping systems at Biswanath Chariali maximum maize equivalent yield of 9624 kg/ha was obtained with maize-potato system with net monetary return of Rs.52932/ha and B:C ratio of 1.85, followed by maize-maize system.
- At Jagdalpur, under *marhan* conditions, rice + pigeonpea (5:1) with transplanting of pigeonpea at 40 days after sowing + sodium molybdate seed treatment @ 4 g/kg seed of pigeonpea gave maximum rice yield of 2186 kg/ha followed by rice + pigeonpea (5:1) line sowing + sodium molybdate seed treatment @ 4 g/kg seed to pigeonpea (2063 kg/ha).

Rice + pigeon pea intercropping (5 :1) under Marhan condition

- Groundnut + castor (3:1) intercropping at Rajkot registered higher seed yield (1433 kg/ha) and gross monetary returns (GMR) of Rs.79185/ha compared to groundnut + cotton (3:1) which recorded lower seed yield (843 kg/ha) and gross monetary returns (GMR) of Rs. 20796/ha.
- At Rewa, chickpea + linseed (2:1) performed better with higher net monetary returns (NMR) of Rs.8022/ha and B:C ratio of 1.52. However, the mean chickpea equivalent yield was higher with chickpea + linseed in 4:2 ratio (1226 kg/ha).

4.1.1.3 Nutrient management

- Evaluation of N requirement for toria, gobhi sarson and toria + gobhi sarson intercropping system at Ballowal Saunkhri indicated that application of 30 kg N at sowing of toria + 25 kg N at sowing of gobhi sarson + 25 kg N at harvesting of toria recorded maximum gobhi sarson equivalent yield of 1250 kg/ha (1231 kg/ha mean over 4 years), NMR (Rs. 21652/ha), B:C ratio (2.14) and RWUE (4.50 kg/ha-mm) compared to control.
- For pearlmillet - ghobi sarson sequence at Rakh Dhiansar, application of N through vermicompost gave highest gobhi sarson seed yield (1417 kg/

ha), NMR (Rs. 35561/ha), B:C ratio (3.18) and RWUE (8.15 kg/ha-mm) compared to control.

- At Akola, significantly higher mean seed yield of soybean (1967 kg/ha), RWUE (3.04 kg/ha-mm), productivity rating index (72.7), sustainability yield index (0.47) and NMR (Rs.27868/ha) were recorded with application of 100% RDF + 25 kg K/ha + bio-fertilizers as compared to all other treatments without K application.
- In a permanent manurial trial at Biswanath chariali integrated nutrient management involving application of 75% RDF + 5 t/ha vermicompost in *ahu* rice-greengram-toria sequence gave maximum grain yield of rice (1134 kg/ha) with RWUE of 1.46 kg/ha-mm, net returns of Rs.3826/ha and B:C ratio of 1.43, and 1275 kg/ha of greengram yield and 617 kg/ha of toria compared with other treatments including 100% RDF.
- In finger millet-groundnut cropping system (8:2) at Bangalore, application of 10 t/ha FYM + recommended NPK + bio-fertilizers recorded higher finger millet grain yield (3624 kg/ha) followed by *ex-situ* green manure (7.5 t/ha) + 75% NP + 100% K + bio-fertilizers (3472 kg/ha) as compared to recommended NPK (2995 kg/ha) resulting in 17.5% yield increase with a higher net returns of Rs. 58534/ha.
- Application of different doses of selenium at panicle initiation stage in finger millet at Bangalore did not indicate significant difference, although higher grain and straw yield was recorded with foliar spray of sodium selenite @ 20 g/ha (3781 and 5270 kg/ha, respectively) with highest B:C ratio (4.14). Further, highest RWUE was recorded with foliar spray of sodium selenite @ 20 g/ha at panicle initiation (7.18 kg/ha-mm).
- Application of FYM @ 10 t/ha + Kaoline @ 4% spray gave maximum groundnut pod yield (1168 kg/ha) and stalk yield (3662 kg/ha) compared to without foliar spray (946 kg/ha) at Rajkot.
- At Indore, spraying of VAM-C 50% SL @ 375 ml/ha recorded significantly higher seed/grain yield of soybean (737 kg/ha), maize (3054 kg/ha), blackgram (519 kg/ha) and horsegram (494 kg/ha) followed by polythene mulching. Spray of VAM-C 50% SL @ 375 ml/ha on soybean, maize, blackgram and horsegram recorded 73.0, 19.8, 27.9 and 33.2% higher yield compared to control.
- The maximum groundnut pod yield (1611 kg/ha) was recorded at Rajkot with foliar spray of KNO3 @ 2% at 60 DAS. However, the haulm yield was highest (4569 kg/ha) with foliar spray of 2% urea at 30-35 DAS.
- Recommended dose of fertilizer (120:60:60 kg/ha) with foliar nutrition of 1.0% MgSO4, 0.5% $ZnSO_4$ and 0.2% B at square formation and flowering stages of cotton at Kovilpatti recorded significantly higher seed kapas yield (348 kg/ha) and dry matter production (854 kg/ha).
- At SK Nagar, foliar application of $ZnSO_4$ and $FeSO_4$ each @ 0.5% gave maximum maize grain yield (1137 kg/ha), NMR (Rs.13833/ha), B:C ratio (2.81) and RWUE (1.00 kg/ha-mm) compared to other treatments.

4.1.1.4 Energy management

- At Indore, in an evaluation of different tillage systems, low tillage + 4 t/ha of straw + hand weeding resulted in highest seed yield of soybean (1312 kg/ha), NMR (Rs.26158/ha) and RWUE (0.993 kg/ha-mm) compared to conventional and zero tillage systems.
- In a study on tillage and nutrient management for resource conservation and improving soil quality in sunflower at Bijapur, conventional tillage (1 ploughing + 2 harrowings + 2 hoeings + 1 hand weeding) was superior with maximum seed yield of 730 kg/ha and mean seed yield (5 years) of 898 kg/ha. Among different nutrient management treatments, 100% RDF through inorganic fertilizers gave maximum seed yield (719 kg/ha).
- Among the bullock drawn seed drills at Solapur, CRIDA seed drill recorded 18% higher Chickpea yield (894 kg/ha) than the control and 3% higher than the Bhopal seed drill. In case of tractor

drawn seed drills, 20.6% higher yield (837 kg/ha) was recorded with the CRIDA automatic tractor drawn seed drill than the control.

4.1.1.5 Evaluation of improved varieties

- In an evaluation of rice genotypes in farmers' fields under upland and midland conditions at Jagdalpur, upland rice genotype Sambleshwari recorded highest grain yield (3486 kg/ha), straw yield (4455 kg/ha) and RWUE (2.94 kg/ha-mm). Among 12 midland rice genotypes, Karma Mahsuri gave maximum grain yield (4103 kg/ha) and straw yield (5280 kg/ha) with RWUE of 3.46 kg/ha-mm.
- At Biswanath Chariali, out of 9 varieties of *ahu* rice evaluated under periodic moisture stress, Dehangi gave maximum grain yield (2780 kg/ha), NMR (Rs.18800/ha), B:C ratio (2.09) and RWUE (2.35 kg/ha-mm).
- Screening of germplasm of pearl millet (dual purpose) at Ballowal Saunkhri under rainfed conditions revealed that PHB-2168 gave maximum grain yield of 1853 kg/ha, 38867 kg/ha of fodder, net returns of Rs. 34134/ha and RWUE of 3.23 kg/ha-mm that are superior to local variety.
- Among 16 entries of horsegram tested at Bijapur, GPM-6 gave maximum seed yield of 857 kg/ha while IC100938 was superior with stalk yield of 1148 kg/ha, followed by BJPL-1 with grain yield of 841 kg/ha and AK-42 with fodder yield of 1133 kg/ha.
- In a multi-location varietal trial conducted by Solapur center with 12 genotypes of horsegram at six locations, SHG-0628-4 (1036 kg/ha) and SHG 0631(965 kg/ha) gave significantly superior seed yield over both the check varieties viz. Sina (792 kg/ha) and Man (764 kg/ha).

Horsegram genotype SHG-0628-4

4.1.1.6 Alternate land use systems

- At Solapur, in an evaluation of silvi-pastoral systems, neem + *Acacia nilotica* + *Cenchrus ciliaris* + stylo system was to the superior with significantly higher total grass yield of 12.20 t/ha followed by neem + Anjan grass + *Cenchrus ciliaris* + stylo with total grass yield of 11.31 t/ha.
- In custard apple based agri-horti system at Varanasi involving custard apple + pearl millet, fruit yield (1810 kg/ha), net returns (Rs. 51277/ha) and B:C ratio (3.71) were maximum when pruning distance was 1.5 m and lowest fruit yield (863 kg/ha), net returns (Rs.23214/ha) and B:C ratio (2.56) was recorded with 0.50 m pruning distance. But pearl millet yield was maximum (1834 kg/ha) with 0.5 m pruning distance.

Custard apple + pearlmillet system

- At Bijapur, aonla + custard apple + henna + chickpea system was superior with chickpea equivalent yield of 2270 kg/ha.
- In custard apple based agri-horti system at Bangalore, significantly higher custard apple equivalent yields were obtained with fodder maize (1468 kg/ha) and finger millet (1317 kg/ha) with

net returns of Rs. 59633/ha and 53398/ha, B:C ratios of 3.09 and 3.08, respectively and RWUE (86.85 & 5.58 kg/ha-mm).

Custard apple + fingermillet system

4.1.1.7 Integrated farming systems

- At Kovilpatti, total system productivity (sorghum equivalent yield) was high (10060 kg/ha) with integration of crop, dairy and goat rearing with NMR of Rs. 47,720/ha and B:C ratio of 1.65 as compared to cropping activity alone (230 kg/ha, Rs.8240/ha and 0.25, respectively).
- In an integrated farming system with 6 different component crops at Solapur horticulture, livestock and border plantations in 1 ha area, maximum net returns (Rs. 31286) and B:C ratio (2.10) were attained from dairy farming. Net returns of Rs.54422 with B:C ratio of 1.60 were attained from all the components (crops, horticulture, dairy farming, goat rearing, poultry farming and border plantations). There was a total labour utilization of 510 man-days which comprised of 262 hired labour and 248 family labour. The employment generation in integrated farming system provided net return of Rs.52770/ ha from 510 days of employment.
- In a study on integrated farming system at Jagdalpur for bunded midland (*mal*) and lowland (*Gabhar*) situations, fish rearing in farm ponds in midlands gave additional income of Rs.8340 with pond area of 2250 m^3 while in lowlands Rs.9534 was obtained with pond area of 1650 m^3.
- At Ballowal saunkhri, the area under IFS has been divided into three portions to develop three models *viz.,* i) agriculture + trees on boundary, ii) agriculture + trees in block plantation, and iii) silvi-pasture. Among maize, sesame and blackgram sown during *kharif* in model (i) and (ii), sesame gave highest net returns of Rs. 20,855 & Rs. 12,655/ha along with higher B:C ratio of 2.40 & 1.85, respectively. In *rabi*, under model (i) & (ii), wheat gave highest net returns of Rs. 27,515 & Rs. 22,310/ha and B:C ratio (2.20 & 2.00). In addition, this year fruit bearing started at the age of 3 years in kinnow, guava and peach under the farming system.

4.1.2 Operational Research Project

4.1.2.1 Anantapur (ORP village: Girigetla, Thuggali Mandal, Kurnool district, Andhra Pradesh)

- In an assessment of soil test based (STB) fertilizer application in groundnut, pod (486 kg/ha) and haulm yields (1154 kg/ha), and net returns (Rs 2288/ha) were higher with STB fertilizer application compared to farmers' practice with pod and haulm yields of 442 and 1042 kg/ha, respectively.
- In an on-farm demonstration of foliar application of different micronutrients in cotton, two sprayings with 1% mixed fertilizer (19:19:19), 1% $ZnSO_4$, $MgSO_4$ and 0.15% boron at flowering and 20 days after flowering reduced reddening of leaves by 29% and improved crop yield by 11% (362 kg/ha) compared to farmers' practice (327 kg/ha).

4.1.2.2 Arjia (ORP village: Lapsiya, Rajsamand district, Rajasthan)

- In an on-farm demonstration, protective irrigation from harvested water gave higher groundnut equivalent yield (1210 kg/ha) in groundnut + sesame (6:2) intercropping system as compared to no irrigation (810 kg/ha).
- In an assessment of site specific nutrient management (SSNM) in sorghum, fertilizer dose based on SSNM gave the highest yield of 1433 kg/ha with B:C ratio of 2.22, closely followed by recommended dose of NP as compared to

farmers' practices (1007 kg/ha and B:C ratio of 1.70).

- In an on-farm horti-pasture model, improved grasses like Cenchrus setigerus and Stylosanthus hamata performed better and gave the highest dry grass yield (4800 kg/ha) as compared to local grass (1300 kg/ha). After fifth year, the improved practice gave higher B:C ratio (2.52) in comparison to farmers' practice.

4.1.2.3 Ballowal Saunkhri (ORP village: Naude Majra, Nurpur Bedi block, Rupnagar district, Punjab)

- Application of two supplemental irrigations from harvested rainwater at CRI and flowering stages in rainfed wheat (PBW-175) resulted in highest grain yield (3646 kg/ha) which was 53% higher over rainfed wheat with no irrigation. The B:C ratio was also higher (3.07) with supplemental irrigation at CRI and flowering stages.
- In an assessment of intercropping systems, among two raya cultivars, RLM-619 intercropping in wheat recorded highest wheat equivalent yield (WEY) of 3128 kg/ha, which was 6 and 18% higher over raya var. PBR-97 intercropped in wheat and sole wheat.
- In an assessment of different implements for field preparation, seed yield of raya increased by 16% with B:C ratio of 3.62 with rotavator as compared to cultivator. In case of taramira, one ploughing with rotavator followed by planking gave grain yield of 650 kg/ha, which is 12% higher as compared to cultivator.

4.1.2.4 Bangalore (ORP village: Alanatha cluster, Kanakapura taluk, Ramanagara district, Karnataka)

- In an assessment of site specific nutrient management (SSNM) in groundnut + pigeonpea (8:2) intercropping system, SSNM with micronutrients and bio-fertilizers recorded higher groundnut equivalent yield (890 kg/ha) and B:C ratio (2.57) compared to farmers' practice of blanket fertilizer application (388 kg/ha and 1.21, respectively).
- In an on-farm demonstration of fingermillet varieties, MR-1 (2578 kg/ha) among long duration, GPU-28 (2425 kg/ha) among medium duration and GPU-48 (2184 kg/ha) among short duration varieties recorded higher grain yield.

4.1.2.5 Chianki (ORP village: Sua, Palamau district, Jharkhand)

- In an assessment of different tillage systems, higher mean grain yield of wheat variety HUW 234 (2725 kg/ha) was recorded under zero tillage condition than under conventional tillage (2220 kg/ha). Zero tillage facilitated 8 to 10 days early sowing. It gave higher benefit cost ratio (2.08) as compared to conventional tillage (1.56).

4.1.2.6 Hisar (ORP village: Kheri, Sirsa district, Haryana)

- In an assessment of production technologies in greengram, an increase of 194 kg/ha seed yield was observed due to adoption of full package of practices (857 kg/ha) as compared to farmers' practices (663 kg/ha).
- In an assessment of the effect of pond silt @ 40 t/ha on performance of mustard on selected farmers' fields revealed that maximum seed yield (1534 kg/ha) and net returns (Rs 33123/ha) was recorded with pond silt application compared to no pond and silt application (1398 kg/ha and Rs 28544/ha).

4.1.2.7 Solapur (ORP village: Maniknal, Jat tahsil, Sangli district, Maharashtra)

- In an assessment of in-situ moisture conservation measures on the yield of pigeonpea on 12 farmers' fields at Maniknal, a higher mean seed yield of 631 kg/ha, stalk yield of 1663 kg/ha and B:C ratio of 2.55 were attained with ridges and furrow system compared to the farmers' practice of flat bed system (seed yield of 540 kg/ha, stalk yield of 1528 kg/ha and B:C ratio of 1.22).
- In the demonstration-cum-verification trials on pearlmillet (cv. Shanti) on 17 farmers' fields, with 50 kg N, 25 kg P_2O_5 and 25 kg K_2O/ha and without potassium, the variety Shanti produced 26.5% higher grain yield with B:C ratio of 1.64 due

to application of 25 kg K_2O with recommended dose of NP.

- In an evaluation of different implements for seeding and fertilization of *rabi* sorghum on 10 farmers' fields, two bowl ferti seed drill was found superior with maximum effective field capacity (1.80 hr/ha), lower power requirement (4.44 hr/ha) of machine, 8.88 hr/ha of human labour and 8.88 hr/ha of bullock with a cost of operation of Rs.555/ha. The two bowl ferti seed drill gave the highest grain yield of 1010 kg/ha and fodder yield of 2300 kg/ha.

4.1.3 Achievements under AICRPDA -NICRA

The NICRA program at 23 AICRPDA network centres (including IGFRI, Jhansi) was initiated during 2010-11, both on-station and on-farm. The on-farm program is being implemented in 34 adopted villages in 26 districts across 15 states. The major interventions broadly include real time contingency crop plan implementation, rainwater harvesting (*in-situ* and *ex-situ*), efficient energy use and management, and alternate land use. The salient achievements are summarized below:

4.1.3.1 Contingency planning

- Under delayed onset of monsoon by 10 days at Achalpur village (Garhshankar block, Hoshiarpur district, Punjab), intercropping of maize + blackgram gave highest MEY (3023 kg/ha) and RWUE (5.29 kg/ha-mm) with NMR of Rs. 20752/ha and B:C ratio of 1.71 followed by maize + greengram intercropping system and sole crops.
- At Indore, under delayed onset of monsoon by 10 days, seed treatment with molybdenum @ 1 g/kg gave highest seed yield of soybean (426 kg/ha) and chickpea (1141 kg/ha) with soybean equivalent yield of 1948 kg/ha while 2 foliar sprays of molybdenum @ 0.1% to soybean gave 412 kg/ha and chickpea gave 1096 kg/ha with SEY of 1794 kg/ha.
- Under early onset of monsoon by 6 days, followed by early season drought at Anantapur, improved varieties of groundnut (K-9) and pigeonpea (WRG-53) performed better resulting in higher pod yield (538 kg/ha) and seed yield (353 kg/ha) with higher RWUE (1.62 and 0.97 kg/ha-mm, respectively).

4.1.3.2 Rainwater management

- At Achalpur village (Garhshankar block, Hoshiarpur district, Punjab), summer ploughing of field immediately after the wheat harvest conserved moisture and gave the maize yield of 3000 kg/ha with NMR of Rs 27,100/ha which was 12% higher in comparison to sowing without summer ploughing.
- At Chikkamaranahalli village (Nelamangala taluk, Bangalore rural district, Karnataka), finger millet (MR-1) + pigeonpea (TTB-7) in 8:2 ratio with conservation furrow between paired rows of pigeonpea recorded higher yield (1973 kg/ha) and net return (Rs.21936/ha) as compared to farmers' practice (1333 kg/ha and Rs.9929/ha, respectively).
- At Nignoti village (Indore district, Madhya Pradesh), supplemental irrigation from harvested rainwater in farm pond to onion (Red-3) gave maximum yield of 10650 kg/ha with net return of Rs.81500/ha and 4.3 B:C ratio as compared to local cultivar (8300 kg/ha) and the yield was 28.3% more than the local cultivar.

4.1.3.3 Efficient energy use and management

A Custom Hiring Centre (CHC) was established in each NICRA village with need based implements (both bullock drawn and tractor drawn) made available to the farmers which ensured timeliness and precision in agricultural operations covering large areas in short time. Further, CHCs significantly contributed to alleviate labour shortage during peak demand period.

- At Rakh Dhiansar, sowing with maize planter recorded maximum total output energy (82031 MJ/ha) with yield of 1980 kg/ha over farmers' practice (broadcasting) (59558 MJ/ha). Similarly, maximum wheat yield (3150 kg/ha) was attained when sown with seed-cum-fertilizer drill (output energy of 116392 MJ/ha).
- Sowing of wheat with seed cum fertilizer drill gave grain yield of 3048 and 3150 kg/ha which

was 37 and 34% higher over broadcast method of sowing with yields of 2224 kg/ha and 2350 kg/ha, respectively at villages Achalpur and Nainwan (Garhshankar, Hoshiarpur district, Punjab).

- At Varkhed village (Barshi Takali Taluka, Akola District, Maharashtra), use of multipurpose thresher was introduced for threshing of soybean which reduced harvesting time, labour cost by 33.3% and reduced harvesting costs.

4.1.4 Salient achievements under AICRPDA -TSP

The TSP program is being implemented since 2011 by 7 network centers of AICRPDA (Arjia, Biswnath Chariali, Chianki, Indore, Jagdalpur, Phulbani and SK Nagar) in 70 villages in 8 districts in Rajasthan, Jharkhand, Madhya Pradesh, Odisha, Assam, Chhattisgarh and Gujarat states.

Interventions: The major interventions in TSP villages are demonstration of improved rainfed technologies on rainwater management, drought tolerance, crop management, cropping systems, nutrient management including foliar sprays, farm mechanization with improved machinery and most importantly need based capacity building programmes both for tribal men and women. The livelihoods of the beneficiaries were improved through enhancing productivity, profitability and livelihood interventions.

Productivity and profitability: By introduction of improved varieties of rainfed crops (soybean, maize, finger millet, groundnut, wheat, chickpea, lentil, barley, mustard and taramira) and demonstration of improved crop management practices such as seed inoculation, seed treatment, balanced nutrition, better nutrient management practices, better rainwater management practices (in-situ moisture conservation), supplemental irrigation, plant protection measures to IPM package providing improved bullock drawn implements (seed cum ferti drill, zero till drill, reversible plough, happy sedder, cultivators, MB ploughs etc) and plant protection equipments etc., These interventions in combination resulted in the increase in productivity of rainfed crops upto 30% compared to the traditional practices in various TSP villages. Further, this also resulted in increased profitability upto 25-30% and contributed to enhancing the livelihoods of individual beneficiaries.

Livelihood interventions: In the TSP villages, the AICRPDA centers introduced need based livelihood interventions such as green fodder banks, poultry (dual purpose vanaraja birds), duckery, piggery, milch animals, apiculture, mushroom cultivation, vermi-compost production, fish production and management techniques, sewing machines to widows etc. To strengthen the implementation of these interventions, activities like animal health camps, breed upgradation, need based skill development and capacity building (trainings/exposure visits, filed visits etc) were organized from time to time. Adoption of these interventions benefited individuals and also families leading to better livelihood through higher employment and income generation.

Farmers' day and Field day in Ramgarh village, Bhilwara district, Rajasthan

Introduction of poultry birds and low-cost vermicomposting – Jalakia Uta, Dhemaji district, Assam

District Collector of Bastar visited AICRPDA-TSP activities in Tahkapal village, Bastar

4.1.5 Monitoring and Evaluation

4.1.5.1 Review meeting of AICRPDA

A two-day review meeting was held at CRIDA, Hyderabad during 29-30 May, 2014. Dr. SM.Virmani, Former Programme Leader, ICRISAT, while highlighting the impacts of drought on agriculture, water resources, livestock, and livelihood security of the small and marginal farmers emphasized on the need for developing a Drought Year Code by AICRPDA network for crop/soil/water management. Dr Ch Srinivasa Rao, Project Coordinator, AICRPDA, presented the research highlights of 2013-14 across the centres. During the meeting, 22 AICRPDA centres and 8 ORPs presented the research highlights (2013-14) and technical programme (2014-15) was finalized. Disucussions were also held on on-farm demonstration of real-time contingencies in 23 village clusters by AICRPDA network centres, and also details of new initiatives in AICRPDA Network. Eight centres presented the progress under TSP.

Release of publications

4.1.5.2 XXIV Biennial Workshop of AICRPDA

The XXIV Biennial Workshop of AICRPDA was held during 26-29, December, 2014 at College of Agriculture, Indore, RVSKVV, Madhya Pradesh with an objective to review the progress of research achieved during 2012-14 across 22 AICRPDA centres and 8 ORP centres, and further finalization of technical programme for 2015-16. Dr. Panjab Singh, former Secretary, DARE & DG, ICAR emphasized the need for concerted research and development in dryland agriculture as further scope for irrigated agriculture is limited and future needs of food are expected majorly from rainfed agriculture in India. Dr. A.K. Singh, Hon'ble Vice Chancellor, RVSKVV, Gwalior, advocated efficient harvesting of rainwater, its conservation and efficient utilization, adaptation and mitigation to climate change and variability, soil carbon management with focused research in dryland agriculture. Dr. Ch. Srinivasa Rao, Director, CRIDA presented the objectives of the workshop and the refined agenda for rainfed agriculture research in India. He also explained the status of upscaling of rainfed technologies and future strategies. Dr. Masood Ali, Former Director, IIPR, Kanpur informed the house the challenges of rainfed agriculture and the role of pulse crops in rainfed systems. On the occasion, "Best Dryland Farmer Award" was given to 18 innovative farmers from across the country who are leading the implementation of rainfed technologies among rainfed farming community and also "Best Centre Award" to 3 AICRPDA centres and 2 ORP centers. The progress report of 2012-13 & 2013-14, technical programme 2014-15 and tentative technical programme of 2015-16 with the details on concluding experiments and new experiments were discussed.

Release of publications

Presentation of "Best Dryland Farmer Award"

4.1.6 Training Programmes/Workshops/Meetings Conducted

4.1.6.1 Brainstorming Session on Rainfed Agriculture Network Research and Drought Preparedness

AICRPDA and National Academy of Agricultural Sciences (NAAS)-Hyderabad Chapter jointly organized a two-day brainstorming session on "Rainfed Agriculture Research and Drought Preparedness for the year 2014" during 9-10 May, 2014 at NASC, New Delhi. Overall objective of the two-day deliberations was to review and revisit rainfed agriculture research being carried out under AICRPDA network and preparing for drought in 2014 by operationalization of contingency plans prepared by CRIDA-DAC, Ministry of Agriculture. Deliberations were chaired by Dr. SM.Virmani, Former Programme Leader, ICRISAT and presently NAAS Foreign Secretary, along with Dr. JS.Sandhu, Agricultural Commissioner, Dr. AK. Sikka, DDG (NRM and Extension), Dr. B.Venkateswarlu, VC, VNMKV, Dr. D.Rama Rao, National Director (NAIP and DDG, Engineering), Dr. Meena Kumari, DDG (Fisheries), ADGs and Directors of NRM Division, Senior Officials of Ministry of Agriculture, Chief Scientists (AICRPDA) and Scientists from CRIDA.

Release of publications

Deliberations focused on the network research status and future research thrusts in the thematic areas of rainwater management, nutrient management, soil health and carbon sequestration, crops and cropping systems, farm machinery and energy management, alternate land use, integrated farming systems and technology development and impacts. The research work under these themes was revised with emerging scenarios of increased delay in onset of monsoon, midseason droughts and terminal droughts, and frequency of high rainfall events. Second day deliberations addressed the drought preparedness and mitigation of drought by operationalization of agricultural contingency plans. Discussions were held on "Monsoon-2014" based on IMD predictions, status of contingency plans in different states and implementation of contingency measures on real time basis. Availability of early maturing varieties, change of crops, timely availability of various inputs, farm machinery to complete sowing operation in limited sowing window available, fodder systems, livestock, management of fish ponds if monsoon is delayed were also discussed and road map for operationalization of contingency plans was developed.

4.1.6.2 District Level Stakeholder Consultation Workshops organized at AICRPDA Centres

A one-day District level Stakeholder Consultation Workshops were organized at 4 ACIRPDA centres viz., Anantapur, Bangalore, Faizabad and Parbhani during September 2014 to January 2015 with the objective of sensitizing various stakeholders (farmers, district officials, line department officials, KVKs, NGOs etc) about rainfed technologies emanated at each ACIRPDA centre, further to discuss about performance of each technology and its impact on productivity and income, its potential, refinement and scope for convergence with national/state govt. programmes/schemes for upscaling in the domain districts of the centre. Honorable Vice Chancellors, Director, CRIDA, PC (ACIRPDA), Directors of Research and Extension, MLA's , District Collectors, Public representatives, Scientists from CRIDA,SAU's, KVKs, Officials from line departments, NGOs and farmers from the domain districts of the centers have participated. The stakeholders emphasized the need for technological backstopping and investment policy support for NRM technologies, subsidy for costly implements and also suggested issues for prioritized rainfed agriculture research. The action plans were developed for upscaling of doable rainfed technologies through demonstration by KVKs, ACIRPDA centres, state line departments etc and in convergence with government schemes.

Workshop at Anantapur centre

Workshop at Bangalore centre

Workshop at Parbhani centre

4.1.7 Publications

Overall, 336 publications were contributed by AICRPDA team comprising of 71 research papers, 44 papers in conferences, 54 books/bulletins/reports and 60 popular articles during the year. The scientists gave 29 Radio talks, 23 Television talks and delivered 55 lectures during the year.

4.2 All India Coordinated Research Project on Agrometeorology (AICRPAM)

The salient research achievements of various AICRPAM centers during 2014 *kharif* and 2014-15 *rabi* seasons are summarized under the following five themes viz. agroclimatic characterization, crop weather relationships, crop growth modeling, effects of weather on pests and diseases and weather based agromet advisories.

4.2.1 Research findings

4.2.1.1 Agroclimatic characterization

- Meteorological drought analysis carried out using SPI for Eastern, Western and Central Vidarbha zones indicated that August precipitation has increased over the past 112 years in Eastern and Central zones.
- Trend analysis of maximum temperature during 1959-2009 for Godhra district of Gujarat showed significantly increasing trend for winter (0.03 °C/year), monsoon (0.02 °C/year), post-monsoon (0.04 °C/year) and on annual (0.03 °C/year) time scales.
- Ideal crop growing period for Bangalore was identified as 28-44 standard meteorological weeks using rainfall probability analysis.
- Analysis of meteorological drought climatology of Bijapur district of Karnataka revealed that the incidence of moderate drought years was more during the period 1961-90.
- Extreme event analysis using 'RClimdex 1.1' for Upper Brahmaputra Valley Agroclimatic Zone (UBVZ) of Assam indicated that Dibrugarh has experienced more intense rainfall events, where as its number of rainy days have decreased during the last 30 years.
- Length of Growing Period (LGP) analysis carried out for Southern agroclimatic zone of Tamil Nadu showed that LGP ranged from 7-45 SMW with an average of 12 weeks.
- Analysis of weather data during 1985-2013 revealed that hailstorm events (0.18 per year) and dew days (3 per year) increased at Palampur.
- Changes in quantum of rainfall received on seasonal and annual basis during 1991-2013 was compared against the base period (1961-1990) for Chhattisgarh. Most of the districts showed negative departure of SW monsoon and it decreased by 20.8 per cent in Raigarh and by about 11.4 per cent rainfall in Rajnandgaon.

4.2.1.2 Crop weather relationships

- Among different pearl millet varieties, ICTP-8203 recorded highest consumptive use of moisture (CUM) and moisture use efficiency (MUE) compared to Mahyco and Shanti at Solapur.
- Soybean variety TAMS-98-21 showed highest crop water use, water use efficiency (WUE) and water productivity (WP) than JS-335 and JS-9305 when sown during four sowing windows (26,27,28 and 29 SMW) at Akola.
- Optimum moisture use efficiency (MUE) for attaining higher grain yield in sunflower was found to be 3.5 to 4.0 kg ha/mm at Solapur.

- Among different adaptation strategies used for increasing WUE in cotton, dead mulch showed highest WUE and WP (1.82 and 2.92 kg ha-mm^{-1}), followed by conservation furrows at Akola.
- A mean temperature of 15.2 to 18.3°C and 18.5 to 21.2°C during heading to milk stage and during milk to dough stage, respectively was found conducive for getting higher grain yield of wheat at Udaipur.
- In Anantapur, it was observed that chickpea pod set on the day of fog occurrence was low in crop grown in control plots for all desi varieties.
- Optimum minimum and maximum temperatures for the growth of tea bush were found to be between 8.5-20.5 and 21.5-31.5°C, respectively at Palampur.
- Models based on linear regression technique were developed for predicting vegetative flush and flowering of mango at Dapoli.

4.2.1.3 Crop growth modeling

- Soybean model (DSSAT v 4.5) was evaluated for three varieties JS-335, JS 9305 and TAMS 98-21 at Akola and its performance in respect of phenological phases and seed yield is reliable.
- Calibration and validation of rice c.v. Karma Mahsuri and Satabdi are in progress at Raipur and Mohanpur, respectively. A minimum data set for rice variety Vandana was prepared at Ranchi.
- Regression based models were developed for groundnut using duration of phenological stages and GDD, these were evaluated with observed values at Anantapur. The models predicted flowering, pod initiation (< 1 day error) and maturity (3-5 days error) accurately under all dates of sowing.

4.2.1.4 Effects of weather on pests and diseases

- Multiple regression models were developed for predicting Karnal bunt incidence in wheat for Karnal, Rewari, Hisar and Sirsa regions of Haryana using selected meteorological parameters during 6-12 standard meteorological weeks.
- Weather based linear regression model for Alternaria leaf spot of safflower was developed at Solapur.
- Mean temperature of 19-25.5 °C, temperature range of 14-19 °C, Mean RH (53-70 %) and THI (2-3) were found most congenial weather conditions for peak aphid attainment in mustard at Anand.
- Correlation analysis between yellow stem borer incidence and weather parameters at Raipur revealed that minimum temperature, rainfall and afternoon relative humidity were negatively correlated with yellow stem borer incidence, which was statistically significant.

4.2.1.5 Agromet advisory services

- With the MOU between ICAR & IMD, National Agro-Advisory Services bulletins were issued for southwest monsoon-2014. Thirteen weekly NAAS bulletins were prepared in collaboration with Agromet division, IMD, Pune.
- Thirteen weekly special bulletins on status of monsoon and contingency plans for rainfall deficit/excess areas were prepared with the inputs from AICRPAM cooperating centers.
- Daily progressive rainfall situation during southwest monsoon-2014 were prepared and communicated to ICAR head quarters as well as updated in the crop weather outlook web site.
- Weekly rainfall situation and crop condition along with contingency plans were prepared with the inputs from AICRPAM cooperating centers and communicated to ICAR head quarters as well as updated in the crop weather outlook web site.

4.2.2 Widening of AICRPAM Network

As per the approval accorded vide EFC for the 12th five year plan, ten additional centers will be added to existing 25 cooperating centers of AICRPAM during 2015. The network of AICRPAM that will operate from 2015 is presented in Figure 4.1.

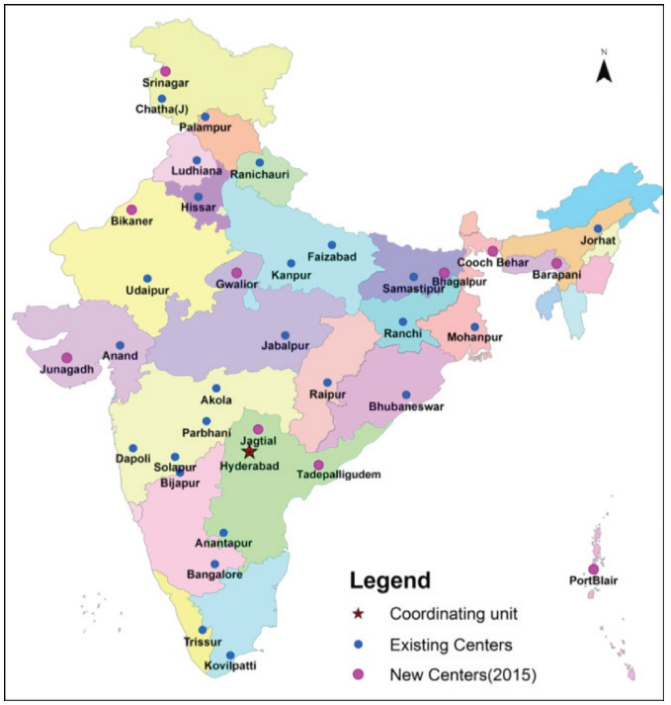


Fig 4.1 : Network of AICRPAM with new centres

4.2.3 Trainings/Workshops/Symposia Conducted

4.2.3.1 Annual review meeting of AICRPAM-NICRA

The annual review meeting of AICRPAM-NICRA was held at CRIDA, Hyderabad during 26-27, August 2014. Dr. M. Maheswari Director (Acting), CRIDA pointed out the need for down-scaling the Agromet Advisory Services (AAS) to cover the entire country Dr. N. Sudhakar, Zonal Project Director (Zone-5) and chief guest pointed out the importance of accurate weather information at the micro level, which is the need of the hour, wherein KVK has a great role to play. Dr. VUM Rao, Project Coordinator (AICRPAM), reiterated the need to reach farmers as emphasized by DG, ICAR, and the challenges ahead in achieving the targets like reaching the farmers with real-time Agromet Advisory Services. The inaugural session was followed by eight technical sessions in which all the technical, financial and administrative issues of each center were discussed.

4.2.3.2 XIII biennial workshop of AICRPAM

The XIIIth biennial workshop of AICRPAM was held at IGKV Raipur during 5-7 November 2014. Shri. Brijmohan Aggarwal, Honorable Minister for Agriculture, Animal Husbandry, Fisheries and Water Resources Govt of Chhattisgarh was the Chief Guest and Dr. S. K. Patil, Vice Chancellor, IGKV chaired the inaugural function. Dr. Ch. Srinivasa Rao, Director, CRIDA was the guest of honor. Six technical sessions on various themes (crop-weather relationships, weather based crop insurance, weather effects on pests and diseases, agroclimatic characterization, crop growth modeling and finalization of technical programme) were conducted separately. Experts from the concerned subjects chaired each session during the workshop. The workshop was concluded with the presentation of Dr. VUM Rao, during the plenary session, who summarized the recommendations made from the three days' deliberations.

4.2.3.3 Brainstorming session

A brainstorming session on 'Strengthening of AICRPAM research activities' was held on 23rd May 2014 at CRIDA, in which staff from all the cooperating centers attended. The session was intended to discuss about the ongoing research programmes of AICRPAM, their functioning and modifications to be taken up for strengthening or refinement of the research programs for better output and clientele service. Renowned agrometeorologist and Former Project Coordinator, Prof. B. V. Ramana Rao was the chief guest for the session.

4.2.3.4 Customized training program to AIC Officers

A customized training programme for officers of Agriculture Insurance Company (AIC) was organized during 11-16th August, 2014 at CRIDA. Six members from different zonal offices of AIC attended the training. The participants were exposed to a series of lectures delivered by CRIDA scientists on climate change and risk management, extreme weather events, monsoon, crop cutting experiments etc. A field visit was also included to Hayathnagar Research Farm (HRF) for learning the agrometeorological observation and working principle of Automatic Weather Station. In addition to this, the participants were given hands on training on quality checking of weather data with Weather Cock software. Dr. B. Venkateswarlu, Vice-Chancellor of VKMKV, Parbhani has delivered an invited talk on 'Role of Insurance in Managing Climate Risks in India' during the training.

4.2.3.5 Capacity building

Based on the recommendations of the XIII Biennial workshop of AICRPAM held in November 2014 at Raipur, a 10 day in-service capacity building programme was conducted at CRIDA from 3-12th February, 2015 for the scientists of all the coordinating units. Crop growth simulation studies using DSSAT model and crop-weather relationships were the two research areas where the scientists were trained during the program. Unlike in other capacity development programmes, exchange of knowledge among the participants was facilitated and some participants acted as trainers too.

4.2.4 NICRA component of AICRPAM Project

4.2.4.1 Development and dissemination of micro-level agromet advisories

A conceptual framework for development and dissemination of agromet advisories was developed at Jammu and Raipur centers. Agromet advisories were prepared in collaboration with AICRPAM-NICRA and KVK. The methodology followed and flow chart of various steps in dissemination of agromet advisories is represented in Fig. 4.1.

4.2.4.2 Farmers awareness programs on climate change

During 2014, 68 farmers awareness programs on climate change were conducted across the country which benefitted 11,312 farmers (9094 men and 2218 women).

4.2.4.3 Effect of El Niño on rainfall and crop productivity in NICRA district Hamirpur (Palampur center)

The monthly rainfall data of NICRA district for the years 1971-2009 was used in this study. It was noticed that the average rainfall in southwest monsoon (June-September), winter season (October-May) and annual rainfall during El Niño years was higher than non-El Niño years in this district and the departure in all the cases was more than 15 per cent. It was also found that though the average production was not affected, but productivity was affected up to 5 per cent due to El-Nino.

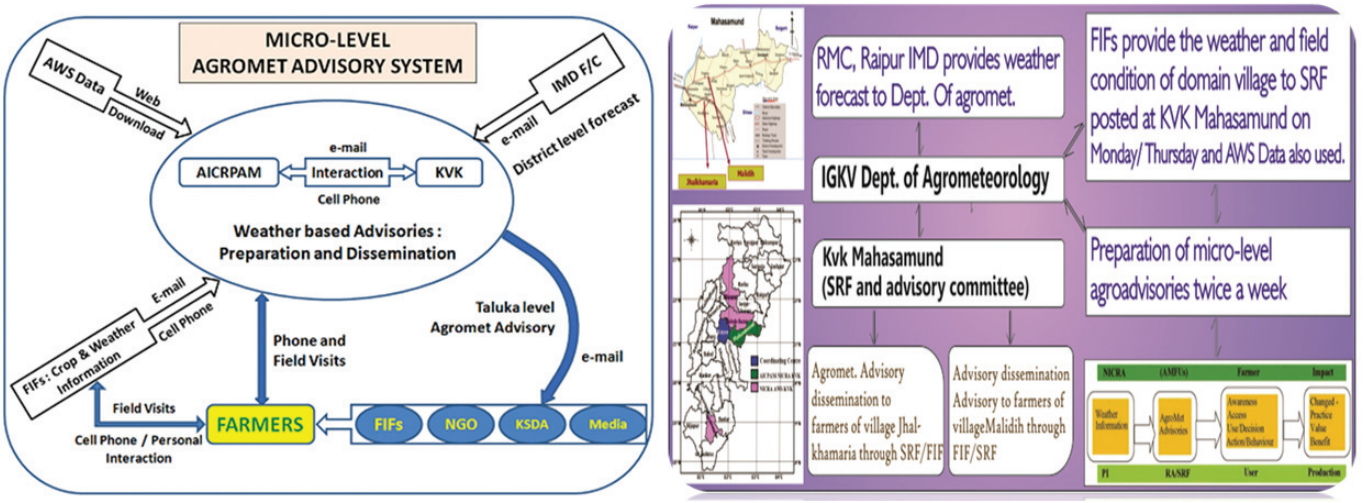


Fig. 4.1: Framework for development and dissemination of micro-level agromet advisories at NICRA villages of Kathua district, Jammu and Mahasamund district of Chhattisgarh

5 Krishi Vigyan Kendra

Krishi Vigyan Kendra (KVK) of CRIDA was established in 1976 to cater to the needs of the farming community of Ranga Reddy district. The major objectives of KVK is to organize need based and skill oriented training programs for practicing farmers and farm women by the principles of 'Learning by doing' and 'Teaching by doing'. Considerable amount of work has been done by the KVK by way of transferring technologies related to rainfed farming through On Farm Testing (OFTs), Front Line Demonstrations (FLDs), Trainings and Extension activities. The farmers, farm women and rural youth in Ranga Reddy District are being benefited by the KVK activities and trainings since its inception. For the period under review the following activities were accomplished.

5.1 On Farm Testing (OFT)

The KVK under Technology Assessment and Refinement has assessed 14 technologies (Varietal trails, ICM, IPM, horticulture, farm mechanization and livestock management) in the KVK adopted villages during *kharif* and *rabi*, 2014-15.

Table 5.1: Results of OFTs during 2014-15

Technology	No. of Trials	Yield (kg/ha)		Net return (Rs)	B:C Ratio
		Farmers Practice	Improved Practice		
Assessment of high yielding and stress tolerant bajra hybrid (PHB-3)	3	700	1055	2270	1.18
Assessment of short duration and high yielding redgram variety (PRG-176)	3	375	475	3812	1.62
Assessment of wilt tolerant and high yielding castor variety (DCS-107)	4	375	62	3308	1.19
Assessment of wilt tolerant and high yielding chickpea variety (Nandyala senega-1)	8	625	9875	11762	1.62
Assessment of triple resistant tomato hybrid (Arka Rakshak)	8	58000	66000	217500	2.93
Use of 'Arka vegetable special' for higher flower and fruit set in tomato	10	63500	70750	231750	2.90

Technology	No. of Trials	Farmers Practice	Improved Practice	Results
Efficacy of coated vitamins and chelated minerals in anoestrous condition due to nutritional deficiency in bovine cattle.	11	Natural grazing	Natural grazing + Balanced ration supplementation of coated vitamins, chelated minerals	Nine animals showed heat signs in time and conceived. Two animals not conceived due to ill developed genetalia

Effect of area specific mineral mixtures on livestock productivity at farmer level	25	Natural grazing	Natural grazing + Balanced ration supplementation of area specific mineral mixtures (Ca,P,S,Cu,Zn,Co, I)	Improved quantity of milk (41.6%) and fat (20%). Revenue through sale of milk increased by 47.6% and calves health and body weight also improved.
Efficacy of Oxyclozanide and Levamisole in control of antihelminthics in calves and lambs	20	No deworming	Deworming with Oxyclozanide and Levamisole.	Reduction of diarrhea and improved body hair coat
Effect of mineral bricks supplementation on growth in grazing lambs	15	Natural grazing , no supplemen-tation of minerals	Natural grazing + Balanced ration with supplementation of mineral	Improved hair coat, appetite, immune response, body weight increased by 58%
Assessment & performance of new dual purpose Srinidhi breed	25	Local desi birds	Improved breed birds given to farmers @ 10 birds per farmer	More body weight, egg weight, egg production, survivability in new breeds over desi breeds
Performance of Hybrid bajra napiers Co4 and RBN-13 (Phule Jaywanth)	2	Fodder variety Co-4	Fodder variety RBN-13	RBN-13 matured early with longer leaf length.

OFT on bajra hybrid, PHB-3 at GM guda

OFT on chickpea variety, NBeg-3 at Medipalli

OFT on Silage making at GM guda

5.2 Front Line Demonstrations (FLDs)

FLDS on different components were conducted in redgram (25), cotton (15), horsegram (25), ragi (6), tomato (10), brinjal (3), chillies (5), fodder (16) and cattle (10) including home sciences and veterinary sciences (2).The details of FLDs are given below:

FLD on Chaff Cutter at GM guda

Table 5.2: Results of FLDs during 2014-15

Crop	Technology	Demos	Yield (kg/ha)		% Increase
			Farmers Practice	Improved Practice	
		Kharif			
Cotton	Sucking pest management with stem application and verticillium spray	15	425	550	29.4
Redgram	Wilt tolerant and high yielding variety of redgram, PRG-158	25	375	467	24.53
Horsegram	Demonstration of horsegram varieties CRHG-4 and CRHG-18 R	25	350	499	42.57
Ragi	Demonstration of high yielding and blast tolerant ragi, variety PRS-2	6	625	800	28.0
Tomato	Raising hybrid tomato nursery in pro-trays under shade net	10	Cost of raising nursery under FP is Rs.4900 and Cost of raising nursery under shade net is Rs. 2300		Rs. 2600/- saving at nursery stage
Brinjal	Use of plastic mulching in brinjal	3	48000	70000	45.8
		Rabi			
Brinjal	Demonstration of luci water pheromone traps for shot and fruit borer on brinjal	10	18500	20000	8.11
Chilli	Nursery in pro-trays under shade net	3	Cost of raising nursery under FP is Rs.6200 while the same under shade net was Rs. 3100		Rs. 3100 saving at nursery stage alone

Cattle	Demonstration of vitamin E, Selenium along with Meloxicam plus, Enrofloxacillin in treatment of Bovine mastitis.	10	Indiscriminate use of antibiotics and severe economics loss	Symptomatic treatment, Vit E, Se suple-mentation, painkiller, antibiotics treatment. Awareness on mastitis by CMT kit	Complete recovery of milch animals.
Perennial fodder	Demonstration of Co-4 fodder variety	16	Local varieties 220 t/ha	Co-4 350 t/ha	59

FLD on area specific mineral mixture

FLD on luci traps in brinjal

FLD on CRIDA horsegram variety CRGH-4 at GM Guda

FLD on raising vegetable nursery in portrays and shade nets

FLD on plastic mulching in vegetables

5.3 Home Science

About 60 demonstrations on drudgery reduction and nutritional aspects for rural farm-women viz., cotton gloves for plucking bhendi, bhendi cutters andCaprons,and a vocational training program on preparation of multigrain atta was organized in KVK adopted villages during the year 2014-15.

5.4 NICRA intervention modules in CRIDA-KVK adopted villages

5.4.1 Module 1: Soil and Water Conservation Activities

National Initiative on Climate Resilient Agriculture (NICRA) Project was launched at Kandlapalli, Mirzapur and Yenkepalli villages in Pudur Mandal, 100 km away from Hyderabad. The population of three villages was 4255 and the total cultivated area is 11398 ha, the cluster consists of red and block cotton soils. Analysis of various types of rainfed situations revealed that soil and water conservation, and efficient water management are the key to sustainable development. As part of NRM activities in the three villages the various activities were taken up.

A close analysis of various types of rainfed situations would reveal that soil and water conservation, watershed development and efficient water management are the key to sustainable development of rainfed areas. The watershed approach has been accepted as a major theme for development of rainfed areas with a view to conserving natural resource. NRM activities were done in three adopted villages selected in Rangar Reddy Dist, Pudur Mandal, viz., Knanlapalli, Mirzapur and Yenkepalli.

- Rain water harvesting structures and reusing methods (Farm Pond Technology)
- Renovation of water bodies (Percolation tanks)
- De-silting of tanks and canals
- Land development and leveling for additional cultivation
- Flood control measures in different rainwater harvesting structures
- Micro irrigation facilities to conserve the water and efficient irrigation to crop
- Custom hiring equipments for farmer's benefit

Groundwater use in pre-project period

In the pre-project period (2010–11), total water requirement for irrigation during *kharif* and *rabi* was 15%. This requirement was met by rainfall (0.5 ha m) and the net availability of groundwater (53.4 ha m) This resulted in a desirable situation of groundwater surplus to tide over drought years, which is a common occurrence (once in three years) in this arid to semi-arid tract.

Groundwater use in post-project period

In the post-project period (2011–2014), the average irrigated area increased. Correspondingly, the average groundwater draft also increased. Irrigation water was met by direct rainfall and natural recharge plus recharge due to existing Tank in the vicinity. Among the existing eighteen open wells (average depth 15 m) some of the wells dried up since 2006 due to the indiscriminate drilling of bore wells became functional by ground water recharge. Further, failure rate of the bore wells also dicreased considerably during the post project period.

Table 5.3: Change in ground water levels in three villages

Village Name	Open wells			Bore wells		
	Pre Project (m)	Post Project (m)	Change (%)	Pre Project (m)	Post Project (m)	Change (%)
Kandlapalli	20	15	25	25	18	28
Mirzapur	10	6	40	20	15	25
Yenkepalli	13	9	31	20	15	25

Table 5.4: Increase in ground water use for irrigation

Project period	Year	Rainfall (mm)	Irrigation quantity required (ha m)	Water availability (ha m)
Pre-project	2010	1108	14	15.51
Post-project	2011	612	28	17.13
	2012	780	36	28.08
	2013	655	30	19.65
	2014	520	33	17.43
Average		**641.75**	**31.75**	**20.57**

Table 5.5: Changed in crop area during pre and post project period

Crops	Pre project area (ac)	Post-Project area (ac)				% Increase
	2010	2011	2012	2013	2014	
Paddy	12.3	14.5	15.6	16.3	15.2	25.20
Maize	4.7	5.1	5.3	6.5	6.6	25.00
Redgram	12.2	14.1	16.4	20.2	15.2	35.04
Jowar	7.5	8.3	9.1	9.8	8.3	18.33
Turmeric	3.2	3.5	4.3	5.8	4.4	40.62
Vegetables	6.5	7.2	7.7	8.3	12.1	35.76
Fodder	2.1	2.4	3.2	3.5	4.6	63.09

Impact

- Productive wells increased
- Area under irrigation increased
- Cropped area increased
- Production of Fodder crops increased
- Vegetable production increased

Percolation tank renovated at KVK adopted village

5.4.2 Module 2: Production of Quality Seedlings in Pro-trays under Shadenet Nursery: A low Cost Technology for Small and Marginal Farmers

Background

Ranga Reddy, a peri urban district of Telangana has immense potential for fruits and vegetable cultivation. To meet the growing demand for fresh produce, intensive cultivation is need of the hour. Unpredictable rains and fluctuations in extreme temperatures during nursery cause severe loss to farmers. Seeds of hybrid vegetables are sold at very high price, hence converting every individual seed into a healthy seedling becomes essential and this requires intensive nursery management. Use of shade net nursery by individual farmer, particularly those with small land holding was found to be feasible and economically viable.

KVK intervention

Creating Awareness: Participatory rural appraisal was conducted in Gaddamaliahguda village of Yacharammandal, Rangareddy district through focused group discussion and one to one interaction with vegetable growers. It was found that a setback of knowledge levels of the farmers is one of the important reasons for low yields. Training cum demonstration program was organized at village level in which 40 farmers have participated. The technique of raising pro tray seedlings in different stages were explained and demonstrated. The cost of production of seedlings was also explained.

Supply of inputs for establishment of individual shade net nursery: Fifteen Shade net nurseries of 25 × 1.5 m dimension was established using locally available materials such as bamboo sticks, plastic pipes using the sidewalls. UV stabilized HDPE net of 50 per cent intensity was used to cover the nursery. Fifty protrays (98 celled) and three bags (75 kg) of coco peat were supplied to each farmer.

Table 5.6: Cost of production of one seedling in protrays

Crop	Cost (Rs)
Tomato	0.35
Capsicum	0.68
Chilli	0.35
Cabbage	0.24
Cauliflower	0.23
Brinjal	0.27

Table 5.7: Comparison of tomato nursery production

Particulars	Farmers Practice	Shade net Nursery
Land preparation	Rs. 400	Rs. 200
Seed rate	150 g/acre	60 g/acre
Cost of seed	Rs. 6000	Rs. 2400/-
Growth of seedling after 25 DAS	8-10 cm	12-15 cm
Root proliferation	Average	High
Pest & disease incidence	High	Negligible
Mortality after transplanting	High	Very low

Impact of the technology

As a part of technology dissemination and demonstration, 15 farmers from KVK adopted villages were selected for supply of inputs (shade net, pro-trays and coco peat) for nursery rising in 7.5 acres of tomato. After the completion of the first crop season, 50 farmers adopted this technology on their own and the area of nursery increased to 25 ac. Production of vegetable seedlings in portrays under shade net reduces cost of production and enhances productivity. Department of Horticulture, Government of Andhra Pradesh recognized the need for promotion of small nurseries by individual farmers. With the inputs from KVK, Ranga Reddy Dt, Govt. of Telangana is providing units consists of 100 pro-trays, 6 coco peat bags, 100 sq m shade net (40 %) all of which costs about Rs. 6000, of which 50 % (Rs. 3000) is being borne by State Government under subsidy.

5.4.3 Module 3: Plastic mulching in brinjal

Mulching with 30 micro five layered polythene plastic sheet having silver colour on top and black colour on the bottom was demonstrated in the farmer's fields. Demo plot had showed higher plant growth, flowers, fruit set and yields due to the improvement in water, fertilizer use efficiency along with effective weed management when compare to farmer practice. Yield increase was up to 52.1 per cent in demo plots. The added advantage of mulching is that there is low incidence of sucking pest and disease due to the reflective heat of sunlight which penetrates in to the under parts of the leaf. However feedback from farmers is that Initially laying of beds & spreading of mulching sheet was tedious and involves cost.

Table 5.8: Cost benefit analysis of plastic mulching in brinjal

Particulars (per acre)	Farmer Practice	Mulching
Growth of the plant at 30 DAT	45 cm	63 cm
Manual weddings	4 times (Rs. 12000)	Nil
Pest and disease incidence	High	Negligible
Pesticide sprays	8	5
Cost of plant protection sprays	Rs. 4800	Rs. 3000
Cost of Inputs for mulching	Nil	10000
Total no. of pickings	8	12
Total yields(t/acre)	19.2	28
Cost of cultivation	Rs. 45500	Rs. 45700
Gross income	Rs. 57600	Rs. 84000
Net income	Rs. 12100	Rs. 38300
BC ratio	1.26	1.84
Per cent increase in Yield	---	45.8


Plastic mulching in Medipalli village, Moinabad mandal, Ranga Reddy District

5.4.4 Module 4: Scarcity to Surplus Fodder with Enhanced Milk Productivity – A Success Story in KVK adopted Villages

Introduction and background

Jalaguda, Pamina (Chevella Mandal) and Thimmareddiguda (Shabad Mnandal) in Ranga Reddy district lack quality fodder, especially during November to May, which is a major limiting factor for improving livestock production. These villages possess 2819 buffaloes, 1637 cattle, 26650 sheep and 11437 goat populations. The benchmark of milk productivity in the cluster was 2.5 litres/day per animal with a fat content of 4-5%. The sale price of milk was Rs.18 per litre. During summer all livestock has to rely on crop residues like paddy straw and hence many animals go undernourished and weak leading to severe anoestrous condition. Because of urbanization, small land holdings and lack of water, fodder crop cultivation is practiced by a very few farmers in the village.

Traditional forage production techniques

- Generally paddy straw and sorghum stover account for about 70 - 80 % of the available feed. However its quality is poor, especially in terms of protein to meet their dietary needs. The feed conversion can be improved by urea treatment of straw and by feeding concentrates to milking cows.
- Sowing fodder Jowar locally called "Bhujonnallu" once or twice a year with recommended seed rate and thinning for green fodder. The straw from this generally gives poor quality fodder besides giving low yields.
- Some of the farmers graze their large and small ruminants on cotton crop residues after harvesting

Institutional Interventions

Farmers of KVK in its adopted villages namely Jalaguda, Pamina and Thimmareddiguda, Ranga Reddy dt were introduced to improved fodder crops (Jowar var. *M.P. Chari* at 75% subsidy from State Animal Husbandry department in an area of 20 acres by about 88 farmres in 2009. Later under KVK FLD program perennial cereal (Hybrid Napier grass- APBN1) and leguminous fodder (*Stylohamata*) weredemonstrated with 40 farmers. Besides this in collaboration with Regional Station for Fodder Production and Demonstration, about 52 FLDs consisting cereal fodder crops viz., maize (*Var:African tall*), jowar (*Var: SSG*) and guinea grass (*Var: Macunae*) were introduced in these three villages. The farmers were also provided fertilizers each 8 kg Urea and 5 kg DAP and a one day training on production techniques. A total of 180 farmers got benefited through KVK intervention.All farmers were also trained in preparation of balanced concentrate mixture and enrichment of locally available paddy straw with urea molasses and urea molasses bricks.

Impact

With these techniques, the livestock got maximum nutritional benefit and balanced ration. This in turn resulted in the ability of the animals to convert feed to meat and milk more efficiently, and improved the quality of the final product. The milk productivity in the cluster increased from 2.5 to 5.5 liters/day/animal. Fat content increased from 4-5% to 10-11%, and price of milk was fetched @ Rs.38 per liter (initial price was Rs. 30/lt).

Improved fodder production

5.5 Training Programs

The Krishi Vigyan Kendra organized need based and skill oriented training programs on various aspects of improved technologies to clientele Farmers, Farm women, rural youth and field level extension workers.

Table 5.9: List of trainings organized by KVK during 2014-15

Theme	No. of trainings	Participants		Total
		Male	Female	
Crop Production	6	161	32	193
Plant Protection	5	170	30	200
Home Science	12	-	273	273
Veterinary Science	19	576	83	659
Agricultural Engineering	5	189	10	199
Horticulture	16	250	217	467
Total	63	1346	645	1991

Table 5.10: Extension activities by KVK during 2014-15

Activity	Numbers
Field diagnostic visits	16
Animal health camps	1
Field days	2
Radio talks	18
Agro-advisory services through mobile contacts and SMS	670
National nutrition week	1
Women in Agriculture day	1
Exposure visits	4
ATMA trainings	8

Animal health camp at GM Guda

Off campus training on PPV & FR Act at Vikarabad

Exposure visit to livestock research station, Mahabubnagar

Diagnostic field visits to assess pest damage

Exposure visit to KVK, Banaganapalle, Kurnool District on hydroponic fodder production

Drought assessment in the KVK village

Exposure visit to IIMR, Hyderabad

Field day on plastic mulching in chilli at GM Guda, Yacharam

Visit of Ethiopean delegates to KVK

PRA in the new KVK adopted village, GM Guda, Yacharam

Swatch Bharath at HRF and KVK

Table 5.11: Seed/planting material and bio fertilizers produced at KVK during 2014-15

		Quantity	Value (Rs.)	Beneficiaries
Flowers	Chrysanthemum (PBAU 107, Silper, Raichur, Poornima)	28000 seedlings	56000	11
	Tube rose (Hyderabad single)	500 seedlings	2500	3
	Gaillardias (Mixed variants)	5 kg	5000	21
Fruits	Mango (Beneshan, Dasheri, Punasa)	50 seedlings	1250	12
	Custard apple (Balanagar)	80 seedlings	800	7
	Jamun (Allanerudu)	200 seedlings	2000	28
Other crops	Velvet bean (ArkaAswini, ArkaDanvantari)	10 kg	700	4
	Curry leaf (Suvasini)	300 seedlings	3000	6
Fodder	Hybrid Napier (Co-4)	1,24,000 slips	39570	35
Bio fertilizers/Bio-pesticides	Azospirillum, Azotobactor, PSB, ZSB, KMB, Rhizobium, Trichoderma and Pseudomonas	3801 kg	1,81,270	950
Total			**2,92,270**	**1077**

6 Human Resource Development

6.1 Deputation within India

Name	Title	Duration	Venue
B.M.K. Raju	Training Workshop on DSSAT4.6 and CCAFS's Regional Agricultural Forecasting Toolkit (CRAFT)	29 June – 02 July, 2014	New Delhi
K. Nagasree	DST sponsored Training Programme on Advanced Techno Management for Scientists	27 October – 28 November, 2014	ASCI, Hyderabad
V. Maruthi	Managing Innovation and Technology for Competitiveness	01-12 December, 2014	ASCI, Hyderabad

6.2 Deputation outside India

Name	Title	Duration	Venue
M. Prabhakar	International R&D course on Integrated Pest Management held by Ministry of Agriculture and Rural Development, Govt. of Israel.	11 May -03 June, 2014.	CINADCO's Training Centre, Volcani Agricultural Complex, Tel Aviv, Israel
S. K. Yadav	Norman E. Borlaug International Agricultural Science and Technology Fellowship Program 2014, Sponsored by USDA-FAS	15 February -09 May, 2015	University of Georgia, USA

6.3 Undergraduate and post graduate research and training

Scientist	Student	Degree	Discipline	Institute/University
K.A. Gopinath	K. Ramesh	M.Sc.	Agronomy	PJTSAU, Hyderabad
I. Srinivas	P. Venkataramana Reddy	B.Tech	Agricultural Engineering	College of Agricultural Engineering, ANGRAU, Bapatla
I. Srinivas	A. Naga Bhargavi	B.Tech	Agricultural Engineering	College of Agricultural Engineering, ANGRAU, Bapatla
I. Srinivas	G. Pragna	B.Tech	Agricultural Engineering	College of Agricultural Engineering, ANGRAU, Bapatla
N. Jyothi Lakshmi	Ch.Ram Prasad	Ph.D	Genetics	OU, Hyderabad
K.L. Sharma	D.Suma Chandrika	Ph.D	Environmental Science	JNTU, Hyderabad

K.S. Reddy	B. Umesha	Ph.D	SWC Engineering	UAS, Raichur
Minakshi Grover	Shrey Bodhankar	Ph.D	Microbiology	Osmania University, Hyderabad
M. Srinivasa Rao	Abdul khadar Biradar	Ph.D	Agricultural Entomology	UAS, Raichur
M. Srinivasa Rao	D. Manimanjari	Ph.D	Zoology	OU, Hyderabad
M. Srinivasa Rao	Divya Bharati	Ph.D	Agricultural Entomology	ANGRAU, Bapatla
N.N. Reddy	K.Venkata Subbaiah	Ph.D	Horticulture	Dr YSR Horticultural University, Venkataramannagudem
N.N. Reddy	P. Nagi Reddy	Ph.D	Horticulture	Dr YSR Horticultural University, Venkataramannagudem
D.B.V. Ramana	S.A. Kochewad	Ph.D	LPM	SVVU, Hyderabad
D.B.V. Ramana	Praveena	M.Sc.	Biotechnology	Layola Academy Degree and PG college, Hyderabad
S. K. Yadav	M. Gopala Krishna	Ph.D	Genetics	OU, Hyderabad
S. K. Yadav	Yogesh Kumar Tiwari	Ph.D	Biochemistry	JNTU, Hyderabad
M. Vanaja	G. Vijay Kumar	Ph.D	Genetics	OU, Hyderabad
M. Vanaja	Y. Anitha	Ph.D	Genetics	OU, Hyderabad
M. Vanaja	Sowmya	Ph.D	Genetics	OU, Hyderabad
M. Vanaja	Sunitha Vaidya	Ph.D	Botany	OU, Hyderabad
M. Vanaja	Ira Khan	Ph.D	Botany	OU, Hyderabad
M. Vanaja	P. Vagheera	Ph.D	Environmental Science	OU, Hyderabad
M. Vanaja	Satyavathi	Ph.D	Environmental Science	OU, Hyderabad
K. Nagasree	T. Archana	Ph.D	Agricultural Extension	ANGRAU, Hyderabad

6.4 Higher studies

Scientist	Supervisor	degree	Discipline	Institute/University
R. Nagarjuna Kumar	K. S. Reddy	Ph.D	Computer Applications	Birala Institue of Technology, Ranchi
G. Venkatesh	B. Venkateswarlu	Ph.D	Environmental Sciences	JNTU, Hyderabad

7 Women in Agriculture

KVK-Rangareddy under ICAR- CRIDA carried out many training programmes, exposure visits, FLDs for farm women for their skill development and income generation. It has conducted 20 programmes,on and off campus, short and long duration, in which 561 farm women were trained in various aspects.

7.1 Training Programmes for Farm Women

Total No. of Programmes conducted : 11
Total No. of Women Trained : 336
Duration of the training (days) : 1-30
Venue : On/Off campus

S. No	Title of the course	Duration	Venue On/off	Villages	No.of participants
1	Value addition to Mango and marketing	3	On	Mirzapur	18
2	Value added products/market led extension	1	On	Sponsered by ATMA	37
3	Use of millets in daily diet	3	Off	Mirzapur	15
4	Entrpreneurship development	7	Off	Mirzapur	16
5	Preparation of vermicompost - uses	1	Off	Gaddamallaiah guda	20
6	Preparation of nutritious recipes using locally available foods	2	Off	Gaddamallaiah guda	27
7	Deficiency disorders-and their correction	1	Off	Gaddamallaiah guda	23
8	National Nutrition week		Off	Gaddamallaiah guda	100
9	Introduction of recipes with minor millets	2	Off	Gaddamallaiah guda	15
10	Candle making	1	Off	Gaddamallaiah guda	30
11	Tomato preservation	1	On	Yacharam mandal	35

Demonstration of vermicompost bed preparation

7.2 Vocational Training Programmes for Rural Youth

Total no of Vocational Training Programmes : 2
No. of Adolescent Girls trained : 60
Duration of the training (days) : 1- 30
Venue : On/Off

S. No	Title of the course	Duration	Venue On/off	Villages	No.of participants
1	Bakery	6	Off	Gaddamallaiahguda	30
2	Preservation of fruits and vegetables	6	Off	Gaddamallaiahguda	30

7.3 Exposure visits

Total no. of Exposure visits : 3
No. of farm women participated : 70

S. No	Places visited	Duration	Villages participated	No.of participants
1	NIRD, rural technology park	1	Gaddamallaiah guda	18
2	Directorate of sorghum research	1	Gaddamallaiah guda	37
3	Millet fest organised by PJSAU	1	Gaddamallaiah guda	15

Trainees displaying biscuits made from Jowar flour

Women of Rangareddy district at the Millet festival organised by PJTSAU

7.4 Front Line Demonstrations (FLDs)

Season	Intervention	No. of women farmers
Rabi	Cotton gloves for plucking bhendi	20
	Bhendi cutters	10
	Caprons	10
	Multi grain atta	25

7.4.1 Cotton gloves for cutting Bhendi (*Abelmoschus esculentus*)

Wearing cotton gloves while manual harvesting of bhendi vegetable has found to reduce the drudgery for women as bhendi crop has mild thorns. Ten farm women have tried this intervention in their fields and found it acceptable and would continue to use it in all seasons.

Farm woman wearing cotton gloves

7.4.2 Bhendi cutters

Use of Bhendi cutters has found to reduce the drudgery while harvesting the crop. Ten farm women have tried this intervention in their fields and found it acceptable and would continue to use it in 2015-2016.

Farm woman using bhendi cutter

7.4.3 Capron

Use of caprons reduced injuries and exposure to harmful substances such as dust, chemicals, etc while providing protection from sun.

Farm woman wearing capron

7.4.4 Multi grain atta

Twenty- five farm families have been demonstrated on use of multi grain atta i.e flour made from grains of Jowar (*Sorghum bicolor*), maize (*Zea mays*), bajra (*Pennisetum glaucum*), ragi (*Eleusine coracana*)and korra (*Setaria italica*). Rotis prepared from multi grain atta or flour has found to be aceptable with women because they are soft, palatable, locally available grains can be used, almost consistent with their regular jowar rotis. It is also nutritionally significant with good quality proteins, minerals and vitamins. Women found it useful and would continue using it for their household purpose.

Women preparing roti using multigrain atta

7.5 Radio Talks

Radio talks covered topics in local language relevant to women needs such as balanced diet for women, skill development programmes for women, awareness program on consequences of nutritional defficencies in diet and importance of millets in daily diet.

- *Grameena kutumbalalo poushtikahara lopalu*
- *Vruthi nypunyam penchukovadaniki grameena mahilalaku sikshana*
- *Vermicompost thayari*
- *Aaharamlo zinc lopam, avagahana, savarana*
- *Grameena kutumbalalo chiru dhanyaala vaadakam*
- Balanced diet for infants, pregnant and lactating mothers

7.6 Events organised for farm women

7.6.1 National Nutrition week

Organised National nutrition week from 1-7 September, 2014. 100 farm women participated in the celebration ,in the KVK adopted villages. Topic of the week was balanced diet for different age groups, importance of millets in the diet, and deficiency disorders.

Food and Nutrition scientist interacting with farm women and school children on importance of nutrition

7.6.2 Women in Agriculture Day

Women in Agricultural Day was celebrated on 4 December, 2014 at KVK, RR Dist, CRIDA. On this occasion a program was organized to create awareness on agriculture produce value addition and women empowerment to about 50 women farmers from four different villages of Ranga Reddy District. Director, CRIDA, Dr. Ch. Srinivasa Rao presided over the inaugural function and interacted with them over the women related issues in agriculture. In the inaugural address he shared his experiences from NAIP project of tribal women of Nalgonda District and the success story of community biogas production linked to community vermicomposting in the tribal areas. He further emphasized the need for strengthening the Self Help Groups (SHGs) in the villages, develop entrepreneurship among rural women through community approach and enhance nutritional security in adolescent women and children, particularly in rural areas. The participants had hands-on training on value addition of tomato by making pickles, ketchup, sauce etc.

Women participating in Women in agriculture day

8 Awards and Recognition

AICRP on Agrometeorology (AICRPAM) was awarded the Chaudhary Devi Lal Outstanding All India Coordinated Research Project Award - 2013 for outstanding work on climatic variability and development of real-time contingency plans. Dr. VUM Rao, Project Coordinator (AICRPAM) received the award on 29th July 2014 during the ICAR awards ceremony from Dr. Sanjeev Kumar Balyan, Minister of State for Agriculture, Govt. of India.

Dr. G. Ravindra Chary, Principal Scientist (Agronomy), AICRPDA, received **Fellow of Indian Society of Agronomy Award** for outstanding contributions in the field of agronomy. The award was presented on 18th November 2014 during National Symposium on Agricultural diversification for sustainable livelihood and environmental security organized by Indian Society of Agronomy at PAU, Ludhiana.

Dr. Ch. Srinivasa Rao, Director, CRIDA was awarded **National Academy of Agricultural Sciences (NAAS) Recognition Award** for 2013-14. The award was presented during the inaugural session of 12th Agricultural Science Congress, held at NDRI, Karnal for his significant research contributions in the field of Soil, Water and Environmental Sciences.

Dr. M Prabhakar, Principal Scientist was awarded with **MASHAV International Fellow** by the Israel's Agency for International Development Cooperation, Ministry of Foreign Affairs, Government of Israel, 2014.

Dr. Arun K Shanker, Principal Scientist was honored with **Fellow Award of the Society of Applied Biotechnology** in recognition of outstanding contribution in the area of bioinformatics.

Dr. DBV Ramana, Principal Scientist, received **Fellow of National Animal Production Management (FNAPM) Award** from Indian Society of Animal Production and Management during National Symposium and XXII annual Convention held at Aizwal, CAU during 28-30 January, 2015.

Dr. KA Gopinath, Senior Scientist received the **Best Editor** Award for outstanding contribution in bringing out "International Journal of Bio-resource and Stress Management" for the year 2013. The award was presented on 7th January, 2015 during the 2nd International Conference on Bio-resource and Stress Management at Hyderabad.

Dr. K. Ravi Shankar, Senior Scientist received the **Young Scientist** Award-2014 from Society of Extension Education, Agra at the 7th National Extension Education Congress on "Translational Research-Extension for Sustainable Small Farm Development" at ICAR RC for NEH Region at Barapani, Meghalaya during November 8-11, 2014.

Dr. K Nagasree, Senior Scientist (Agricultural Extension) was conferred with Indian Society of Extension Education (ISEE) **Young Scientist Award -2014** in recognition of outstanding work done in the field of extension research and grass root extension services. The award was presented by Dr. A.K. Singh, VC, RVSKVV in ISEE National Seminar-2014 on Extension Innovations and Methodologies for Market-led Agricultural Growth and Development held at Rajmata Vijayaraje Scindia Krishi Vishwa Vidayalaya (RVSKVV), Gwalior (M.P) during February 26-28, 2015.

Er. R. Nagarjuna Kumar, Scientist, received **Scientist of the Year Award-2013** of Society for Scientific Development in Agriculture and Technology (SSDAT) for the best work done in the field of computer applications in agriculture. The award was given by Dr. V. Ravindra Babu, Project Director, DRR, Hyderabad in National Conference on Emerging Challenges and Opportunities in Biotic and Abiotic Stress Management (ECOBASM-2014), held during December 13–14, 2014 at Directorate of Rice Research, Rajendranagar, Hyderabad.

Dr. Kaushalya Ramachandran, National Fellow and her GIS team were awarded the **Asia Geospatial Excellence Award-2014** for assessing agricultural vulnerability using satellite data to improve adaptive capacity of rainfed farmers in India on 25th November 2014 at Jakarta, Indonesia.

Rajkumar Dhakar and Sehgal VK. 2014. Geospatial approach for assessing environmental vulnerability of agricultural drought in Rajasthan. **Best oral presentation award** under the theme 'New tools and techniques in geospatial technology for agromet applications' in the International symposium on 'New dimensions in Agrometeorology for sustainable agriculture held during 16-18 November 2014 at GBPUAT, Pantnagar.

Subba Rao AVM, Rao VUM, Narsimha Rao V, Vijaya Kumar P, Bapuji Rao B, Arun Shankar, Rajkumar Dhakar and Sarath Chandran MA. 2014. Climate change impact assessment and adaptation strategy for paddy crop in eastern region of India- a simulation approach. **First runner up oral presentation award** under the theme 'Responding to climate change through managing climatic variability' in the International symposium on New dimensions in Agrometeorology for sustainable agriculture held during 16-18 November 2014 at GBPUAT, Pantnagar.

Dr. Kausalya Ramachandran, Shubhasmita S and Praveen V 2014. Climate change hazard to rainfed agriculture in India. **Best poster award** (3rd prize) in ISPRS Mid-term Symposium held during 09-12 December, 2014 at HICC, Hyderabad.

Vijaya Kumar S. 2014. Impact of Community Based Watershed Development: A Case Study. **Best paper award** in 4th International Conference on Hydrology and Watershed Management Ecosystem Resilience-Rural and Urban Water Requirements held during 29 October - 1 November, 2014 at Center for Water Resource, JNTU, Hyderabad.

Rejani R, Jha MK, and Panda SN. 2014. Groundwater simulation and optimization modeling for sustainable management of a coastal river basin in Eastern India. **Best oral presentation** under the session on 'Groundwater Modelling' in the 4th International Conference on "Hydrology and Watershed Management" held during 29 October to 01 November 2014 at Centre for Water Resources, Jawaharlal Nehru Technological University, Hyderabad.

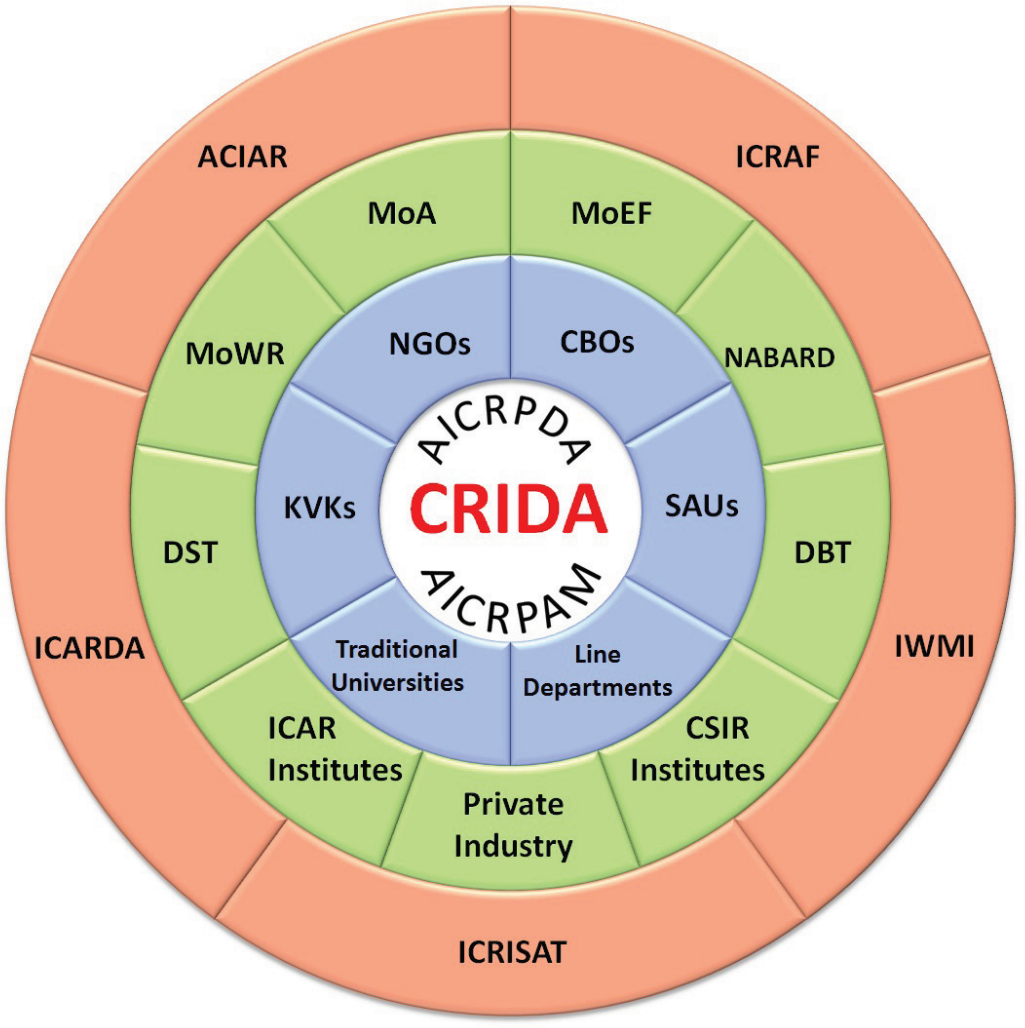
Venkatesh G, Srinivasarao Ch, Gopinath KA, Sammi Reddy K and B Venkateswarlu. 2014. Biochar production from crop residues and its use for climate change mitigation through soil carbon sequestration. **Best oral presentation award** for oral presentation at the National Conference on Emerging Challenges and Opportunities in Biotic and Abiotic Stress Management at ICAR-Directorate of Rice Research, Hyderabad during December 13-14, 2014.

Dr. DBV Ramana, Principal Scientist developed CO-4 **organic fodder production** plot at HRF and obtained conversion **certification** for the second successive year.

Smt. DGM Saroja, Technical Assistant bagged the **Silver Medal in Womens' Chess** in the ICAR Inter Zonal Sports Tournament, 2014 held at NDRI, Karnal during 11-14 March 2015.

9 Linkages and Collaborations

CRIDA continually endeavors to establish new linkages with stakeholders while renewing and strengthening old ones. CRIDA promotes action oriented research in public- private partnership mode through consortium approach. It has strong collaboration with ICRISAT, IWMI, Prof. Jayashankar Telangana State Agricultural University (PJTSAU), Acharya NG Ranga Agricultural University (ANGRAU) and other SAUs, JNTU, Osmania University and other traditional universities, and NGOs for developing and refining technologies for improving profitability in rainfed agriculture. CRIDA also plays a role in advising agencies such as central/state line departments in formulating science based policies on rainfed agriculture. The Institute undertakes specific basic, applied, strategic and anticipatory research programmes fulfilling mandates of both itself and donor agencies. The partners in this mode include CSIR, DBT, DST, etc. CRIDA also takes up consultancy programme for specific tasks from different institutes/organizations. CRIDA takes inputs from IMD and NCMRWF and generates value added outputs for the benefit of the rainfed farmers.



10 Publications

Research papers

Abdul Khadar B, Prabhuraj A, Srinivasa Rao M, Sreenivas AG, Nagangoud A. 2014. Effects of elevated CO_2 associated with chickpea chemistry and its impact on developmental biology of *Helicoverpa armigera* (Hubner). Applied Ecology and Environmental Research, 12 (2): 345-353.

Adake RV, Mayande VM, Srinivas I, Reddy BS, Thyagaraj CR and Kumar ACS. 2014. Modifications and development of critical components of rotary tiller for improving biomass incorporation efficiency (in-situ) in dryland situations. Indian Journal of Dryland Agricultural Research and Development, 29 (2):100 – 103.

Agarwal RK, Das MM, Singh JB, Satya Priya, Sunil Kumar, Sahai CS and Ravindra Chary G. 2014. On farm appraisal of feeding of urea treated straw to lactating buffaloes as means of climatic resilience. Range Management and Agroforestry, 35(2): 245-248.

Banik S, Naskar S, Pankaj PK Pourouchottamane, Barman K, Kaushik P and Tamuli MK. 2015. Effect of different genetic and non-genetic factors on pre-weaning growth performance of pigs. Veterinary practitioner, 15(1): 112-113.

Bapuji Rao B, Rao VUM, Linitha Nair, Prasad YG, Ramaraj AP and Chattopadhyay C. 2014. Mustard aphid infestation in India: Development of forewarning models. Journal of Environmental Biology, 35: 68-74.

Bapuji Rao B, Santhibhushan Chowdary P, Sandeep VM, Pramod VP, Rao VUM. 2015. Spatial analysis of the sensitivity of wheat yields to temperature in India. Agricultural and Forest Meteorology, 200: 192–202.

Bhattacharyya R, Pandey AK, Gopinath KA, Mina BL, Bisht JK and Bhatt JC. 2014. Fertilization and crop residue addition impacts on yield sustainability under a rainfed maize–wheat system in the Himalayas. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences, (DOI: 10.1007/s40011-014-0394-8).

Chary GR., Rao GR, Naidu LKG, Srinivas S, Sunil S, Maruthi Sankar S, Srinivasarao Ch, Ramamurthy V, Pratibha G and Rani N. 2014. Climate and site suitability criteria for *Jatropha curcas* L. cultivation under non-arable marginal lands in different agro-ecological regions of India. Range Management and Agroforestry, 35 (2): 210-219.

Dhadge SM, Satpute NR, Satpute DK, Kathmale DK,. Patil SV, Ravindra Chary G, Srinivasa Rao Ch, Jadhav JD and Kadam JR. 2014. A study on sorghum (*sorghum bicolor* L.) + Chickpea (*Cicer arietinum*) intercropping systems with varying row proportions on a semi-arid vertisol. Indian Journal of Dryland Agricultural Research and Development, 23(2): 34-40.

Girija Veni V, Rattan RK, Datta SP and Sharma KL. 2014. Zinc sorption behavior in soils with divergent characteristics. Communications in Soil Science and Plant Analysis, 45(20): 2697-2711

Gopinath KA, Srinivasarao Ch, Chary GR, Dixit S, Osman M, Raju BMK, Ramana DBV, Saroja DGM, Venkatesh G and Maheswari M. 2014. Improving the productivity of rainfed farming systems of small and marginal farmers in Adilabad district, Telangana. Indian Journal of Dryland Agricultural Research and Development, 29(1): 52-56.

Grover M, Madhubala R, Ali Sk Z, Yadav SK and Venkateswarlu B. 2014. Influence of *Bacillus* spp. strains on seedling growth and physiological parameters of sorghum under moisture stress conditions. Journal of Basic Microbiology, 54(9): 951-61.

Jawahar D, Maruthi Sankar GR, Renuka Devi A, Rajeswari M, Subramanian V, Sharma KL, Mishra PK, Ravindra Chary G and Bhaskar K. 2014. Modeling effects of soil fertility of nutrients and precipitation of twenty two years on sustainable productivity and profitability of pearl millet and sorghum rotation in semi-arid vertisols. Communications in Soil Science and Plant Analysis, 45 (3): 251–270.

Josily Samuel, Rama Rao C A, Raju BMK, Rao KV, Rejani R, Ravi Dupdal, Sharma KL and Maheshwari M. 2014. Economic Implications of Soil Erosion: A methodological framework. Life Sciences Leaflets, 53:22-30

Karthikeyan K, Pushpanjali and Jagdish Prasad. 2014. Soil fertility status of soybean (*Glycine max* l.) growing soils of Malwa plateau, Madhya Pradesh. Journal of the Indian Society of Soil Science, 62(2): 174-178.

Kathmale DK, Dhadge SM, Satpute NR, Patil SV, Ravindra Chary G, Srinivasarao Ch, Jadhav J D and Kadam JR. 2014. Evaluation of pigeonpea (*Cajanus cajana* L.) based intercropping systems under semi-arid vertisol in scarcity zone of Maharashtra. Indian Journal of Dryland Agricultural Research and Development, 29 (1): 27-34.

Kaushalya Ramachandran, Gayatri M, Praveen V and Satish J. 2014. Use of NDVI variations to analyse variability in LGP to assess agricultural vulnerability in Andhra Pradesh. Journal of Agrometeorology, 16(1):112-115.

Kaushalya Ramachandran, Praveen V and Shubhasmita S. 2014. Assessing agricultural vulnerability in India using NDVI data products. Archives of International Society of Photogrammetry and Remote Sensing, XL (8):39-46.

Kaushalya Ramachandran, Rama Rao CA, Raju BMK, Gayatri M, Praveen Kumar V and Satish J. 2013. Mapping agricultural vulnerability for India employing time-series satellite data products. Indian Cartographer, 33: 391-396.

Kaushalya Ramachandran, Shubhasmita S, Praveen V, Kalaiselvi B, and Satish V. 2014. Use of NDVI to Assess Variability in Length-of-Crop-Growing-Period Inducing Agricultural Vulne*rabil*ity – a study of Telangana Region in Peninsular India. Special GLP issue of global environmental research. Association of International Research Initiatives for Environmental Studies, 18(2):161-170.

Krishna H, Grover M, Das B, Attri BL, Maheshwari SK and Ahmed N. 2014. Antagonistic activity of fluorescent Pseudomonas isolate against stem bark canker and white root rot of apple. Annals of Plant Protection Sciences, 22(2): 452-454.

Kumar M, Reddy KS, Ravi Kumar N, Sammi Reddy K and Srinivasa Rao Ch. 2015. Spatial modelling of evapotranspiration for efficient water management at regional scale. Indian Journal of Dryland Agriculture Research and development, 29(2): 23-28.

Kumar M, Singh KP, Srinivas K and Reddy KS. 2014. In-situ water conservation in upland paddy field to improve productivity in north-west himalayan region of India. Paddy water and environment, 12(1): 181-191.

Mahanta D, Bhattacharyya R, Sahoo DC, Tuti MD, Gopinath KA, Arunkumar R, Mina BL, Pandey BM, Bisht JK, Srivastva AK and Bhatt JC. 2015. Optimization of farmyard manure to substitute mineral fertilizer for sustainable productivity and higher carbon sequestration potential and profitability under gardenpea-french bean cropping system in the Indian Himalayas. Journal of Plant Nutrition, (DOI: 10.1080/01904167.2015.1009096).

Manimanjari D, Srinivasa Rao M, Swathi P , Rama Rao CA, Vanaja M and Maheswari M. 2014. Temperature and CO_2 dependent life table parameters of Spodoptera litura Fab. on sunflower and prediction of pest scenarios Journal of Insect Science 14, (DOI: 10.1093/jisesa/ieu159).

Maruthi Sankar GR, Sharma KL, Gabhane VV, Nagdeve MB, Pushpanjali, Gopinath KA, Reshma Shinde, Ganvir MM, Osman M, Karunakar AP,

Anitha Chorey B, Mishra PK, Venkateswarlu B, Singh AK, Suma Chandrika M and Sammi Reddy K. 2014. Effect of long-term fertilizer application and rainfall distribution on cotton productivity, profitability and soil fertility in a semi-arid vertisol. Communications in Soil Science and Plant Analysis, 45: 362–380.

Mohanty M, Sinha NK, Painuli DK, Bandyopadhyay KK, Hati KM, Sammi Reddy K and Chaudhary RS. 2014. Pedotransfer functions for estimating water content at field capacity and wilting point of Indian soils using particle size distribution and bulk density. Journal of Agricultural Physics, 14 (1): 1-9.

Muneswar Singh, Wanjari RH, Manna MC, Lakaria BL, Pramod Jha and Srinivasarao Ch. 2014. Soil carbon management: issues and strategies. Indian Journal of Fertilisers, 10(5):118-132.

Padmakumari AP, Katti G, Sailaja V, Padmavathi Ch, Jhansi Lakshmi V, Prabhakar M and Prasad YG. 2014. Delineation of larval instars in field populations of rice yellow stem borer, *Scirpophaga incertulas* (Walk.). Oryza, 50 (3): 259-267.

Pankaj PK, Mishra A, Pourouchottamane R, Venkatasubramanian V, Ramana DBV and Sahoo NR. 2014. Designing of suitable adjustable dipping tank for organized piggery. Veterinary Practitioner, 14(2) (Supplement-1): 579-581.

Pankaj PK, Raina VS, Pourouchottamane R, Venkatasubramanian V, Mohanty TK and Muzamil S. 2014. Relative efficiency of sterilization methods for the treatment of glassware part of artificial vagina to be used for bovine semen collection. Applied Biological Research, 16(1): 95-98.

Pankaj PK, Ramana DBV, Srinivasa Rao Ch, Saxena MJ, Ravikanth K, Rita Rani, Nikhila M and Adarsh. 2014. Methane mitigation potential assessment of herbal lean meat product in Deccani sheep. British Biomedical Bulletin, 2(4): 719-727.

Pendke MS, Choulwar SB, Srinivasa Rao Ch, Ravindra Chary G and Baviskar VS. 2014. Design, development and evaluation of artificial well recharging system for groundwater enhancement. Indian Journal of Dryland Agricultural Research and Development, 23(2): 17-22.

Pourouchottamane R, Pankaj PK, Banik S, Venkatsubramanian V, Das HK and Konwar P. 2014. Effect of improved shelter management on micro-climatic conditions and performance of ghungroo pigs. The Indian Veterinary Journal, 91(6): 93-95.

Pratibha G, Srinivas I, Rao KV, Raju BMK, Thyagaraj CR, Korwar GR, Venkateswarlu B, Arun K Shanker, Deepak K Choudhary, Srinivas Rao K and Srinivasarao Ch. 2015. Impact of conservation agriculture practices on energy use efficiency and global warming potential in rainfed pigeonpea–castor systems. European Journal of Agronomy, 66: 30-40.

Radha Jain, Chandra A, Visha K Venugopalan and Solomon S. 2014. Physiological changes and expression of SOD and P5CS genes in response to water deficit in sugarcane. Sugar Tech, (DOI: 10.1007/s12355-014-0317-2).

Rajinder Reddy G, Sudhakar N, Srinivasa Rao Ch and Kokate KD. 2014. Status of sulphur and soybean response to sulphur application in rainfed conditions. Indian Journal of Fertilisers (Fertilizer News), 10(4): 38-41.

Raju BMK, Rama Rao CA, Rao VUM, Srinivasa Rao M and Maheswari M. 2014. Effect of climate on productivity of pigeonpea and cotton in Andhra Pradesh – A panel data regression. Indian Journal of Dryland Agricultural Research and Development, 29(1): 6-10.

Rama Rao CA, Josily Samuel, Shalander Kumar, Raju BMK, Ravi Dupdal and Venkateswarlu B. 2014. Role of technology and credit in improving farm incomes in rainfed regions in Andhra Pradesh. Agricultural Economics Research Review, 27 (2): 187-198.

Ramana Reddy DV, Maruthi Sankar GR, Rama Subbaiah K, Sreenivasa Chari M, Harish Kumar

Sharma S, Pushpanjali, Visha Kumari V and Naga Sravani P. 2014. Assessment of soil-plant-fertilizer nutrient relationships for sustainable productivity of turmeric under alfisols and inceptisols in south India. Communications in Soil Science and Plant Analysis, (DOI: 10.1080/00103624.2015.1006368).

Ramasundaram P, Suresh A, Josily Samuel and Shwetal Wankhade. 2014. Welfare gains from application of first generation biotechnology in Indian agriculture: The case of Bt cotton, Agricultural Economics Research Review, 27 (1):73-82.

Ramesh K, Sammi Reddy K, Rashmi I and Biswas AK. 2014. Porosity distribution, surface area and morphology of synthetic potassium zeolites: A SEM and N2 adsorption study. Communications in Soil Science and Plant Analysis, 45 (16): 2171-2181.

Ramesh S, Nagalakshmi D, Ramana Reddy Y and Ramana DBV. 2014. Assessment of feeding practices and nutritional evaluation of locally available feedstuffs use for dairy animals in Mahaboobnagar district of Andhra Pradesh. International Journal of Agricultural Science and Vetenary Medicine, 2(3):1-7.

Rao GR, Prasad JVNS, Raju BMK, Sathi Reddy P, Sharath Kumar P and Venkateswarlu B. 2014. Allometric models for estimation of above and below ground biomass of Jatropha curcas L. in semi-arid regions of southern India. International Journal of Green Energy, (DOI:10.1080/15435075.2014.962035).

Rao VUM and Bapuji Rao B. 2014. Role of agromet advisories in climate risk management. Annual Agriculture Research New Series, 34 (1): 15-25.

Ravindra Chary G, Srinivasa Rao Ch, Raju BMK, Vittal KPR and Suresh Babu V. 2014. Integrated land use planning for sustainable for rainfed agriculture and rural development: A rainfed agro-economic zone approach. Agropedology, 24 (2): 234-252.

Ravindra Chary G, Srinivasarao Ch, Maruthi Sankar GR, Patel PG, Singh RN, Mganvir M, Nagdeve MB, Mohod VD, Rajbir Singh, Rani N and Siddaram. 2014. Sustainability assessment of cotton based intercropping systems for productivity and profitability using different quantitative indices under semi-arid Vertisols. Indian Journal of Agronomy, 59 (4): 587-595.

Reddy KS, Kumar M, Maruthi V, Umesha B, Vijayalaxmi and Nageshwar Rao CVK. 2014. Application of LARS-WG model for climate change analysis in southern Telangana region, Andhra Pradesh. Current Science, 107(1): 54-62.

Sahadeva Reddy B, Ramana DBV, Ashoka Reddy Y and Pankaj PK. 2014. Nutritive value of commonly used groundnut varieties in dryland areas of Andhra Pradesh. Indian Journal of Dryland Agricultural Research and Development, 29 (2): 112-114

Sam Koshy S, Nagaraju Y, Sowjanya P, Prasad YG, Naveen Kumar P. 2014. Wireless sensor network based forewarning models for pests and diseases in agriculture – a case study on groundnut. International Journal of Advancements in Research and Technology, 3 (1): 74-82.

Sarma D, Saikia P, Sarma PK, Hazarika M, Bhattacharya M, Sarma MK, Neog P, and Ch. Srinivasarao Ch. 2014. Effect of seed priming of toria (*Brassica napus* L Var. *Napus* L.) on drought tolerance and its yield performance. Indian Journal of Dryland Agricultural Research and Development, 29 (1): 35-39.

Sathish P, Vijay Kumar G, Jyothi Lakshmi N, Vanaja N, Yadav SK and Vagheera P. 2014. Impact of CO2 enhancement on photosynthesis and protein profile - response studies with a CO2 responsive black gram genotype. Journal of Applied Biology and Pharmaceutical Technology, 5(3): 93-98.

Satyavathi P, Vanaja M, Gopala Krishna Reddy A, Vagheera P, Narasimha Reddy A, Vijay Kumar G, Abdul Razak, Sunitha Vaidya, Sowmya P and Ira Khan. 2014. Identification of suitable guar genotypes for summer season of semi-arid region. International Journal of Applied Biology and Pharmaceutical Technology, 5(4): 71-73.

Shanker AK, Maheswari M, Yadav SK, Desai S, Bhanu D, Attal NB and Venkateswarlu B. (2014). Drought stress responses in crops. Functional and Integrrative Genomics, 14:11–22.

Sharma KL, Kusuma Grace J, Suma Chandrika D, Vittal KPR, Singh SP, Nema AK, Chauhan SPS, Maruthi Sankar GR, Mandal UK, Korwar GR, Venkateswarlu B, Ramesh G, Ravindra Chary G, Madhavi M, Pravin G. Gajbhiye, Munna Lal, Satish, Kumar T and Usha Rani K. 2014. Effect of soil management practices on key soil quality indicators and indices in pearl millet (*Pennisetum americanum* (L.) Leeke) based system in hot semi-arid inceptisols. Communications in Soil Science and Plant Analysis, 45:6, 785-809.

Sharma KL, Maruthi Shankar GR, Suma Chandrika D, Kusuma Grace J, Sharma SK, Thakur HS, Jain MP, Sharma RA, Ravindra Chary G, Srinivas K, Pravin Gajbhiye, Venkatravamma K, Munnalal, Satish kumar, T, Usha Rani K, Sammi Reddy K, Reshma Shinde, Korwar GR and Venkateswarlu B. 2014. Effects of conjunctive use of organic and inorganic sources of nutrients on soil quality indicators and soil quality index in sole maize, maize + soybean and sole soybean cropping systems in hot semi-arid tropical vertisol. Communications in Soil Science and Plant Analysis, 45:2118–2140.

Sharma KL, Sharma SC, Bawa SS, Sher Singh, Suma Chandrika D, Kusuma Grace J, Srinivasa Rao Ch, Maruthi Sankar GR, Ravindra Chary G, Munna Lal, Satish, Kumar T, Pravin G, Gajbhiye,K Usha Rani K and Indoria AK. 2014. Effect of conjunctive nutrient management on soil fertility and overall soil quality index in sub -mountainous Inceptisol soils under rainfed Maize (*Zea mays* L.) – Wheat (*Triticum aestivum*) based system. Communications in Soil Science and Plant Analysis, 46(1): 47-61.

Sharma KL, Sharma SC, Bawa SS, Sher Singh, Suma Chandrika D, Vivek Sharma, Anil Khokhar J, Kusuma Grace J, Srinivasa Rao Ch, Maruthi Sankar GR, Ravindra Chary G, Sammi Reddy K, Srinivas K, Munna Lal, Satish, Kumar T and Usha Rani K. 2014. Combined effect of tillage and organic fertilization on soil quality key indicators and indices in alluvial soils of Indo-Gangetic Plains under rainfed maize–wheat system. Archives of Agronomy and Soil Science, 61(3): 313-327

Sharma KL, Suma Chandrika D, Kusuma Grace J, Srinivas K, Mandal UK, Raju BMK, Munnalal, Satish Kumar T, Srinivasa Rao Ch, Sammi Reddy K, Osman M, Indoria AK, Usha Rani, K and Sreedevi Shankar K. 2014. Long-term effects of soil and nutrient management practices on soil properties and additive soil quality indices in alfisols. Indian Journal of Dryland Agriculture Reseasrch and Development, 29(2): 56-65.

Somasundaram J, Lakaria BL, Saha R, Sinha NK, Jha P, Chaudhary RS, Singh RK, Mandal D, Hati KM, Ramesh K, Vassanda Coumar M, Biswas AK, Dey P, Sammi Reddy K and Subba Rao A. 2014. Management of stressed soils of dryland agriculture in semi-arid tropics – A Review. Indian Journal of Soil Conservation, 42(2): 178-187.

Sreedevi Shankar K, Suma K, Chary KB, Kumar AP, Grover M, Mekala S, Shankar M, Vanaja M and Sharma KL. 2014. Improving phytochemical and nutritional quality of spinach (*Spinacia oleracia*) through phosphate solubilizing bacteria. Indian Journal of Dryland Agricultural Research and Development, 29 (2): 104-107.

Srinivasa Rao M, Manimanjari D, Rama Rao C A and Vennila S. 2014. Prediction of number of generations of spodoptera litura fab. on peanut under climate change scenarios. Global Journal of Biology, Agriculture & Health Science, 3(1): 244-250.

Srinivasa Rao M, Manimanjari D, Rama Rao C A, Swathi P and Maheswari M. 2014. Effect of climate change on Spodoptera *litura* Fab. on peanut: a life table approach. Crop Protection, 66:98-106.

Srinivasa Rao M, Rama Rao CA, Vennila S, Manimanjari D, Maheswari M and Venkateswarlu B. 2014. Estimation of number of generations

of *Spodoptera litura* Fab. on peanut in India during near and distant future climate change scenarios. Scientific Research and Essays, 9(7):195-203.

Srinivasa Rao M, Swathi P, Rama Rao CA, Rao KV, Raju BMK, Srinivas K, Manimanjari D and Maheswari M. 2015. Model and scenario variations in predicted number of generations of *Spodoptera litura* Fab. on peanut during future climate change scenario. PLOS ONE (doi:10.1371/journal.pone.0116762).

Srinivasarao Ch, Ravindra Chary G, Raju BMK, Vijay S Jakkula Sudha Rani Y and Rani N. 2014. Land use planning for low rainfall (450-750 mm) regions of India. Agropedology, 24 (2): 197-221.

Srinivasarao Ch, Sharan Bhoopal Reddy and Sumanta Kundu. 2014. Potassium nutrition and management in Indian agriculture: Issues and strategies. Indian Journal of Fertilisers (Fertilizer News), 10 (5): 51-80.

Srinivasarao Ch, Girija Veni V, Sharma KL, Raju BMK, Pasricha NS, and Rajbir Singh. 2015. Phosphorus fertility status and strategies to improve its use efficiency in Indian soils. Indian Journal of Fertilisers, 11 (3): 22-36.

Srinivasarao Ch, Rattan Lal, Sumanta Kundu, Prasad Babu MBB, Venkateswarlu B and Anil Kumar Singh. 2014. Soil carbon sequestration in rainfed production systems in the semiarid tropics of India. Science of the Total Environment, 487: 587-603.

Srinivasarao Ch, Ramachandrappa BK, Vijay S Jakkula, Sumanta Kundu, Venkateswarlu B, Pharande AL, Rupendra Manideep V, Prakash Naik R, and Venkanna K. 2014. Nutrient balance after thirteen years of organic and chemical nutrient management and yield sustainability of groundnut-fingermillet rotation in rainfed alfisols of semi-arid India. Journal of the Indian Society of Soil Science, 62 (3): 235-247.

Srinivasarao Ch, Sudha Rani Y, Girija Veni V, Sharma KL, Maruthi Sankar GR, Prasad JVNS, Prasad YG and Sahrawat KL. 2015. Assessing village level carbon balance due to greenhouse gas mitigation interventions using EX-ACT model. International Journal of Environmental Science and Technology, (DOI: 10.1007/s13762-015-0788-z).

Srinivasarao Ch, Sumanta Kundu, Ramachandrappa BK, Sharanbhoopal Reddy, Rattan Lal, Venkateswarlu B, Sahrawat KL, and Prakash Naik R. 2014. Potassium release characteristics, potassium balance, and fingermillet (*Eleusine coracana* G.) yield sustainability in a 27- year long experiment on an alfisol in the semi-arid tropical India. Plant and Soil, 374 (1-2): 315-330.

Subba Rao AVM, Arun K Shanker, Rao VUM, Narsimha Rao V, Singh AK, Pragyan Kumari, Singh CB, Praveen Kumar Verma, Vijaya Kumar P, Bapuji Rao B, Rajkumar Dhakar, Sarath Chandran MA, Naidu CV, Chowdary JL, Srinivasarao Ch, and Venkateshwarlu B. 2015. Predicting irrigated and rainfed rice yield under projected climate change scenarios in the eastern region of India. Environmental Modeling and Assessment, (DOI 10.1007/s10666-015-9462-6).

Suresh A, Ramasundaram P, Josily Samuel and Shwetal Wankhade. 2014. Cotton cultivation in India since the green revolution: technology, policy, and performance. Review of Agrarian Studies, 4 (2): 25-52.

Usha Rani K, Sharma KL, Sammi Reddy K, Srinivas K, Suma Chandrika D, Nagasri K and Munna Lal. 2014. Effect of Different sources and levels of sulphur on Nitrogen, Phosphorus and Sulphur Ratios and use efficiencies in Sunflower. Progressive Research, 9:251-254.

Vanaja M, Maruthi Sankar GR, Maheswari M, Jyothi Lakshmi N, Yadav SK, Vagheera P, Abdul Razak SK, Babu Abraham, Vijay Kumar G and Venkateswarlu B. 2015. Genotypic variation for growth and yield response at two elevated levels of CO_2 and three seasons in blackgram (*Vigna mungo*). Indian Journal of Agricultural Sciences, 85 (3): 29-38.

Venkata Raju N, Pankaj PK, Ramana DBV, Rita Rani, Nikhila M and Sudheer D. 2015. Physiological responses to intensification in Deccani sheep.

International Journal of Plant, Animal and Environmental Sciences, 5(1): 50-55.

Venkateswarlu B, Raju BMK, Rao KV and Rama Rao CA. 2014. Revisiting drought prone districts in India. Economic and Political Weekly, 49(25): 71-75.

Vijay Kumar G, Vanaja M, Raghu Ram Reddy P, Salini K, Babu Abraham, and Jyothi Lakshmi N. 2014. Studies on combining ability and genetic advance in blackgram (*Vigna mungo* L. Hepper) under rainfed condition. Research and Reviews: Journal of Agriculture and Allied Sciences, 3(3): 14-24.

Vijay Kumar G, Vanaja M, Sathish P, Vagheera P, Shishodia SS and Abdul Razak. 2014. Correlation and path analysis of seed yield and yield contributing components of blackgram (*Vigna mungo* l. Hepper) under rainfed condition from Andhra Pradesh, India. International Journal of Applied Biology and Pharmaceutical Technology, 5(3): 137-140.

Vijaya Kumar P, Rao VUM, Bhavani O, Dubey AP and Singh CB. 2015. Effect of temperature and photothermal quotient on the yield components of wheat (*Triticum aestivum* L.) in Indo-Gangetic plains of India. Experimental Agriculture, (doi: 10.1017/S0014479714000532).

Vijaya Kumar P, Rao VUM, Bhavani O, Dubey AP and Singh CB. 2015. Sensitive growth stages and temperature thresholds in wheat (L.) for index based crop insurance in the Indo-Gangetic Plains of India. Journal of Agricultural Science, Cambridge, available on CJO2015. doi:10.1017/S0021859615000209.

Vijaya Kumar P. 2014. Development of weather-based prediction models for leaf rust in wheat in the Indo-Gangetic plains of India. European Journal of Plant Pathology, 140: 429-440.

Visha Kumari V, Owen Hoekenga, Salini K and Sarath Chandran MA. 2014. Biofortification of Food Crops in India: An Agricultural Perspective. Asian Biotechnology and Development Review, 16 (2):45-55.

Vishal Mudgal, Vishnu Kumar Gupta, Prabhat Kumar Pankaj, Shalini Srivastava, Azad Ahmed Ganai. 2014. Effect of copper supplementation on the onset of estrus in anestrous buffalo cows and heifers. Buffalo Bulletin, 33(1): 1-5.

Books/Reports/Bulletins/Technical Brochures

Girish PS, Ramana DBV. 2014. Experiments on organic meat value chain. Newsletter - IAHA – IFOAM Animal Husbandry Alliance, 3: 8-9.

Gopinath KA, Srinivasa Rao Ch, Ramanjaneyulu AV, Ravindra Chary G and Venkatesh G. 2015. Organic farming research in India: Present status and way forward, In: Souvenir of the 2nd International Conference on Bio-resource and stress management, Hyderabad, India, Pp 29-33. ISBN 978-81-920073-8-0.

Kaushalya Ramachandran. 2015. Consolidated Report of National Fellow Scheme 2nd Phase (2010-2015) : Assessment of Sustainability of Treated/ Developed Watersheds in Rainfed Agro-eco -sub-regions of Peninsular India using GIS & Remote Sensing - Project Code: 803105 (2010-2015).

Kaushalya Ramachandran. 2015. Fourth Annual Report of National Fellow Scheme (2013-2014): Assessment of Sustainability of Treated/ Developed Watersheds in Rainfed Agro-eco -sub-regions of Peninsular India using GIS & Remote Sensing - Project Code: 803105 (2010-2015).

Maheswari M, Prasad JVNS, Rao KV, Rama Rao CA, Srinivas Rao Ch, Bapuji Rao B, Rao VUM, Prasad YG and Sikka AK. 2015. India's first biennial update report- Agricultural sector- mitigation, gaps and constraints. CRIDA, Hyderabad, 94 p.

Maheswari M, Srinivasa Rao M, Rao VUM, Srinivas Rao Ch, Reddy KS, Ramana DBV, Rama Rao CA, Vijay Kumar P, Prasad YG, Venkatesarlu B and Sikka AK. 2014. National Initiative on Climate Resilient Agriculture (NICRA), Research Highlights (2013-14) CRIDA, Hyderabad, 116 p.

Nirmala G, Prasad MS, Ravi Shankar K, Nagasree K, Adake RV, Pankaj PK, Sreedevi Shankar,

K and Srinivasarao Ch. 2014. Compendium of lectures on sustainable conservation technologies for enhancing resource use efficiency in rainfed farming. CRIDA, Hyderabad, 296 p.

Nirmala G, Vidyasekhar SM, Anantarao D, Maruthi V, Prasad, MS, Srinivas V and Sanjay Singh. 2014. "Nanyamaina pantala utpadanaku melaina saagu padhatulu" (Good Agricultural Practices for quality crop production). Good Agricultural Practices series-2. CRIDA, Hyderabad, 24 p.

Padmavathi CH, Katti G, Padmakumari AP, Jhansilakshmi V, Prabhakar M and Prasad YG. 2014. Development of decision support system for the management of rice leaf folder, Cnaphalocrocis medinalis Guenee, 40 p.

Prasad YG, Maheswari M, Dixit S, Srinivasarao Ch, Sikka AK, Venkateswarlu B, Sudhakar N, Prabhu Kumar S, Singh AK, Gogoi AK, Singh AK, Singh YV and Mishra A. 2014. Smart practices and technologies for climate resilient agriculture. CRIDA, Hyderabad. 76 p.

Prasad YG, Osman M, Singh SS, Manoranjan Kumar, Singh KM, Dixit S, Singh RD, Singh AK, Maheswari M, Bhatt BP, Venkateswarlu B, and Sikka AK. 2014. Contingency measures for deficit rainfall districts in south Bihar. CRIDA, Hyderabad, 19 p.

Prasad YG, Prabhakar M, Katti G, Nagrare VS, Vennila S, Sujay Dutta. 2014. Research into development of decision support system for insect pests of major rice and cotton based cropping systems - Final Report, CRIDA, Hyderabad, 120 p.

Prasad YG, Prabhakar M, Ravikumar N, Rajeshwar Rao G and Sailaja V. 2014. Compendium of lectures on Advances in pest forecast models and decision support systems for crop protection in changing climate scenario (ICAR Winter School), CRIDA, Hyderabad, 348 p.

Raju BMK, Rama Rao CA, Rao KV, Josily Samuel, Subba Rao AVM, Ravi Kumar N, Kareemulla K, Ravi Dupdal, Gopinath KA, Ravi Shankar K, Nagasree K, Srinivasa Rao M, Manish Tomar, Swapna N, Venkateswarlu B, Maheswari M and Srinivasa Rao Ch. 2014. District Database of Agricultural Statistics - A Database Management System. ICAR-Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, 42 p.

Ramachandrappa BK, Thimmegowda MN, Shankar MA, Balakrishna Reddy PC, Mariraju H, Dhanapal GN, Sathish A, Jagadeesh BN, Indrakumar N, Maruthi Sankar GR, Murukanappa and Srinivasarao Ch. 2014. Thirty five years of operational research project for dryland agriculture: Achievements and impacts (1976-2012). AICRP for Dryland Agriculture, University of Agricultural Sciences, Bangalore, 90 p.

Rao VUM, Bapuji Rao B, Rajkumar Dhakar, Vijayakumar P, Subbarao AVM and Sarath Chandran MA. 2014. Annual report 2013-14, National Initiative on Climate Resilient Agriculture-AICRPAM, CRIDA, Hyderabad, 52 p.

Rao VUM, Bapuji Rao B, Sikka AK, Subba Rao AVM, Rajbir Singh and Maheswari M. 2014. Hailstorm threat to Indian agriculture: A historical perspective and future strategies. CRIDA, Hyderabad, 44 p.

Rao VUM, Bapuji Rao B, Vijayakumar P, Subbarao AVM and Sarath Chandran MA. 2014. Annual Report 2013-14. All India Coordinated Research Project on Agrometeorology, CRIDA, Hyderabad. 116 p.

Rejani R, Rao KV, Osman M, Chary GR, Puspanjali and Pratyusha G. 2014. Spatial estimation of soil loss from Amistapur micro watershed in Mahabubnagar district of Telengana. Session 6: Floods, reservoir sedimentation and sea water intrusion, Proceedings of the 4th International Conference on Hydrology and Watershed Management, Vol.1, Reddy, KR, Rao BV and Sarala C (Eds.), Centre for Water Resources, Jawaharlal Nehru Technological University Hyderabad, Allied Publishers Pvt. Ltd., New Delhi, ISBN: 978-81-8424-952-1, pp: 503-507.

Sreedevi Shankar K, Mohammed Osman, Reddy NN, Maheswari M and Srinivasa Rao Ch. 2014. Potential utilization and value addition of Palmyra fruit (Borassus flabellifer). Technical Bulletin

01/2014. ICAR- CRIDA, Hyderabad.

Srinivas I, Sanjeeva Reddy B, Adake RV, Mayande VM, Thyagaraj CR, Pratibha G, Rao KV, Sammi Reddy K and Srinivasa Rao Ch. 2014. Farm mechanization in rainfed regions: Farm implements developed and commercialized. CRIDA, Hyderabad, 31 p.

Srinivasarao Ch, Gopinath KA, Venkatesh G and Jain MP. 2014. Climate change adaptation and mitigation strategies in rainfed agriculture, In Souvenir of the National Seminar on Technologies for Sustainable Production through Climate Resilient Agriculture, Pp 59-73.

Srinivasarao Ch, Manoranjan Kumar and Rejani R. 2014. Watershed management. Session 3: Watershed Management: Hydrological, Socio-Economic and Cultural Models. Proceedings of the 4th International Conference on Hydrology and Watershed Management, Vol.1. Reddy, KR, Rao BV and Sarala C (Eds.), Centre for Water Resources, Jawaharlal Nehru Technological University Hyderabad, Allied Publishers Pvt. Ltd., New Delhi, ISBN: 978-81-8424-952-1, Pp: 261-270.

Srinivasarao Ch, Ravindra Chary G and Gopinath KA. Annual Report 2013-14. All India Coordinated Research Project for Dryland Agriculture. ICAR-Central Research Institute for Dryland Agriculture, Indian Council of Agricultural Reserch, Hyderabad – 500 059, India. 360 p.

Srinivasarao Ch, Ravindra Chary G, Maruthi Sankar GR, Nagarjuna Kumar R and Venkateswarlu B. Technical Program of AICRPDA 2013-14. All India Coordinated Research Project for Dryland Agriculture, CRIDA, Hyderabad, 259 p.

Srinivasarao Ch, Ravindra Chary G, Maruthi Sankar GR, Nagarjuna Kumar R and Venkateswarlu B. Technical Program of NICRA-AICRPDA 2013-14. National Initiative on Climate Resilient Agriculture - All India Coordinated Research Project for Dryland Agriculture, CRIDA, Hyderabad, 194 p.

Srinivasarao Ch, Ravindra Chary G, Mishra PK, Subba Reddy G, Sankar GRM, Venkateswarlu B and Sikka AK. 2014. Rainfed Farming-A Compendium of Doable Technologies. All India Coordinated Research Project for Dryland Agriculture, CRIDA, Hyderabad 194 p.

Srinivasarao Ch, Rejani R and Prasannakumar, 2014. Climate resilient water management practices for improving water use efficiency and sustaining crop productivity. Proceedings of the National Workshop on Climate Change and Water-Improving water use efficiency, WALAMTARI Hyderabad, Pp 9-30.

Srinivasrao Ch, Prasad YG, Ravindra Chary G, Rama Rao CA, Rao KV, Ramana DBV, Subba Rao AVM, Rajbir Singh, Rao VUM, Maheswari M and Sikka AK. 2014. Compensatory Production Plan for Rabi 2014. CRIDA Technical Bulletin/02/2014. CRIDA, Hyderabad and NRM Division, ICAR, 80 p.

Varaprasad KS, Prasad YG and Katiha PK. 2014. Cross Learning- Reflections and Experiences of NAIP. Directorate of Oilseeds Research, Hyderabad, 149 p

Vidya Sekhar SM, Sri Krishna G, Salini K, Sarkar B, Prabhakar M, Srinivasa Rao Ch. 2015. Protection of Plant Varieties and Farmer's rights Act-2001

Vidya Sekhar SM, Sri Krishna G, Salini K, Sarkar B, Prabhakar M, Srinivasa Rao Ch. 2015. Protection of Plant Varieties and Farmer's rights Act-2001

Book chapters

Banik S, Pankaj PK and Naskar S. 2014. Climate change impacts on livestock diversity in tropical countries, In Livestock Production and Climate Change. Malik PK, Bhatta R, Takahashi J, Kohn RA and Prasad CS. (Eds.), CAB International (ISBN-13: 978 1 78064 432 5), Pp-162-182.

Bapuji Rao B. 2014. Weather based forewarning for current and future climates-case studies, In: Advances in pest forecast models and decision support systems for crop protection in changing climate scenario. Prasad YG, Prabhakar M, Ravi Kumar N, Rajeshwar Rao G, Sailaja V. (Eds.), Hyderabad, Pp 127-137.

Bhavani B, Bapuji Rao, B and Venugopalarao N. 2015. Impact of weather parameters on the incidence of early shoot borer (Chilo infuscatellus) and scale insect (Melanaspis glomerata) in sugarcane in north coastal region of Andhra Pradesh, India. In Current status of sugarcane research in India. Tiwari AK, Lal M and Singh AK (Eds.), Nova Science Publishers Inc., New York, Pp 1-14.

Gopinath KA, Srinivasa Rao Ch, Ramanjaneyulu AV, Ravindra Chary G and Venkatesh G. 2015. Organic Farming Research in India: Present Status and Way Forward. In: The Second International Conference on Bio-Resource and Stress Management, PJTSAU-ANGRAU, Hyderabad. Pp 29-33.

Mandal UK, Venkanna K, Sharma KL and Kaushalya Ramachandran. 2014. Assessing soil quality in semi-arid tropical region of southern India using GIS and remote sensing In Global Soil Map: Basis of the global spatial soil information system, Proc. of the 1st global soil map conference. Arrouays D, McKenzie N, Hempel J, de Forges AR, McBratney A (Eds.), ISBN 978-1-138-00119-0, Pp455-459.

Nagarjuna Kumar R, Sailaja B, Showri Raju N , Ravi Kumar N and Maruthi Sankar GR. 2015. Information and communication technology initiatives in agriculture research and development, In Emerging Technologies of the 21st Century. Roy AK (Eds.), New India Publishing Agency, ISBN 978-93-83305-33-9, Pp 747-762.

Nirmala G and Prasad MS. 2014. Zero tillage Maize, In Sustainable conservation technologies for enhancing resource use efficiency in rainfed farming. Nirmala G, Prasad MS, Ravishankar K, Nagasree K, Pankaj PK, Adake RV and Sreedevi Shankar (Eds.), (ISBN No.978-93-80883-31-1) Pp. 181-188.

Prasad JVNS and Kulkarni HD. 2014. Eucalyptus in Agroforestry: Planting designs. In: Eucalypts in India Bhojvaid PP, Kaushik S, Singh YP, Dinesh Kumar, Thapliyal M and Barthwal S (Eds.), ENVIS Center on Forestry. National Forest Library and Information Center, Forest Research Institute, Dehradun. 505 p

Pratibha G, Korwar GR, Srinivas I, Rao KV, Raju BMK, Maheswari M, Indoria AK, Srinivasa Rao K, Choudhary DK and Rama Devi B. 2014. Conservation Agriculture – A New Paradigm for Climate Change Mitigation in Rainfed Indian Agriculture. In Geostatistical and geospatial approaches for the characterization of natural resources in the environment: Challenges, processes and strategies. Janardhana Raju N. (Ed.), Capital Publishing Company, New Delhi, Pp 532-535

Pushpanjali. 2014. Soil site suitability mapping for different crops in rainfed environment. In Sustainable Conservation Technologies for Enhancing Resource Use Efficiency in Rainfed Farming. Nirmala G, Prasad MS, Ravishankar K, Nagasree K, Pankaj PK, Adake RV and Sreedevi Shankar (Eds.), CRIDA, Hyderabad, (ISBN No.978-93-80883-31-1) Pp 224-227.

Ramana DBV. 2014. Pasture management for resource efficiency in drylands. In Sustainable conservation technologies for enhancing resource use efficiency in rainfed farming. Nirmala G, Prasad MS, Ravishankar K, Nagasree K, Pankaj PK, Adake RV and Sreedevi Shankar (Eds.), CRIDA, Hyderabad, (ISBN No.978-93-80883-31-1) Pp 156-161.

Rao KV, Pratyusha Krnati, Hamsa Sandeep, Sreedevi PD and Shakeel Ahmed. 2015. Sustainable Watershed Design Development and Methodology. In Integrated Assessment of Sclae Impacts of Watershed Intervention: Assessing Hydrological and Biophysical Influences on Livelihoods. Ratna Reddy V and Geoffrey J.Syme (Eds.), Elsevier Publication

Rao VUM. 2014. Monsoon concept and its features, In Advances in pest forecast models and decision support systems for crop protection in changing climate scenario. Prasad YG, Prabhakar M, Ravi Kumar N, Rajeshwar Rao G, Sailaja V. (Eds.), Hyderabad, Pp 1-10.

Ravi Shankar K, Nagasree K, Nirmala G, Prasad MS, Venkateswarlu B and Srinivasarao Ch. 2015. Climate Change and Agricultural Adaptation in

South Asia, In Hand book of climate change adaptation, (DOI 10.1007/978-3-642-40455-9_50-1#) Springer-Verlag Berlin Heidelberg.

Ravindra Chary G, Gopinath KA, Maruthi Sankar GR, Pratibha G, Venkatesh G, Ganesh Kute and Venkateswarlu B. 2014. Moisture stress and its management in pulses through resource conservation technologies in rainfed areas. In Resource conservation technology in pulses. P.K. Ghosh PK, Narendra Jumar, Venkatesh MS, Hazra KK and Nadarajan N (Eds.), Scientific Publishers, India, Pp 483-493.

Reddy KS, Kumar M, Maruthi V, Ravikumar N, Maheswari M, Vijayalaxmi and Umesha B. 2014. Impact of Climate Change on Crop Water Balance of Maize (*Zea May's* L) and Cotton (*Gossypium hirsutum*) in rainfed districts of Telangana, In the proceedings of 4th International Conference on Hydrology and Watershed Management. Reddy KR, Rao BV and Sarala C (Eds.), Pp 1025-30.

Rejani R, Rao KV, Osman M, Chary GR, Pushpanjali and Pratyusha G. 2014. Spatial estimation of soil loss from Amistapur microwatershed in Mahabubnagar district of Telengana. Floods, Reservoir Sedimentation and sea water intrusion In Proceedings of the 4th International Conference on Hydrology and Watershed Management. Reddy KR, Rao BV and Sarala C (Eds.), Centre for Water Resources, Jawaharlal Nehru Technological University Hyderabad, Allied Publishers Pvt. Ltd., New Delhi, ISBN: 978-81-8424-952-1, Pp 503-507.

Rymbai H, Patel NL, Patel CR, Reddy AGK, Hiwale SS, Chovatia RS and Varu DK. 2014. Custard Apple in tropical and subtropical fruit Crops In Crop Improvement and Varietal Health Part –I, Jaya publishing house, Delhi, ISBN: 978-93-82471-97-4.Pp 237-267.

Sailaja, B, Padma Kumari, APK, Krishnaveni D, Shaik N Meera, Nagarjuna Kumar R, Gayatri S and Maruthi Sankar GR. 2015. Web based expert system for identifying pests and disease problems of rice crop, In Emerging Technologies of the 21st Century. A.K.Roy (Ed.), New India Publishing Agency, ISBN 978-93-83305-33-9, Pp 355-364.

Showri Raju N, Maruthi Sankar GR and Nagarjuna Kumar R. 2015. Framework for development of meteorological data warehouse, In Emerging Technologies of the 21st Century. A.K.Roy (Eds.), New India Publishing Agency, ISBN 978-93-83305-33-9, Pp 557-568.

Srinivasa Rao M. 2014. Potential Impacts of climate change on insect pests, In measurement and management of resistance to chemical insecticides. TVK Singh et al., (Eds.,), Jayashanker Telangana State Agricultural University, Rajendranagar Hyderabad, Pp 407-413 .

Srinivasarao Ch and Venkateswarlu B. 2014. Soil carbon sequestration in rainfed agriculture, In conservation agriculture for carbon sequestration and sustaining soil health. Somasundaram J, Chaudhary RS, Subba Rao A, Hati KM, Sinha NK and Vassanda M (Eds.), New India Publishing Agency, New Delhi, Pp 247-262.

Srinivasarao Ch, Gopinath KA, Venkatesh G and Jain MP. 2014.. Climate change adaptation and mitigation strategies in rainfed agriculture, In Souvenir of National Seminar on Technologies for Sustainable Production through Climate Resilient Agriculture Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP), Pp 59-73.

Srinivasarao Ch, Rattan Lal, Sumanta Kundu and Pravin B Thakur. 2015. Conservation agriculture and soil carbon sequestration, In Conservation Agriculture. Farooq M and Siddique K HM Eds.), Springer International Publishing, Switzerland, Pp 479-524.

Srinivasarao Ch, Venkateswarlu B, Sudha Rani Y, Singh AK and Dixit S. 2014. Soil carbon sequestration with improved soil management in three tribal villages in India In Soil Carbon. Alfred E. Hartemink and Kevin McSweeney (Eds.), Springer International Publishing, Switzerland, Pp 239-248.

Srinivasarao Ch. 2014. Rainfed Ecosystem: Need for Conservation Technologies in Natural Resource Management and Sustainable Crop Productivity,

In Model Training course on Sustainable Conservation Technologies for enhancing Resource Use efficiency in Rainfed Farming. Nirmala G, Prasad MS, Ravi Shankar K, Nagasree K, Adake RV, Pankaj PK, Sreedevi Shankar K and Srinivasarao Ch (Eds.), CRIDA, Hyderabad, Pp 1-7.

Srinivasarao Ch, and Gopinath KA. 2015. Rainfed Farming in India: Status and way forward. In: Souvenir-International Conference on Natural Resource Management for Food Security and Rural Livelihoods, 10-13th February, 2015, New Delhi. Pp 39-45.

Srinivasarao Ch, Sumanta Kundu and Pravin B. Thakur. 2015. Climate Change and Carbon Sequestration. In: The Second International Conference on Bio-Resource and Stress Management, 7-10th January, 2015, PJTSAU-ANGRAU, Hyderabad, Pp 94-99.

Sumanth Kumar VV, Showri Raju N, Nagarjuna Kumar R, Ravi Kumar N and Maruthi Sankar GR. 2015. Distributed databases in automating processes with some applications In Emerging Technologies of the 21st Century. Roy AK (Ed). New India Publishing Agency, ISBN 978-93-83305-33-9, Pp 549-556.

Venkatesh G. 2014. Application of biochar technology as an amendment for conservation of soil and water, In Sustainable conservation technologies for enhancing resource use efficiency in rainfed farming. Nirmala G, Prasad MS, Ravishankar K, Nagasree K, Pankaj PK, Adake RV and Sreedevi Shankar (Eds.), CRIDA, Hyderabad, (ISBN No.978-93-80883-31-1), Pp115-124.

Venkateswarlu B and Gopinath KA. 2014. Integrated farming systems for rainfed agriculture, In Research in Farming Systems. Gangwar B, Singh JP, Prusty AK and Kamta Prasad (Eds.), Today & Tomorrow's Printers and Publishers, India, Pp 177-199

Vijaya Kumar P, Rao VUM, Tripati PK and Venkateswarlu B. 2014. The effect of rice transplanting date on rice-wheat cropping system performance in the middle IGP of India - A simulation study using APSIM, In "SAC Monograp: The SAARC-Australia Project-Developing capacity in cropping systems Modelling for South Asia". Gaydon DS, Saiyed I and Roth C (Eds.), SAARC Agriculture Centre, Dhaka, Bangladesh, Pp 75-85.

Vijaya Kumar P. 2014. Weather thresholds for insurance products: concept and practice, In: Advances in pest forecast models and decision support systems for crop protection in changing climate scenario. Prasad YG, Prabhakar M, Ravi Kumar N, Rajeshwar Rao G, Sailaja V (Eds.), CRIDA, Hyderabad, Pp 159-171.

Wendy Merrit, Rao KV, Brendan Patch, Ratna Reddy V, Syme G and Sreedevi PD. 2015. Exploring implications of climate, land use and policy intervention scenarios on water resources, livelihoods and resilience, In Integrated assessment of sclae impacts of watershed intervention: assessing hydrological and biophysical influences on livelihoods. Ratna Reddy and Geoffrey J.Syme (Eds.), Elsevier Publication.

Popular articles

Bapuji Rao B and Rao VUM. 2014. Can we minimize the agriculture losses from hailstorm events? *Rythu Nestam*, April 2014: 44-46.

Bapuji Rao B, Rao VUM and Rao KV. 2014. Rice cultivation in Andhra Pradesh may face further challenges, *Rythu Nestam*, June 2014: 36-40.

Bapuji Rao B, Rao VUM and Subba Rao AVM. Influence of El-Nino episodes on the agriculture of Andhra Pradesh and Telangana. *Rythu Nestam*, May 2014: 41-44.

Nagasree K, Reddy KS, Kurmaiah, Prasad MS, Ravi Shankar K, Padmanabhan MV, Savithri and Usha Rani. 2014. *Sprinkler sedhyam. Vyavasaya Paadi Pantalu*, April 2014: 26-27.

Nagasree K, Srinivas K, Maruthi V, Ravi Shankar K, Nirmala G, Sreedevi Shankar, Usha Rani, K, Ramana DBV and Pankaj PK. 2014. *Jeevana yeruvulathone pyrlaku jeevam. Rythu Ratna*, December:

20-21.

Nagasree K, Srinivas K, Maruthi V, Usha Rani K, Ravi Shankar K, Nirmala G, Ramana DBV and Pankaj PK. 2014. V*ermicompost Varevva. Rythu Ratna*, September 2014: 16-17.

Nirmala G, Ravi Shankar K and Nagasree K. 2014. Utpadakatanu penche upaayaalenno. Rythu Ratna May 2014, 20-23.

Ramana DBV, Ravi Shankar K and Pankaj P.K. 2014. Peratlo azolla pempakam. Sedya Phalam, November 2014: 44-46.

Ramana DBV, Ravi Shankar K, Nagasree K and Pankaj PK. 2014. *Karuvu teera pashugraasam Rythu Ratna*, September 2014: 32-34.

Ramana DBV, Ravi Shankar K, Nagasree K and Pankaj PK. 2014. *Karuvukalamlo pasuposhana mariyu yajamanya paddatulu. Sedya Phalam*, September 2014: 59-61.

Ravi Shankar K, Nagasree K, Nirmala G, Ramana DBV, Sridevi Shankar K and Adake RV. 2014. *Prakrutini anusarinchi pantalu. Rythu Ratna*, December 2014: 26-27.

Reddy AGK, Venkatasubbiah K and Raju NS. 2014. *Nimmaku nithya demand. Rythu Ratna*, November 2014: 5-6.

Sanjeeva Reddy B, Ravi Shankar K and Ravikant Adake. 2014. *Adde parikarala andubatu peragali, Rythu Ratna* August, 2014: 22-27.

Santanu Banik, Pankaj PK, Naskar S, Pourouchottamane R and Ganguli I. 2014. *Sukar prajanan kaa paridrishya. Pashudhan Prakash*, 5: 33-35.

Sarath Chandran MA and Visha Kumari V. 2015. Climate change: the science behind and impact on Indian agriculture. Wide channel, February 2015: 63-66.

Sreedevi Shankar K, Ravi Shankar K and Nagasree K. 2014. *Vitamin-A lopisthe vipatthe, Rythu Ratna*, November 2014: 34.

Sri Krishna G, Vidhyasekhar SM, Salini K and Prabhakar M. 2014. *Panta vangadala rythu hakkula chattam-2001, Annadata*, October 2014: 55.

Vijay Kumar S, Srinivas I, Sanjeeva Reddy B, Ravishankar K, Nagasree K and Prabhakar M. 2014. *Vari saguku neruga vithanam vithu padhati. Rythu Bandhu*, November 2014: 26 - 29.

Visha K. Venugopalan, Sarath Chandran MA and Singh AK. 2014. *Ganna krishi kshethra mein jalvayu parivartan aur mahilayem. Ikshu*, June 2014: 32.

Visha Kumari V, Srivastava TK and Sarath Chandran MA. 2014. Technologies for improving water use efficiency in sub-tropical sugarcane production. *Popular Kheti*, 2(3): 58-63.

E-publications

Nirmala G, Prasad MS, Ravi Shankar K, Nagasri K, Adake RV, Pankaj PK, Sreedevi KS and Srinivasa Rao Ch. 2014. Compendium of lectures on "Sustainable conservation technologies for enhancing resource use efficiency in rainfed farming". CRIDA, Hyderabad, Pp 296. (http://www.crida.in/Training%20manual-2014.pdf).

Sreedevi Shankar K and Nirmala G. 2014. Food consumption trends and nutritional assessment of semi urban women using GIS tools in rain fed regions of Ranga Reddy, Telangana State. http://www.agriculture.frih.net/NutritionalAssessment.htm

Sreedevi Shankar K, Harini B, Harish V, and Anjani CH. 2014. Effect of processing methods on the nutrient quality and anti-nutritional constituents of Moringa oliefera leaves (drum stick). (http://www.agriculture.frih.net/DrumstickProcessing.htm)

TV shows/Radio talks

Reddy AGK. Vegetable cultivation on pendal system and mulching in vegetable crops (Live show) from 6:30 to 7:00 p.m on 23-06-2014, V6 News Channel.

Nagasree, K. Mobile Telephony on 08-01-2014, All India Radio, Hyderabad.

Nagasree, K. *Vyavasaayam pai vaatavarana prabhavam* on 05.06.2014, All India Radio, Hyderabad.

Ramana DBV. *Chalikalaamlo pashuvula poshana mariyu yajamaanyam* on 02.01.2015, All India Radio, Hyderabad.

Sri Krishna G. Contingency vegetable cultivation on 27.11.2014, All India Radio, Hyderabad

Sri Krishna G. *Kharif* vegetables on 07.06.2014, All India Radio, Hyderabad.

Sri Krishna G. *Pandlu, kooragaayala pantalaku suchanalu* on 18.09.2014, All India Radio, Hyderabad.

Sudheer D. Diseases which cause economics losses in dairy farming on 16.08.2014, All India Radio, Hyderabad.

Sudheer D. Ram lamb production on 06.03.2015, All India Radio, Hyderabad

Sudheer D. Scientific dairy farming and its management (Live recoding) on 27.11.2014, All India Radio, Hyderabad.

Vidyaadhari A. *Aaharamlo zinc lopam* on 21.10.2014, All India Radio, Hyderabad

Vidyaadhari A. *Grameena kutumbalalo chirudhanyavasaram* on 01.03.2015, All India Radio, Hyderabad.

Vidyaadhari A. *Grameena kutumbalalo poustikalopalu* on 01.10.2014, All India Radio, Hyderabad.

Vidyaadhari A. *Pillalaku, garbavathulaku, balikalaku poustika tayari mariyu awasaram* on 08.03.2015, All India Radio, Hyderabad.

Vidyaadhari A. *Vermicompost tayari* on 14.10.2014, All India Radio, Hyderabad.

Vidyaadhari A. *Vruthi nypunyam penchukovadhaniki grameena mahilalaku shikshana* on 07.10.2014, All India Radio, Hyderabad.

Vidya Sekhar SM. Crop protection measures to be followed in *kharif* rice on 22.07.2014, All India Radio, Hyderabad.

Vidya Sekhar SM. Fruits, vegetables and field crops on 18.09.2014, All India Radio, Hyderabad

Vijay Kumar S. *Varshapu neeti samrakshana, viniyoga paddhathulu* on 28.02.2015, All India Radio, Hyderabad.

Vijaya Kumar S. *Varilo yaantrikarana paddhathulu hythulaka avagaahana, anusarana* on 29.02.2014, All India Radio, Hyderabad.

Vijaya Kumar S. *Yantreekarana dwaara varisaagu* on 15.07.2014, All India Radio, Hyderabad.

Software developed

Rao VUM, Subba Rao AVM, Santibhushan chowdary P and Ramamohan I. 2014. Weather Cock14. CRIDA, Hyderabad.

Ravi Kumar N and Anitha G. 2014. Web based Interactive Thematic MapGen Tool. (http://www.crida.in/onlinemap.html).

Ravi Kumar N, Deepak Kumar, K and Arun K Shanker. 2014. Open source based CRIDA digital repository (www. eprints-crida.in).

Ravi Kumar N, Prasad YG, Anitha G, Srinivasarao Ch, Ravindra Chary G. Rao KV, Ramana DBV, Rao VUM and Subba Reddy G. 2014. Online query based contingency planning retrieval system (http://www.crida.in:82/CFCP/).

Showri Raju N, Nagarjuna Kumar R, Osman M D Balloli SS and G Anitha 2014. NICRA-RFD database management system (http://www.nicraicar.in/nicrarevised/index.php/monthly- rfd).

Srinivasa Rao M, Rama Rao CA, Raju BMK, Manimanjari D, Srinivas K, Maheswari M and Ramamohan I. 2014. Ingen (insect generations calculator). National Initiative on Climate Resilient Agriculture, CRIDA, Hyderabad.

Websites/Databases developed/ Maintained

Nagarjuna Kumar R, Ravindra Chary G, Srinivasa Rao Ch, Maruthi Sankar GR and Raju NS. 2015. AICRPDA website was developed (www.aicrpda.in).

Ravi Kumar N and Chandrasekhar P. 2014. CRIDA website (www.crida.in)

Ravi Kumar N, Anitha G and Srinivasarao Ch. 2014. Database on monthly research activities and work done by RA/SRF (www. Crida.in:82/RAIS).

Ravi Kumar N, Anitha G, Kesava Rao AVR, Rao KV,

Rao VUM, Raju BMK and Venkateswarlu B. 2014. Districtwise Weather Database (http://www.nicra-icarrevised/index.php/tools-services).

Ravi Kumar N, Anitha G, Rajeshwar Rao, G, Shanker AK, Ramana DBV, Osman M and Sharma KL. 2014. ISDA website (www.drylandagri.org.in).

Ravi Kumar N, Prasad YG, Anitha G, Srinivasarao Ch, Ravindra Chary G. Rao KV, Ramana D B V, Rao VUM and Subba Reddy G. 2014. Database on Districtwise Contingency Plans (http://crida.in:82/contigencyplanning/).

Ravi Kumar N, Prasad YG, Anitha G, Srinivasarao Ch, Ravindra Chary G. Rao KV, Ramana D B V, Rao VUM and Subba Reddy G. 2014. Database on Themewise Contingency Plans (http://www.crida.in:82/CFCP/)

Showri Raju N, Nagarjuna Kumar R, Osman M D and Balloli SS. Database application to manage the information on publications, symposia, seminars, trainings, etc.

Showri Raju N, Sanjeeva Reddy B, Nagarjuna Kumar R and Adake RV. 2014. Database to know profitability of agricultural implements (http:localhost/calcy/cal.php).

Showri Raju N. 2014. KRISHI Database (Under development)

Showri Raju N. 2014. PIMS Database (http://pimsonline.com)

Showri Raju N. 2014. HYPM Database (http://hypm.iasri.res.in/)

11 Ongoing Projects

Institute Code No	Title of the Project	Investigators	Year of Start	Year of close
National Fellows				
1.EF026 (National Fellow Scheme)	Assessment of Sustainability of Treated/ Developed Watersheds in Rainfed Agro-Eco-Sub Regions of Peninsular India using GIS and Remote Sensing	**Kaushalya Ramachandran**	2010	2015
2.NICRA/12/2012	Study of Satellite-derived NDVI variations to assess agricultural vulnerability in rainfed regions due to climate change	**Kaushalya Ramachandran** C.A. Rama Rao V.U.M. Rao B.M.K. Raju A.V.M. Subba Rao K. Nagasri K. Ravi Shankar D.B.V. Ramana	2012	2017
3.EF027 (National Fellow Scheme)	Assessing soil quality key indicators for development of soil quality index using latest approaches under predominant management practices in rainfed agro-ecology.	**K.L. Sharma**	2010	2015
4.NICRA/14/2012	Quantitative assessment of potential positive impacts of long term conservation agricultural practices on climatically resilient soil parameters in rainfed Alfisol	**K.L. Sharma** K. Srinivas Ch. Srinivasa Rao Pushpanjali	2012	2017
5. RM/LU/13	Conservation tillage farming strategies and crop residue management for soil health improvement and higher crop productivity in sorghum – black gram system in rainfed Alfisol	**K.L. Sharma** Ch. Srinivasa Rao K. Srinivas G. Pratibha K. Sammi Reddy S.S. Balloli B. Sanjeeva Reddy	2013	2020
Division of Resource Management				
6. RM/RM/14	Assessment of relative performance of crop simulation models for dryland crops	**A.S. Rao** B.M.K. Raju A.V.M.S. Rao V.U.M. Rao	2012	2015
7. EF006 (NOVOD BOARD)	National Network project on integrated development of Jatropha and Pongamia	**G. Rajeshwara Rao** M. Prabhakar	2012	March 2017

8. NICRA/21 /2012	Role of bio-fuel crops in rural energy supply and GHG mitigation	**G. Rajeswara Rao** J.V.N.S. Prasad I. Srinivas S.S. Balloli	2012	2017
9. RM/RM/08	Effect of Biochar amendment on soil properties and growth of crops	**G. Venkatesh** Ch. Srinivasa Rao K.A. Gopinath K. Sammi Reddy G.R. Rao G. Pratibha Minakshi Grover B. Sanjeeva Reddy	2009	2015
10.NICRA/17/2011	Biochar amendment for improving the performance of maize in drylands – climate change adaptation and mitigation strategy	**G. Venkatesh** J.V.N.S. Prasad Ch. Srinivasa Rao K.A. Gopinath G. Ravindra Chary Arun Kumar Shankar N.S. Raju	2011	2017
11.NICRA/24/2012	Conservation Agriculture (CA) for productivity enhancement and mitigating GHG emissions in maize-horse gram system in Alfisols of semi-arid tropics	**Sumanta Kundu** Ch. Srinivasa Rao V. Girija Veni	2012	2017
12. RM/RM/18	Evaluation of different polymers for improving water and fertilizer use efficiency in different crops grown in semi-arid regions	**K. Sammi Reddy** A.K. Indoria A.G.K. Reddy K. Srinivas K.L. Sharma Minakshi Grover	2012	2016
13.NICRA/04/2012	Understanding the role of plant roots in soil carbon sequestration	K. Srinivas V. Maruthi	2012	2015
14.RM/NM/06	Impact of Conservation Agriculture Practices on Soil Physical Properties in Maize-Pigeonpea crop rotation under Rainfed Alfisols	**Ashok Kumar Indoria** Ch. Srinivasa Rao G. Pratiba K. Sammi Reddy	2012	2017
15. NICRA/05/ 2012	Potential of rainwater harvesting and recycling as an adaptation strategy to climate variability change in rainfed crops	**K.Srinivasa Reddy** K.V. Rao Manoranjan Kumar V. Maruthi S.S. Balloli R. Nagarjuna Kumar	2012	2017
16. NICRA/06/ 2012	Development of SCADA based rainfall simulation facility and precision type Lysimeter with open top climate chambers for assessing the impact of climate change to resource loss and soil water balance for rainfed crops	**K.Srinivasa Reddy** Manoranjan Kumar S.S. Balloli M. Vanaja, V. Maruthi	2012	2017

17. EF040 ACIAR	Impact of meso-scale watershed development in Andhra Pradesh (India) and comparative catchments in Australia	**K.V. Rao**	2011	2015
18. RM/RM/17	Watershed based soil and water conservation interventions prioritization in different rainfall zones	**R. Rejani** K.V. Rao G.Ravindra Chary M. Osman	2012	2015
19. RM/RM/ 04	Soil and crop management strategies for resource conservation, weed control and carbon sequestration in pigeonpea-castor system	**G. Pratibha** K.V. Rao K. Srinivas I. Srinivas M. Srinivasa Rao K.L. Sharma Arun Kumar Shanker	2008	2018
20. RM/RM/ 09	Potential role of conservation agriculture on resource conservation and soil carbon sequestration in pigeon pea castor systems in rainfed regions	**G. Pratibha** I. Srinivas, K.V. Rao K. Srinivas B.M.K. Raju	2009	2018
21. EF048/2012	Crop residue management for enhancing soil quality, crop productivity and mitigation of climate change	**G. Pratibha** Ch.S. Rao G. Ravindra Chary S.K. Yadav K.V. Rao J.V.N.S. Prasad	2012	2015
22. NICRA/30 /2012	Mitigation of Climate Change through conservation agriculture in rainfed regions of India	G. Pratibha KV Rao I. Srinivas	2012	2017
23. RM/FM/13	Development of low to medium scale propelled harvesting equipment for sorghum and maize	**I.Srinivas** C.R. Thyagaraj R.V. Adake	2012	2015
24. RM/FM/10	Development of an electronic sensors based instrumentation system to evaluate seed planter performance	**B. Sanjeeva Reddy** Ravikant V. Adake N. Ravi Kumar	2010	2015
25. RM/FM/12	Development of machinery for handling and utilization of crop residue of maize and cotton	**B. Sanjeeva Reddy** Ravikanth V.Adake G. Venkatesh K.A. Gopinath A.K. Indoria	2012	2016
26.RM/FM/11	Development of dual-energy pumpset for lifting harvested water from pond and shallow dug wells	**R. V. Adake** I. Srinivas Manoranjan Kumar C.R. Thyagaraj	2012	2016
27. DRM/ NICRA / 34	Database, Web Application design and Development for CRIDA and NICRA	**N.S. Raju** M. Osman R. Nagarjuna Kumar S.S. Balloli	2013	2016

28. RM/RM/15	Spectral signature development for rainfed cotton and castor crops using remote sensing to assess the trends in crop growth	**N.S. Raju** K.V. Rao N. Ravi Kumar J.V.N.S. Prasad R. Nagarjuna Kumar	2012	May 2015
29.RM/RM/19	Design, Construction and Evaluation of Field dikes using Plastics and Bioengineering Techniques	**Manoranjan Kumar** M. Osman K.Srinivasa Reddy K.V. Rao R. Rejani	2013	2017
30.RM/RM/20	Development of Water Application System (WAS) Software for efficient utilization of farm pond water	**Manoranjan Kumar** K. Srinivasa Reddy N. Ravi Kumar	2014	2017
31. EF034 (NAIP Com-I)	Enabling small stakeholders to improve livelihoods and benefits from carbon finance(EF)	**J.V.N.S. Prasad**	2009	2014
32.DRM/NICRA/35	Quantification of Green house gas emissions from rainfed systems	**J.V.N.S. Prasad** Ch.Srinivasa Rao K. Srinivas	2013	2017
33.RM/RM/21	Spatial estimation of soil moisture using microwave remote sensing	**Pushpanjali** R. Rejani K.V. Rao K. Srinivas Kaushalya Ramachandran K.L. Sharma N.S. Raju	2013	2016
34.RM/RM/22	Zeolite characterization and its application effect on enhancing water and nutrient use efficiency in rainfed crops.	**V. Girija Veni** Sumantha Kundu Pushpanjali K. Sammi Reddy Ch. Srinivasa Rao	2014	2017
Division of Crop Sciences				
35. CS/CP/19	Candidate gene approach for improvement of drought tolerance and yield in drylands	**M. Maheswari**	2008	2015
36.DCS/NICRA/32/ 2012	National Initiative on climate Resilient Agriculture – Subproject on Phenotyping	**M. Maheswari** M. Vanaja S.K. Yadav N. Jyothi Lakshmi N. Ravi Kumar AK Shankar K. Salini Minkakshi Grover V. Maruthi K. Sreedevi Shankar Basudeb Sarkar	2012	2017

37. DCS/ NICRA/31/2012	Productivity of rainfed crops under enhanced carbondioxide and its interaction with water deficit and elevated temperature	**M. Vanaja** M. Maheswari S.K. Yadav N. Jyothi Lakshmi K. Sreedevi Shankar	2012	2017
38. DCS/ NICRA/15/2012	Computational genome analysis and in vivo validation of genes and transcription factors involved in Abiotic Stress in Maize	**Arun Kumar Shankar** M. Maheswari N. Ravi Kumar N. Jyothi Lakshmi S.K. Yadav	2012	2017
39. CS/CP/28	Simulation modelling of crop growth and development in Maize	**Arun Kumar Shankar** A.V.M. Subba Rao M. Vanaja N. Jyothi Lakshmi K.V. Rao P. Vijaya Kumar	2013	2016
40. DCS/ NICRA/28/2012	Transpiration efficiency and water use variations in maize	**N. Jyothi** M. Maheswari M. Vanaja S.K. Yadav A.K. Shankar K. Salini	2012	2017
41. DCS/NICRA / 33	Physiological and metabolic indices for heat tolerance in maize	**S.K. Yadav** M. Maheswari N. Jyothi Lakshmi M. Vanaja A.K. Shankar	2010	2017
42. EF 045 (DBT)	Molecular and physiological characterization of annexin transgenics of greengram (Vigna radiate L) for oxidative stress tolerance	**S.K. Yadav** M. Maheswari	2011	May 2015
43.DCS/ NICRA/11/2012	Phenotyping of rainfed Maize inoculated with heat tolerant PGPR for enhanced adaptation	**Minakshi Grover** S. Desai K.A. Gopinath	2012	2015
44. EF051	Endophytic microorganisms for management of drought in rainfed maize and pigeonpea	**Minakshi Grover** S.K. Yadav S. Desai	2014	2017
45. EF046 (CROPSAP)	Crop Pest Surveillance and Advisory project (CROPSAP) 2011-12 in Maharashtra	**Commissioner, State Department of Agriculture, Maharashtra** Y.G. Prasad V.U.M. Rao M. Prabhakar AVM Subba Rao	2011	2015
46. EF050 (NCIPM)	Online Pest Monitoring and Advisory Services (OPMAS) NFSM (CC) – Cotton	**R.K. Tanwar, NCIPM, New Delhi** Y.G Prasad	2014	2015

47. EF050 (TMC MM1)	Development of pest models using AICCIP	**S. Kranthi, CICR, Nagpur** Y.G. Prasad M. Prabhakar	2013	2015
48. DCS/ NICRA/16/2012	Demonstration of appropriate practices and technologies in farmers' fields (NICRA-TDC)	**Y.G. Prasad** Dr. Ch. Srinivasa Rao K.A. Gopinath K.V. Rao D.B.V. Ramana	2012	2017
49. DCS/ NICRA/13/2012	Pest and disease dynamics under climate change scenario	**M. Srinivasa Rao** S. Desai Y.G. Prasad M. Prabhakar AVMS Rao VUM Rao	2012	2017
50. CS/Horti/09	Integrated nutrients & bio-inputs as components of horticultural crop production in dryland regions	**N.N. Reddy** V.S. Rao A. Gopala Krishna Reddy Minakshi Grover	2010	2014 Dec.
51.DCS/NICRA/22/ 2012	Scope for enhanced adaptation strategies for climate resilience in horticultural crops through improved management practices	**N.N. Reddy** B.M.K. Raju P. Vijaya Kumar V.S. Rao A. Gopala Krishna Reddy	2012	2017
52.CS/Hort/10	Developing supplemental irrigation schedules for sustainable vegetable production in dryland regions	**A. Gopala Krishna Reddy** N.N. Reddy V.S. Rao K.S. Reddy	2012	Dec. 2015
53.DCS/ NICRA/20/2012	Assessing the plant root adaptive plasticity in the stressed environments of moisture deficits and excess in rainfed agriculture-Maize	**V. Maruthi** K. Srinivas K. Srinivas Reddy M. Maheswari N. Ravi Kumar	2012	2017
54. DCS/ NICRA/03/2011	Potential of organic crop production as a climate change mitigation and adaptation strategy in rainfed agriculture	**K.A. Gopinath** J.V.N.S. Prasad G. Venkatesh Ch. Srinivasa Rao S.K. Yadav	2011	2017
55.CS/ALU/06	Intercropping of various cereals	**G. Jayaram Reddy**	2012	2017
56.DCS/ NICRA/27/2012	Genetic enhancement of pigeonpea germplasm for moisture stress tolerance	**K. Salini** N. Jyothi Lakshmi M. Vanaja M. Maheswari Basudeb Sarkar	2012	2017

57. CS/LP/18	Evaluation of horsegram mutants in multi-locational AICRP trials	**K. Salini** V. Maruthi Basudeb Sarkar	2007	2015
58. CS/CP/27	Genetic improvement in clusterbean for dryland agriculture	**K. Salini** A.G.K. Reddy Jyothi Lakshmi S.K. Yadav V. Maruthi K. Sreedevi Shankar Basudeb Sarkar	2013	2016
59.DCS/ NICRA/19/2012	Impact of elevated CO_2 and high temperature on nutrient quality of dryland crops	**K. Sreedevi Shankar** M.Vanaja	2012	2017
60.CS/FN/01	Biofortification for improved nutritional traits in selective dryland crops grown under rainfed conditions	**K. Sreedevi Shankar** Minakshi Grover K. Srinivas M. Vanaja S.K. Yadav V. Visha Kumari	2014	2019
61. DCS/ NICRA/09/2012	Developing Image processing methodologies for Analyzing high throughput plant phenotyping imageries	**N. Ravi Kumar** M. Maheswari A.K. Shankar	2012	2017
62. CS/SS/04	Improving Nutrient use Efficiency through foliar nutrient supplementation	**S.S. Balloli** M. Osman Ch. Srinivasa Rao S.K. Yadav N. Jyothi Lakshmi	2012	2015
63. CS/CP/29	Development of mapping population and genetic enhancement for drought tolerance and nitrogen use efficiency in maize	**Basudeb Sarkar** M. Maheswari K. Salini S.K. Yadav N. Jyothi Lakshi V. Visha Kumari	2014	2019
Section of Design and Analysis				
64 .DCS/ NICRA/02/2011	Assessing vulnerability to Climate Change	**C.A. Rama Rao** B.M.K. Raju K.V. Rao V.U.M. Rao A.V.M. Subba Rao Kaushalya Ramachandran K. Nagasri K. Ravi Shankar Josily Samuel Ravi Dupdal	2011	2017

65. D&A/AS/01	Development of a database of rainfed districts	**B.M.K. Raju** K.V. Rao C.A. Rama Rao A.V.M. Subba Rao Josily Samuel N. Ravi Kumar	2009	2015
66. D&A/AS/02	Unreaped yield potentials of major rainfed crops	**B.M.K. Raju** C.A. Rama Rao K.V. Rao A.V.M. Subba Rao B.M.K. Raju M. Osman Ravi Dupdal Josily Samuel	2011	2015
67. D&A/AE/12	Economic implications of soil erosion - A farm level study	**Josily Samuel** C.A. Rama Rao B.M.K. Raju Ravi Dupdal K.V. Rao K.L. Sharma R. Rejani	2012	2015
Section of Transfer of Technology				
68. TOT/ NICRA/18/2012	Adaptive management of small ruminants under grazing conditions to climate change	**D.B.V. Ramana** N. Ravi Kumar P.K. Pankaj	2012	2017
69. TOT/LM/06	Development of Inventory of Technologies for Livestock Production for counteracting seasonal stress in rainfed areas	**Prabhat Kumar Pankaj** D.B.V. Ramana K. Ravi Shankar Ravi Dupdal G. Nirmala	2012	2016
70. TOT/AE/31	Gender dimensions of climate change impacts: A participatory assessment of vulnerability and adaptation in agriculture	**G. Nirmala** K. Nagasree K. Ravishankar Ravikant V Adake	2013	2015
71. TOT/ NICRA/1/2012	Knowledge Management for Climate Resilient Agriculture (NICRA)	**K. Nagasree** N. Ravi Kumar Y.G. Prasad C.A. Rama Rao K. Ravi Shankar	2012	2017
72. TOT/AE/30	A study on assessment of post training impact and effectiveness for technology transfer in Rainfed Agriculture	**K. Nagasree** M.S. Prasad G. Nirmala K. Ravi Shankar P.K. Pankaj	2013	2016

73. TOT/AE/29	Understanding farmer knowledge, attitude and adaptation strategies to climate variability and change in semi-arid regions of India	**K. Ravi Shankar** K. Nagasree B.M.K. Raju M.S. Prasad	2012	2015
74. TOT/AE/32	Assessment of KVK Ranga Reddy Interventions on Knowledge and Adoption of Farmers	**K. Ravi Shankar** K. Nagasree M. S. Prasad G. Nirmala Josily Samuel BMK Raju	2014	2017
AICRPDA				
75. AICRPDA/ NICRA/29/2012	Adaptation strategies through cropping systems at selected soil benchmark sites	**G.Ravindra Chary** G. M. Sankar S.S. Balloli Pushpanjali Manoranjan Kumar C.A. Rama Rao R. Nagarjuna Kumar Ch.S. Rao G. Pratibha M. Osman	2012	2017
76. PC(D)/3	Decision Support System for Real-time Management of Agricultural Practices (DSS-RTMAP)	**R. Nagarjuna Kumar** B.M.K. Raju G. Ravindra Chary All AICRPDA Chief Scientists	2012	2015
77. PC(D)/4	Rainfed Area Research Network Information Management System (RANIMS)	**R. Nagarjuna Kumar** B.M.K. Raju G. Ravindra Chary N.S. Raju All AICRPDA Chief Scientists	2012	2015
78. EF 044 (DST)	Quantifying Green House Gas (GHG) emissions in rainfed production systems	**Ch. Srinivasa Rao** G. Pratibha V.U.M. Rao K.L. Sharma J.V.N.S. Prasad A.K. Indoria Sumanta Kundu	2012 May	2015
79. AICRPDA/ NICRA/25/2012	Soil Carbon Sequestration strategies for improving soil health, productivity enhancement, enhancing nutrient use efficiency and reducing GHG emissions in rainfed production systems of India	**Ch. Srinivasa Rao** Sumanta Kundu V. Girija Veni Raj Kumar Dhakar	2012	2017

AICRPAM				
80. AICRPAM/ NICRA/26/2012	Development of strategies for improved agromet advisories at micro level and their dissemination	**V.U.M. Rao** B. Bapuji Rao P. Vijaya Kumar A.V.M. Subba Rao Raj Kumar Dhakar Sarath Chandran	2012	2017
81.AICRPAM/ NICRA /08/2012	Development of weather index based insurance module for selected crops and other agricultural sectors	**P. Vijaya Kumar** V.U.M. Rao M. Osman B.M.K. Raju A.V.M. Subba Rao	2012	2017
82.AGMET/04	Assessing the Impact of climate change on rice production in the eastern region of India using DSSAT (CERES) rice model	**A.V.M. Subba Rao** V.U.M. Rao B. Bapuji Rao P. Vijaya Kumar Raj Kumar Dhakar	2012	2015

12 Consultancy, Commercialization and Intellectual Property Management

- CRIDA designed implements were commercialized to 5 major firms from Maharashtra viz. M/s Rohit Steel Works, Pune; M/s S.R. Engineering Services, Wardha; M/s Sai Agrotech, Yavatmal; M/s Mahashakti Agro Energy Innovation Ltd., Wardha and M/s Shri Balaji & Co., Gondia.
- A consultancy project on preparation of India's First Biennial Update Report- Agricultural Sector-Mitigation and Gaps and Constraints was awarded to CRIDA by Ministry of Environment and Forests, Government of India and successfully completed.
- Department of agriculture, Government of Telangana awarded a consultancy project on Impact Evaluation of Bhuchetana Project in Adilabad, Karimnagar, Medak, Ranga Reddy and Mahabubnagar Districts of Telangana State to CRIDA. Drs. K. Sammi Reddy, Ch. Srinivasa Rao, I. Srinivas, K. Nagasree, K. Srinivas, V. Maruthi, S. Kundu, G. Rajeshwar Rao, K. A. Gopinath, G. Nirmala, S. S. Balloli, G. Pratibha, K. Ravi Shankar, K. V. Rao, G Ravindra Chary and J. V. N. S. Prasad carried out the impact evaluation.
- Dr. P.K.Pankaj, Senior Scientist (LPM), was a member of the team that submitted the following 4 gene sequences to NCBI (*Sus scrofa* Nucleotide sequences)

Gene/Receptor	Authors	Accession Number	Date accepted
Sus scrofa isolate Ghoongroo 12S ribosomal RNA gene	Sahoo,N.R., Nesa,N., Das,A., Naskar,S., Banik,S., Pankaj,P.K. and Sahoo,M	KJ651276	21-JUN-2014
Sus scrofa isolate Tenyi Vo 12S ribosomal RNA gene	Sahoo,N.R., Nesa,N., Das,A., Naskar,S., Banik,S., Pankaj,P.K. and Sahoo,M.	KJ651275	21-JUN-2014
Sus scrofa isolate Niang Megha 12S ribosomal RNA gene	Sahoo,N.R., Nesa,N., Das,A., Naskar,S., Banik,S., Pankaj,P.K. and Sahoo,M.	KJ651274	21-JUN-2014

13 Meetings of IRC, IMC, RAC

13.1 Institute Research Committee (IRC) Meeting

The Institute Research Committee (IRC) Meeting for 2013-14 was held during 27- 29 May, 2014 and June 9, 2014 under the Chairmanship of Dr M Maheswari Director (Acting). Ongoing projects under all the divisions were discussed in detail and suggestions were made. Five new projects were approved, 11 projects concluded and 12 projects were extended in the IRC. A Midterm IRC was also held in February 2015. In this all the ongoing projects under all divisions were discussed in detail and suggestions were made. New project proposals have been reviewed and approved by Dr Ch Srinivasa Rao Director, CRIDA and Chairman of the committee.

Midterm IRC in February 2015

13.2 Institute Management Committee (IMC) meeting of CRIDA

The IMC was held in CRIDA on August 18, 2014 under the Chairmanship of Dr M Maheswari, Acting Director, CRIDA. Members present were Shri Marreddy Srinivasa Reddy, Purimetla Village, Mundlamuru mandal, Prakasam District, A.P. Shri. Sivaji Yelamanchili, EX-MP (RS),Brindavan Gardens, Guntur, Dr V U M Rao, Project Coordinator (Agromet), CRIDA, Dr P Ramesh, Principal scientist (Agronomy), NAARM, Dr.S.R.Voleti, Principal Scientist (Plant Physiology), DRR, and Member–Secretary Shri Ashish Roy, Chief Administrative Officer. Special Invitees from CRIDA: Drs C R Tygaraj, OIC (works) ,G.R.Maruthi Shankar, I/c. PC (R), K. Sammi Reddy, Head, DRM, Mohd. Osman, Head, PME Cell, M.S.Prasad, Head, TOT and C.A.Rama Rao, Head, Design & Analysis were present. The committee discussed action taken on previous IMC, promotions of technical officers to senior technical officers, implementation of ISO-9001:2008, new works to be taken up, progress of expenditure, research highlights and HRD activities of the Institute.

Institute Management committee meeting

13.3 Research Advisory Committee (RAC) Meeting

The XXIII meeting of the Research Advisory Committee (RAC) and IV Common RAC of CRIDA & CAZRI was held at CRIDA Hyderabad during 20th and 21st November, 2014 and were attended by Dr. MC Saxena, Chairman and members Dr. YS Ramakrishna, Dr. A Padmaraju, Dr. KD Singh, Dr. RP Singh, Dr. CL Acharya, Dr. S Pandey, Dr. MM Roy, Director, CAZRI, Dr. BM Kumar, ADG, (Agronomy, Agroforestry & Climate Change), Dr. Ch Srinivasa Rao Director, CRIDA, Dr. G Rajeshwar Rao Member Secretary. There was brief presentation on three

Consortium Research Platforms *viz*., conservation agriculture, water, and small farm mechanization. RAC members interacted with all the scientist of CRIDA in 7 thematic group meetings. RAC approved long and short term collaborative projects proposed by CRIDA and CAZRI. The RAC team visited on-farm trial sites of CRIDA in tribal village of Peddamalkapur in Sitagondi gram panchayat of Adilabad District on 21st November, 2014 and were impressed with pond technology and reuse of water for supplemental irrigation.

RAC Meeting in CRIDA

13.4 Research Advisory Committee (RAC) meeting at CAZRI

CRIDA had attended the IX RAC meeting of CAZRI held on March, 17-18, 2015 under the Chairmanship of Dr. M C Saxena and members present were Dr. Y.S. Ramakrishna, Former Director, CRIDA, Dr. K.D. Singh, FAO Forestry Expert, Dr. R.P. Singh, Former Prof. & Head, Division of Agriculture Economics, IARI, New Delhi, Dr. C.L. Acharya, Former Director, IISS, Bhopal, Dr. Shatrughan Pandey Former Principal Scientist, IISR, Lucknow Dr. Ch. Srinivasa Rao Director, CRIDA, Dr. B. Mohan Kumar, Asst. Director General (Agro-forestry), ICAR Dr. R.K. Bhatt, Director (Acting), CAZRI, Jodhpur and Member Secretaries Dr. G. Rajeswara Rao, Principal Scientist (Agro Forestry) CRIDA and Dr. P C Moharana, Principal Scientist, CAZRI were present. Some of the action points that emerged during the meeting related to CRIDA were CRIDA & CAZRI institutes would start the combined long term project on Clusterbean with funds available at their command, Quantification and characterization of stress on plants and animals and also photovoltaic agriculture and to grow crops under shade of Photovoltaic structures.

CRIDA participated in RAC meeting of ICAR-CAZRI

14 Participation of Staff in Conferences, Meetings, Workshops, Seminars and Symposia

Name	Title	Duration	Venue
KA Gopinath	ZMC meeting for review of progress under TDC-NICRA	13-16 April, 2014	KVK-Bahraich KVK-Gonda KVK-Chitrakoot
I Srinivas	Stakeholder Consultation on Technological Inputs for Dry Land Farming Mission in Maharashtra at VN Marathwada Krishi Vidyapeeth, Parbhani	25 April, 2014	Parbani, Maharahstra
M Prabhakar K Ravi Shankar	Zonal Research Extension and Advisory Council 2014 meeting of South Telangana Zone	16 - 17 April, 2014	Nalgonda, Telangana
CA Rama Rao G Ravindra Chary I Srinivas KA Gopinath	Brain-storming session on rainfed agriculture research review and refinement in AICRPDA-CRIDA network, and contingency planning discussions	09-10 May, 2014	NAAS, NASC Complex, New Delhi
CA Rama Rao	Workshop on Climate Change Projections, Impacts – Vulnerability Adaptation	21-22 May, 2014	MoEF, New Delhi
CA Rama Rao KA Gopinath	Review meeting on technical programme of AICRPDA, NICRA & TSP	29-30 May, 2014	CRIDA, Hyderabad
SM Vidya Sekhar	Training programme on Production protocol for Bio agents and Bio-pesticides and quality control	23 May to 12 June, 2014	NIPHM, Hyderabad
G Rajeshwar Rao	NAIP Review workshop	03-05 June, 2014	IARI, New Delhi
K Salini	30th Annual Workshop of National Network Research Project on Arid Legumes	07-08 June, 2014	RVSKV, Gwalior
CA Rama Rao	Collaboration Meet on Development of Agriculture	12 June, 2014	NABARD, Hyderabad
V Maruthi K Nagasree K Sreedevi Shankar G Nirmala PK Pankaj	MSSRF-LANSA workshop on Using evidence based research tools	25 June, 2014	CRIDA, Hyderabad
CA Rama Rao	Brainstorming Session (BSS) on Monitoring and Evaluation of Agricultural Research, Education and Extension for Development (AREE4D)	28 June, 2014	ISEC, Bangalore

S Vijaya Kumar	National Conference on Water, Environment & Society (NCWES-2014)	30 June to 01 July, 2014	JNTU, Hyderabad
M Srinivasa Rao K Sammi Reddy CA Rama Rao	3rd Annual Workshop on NICRA	03-05 July, 2014	NASC, New Delhi
KA Gopinath	Regional workshop on strengthening partnerships and refined methodology for on-station experiments of AICRP on IFS	09 July, 2014	ANGRAU, Hyderabad
CA Rama Rao	Executive Committee Meeting of National Food Security Mission (NFSM), Govt. of Telangana, Department of Agriculture	17 July, 2014	Hyderabad
S Vijaya Kumar	National workshop on Managing Water for Sustainable Water Supply, Sanitation and Irrigation Services-Innovation and Best Practices	18-19 July, 2014	NIMSME, Hyderabad
KV Rao	Drought monitoring in Khammam district	21 July, 2014	Khammam, Telengana
G Sri Krishna	Training programme on Writing for print and electronic media	21-25 July, 2014	MANAGE, Hyderabad
V Maruthi	Review of monsoon situation in 2014 by Principal Secretary to Telangana	22 July, 2014	NAARM, Hyderabad
BMK Raju	Workshop on Implications of Climate Change on Water Resources and Agriculture	25-26 July, 2014	Bhubaneswar, Odisha
JVNS Prasad	Annual workshop of AICRP on Agroforestry	25 - 27 July, 2014	Bhubaneswar, Odisha
SS Balloli	Priority setting, Monitoring and Evaluation of Agricultural Research Projects	04-08 August, 2014	NAARM, Hyderabad
P Vijaya Kumar	National seminar on Technologies for sustainable production through climate resilient agriculture.	08-09 August 2014	JNKVV, Jabalpur
M Prabhakar YG Prasad	Interface workshop of KVKs	19 - 20 August, 2014	NASC Complex, New Delhi
CA Rama Rao KL Sharma DBV Ramana M Vanaja K Sreedevi Shankar V Visha Kumari	Silver Jubilee Symposium on 'Nutritionally sensitive and environmentally sustainable agriculture for India's food and nutrition security : Challenges and Opportunities'	23 August, 2014	NAARM, Hyderabad

K Sammi Reddy KA Gopinath G Venkatesh Sumanta Kundu	Workshop on Use of biochar in agriculture and pollution control jointly organised by GTU Board of Environment and Green Technologies and CRIDA, Hyderabad	24 August, 2014	Gujarat Technological University, Ahmedabad
VUM Rao P Vijaya Kumar B Bapuji Rao AVM. Subba Rao MA Sarath Chandran	AICRPAM-NICRA workshop	26-27 August, 2014	CRIDA, Hyderabad
M Prabhakar	District Farmers Advisory Committee (DFAC) and ATMA Management Committee (AMC) meetings	27 August, 2014	Hyderabad
S Vijaya Kumar	Training programme on Geospatial Knowledge Management for Sustainable Agriculture Using Open Source GIS	02-12 September, 2014	NAARM, Hyderabad
V Maruthi	Interaction meeting on Best bet practices in Agriculture with trainees from CCDM of Dr MCRHRD	10 September, 2014	CRIDA, Hyderabad
DBV Ramana	2nd international conference on Animal & Dairy Sciences	15-17 September, 2014	Hyderabad International Convention Centre, Hyderabad
N Ravi Kumar	GARUDA- NKN Partners meeting	19-20 September, 2014	IISC, Bangalore
SM Vidya Sekhar	Orientation programme on Protection of Plant varieties and Farmers Rights Act-2001	24 September, 2014	ZPD, Zone-V, Hyderabad
DBV Ramana	Feed and fodder development	25-27 September, 2014	AHD, Govt. of AP, Hyderabad
M Prabhakar	Annual Zonal workshop of KVKs, Zone-V, 2014	29 September - 01 October, 2014	Baramati, Pune
K Sammi Reddy M Srinivasa Rao	ICAR-DAC Interface Meeting for Up Scaling of Climate Resilient Practices through NMSA	13 October, 2014	NASC, New Delhi
P Vijaya Kumar	Brain storming session on Shifting pattern of major and minor rice diseases as function of climate change and develop road map for addressing the issue	14 October, 2014	CRURRS, Hazaribagh
G Ravindra Chary	District Level Consultation Workshop for Upscaling of Rainfed Technologies	15 October, 2014	AICRPDA centre, Faizabad

BMK Raju	National Workshop on Climate Change Adaptation in Drought Affected Areas: Policies, Programmes and Traditional Coping Mechanisms	16 October, 2014	New Delhi
VUM Rao AVM Subba Rao Rajkumar Dhakar MA Sarath Chandran CA Rama Rao G Nirmala R Rejani PK Pankaj	International symposium on New dimensions in Agrometeorology for sustainable agriculture	16-18 October , 2014	GBPUAT, Pantnagar
K Sammi Reddy CA Rama Rao MS Prasad KA Gopinath Puspanjali G Venkatesh	Brainstorming session on technical and non-technical constraints impeding the upscaling of watershed programmes in rainfed areas and a way forward	20 October, 2014	CRIDA, Hyderabad
G Ravindra Chary	District Level Consultation Workshop for Upscaling of Rainfed Technologies	21 October, 2014	AICRPDA centre, Bangalore
V Maruthi R Nagarjuna Kumar NS Raju	3rd International conference on agriculture and horticulture	27-29 October, 2014	HICC, Hyderabad
KS Reddy S Vijaya Kumar R Rejani	4th International Conference on Hydrology and Watershed Management (ICHWM-2014)	29 October to 01 November, 2014	JNTU, Hyderabad
Minakshi Grover	National Conference on Plant-Microbe Interactions	05- 06 November, 2014	ANGRAU, Hyderabad
VUM Rao P Vijaya Kumar B Bapuji Rao AVM Subba Rao MA Sarath Chandran	XIII Biennial workshop of AICRP on Agrometeorology	05-07 November, 2014	IGKV, Raipur
NN Reddy A Gopala Krishna Reddy	6th Indian Horticulture congress National Conference on	05-09 November, 2014	CODISSIA Trade Fair Complex, Coimbatore
NS Raju	6th International Exhibition and Conference on Scientific, Laboratory, Analytical & Biotechnology Instruments	06-08 November, 2014	Hitex Exhibition Center, Hyderabad
K Ravi Shankar G Nirmala	7th National Extension Education Congress.	08-11 November, 2014	ICAR RC for NEH Region, Barapani
G Sri Krishna	Training programme on Strategic Research and Extension Planning	10-11 November, 2014	ATMA & MANAGE, Hyderabad

D Sudheer	National Symposium and made Oral presentation on topic Mitigation of fodder shortage in Ranga Reddy district, Telangana state through technology demonstrations.	13-14 November 2014	BCKV, Kalyani
CA Rama Rao	Brainstorming Meeting for pre-testing of ASTI forms (NAARM-IFPRI Collaborative Project)	17 November, 2014	NAARM, Hyderabad
KV Rao	National Workshop on "Assessing Scale Impacts of Watershed Development: An Integrated Approach"	17-19 November,2014	NASC Complex, New Delhi
G Ravindra Chary	National Symposium on Agricultural Diversification for Sustainable Livelihood and Environmental Security	18- 20 November, 2014	PAU, Ludhiana
N Jyothi Lakshmi	National Conference of Plant Physiology on Frontiers of Plant Physiology Research: Food security and environmental challenges.	23-25 November, 2014	OUAT, Bhubaneswar, Orissa.
K Sammi Reddy SS Balloli K Srinivas K Sreedevi Shankar AK Indoria	79th Annual Convention of Indian Society of Soil Science	24-27 November 2014	ANGRAU, Hyderabad
DBV Ramana	Workshop on fodder production and its impact on milk production	25 November , 2014	Hyderabad
KA Gopinath	Review workshop of TDC-NICRA-Core Institutes	28 November, 2014	CRIDA, Hyderabad
G Ravindra Chary KV Rao	Brain Storming Workshop on Sustaining Soybean Production and Productivity in India: A Resource Domains Initiative	28 November, 2014	NASC, New Delhi
DBV Ramana P Vijaya Kumar CA Rama Rao BM K Raju KA Gopinath K Nagasree G Venkatesh	Brainstorming workshop on Evolving a framework for Climate Resilient Villages (CRVs)	29 November, 2014	CRIDA, Hyderabad
G Rajeshwar Rao	NAAS and PAAS meeting	02 December, 2014	NASC, New Delhi
NN Reddy	National Seminar cum exhibition on Pomegranate for Nutrition, Livelihood Security and Entrepreneurship Development	05-07 December 2014	ICAR- NRC on Pomegranate , Solapur

Minakshi Grover	Group meeting of All India Network Project on Soil Biodiversity and Biofertilizers	06-08 December, 2014	Directorate of Groundnut Research, Junagadh
P Vijaya Kumar	High level meeting for declaration of drought affected mandals in Andhra Pradesh	09 December, 2014	A.P. Secretariat, Hyderabad
K Nagasree	Interaction meeting on the development of Information kiosk	09 December, 2014	ANGRAU, Hyderabad
Kaushalya Ramachandran	International Society of Photogrammetry and Remote Sensing (ISPRS) Technical Committee VIII Mid-term Symposium, 2014	09 - 12 December, 2014	NRSC, Hyderabad
CA Rama Rao KA Gopinath Josily Samuel	National Workshop on Promoting integrated farming systems in IWMP : Critical Issues	11-12 December, 2014	NIRD, Hyderabad
NN Reddy R Nagarjuna Kumar G Venkatesh A Gopala Krishna Reddy	National Conference on Emerging Challenges and Opportunities in Biotic and Abiotic Stress Management	13-14 December, 2014	DRR, , Hyderabad
Kaushalya Ramachandran	Indian National Cartographers Association XXXIV International Congress, 2014	16 - 18 December, 2014	Survey of India, Hyderabad
KS Reddy	National Conference on Water and Food Security for All	19- 20 December, 2014	Jalgaon, Maharastra
Ch Srinivasa Rao G Ravindra Chary KA Gopinath K Sammi Reddy Mohammed Osman K Srinivas Reddy CA Rama Rao JVNS Prasad KV Rao R Rejani G Venkatesh Sumanta Kundu	XXIV Biennial Workshop of All India Coordinated Research Project for Dryland Agriculture	26-29 December, 2014	AICRPDA Center, Indore, RVSKVV, Madhya Pradesh
P Vijaya Kumar	High level meeting for declaration of drought affected mandals in Andhra Pradesh	06 January, 2015	A.P. Secretariat, Hyderabad
KA Gopinath K Salini	The second International Conference on Bio-resource and Stress Management	07-10 January, 2015	Hyderabad
KV Rao	Standing Technical Committee meeting of National Mission on Sustainable Agriculture	09 January 2015	DAC, New Delhi

G Ravindra Chary KA Gopinath	Stakeholder consultation workshop on upscaling of doable rainfed technologies in the domain districts of AICRPDA Centre, Parbhani	13 January, 2015	AICRPDA Centre, Parbhani
M Prabhakar B Sanjeeva Reddy	National seminar on Technologies for enhancing oilseeds production through NMOOP	18 – 19 January, 2015	PJTSAU, Hyderabad
Minakshi Grover	Annual review meeting of AMAAS project	22- 23 January, 2015	NASC, New Delhi
S Vijaya Kumar	Process Documentation and Presentation Skills	22-25 January, 2014	ANGRAU, Hyderabad
JVNS Prasad	Workshop on preparation of India's Intended Nationally Determined Contributions (INDCs)	23 January, 2015	Ministry of Environment and Forests, Delhi
KV Rao	Review of external funded projects at NRM division of ICAR	27 January, 2015	ICAR, New Delhi
SS Balloli	Ensuring Balanced Fertilization through Speciality Fertilizers and Micro-irrigation	28 January, 2015	Hyderabad
DBV Ramana	National Conference on Livestock Production Practices for Small Farmers of Marginalized Groups and Communities in India	28-30 January, 2015	CAU, Aizwal
G Ravindra Chary	National Seminar on sustainable management of land resources for livelihood security	28-30 January, 2015	ICAR-NBSSLUP, Nagpur
NS Raju	68th Annual Conference - Indian Society of Agricultural Statistics (ISAS)	29-31 January, 2015	IASRI, Delhi
KS Reddy	International Workshop on Water Security and Groundwater Management for Agriculture in the Age of Climate Change	03-04 February, 2015	India Habitat Centre, New Delhi
M Prabhakar	National workshop on Popularization and commercialization of low cost agricultural Technologies	04 -06 February, 2015	NIPHM, Hyderabad
M Srinivasa Rao	National Entomologists' Meet	05-07 February, 2015	ICAR-IINRG, Ranchi
K Nagasree K Ravi Shankar	National Workshop on Farmers' Field School	06-07 February, 2015	NIPHM, Hyderabad
Kaushalya Ramachandran	India Geospatial Forum, 2015	10-12 February, 2015	HICC, Hyderabad
KV Rao	India Water Week	13-17 February, 2015	Pragati Maidan, New Delhi

JVNS Prasad	National workshop on linkages between National Action Plan on Climate Change and State Action Plans on Climate Change	17-18 February, 2015	Ministry of Environment and Forests, New Delhi
B Sanjeeva Reddy	49th Annual Convention of Indian Society of Agricultural Engineers (ISAE) and symposium on Engineering Solutions for Sustainable Agriculture and Food Processing	23-25 February, 2015	PAU, Luthiana
BMK Raju	17th Annual Conference of Society of Statistics, Computer and Applications on Statistics & Informatics for smart decisions in managing resources: Issues & Challenges	23-25 February, 2015	BIMT, Bhubaneswar
SS Balloli	Training Needs Assessment for HRD Nodal Officers of ICAR	26 February, 2015	NAARM, Hyderabad
K Nagasree	ISEE National Seminar-2014 on Extension Innovations and Methodologies for Market-led agricultural growth and development	26-28 February, 2015	RVSKVV, Gwalior
NN Reddy	National Seminar on Horticulture vis-a vis Changing Environment	26-28 February, 2015	Medziphema, Nagaland
K Nagasree	Rural Programme Advisory Committee meeting	04 March, 2015	All India Radio, Hyderabad
I Srinivas	National Conference on Emerging Trends in AgriNano Technology	11-12 March, 2015	ANGRAU, Tirupati

15 Workshops, Seminars, Trainings and other Activities Organized by the Institute

Programme	Period	Venue
Institutional training programme for B.Tech (Ag Engg.) students from KAU, Thrissur, Kerala	01- 21 May, 2014	CRIDA, Hyderabad
Professional attachment training of FOCARS Scientist- Mr. S. Gurumurthy, Scientist (Plant Physiology), IIPR, Kanpur	12 May to 11 August 2014	CRIDA, Hyderabad
In-plant training programme on Farm machinery and power for Final Year B.Tech (Ag.Engg) Students, College of Agricultural Engineering, ANGRAU, Hyderabad	02 June – 30 September, 2014	CRIDA, Hyderabad
Training Programme on Introduction to ArcGIS 10.2	12-16 June, 2014	CRIDA, Hyderabad
Workshop on India's First Biennial Update Report Agricultural sector- Mitigation, Gaps and Constraints	21 June 2014	CRIDA, Hyderabad
Capacity development training programme on Climate Resilient Agriculture at ICAR-CRIDA for 100 NICRA-KVK Staff	19-31 January, 2015	CRIDA, Hyderabad
Institutional training programme for M.Tech (S&WE) Students from Bapatla, Guntur, Andhra Pradesh	18 August to 12 September 2014	CRIDA, Hyderabad
Awareness Programme on Biodiversity	05 September, 2014	CRIDA, Hyderabad
Field training on Natural Resources Conservation in Relation to Climate Change Adaptation to students of B.Sc - M.Sc (Integrated) course on Climate Change Adaptation from Academy of Climate Change Education and Research, KAU, Thrissur, Kerala	23 September to 15 October 2014	CRIDA, Hyderabad
District level consultation workshops for upscaling of rainfed technologies	October, 2014 to January, 2015	AICRPDA centres Faizabad, Bangalore and Parbhani
Organized a brainstorming workshop on climate resilient villages (CRVs)	29 November, 2014	CRIDA, Hyderabad
Capacity Building Program on Technology demonstrations for climate resilience and value-added agro-met advisories	19-31, January 2015	CRIDA, Hyderabad
Capacity development program for KVK Staff in four batches	19-31 January, 2015	CRIDA, Hyderabad

National Workshop on Assessing Scale Impacts of Watershed Development: An Integrated Approach

A National workshop on Assessing Scale Impacts of Watershed Development: An Integrated Approach was organized by CRIDA along with Livelihoods and Natural Resources Management Institute (LNRMI), Hyderabad at the NASC Complex, ICAR, New Delhi from 17 to 19, November, 2014. The workshop was a part of the collaborative research project funded by Australian Centre for International Agricultural Research (ACIAR), Australia. The workshop was aimed to share the planning, design, implementation issues addressing hydrology, bio physical, production systems and human and social issues within a meso watershed by the implementing agencies. The workshop was attended by Mr. Bernard Philip, Acting High Commissioner, Australia, Dr AK Sikka, DDG(NRM), ICAR, Dr Ch. Srinivasarao, Director, CRIDA and representatives from different NGOs WASSAN, FES, BAIF, PRADAN, Dhan Foundation, RDT etc., besides project staff from organizations of India and Australia. The workshop acted as a platform for the watershed implementing agencies, policy makers and the researchers working on watershed development to participate and discuss the feasibility of adopting an integrated approach (bio physical, hydro-geological and socio-economic sciences) in implementing the watershed development programs at meso scale. These case studies helped the participants to verify and validate the research findings across different bio-physical, socio-economic and hydro-geological contexts. The project team shared their research findings of the integrated approach (ACIAR project) and facilitated a discussion on feasibility of adopting this integrated approach in watersheds. The feedback from the implementing agency showed the constraints in taking up the watershed management activities considering the equity and climate change aspects at meso-scale.

ICAR Winter School

ICAR sponsored winter school on Advances in pest forecast models and decision support systems for crop protection in changing climate scenario was inaugurated by Dr N.K. Krishna Kumar, DDG (Horticulture Science), ICAR at CRIDA, Hyderabad on 29 October 2014. The objective of the winter school was to impart knowledge to plant protection scientists in the latest advances in the field of pest forecast research, development of forewarning models and decision support systems that can be used in operational pest forecasting for effective pest management in field crops. The school offered an opportunity to share the outputs of the National Agricultural Innovation Project (NAIP) funded sub-project on development of Decision Support Systems (DSS) for pest management. A compendium of lectures contributed by the resource faculty was released on the occasion for use by the participants. Twenty five participants from 12 states attended the winter school with various backgrounds i.e. research (13 candidates), teaching (7) and extension (3). Fifteen participants were from Agricultural Entomology discipline, 6 from Plant Pathology, 3 from Agro-meteorology and 1 from Nematology.

Dr. Y.G. Prasad, Principal Scientist (Entomology) was the course director while Dr. M. Prabhakar,

Dr. N. Ravi Kumar and Dr. G. Rajeshwar Rao were the course coordinators. The valedictory session was presided over by Dr. Ch. Srinivasa Rao, Director, CRIDA and the valedictory address was delivered by Dr. C. Chattopadhyay, Director, NCIPM, New Delhi.

Workshop on Use of Biochar in Agriculture and Pollution Control

One day workshop on "Use of Biochar in Agriculture and Pollution Control" was organized jointly by CRIDA, Hyderabad and Gujarat Technological University Board of Environment & Green Technologies on 24th August 2013 at GTU, Ahmedabad. About 50 delegates consists of faculty, ME and Ph D students of Environmental Engineering and Chemical Technology disciplines from different engineering colleges of Gujarat participated in the workshop. Prof. Dr. K. N. Sheth, Dean – GTU welcomed experts with flowers and in his inaugural speech talked about the importance of the topic. Drs K Sammi Reddy, KA Gopinath, G Venkatesh, and S Kundu, CRIDA, Hyderabad and Dr H. Pathak, IARI, New Delhi presented their papers on various aspects of biochar use in the workshop. The valedictory session of workshop was chaired by Dr. Akshai Aggarwal, Vice Chancellor, GTU. He appreciated the theme of workshop and said that it is relevant to Indian conditions. The major conclusions and recommendations emerged out of workshop were; (i) We should be cautious in recommending biochar to black soils with high pH, (ii) Urgent need to develop quality standards for biochar for using in agriculture, (iii) Chemical Technology and Environmental Engineers of GTU can take up the research work on how to utilize the syngas emitted during the preparation of biochar, use of biochar in remediation of polluted waters and soils and to develop cost-effective machinery for preparation of biochar with temperature control.

Brainstorming Session on Upscaling of Watershed Programmes in Rainfed Areas

A Brainstorming Session on Technical and non-technical constraints impeding the up-scaling of watershed programmes in rainfed areas and a way forward was organized at Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad on October 20, 2014 (Monday) to identify the constraints particularly non-technical in nature that impeding the scaling-up of watershed programmes in rainfed areas and to find out ways to overcome those constraints. About 65 delegates from all stake holders associated with watershed programmes such as research institutes, agricultural universities, ICRISAT, NGOs, Government of Telangana, KVKs, and farmers from watershed areas were participated in the brainstorming session. Dr K. P. R. Vittal, Ex-Director, NIASM, Baramati was the Chief Guest. DrVittal while addressing the gathering emphasized on implementation of holistic approach to tackle water scarcity for overall development of watershed. Altogether 7 invited speakers from research institutes, NGOs, State Governments and AICRP on Dryland Agriculture from different rainfed regions of the country presented papers. A progressive farmer associated with watershed activities in Ranga Reddy district, Telangana state shared his experiences and highlighted the issues faced by farmers in watershed areas. This farmer has suggested the policy makers to develop land registration act for protecting water harvesting structures when the lands in the watershed areas are sold by one farmer to another farmer. In the concluding session, the constraints related to institutional, policy, socio-economics, Research & Development and technical in nature those hindering the scaling-up of watershed programmes in rainfed areas of India are identified for submission to the

quarter concerned at different levels. On this occasion, the On-line Contingency Crop Planning Tool was launched by the Chief Guest during the inaugural session for public use. It is a menu-driven contingency crop planning tool which can be accessed by farmers and other end users readily to get contingency practices suitable for different climatic situations.

Guest Lecture on Role of CGIAR in Indian National Agricultural Research System

ICAR-Central Research Institute of Dryland Agriculture, Hyderabad and National Academy of Agricultural Sciences-Hyderabad chapter jointly organized a Guest Lecture on Role of CGIAR in Indian National Agricultural Research System by Dr. David Bergvinson, Director General, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad at ICAR-CRIDA on 13th March 2015.

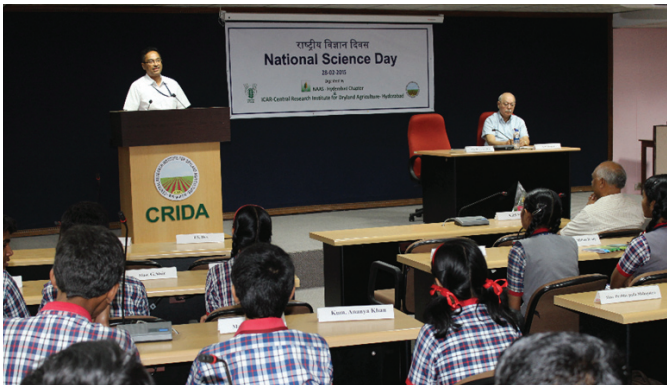
Dr David Bergvinson in his lecture highlighted that the CGIAR system is committed to reduce poverty and hunger, improve human health and nutrition, and enhance ecosystem resilience through high end science research. He felt that there is a need for stronger coordination and complementarity between ICAR and CGIAR institutions. He suggested action plan for strategic partnerships that accelerate the development and delivery of farmer-preferred technologies in dryland areas. He was accompanied by Dr. Peter Carberry, DDG and Dr Anthony Whitbread, Director, Resilient Dryland Systems, ICRISAT. Dr Ch. Srinivasa Rao, Director, CRIDA, welcomed the delegates and appraised that the main purpose of guest lecture was to further strengthen the linkage between ICAR institutes/SAUs with the ICRISAT.

Model Training Course on Resource Conservation Technologies in Rainfed Farming

A model training course on Sustainable conservation technologies for enhancing resource use efficiency in rainfed farming, sponsored by Directorate of Extension, Ministry of Agriculture was organized at CRIDA during 16th to 23rd September, 2014, for senior and middle level extension personnel of State Departments of Agriculture, Animal Husbandry and Horticulture. Twenty five participants from Andhra Pradesh, Telangana, Chhattisgarh, Gujarat, Haryana, Orissa, Punjab, Rajasthan, Tamil Nadu, Maharashtra, Madhya Pradesh and Uttar Pradesh participated in the training. Dr. G. Nirmala, Principal Scientist was the course Director and Drs. K. Ravi Shankar, K. Nagasree, P. K. Pankaj, R. V. Adake and Sreedevi Shankar were the Co-Directors. The valedictory session of the course was attended by Dr. S. M. Virmani, Emeritus Scientist, ICRISAT, Dr. A. K. Sikka, DDG (NRM) and Dr. Ch Srinivasarao, Director, CRIDA.

National Science Day

CRIDA and NAAS-Hyderabad chapter jointly organized National Science Day on 28th February, 2015 for the students of Kendriya Vidyalaya and Bharatiya Vidya Bhavan of twin cities of Secunderabad and Hyderabad. A debate competition on the topic "Agricultural Research as a Career Option" was held on the occasion. Twenty nine students from 15 schools spoke for and against the topic. During the debate, some of the students expressed concerns on quality of food produce, food security issues, gender equality, farmers livelihood issues, changing climate and socio economic issues and some of them on prospects in terms of pay package, human resource development benefits, meeting human needs through agriculture etc., Lack of awareness on career opportunities among teachers as well as parents was one of key reasons for agriculture research not being opted as a career option. Four students, Ms. Ananya Khan (XI class, Kendriya Vidyalaya 1 Dundigal), Master Sai Ram (IX class, Kendriya Vidyalaya 1 Uppal), Master Anurag Panda (IX class, Bharatiya Vidya Bhavan, NIRD campus) and Ms Anjali Bhadani (XI class, Kendriya Vidyalaya, SVPNPA) bagged first, second, third and consolation prizes respectively. Prizes were given away by Chief Guest Dr S M Virmani , NAAS-Foreign Activities In-charge.



Commercialization of Farm Machinery

CRIDA successfully commercialized farm machinery technology to 5 firms from Maharashtra viz. M/s Rohit Steeel Works, Pune; M/s S.R. Engineering Services, Wardha; M/s Sai Agrotech, Yavatmal; M/s Mahashakti Agro Energy Innovation Ltd., Wardha and M/s Shri Balaji & Co., Gondia. The institute showcased designs of 15 farm implements viz. CRIDA ridger planter/BBF planter (tractor drawn), CRIDA precision planter cum herbicide applicator, CRIDA 9- row planter, CRIDA 6- row planter, CRIDA 3/4 row planter (bullock drawn), CRIDA 2 row planter (bullock drawn), CRIDA plough planter & drill plough, CRIDA manual weeder, CRIDA bullock drawn weeder, CRIDA orchard sprayer, CRIDA castor sheller, CRIDA groundnut stripper, CRIDA mini dhal mill, CRIDA herbal dryer and CRIDA vegetable preservator to the firms for non-exclusive licensing. Six designs to M/s Rohit Steel Works; 9 designs to M/s Balaji & Co.; 15 designs to M/s Sai Agrotech; 13 designs to M/s Mahashakti Agro Energy Innovation Ltd. and 12 designs to M/s S.R. Engineering Services were transferred through memoranda of agreement on 6th March, 2015. The agreement included one time contracting fee and periodic royalty payment on sale proceeds.

Swachh Bharat Mission

Swachh Bharat Mission programmes were implemented at CRIDA main office on 2nd October, 2014 and 27th January, 2015; at Hayathnagar Research Farm on 2nd October, 2014 and 28th January, 2015; and at Gunegal Research Farm on 28th March, 2015. The Director and all the staff members participated in the programmes and undertook cleaning up in and around the premises of office and farms.

16 DISTINGUISHED VISITORS

- Dr. A.K. Sikka, Dy. Director General (NRM), ICAR visited CRIDA on 8th April, 2014 and interacted with the Director, Project Coordinators and all Heads of Divisions

DDG (NRM) interacting with Scientists

- Dr. S. Ayyappan, Secretary, Department of Agricultural Research and Education (DARE) and Director General, Indian Council of Agricultural Research (ICAR) inaugurated high-throughput plant phenotyping platform facility at Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad, on 1st July 2014. This unique state of the art facility has been installed under National Initiative on Climate Resilient Agriculture (NICRA) project launched by ICAR to develop adaptation and mitigation strategies to deal with climate change impacts on Indian agriculture. Dr. Ayyappan highlighted the importance of investing on such state-of-the art high end research facilities for climate resilient agriculture. He appreciated the lead role taken by CRIDA for creation of such facility not only in Hyderabad but in other parts of India through NICRA. Dr. A.K. Sikka, Deputy-Director General (DDG) Natural Resource Management (NRM), in his remarks emphasized the need to develop guidelines to use these facilities by all stakeholders. Dr. M. Maheswari, Director (Acting), CRIDA while welcoming the dignitaries briefed about the facility and explained a roadmap for its scientific use in Climate Research with special reference to multiple abiotic stress tolerance. Dr. B. Venketeswarlu, VC, VNMKU, Parbhani, senior officers from ANGRAU, directors of ICAR institutes located in Hyderabad graced the occasion.

DG ICAR inaugurates phenotyping facility at CRIDA

- Trainee IAS Officers of 2013 batch from Dr. MCR HRD IAP visited CRIDA on 12th August, 2014. They were apprised of the CRIDA activities, watershed development programmes.
- Dr. Dath Mita, Senior Crop Analyst, International Production Assessment Division, USDA and his two colleagues visited CRIDA on 25th August,

Trainee IAS officers at CRIDA dryland gallery

2014 to discuss the cotton crop production, planting area and general assessment of the crop.

- Dr. A.K. Sikka, DDG (NRM) visited CRIDA on 23rd September 2014 to review the NICRA program: strategic research activities.
- Shri N. Sudhakar, Senior Manager- Rural Livelihoods and Mr. Vishal of Dr. Reddy's Lab visited CRIDA on 12th November, 2014 and interacted with scientists on possible linkages.
- Delegates from MANAGE, visited CRIDA on 12th March, 2015. They were apprised of NICRA programmes handled by CRIDA. Dr Maheswari NICRA PI, Dr YG Prasad TDC- PI and Dr Md. Osman briefed about the NICRA activities.

Delegates from MANAGE interacting with Director

- A team of 30 students on study tour from College of Agriculture, Cornell University pursuing their Bachelors in International Agriculture and Rural Development course visited CRIDA on 05.01.2015. Faculty members Dr. Peter Hobbs and Dr. Peter Davies accompanied them. The team also consisted of students and faculty from Tamil Nadu Agricultural University, Assam Agricultural University and Benares Hindu University.

- A 19-member delegation from Bureau of Agriculture, Ethiopia along with two faculty members of BASIX Academy for Livelihood and Micro-enterprises Promotion, Hyderabad visited Krishi Vigyan Kendra, CRIDA and Hayathnagar Research Farm on 20 February 2015 as part of their six-day study program.
- On 27th March, 2015, 60 ARS probationers visited CRIDA. Dr Ch Srinivasa Rao, Director, CRIDA made presentation on rainfed research, technology and upscaling.

Director interacting with ARS probationers

- Dr. V N Sharda, Member, ASRB visited CRIDA on 30th March, 2015. He interacted with scientists on issues relevant to research, discipline and criteria for selection to RMP posts. All scientists had participated in the discussion.
- A large number of students, farmers, delegates visited CRIDA. The details are furnished in the following table.

Dr Sharda interacting with CRIDA Scientists

16.1 Students, farmers, delegates and other visitors

Date	Visitors	Affiliation of visitors	No of visitors
01.04.2014	B.Sc.(Ag.) students	College of Agriculture, Padannakkad, KAU	51
07.04.2014	M.Sc.(Integrated) students	Academy of Climate Change Education and Research, Thrissur, KAU	18
28.04.2014	Farmers	Regional Agricultural Research Station, Anakapalle, ANGRAU	50
11.08.2014	B.Sc.(Ag) students	Vanavarayar Institute of Agriculture, Manakkadavu, TNAU	109
23.08.2014	Farmers	Farmers Welfare and Agriculture Development, Guna, MP	14
10.09.2014	Trainees	Centre for Climate & Disaster Management (CCDM), Dr.MCR HRD Institute, Jubilee Hills, Hyderabad	38
11.09.2014	Ph.D. Students	Department of Genetics and Plant Breeding, College of Agriculture, Hyderabad, ANGRAU	24
15.09.2014	Meghalaya delegates	Nehru Yuva Kendra, Ministry of Skill Develoment, Enterpreneurship, Youth Affairs and Sports, Government of India	32
15.09.2014	Agricultural Officers	Government of Odisha	18
19.09.2014	B.Sc. (Ag.) Students	College of Agricultural Technology, Theni (TNAU)	75
20.09.2014	Foreign trainees	MANAGE Foreign Trainees, US-Africa Triangular International Training Programme, Hyderabad	30
20.09.2014	Trainee Scientists	FOCARS 100th Batch, NAARM, Hyderabad	71
24.09.2014	M.Sc. (Integrated) Students	Academy of Climate Change Education and Research, Thrissur, KAU	04
03.10.2014	B.Sc. (Ag.) Students	Agricultural College and Research Institute, Killikulam, TNAU	57
04.10.2014	B.Sc. (Ag.) Students	Adhiparasakthi Agricultural College, Kalavai, Tamil Nadu	107
04.10.2014	B.Sc. (Ag.) Students	Pandit Jawaharlal Nehru College of Agriculture and Research Institute Karaikal, Puducherry	38

04.10.2014	B.Sc.(Ag.) Students	Agricultural College and Research Institute, Coimbatore, TNAU	109
07.10.2014	B.Sc. (Ag.) Students	Thanthai Roever Instt.of Agril.& Rural Development, TNAU, Parambalur, Tamilnadu	81
08.10.2014	B.Sc. (Ag.) Students	Agricultural College and Research Institute, Madurai, TNAU	79
08.10.2014	B.Sc. (Ag.) Students	College of Agriculture, Gulbarga, UAS Raichur	39
08.10.2014	B.Sc.(Ag.) Students	Bharathiar University, Coimbatore, Tamil Nadu	38
22.10.2014	B.Sc.(Ag.) Students	College of Agricultural Engineering, Raichur, UAS Raichur	49
27.10.2014	B.Sc. (Ag. MaCo.) Students	College of Agriculture, Dharwad, UAS Dharwad	47
03.11.2014	B.Sc.(Forestry) Students	College of Forestry, Shivamogga, University of Agricultural and Horticultural Science	49
03.11.2014	B.Sc. (Ag. MaCo.) Students	College of Agriculture, Dharwad, UAS Dharwad	42
07.11.2014	B.Sc. (Ag. MaCo.) Students	College of Agriculture, Dharwad, UAS Dharwad	37
10.11.2014	B.Sc. (Ag. MaCo.) Students	College of Agriculture, Dharwad, UAS Dharwad	46
11.11.2014	M.Sc.(Agronomy) Students	College of Agricultural Engineering, Raichur, UAS Raichur	25
13.11.2014	B.Sc. (Ag.) Students	College of Agriculture, Hanumanamatti, UAS Dharwad	50
14.11.2014	B.Sc.(Ag) Students	College of Agriculture, Bijapur, UAS Dharwad	66
16.11.2014	B.Sc. (Hort.) Students	College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga	62
17.11.2014	B.Sc.(Ag) Students	College of Agriculture, Bijapur, UAS Dharwad	66
17.11.2014	B.Sc. (Hort.) Students	College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga	65
21.11.2014	B.Sc.(Forestry) Students	College of Forestry, Sirsi, UAS Dharwad	61
28.11.2014	B.Tech. Students	College of Agricultural Engineering, Jabalpur, JNKVV	60
04.12.2014	Officers	District Water Management Agency, Kadapa, AP	45
05.12.2014	B.Sc. (Ag.) Students	College of Agriculture, Bangalore, UAS Bangalore	41
05.12.2014	B.Sc. (Ag.) Students	Sericulture College, Chintamani, UAS Bangalore	64
07.12.2014	B.Sc. (Ag.) Students	College of Agriculture, Bangalore, UAS Bangalore	56
07.12.2014	M.Sc./Ph.D.(Ag.) Students	College of Agriculture, Ratnagiri, BSKKV	27
08.12.2014	B.Sc. (Hort.) Students	College of Horticulture, Sirsi, UHS, Bagalkot	35
10.12.2014	B.Sc. (Ag.) Students	College of Agriculture, Navile UAHS, Shivamogga	71
11.12.2014	Farmers	Farmer's Welfare and Agriculture Development, Chindwara, MP	11
15.12.2014	B.Sc. (Hort.) Students	College of Agriculture, Mandya, UAS Bangalore	41
18.12.2014	B.Sc. (Ag.)	College of Agriculture, Mandya, UAS Bangalore	49

19.12.2014	B.Sc. (Ag.) Students	College of Agriculture, Bangalore, UAS Bangalore	43
26.12.2014	B.Tech. Students	College of Agricultural Enginnering and Post Harvest Technology, Gangtok	37
07.01.2015	Farmers	KVK, Baramati	11
08.01.2015	B.Sc. (Ag.) Students	College of Agriculture, Bhawanipatna, OUAT	40
12.01.2015	B.Sc. (Ag.) Students	Biswanath College of Agriculture, Sonitpur, AAU	25
17.01.2015	B.Sc. (Horti.) Students	College of Horticulture, Kolar, University of Horticultural Sciences, Bangalore	40
27.01.2015	B.Sc.(Hons.) Students	College of Forestry, Nauni, Dr Yashwant Singh Parmar University of Horticulture and Forestry	63
17.02.015	B.Sc. (Hons) Students	CP College of Agriculture, Sardar Krushinagar SD Agricultural University	116
20.02.2015	M.Sc. (Ag.) Students	Department of Botany, Savitribai Phule Pune University	12

Farmers visiting dryland gallery

17 PERSONNEL

(As on 31 March, 2015)

Dr. Ch. Srinivasa Rao	Director

Division of Resource Management

Dr. K. Sammi Reddy	Principal Scientist (Soil Science) & Head
Dr. C.R.Thyagaraj	Principal Scientist (Farm Machinery and Power)
Dr. K. Srinivas Reddy	Principal Scientist (Soil and Water Conservation Engineering)
Dr. G. Rajeshwara Rao	Principal Scientist (Forestry)
Dr. G. Pratibha	Principal Scientist (Agronomy)
Dr. K. Srinivas	Principal Scientist (Soil Science)
Dr. I. Srinivas	Principal Scientist (Farm Machinery and Power)
Dr. K.V. Rao	Principal Scientist (Soil and Water Conservation Engineering)
Dr. J.V.N.S. Prasad	Principal Scientist (Agronomy)
Dr. B. Sanjeeva Reddy	Principal Scientist (Farm Machinery and Power)
Dr. Ravikanth V. Adake	Senior Scientist (Farm Machinery and Power)
Dr. Manoranjan Kumar	Senior Scientist (Soil and Water Conservation Engineering)
Dr. R. Rejani	Senior Scientist (Soil and Water Conservation Engineering)
Sri. G. Venkatesh	Scientist (Forestry)
Sri . N. S. Raju	Scientist (Computer Applications)
Smt. Pushpanjali	Scientist (Soil Science - Pedology)
Dr. A. K. Indoria	Scientist (Soil physics/Soil and Water Conservation Engineering)
Dr. Sumanta Kundu	Scientist (Agronomy)
Smt. V. Girija Veni	Scientist (Soil Science)
Er. C. V. K. Nageswara Rao	Instrument Engineer (Chief Technical Officer)
Dr. K. Usha Rani	Assistant Chief Technical Officer
Dr. K. Venkanna	Assistant Chief Technical Officer
Sri. Ram Kumar	Assistant Chief Technical Officer
Sri. K. L. Prasad	Senior Technical Officer
Smt. V.Renu	Personal Assistant

Division of Crop Sciences

Dr. M. Maheshwari	Principal Scientist (Plant Physiology) & Head
Dr. V.S. Rao	Principal Scientist (Horticulture)
Dr. N.N. Reddy	Principal Scientist (Horticulture)

Dr. S. Desai	Principal Scientist (Plant Pathology)
Dr. S.K. Yadav	Principal Scientist (Biochemistry)
Dr. Y.G. Prasad	Principal Scientist (Entomology)
Dr. M. Vanaja	Principal Scientist (Plant Physiology)
Dr. S.S. Balloli	Principal Scientist (Soil Science)
Dr. M. Srinivasa Rao	Principal Scientist (Entomology)
Dr. V. Maruthi	Principal Scientist (Agronomy)
Dr. Arun Kumar Shanker	Principal Scientist (Plant Physiology)
Dr. M. Prabhakar	Principal Scientist (Entomology)
Dr. N. Jyothi Lakshmi	Principal Scientist (Plant Physiology)
Dr. B. Sarkar	Principal Scientist (Plant Breeding)
Dr. Minakshi Grover	Senior Scientist (Microbiology-Plant Science)
Dr. N. Ravi Kumar	Senior Scientist (Computer Applications)
Dr. K. Sreedevi Shankar	Senior Scientist (Food & Nutrition)
Dr. G. Jayaram Reddy	Scientist (Senior Scale) (Agronomy)
Dr. A. G. K. Reddy	Scientist (Horticulture)
Dr. K. Salini	Scientist (Plant Breeding)
Smt. V. Visha Kumari	Scientist (Agronomy)
Smt. M. Pushpalata	Asssistant Chief Technical Officer
Sri. Jainender	Asssistant Chief Technical Officer
Sri. S.S. Shishodia	Technical Officer
Smt. D. G. M. Saroja	Technical Asistant
Sri. P. Satish	Technical Assistant
Sri. G. Lingaiah	Technician
Smt. B. Saraswati	Personal Assistant

Section of Design and Analysis

Dr. C.A. Rama Rao	Principal Scientist (Agricultural Economics) & Head
Dr. B.M.K. Raju	Senior Scientist (Agricultural Statistics)
Sri. R. Nagarjuna Kumar	Scientist (Computer Applications)
Dr. Josily Samuel	Scientist (Agricultural Economics)
Sri. Ravi Dupdal	Scientist (Agricultural Economics)
Sri E. Ravindranath	Technical Officer
Smt. C. Kanaka Durga	Personal Assistant

Section of Transfer of Technology

Dr. M.S. Prasad	Principal Scientist (Agricultural Extension) & Head
Dr. G.Nirmala	Principal Scientist (Agricultural Extension)
Dr. D.B.V. Ramana	Principal Scientist (Livestock Production and Management)

Dr. K. Ravi Shankar	enior Scientist (Agricultural Extension)
Dr. K. Nagasree	Senior Scientist (Agricultural Extension)
Dr. P. K. Pankaj	Senior Scientist (Livestock Production and Management)
Sri. K.V.G.K. Murthy	Chief Technical Officer (Artist)
Sri. K. Surender Rao	Chief Technical Officer (Photography)
Smt. V.L. Savithri	Senior Technical Officer (Economics)
Sri. S. Yadagiri	Senior Technical Officer
Sri. K. Satthaiah	Technical Officer
Smt. S. Lakshmi Prasunamba	Personal Assistant

All India Coordinated Research Project for Dryland Agriculture

Dr. G. Ravindra Chary	Principal Scientist (Agronomy)
Dr. K. A. Gopinath	Senior Scientist (Agronomy)
Dr. A. Girija	Chief Technical Officer (Computer)
Dr. P. Anantha V. Rao	Chief Technical Officer (Agronomy)
Smt. N. Lakshmi Narasu	Private Secretary

All India Coordinated Research Project on Agrometeorology

Dr. V.U.M. Rao	Principal Scientist (Agricultural Meteorology) & Project Coordinator
Dr. P Vijay Kumar	Principal Scientist (Agricultural Meteorology)
Dr. B. Bapuji Rao	Principal Scientist (Agricultural Meteorology)
Dr. A.V.M. Subba Rao	Scientist Selection Grade (Agricultural Meteorology)
Sri Rajkumar Dhakar	Scientist (Agricultural Physics)
Sri. M.A. Sarath Chandran	Scientist (Agril. Meteorology)
Sri. I. R. Khandgonda	Senior Technical Officer
Sri. M.Yadaiah	Assistant

National Fellow

Dr. K.L.Sharma	Principal Scientist (Soil Science) & ICAR National Fellow
Dr. Kaushalya Ramachandran	Principal Scientist (Geography) & ICAR National Fellow

Prioritization, Monitoring and Evaluation Cell

Dr. M. Osman	Principal Scientist (Agronomy) & Head
Dr. S.S. Balloli	Principal Scientist (Soil Science)
Dr. Arun Kumar Shanker	Principal Scientist (Plant Physiology)
Dr. B. M. K. Raju	Senior Scientist (Agricultural Statistics)
Sri . N. S. Raju	Scientist (Computer Applications)
Dr. Josily Samuel	Scientist (Agricultural Economics)
Sri. M.A. Sarath Chandran	Scientist (Agril. Meteorology)
Sri. Manish Tomar	Technical Assistant (Computer)

NICRA Strategic Research

Dr. M. Maheshwari	Principal Scientist (Plant Physiology) & PI
Dr. M. Srinivasa Rao	Principal Scientist (Entomology) & CoPI
Smt. P. Lakshmi Narasamma	Assistant Chief Technical Officer (Computer)

NICRA Technology Demonstration Component

Dr. Y.G. Prasad	Principal Scientist (Entomology) & PI
Dr. J.V.N.S. Prasad	Principal Scientist (Agronomy) & CoPI
Smt. M.A.Rekha	Personal Assistant

KVK

Dr. M. Prabhakar	Principal Scientist (Entomology) & OIC
Dr. K. Ravi Shankar	Senior Scientist (Agricultural Extension)
Dr. S.M. Vidyasekhar	Chief Technical Officer
Smt. A. Vidyadhari	Assistant Chief Technical Officer
Dr. D. Sudheer	Senior Technical Officer
Er. S. Vijaya Kumar	Senior Technical Officer
Sri. G. Srikrishna	Senior Technical Officer
Smt. G.M. Shashi Rekha	Junior Stenographer

Agricultural Knowledge Management Unit

Dr. N. Ravi Kumar	Senior Scientist (Computer Applications) & OIC
Sri. P. Chandra Sekhar	Assistant Chief Technical Officer (Computer)

Library

Dr. Arun Kumar Shankar	Senior Scientist (Plant Physiology) & OIC
Sri. A. Malla Reddy	Assistant Chief Technical Officer
Sri. G. Prabhakar	Senior Technical Officer

Farm Management

Dr. S. Desai	Principal Scientist (Plant Pathology) & Chairman
Dr. G. Rajeshwara Rao	Principal Scientist (Forestry)
Dr. K. Srinivas Reddy	Principal Scientist (Soil and Water Conservation Engineering)
Dr. M. Srinivasa Rao	Principal Scientist (Entomology)
Dr. K. A. Gopinath	Senior Scientist (Agronomy)

Hayathnagar Research Farm

Sri. S. Srinivasa Reddy	Assistant Chief Technical Officer
Sri. Ganesh Ramji Hedau	Senior Technical Officer
Sri. K. Shankaraiah	Senior Technical Assistant

Sri. Y. Yellappa	Senior Technical Assistant
Sri. Hemanth Sahu	Technical Assistant
Sri. Buchaiah	Technician
Sri. G. Raju	Technician
Sri. Ch. Mukund	Technician
Sri. B. Krishna	Technician
Sri. B. Kurmaiah	Technician

Gunegal Research Farm

Sri. R. Lingamaiah	Technical Officer
Sri. A. Chandraiah	Senior Technical Assistant
Sri. K. Rajeshwar	Technician

Vehicles

Dr. C.R.Thyagaraj	Principal Scientist (Farm Machinery and Power) & OIC
Sri. T. Ravi Kumar	Technical Officer (Driver)
Sri. K. Ganesh	Senior Technical Assistant (Driver)
Sri. P. Raju	Technician (Driver)
Sri. Ahmed Pasha	Technician (Driver)
Sri. K. Shanker	Technician (Driver)

Official Language Unit

Dr. S.R.Yadav	Asst. Director (OL) and Public Relations Officer

Institute Works Committee

Dr. C.R.Thyagaraj	Principal Scientist (Farm Machinery and Power) & Chairman
Sri. J. B. Ramappa	Assistant Chief Technical Officer
Sri. D. Srinivas	Technical Officer (Electrician)

Landscaping

Sri. P. Yadagiri	Technical Officer

Reception

Sri. K. Ramakrishnaiah	Technical Officer

International Guest House (IGH)

Sri. D.Sridhar	LDC

Director's Office

Sri. M.S.R.Anjaneyulu	Personal Assistant
Smt. M.Vanitha Raman	Personal Assistant

Administration

Sri. Ashish Roy	Chief Administrative Officer (CAO)
Er. C.V.K.N Rao	Drawing and Disbursing Officer
Er. C.V.K.N Rao	Stores & Purchase Officer
Sri. V. Sanu	Assistant Administrative Officer
Sri. G. Prem Kumar	Senior Technical Officer
Sri. Ch. Srinivas	Senior Technical Officer (Computer)
Smt. K.V. Manikyam	Private Secretary
Sri. P. Somesh Kumar	Assistant
Sri. M. Krishna Reddy	Assistant
Sri. P. Srinivasa Rao	Assistant
Sri. K. Gowtham Reddy	Assistant
Sri. S. Ratna Shankar Rao	Personal Assistant
Sri. K. Narasimha	Assistant
Sri. A. Nageswara Rao	Assistant
Smt. S. Kavitha	LDC
Smt. S. Swathi Kiran	LDC

Finance

Sri. Z.H. Khilji	Senior Finance & Accounts Officer (SFAO)
Sri. G. Jaganmohan Rao	Asst. Finance & Accounts Officer (AFAO)
Smt. N.K. Anupama	Junior Accounts Officer

Audit & Accounts

Sri. A. Mahesh Kumar	Assistant
Sri. Ch. Ramalingeswara Rao	Assistant
Smt. D. Kalpana	Assistant
Sri. Buchaiah	UDC
Sri. V. Venunath	LDC
Sri. G. Udaya Bhaskar	LDC

Supporting Staff

Head Quarters

Sri. B. Jangaiah	Skilled Support Staff
Sri. B. Anjaiah	Skilled Support Staff
Sri. K. Chandraiah	Skilled Support Staff
Sri. K. Sobhan Babu	Skilled Support Staff
Smt. Roshni Devi	Skilled Support Staff
Sri. Md. Asif Ahmed	Skilled Support Staff

Sri. Ch. Balaiah	Skilled Support Staff
Smt. B. Buggamma	Skilled Support Staff
Sri. Prem Babadur Karki	Skilled Support Staff
Sri. Kesar Bahadur Karki	Skilled Support Staff
Sri. A. Mallesh Yadav	Skilled Support Staff
Sri. N. Manikya Rao	Skilled Support Staff
Sri. K. Shanker Reddy	Skilled Support Staff
Sri. G. Anjaiah	Skilled Support Staff

Hayatnagar Research Farm (HRF)

Sri. N. Ramappa	Skilled Support Staff
Sri. B. Sattaiah	Skilled Support Staff
Sri. B. Sankar	Skilled Support Staff
Sri. S. Satti Reddy	Skilled Support Staff
Smt. N. Indiramma	Skilled Support Staff
Sri. J. Jangamaiah	Skilled Support Staff
Smt. A. Lalitha	Skilled Support Staff
Smt. N. Laxmamma	Skilled Support Staff
Sri. J. Mallesh	Skilled Support Staff
Sri. K. Narayana	Skilled Support Staff
Sri. V. Pandurangaiah	Skilled Support Staff

Gunegal Research Farm (GRF)

Sri. P. Venkataiah	Skilled Support Staff
Smt. B. Anjamma	Skilled Support Staff
Sri. S. Balaiah	Skilled Support Staff
Sri. A. Kistaiah	Skilled Support Staff

18 Acronyms

AAS	Agro-Advisory Services
ACIAR	Australian Centre for International Agricultural Research
ACU	Adult Cattle Unit
AICRPAM	All India Coordinated Research Project on Agrometeorology
AICRPDA	All India Coordinated Research Project for Dryland Agriculture
BC	Benefit Cost
BD	Bulk Density
CAZRI	Central Arid Zone Research Institute
CBO	Community Based Organization
CGIAR	Consultative Group on International Agricultural Research
CSIR	Council of Scientific and Industrial Research
DAC	Department of Agriculture and Cooperation
DAS	Days After Sowing
DBT	Department of Biotechnology
DRR	Directorate of Rice Research
DSS	Decision Support System
DST	Department of Science and Technology
FACE	Free Air CO2 Enrichment
FATE	Free Air Temperature Enrichment
FLD	Front Line Demonstration
FP	Farmers Practice
FYM	Farm Yard Manure
GIS	Geographical Information System
GRF	Gunegal Research Farm
HC	Hydraulic Conductivity
HQ	Headquarters
HRD	Human Resource Development
HRF	Hayathnagar Research Farm
IAA	Indole Acetic Acid
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-arid Tropics
ICT	Information and Communication Technology
IIHR	Indian Institute of Horticultural Research
IISc	Indian Institute of Science
IISS	Indian Institute of Soil Science
IMD	India Meteorological Department
IPE	Institute of Public Enterprise
IPM	Integrated Pest Management
IPNI	International Plant Nutrition Institute
IWMI	International Water Management Institute
JNTU	Jawaharlal Nehru Technological University

KVK	Krishi Vigyan Kendra
LAI	Leaf Area Index
LER	Land Equivalent Ratio
LGP	Length of Growing Period
MBC	Microbial Biomass Carbon
MBN	Microbial Biomass Nitrogen
MoA	Ministry of Agriculture
MoEF	Ministry of Environment, Forests and climate change
MoWR	Ministry of Water Resources
MSSRF	M.S. Swaminathan Research Foundation
MtlD	Mannitol-1-Phosphate Dehydrogenase
MWD	Mean Weight Diameter
NAA	Naphthalene Acetic Acid
NAARM	National Academy of Agricultural Research Management
NABARD	National Bank for Agriculture and Rural Development
NASC	National Agricultural Science Complex
NBAIM	National Bureau of Agriculturally Important Microorganisms
NCMRWF	National Center for Medium Range Weather Forecasting
NDVI	Normalized Difference Vegetation Index
NGO	Non-governmental Organization
NICRA	National Initiative on Climate Resilient Agriculture
NIR	Near Infra Red
NIRD	National Institute for Rural Development
NRAA	National Rainfed Area Authority
NRM	Natural Resource Management
NWDPRA	National Watershed Development Program for Rainfed Areas
OFT	On-farm trials
ORP	Operational Research Project
OTC	Open Top Chambers
OU	Osmania University
PET	Potential Evapotranspiration
PRA	Participatory Rural Appraisal
PSB	Phosphorus Solubilizing Bacteria
QRT	Quinquennial Review Team
RAC	Research Advisory Committee
RDF	Recommended Dose of Fertilizer
RH	Relative Humidity
RSQI	Relative Soil Quality Index
RUE	Radiation Use Efficiency
SAU	State Agricultural University
SMW	Standard Meteorological Week
TAR	Technology Assessment and Refinement

Appendix 1

RFD

Results-Framework Document
For
Central Research Institute for Dryland Agriculture
(2013-14)

Section 1

Vision, Mission, Objectives and Functions

Vision

Stable and sustainable agriculture production in rainfed regions, ensuring enhanced income and livelihood security to farmers and land less.

Mission

Ensuring enhanced growth and sustainability of rainfed agriculture through the application of basic and strategic research outcomes combined with institutional and policy innovations.

Objectives

- Improving resource use efficiency in rainfed agriculture with focus on rainwater management
- Enhancing productivity and profitability in rainfed farming systems
- Climate resilient agriculture
- Capacity building and knowledge dissemination

Functions

- To undertake basic and applied research for sustainable rainfed farming systems
- To provide leadership and co-ordinate network research with state agricultural universities for generating location-specific technologies for rainfed areas including climate resilient agriculture
- To undertake capacity building of all stakeholders in rainfed agriculture
- To act as a repository of information on rainfed agriculture and provide policy backstopping

Section 2

Inter se Priorities among Key Objectives, Success Indicators and Targets

S. No	Objective	Wei-ght	Actions	Success Indicators	Unit	Wei-ght	Target / Criteria Value				
							Exce-llent	Very Good	Good	Fair	Poor
							100%	90%	80%	70%	60%
1.	Improving resource use efficiency in rainfed agriculture with focus on rainwater management	18	In situ conservation and ex situ harvesting and recycling of rainwater	Practices evaluated/ developed	No.	6	5	4	3	2	1
			Maintenance and improvement of soil quality	Technologies for improving soil health and enhancing nutrient use efficiency developed	No.	6	5	4	3	2	1
			Development of cost effective and energy efficient farm implements/ tools	Prototypes developed/ improved/evaluated	No.	6	3	2	1	-	-
2.	Enhancing productivity and profitability in rainfed farming systems	11	Development and evaluation of improved crops and cropping systems	Efficient crops and cropping systems identified/ developed	No.	6	3	2	1	-	-
			Identification of profitable rainfed farming/ alternate land use systems	Number of systems identified/developed/ evaluated	No.	5	3	2	1	-	-

S. No	Objective	Weight	Actions	Success Indicators	Unit	Weight	Target / Criteria Value				
3.	Climate resilient agriculture	40	Undertaking basic and strategic research in agriculture and allied sectors for tolerance to biotic and abiotic stresses	Crop varieties/breeds tested for climate resilience	No.	6	9	8	7	6	5
				Adaptation and mitigation strategies developed/ identified	Nos.	5	4	3	2	1	-
			Human resource development and technology demonstration	Programmes organized for developing trained manpower in research and technology dissemination	No. of programmes	6	28	25	20	15	10
				Training/ demonstrations conducted to create awareness amongst stakeholders	No. of programmes	7	100	90	80	70	60
			Agro - climatic analysis and development of weather indices	State level agroclimatic atlases prepared	No.	3	2	1	-	-	-
				Agromet advisories issued	No.	8	48	40	36	32	30
				Crop -weather-pest bulletin, forewarning models/ tools/ indices developed	No.	5	6	4	2	1	-

S. No	Objective	Weight	Actions	Success Indicators	Unit	Weight	Target / Criteria Value				
4.	Capacity building and knowledge dissemination	20	Organizing HRD programmes for different stakeholders	Training/seminar/ symposium/ workshop/summer and winter school organized	No.	12	5	4	3	2	1
			On-farm research	OFTs/FLDs conducted	No.	8	100	90	80	70	60
	Efficient functioning of the RFD System	3	Timely submission of Draft RFD (2013-14) for approval	On-time submission	Date	2	May 15, 2013	May 16, 2013	May 17, 2013	May 20, 2013	May 21, 2013
			Timely submission of Results for RFD (2012-13)	On-time submission	Date	1	May 1 2013	May 2 2013	May 5 2013	May 6, 2013	May 7, 2013
	Administrative Reforms	4	Implement ISO 9001 as per the approved action plan	% implementation	%	2	100	95	90	85	80
			Prepare an action plan for Innovation	On-time submission	Date	2	Jul 30, 2013	Aug. 10, 2013	Aug. 20, 2013	Aug, 30, 2013	Sept. 10, 2013
	Improving internal efficiency/ responsiveness/ services delivery of Ministry/ Department	4	Implementation of Sevottam	Independent Audit of Implementation of Citizen's Charter	%	2	100	95	90	85	80
				Independent Audit of implementation of public grievance redressal system	%	2	100	95	90	85	80

Section 3

Trend Values of the Success Indicators

S. No.	Objective	Action(s)	Success Indicator(s)	Unit	Actual value of FY 11/12	Actual value of FY 12/13	Target Value for FY 13/14	Projected value of FY 14/15	Projected Value for FY 15/16
1	Improving resource use efficiency in rainfed agriculture with focus on rainwater management	In situ conservation and ex situ harvesting and recycling of rainwater	Practices evaluated/ developed	No.	4	3	4	5	5
		Maintenance and improvement of soil quality	Technologies for improving soil health and enhancing nutrient use efficiency developed	No.	3	4	4	5	6
		Development of cost effective and energy efficient farm implements/ tools	Prototypes developed/ improved/ evaluated	No.	2	4	2	3	3
2	Enhancing productivity and profitability in rainfed farming systems	Development and evaluation of improved crops and cropping systems	Efficient crops and cropping systems identified/ developed	No.	-	3	2	3	4
		Identification of profitable rainfed farming/alternate land use systems	Number of systems identified/developed/ evaluated	No.	-	-	2	2	3
3	Climate resilient agriculture	Undertaking basic and strategic research in agriculture and allied sectors for tolerance to biotic and abiotic stresses	Crop varieties/ breeds tested for climate resilience	No.	7	10	8	9	10
			Adaptation and mitigation strategies developed/identified	No.	-	-	3	4	5
		Human resource development and technology demonstration	Programmes organized for developing trained manpower in research and technology dissemination	No.	-	-	25	28	30

			Training/ demonstrations conducted to create awareness amongst stakeholders	No.	100	150	90	95	100
		Agro - climatic analysis and development of weather indices	State level agroclimatic atlases prepared	No.	-	-	1	2	2
			Agromet advisories issued	No.	51	40	40	44	48
			Crop–weather-pest bulletins, forewarning models/tools/indices developed	No.	4	3	4	4	4
4	Capacity building and knowledge dissemination	Organizing HRD prorammes for different stakeholders	Training/seminar/ symposium/workshop/ summer and winter school organized	No.	5	-	4	5	6
		On-farm research	OFTs/FLDs conducted	No.	100	55	90	100	110
	Efficient functioning of the RFD System	Timely submission of Draft RFD (2013-14) for approval	On-time submission	Date	-	-	May 16, 2013	-	-
		Timely submission of Results for RFD (2012-13)	On-time submission	Date	-		May 2 2013	-	-
	Administrative Reforms	Implement ISO 9001 as per the approved action plan	% implementation	%	-	-	95	-	-
		Prepare an action plan for Innovation	On-time submission	Date	-	-	Aug. 10, 2013	-	-
	Improving internal efficiency/ responsiveness/ services delivery of Ministry/ Department	Implementation of Sevottam	Independent Audit of Implementation of Citizen's Charter	%	-	-	95	-	-
			Independent Audit of implementation of public grievance redressal system	%	-	-	95	-	-

Section 4
Description and Definition of Success Indicators and Proposed Measurement Methodology

Sl. No.	Success Indicator	Description	Definition	Measurement	General Comments
1.	Practices evaluated/ developed	Practices related to in situ and ex situ rainwater conservation will be evaluated at farm and farmers' fields for improving rainwater productivity	Methods of conserving/ harvesting and storing rainwater	Number	The success of rainfed agriculture lies in efficient methods of rainwater conservation and harvesting of excess runoff
2.	Technologies for improving soil health and enhancing nutrient use efficiency developed	Evaluation of tillage, crop residue management (soil cover) and nutrient management practices will lead to identification of best practices for yield, nutrient use efficiency, carbon sequestration and soil quality improvement	The main function of the soil is to supply all essential nutrients in available forms and in adequate quantities for plant growth	Number	Majority of the rainfed soils are not only thirsty but are also hungry. Efforts are made to modify/improve the soil properties for optimum plant growth
3.	Prototypes developed/ improved/ evaluated	Crop production and productivity in rainfed areas is constrained by narrow sowing window and lack of availability of suitable farm implements and tools. The profitability in rainfed areas is under decline due to increased costs of inputs and labour wages. Small farm mechanization is one of the options to overcome these constraints. The institute along with its network centres will design and develop of crop and soil specific farm implements, which will reduce drudgery and consumption of energy	Development of cost effective, energy efficient and labour saving farm implements	Number	Due to paucity of labour it is difficult to carry out agricultural operations in time because of narrow window which, necessitates development of farmers' friendly tools and implements
4.	Efficient crops and cropping systems identified/ developed	Location and crop specific agronomic practices for different crop and cropping systems in various agro-ecological regions in India will be evaluated and developed which will help in bridging the yield gap	Productive and profitable crops and cropping systems matching to the soil and climatic conditions	Number	Need to come up with profitable crops and cropping systems keeping in view the demand and supply situations at local/national/international levels

Sl. No.	Success Indicator	Description	Definition	Measurement	General Comments
5.	Number of systems identified/ developed/ evaluated	Integrated farming systems involving crops, trees and livestock will be identified across the country. These systems will be evaluated keeping in view the productivity, profitability and ecosystem services.	Harnessing synergy of different components like crops-trees-livestock, etc for risk minimization	Number	Systems approach for maximizing profits and adapting to changing climatic scenario
6.	Crop varieties/ breeds tested for climate resilience	State of art facilities like phenomics, FACE and FATE and other advanced techniques will be employed in identifying the germplasm tolerant to biotic and abiotic stresses. Similar efforts will be made in case of livestock and fisheries for identifying breeds/species tolerant to various stresses	Germplasm/ varieties/ livestock breeds / fisheries species that can tolerate biotic and abiotic stresses	Number of germplasm/ varieties/ livestock breeds / fisheries species	With increased frequency of occurrence of weather aberrations, there is need to develop climate resilient germplasm/ varieties/ livestock breeds / fisheries species
7.	Adaptation and mitigation strategies developed/ identified	Promising technologies relating to conservation of soil, water and energy will be tested on farm for coping with long term dry spells and to mitigate negative impacts of climate change	Technologies that can cope with extreme weather conditions	Number	Increased frequency of extreme climatic conditions calls for development of location specific strategies that can minimize risk/losses
8.	Programmes organized for developing trained manpower in research and technology dissemination	Seminar/symposium/workshop/summer and winter school will be organized for exchange and cross fertilization of recent advances in rainfed agriculture among various researchers, policy makers, farmers, extension agencies and civil society organizations, etc. This will enable reduction in time lag in transfer of technology from lab to land	Enhancing the knowledge of scientists and officials in understanding climatic variability and coping strategies	Number of training programmes	Human capital development in coping with changing climatic scenario
9.	Training/ demonstrations conducted to create awareness amongst stakeholders	Under NICRA project, it has been envisaged to educate the primary and secondary stakeholders by conducting numerous training programmes and frontline demonstrations across the country with the help of SAUs and KVKs	Exposure to advanced techniques in understanding and managing climatic risks	Number of programmes	Skill enhancement of primary and secondary stakeholders

Sl. No.	Success Indicator	Description	Definition	Measurement	General Comments
10.	State level agroclimatic atlases prepared	Collection of micro-level data (crop and weather) wherever available will be analyzed for preparation of tables and maps. This will be useful for understanding crop-weather relations as well as weather aberrations at micro level	State level schematic diagram/ plan based on long term crop and weather data	Number	Atlases prepared based on long-term will assist policy makers, researchers and line departments in taking appropriate decisions
11.	Agromet advisories issued	The meteorological information received from IMD and other sources will be fine-tuned to prepare location and crop specific agro-advisories keeping in view the rainfall, soil and crop status of the region	Agronomic activities and contingency measures to be employed based on weather forecast	Number	Issuing of weekly advisories will enable the primary and secondary stakeholders to take timely and appropriate measures
12.	Crop–weather-pest bulletin forewarning models/tools/ indices developed	The database developed on crops, pests and weather conditions would be analyzed to forecast the incidence of pest and diseases. Decision Support Systems (DSS) would be developed as a ready reckoner for taking up timely control measures	User's friendly scientific information for decision making	Number	Models developed by correlating long term weather with crop pest and diseases for different locations
13.	Training/seminar/ symposium/ workshop/ summer and winter school organized	Seminar/symposium/workshop/summer and winter school will be organized for exchange and cross fertilization of recent advances in rainfed agriculture among various researchers, policy makers, farmers, extension agencies and civil society organizations, etc. This will enable reduction in time lag in transfer of technology from lab to land	Knowledge sharing and dissemination	Number	Exchange of ideas and information among different stakeholders on recent advances in rainfed agriculture
14.	OFTs/FLDs conducted	Proven rainfed technologies relating to soil, water and nutrient, variety and energy management options will be showcased in farmers' fields for educating and up-scaling through line departments	Demonstration of promising technologies	Number	Transfer of locations specific technologies in a participatory mode and their up-scaling

Section 5
Specific Performance Requirements from other Departments

Location Type	State	Organization Type	Organization Name	Relevant Success Indicator	What is your requirement from this organization	Justification for this requirement	Please quantify your requirement from this organization	What happens if your requirement is not met
National/ international	NA	CG IAR Institutes	International	Crop varieties/ breeds tested for climate resilience	Germplasm	To have a broad range of germplasm for screening	20%	We may miss some adapted sources in the screening process
National	NA	Govt. of India	Ministry of Finance	• Programmes organized for developing trained manpower in research and technology dissemination • Training/ demonstrations conducted to create awareness amongst stakeholders	Timely release of adequate funds as per the approved budget	Timely availability of funds determine the success of the interventions	75%	There will be significant delay in implementation of the scheme

Note : Per cent increase over base year (2009-10)

Section 6
Outcome/Impact of Department/Ministry

Sl. No.	Outcome / Impact of Ministry / Department	Jointly responsible for influencing this outcome / impact with the following departments/ ministry(ies)	Success Indicator(s)	Unit	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
1.	Increased productivity and livelihoods in rainfed areas/ dryland regions	Ministry of Water Resources and Ministry of Rural Development, All State line departments	Increased productivity of dryland crops in the target domain/ operational area of the Institute	%	5	3	2	2	2
			Increased household income of dryland farmers in the target domain/ operational area of the Institute due to adoption of improved technologies	%	5	5	5	5	5

Performance Evaluation Report

Objective	Weight	Actions	Success Indicators	Unit	Weight	Target/ Criteria Value Performance			Target achieved	Performance		Percent achievements against target values of 90% col.	Reasons for shortfalls or excessive achievements, if applicable
						Excellent	Very Good	Good		Raw score	Weighted score		
						100%	90%	80%					
Climate resilient agriculture (NICRA)	40	Undertaking basic and strategic research in agriculture and allied sectors for tolerance to biotic and abiotic stresses	Testing crop varieties/ breeds for climate resilience for different locations	No.	6	9	8	7	9	100	6	112.5	-
			Number of adaptation and mitigation strategies developed/identified	Nos.	5	4	3	2	10	100	5	333.3	Additional studies were carried out in the states of Maharashtra and Bihar to identify mitigation strategies on the suggestion of Council
		Human resource development in climate resilient agriculture	Programmes organized for developing trained manpower in research and technology dissemination	No. of programmes	6	28	25	20	29	100	6	116	-

			Awareness building among stakeholders through trainings/ demonstrations	No. of programmes	7	100	90	80	118	100	7	131.1	-
		Agro-climatic analysis and development of weather indices	Preparation of state level agroclimatic atlases	No.	3	2	1	-	2	100	3	200	-
			Agromet advisories issued	No.	8	48	40	36	48	100	8	120	-
			Crop–weather-pest bulletin, forewarning models/tools/indices developed	No.	5	6	4	2	13	100	5	325	Additional studies were carried out on demand from clients
Capacity building and knowledge dissemination	20	Organizing HRD programmes for different stakeholders	Training/Seminar/ symposium/workshop/ summer and winter school organized	No.	12	5	4	3	15	100	12	375	Conducted training programmes due to high demand of sponsoring agencies
		On farm research	OFTs/FLDs conducted	No.	8	100	90	80	190	100	8	211.1	Due to high demand from farmers
Improving resource use efficiency in rainfed agriculture with focus on rainwater management	18	In situ conservation and ex situ harvesting and recycling of rainwater	Practices evaluated/ developed	No.	6	5	4	3	5	100	6	125	-
		Maintenance and improvement of soil quality	Technologies for improving soil health and enhancing nutrient use efficiency	No.	6	5	4	3	5	100	6	125	-

		Development of cost effective and energy efficient farm implements/ tools	Prototypes developed/ improved/evaluated	No.	6	3	2	1	3	100	6	150	-
Enhancing productivity and profitability in rainfed farming systems	11	Development and evaluation of improved crops and cropping systems	Efficient crops and cropping systems identified/ developed	No.	6	3	2	1	6	100	6	300	Promising results obtained from the ongoing and concluded projects during the year
		Identification of profitable rainfed farming/ alternate land use systems	Number of systems identified/developed/ evaluated	No.	5	3	2	1	3	100	5	150	-
Efficient functioning of the RFD System	3	Timely submission of Draft RFD (2013-14) for approval	On-time submission	Date	2	May 15, 2013	May 16, 2013	May 17, 2013	April 26, 2014	0	0	0	-
		Timely submission of Results for RFD (2012-13)	On-time submission	Date	1	May 1, 2013	May 2, 2013	May 5, 2013	April 16, 2014	100	1	100	-

Administrative Reforms	4	Implement ISO 9001 as per the approved action plan	% implementation	%	2	100	95	90	0	0	0	0	-
		Prepare an action plan for Innovation	On time submission	Date	2	Jul 30, 2013	Aug. 10, 2013	Aug. 20, 2013	June 26, 2013	100	2	100	-
Improving internal efficiency/ responsiveness/ services delivery of Ministry/ Department	4	Implementation of Sevottam	Independent Audit of Implementation of Citizen's Charter	%	2	100	95	90	100	100	2	105	-
			Independent Audit of implementation of public grievance redressal system	%	2	100	95	90	100	100	2	105	-

Total Composite score : 96%

Rating: Excellent

Our contact address

Dr. Ch. Srinivasa Rao, Director
Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad – 500 059 Tel (O) +91-40-24530177 (R) 24532262
Fax: +91-40-24531802, 24535336 E-mail: director@crida.in

केंद्रीय बारानी कृषि अनुसंधान संस्थान, संतोषनगर, हैदराबाद - ५०० ०५९

Central Research Institute for Dryland Agriculture

Santoshnagar, Hyderabad - 500 059