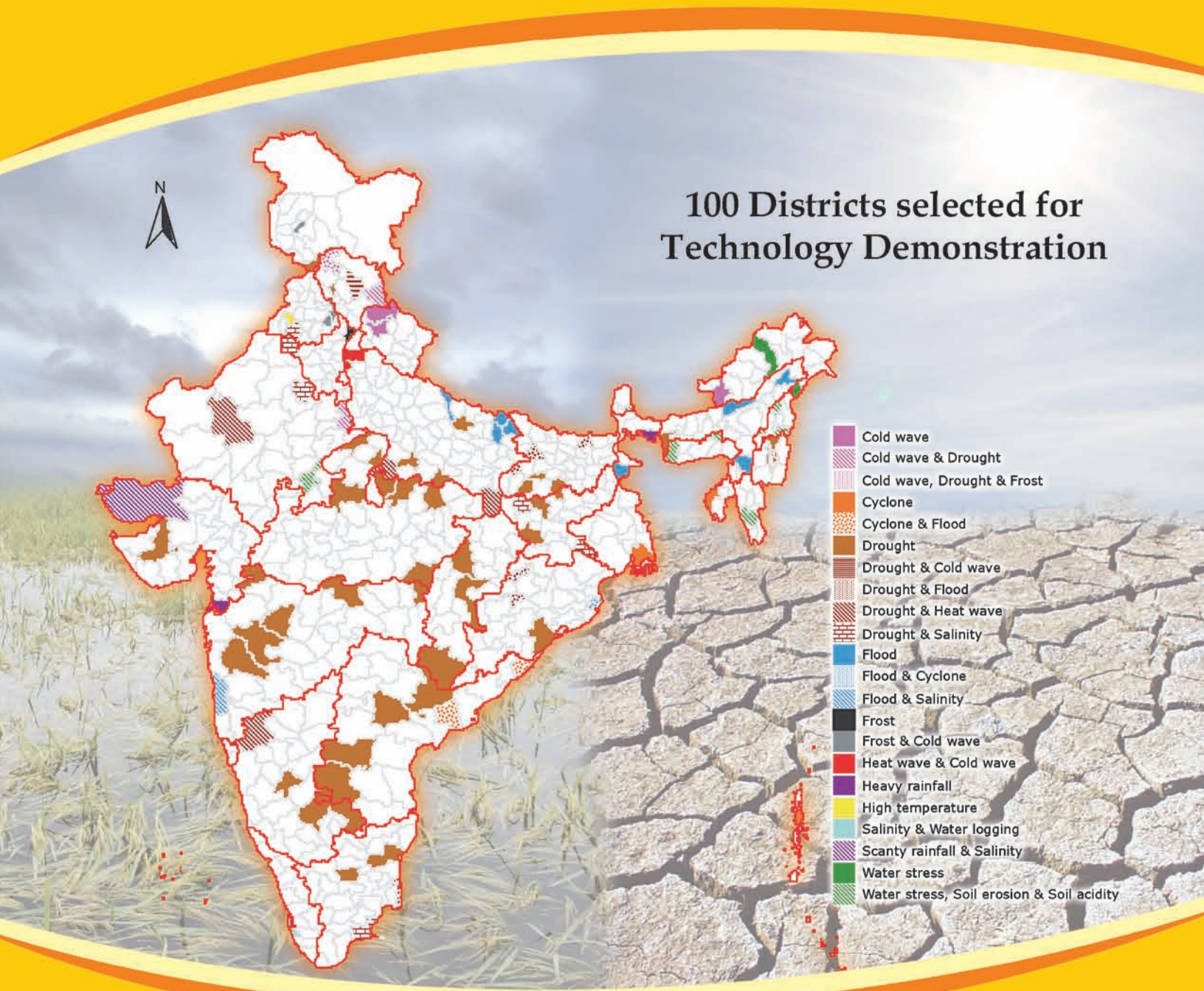
CRIDA

वार्षिक प्रतिवेदन
Annual Report 2010-11



हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद
Agrisearch with a human touch

भाकृअनुप
ICAR

Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad 500 059

CENTRAL RESEARCH INSTITUTE FOR DRYLAND AGRICULTURE
केवाकृअनुसं-CRIDA
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Front Cover
Map depicting the 100 districts selected for demonstrating climate resilient agricultural technology under the National Initiative on Climate Resilient Agriculture (NICRA)

Back Cover
Launch Workshop of NICRA organized during February, 2011 at New Delhi

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वार्षिक प्रतिवेदन

Annual Report

2010-11

केंद्रीय बारानी कृषि अनुसंधान संस्थान

संतोषनगर, हैदराबाद - 500 0059

Central Research Institute for Dryland Agriculture

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Preface

Rainfed agriculture, practiced in 60% of the cultivated area in India, is critically dependent on climate. Climate variability, including extreme weather events, resulting from global climate change, poses serious threat to rainfed agriculture. Alert to this impending threat, CRIDA initiated network research on climate change effects on agriculture during the X five year plan. In recognition of its leadership in the area of rainfed agriculture and climate change, CRIDA has been bestowed with the responsibility of leading a mega project, the National Initiative on Climate Resilient Agriculture (NICRA) by ICAR. This project aims to develop and demonstrate technologies that enhance the resilience of rainfed agriculture to climate variability. While we take pride in being chosen for this important assignment, we are aware of the tremendous responsibility it entails, and are bracing ourselves to live up to the Nation's expectations. We have been placing increasing emphasis on climate change and climate variability research over the past few years and our annual reports reflect this emphasis. With the launch of NICRA, we are set for a major shift in our research focus and much of our future work will be oriented towards addressing the challenges of climate change and climate variability. In this annual report, we have added a separate chapter on NICRA to do justice to the magnitude of the initiative and the large number of activities envisaged. While being justifiably concerned about the future of rainfed agriculture in the country, we are firmly rooted in the present, and endeavour to provide technological solutions to the current problems of rainfed farming. This annual report documents the activities and achievements of CRIDA, AICRPDA and AICRPAM for the year 2010-11.

Significant progress was made during 2010-11 in all the programme areas of resource characterization, climate change, rainwater management, crops and cropping systems, soil health and nutrient management, land use diversification, livestock management, energy management, socioeconomic studies and transfer of technology. The probability of occurrence of moderate and severe droughts in the country was determined with updated weather data. Analysis of extreme weather events showed that trends were not uniform across the country. The effects of elevated CO_2 on plant growth, yield formation, and enzyme activities, and on the fertility of

soils on which the plants are grown, were elucidated. Response of microbial strains to elevated CO_2 was studied. Enhancement of water productivity through rainwater harvesting in farm ponds and supplemental irrigation of crops with harvested water was demonstrated. The benefit of paired row planting of crops with ridger equipment was further confirmed. Work on low weight pump for lifting harvested water and solar powered lifting of water and distribution by gravity operated emitters is giving encouraging results.

CRIDA's new horse gram varieties, CRIDA 18R and CRHG 4 performed well in field trials across South India. Our work on transgenic sorghum for drought tolerance has progressed further and we conducted open field trials for the first time with encouraging results. Organic production was extended to fruit crops in addition to field crops. Developmental thresholds and thermal constants were determined for all the life stages of cotton mealybug. A decision support system for fungicide spray advisory based on leaf wetness index was developed and validated. Two bacterial consortia, formulated and tested for drought and heat stress alleviation, showed promise. The benefits of minimum tillage manifested for the first time after several years of adopting the practice. A precision planter cum herbicide applicator for mechanizing sweet sorghum production was developed and tested in the farmers' fields with success. Seed treatment with bacterial strains for mobilizing soil zinc showed positive results. Application of crop residue biochar resulted in increased soil moisture and improved plant growth and yield of pigeonpea. Work on biofuels and livestock nutrition and health is on course.

Efforts towards sustainable rural livelihoods through enhanced farming systems productivity and efficient support systems showed that use of harvested rainwater and balanced nutrition helped in significant yield increases in cotton, groundnut and vegetables. Community based green house gas emission reduction activities were promoted with implementation of carbon sequestration activities in various land use systems in a participatory mode in a village cluster. A study of ICT services revealed that farmers were most interested in market based information followed by weather alerts and information on outbreak of pests and their management. The work of the Institute during the year has been of a very high order, as testified by the numerous publications brought out and the institutional and individual awards received.

I am pleased to present the Annual Report of CRIDA for the year 2010-11. I am grateful to ICAR, all our collaborating institutions and stakeholders for supporting us and strengthening us in the pursuit of our goals. I commend the editorial team members K. Srinivas, M. Prabhakar, U. K. Mandal and K. A. Gopinath for their efforts in bringing out a well put together annual report that showcases our activities and achievements over the past year.

B. Venkateswarlu

Hyderabad,
June, 2011

(B. Venkateswarlu)

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कार्यकारी सारांश

संसाधन लक्षण

- आंध्र प्रदेश में मंडल स्तर पर `मौसमवैज्ञानिक सूखों' (Meteorological droughts) ने स्पष्ट किया कि विभिन्न जिलों के करीब सभी मंडलों में मध्यस्तरीय सूखा पड़ने की संभावना 10-25 प्रतिशत थी। राज्य के अधिकतर मंड़लों में भीषण सूखे की संभावना मात्र 0-2 प्रतिशत थी।
- कृषि क्षेत्र के दशक झुकाव विश्लेषण से स्पष्ट हुआ कि पिछले दशकों की तुलना में वर्तमान दशक के दौरान, विशेषकर तेलंगाना क्षेत्र के जिलों में चावल की कृषि के अंतर्गत क्षेत्रफल में वृद्धि हुई है। यह भी ज्ञात हुआ कि कड़पा, नलगोंड़ा, गुंटूर, कृष्णा एवं विजयनगरम जिलों में चावल के उत्पादन में कमी आई है और चित्तूर, रंगारेड्डी, करीमनगर एवं खम्मम जिलों में पिछले दो दशकों के दौरान उत्पादन में कोई परिवर्तन नहीं हुआ।
- आंध्र प्रदेश में मूगफली मुख्य रूप से रायलसीमा(80 प्रतिशत) क्षेत्र में उगाई जाती है। इसका 48 प्रतिशत क्षेत्र अनंतपुर जिले में आता है। 1971-80 के दौरान अनंतपुर जिले में मूंगफली के क्षेत्रफल का विस्तार 2,82,000 हेक्टेयर था जो बढ़कर वर्तमान दशक के दौरान 7,95,000 हेक्टेयर हो गया। शेष जिलों में, वर्तमान दशक के दौरान इसमें कमी आई है। जब उत्पादन आंकड़ों को जांचा गया तो यह अनुभव किया गया कि अनंतपुर एवं कड़पा जिलों के उत्पादन में कमी आई जबकि शेष जिलों में, विशेषकर तटवर्ती क्षेत्रों में वृद्धि हुई।
- अनंतपुर में मूंगफली की फसल में पर्ण सुरंगी नामक कीट पतंग के पूर्वानुमान के लिए वर्षा एवं तापमान डेटा का उपयोग कर एक समीकरण का विकास किया गया और मॉडल को अवलोकित मौसम डेटा एवं नाशीजीव प्रकोप से मान्यकृत किया गया। यह देखा गया कि मॉडल नाशीजीव प्रकोप का पूर्वानुमान तो सही रूप में कर रहा है लेकिन पूर्वानुमान की मात्रा में भिन्नता है। जब एन.सी.एम.आर.डब्ल्यू.एफ. (NCMRWF) मौसम पूर्वानुमान डेटा को समीकरण में समाविष्ट किया गया तब परिणामों ने दर्शाया कि मौसम पूर्वानुमान तो सही था लेकिन नाशीजीव प्रकोप के `स्तर' का पूर्वानुमान सही नही लग सका।
- परभनी केंद्र के लिए कपास के विभिन्न घटनाक्रमों से मौसम प्राचलों के संबंध की पहचान की गई, एवं परिणामों ने दर्शाया कि गलर निर्माण (boll formation)तथा गलर विस्फोटन (boll bursting)के दौरान वर्षा एवं धूप की अवधि का उत्पादन से काफी निकट संबंध है। बहुकिस्म समाश्रयण विश्लेषण ने गलर निर्माण तथा गलर विस्फोटन के दौरान आवश्यक अधिकतम वर्षा का अनुमान 249 मि.मी. के रूप में लगाया अर्थात् कपास की फसल को इन दो घटनाक्रमों के बीच लगभग 249 मि.मी. वर्षा की आवश्यकता होती है।
- हैदराबाद के अर्ध-शुष्क जलवायु के अंतर्गत सुबह की सापेक्ष आर्द्रता के साथ-साथ दैनिक औसत न्यनतम वायु तापमान के मूल्यों से सापेक्ष आर्द्रता के दैनिक पैट्रन के निर्माण के लिए सिनुसोडियल एवं एक्सपोनेनशियल मॉडलों का उपयोग किया गया।

जलवायु परिवर्तन

- चरम तापमान की घटनाओं के विश्लेषण से ज्ञात हुआ कि अकोला, आनंद, लुधियाना एवं सोलापुर में ठंड़ी रातों का प्रतिशत महत्वपूर्ण रूप से कम हो रहा हैं जबकि कानपुर में ठंड़ी रातें बढ़ रही हैं। अनंतपुर, सोलापुर, आनंद, भुवनेश्वर, जबलपुर एवं कानपुर में ठंड़े दिनों की प्रतिशत में महत्वपूर्ण कमी देखी गई। जोरहाट में वर्ष का कुल अवक्षेपण (precipitation) महत्वपूर्ण रूप से कम था जबकि परभनी एवं रायपुर में यह महत्वपूर्ण रूप से अधिक था।
- उत्थित कार्बन डाइआक्साइड (700 पी.पी.एम.) की स्थिति में अनाच्छदित प्रकोष्ठों में चार वर्षों के लिए उगाई गई विभिन्न फसलों वाली मृदा में जैविक कार्बन स्तर में 0.36 प्रतिशत से 0.55 प्रतिशत तक वृद्धि हुई। अनाच्छादित प्रकोष्ठों के बाहर असिंचित उथली भूमियों की तुलना में यह वृद्धि 52 प्रतिशत अधिक दर्ज की गई। सिंचित एवं नियंत्रित (43.4 मि.ग्रा प्रति कि.ग्रा) भूमियों की तुलना में असिंचित उथली भूमि में न्यूनतम सूक्ष्मजीवीय बायोमॉस कार्बन (39.1 मि.ग्रा प्रति कि.ग्रा) रिकार्ड किया गया।
- जलवायु परिवर्तन के परिप्रेक्ष में वर्षा आधारित मक्का की वर्तमान उत्पादकता स्तर की तुलना करने के लिए फसल सिमुलेशन मॉडल (डी.एस.एस.ए.टी) का उपयोग किया गया।

विभिन्न स्थानों में मक्का का औसत विभव उत्पादन 2530 कि.ग्रा. प्रति हेक्टेयर था। हैदराबाद, अनंतपुर एवं अरजिया में उत्पादन विभव औसत से अधिक दर्ज किया गया। जबकि, महाराष्ट्र के विभिन्न स्थानों में मक्का उत्पादन का विभव औसत स्तर **(Average potential yield)** भी कम हुआ।

- शीर्ष वानस्पतिक स्तर पर सूरजमुखी में अनुमानित `नाइट्रेट रेडकटेस' एवं `ग्लुटामिन सिंथटेस' ने परिवेश परिस्थितियों की तुलना में 700 पी.पी.एम. कार्बन डाइआक्साइड पर कमी का रूझान दर्शाया। उत्थित कार्बन डाइआक्साइड एवं नाइट्रोजन की आपूर्ति से पर्ण प्रकाश संश्लेषण एवं बायोमॉस में भी वृद्धि हुई।
- उडद जीनरूपों ने परिवेश नियंत्रण कार्बन डाइआक्साइड की तुलना में औसतन 550 पी.पी.एम. एवं 700 पी.पी.एम. कार्बन डाइआक्साइड स्तरों पर उत्पादन वृद्धि क्रमशः 21.37 प्रतिशत एवं 36.64 प्रतिशत दर्शाई। जबकि, कुछ चयनित जीनरूपों में इस प्रकार का रूझान नहीं देखा गया।
- ठंड़ के मौसम के दौरान सूरजमुखी फसल में परिवेश नियंत्रण कार्बन डाइआक्साइड की तुलना में बॉयोमास एवं अनाज में 700 पी.पी.एम. पर क्रमशः 45.19 प्रतिशत एवं 46.09 प्रतिशत तथा 550 पी.पी.एम. पर क्रमशः 18.68 प्रतिशत एवं 20.86 प्रतिशत वृद्धि अनुभव की गई। गर्मी के मौसम में इन प्राचलों की प्रतिक्रिया परिवेश नियंत्रण की तुलना में 700 पी.पी.एम. एवं 550 पी.पी.एम. कार्बन डाइआक्साइड की सांद्रताओं पर क्रमशः बायोमॉस के लिए -3.30 प्रतिशत एवं -1.76 प्रतिशत और बीज उत्पादन के लिए -3.16 प्रतिशत एवं -8.74 प्रतिशत रही। उत्थित कार्बन डाइआक्साइड स्तरों पर पुष्पण एवं बीज भराव के दौरान अधिक तापमान के कारण बीजों की कुल संख्या में कमी एवं बीज रहित फूलों की संख्या में वृद्धि देखी गई।
- स्पोडेप्टेरा लिटुरा के `पुपल पूर्व' एवं `वयस्क' स्तरों के लिए 40 मि.मी. प्रति दिन वर्षा हानिकारक पाई गई जिससे इसकी जनन क्षमता एवं जनसंख्या वृद्धि विभव पर प्रतिकूल प्रभाव पड़ा।
- अस्सी पीढ़ियों के बाद उत्थित एवं परिवेश कार्बन डाइआक्साइड दोनों परिस्थितियों पर सिडेरोफोर एवं अमोनिया उत्पादन के लिए जांचे गए सभी स्युडोमोनॉस विगलक सकारात्मक पाए गए। जबकि उत्थित कार्बन डाइआक्साइड पर सभी स्युडोमोनॉस विगलकों द्वारा उत्पन्न सिडेरोफोर, लाइपेज **(Lipase)** एवं आई.ए.ए. में क्रमशः कमी आई।
- चार पादपरोगजननों के विरूद्ध ट्राइकोडेरमा की बायोएफिकसी पर उत्थित कार्बन डाइआक्साइड के प्रभाव का अध्ययन किया गया एवं पाया गया कि परिवेश परिस्थितियों की तुलना में उत्थित कार्बन डाइआक्साइड के अंतर्गत सभी रोजनकों की रेडियल वृद्धि में निरोध प्रतिशत महत्वपूर्ण रूप से अधिक था।

वर्षाजल प्रबंधन

- एस.सी.एस. वक्र संख्या पद्धत्ति **(SCS curve number method)** एवं कृषि तालाब में जल शेष **(Water balance)** को जोड़ते हुए सूक्ष्मजलग्रहण में विभिन्न भूमि उपयोगों के लिए वक्रों **(curve numbers)** की संख्या को स्थिर करने के लिए सतही जल उत्पादन मॉडल का विकास किया गया। रिसाव द्वारा तालाब के जल में हानि **(Seepage loss)**, की मात्रा को तालाब के जलस्तर, वर्षा की मात्रा एवं वाष्पीकरण डेटा की मॉनिटरी द्वारा किया गया। यह देखा गया कि प्रथम दो वर्षों के दौरान 40-80 मि.मी. प्रति दिन रिसाव की तुलना में तीसरे वर्ष के दौरान यह घटाकर 20 मि.मी. प्रति दिन रह गया। 14.5 हेक्टेयर के जलग्रहण क्षेत्र में चार अपवाह उत्पन्न करने वाली घटनाओं से तालाब में कुल 1992 घन मीटर अपवाह एकत्र किया गया। 0.9 एकड़ मूंगफली एवं 0.74 एकड़ मक्का की बोवाई पूर्व सिंचाई करने के लिए कुल 219 घन मीटर जल का उपयोग किया गया। कुल अपवाह के 14 प्रतिशत को वाष्पन हानि के रूप में लिया गया। बिना तालाब गाद **(Tank silt)** के प्रयोग के 20.31 कि.ग्रा. प्रति हेक्टेयर प्रति मिलिमीटर की तुलना में तालाब गाद के प्रयोग से मूंगफली में 23.77 कि.ग्रा. प्रति हेक्टेयर प्रति मिलिमीटर की अधिकतम वर्षा जल उत्पादकता **(Rain water productivity)** प्राप्त हुई। भिंड़ी में, तालाब गाद के प्रयोग से 29.15 कि.ग्रा. प्रति हेक्टेयर प्रति मिलिमीटर एवं बिना तालाब गाद के प्रयोग से 24.14 कि.ग्रा. प्रति हेक्टेयर प्रति मिलिमीटर की जल उत्पादकता प्राप्त की गई।
- रिडजर से द्वि पंक्ति रोपण (जोड़ियों में 60 सें.मी., जोड़ियों के बीच 120 सें.मी.) से जल अपवाह हानि को कम किया गया। यह अपवाह साधारण बोवाई की तुलना में (8-10 प्रतिशत) द्वि पंक्ति रोपण प्रणाली में 1-15 प्रतिशत के बीच था। अरहर का उत्पादन साधारण बोवाई एवं द्वि पंक्ति रोपण से क्रमशः 1700-1900 कि.ग्रा. प्रति हेक्टेयर एवं 2200-2250 कि.ग्रा. प्रति हेक्टेयर के बीच दर्ज किया गया।
- सौर ऊर्जा से चालित जलोद्वाही प्रणाली एवं गुरूत्वाकर्षण से चालित जल उत्सर्जक उपकरणों का उपयोग कर जल वितरण द्वारा जल प्रबंधन प्रणाली का विकास किया गया। उत्सर्जकों का औसत विसर्जन 2.92 लीटर प्रति घंटा था। उत्सर्जकों का विसर्जन 90.63 प्रतिशत तक के संपूर्ण समान वितरण सहित 26 मीटर से भी लंबे पार्श्वों के अनुकूल पाया गया।
- वर्तमान पंप सेट (1.5 एच पी) की सुवाह्यता में सुधार करने के लिए कम उंचाई वाले नाइलॉन पंप का विकास किया गया एवं विसर्जन क्षमता एवं दबाव में बिना किसी कमी के 34 कि.ग्रा. वाले वर्तमान पंपसेट का वज़न घटाकर 23 कि.ग्रा. कर दिया गया।

फसल एवं फसल प्रणालियां

- संस्थान की नई कुलथी किस्मों `क्रीडा'-18 आर. एवं सी.आर.एच.जी.-4 में आंध्र प्रदेश, तमिलनाडु एवं केरल में स्थानीय किस्मों की तुलना में (33 प्रतिशत अधिक बेहतर अनाज उत्पादन एवं शीर्घ परिपक्वता में 10-25 दिनों की कमी) उपज बेहतर पाई गई।
- नियंत्रित परिस्थितियों के अंतर्गत दबाव सहीष्णुता के लिए **mtlD** ट्रांसजेनिक ज्वार की छः वंशावलियों की जांच की गई। यह वंशावलियां मुख्य कार्यिकीय प्राचलों के आधार पर अपरिवर्तित पौधों से बेहतर पाई गई।
- *ज्वार बाइकोलर* में डेहाइड्रिन जीन का आतपन, क्लोनिंग, लक्षणचित्रण एवं निष्पीड़न विश्लेषण किया गया एवं दोनों जेनोमिक तथा **cDNA** अनुक्रमों को अलग कर क्रमशः आगमन संख्या जी.यू.137312.1 एवं एच.एम.243499 नाम से एन.सी.बी.आई. जीन बैंक में जमा कर दिया गया।
- निरंतर जल कमी के दबाव से प्रभावित श्रेष्ठ जीनों की पहचान के लिए सूखा सहीष्णु बाजरा (नर जनक) आई.सी.एम.आर. 356 के पत्तों से सप्रेशन सबस्ट्राक्टिव हाइब्रिडाइजेशन का उपयोग कर **cDNA** संग्रह का निर्माण किया गया।
- **CaMV35S** वर्धक के नियंत्रणाधीन *annexin Bj1* युक्त **pCAMBIA 2301** बाइनरी वेक्टर सहित *Agrobacterium tumefaciens* के **LBA 4404** विगलक का उपयोग कर दबाव सहिष्णु, बेहतर पुनर्जनन एवं दोहरे कोटिलेडोनरी नोड कर्तोतकों के रूपांतरण के लिए मूंग के जननिक रूपांतरण पर किए जा रहे प्रयासों को बढ़ाया गया।
- मूंग की किस्मों (डब्ल्यु.जी.जी.37 एवं एम.एल.267) में जड़ वृद्धि पर किए जा रहे अध्ययनों से यह ज्ञात हुआ कि पुष्पण स्तर पर दोनों किस्मों की कुल जड़ की लंबाई में महत्वपूर्ण कमी थी लेकिन एम.एल.267 की तुलना में डब्ल्यु.जी.जी.37 में कमी का दर अधिक था।
- जैविक फसल उत्पादन पर किए जा रहे अध्ययन ने स्पष्ट किया कि जैविक प्रबंधन से प्रथम वर्ष के दौरान तिल की उपज में 19 प्रतिशत, सूरजमुखी में 13 प्रतिशत एवं अरहर में 25 प्रतिशत कमी आई।
- जैविक प्रबंधन के अंतर्गत सीताफ्ल एवं अमरूद दोनों ने उत्पादन एवं फल की गुणवत्ता (सीताफल में कम बीज भार एवं बेहतर गुदा; अमरूद में बेहतर कुल घुलनशली चीनी एवं कम आम्लता) में बेहतर प्रदर्शन किया।
- पौधों में नाशीजीवों के आक्रमण से आए आकृतिक एवं रासायनिक परिवर्तनों को स्पेक्ट्रोमीटर द्वारा आंका गया। इस आधार पर, छोटे बैंड हाइपरस्पेक्ट्रल सूचकों का विकास किया गया जिनमें कपास पातफुदक आपतन एवं मूंगफली में देर से आने वाले पर्णचित्ती रोग की तीर्वता को पहचानने की क्षमता है।
- वितान उंचाई पर बेतार सेनसर मोट द्वारा मापे गए पर्ण आर्द्रता सूचक पर आधारित फंगसनाशी छिड़काव की सलाह के लिए निर्णय सहायक प्रणाली **(Decision support system)** का मान्यकरण किया गया। बोवाई के 77 और 94 दिनों के बाद निर्णय सहायक प्रणाली द्वारा दी गई फंगसनाशी छिड़काव की सलाह सही पाई गई।
- सूखा एवं गर्म दबाव प्रबंधन के लिए प्रयोगशाला एवं क्षेत्रीय परिस्थितियों में दो जीवाणु संघों (ज्वार के लिए **P7+B30+G12** एवं सूरजमुखी के लिए **P45+B17+G12)** का निर्माण कर जांचा गया। वर्षा आधारित परिस्थितियों के अंतर्गत ज्वार एवं सूरजमुखी की बेहतर पादप वृद्धि एवं उत्पादन के लिए संघ टीकाकरण द्वारा नाइट्रोजन, फासफोरस एवं पोटाश के उपयोग की सिफारिश की गई।

मृदा एवं पोषण प्रबंधन

- 12 वर्षों के प्रयोगों के बाद, औसतन, ज्वार एवं मूंग बीन के उत्पादनों में पारंपरिक कर्षण की तुलना में कम कर्षण में क्रमशः 10.7 एवं 1.6 प्रतिशत बेहतर वृद्धि हुई। आगे, पारंपरिक कर्षण की तुलना में कम कर्षण के परिणामस्वरूप मृदा में कुल हाइड्रालिजिबल नाइट्रोजन (6.98 प्रतिशत), हाइड्रालिजिबल NH_4-N (6.01 प्रतिशत), हेक्सोसामिने नाइट्रोजन (12.9 प्रतिशत), उपलब्ध नाइट्रोजन (9.61 प्रतिशत) एवं कुल नाइट्रोजन (4.07 प्रतिशत) की मात्रा में दृष्टिगोचर वृद्धि हुई। नियंत्रण की तुलना में संयुक्त पोषक उपयोग उपचारों से नाइट्रोजन के सभी भिन्नों में महत्वपूर्ण रूप से बेहतर सुधार हुआ।
- 4 टन प्रति हेक्टेयर$^{-1}$ की दर से ज्वार की कड़बी के प्रयोग से महत्वपूर्ण रूप से बेहतर लोबिया उत्पादन (870 कि.ग्रा. प्रति हेक्टेयर$^{-1}$) दर्ज किया गया। अवशेष प्रयोग ने विनिमययोग्य NH_4-N, कुल हाइड्रालिजिबल नाइट्रोजन, हाइड्रालिजिबल NH_4-N, हेक्सोसामिने नाइट्रोजन, एमिनोएसिड नाइट्रोजन, उपलब्ध नाइट्रोजन एवं कुल नाइट्रोजन अंशों को महत्वपूर्ण रूप से प्रभावित किया जबकि स्थिर एमैनिकल नाइट्रोजन एवं अनऐडेनटिफाइड नाइट्रोजन अंशों पर कोई प्रभाव नहीं पड़ा।
- पारंपरिक कर्षण (1211 कि.ग्रा. प्रति हेक्टेयर$^{-1}$) की तुलना में न्यनतम कर्षण (केवल हल रोपण) से समान या उससे थोड़ी बेहतर औसत अरंड़ बीन का उत्पादन (1261 कि.ग्रा. प्रति हेक्टेयर$^{-1}$) रिकार्ड किया गया । अवशेषों में, ज्वार की कड़बी के प्रयोग के परिणामस्वरूप बिना अवशेष प्रयोग (1111 कि.ग्रा. प्रति हेक्टेयर$^{-1}$) की तुलना में बेहतर औसत अरंड़ बीन उत्पादन (1325 कि.ग्रा. प्रति हेक्टेयर$^{-1}$) प्राप्त

किया गया जबकि ग्लीरिसिडिया कर्तनों के उपयोग से अरंड़ बीन उत्पादन 1273 कि.ग्रा. प्रति हेक्टेयर$^{-1}$ रहा।

- सोलापुर केंद्र (अर्ध शुष्क वर्टीसोल्स) पर वर्षा आधारित रबी ज्वार प्रणाली के अंतर्गत लंबी अवधि के कर्षण एवं पोषक प्रबंधन पर किए गए प्रयोगों में मृदा गुणवत्ता का मूल्यांकन किया गया। मृदा गुणवत्ता सूचक का क्रम मध्यम कर्षण>कम कर्षण>पारंपरिक कर्षण था। पोषक प्रबंधन उपचारों में, जैविक माध्यम से 50 कि.ग्रा. नाइट्रोजन+no P_2O_5 ने अधिकतम मृदा गुणवत्ता बनाई रखी, उसके बाद 25 कि.ग्रा. नाइट्रोजन (जैविक) + 25 कि.ग्रा. नाइट्रोजन (यूरिआ) + 12.5 कि.ग्रा. प्रति हेक्टेयर$^{-1}$ P_2O_5 एवं 50 कि.ग्रा. नाइट्रोजन(यूरिआ) + 25 कि.ग्रा. प्रति हेक्टेयर$^{-1}$ P_2O_5 का स्थान आता है।
- हैदराबाद में, नियंत्रण की तुलना में विभिन्न उपचारों जैसे कि 25 कि.ग्रा. प्रति हेक्टेयर की दर से जिंक सल्फेट का मृदा प्रयोग, स्युडोमोनास विगलक संख्या पी29, पी33 एवं बेसिलियस विगलक संख्या बी116 से 250 ग्राम बीजों के लिए 10 ग्राम की दर से बीजों का टीकाकरण इत्यादि के परिणामस्वरूप मक्का के अनाज उत्पादन में महत्वपूर्ण वृद्धि हुई। अरजिया में, जिंक सल्फेट का मृदा में प्रयोग करने से मक्का का अधिकतम (4433 कि.ग्रा. प्रति हेक्टेयर) उत्पादन हुआ। पी29 एवं पी33 के उपचार क्रमशः दूसरे एवं तीसरे स्थान पर रहे।
- फूलबनी(ओक्सीसोल्स-चावल आधारित प्रणाली) में विभिन्न कर्षण पद्धतियों के अंतर्गत कार्बन पृथक्करण क्षमता पर किए जा रहे अध्ययनों ने स्पष्ट किया कि कम कर्षण एवं 100 प्रतिशत जैविक उपचार में पार्टीकुलेट (Particulate) जैविक कार्बन एवं सूक्ष्मजीवीय बायोमॉस कार्बन अधिकतम थे।
- नियंत्रण (बिना बायोचर+सिफारिश की गई उर्वरकों की मात्रा) की तुलना में सिफारिश की गई उर्वरकों की मात्रा (नाइट्रोजन फासफोरस पोटाशियम 20:50:0 कि.ग्रा. प्रति हेक्टेयर) सहित 3 एवं 6.0 टन प्रति हेक्टेयर की दर से कपास वृंत बायोचर (Cotton stalk biochar) के प्रयोग से अरहर उत्पादन में क्रमशः 26.9 एवं 39.8 प्रतिशत की वृद्धि हुई। नियंत्रण की तुलना में सिफारिश की गई उर्वरकों की मात्रा सहित 3 एवं 6.0 टन प्रति हेक्टेयर की दर से अरहर वृंत बायोचर (Pigeonpea stalk biochar)के प्रयोग से अनाज उत्पादन में क्रमशः 21.6 एवं 32.1 प्रतिशत की वृद्धि हुई।
- बंगलौर (एल्फीसोल मृदा प्रकार, जलवायु अर्ध-शुष्क (नम) प्रकार) में मूंगफली और रागी के लिए क्रमशः सिफारिश किए गए रासायनिक उर्वरकों (25:21.8:20.7 एवं 50:21.8:20.7 कि.ग्रा. नाइट्रोजन, फासफोरस, पोटाशियम प्रति हेक्टेयर$^{-1}$) के साथ-साथ नम भार आधार पर 10 टन प्रति हेक्टेयर$^{-1}$ आहात खाद (FYM) के प्रयोग से बेहतर प्रोफाइल मृदा कार्बन (73.0 टन प्रति हेक्टेयर), कार्बन निर्माण (41.2 प्रतिशत) एवं कार्बन पृथक्करण (9.3 टन कार्बन प्रति हेक्टेयर$^{-1}$) देखे गए। मृदा जैविक कार्बन स्तर को बनाए रखने के लिए (सस्यन के कारण शून्य परिवर्तन) निवेश के रूप में प्रति वर्ष प्रति हेक्टेयर के लिए 1.62 टन कार्बन की न्यनतम मात्रा को प्रयोग करने की आवश्यकता है।
- बाजरा में 20 कि.ग्रा. नाइट्रोजन (अहाता खाद)+ 20 कि.ग्रा. नाइट्रोजन(यूरिआ) प्रति हेक्टेयर+10 कि.ग्रा. फासफोरस प्रति हेक्टेयर के उपयोग से वर्षाजल उपयोग दक्षता नियंत्रण (0.83 कि.ग्रा. प्रति हेक्टेयर प्रति मि.मी.) से बढ़कर 1.47 कि.ग्रा. प्रति हेक्टेयर प्रति मि.मी हो गई। जबकि कोविलपट्टी में ज्वार में 40 कि.ग्रा. नाइट्रोजन(यूरिआ) + 20 कि.ग्रा. फासफोरस प्रति हेक्टेयर+25 कि.ग्रा. $ZnSO_4$ प्रति हेक्टेयर से नियंत्रण की अपेक्षा (1.74 कि.ग्रा. प्रति हेक्टेयर प्रति मि.मी) उपयोग दक्षता 2.91 और 1.47 कि.ग्रा. प्रति हेक्टेयर प्रति मि.मी हो गई।
- सूपर जल-शोषक जेल (Gel) फार्मिंग पालिमरों ने अपने भार से 350-450 गुणा जल सोंखकर खरीफ मौसम में शुष्क दौर के दौरान वर्षा आधारित टमाटर की उपज में वृद्धि की। टमाटर के लिए पालिमर प्रयोग की सकल सस्य क्षमता 35 कि.ग्रा. टमाटर प्रति कि.ग्रा. पालिमर था। रबि मौसम के दौरान टमाटर के परिणामों ने सूचित किया कि पालिमरों के प्रयोग से प्रति तीन सप्ताहों की सिंचाई में कम से कम एक सिंचाई कम की जा सकती है।

भूमि उपयोग विविधता

- अमरूद, सीताफल, आम एवं सिट्रस में विभिन्न सूक्ष्मजीवों (जैव उर्वरक) (वी.ए.एम. या पी.एस.बी. या के मोबिलाइज़र) का मृदा में समावेश करने से पौधों में जल्द वृद्धि, पुष्पण, फल वृद्धि, फलों की संख्या एवं उत्पादन में वृद्धि हुई।
- जट्रोफा में, सिंचाई के अंतर्गत 4 X 3 का अंतराल एवं 67.5 ग्रा. नाइट्रोजन तथा 150 ग्रा. फासफोरस प्रति पौधा डालने से अधिकतम बीज उत्पादन हुआ। इसी प्रकार बिना कांट-छांट की तुलना में 50 प्रतिशत की उंचाई पर कांट-छांट करने से बेहतर उत्पादन प्राप्त हुआ।
- पोंगामिया में, छटे वर्ष के रोपण के दौरान पादप ज्यामिति (5X5 मी., 6X4 मी., 6X6 मी., एवं 8X6 मी.,) से उत्पादन (Kernel) पर कोई महत्वपूर्ण प्रभाव नहीं पड़ा।
- पोंगामिया में रोपण के पांचवें वर्ष के दौरान अंतरफसल के रूप में खीरा अच्छी उपज देकर (645 कि.ग्रा. प्रति हेक्टेयर) बेहतर साबित हुआ।

पशुधन प्रबंधन

- इक्यु-एनर्जी एवं नाइट्रोजन के आधार पर दोनों का सांद्रित मिश्रण खिलाने की तुलना में कुलथी या अज़ोला के अतिरिक्त

पोषण से दक्कनी भेड़ों में औसत दैनिक वृद्धि में महत्वपूर्ण रूप से सुधार हुआ।

- फसलों के अवशेषों पर आधारित सूखे चारे के साथ मिलाकर स्थानीय रूप से उपलब्ध पत्तों *(स्टाइलोसेंथिस हमाटा* या *ल्युकेना ल्युकोसेफाला* या *ग्लिरिसिडिया सेपियम*) के अतिरिक्त पोषण से पशुओं के प्रथम अमाशय में मनवोद्भवी उत्सर्जन (गैस का जमा होना) में कमी आई।
- दक्कनी भेड़ों में शाक इम्युनोमॉडलेटरों (रेस्टोबल एवं स्ट्रेस्सोमिक्स) के प्रयोग से उनकी प्रतिरक्षा प्रतिक्रिया क्षमता में वृद्धि हुई।

ऊर्जा प्रबंधन एवं संरक्षण कृषि

- पारंपरिक प्रक्रिया, जिसका अनाज उत्पादन 3932 कि.ग्रा. प्रति हेक्टेयर एव बायोमॉस उत्पादन 4016 कि.ग्रा. प्रति हेक्टेयर था, की तुलना में डिस्क हैरो से दो बार कड़बी की कटाई, फैलाव एवं कर्षण से 4797 कि.ग्रा. प्रति हेक्टेयर की दर से अधिकतम मक्का उत्पादन एवं 4954 कि.ग्रा. प्रति हेक्टेयर की दर से बायोमॉस उत्पादन दर्ज किया गया। ट्रेक्टर के सामने लगी कटाई की मशीन कड़बी को एक तिहाई हिस्से में काटकर समान रूप से फैला देती है। तीन वर्षों के अध्ययन के बाद किए गए मृदा विश्लेषणों से ज्ञात हुआ कि पारंपरिक प्रक्रिया की तुलना में कम कर्षण और शून्य कर्षण + मक्का की कड़बी डालने से मृदा कार्बन एवं मृदा फासफोरस में काफी बढ़ोत्तरी हुई।
- फ्युसिबल अलॉय नेनो पदार्थों पर आधारित **Ni (Nickle)** से कोटिंग करने के बाद कल्टीवार शोवेल्सों की टूट-फूट की जांच की गई।

सामाजिक आर्थिक अध्ययन

- **ArcGIS** पर्यावरण में रॉसटर केलकुलेटर का उपयोग कर जलग्रहण विकास कार्यक्रमों, के प्रभाव के मूल्यांकन के लिए विकसित प्रणाली का सुधार किया गया। इस विधि के प्रारंभिक परिणाम आशाजनक हैं।
- जलग्रहण विकास कार्यक्रमों में लिंग विश्लेषण ने स्पष्ट किया कि शारीरिक श्रम के संबंध में महिलाओं का योगदान पुरुषों से महत्वपूर्ण रूप से बेहतर था। जबकि निर्णय लेने में महिलाओं की तुलना में पुरुषों की भूमिका महत्वपूर्ण थी।
- अनंतपुर जिले में कृषि तालाबों को अपनाने के कारण कृषि क्षेत्र में करीब 30 प्रतिशत की वृद्धि हुई एवं सस्य सघनता 138 से बढ़कर 143 प्रतिशत हो गई। सूरजमुखी एवं बाजरा के मामले में उत्पादन वृद्धि का प्रभाव अधिक स्पष्ट था जहाँ उत्पादन वृद्धि 26 से 40 प्रतिशत तक थी।

प्रौद्योगिकी हस्तांतरण

- राष्ट्रीय कृषि नवोन्मेषी परियोजना के अंतर्गत आने वाले आठ जिलों में सूचना एवं संचार प्रौद्योगिकी सेवाओं के उपयोग पर किए गए अध्ययन ने स्पष्ट किया कि अधिकतर किसानों (92 प्रतिशत) ने बाज़ार संबंधी सूचना में रुचि दिखाई तथा उसके उपरांत मौसम चेतावनी (83 प्रतिशत) तथा नाशीजीवों का प्रकोप एवं उनके प्रबंधन (63 प्रतिशत) का स्थान आता है।

राष्ट्रीय कृषि नवोन्मेषी परियोजना

- मन्न-केनडल्ल **(Mann-Kendall)** जांच का उपयोग कर वार्षिक वर्षा के झुकाव पर किए गए विश्लेषण ने स्पष्ट किया कि बिहार के पूर्वी भागों, उडीसा के उत्तर पूर्वी भाग एवं दक्षिणपूर्व के अलावा पश्चिम बंगाल के सभी क्षेत्रों में वार्षिक वर्षा की मात्रा में वृद्धि हुई, जबकि उडीसा के पश्चिमी भाग में कमी आई।
- मक्का उत्पादन संबंधी 16 वर्षों के अध्ययन ने स्पष्ट किया कि सिंचाई के अंतर्गत प्रतिशत क्षेत्र, अधिक उत्पादन देने वाली किस्में एवं प्रति हेक्टेयर उर्वरकों का उपयोग इत्यादि घटकों ने मक्का के उत्पादन में सकारात्मक तथा महत्वपूर्ण भूमिका निभाई। जबकि खरीफ के दौरान तापमान का प्रभाव मक्का के उत्पादकता पर महत्वपूर्ण था।
- विभिन्न कृषि प्रणालियों की उत्पादकता में बढ़ोत्तरी एवं बेहतर सहायक प्रणालियों द्वारा टिकाऊ ग्रामीण रोज़गारोन्मुख संबंधी प्रयास परियोजना के चौथे वर्ष के दौरान भी जारी थे। फसल आधारित हस्तक्षेपों के अंतर्गत कपास, मूंगफली एवं सब्जियों में सिंचित वर्षाजल के उपयोग एवं संतुलित पोषण ने उत्पादन वृद्धि में महत्वपूर्ण योगदान दिया। इसके अतिरिक्त जल एकत्रण और सिंचाई इत्यादि के पुराने स्त्रोतों को ठीक कर वर्षाजल द्वारा सिंचाई करके सस्य सघनता एवं उत्पादकता को बढ़ाकर किसानों को अधिक लाभ पहुंचता है।
- लोगों की भागीदारी से विभिन्न भूमि उपयोग प्रणालियों में भिन्न कार्बन पृथक्करण गतिविधियों के कार्यान्वयन सहित आंध्र प्रदेश के ज़फरगुडेम केंद्र में ग्रीन हाडस गैस उत्सर्जन कटौती गतिविधियों को प्रोत्साहित किया है। इस केंद्र में बड़ी संख्या में पुराने बल्बों के स्थान पर समान प्रकाश वाले सी.एफ.एल बल्ब लगाए गए जिसके परिणामस्वरूप कार्बन डाइआक्सइड उत्सर्जन में करीब 40 टन प्रति वर्ष की कमी आई। 600 बेहतर चूल्हों से ग्रीनहाउस उत्सर्जन में करीब 1260 टन प्रति वर्ष की कमी आई।
- मीठी ज्वार उत्पादन में यांत्रिकीकरण को बढ़ावा देने के उद्देश्य से परिशुद्धता रोपक **(Precision planter)** एवं शाकनाशी प्रयोग करने वाले यंत्र **(Herbicide applicator)** का विकास किया गया एवं इसे किसानों के खेतों में सफलतापूर्वक जांचा

गया। इस उपकरण से बीजी गई मीठी ज्वार की फसल में अंकुरण लगभग 86 प्रतिशत था। मीठी ज्वार में पर्ण स्ट्रिपर को भी परखा गया। रोलर क्रशर से जब बिना पत्तों के रस निकाला गया तो रस की प्राप्ति 30 से 34 प्रतिशत रही।

- सूखा सहिष्णुता दर्शाने वाले 14 विगलकों सहित तापमान एवं लवणता सहिष्णु के लिए प्रत्येक के करीब 7 स्युडोमोनॉस विगलकों की पहचान की गई एवं दबाव परिस्थितियों के अंतर्गत उनकी जनसंख्या की घटत-बढ़त संबंधी जानकारी उपलब्ध की गई। दबाव सहिष्णता वाले जीनों की पहचान के लिए संपूर्ण जीनोम के अनुक्रम का कार्य जारी है।
- कपास मीलीबग, *फेनाकोक्कस सोलेनोपसिस* के संपूर्ण जीवन चक्र के लिए विकास प्रभावसीमा एवं ऊष्म-स्थिरता की पहचान की गई। कपास एवं अन्य वैकल्पिक खरपतवारों पर इसके *पारासिटॉइड*, *एनासियस बमबावालेया* के मौसमी आपतनों को दर्ज किया गया।
- सी.एम.एस. के रूप में जूमला से संस्थान एवं अखिल भारतीय समन्वित बारानी कृषि अनुसंधान परियोजना के लिए एक नए वेब पेज का विकास किया गया।

राष्ट्रीय जलवायु समुत्थान कृषि पहल

- राष्ट्रीय जलवायु समुत्थान कृषि पहल का औपचारिक उद्घाटन दिनांक 2 फरवरी 2011 को माननीय कृषि एवं उपभोक्ता मामलों के मंत्री श्री शरद पवार द्वारा किया गया। अनुकूलन एवं प्रशमन पर अनुकूल अनुसंधान, 100 सुभेद्य जिलों में वर्तमान जलवायु विविधता से जूझने के लिए प्रौद्योगिकी का प्रदर्शन, क्षमता निर्माण एवं क्रांतिक दूरियों को मिटाने के लिए प्रायोजित अनुसंधान द्वारा देश के सुभेद्य क्षेत्रों में कृषि उत्पादन के समुत्थान को बढ़ाने के उद्देश्य से 350 करोड़ रुपए की परियोजना प्रारंभ की गई। प्रारंभ के बाद इतने कम समय में परियोजना ने काफी प्रगति की।

कृषि विज्ञान केंद्र

- वर्ष के दौरान, मक्का, कपास, अरहर, चावल एवं सब्जियों की बेहतर प्रक्रियाओं पर आंध्र प्रदेश के रंगारेड्डी जिले में कुल 196 अग्रिम प्रदर्शनों का आयोजन किया गया। फसल एवं पशुधन उत्पादन के विभिन्न पहलुओं को शामिल कर करीब 1786 किसानों को 58 आवश्यकता आधारित एवं कौशलोन्मुख प्रशिक्षण दिए गए। इसके अतिरिक्त गरीब एवं सीमांत किसानों के लाभ के लिए कई क्षेत्रीय दिवस एवं पशु स्वास्थ्य कैंपों का आयोजन भी किया गया।

मानव संसाधन विकास

- वर्ष के दौरान कई संस्थान के वैज्ञानिकों ने देश और विदेश दोनों जगहों के प्रशिक्षणों में भाग लिया। संस्थान में भारी संख्या में स्नातकोत्तर विद्यार्थियों ने अपनी परियोजना/अनुसंधान कार्य पूरे किए।

पुरस्कार एवं मान्यताएं

- अखिल भारतीय समन्वित बारानी कृषि अनुसंधान परियोजना के केंद्रों द्वारा स्थान विशेष की प्रौद्योगिकियों को ध्यान में रखते हुए वर्षाजल प्रबंधन, फसल प्रणालियों, आकस्मिक योजनाओं, समेकित पोषण प्रबंधन, कृषि यांत्रिकीकरण एवं वैकल्पिक भूमि उपयोग प्रणालियों पर किए गए अनुसंधान कार्यों के लिए चौधरी देवी लाल उत्कृष्ट अखिल भारतीय समन्वित अनुसंधान परियोजना पुरस्कार 2009, अखिल भारतीय समन्वित बारानी कृषि अनुसंधान परियोजना, हैदराबाद को प्राप्त हुआ।
- संस्थान एवं सहयोगी वैज्ञानिकों से जुड़े दल को बारानी कृषि में अनुसंधान प्रयोगों के लिए वसंतराव नायक पुरस्कार 2009 प्राप्त हुआ। यह पुरस्कार जल सिंचाई एवं पुनचक्रण के क्षेत्र में वैज्ञानिकों द्वारा किए गए अनुसंधान कार्य की मान्यता के रूप में भारतीय कृषि अनुसंधान परिषद द्वारा दिया गया।
- संस्थान एवं सहयोगी वैज्ञानिकों से जुड़े दल को किसान भागीदारी कार्य अनुसंधान कार्यक्रमों को कार्यान्वित करने वाले संस्थानों के वर्ग में सम्माननीय भूमिजल बढ़ावा पुरस्कार 2009 दिया गया, यह पुरस्कार देश के चार राज्यों एवं छः जिलों में वैज्ञानिक उपकरणों का उपयोग कर तालाब गाद (Tank silt) प्रयोग के देशी तकनीकी ज्ञान को आधुनिकता प्रदान करने के लिए जल संसाधन मंत्रालय, भारत सरकार द्वारा शुरू किया गया है।
- संस्थागत एवं दलीय पुरस्कारों के अलावा, संस्थान के कई वैज्ञानिकों को उनके कार्य के लिए कई व्यक्तिगत पुरस्कार एवं मान्यताएं प्राप्त हुई।

संपर्क एवं सहयोग

- संस्थान पणधारियों एवं संगठनों से नए संपर्क एवं सहयोगों के लिए निरंतर प्रयासरत हैं जबकि अपने तकनीकी कार्यक्रमों के ओर अधिक प्रभावी कार्यान्वयन के लिए अपने पुराने संपर्क एवं सहयोगों का नवीकरण भी जारी है।

प्रकाशन

- संस्थान के वैज्ञानिकों ने अभिजात समीक्षा पत्रिकाओं में लगभग 59 अनुसंधान लेख प्रकाशित किए हैं । इसके साथ ही साथ भारी संख्या में पुस्तक, बुलेटिन एवं पुस्तकों के अध्याय भी प्रकाशित किए हैं।

Executive Summary

Resource characterization

- Analysis of meteorological droughts at Mandal level in Andhra Pradesh revealed 10-25% probability of occurrence of moderate drought in almost all the mandals in different districts. The probability of occurrence of severe drought was only 0- 2% in most of the mandals of the state.
- Decadal trend analysis of cropped area showed that the area under rice cultivation is increasing, especially in districts of Telangana region during the current decade when compared to previous decades. The yield of rice is decreasing in Kadapa, Nalgonda, Guntur, Krishna and Vizianagaram districts and there is no change in yield during the last two decades in Chittoor, Rangareddy, Karimnagar and Khammam districts.
- Groundnut is mainly cultivated in Rayalaseema region of Andhra Pradesh (80 %), particularly in Anantapur district (48% of state area). Area of groundnut has increased in Anantapur district from 2, 82,000 ha during 1971-80 to 7, 95, 000 ha during the current decade. In the remaining districts, it is decreasing during the current decade. However, in case of yield, declining tendency was observed in Anantapur and Kadapa districts while in the remaining districts, especially in coastal regions, increasing trend was observed.
- An equation was developed using rainfall and temperature data for prediction of Groundnut leaf miner at Anantapur and the model was validated with observed weather data and pest infestation. It was observed that the model is predicting pest infestation well but quantity is varied. The NCMRWF weather forecast data was incorporated in the equation and the results showed that the weather forecast predicted the events of occurrence well but the degree of pest infestation is not accurately predicted.
- The relationship of weather parameters with different phenological phases of cotton was identified for Parbhani centre and the results showed that rainfall and sunshine hours during boll formation to boll bursting have higher linear correlation with yield. Multivariate regression analysis estimated the optimum rainfall required during boll formation to boll bursting to be 249 mm.
- Sinusoidal and exponential models were used to generate diurnal patterns of relative humidity from daily values of mean minimum air temperature as well from the morning relative humidity under semi-arid climate of Hyderabad.

Climate change

- Analysis of extreme temperature events indicated that percentage of cold nights was declining more significantly at Akola, Anand, Ludhiana and Solapur where as cold nights were rising at Kanpur. Significant decreasing trend in percentage of cold days was noticed at Anantapur, Solapur, Anand, Bhubaneswar, Jabalpur and Kanpur. Annual total precipitation showed significant decreasing trend at Jorhat whereas Parbhani and Raipur showed significant increasing trend.
- Elevated carbon dioxide (700 ppm) increased the organic carbon status of soil in open top chambers (OTCs) in which different crops were grown for four years, from 0.36% to 0.55%, registering a 52% increase over uncultivated fallow outside the OTCs. Uncultivated fallow showed the lowest microbial biomass carbon (39.1 mg/kg) compared to cultivated control (43.4 mg/kg).
- Crop simulation model (DSSAT) was used to compare current productivity level of rainfed maize with that of climate change scenarios. The average potential yield among the locations is 2530 kg/ha, and Hyderabad, Anantapur and Arjia recorded yield

potential above the average value. However, maize yield potential of different locations from the state of Maharashtra fell below the average level.

- Nitrate reductase (NR) and glutamine synthetase (GS) estimated in sunflower at peak vegetative stage showed decreasing trend at 700 ppm CO_2 compared to ambient conditions. Similarly higher nitrogen supply recorded higher shoot N% in ambient conditions compared to 700 ppm. Leaf photosynthesis and biomass also increased significantly with elevated CO_2 and nitrogen supply.
- Black gram genotypes showed yield increment of 21.37% and 36.64% on an average at 550 ppm and 700 ppm CO_2 levels respectively over ambient control. However the selected genotypes did not show similar response in terms of magnitude as well as trend with increased CO_2 concentration for all the characters studied.
- During the cool season, the sunflower crop showed an improvement of biomass and grain yield of 45.19% and 46.09% at 700 ppm and 18.68% and 20.86% at 550 ppm over ambient control. The response for these parameters for the warm season was -3.30% and -1.76% for biomass and 3.16% and 8.74% for seed yield at 700 ppm and 550 ppm CO_2 concentrations respectively over ambient control. A significant decrease was observed for the total number of seeds and an increase in the number of unfilled seed due to higher temperatures during flowering and seed filling at elevated CO_2 levels.
- Rainfall event of 40 mm/day was found detrimental to pre-pupal and adult stages of s*podoptera litura,* thereby adversely affecting its fecundity and the population growth potential.
- All the *Pseudomonas* isolates tested were positive for siderophore and ammonia production at both the elevated and ambient CO_2 conditions after eighty generations. However, siderophore, lipase and IAA production by all the *Pseudomonas* isolates gradually decreased at elevated CO_2.
- Effect of elevated CO_2 on the *in vitro* bio-efficacy of *Trichoderma* against four phytopathogens was studied and it was found that the per cent inhibition in radial growth of all pathogens under elevated CO_2 was significantly higher than the ambient condition.

Rainwater management

- A surface water yield model was developed to fix the curve numbers for different land uses in a microwatershed by integrating the SCS curve number method and water balance in a farm pond. The seepage loss of pond was calculated by monitoring pond water level, rainfall and evaporation data and it was reduced to 20 mm/day during third year as compared to 40-80 mm/day during the first two years. The total runoff collected at the pond was 1992 m^3 from four runoff producing events with a catchment area of 14.5 ha. An amount of 219.4 m^3 was used as pre sowing irrigation in an area of 0.9 acre with groundnut and 0.74 acre with maize. The evaporation loss was calculated as 14% of the total runoff. The maximum rain water productivity of 23.77 kg/ha mm was achieved in groundnut with tank silt application as compared to 20.31 kg/ha mm with no tank silt application. In okra, the water productivity obtained with tank silt application was 29.15 kg/ha mm and 24.14 kg/ha mm without tank silt.
- Paired row planting with ridger (60 cm within pair, 120 cm between pairs) reduced the runoff loss and was in the range of 1-15% of crop season rainfall as against 8-10% in normal planting. The yields of pigeonpea recorded were in the range of 1700-1900 kg/ha and 2200-2250kg/ha with normal and paired row planting respectively.
- A water management system was developed with solar powered water lifting system and water distribution using gravity operated water emitting devices. The average discharge of the emitters was 2.92 lph (litre per hour). The emitter discharge was found consistent over 26 m long laterals with overall distribution uniformity of 90.63%.
- A low weight nylon pump was developed to improve the portability of existing pump set (1.5 HP) and the weight of the pump was reduced to 23 kg as against 34 kg of the existing pumpset, without any reduction in discharge capacity and pressure head.

Crops and cropping systems

- CRIDA's new horse gram varieties, CRIDA 18R and CRHG 4 performed better (up to 33% higher grain yield and 10-25 days early maturity) than

local checks in Andhra Pradesh, Tamil Nadu and Kerala.

- Six lines of mtlD transgenic sorghum were tested for stress tolerance under controlled conditions. These lines were found superior to untransformed plants in terms of key physiological parameters.
- Isolation, cloning, characterization and expression analysis of dehydrin gene from *Sorghum bicolor* was carried out and both genomic and cDNA sequences isolated were deposited in the NCBI Gene Bank with accession # GU137312.1 and HM243499, respectively.
- In order to identify novel genes induced under gradual water deficit stress, a cDNA library was constructed using suppression subtractive hybridization (SSH) from the leaves of a drought tolerant pearlmillet male parent ICMR 356.
- As part of efforts on genetic transformation of green gram for stress tolerance, efficient regeneration and transformation of double cotyledonary node explants was optimized by using LBA 4404 strain of *Agrobacterium tumefaciens* carrying pCAMBIA 2301 binary vector containing *annexin Bj1* under the control of CaMV35S promoter.
- Studies on root growth in green gram cultivars (WGG37 and ML267) showed that there was significant reduction in total root length of both cultivars at flowering stage but the rate of reduction was higher in WGG37 than ML267.
- Studies on organic crop production showed that the yield reduction during the first year under organic management was 19% in sesame, 13% in sunflower and 25% in pigeon pea.
- Custard apple and guava performed better under organic management in terms of both yield and quality of fruits (less seed weight and higher pulp in custard apple; higher total soluble sugars and less acidity in guava).
- Morphological and chemical changes induced by the pest attack in plants were quantified by spectrometry. Based on this, narrow band hyperspectral indices were developed which have potential to detect the severity of cotton leafhopper incidence and groundnut late leaf spot disease.
- A decision support system (DSS) was validated for fungicide spray advisory based on leaf wetness index (LWI) measured by a wireless sensor moat at canopy height. Fungicide spray advisory was issued by the DSS twice at 77 and 94 DAS which were correctly validated.
- Two bacterial consortia (P7+B30+G12 for sorghum and P45+B17+G12 for sunflower) were formulated and tested in lab and field conditions for drought and heat stress management. Use of recommended NPK with consortium inoculation improved plant growth and yield of sorghum and sunflower under rainfed conditions.

Soil health and nutrient management

- After 12 year of experimentation, on an average, reduced tillage was found superior over conventional tillage by 10.7 and 1.6% in terms of sorghum and mung bean yields, respectively. Further, reduced tillage resulted in significantly higher total hydrolyzable N (6.98%), hydrolyzable NH_4-N (6.01%), hexosamine N (12.9%), available N (9.61%) and total N (4.07%) in soil over conventional tillage. Conjunctive nutrient use treatments significantly improved all the nitrogen pools over control.
- Application of sorghum stover @ 4 t ha^{-1} recorded significantly higher cowpea yields (870 kg ha^{-1}). Residue application significantly influenced exchangeable NH_4–N, total hydrolyzable N, hydrolyzable NH_4-N, hexosamine N, amino acid N, available N and total N pools where as no effect was observed on fixed ammonical N and unidentified N.
- Minimum tillage (only plough planting) could maintain equal or slightly higher average castor bean yields (1261 kg ha^{-1}) compared to conventional tillage (1211 kg ha^{-1}). Among residues, application of sorghum stover resulted in higher average castor bean yield (1325 kg ha^{-1}), which was almost at par with application of gliricidia loppings (1273 kg ha^{-1}) compared to no residue application (1111 kg ha^{-1}).
- Soil quality was assessed in a long-term tillage and nutrient management experiment under rainfed rabi sorghum system at Solapur centre (semi-arid Vertisols). Soil quality index (SQI) was in order of

medium tillage > low tillage > conventional tillage. Among nutrient management treatments, 50 kg N through organics + no P_2O_5 maintained the highest soil quality followed by 25 kg N (organics) + 25 kg N (urea) + 12.5 kg ha^{-1} P_2O_5 and 50 kg N (urea) + 25 kg P_2O_5 ha^{-1}.

- At Hyderabad, soil application of zinc sulphate @ 25 kg/ha, inoculation of seeds @ 10g for 250g of seeds with *Pseudomonas* strain nos. P29, P33 and *Bacillus* strain no. B116 resulted in significant increase in the grain yield of maize as compared to control. At Arjia, highest maize yield of 4433 kg/ha was recorded under soil application of zinc sulphate followed by inoculation with P29 and P 33 strains.
- Studies on carbon sequestration potential under different tillage systems at Phulbani (Oxisols – rice based system) showed that the particulate organic carbon and microbial biomass carbon were highest in reduced tillage and in 100% organic treatment.
- Application of cotton stalk biochar @ 3.0 and 6.0 t/ha with recommended dose of fertilizer (RDF) (20:50:0 kg /ha of NPK) recorded an increase of 26.9 and 39.8% pigeonpea yield over control (no biochar +RDF), respectively. Application of pigeonpea stalks biochar @ 3.0 and 6.0 t/ha with RDF increased the grain yield by 21.6 and 32.1% over control, respectively.
- Higher profile soil organic carbon (73.0 Mg ha^{-1}), C buildup (41.2%) and C sequestration (9.3 Mg C ha^{-1}) was observed with the application of 10 Mg ha^{-1} farmyard manure on wet weight basis along with a recommended dose of chemical fertilizer (25:21.8:20.7 and 50:21.8:20.7 kg N, P, K ha^{-1}) for groundnut and finger millet, respectively at Bangalore (soil type Alfisol, climate semi-arid (moist) type). For sustenance of soil organic carbon level, (zero change due to cropping) a minimum quantity of 1.62 Mg C is required to be added per hectare per annum as input.
- Rain water use efficiency ranged from 0.83 kg/ha/mm in control to 1.47 kg/ha/mm with 20 kg N (FYM) + 20 kg N (urea)/ha +10 kg P/ha in pearl millet, while it ranged from 1.74 kg/ha/mm in control to 2.91 kg/ha/mm with 40 kg N (urea) + 20 kg P + 25 kg $ZnSO_4$/ha in sorghum at Kovilpatti.
- Super water–absorbent gel forming polymers held 350-450 times water of their weight and helped in crop growth of rainfed tomato during dry spell in *kharif* season. The overall agronomic efficiency of polymer application for tomato was 35 kg tomato per kg of polymer. The results for tomato during *rabi* season indicated that at least one irrigation in every three weeks can be cut down by applying polymers.

Land use diversification

- Soil inoculation of different microbes (VAM or PSB or ZSB or K mobilizers) resulted in early flush, flowering and fruit set, enhanced fruit number and yield in guava, custard apple, mango and citrus.
- In jatropha, a spacing of 4 X 3 m and application of 67.5 g N and 150 g P/plant under irrigation gave highest seed yield. Similarly, pruning at 50% height from ground gave better yields than no pruning.
- In pongamia, planting geometry (5 X 5 m, 6 X 4 m, 6 X 6 m and 8 X 6 m) had no significant effect on kernel yield during sixth year of plantation.
- Cucumber performed better as an intercrop yielding about 645 kg/ha in pongmia during fifth year of plantation.

Livestock management

- The average daily gain (ADG) was significantly improved in Deccani lambs with supplementation of either horsegram or *Azolla* than concentrate mixture on equi-energy and nitrogen basis.
- Supplementation of locally available leaf meal (*Stylosanthes hamata* or *Leucaena leucocephala* or *Gliricidia sepium*) with coarse crop residues helped in reduction of anthropogenic emission (cumulative gas production) in rumen of livestock.
- Administration of herbal immunomodulators (Restobal and Stressomix) helped in potentiating immune response in Deccani sheep at the times of vaccination.

Energy management and conservation agriculture

- Stover slashing, spreading and tillage with disk harrow twice recorded highest maize yield of 4797 kg/ha and biomass 4954 kg/ha compared to the conventional practice, which recorded the grain yield of 3932 kg/ha and biomass 4016 kg/ha. The tractor front mounted slasher could cut the stover to one third of its height and spread evenly. Soil analysis after third year of study showed that there was build up of soil carbon and soil phosphorus in low and no till treatments with residue than conventional practice.
- The wear and tear of cultivator shovels were tested after coating with Ni based fusible alloy nano materials.

Socioeconomic studies

- As part of developing methodology for impact of watershed development programmes, assessment methodology was converted into a spatial analyst tool using Raster Calculator in ArcGIS environment and initial results showed the promise of this tool.
- Gender analysis in watershed development programmes revealed that contribution of women in terms of manual labour was significantly more than men. However, men played significant role in decision making than women.
- Cultivated area increased by nearly 30% and the cropping intensity increased from 138 to 143% due to adoption of farm ponds in Anantapur district. The yield-enhancing effect was more visible in case of sunflower and bajra where the yields were reported to increase by 26 to 40%.

Transfer of technology

- A study on use of ICT services in eight NAIP project districts revealed that more farmers (92%) were interested in market based information followed by weather alerts (83%) and information on outbreak of pests and their management (63%).

NAIP

- Trend analysis of annual rainfall carried out using Mann-Kendall test revealed increasing tendency in eastern parts of Bihar, north-eastern part of Orissa and all regions of West Bengal except southeast, while it showed declining trend is in western part of Orissa.
- Sensitivity analysis of maize yields studied over 16 years indicated that percent area under irrigation, high yielding varieties and fertilizer use per ha had positive and significant effect. However temperature during kharif did show significant effect on maize productivity.
- The efforts towards sustainable rural livelihoods through enhanced farming systems productivity and efficient support systems continued during the fourth year of the project. Under crop based interventions, use of harvested rainwater and balanced nutrition helped in significant yield increases in cotton, groundnut and vegetables. Rainwater harvesting by identifying defunct infrastructure and bringing them back to use paid high dividends in terms of increased cropping intensity and productivity.
- Community based green house gas emission reduction activities were promoted in Jaffergudem cluster of A.P. along with implementation of several carbon sequestration activities in various land use systems in a participatory mode. A large number of conventional bulbs were replaced in the cluster with the equivalent lumen output CFL bulbs resulting in a reduction of about 40 t of CO_2 emissions / year. Replacement of 600 improved cooking stoves had a potential reduction in green house gas emissions of about 1260 t/year.
- With the aim of mechanizing sweet sorghum production, a precision planter cum herbicide applicator was developed and successfully tested in the farmers' fields and the germination percentage was around 86%. The sorghum leaf stripper was also tested along with the roller crusher with juice recovery between 30-34%.
- About 7 *Pseudomonas* isolates each for temperature and salinity tolerance along with 14 isolates showing drought tolerance were identified and their population dynamics under stress conditions was established. Sequencing of the whole genome for the identification of genes conferring stress tolerance is under progress.

- Developmental thresholds and thermal constants were determined for all the life stages of cotton mealybug, *Phenacoccus solenopsis*. The seasonal incidence of its parasitoid, *Aenasius bambawalei* was recorded on cotton and other alternate weed hosts.
- A new web page for CRIDA and AICRPDA was developed with Joomla as CMS.

NICRA

- The National Initiative on Climate Resilient Agriculture was formally launched by the Honorable Minister for Agriculture and Consumer Affairs Sri Sharad Pawar on 2nd February, 2011. The Rs. 350 crore project aims to enhance the resilience of agricultural production in vulnerable regions of the country through strategic research on adaptation and mitigation, technology demonstration to cope with current climate variability in 100 vulnerable districts, capacity building, and sponsored research to fill critical gaps. Considerable progress has been made in the project in the short time since its launch.

Krishi Vigyan Kendra

- During the year, a total of 196 front line demonstrations were conducted in Rangareddy district of A.P. on improved practices of maize, cotton, pigeonpea, rice and vegetable crops. The KVK also organised 58 need based and skill oriented training programs to about 1786 farmers covering different aspects of crop and livestock production, and also organised Rythu sadassu, several field days and animal health camps for the benefit of poor and marginal farmers.

Human resource development

- Many scientists underwent training both within the country and outside during the year. A large number of post graduate students carried out project/research work at CRIDA

Awards and recognition

- The All India Coordinated Research Project for Dryland Agriculture (AICRPDA), Hyderabad received the Choudhary Devi Lal Outstanding All India Coordinated Research Project (AICRP) Award 2009 for the research work on location specific technologies focusing on rainwater management, cropping systems, contingency plans, integrated nutrients management, farm mechanization and alternate land use systems carried out by the centres of AICRP for Dryland Agriculture.
- A team consisting of Scientists from CRIDA and collaborators bagged the Vasantrao Naik Award 2009 for research applications in dryland agriculture. This award was given by ICAR in recognition of research carried out by the scientists in the area of water harvesting and recycling.
- A team consisting of Scientists from CRIDA and collaborators was awarded the prestigious Groundwater Augmentation Award 2009 in the category of Institutions implementing the Farmers' Participatory Action Research Programme (FPARP), instituted by Ministry of Water Resources, Government of India, for modernizing the indigenous technical knowledge of tank silt application using science based tools across four states and six districts of the country.
- Apart from institutional and team awards, several Scientists of CRIDA received individual awards and recognition for their work

Linkages and collaboration

- The Institute continued to forge new linkages and collaborations with stakeholders and organizations while renewing and strengthening old ones for more effective implementation of its technical programme

Publications

- The Institute's scientists published 59 research articles in peer reviewed journals. A large number of books, bulletins and book chapters were also published.

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.

The following programmes have been identified to address the mandate:

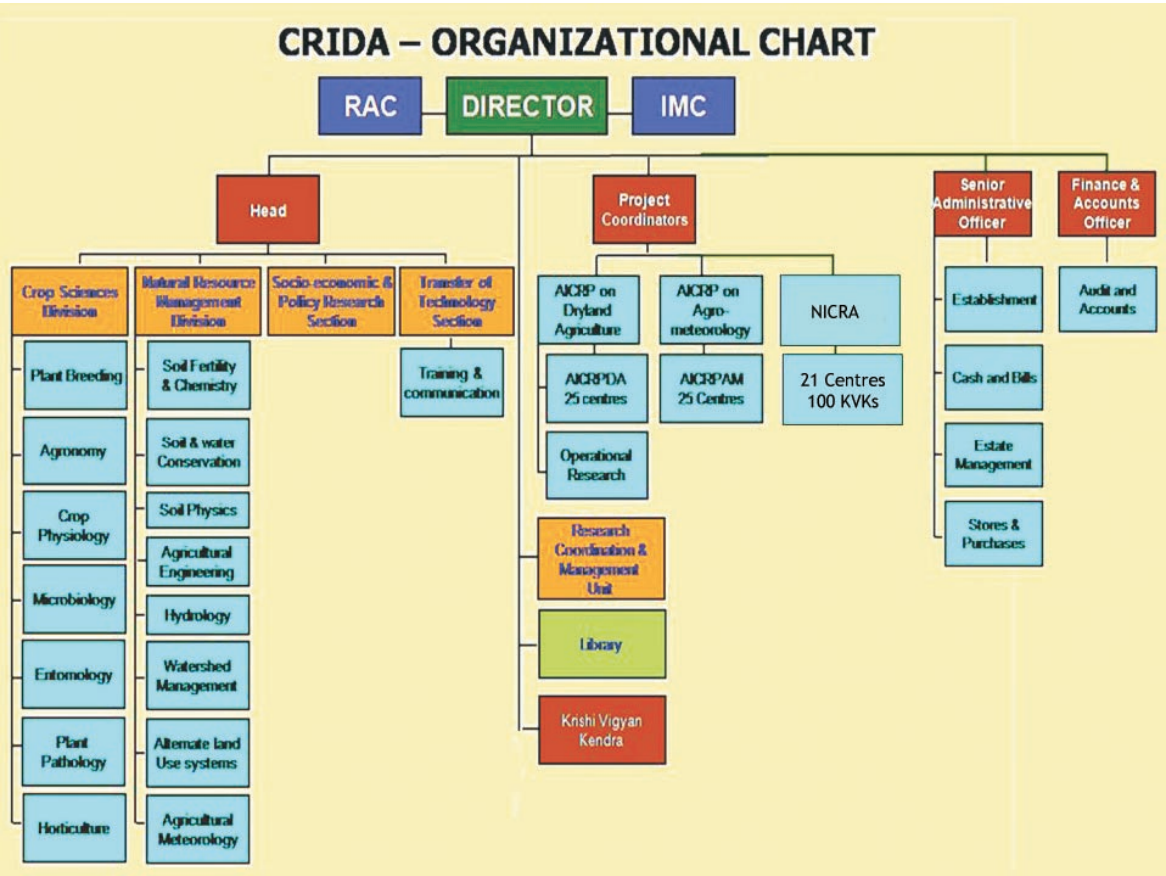
Programme No.	Programme title	Main components of sub-programmes
I	Resource characterization	Rainfall and soil characteristics, length of growing season, land capability based potential and constraints, climatic analysis, crop weather modelling, and geographic information system
II	Rainwater management	*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 health 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, transfer of technology and training	Socio-economic and policy research studies, impact of research, constraints and feedback, training of primary and secondary stakeholders and use of modern tools like ICT.

1.4 Current thrust areas

Along with the key programme areas mentioned above, 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.

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.

- Characterization and inventorisation of natural, bio-physical and socio-economic resources at micro-level.
- Probabilities of occurrence of drought in different regions in India.
- Water requirement of crops in possible future climate scenarios.
- On-farm rainwater management through cost-effective insitu conservation practices and recycling of harvested rain water.

- Technical backstopping for watershed development activities of government and non-government organizations, and meeting their HRD requirement
- Strengthened natural resource management by designing strategies for sustainable and judicious use of resources to generate optimum output.
- Developed a methodology for assessment of soil quality.
- Strategies for agricultural drought management in dryland areas, contingency planning and mid-season corrections
- Sustainability through development of sequence cropping systems, adoption of crop diversification systems/models, management practices, and crop rotations specific to dryland areas
- Alternate land use system models for provision of better land cover, sustainable livelihood options including generation of employment opportunities and income flow to the farming community.
- Agro technologies for maximizing yields in biofuel crops like Jatropha and Pongamia.
- Cost-effective, labour and energy saving technologies by designing need-based implements for timely sowing, intercultural operations and harvesting.
- Impact studies of improved and new dryland farming technologies on socio-economic conditions of rural people in the country to bridge the gap between technology development and technology transfer.
- Innovations in enhancing rural livelihoods through effective technology transfer and up scaling models.
- Weather-based forewarning of crop pests and diseases and value added agrometeorological advisory services through specific website (www.cropweatheroutlook.org)
- Co-learning strategies for farmers and scientists through action learning application at farm and watershed scale

1.7 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 (280+80 ha). 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 research in different disciplines of natural resources management and crop sciences.

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 cropweatheroutlook.ernet.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 lab: 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: CRIDA has set up 6 Open Top Chambers (OTC) to study the impact of elevated carbon dioxide on crops.

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.

ARISNET: The network is being used effectively for e-mail, internet and file transfer protocol. The network currently has a Cat-6 cabling system with Firewall. The internet connectivity is through ERNET. The ARISNET cell trained all the administrative staff on efficient utilization of computer systems and MS Office. http://search.epnet.com provides world wide web access to on-line publications of full length articles/papers or databases to Academic Search Premier. The database is completely searchable.

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.

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.

1.8 Financial Outlay for 2010-11 (as on 31 March, 2011)

(Rupees in lakhs)

	CRIDA		AICRPDA		AICRPAM		NPCC		NICRA	
	Sanctioned	Utilized	Sanctioned	Utilized	Sanctioned	Utilized	Sanctioned	Utilized	Sanctioned	Utilized
Non-Plan	1806.50	1794.60	37.50	33.93	52.50	52.20				
Plan	260.00	259.35	1400.00	1400.00	250.00	**250.00**	249.00	246.00	20000.00	19997.80
Total	**2066.50**	**2053.95**	**1437.50**	**1433.93**	**302.50**	**302.20**	**249.00**	**246.00**	**20000.00**	**19997.80**

1.9 Staff position (as on 31 March, 2011)

Staff	Positions	
	Sanctioned	Filled
Scientific	69	60
Technical	80	74
Administrative	50	46
Supporting	59	43
TOTAL	**258**	**223**

2 Research Achievements

2.1 Resource characterization

2.1.1 Weather conditions at Hayathnagar Research Farm

The southwest monsoon set in on June 10 and caused 47 mm of rainfall in 3 days. Land preparation was taken up and completed during the second week of June. Heavy rainfall occurred during third week of June. Sowing of kharif crops was mostly completed between last week of June and first week of July. The annual rainfall received at Hayathnagar Research Farm, Hyderabad was 1103 mm as against long term (1971-2009) average of 746 mm.

Rainfall of 277 mm received during July was excess (114 %) but well distributed. The rainfall of 277 mm also received during August was also well distributed and above normal (77 %). The rainfall of 121 mm received during September was also, by and large, well distributed. Long duration crops of castor and pigeonpea were benefited by rainfall of 111, 57 and 19 mm during October, November and December, respectively. Most of the crops performed satisfactorily due to good monsoon this year.

The southwest monsoon withdrew on 24th October against the normal date of mid October. The weekly weather data during the year 2010 are given in Table 1. The monthly actual (2010) and long term average (1971-2009) rainy days and rainfall are presented in Fig.1 and Fig.2 respectively.

Table 1 : Weekly meteorological parameters recorded at Hayathnagar Research Farm, Hyderabad (2010)

Standard meteorological Week	Rainfall (mm)	Soil Temperature (°C) at 10 Cm		Air Temperature (°C)		Relative Humidity (%)		Sun Shine (h)	Wind Speed (km h^{-1})	Pan evaporation (mm)
		0716 h	1416 h	Max.	Min.	0716 h	1416 h			
1	0	20.8	29.3	28.2	13.4	86	53	9.4	2.8	3.5
2	10.2	23.3	28.0	27.9	18.7	90	73	3.0	3.1	2.8
3	0	20.2	28.4	27.3	14.7	85	41	7.7	3.0	3.4
4	0	20.5	29.0	27.4	13.6	85	67	8.8	3.2	4.2
5	0	22.1	30.0	28.8	14.7	84	33	8.6	4.2	4.8
6	0	22.8	31.5	30.3	15.3	88	33	8.1	4.1	5.3
7	0	24.9	33.4	33.0	17.7	90	31	8.4	4.9	5.4
8	0.4	27.1	34.8	33.8	20.4	84	35	7.8	4.6	5.6
9	0	26.8	36.4	35.0	19.8	69	32	8.6	4.0	6.4
10	0	28.7	36.9	36.6	21.4	77	35	8.3	4.2	7.4
11	1.2	28.3	36.2	35.8	20.8	70	26	5.6	4.2	7.5
12	0	28.5	37.6	37.9	21.3	67	27	8.5	4.5	8.2
13	4.8	34.2	38.2	37.9	22.9	69	31	6.8	4.8	8.2
14	0	32.0	39.6	38.8	23.2	67	25	7.8	4.4	12.1

Standard meteorol-ogical Week	Rainfall (mm)	Soil Temperature (°C) at 10 Cm		Air Temperature (°C)		Relative Humidity (%)		Sun Shine (h)	Wind Speed (km h^{-1})	Pan evapo-ration (mm)
		0716 h	1416 h	Max.	Min.	0716 h	1416 h			
15	0	32.7	40.9	40.3	26.6	50	24	7.9	4.6	8.6
16	0	33.5	42.6	40.0	24.9	62	29	8.9	5.6	10.0
17	4.0	33.5	43.4	39.9	25.7	75	39	8.4	6.4	9.3
18	5.4	30.8	40.4	36.5	24.9	67	30	5.8	4.6	6.9
19	0	33.0	41.9	40.5	26.6	58	26	7.6	5.1	9.8
20	5.4	32.5	41.1	39.4	26.4	70	41	6.1	5.7	8.6
21	20.9	29.1	38.1	37.0	25.6	72	38	7.5	7.6	9.6
22	0.8	33.3	42.3	40.8	28.4	57	28	6.8	7.9	12.0
23	3.4	33.1	42.1	38.5	27.2	64	33	5.7	7.2	10.9
24	44.7	27.5	34.7	33.5	23.2	85	54	3.7	8.2	6.0
25	137.8	26.3	32.2	31.0	23.4	86	63	1.7	7.4	7.4
26	2.5	29.0	37.7	33.8	24.6	80	47	4.4	6.8	6.7
27	83.0	25.5	31.0	30.6	22.2	90	65	1.9	6.8	6.2
28	82.7	25.6	32.7	29.9	23.2	88	64	4.0	3.8	5.5
29	72.1	26.2	31.5	30.1	22.8	90	73	3.6	4.5	6.3
30	37.1	24.7	27.3	27.8	22.5	94	84	0.1	5.8	4.6
31	5.4	25.2	30.8	29.2	22.4	88	66	3.5	7.6	4.9
32	49.2	25.4	32.7	30.5	22.6	88	71	4.8	4.5	4.7
33	48.9	26.2	34.4	30.8	23.0	93	67	3.6	2.8	3.7
34	128.4	26.3	34.9	30.8	22.0	96	72	6.1	3.0	5.5
35	47.0	24.6	29.7	29.7	22.3	93	81	1.4	5.5	4.5
36	50.3	24.4	29.1	27.0	22.0	89	78	0.8	8.5	3.6
37	20.9	25.6	33.6	30.2	22.6	91	65	4.5	3.0	4.6
38	26.7	25.6	34.6	29.9	21.9	94	65	6.3	3.2	3.7
39	23.1	26.2	35.0	30.3	22.0	96	66	7.7	3.6	4.4
40	17.8	26.2	34.7	30.2	21.7	94	66	5.6	2.1	4.1
41	0	25.7	35.3	31.7	21.0	84	43	7.2	3.0	4.5
42	64.1	24.9	29.8	27.2	21.2	92	80	2.6	3.9	3.5
43	15.6	24.0	32.6	29.7	19.5	95	58	6.7	2.9	3.7
44	24.3	23.0	27.3	25.2	19.2	96	85	1.5	3.7	2.8
45	45.8	22.5	28.9	27.0	19.3	97	75	4.3	2.7	3.7
46	0	24.1	30.5	29.0	20.2	97	74	5.2	5.4	2.7
47	0	23.7	32.0	29.6	18.7	95	68	7.6	3.2	2.8
48	0	22.8	31.1	29.1	16.4	95	60	6.3	3.2	3.2
49	13.2	22.5	27.6	27.5	17.4	90	65	4.0	5.7	4.2
50	5.5	20.3	28.1	27.4	15.7	91	50	6.8	2.0	2.5
51	0	16.2	27.2	26.6	8.3	92	34	9.8	3.1	3.2
52	0	18.1	27.3	27.0	11.8	96	47	7.7	4.0	3.5

Wind speed during 39-52 weeks and pan evaporation during 13th week are estimated values. Rainfall is weekly total. Other parameters are weekly mean values.

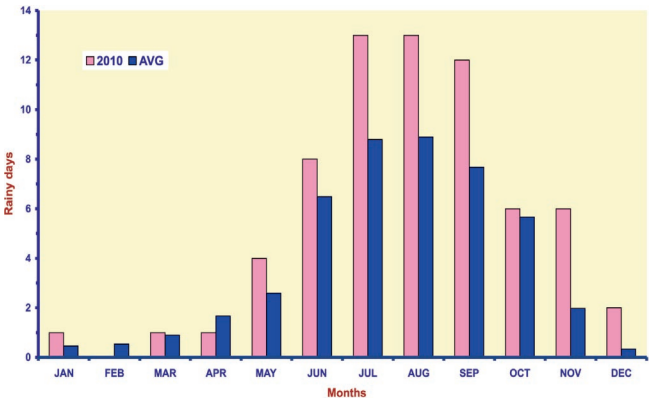


Fig. 1. Actual (2010) and average (1971-2009) number of rainy days at HRF, Hyderabad

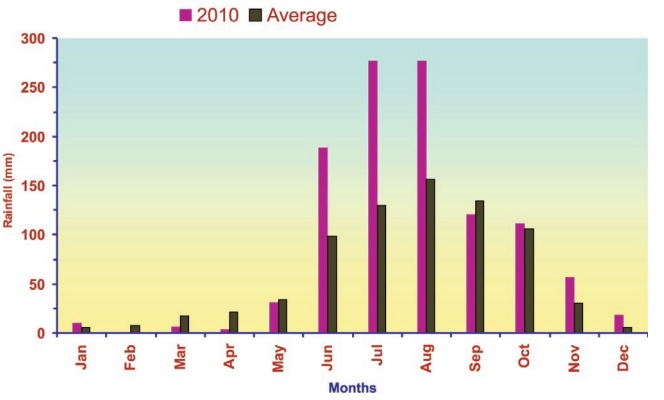


Fig. 2. Monthly actual (2010) and average (1971-2009) rainfall at HRF, Hyderabad

2.1.2. Agroclimatic atlas of Andhra Pradesh

Probability of occurrence of different meteorological droughts in Andhra Pradesh

Meteorological droughts viz. moderate and severe droughts were worked out at mandal level of Andhra Pradesh using IMD criteria. The results revealed that 10-25% probability of occurrence of moderate drought was observed in almost all the blocks in different districts. The probability of occurrence of severe drought was observed to be 0- 2% in most of the blocks of the state (Fig. 3).

Decadal changes in area and yield of different crops over Andhra Pradesh

Decadal changes (1971-80, 1981-90, 1991-00 and 2001-08) in area and yield of rice and groundnut in all districts of Andhra Pradesh were worked out.

Rice

Area under rice cultivation is increasing especially in districts of Telangana region viz., Karimnagar, Warangal, Khammam, Adilabad and Mahabubnagar during the current decade when

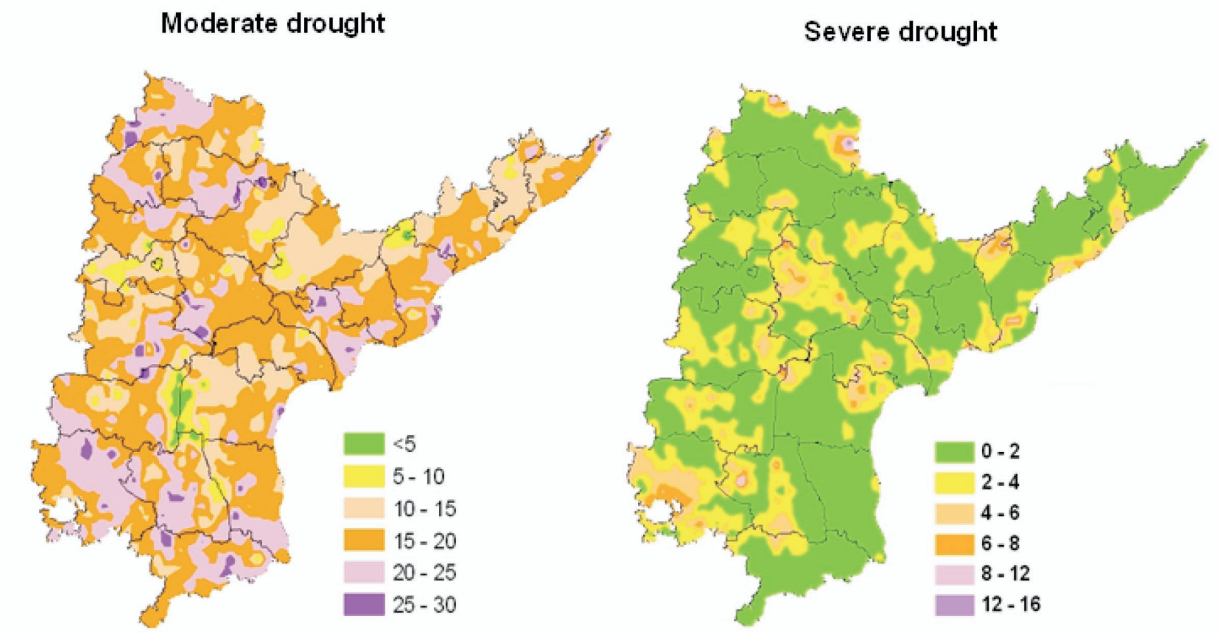


Fig.3. Percentage probability of occurrence of moderate and severe drought in Andhra Pradesh

compared to previous decades. The yield of rice is decreasing in Kadapa, Nalgonda, Guntur, Krishna and Vizianagaram districts and there is no change in yield during the last two decades in Chittoor, Rangareddy, Karimnagar and Khammam districts (Fig. 4). The reason for declining area under rice is mainly due to high water demand, recurrent droughts, and paucity of agricultural labourers, especially for transplanting and harvesting, and also due to poor returns.

Groundnut

Groundnut is mainly cultivated in Rayalaseema region of the State (80 %), particularly in Anantapur district (48% of state area). Area of groundnut is increasing in Anantapur district from 2, 82, 000 ha during 1971-80 to 7, 95, 000 ha during the current decade. In remaining districts it is decreasing during the current decade. However, in case of yield, declining tendency was observed in Anantapur and Kadapa districts and in remaining districts increasing trend was observed, especially in coastal regions (Fig. 5).

2.1.3 Validation of high-resolution model forecasting and utilizing them in pest/disease forewarning and contingency planning for AP

NCMRWF weather forecast data viz. rainfall and temperature (max & min) has been collected along with observed weather data and Groundnut Leaf

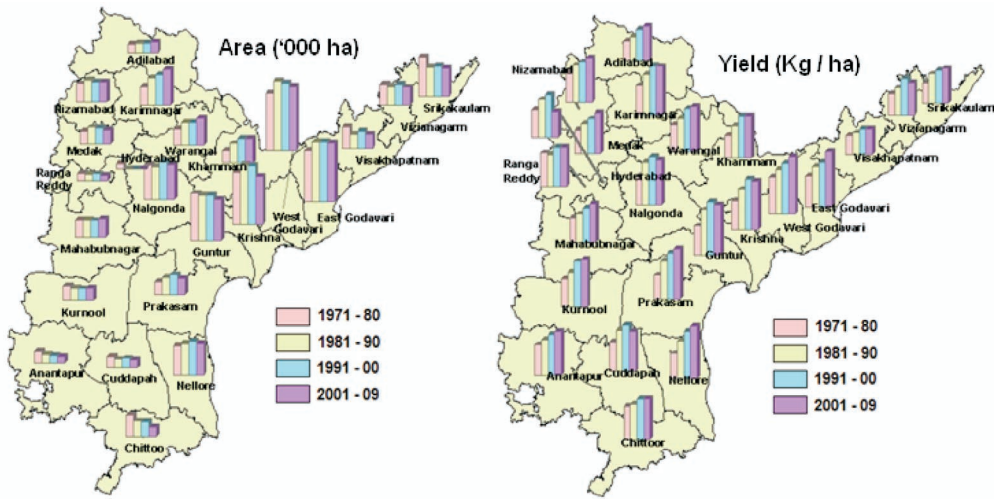


Fig.4. Decadal changes in area and yield of rice in Andhra Pradesh

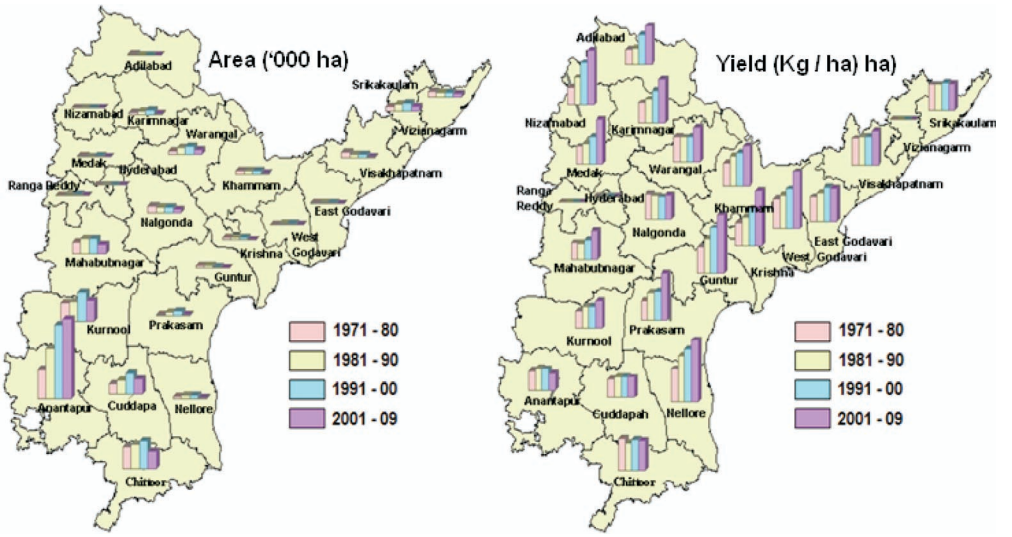


Fig.5. Decadal changes in area and yield of groundnut in Andhra Pradesh

Miner (GLM) pest infestation (%) data at Anantapur. An equation developed for prediction of GLM at Anantapur was validated with 2009 observed weather data and pest infestation. It was observed from the results that the model is predicting pest infestation well but quantity is varied. Further, the NCMRWF forecasted weather data was put to different WMO prescribed statistical tests to look into the skill and accuracy of the forecast. The verified forecast was then incorporated in the GLM equation and the results showed that the forecasted weather has well predicted the events of occurrence but the percentage amount of pest infestation is not accurate (Table 2).

Value Addition to Agromet Database of AICRP on Agrometeorology – Weather indices for Crop insurance

Correlation coefficients

The weather parameters influencing different phenophase of cotton was identified at Parbhani centre based on 11years of experimentation over 6 dates of sowing. Correlation coefficients of yield with individual weather parameters: maximum and minimum temperature, sunshine hours and rainfall during phenological stages, sowing to emergence (P_1), emergence to seedling stage (P_2), seedling to square formation (P_3), square formation to flowering (P_4), flowering to boll formation (P_5), boll formation to boll bursting (P_6), boll bursting to 1st picking (P_7), 2nd picking (P_8), 3rd picking (P_9) and 4th picking (P_{10}), brought out that minimum temperature during P_3 and P_4, sunshine hours and rainfall during P_6 stages, significantly influenced the seed yield (Table 3).

Identification of critical phenological stages of cotton

Though rainfall and sunshine hours during boll formation to boll bursting appeared to have higher linear correlation with yield than in other stages, they both showed higher significant quadratic and exponential relationships, respectively with the yield (Fig. 6).

Step-wise regression of yield performed on all the four weather parameters in all 10 phenological stages brought out rainfall during P_2 and P_6, minimum temperature during P_3, sunshine hours during P_6 and square of rainfall during P_6 to be appropriate parameters for explaining yield variation in cotton. Using these weather parameters, the following regression equation for estimating yield was developed:

$$Y = 3381 + 0.45\ RF\ (P_2) + 5.6\ RF\ (P_6) - 97.1\ MNT\ (P_3) - 113.4\ SSH\ (P_6) - 0.01\ RF^2\ (P_6)\ R^2 = 0.54$$

Though the above multivariable equation is explaining 54 percent of yield variation, the following

Table 2 : Observed pest data and the predicted GLM using both observed and forecasted weather data

WEEK	OBSERVEDGLM	PREDICTED GLM		DEVIATION	
		OBSERVED WEATHER DATA	FORECASTED WEATHER DATA	OBS.W-OBS	FOR.W-OBS
21-Aug	16	9.1	10.0	-6.9	-6.0
28-Aug	13.5	9.8	9.9	-3.7	-3.6
4-Sep	6.5	9.1	9.9	2.6	3.4
11-Sep	9.3	9.0	9.5	-0.3	0.2
18-Sep	7.3	9.2	10.5	1.9	3.2
25-Sep	7.7	10.1	10.2	2.4	2.5
3-Oct	4.6	9.5	9.9	4.9	5.3
10-Oct	5.6	9.8	10.2	4.2	4.6
17-Oct	4.4	9.8	10.4	5.4	6.0

Table. 3 : Correlation coefficient of cotton yield and phenological stage-wise weather parameters at Parbhani.

Phenological stages	Maximum temperature (°C)	Minimum temperature (°C)	Sunshine hours	Rainfall (mm)
P1	0.19	-0.14	-0.11	0.04
P2	0.26	-0.14	-0.16	0.03
P3	0.24	-0.34	0.04	-0.01
P4	0.07	-0.34	-0.19	0.14
P5	-0.09	-0.03	-0.17	-0.13
P6	-0.12	0.29	-0.54	0.35
P7	0.15	0.10	-0.25	0.01
P8	-0.08	-0.16	0.10	-0.13
P9	-0.02	-0.27	-0.04	-0.19

equation with rainfall during P_6 stage and its square as variables, explaining 49 percent of yield variation, was found to be equally good for yield estimation.

$Y = 225.5 + 8.4\ RF\ (P_6) - 0.02\ RF^2\ (P_6)\quad R^2 = 0.49$

From the above equation, optimum rainfall required during boll formation to boll bursting was worked out to be 249 mm.

Identification of average weather conditions for optimum yield of cotton

Mean yield (M) and standard deviation (σ) in yield of cotton over all the six dates and years were worked out to be 820 and 438 kg/ha, respectively. All the 66 values of yield were categorized into five types, *viz.*, Excellent (more than M + 2σ), above average (M + σ to M + 2σ), Average (M + σ), Below average (M-σ) and poor (less than M - σ). Average of weather parameters in different phenological stages over the years under each of the six categories of yield showed that highest average yield is recorded when average rainfall during boll formation to boll bursting (P_6) was highest (209 mm) and *vice versa*.

Decline in yield in each category from excellent to poor was observed to be in proportion to the decrease in average rainfall during boll formation to boll bursting. Nearly 78 percent decrease in rainfall during P_6 resulted in 73 percent decline in yield while 24 percent increase in rainfall resulted in 80 percent increase in yield over average yield. Higher sunshine hours during P_6 stage are also adversely influencing the seed yield. Rainfall lesser than 168 mm coupled with more than 8 sunshine hours during P_6 were found to be responsible for below average and poor yield of cotton at Parbhani (Table 4).

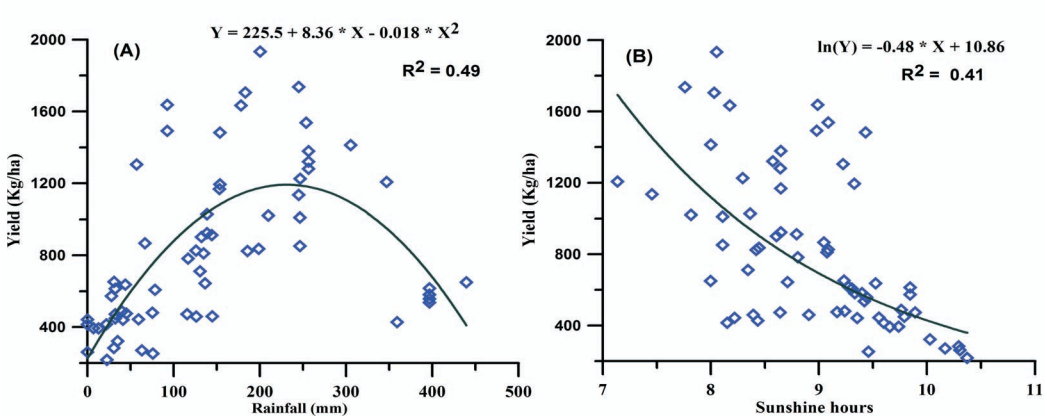


Fig. 6. (A) Relation between cotton yield and rainfall during boll formation to boll bursting
(B): Relationship between yield and sunshine hours during boll formation to 1st picking at Parbhani

Table 4 : Average weather conditions during different phenological phases of cotton in the years under five different yield categories at Parbhani

Weather parameter	Categories of yield (Kg/ha)	P1	P2	P3	P4	P5	P6	P7	P8	P9
MaxT(°C)	Excellent(1792)	33.6	32.9	29.9	30.0	32.3	31.5	31.8	30.7	31.1
	Above average(1448)	31.6	29.9	31.1	31.9	31.1	31.5	30.7	31.0	30.9
	Average(996)	32.2	31.9	31.5	31.0	30.7	32.1	31.7	30.4	31.8
	Below average(539)	32.0	30.5	29.9	31.0	31.5	31.8	31.0	30.8	31.1
	Poor(268)	30.4	30.4	29.9	31.3	32.1	32.7	30.2	31.5	31.3
MinT(°C)	Excellent	23.2	22.9	21.6	21.4	21.8	20.7	15.3	12.4	15.2
	Above average	22.1	21.4	21.1	21.3	21.3	18.8	11.9	16.1	20.6
	Average	22.0	21.6	21.1	21.2	20.9	19.2	13.5	12.2	16.3
	Below average	22.7	22.2	21.9	21.8	21.2	18.2	13.3	15.1	20.2
	Poor	22.3	22.1	21.7	22.1	21.8	17.7	10.2	17.6	22.5
RF(mm)	Excellent	49.4	86.5	198.0	164.7	13.9	209.4	35.6	9.4	72.7
	Above average	70.8	522.7	54.2	60.2	44.0	190.1	7.4	97.3	153.0
	Average	59.5	124.6	37.5	130.3	82.6	168.0	26.5	20.7	78.4
	Below average	58.2	251.3	70.5	82.4	100.6	137.6	25.1	91.2	218.0
	Poor	25.5	384.7	117.0	35.3	23.0	37.8	0.0	61.6	181.5
SSH(hrs)	Excellent	4.2	4.5	1.9	4.3	6.9	6.7	9.2	9.5	7.6
	Above average	4.0	3.5	6.1	6.7	6.2	7.9	9.7	7.6	3.7
	Average	4.4	4.9	5.0	5.0	5.5	7.8	9.3	8.8	6.9
	Below average	5.1	4.3	4.4	6.3	6.6	8.6	9.7	8.2	5.6
	Poor	4.3	5.2	4.9	6.6	8.0	9.7	10.5	7.9	5.1

2.1.4. Modelling diurnal patterns of weather-a case for Hyderabad

Attempts were made to generate diurnal patterns of relative humidity from daily values of mean minimum air temperature as well from the morning relative humidity have been made on weekly basis for semi arid climate of Hyderabad. Hourly relative humidity data (recorded by HMP 35 C temperature and relative humidity probe) for all days of a week were averaged to get mean weekly hourly data for all the 52 weeks for each year during 1995-2008. The sinusoidal and exponential models were used to generate hourly air temperature, which in turn were used for generating hourly saturation vapour pressure using Teten's equation. The data on air temperature and the relative humidity were pooled to work out the diurnal dew point pattern using standard equations. The hourly actual vapour pressure was estimated from the hourly dew point temperature. Hourly relative humidity was, thus, estimated by dividing actual vapour pressure by saturation vapour pressure both on hourly basis. Dew point temperature and in turn the relative humidity could satisfactorily be estimated from the daily mean minimum temperature during the period of weeks 1-6 and 18-52 (Fig. 7). The coefficient of determination has been 0.9883. However, for the period of summer weeks 7-17, the coefficient of determination is 0.9204. If, there are large deviations in weather conditions (un-seasonal heavy rains/heat waves) from the normal during these summer weeks, then diurnal pattern in relative humidity could be satisfactory only if, it is estimated from daily morning time relative humidity records.

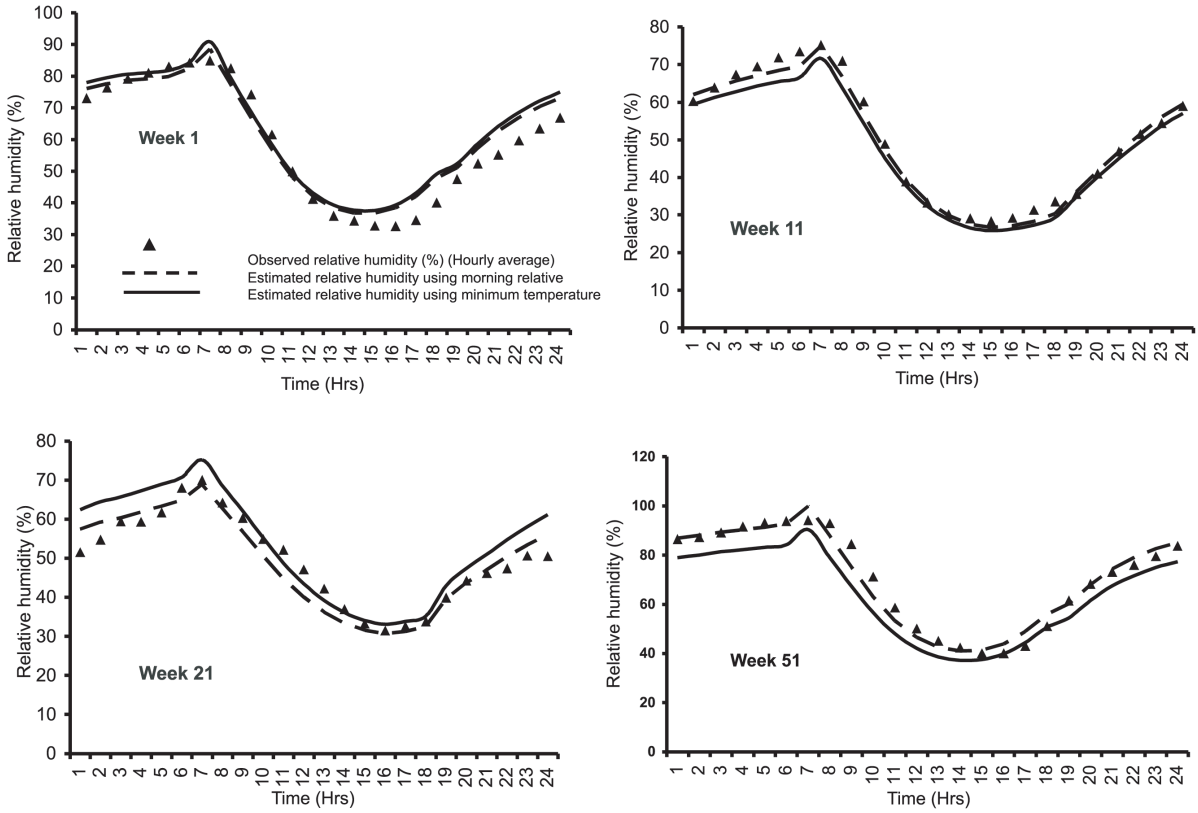


Fig.7 . Diurnal pattern of observed and estimated (using minimum temperature /morning relative humidity) during selected weeks at HRF, Hyderabad

2.2 Climate change

2.2.1 Trends in extreme events for selected locations in India

Trends in temperature extremes

Analysis of extreme temperature events indicated that percentage of cold nights (TN10p) was declining more significantly (p=0.01) at Akola, Anand, Ludhiana and Solapur and less significatly (p=0.05) at Mohanpur. Whereas, cold nights were rising only at Kanpur (p=0.01). Regarding trend in percentage of cold days, significant decreasing trend (p=0.05) was noticed at Anand, Bhubaneswar, Jabalpur and Kanpur and more significant decreasing trend (p=0.01) at Anantapur and Solapur. At the same time, percentage of cold days showed significant increasing trend at Akola and Bangalore with p level 0.05 and 0.01, respectively (Fig.8). Increasing trend in percentage of warm days (TX90p) was observed at Bhubaneswar, Jorhat, and Kanpur at 5 % significance and at Anantapur at 1% significance level. In case of warm nights (TN10p), they are rising at Akola and Jorhat (p=0.05) and also at Ludhainana and Samstipur (p=0.01). Warm nights at Bhubaneswar and Jabalpur are coming down (at 5% level) and also at Parbhani (at 1% level).

Trends in rainfall extremes

Annual total precipitation (PRCPTOT) showed significant (p=0.05) decreasing trend at Jorhat station. Parbhani and Raipur showed significant (p=0.05) increasing trend and Akola exhibited significant decreasing trend in maximum 1-day precipitation (RX1day). Only Raipur has shown increasing trend in extreme wet days (R99p) at 5 % significant level and other stations have not shown any trend in very wet days (R95p) and maximum 5-day precipitation (RX5day) index (Fig.9.)

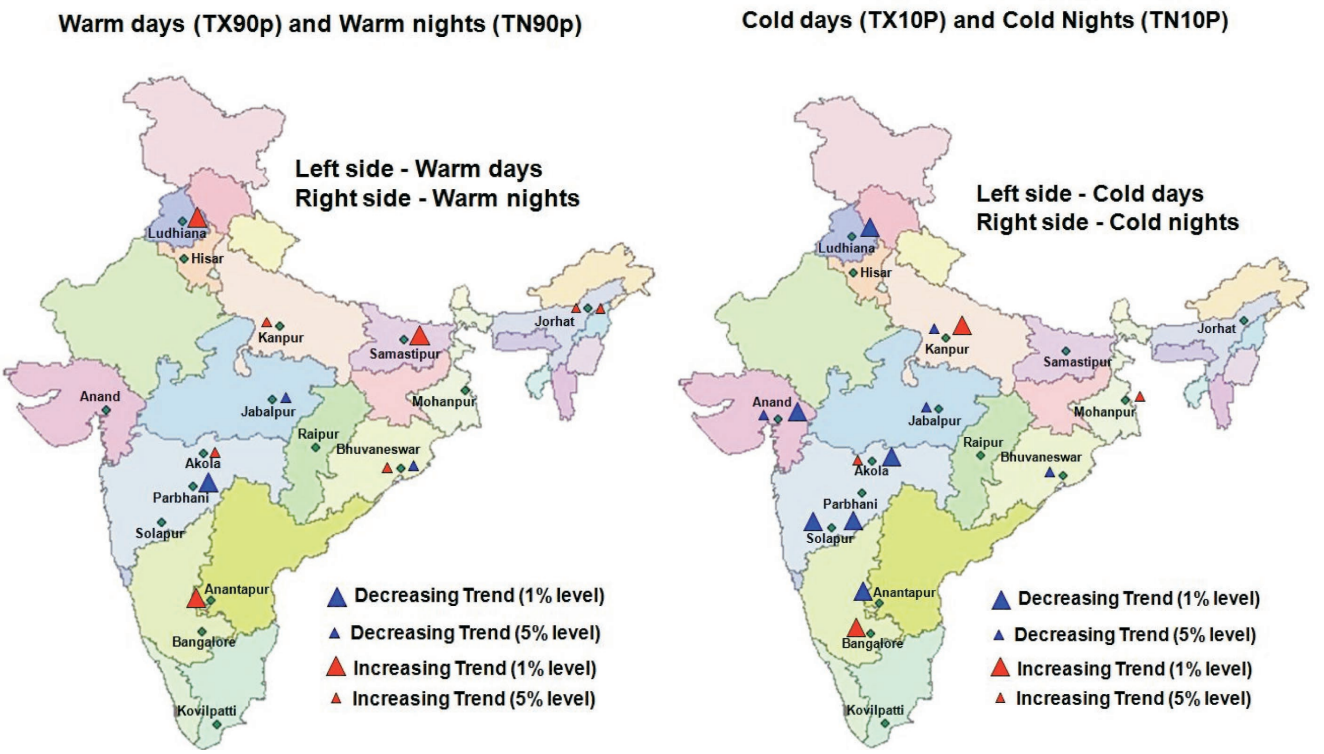


Fig. 8. Trends of cold days and cold nights and warm days and warm nights

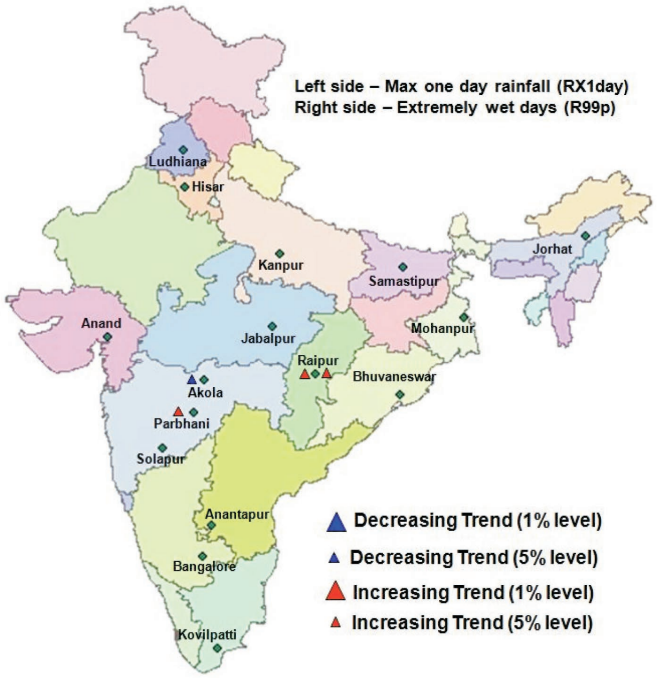


Fig. 9. Trends in rainfall extremes

2.2.2 Evaluation of the PRECIS (HadRM3) model for rainfall

Comparison was made between HadRM3 model predicted rainfall data (Baseline - 1961-2009, 2021-2050 and 2071-2100) of nearest grid point to the selected stations (Anantapur, Mahabubnagar, Akola and Solapur) and the observed rainfall data (1961 – 1990) of these selected stations. For this study A1B scenario was considered, as it is giving emphasis on balanced usage of all energy sources. At Anantapur, model predicted baseline rainfall was close to the observed rainfall in all the months except May, September and October. During 2071-2100 less rainfall is expected during May to November period, the main crop growing season than observed rainfall of 1961 – 1990 (Fig.10). Model predicted baseline monthly rainfall data followed similar pattern as the observed rainfall at Mahabubnagar. Model has slightly overestimated rainfall amount in the months of February to April and July and underestimated the rainfall from August to October months. Decreased rainfall

activity is simulated during May – June and September to November period. During 2071-2100, reduced amount of rainfall is expected in June to October compared to observed rainfall of 1961 – 1990.

At Akola, model predicted baseline rainfall data has closely followed the observed rainfall (1961 – 1990) in all months except in July and September, where model predicted rainfall overestimated than observed one. Higher rainfall has been predicted in almost all months during 2021 – 2050 and 2071-2100, when compared to baseline rainfall. Model predicted baseline monthly rainfall and observed rainfall has followed same trend in all months except July to October at Solapur. Decline in rainfall is expected in June, September and October months during 2071-2100 compared to observed baseline rainfall.

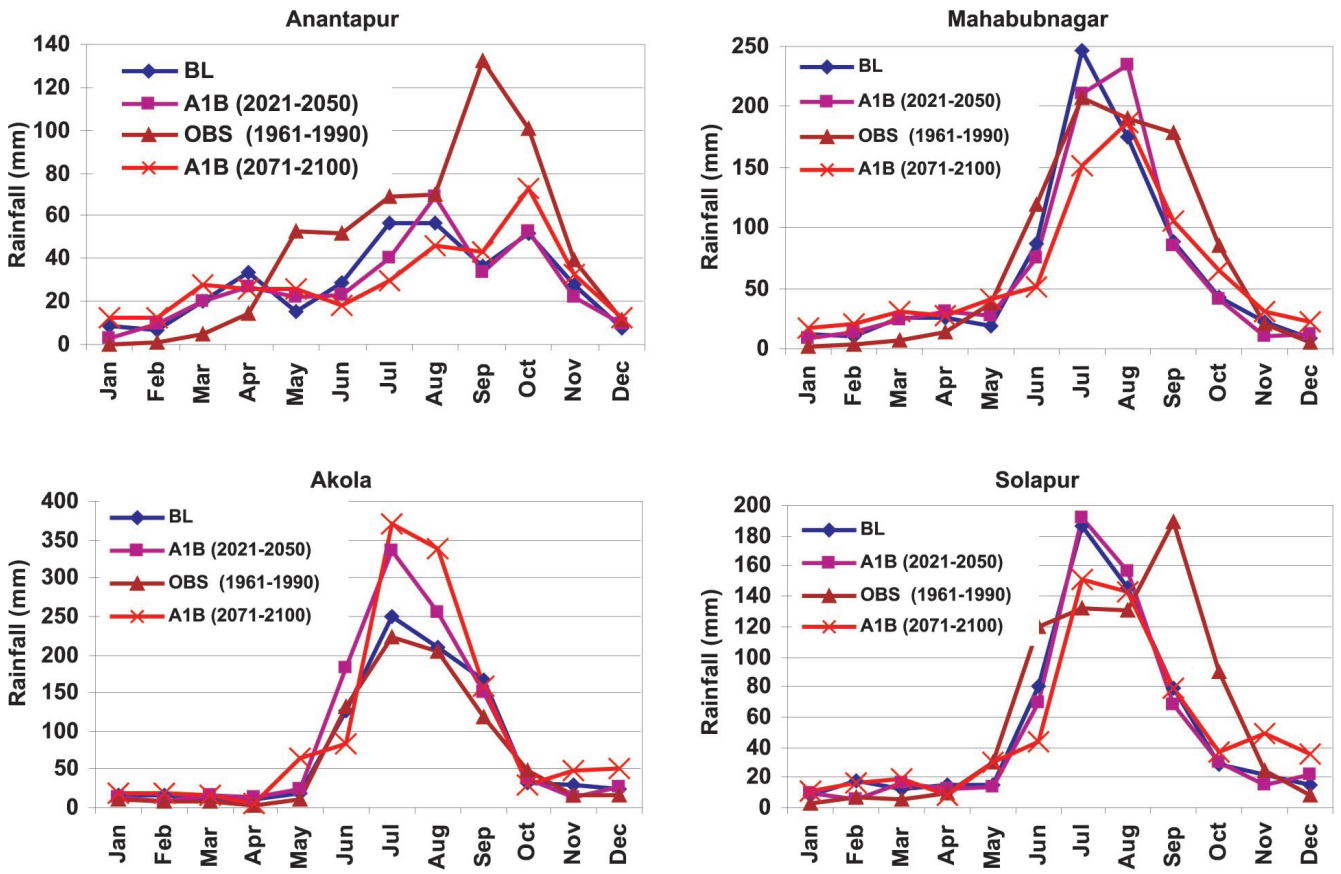


Fig.10. Evaluation of model predicted rainfall with observed rainfall data at selected stations

2.2.3 Impact of elevated carbon dioxide and cropping on soil organic carbon pools and nutrient status

Profile based soil samples were collected from open top chambers (OPC) with elevated CO_2 levels of 300, 550 and 700 ppm along with fallow and control (cultivated) after 4 years of intensive cropping to study the impact of intensive cropping under elevated CO_2 on soil organic carbon pools and nutrient dynamics. Soils are neutral to slightly alkaline in reaction and belong to Alfisols. Soil texture is sandy loam, non-saline, non calcareous with low water retention capacity. Increased carbon dioxide levels improved soil organic carbon status from 0.36 % (Fallow) to 0.55 % (700 ppm) registering 52 % increase over uncultivated fallow

(Fig 11). Compared to cultivated control the increase in soil organic carbon in 700 ppm treatment was 37 %. However, the improvements in soil organic carbon content were more conspicuous at 300 ppm CO_2 and further increase in CO_2 levels at 550 ppm and 700 ppm had not resulted in soil organic carbon improvement to that extent. Profile mean (0-60 cm) soil organic carbon content increased from 0.25 % (fallow) to 0.37 % at 700 ppm CO_2.

Soil organic carbon, microbial biomass carbon (MBC) levels improved substantially with increase in CO_2 levels from 300 to 700 ppm. Uncultivated fallow showed the lowest MBC (39.1 ug/g) and cultivated control showed slightly higher MBC levels (43.4 ug/g) over control. Highest MBC was recorded (141.6 ug/g) with 700 ppm CO_2. In second layer of soil (10-20 cm) also the improvements in MBC levels were significant from 38.1 ug/g (fallow) to 126.4 ug/g (700 ppm). Deeper layers maintained lower MBC levels. This indicates, MBC pool of soil organic carbon is more sensitive to elevated carbon dioxide levels as compared to total organic carbon in soil.

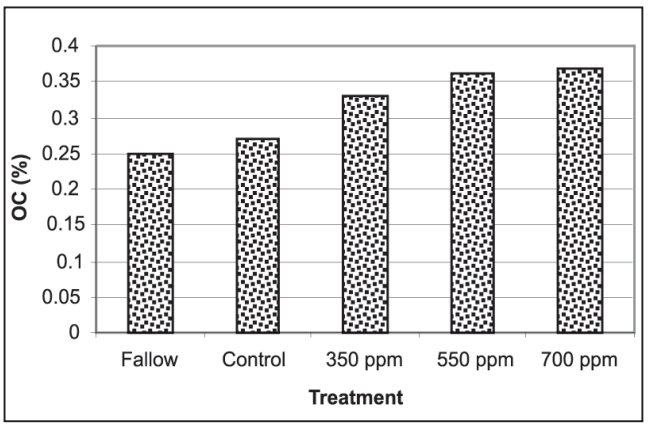


Fig 11. Impact of elevated CO2 and cropping on profile organic carbon

Increase in carbon dioxide levels up to 700 ppm depleted soil nutrients drastically as compared to fallow and cultivated control. Available N content decreased from 210 kg/ha in cultivated to fallow to 151 kg/ha at 700 ppm CO_2 after 5 years of intensive cropping. As such most of the rainfed soils are low in available N (<280 kg/ha). Higher biomass production at elevated CO_2 levels resulted in mining of soil nutrients such as available P from 62 kg/ha (Cultivated control) to 31 kg/ha (700 ppm), available K from 198 (fallow) to 129 kg/ha (700 ppm), available Zn from 0.71 mg/kg (fallow) to 0.34 mg/kg (700 ppm) and available Fe from 3.5 mg/kg (fallow) to 1.7 mg/kg (700 ppm).

2.2.4 Impact of elevated CO_2 on plant nitrogen use efficiency

Plants nitrogen use efficiency (NUE) is most critical for efficient use of N fertilizers. Elevated CO_2 concentration enhances the biomass production and yield. Nitrogen is the nutrient that is often limiting growth and yield. Sunflower (Variety DRSF-1) plants were grown in OTC's at ambient (370 ppm) and elevated CO_2 (550 & 700ppm) conditions with recommended dose of nitrogen (N1) and 50% higher nitrogen (N2) in red loamy soils to study the nitrogen use efficiency under elevated CO_2 conditions. Phosphorus and potassium were applied as recommended.

Estimation of nitrate reductase (NR) and glutamine synthetase (GS), the two important enzymes of nitrogen assimilation was carried out from the leaves at peak vegetative stage. NR and GS activity decreased at 700ppm compared to ambient conditions (Table 5). There was no significant difference in NR activity with higher level of nitrogen but GS activity increased with increase in nitrogen supply. Similarly higher nitrogen supply recorded higher shoot N % in ambient conditions compared to 700 ppm. Leaf photo synthesis and biomass increased significantly with elevated CO_2 and nitrogen supply.

Table 5 : Effect of Elevated CO_2 and Nitrogen levels on NR, GS activity and N % in sunflower

CO_2 levels (C)	Nitrate Reductase (NR) activity (µ moles nitrate reduced g^{-1} FW h^{-1}) Nitrogen levels (N)		LSD's at P=0.05
	N1	N2	
380 ppm	3.33	3.57	C= NS N = NS
550 ppm	3.35	3.41	CxN= NS
700 ppm	3.19	3.07	
Glutamine Synthetase activity (µ moles Glutamyl hydroxamate formed g^{-1} FW 15 min^{-1})			
380 ppm	95.2	102.9	C= NS N = NS
550 ppm	92.2	101.2	CxN= NS
700 ppm	88.8	95.6	
Shoot Nitrogen (N%)			
380 ppm	3.56	3.96	C= NS, N=NS
550 ppm	3.54	3.7	CxN=NS
700 ppm	3.45	3.54	

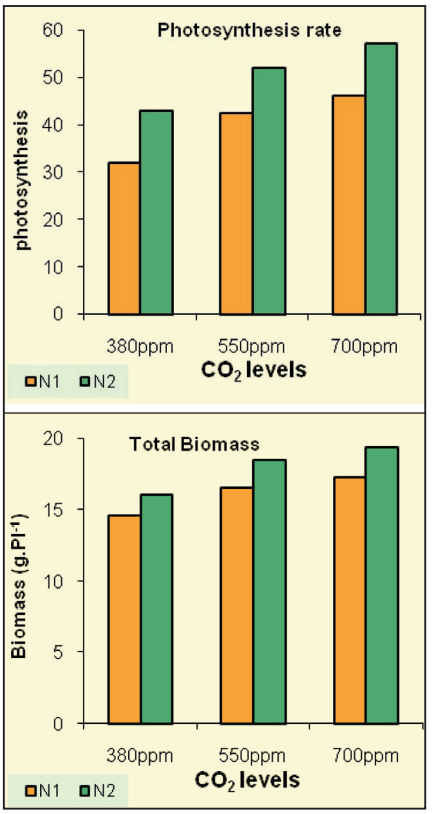


Fig.12. Effect of elevated CO_2 on photosynthetic rate and total biomass of sunflower

2.2.5 Response of black gram genotypes to elevated CO_2

Black gram (*Vigna mungo* (L.) Hepper) is one of the major grain legumes in the rainfed agro-ecosystems of India. It is an important source of protein and cultivated as short duration rainfed crop in semiarid areas. Eighteen genotypes of black gram obtained from NBPGR including three national checks *viz.* LBG-20 from Andhra Pradesh, PU-19 from Punjab and T-9 from Tamil Nadu were studied for their variability in response to higher levels of CO_2. The genotypes were evaluated at ambient (380ppm) and two elevated levels of CO_2 (550ppm & 700ppm) in open top chambers.

The results showed that black gram genotypes recorded significant variability in response for both biomass and grain yield at both elevated CO_2 levels. The average total biomass of eighteen genotypes increased from 22.28g/pl at ambient to 24.12 g/pl at 550ppm and 25.70 g/pl at 700ppm CO_2, there by showing an overall improvement of 11.27% and 19.57% at 550ppm and 700ppm respectively over ambient control (Table 6). The range of different genotypes response to CO_2 levels for total biomass varied from -34.73% to 74.25% at 550ppm and 27.07 to 106.26 % at 700ppm. The average seed yield of eighteen genotypes improved from 8.25 g/pl at ambient to 9.38 g/pl and 10.48 g/pl at 550ppm and 700ppm, respectively (Fig. 13), thereby showing an average increment of 21.37% and 36.64% at 550ppm and 700ppm CO_2 levels respectively over ambient control. The genotypic variation in response to increased CO_2 for seed yield ranged from 59.77 to 161.70% improvement at 550ppm and 27.80% to 216.69% at 700ppm over ambient control. The average pod number per plant for eighteen genotypes showed an increase of 7.21% at 550ppm and 22.16% at 700ppm over ambient chamber control and the response of pod number with enhanced CO_2 ranged from 35.97% to 106.56% improvement at 550ppm and 34.09 to 103.28% at 700ppm. The interesting observation about different black gram genotypes was that

elevated CO_2 condition did not elicited similar response in all the genotypes. However, the increased CO_2 improved the overall performance for both biomass and seed yield. A significant variability in response of different genotypes was observed for both biomass and seed yield. Among the selected three checks PU-19 was the best under ambient condition for all the biomass and yield characters. However the response of this genotype was not linear with increasing CO_2 concentration. At ambient level CO_2 only three genotypes were better than the best check for biomass and two genotypes for seed yield. The number of genotypes performing better than best check was two at 550ppm and three at 700ppm for biomass and this was ten and four for seed yield at respective CO_2 levels. These results clearly indicating that the selected genotypes are not showing similar response in terms of magnitude as well as trend with increased CO_2 concentration for all the characters studied.

Table 6 : Effect of elevated CO_2 on yield attributes of black gram genotypes (mean of 18 genotypes)

Parameters / plant	Ambient	550ppm	700ppm
Total biomass(g)	22.3	24.1 (8.3)	25.7 (15.4)
Fodder weight (g)	14.0	14.7 (5.1)	15.2 (8.4.1)
Number of pods	39.4	40.5 (3.0)	46.7 (18.7)
Pod weight (g)	12.7	14.0 (10.0)	15.8 (24.8)
Seed number	187	200 (7.0)	216 (15.7)
Seed Yield (g)	8.3	9.4 (13.6)	10.5 (24.8)
100 seed weight (g)	4.46	4.83 (8.2)	4.95 (10.8)
Harvest Index (%)	36.8	38.7 (5.1)	40.5 (10.1)

* Figures in parenthesis are the % increase over ambient control

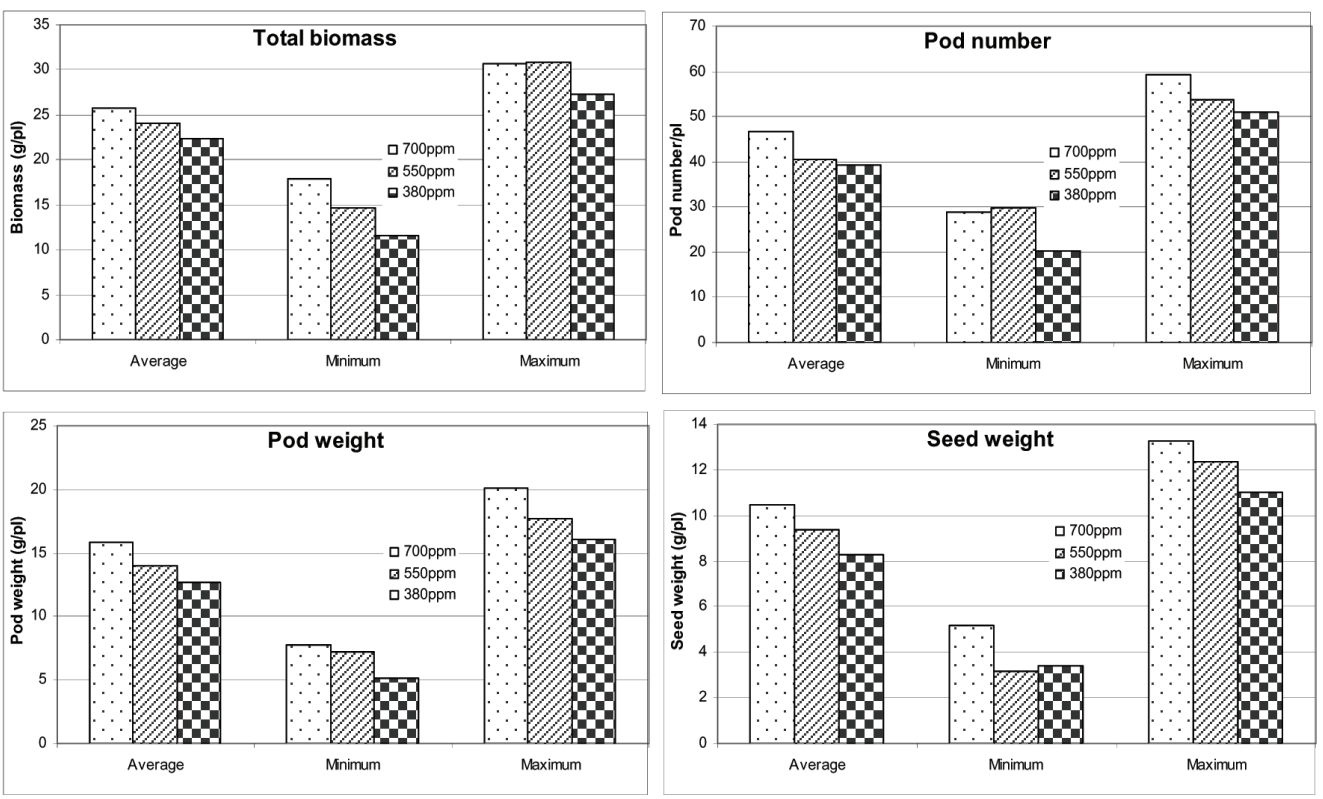


Fig. 13. Average, minimum and maximum values of total biomass, pod number, pod weight and seed yield of eighteen black gram genotypes under two elevated CO_2 levels (700ppm & 550ppm) and ambient (380ppm) control

2.2.6 The interactive effect of increased CO_2 and temperature on sunflower growth and yield

Sunflower (*Helianthus annuus L.*) is one of the important oilseed crops grown in many countries and contributes more than 20% of oilseeds production of the world. Sunflower oil is valuable edible oil that contains more Vitamin E than any other vegetable oil, while the meal is used in animal feed industry.

Sunflower crop can be raised in all the seasons' *viz.*, kharif, post rainy, summer due to its wider adaptability, high yield potential and shorter duration. In order to assess the impact of increased concentration of CO_2 on growth, seed yield and partitioning at different temperature ranges, the sunflower crop was raised during October 2009 to January 2010 wherein the anthesis and seed filling stages experience the temperatures below 35°C (Fig. 14). Similarly to attain more than 40°C during these phenophases, the second crop was raised during January to May 2010 in Open top chambers (OTCs). The crop was sown in 18L plastic buckets and raised at 550ppm and 700ppm CO_2 concentrations along with ambient (380ppm) control in OTCs.

During the cool season the sunflower crop showed an improvement of biomass and grain yield of 45.19% and 46.09% at 700ppm and 18.68% and 20.86% at 550ppm over ambient control. The response for these parameters for the warm season was -3.30% and -1.76% for biomass and 3.16% and 8.74% for seed yield at 700ppm and 550ppm CO_2 concentrations respectively over ambient control. However the response of HI showed more positive response during warm season under elevated CO_2 levels over ambient control as compared with cool season. A significant decrease was observed for the total number of seeds and increase in the number of unfilled seed due to higher temperatures during flowering and seed filling at elevated CO_2 levels. This was the major contributing factor for reduced response for seed yield at elevated CO_2 levels during warm season as compared with cool season. The reduction in biomass was more at all CO_2 levels compared with seed yield with higher temperatures in this particular sunflower hybrid KBSH-1. It is interesting to note that with enhanced CO_2 the sunflower maintained a positive increase of HI in both summer (6.4-12%) and winter (1.8-2.1%) over ambient control (Fig 15). This trend indicating a compensatory mechanism due to higher CO_2 levels i.e., the elevated CO_2 is promoting the mechanism towards better partitioning in both the seasons with varying temperatures.

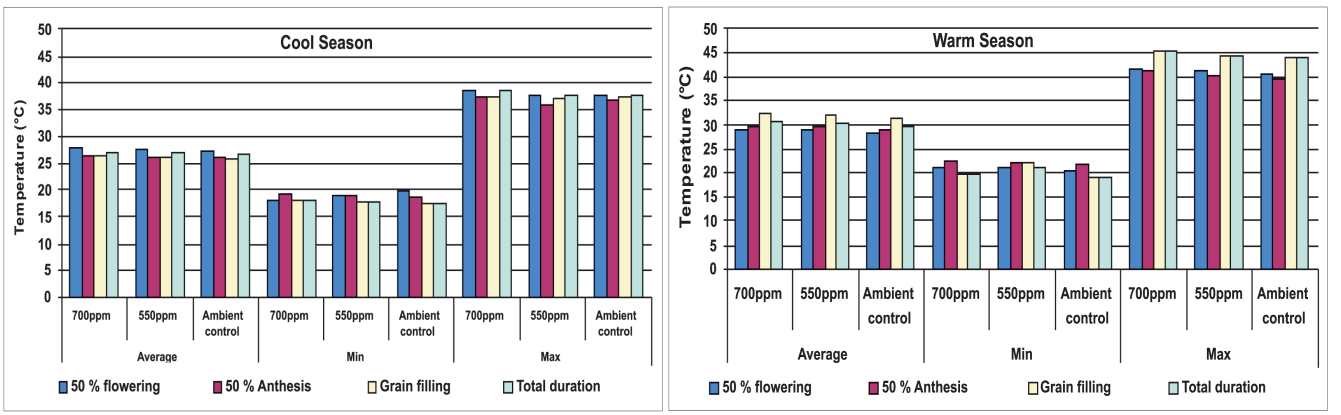


Fig 14. Minimum, maximum and average temperatures of cool season and warm season during different pheno-phases of sunflower (KBSH-1)

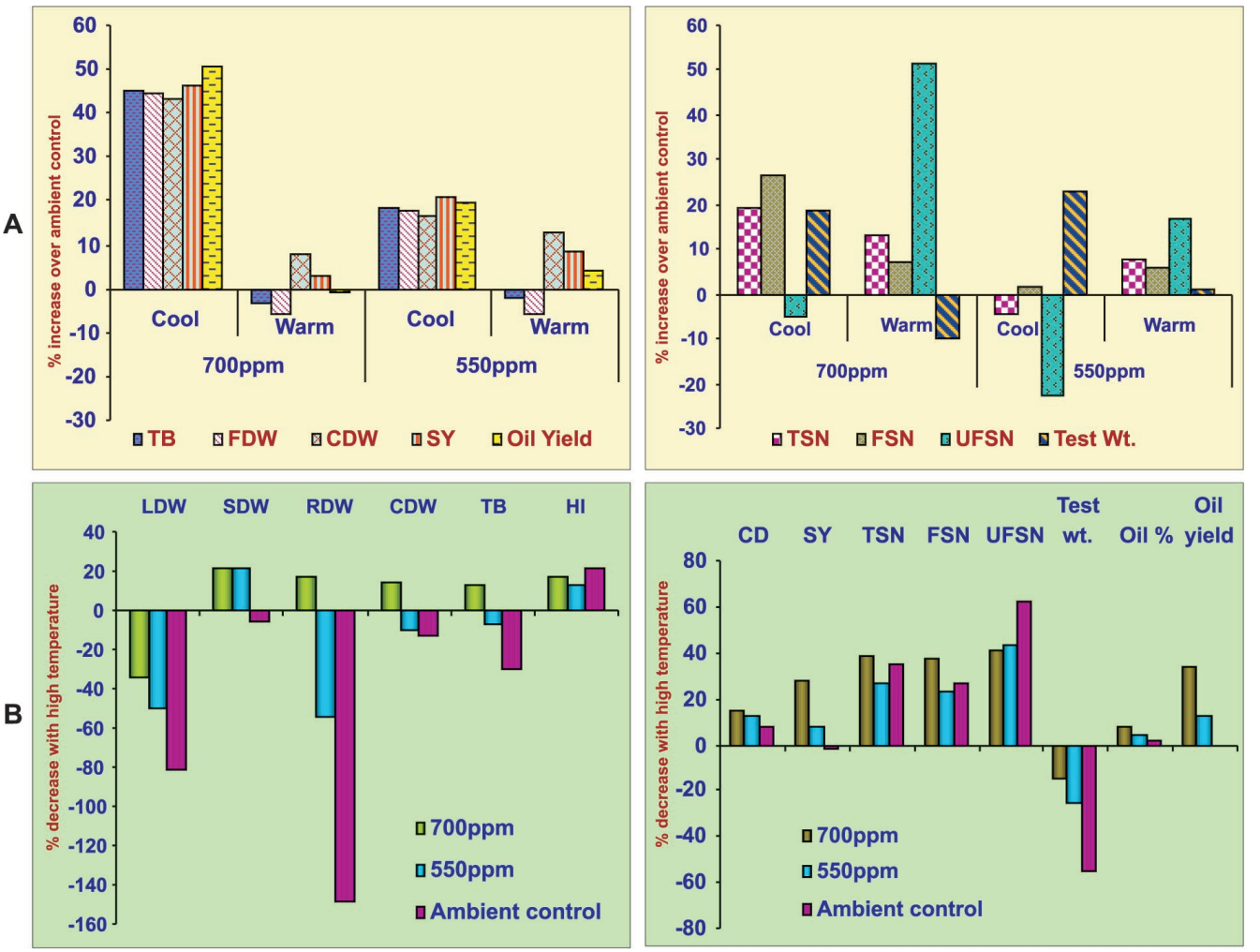


Fig.15. Interaction of increased CO_2 and temperature - Impact on different biomass and yield components of sunflower (KBSH-1) a. the increase (%) in response due to increased CO_2 concentration in both the seasons; b. decrease (%) in different components due to high temperature at different CO_2 levels (TB-total biomass; FDW-Fodder dry weight; CDW- Capitulum dry weight; SY- Seed yield; TSN- Total number of filled seed; FSN- Filled seed number; UFSN- un-filled seed number; LDW- leaf dry weight; SDW- Stem dry weight; RDW- Root dry weight; HI-

2.2.7 Modeling the performance of sorghum and maize in the dryland areas under of climate change

Climate change in terms of changing temperature, rainfall and atmospheric CO_2 concentration is very likely to affect dryland agriculture and farmers need to have a suitable crop to tackle the threat, which can support both sustainable productivity as well as their livelihood. A study was undertaken to assess the comparative suitability of kharif sorghum and maize in the dryland areas using DSSAT crop simulation model with standard inputs and practices and to compare current productivity level with that of under climate change scenarios. Sorghum (CSH-6) and Maize (PB-8) were tested for potential as well as rainfed conditions in few selected dryland locations of AP, Rajasthan and Maharastra. Crops were simulated (DSSAT: CERES-Sorghum and CERES-maize) under normal package of practices and to ensure potential condition 5 cm of irrigation water was provided whenever soil moisture depleted below 50% of field capacity level. The simulation periods varied from 20 to 30 years depending on climatic data

availability. Crop performance under climate change scenarios were studied using HadCM3: A2a scenarios for 2020 and 2050 and enhanced CO_2 was tested for current 360 ppm and future 450 ppm levels. The crops were subjected to different possible drought scenarios and evaluated their performance.

The results (Fig.16) revealed a range of potential production capacity for kharif maize starting from 1379 kg/ha at Dapoli (lowest) to 3512 kg/ha at Arjia (highest). The average potential yield among the locations is 2530 kg/ha and Hyderabad, Anantapur and Arjia recorded yield potential above the average value. However, maize yield potential of locations from the state of Maharastra falls below the average level.

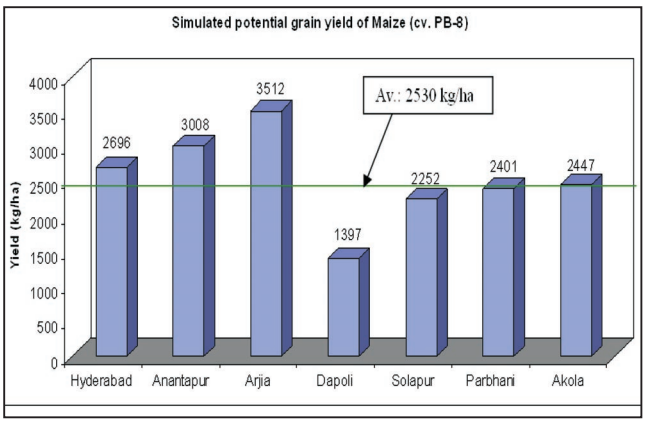


Fig. 16. Simulated potential grain yield of maize (cv. PB-8) at different dryland locations of India

Maize, being a C4 plant, is expected to perform very positively under changing temperature and rainfall conditions during 2020 and 2050. Among the locations at Arjia maize grain yield may increase by 1.6 fold from 1656 kg/ha now to 2700 kg during 2020 and 2050's followed by Hyderabad (1.5 fold) and Anantapur (1.3 fold). More than two fold increase in grain yield is expected at Dapoli from the present 862 kg/ha to 1845 kg/ha during 2020's but may fall marginally by 2050's. At Solapur, Parbhani and Akola the future projected grain yields are likely to fall compared to present level (Fig. 17).

If the level of atmospheric CO_2 increases from current 360 ppm to 450 ppm by 2020 and the same level is maintained up to 2050 then the adverse impact of change in temperature and rainfall regimes may be nullified and maize grain productivity is expected to increase from marginal to moderate extent in all the locations except at Dapoli. Gain in grain productivity is most spectacular at Hyderabad, followed by Anantapur and Arjia, in absolute terms, under projected scenarios compared to current level (Fig. 18).

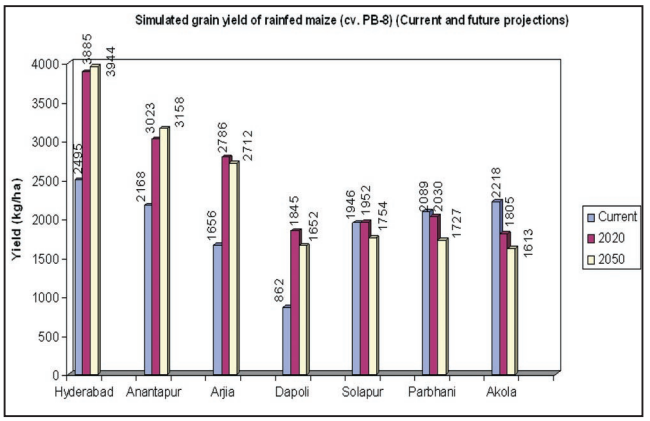


Fig. 17. Simulated grain yield of rainfed maize (cv. PB-8) (Current and future projections)

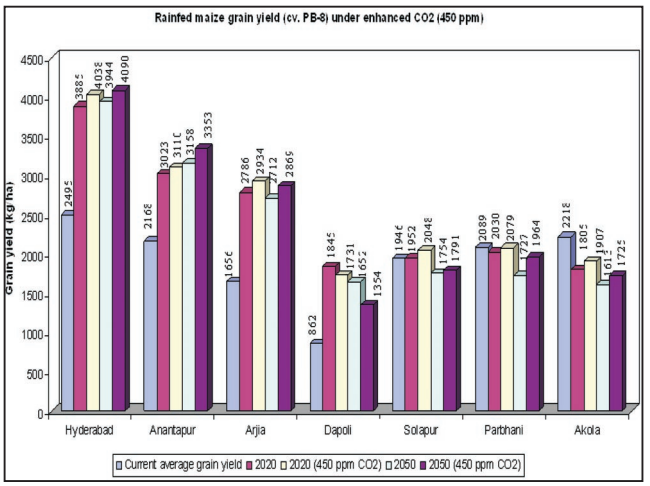


Fig. 18. Rainfed maize (cv. PB-8) grain productivity under enhanced CO_2 (450 ppm) scenario by 2020 and 2050 at different dryland locations

2.2.8 Impact of climate change on crop pests

A study was carried out to understand the effects of elevated CO_2 on leaf quality of castor *(Ricinus communis)* and its impact on growth characteristics of leaf feeding caterpillar, *Achaea janata*. Castor plants were grown under three CO_2 conditions inside OTCs viz., 550 ± 25 ppm, 700 ± 25 ppm and ambient CO_2 (350 ± 25 ppm). The feeding trials were conducted using neonate larvae *A. janata* and continued up to four generations maintaining the CO_2 treatment associations. All four generations received foliage from the same respective CO_2 growing conditions. Longer larval duration, differential pupal weights, reduced fecundity and increased larval survival rates of *A. janata* in successive four generations under elevated CO_2 compared to ambient CO_2 was observed. An increase of approximate digestibility (AD) and relative consumption rate (RCR), decreased efficiency of conversion of ingested food (ECI), efficiency of conversion of digested food (ECD) and relative growth rate (RGR) was recorded in four generations under elevated CO_2 than ambient. Significantly lower larval individuals and food consumption was observed in second, third and fourth generations of *A. janata* when fed on castor grown under elevated CO_2 conditions compared to ambient. The impact of CO_2 concentrations and generation was significant on potential number of larvae of insect species. Significantly lower individuals was observed over generations ($F_{3, 36}$=190.04, P=<0.01) and across CO_2 conditions ($F_{2, 8}$ = 7.83, P =<0.01). The interaction between CO_2 levels and generations was found significant ($F_{6, 36}$ =4.74, P=<0.05). The potential larval individuals were reduced by 0.84, 12.15 %; 10.32, 29.34% and 19.82, 43.13% in second, third and fourth generations under two elevated CO_2 conditions, respectively. The total number of eggs laid by all females was significantly affected by CO_2 levels ($F_{2, 8}$= 13.30, P =<0.01) and generation ($F_{3, 36}$= 150.25, P =<0.01). The interaction between CO_2 conditions and generations was also found significant ($F_{6, 36}$ =7.13, P=<0.01). Similarly the 'potential population increase index' for successive generations was found lower in elevated CO_2 than those in the ambient. The index values were calculated with respect to first generation and values were depicted in the from second to fourth generations. The Index values were 130.95 ± 10.42 in second generations, 135.58 ±15.85 in third generation and 136.51±16.51 in fourth generation of *A. janata* fed on castor grown under 550 ppm CO_2. These index values were still lower under 700 ppm (range 116.36 to 125.39) than ambient (146.08 to 158.35). The percent reduction of index under elevated CO_2 was in the range of 10.35 - 20.54 than ambient and decrease of index was more evident in second to fourth generations (Fig 19).

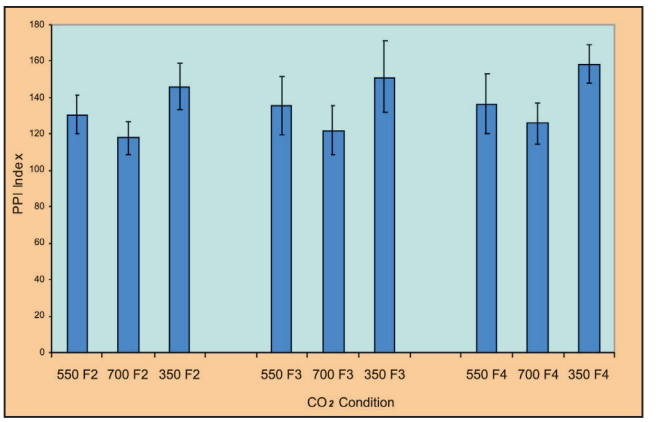


Fig. 19. Potential population increase (PPI) index values in successive generations of *A.janata* on castor under elevated CO_2 conditions

2.2.9 Analysis of severer incidence of *Spodoptera litura* on soybean

S. litura is a serious defoliator on soybean in Maharashtra. Its seasonal incidence was observed to be low in 2010 kharif season compared to the previous year (Fig 20). The incidence was between 3-6 larvae per meter row in 5 blocks in two districts compared to above the economic threshold level of 6 larvae/m row length in 44 blocks in 5 districts during kharif 2009. Further, a delay of 3 weeks was noticed in its peak incidence during 2010. Rainfall and temperature were the two weather

parameters that were significantly different in these years. Weekly rainfall and maximum temperature from the pest affected tehsils were analysed.

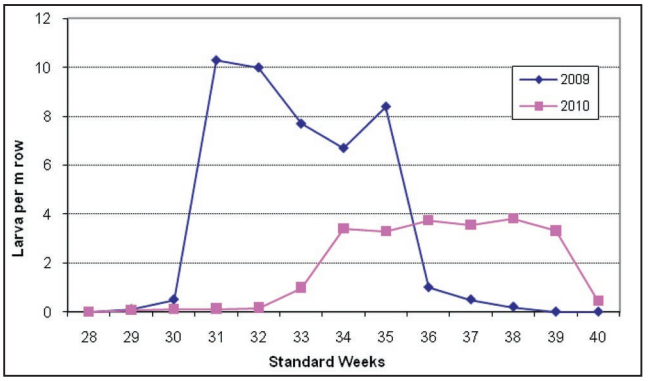


Fig. 20. *S. litura* incidence pattern on Soybean during 2009 and 2010

It was observed that kharif 2010 experienced widespread and frequent rainfall during the months of June, July, August and September. The season witnessed 1.8 fold increase in number of rainy days during the period 9th July to 19th August and 2.1 fold increase in number of rainy days during 27th August to 16th September compared to the corresponding periods in 2009 (Table 7). Similarly in 2010, there was a 4 fold increase in rainfall events of >40mm/day during 9th July to 19th August and 6.8 fold increase in intense rainfall events during the period 27th Aug to 16th September when compared to the corresponding periods in 2009 season.

Rainfall events above 40 mm/day are likely to affect insect vulnerable stages such as pre-pupal stage and adult moth activity and thereby influence the fecundity. This in turn adversely affects the population growth potential which is clearly reflected in the low larval population counts under field conditions. The number of rainfall events > 40 mm are significantly higher during both the seedling stage (July) and flowering stage (August) in 2010 compared to 2009 which explains the lower population levels in this season on soybean. Due to low population growth rate there is a delay in

Table 7: Mean number of rainy days (≥2.5mm/day) and events (>40 mm/day) in six blocks during 2009 and 2010.

Rainfall	23-27 SW (4 June-8 July)		28-33 SW (9 July-19 Aug)		35-37 SW (27 Aug-16 Sept)	
	2010	2009	2010	2009	2010	2009
Rainy days	12.3	9.2	23.1	12.9	10.7	5.1
Rainy days with>40 mm	1.9	1.4	5.6	1.4	3.4	0.5

the peak period in 2010 (Standard weeks 34-37) in 5 affected blocks compared to 2009 (Standard weeks 31-32) in 44 blocks. The excess rainfall and soil moisture saturation coupled with below normal temperature (-1 to -4°C) resulted in less incidence of *S.litura* (Fig. 21 & 22).

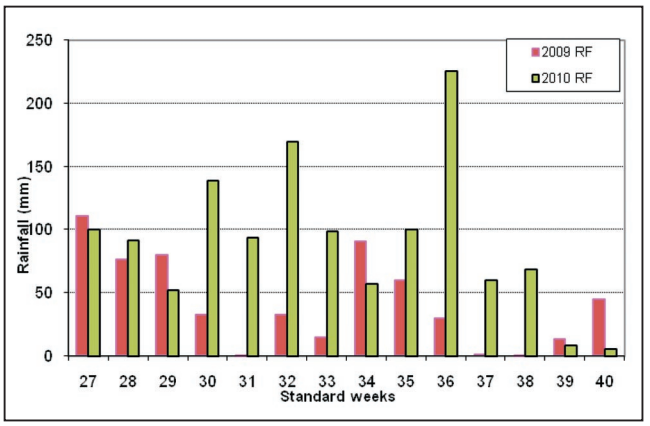


Fig. 21. Rainfall distribution in pest affected tehsils during 2009 and 2010

Fig 22: Maximum Temperature deviation during 2009 and 2010

Field cage studies to assess pre-pupal survival and adult moth emergence

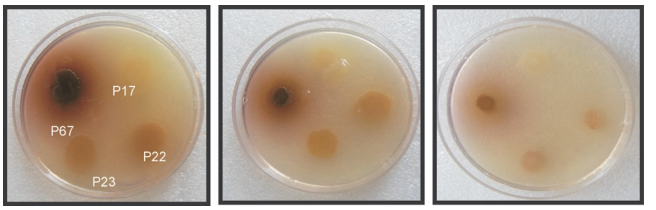
Laboratory studies at CRIDA to assess the effect of saturated soil moisture provided by irrigation to simulate rainfall events on pre-pupal survival and subsequent adult emergence of *S.litura* at different temperatures and two soil types indicated significant adverse impact. When irrigation was provided to simulate a rainfall event to the soils on the second day of pre-pupal stage, adult emergence was to the extent of 33.3% in red soil and 26.7% in black soil whereas in control it was 70% and 66%, respectively. These results explained the low incidence of the pest during August 2010.

2.2.10 Adaptation of plant pathogens and their bio control agents to elevated CO_2 and temperature

To understand the impacts of climate change and variability on plant pathogens and their natural enemies, studies have been initiated on *Sclerotium rolfsii, Macrophomina phaseolina, Fusarium oxysporum* f.sp. *ricini, Botrytis ricini* and *Rhizoctonia solani* which are important soil borne pathogens. Similarly, impacts are also studied on common biocontrol agents namely *Pseudomonas* spp. and *Trichoderma viride*.

Impact of elevated CO_2 on functional and biochemical properties of *Pseudomonas* spp

Four *Pseudomonas* isolates were evaluated for the impact of elevated CO_2 (700 ppm) on their functional and biochemical characterization. All the isolates were positive for siderophore and ammonia production on both the elevated CO_2 and normal conditions after eighty generations. Siderophore, lipase and IAA production by all the *Pseudomonas* isolates gradually reduced at elevated CO_2.



Ist generation 40th generation 80th generation

Lipase production of *Pseudomonas* spp. as influenced by elevated CO_2 conditions

There was a marginal increase in phosphorus solubilising ability of the *Pseudomonas* isolates when exposed to elevated CO_2 conditions over 80 generations. Across the strains, the ability did not drastically change (Fig. 23).

IAA production also decreased across the test isolates of *Pseudomonas*. In P22, the reduction was substantial as compared to P67 after 80 generations of exposure to 700 ppm CO_2 (Fig. 24).

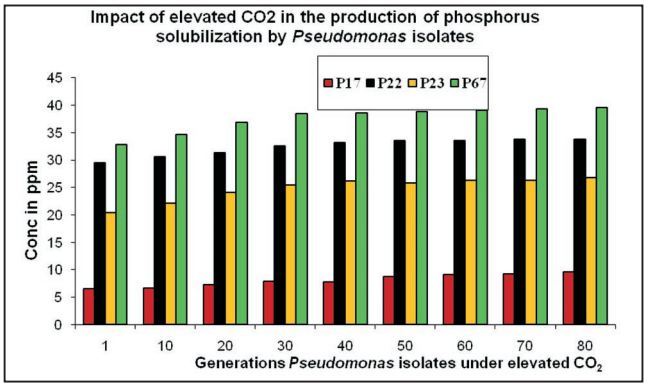


Fig. 23. Phosphorus solubilization by strains of *Pseudomonas* spp. as influenced by elevated CO_2 conditions

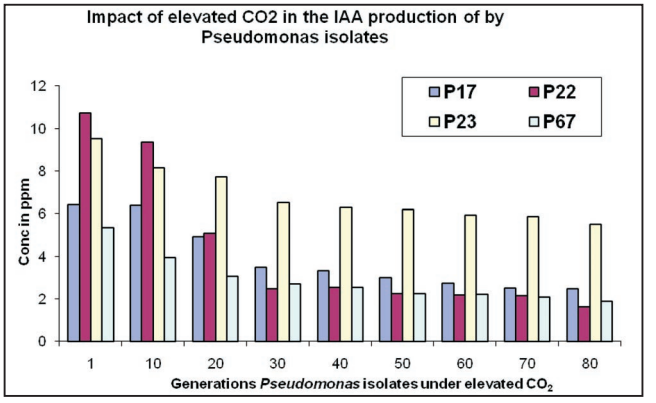


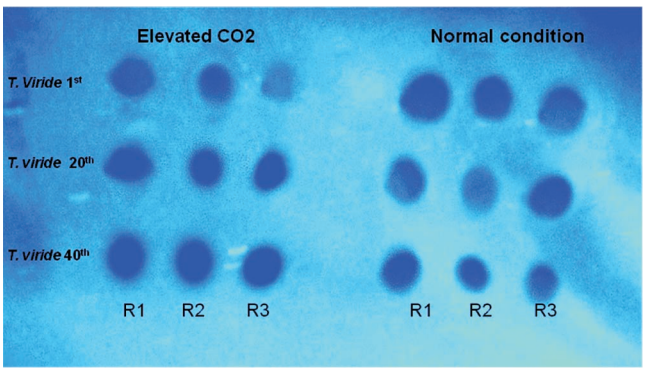
Fig. 24. IAA production by all the *Pseudomonas* isolates gradually reduced under elevated CO_2 at different generations

Impact of elevated CO_2 on antagonistic activity of *Pseudomonas*

Effect of elevated CO_2 (700 ppm) on *in-vitro* biocontrol efficacy of *Pseudomonas* isolates viz. 17, 22, 23 and 67 was tested against four *Macrophomina phaseolina, Fusarium oxysporum* f.sp. *ricini, Rhizoctonia solani* and *Sclerotium rolfsii* by dual-culture assay *in vitro*. *Pseudomonas* isolates were specific for their antagonistic activity against particular fungi in different extent. Their capability of inhibiting the growth of pathogens varied considerably. For instance, per cent inhibition of *S. rolfsii* by P17 and P22 exposed for 40 generations to elevated CO2 (700 ppm) showed 23% and 48% biocontrol ability as compared to 67% inhibition in control by both isolates. However, biocontrol ability of P23 against *F. oxysporum* f.sp. *ciceri* increased slightly (44%) as against control (40%) after 40th generation of exposure to 700 ppm CO_2 concentration.

Impact of elevated CO_2 on the morphology and physiology of *Trichoderma viride*

Chitinolytic activity of *T. viride* was tested using dot-blot assay. *T. viride* when exposed for 40 generations to 700 ppm CO_2 produced maximum chitinase compared to control. Similar results were found on minimal agar plates with 0.1% colloidal chitin where chitinolytic activity was measured as clear halo around the fungal colony. Maximum clearing zone of 37 mm was recorded in *T. viride* after 40th generation of exposure to 700 ppm CO_2 as compared to control.



Chitinase production by *Trichoderma* under elevated CO_2 after different generations of exposure

Impact of elevated CO_2 on biocontrol ability of *Trichoderma viridae*

Effect of elevated CO_2 on the *in vitro* bio-efficacy of *Trichoderma* against four phytopathogens viz. *Macrophomina phaseolina, Fusarium oxysporum* f.sp. *ricini, Rhizoctonia solani* and *Sclerotium rolfsii* was observed by dual culture assay. The per cent inhibition in radial growth of all pathogen under elevated CO_2 was recorded significantly higher than the normal condition. Antagonistic activity of *Trichoderma* isolates increased gradually under elevated CO_2. In these studies, both pathogens and *Trichoderma* were exposed for 40 generations to elevated CO_2 conditions and then dual culture assays were conducted in various combinations. When both *Sclerotium rolfsii* and *Trichoderma* were exposed for 40 generations, the % inhibition was 33% as compared to control where both wild strains were used (27%). When 40th generation *Trichoderma* and 1st generation *S. rolfsii* were used, the inhibition was 30%. This suggests that the interactions of pathogen-biocontrol agent might tilt in favour of biocontrol agent under elevated CO_2 conditions. Similarly, in *Macrophomina phaseoilina* and *Trichoderma* interactions studies, the % inhibition was 42% when both *M. phaseolina* and *Trichoderma* were exposed to elevated CO_2 for 40 generations. It was 38% for the combination of wild type *M. phaseolina* and 40th generation *Trichoderma* and it was 39% inhibition when the combination was 40th generation *M. phaseolina* and wild type of *Trichoderma*.

Impact of elevated CO_2 on pathogenicity of major soil-borne phytopathogens

Castor (*var*-DCS 9) was used to test pathogenicity of *Fusarium oxysporum* f.sp. *ricini* after exposure to 700 ppm CO_2 levels for 60 generations at 10 generations interval. The percent disease incidence and plant growth parameters were recorded after 30 days of sowing. The disease incidence by the 60th generation of *Fusarium oxysporum* recorded 50% which was significantly higher than the 1st generation pathogen where it was only 15% (Fig. 25).

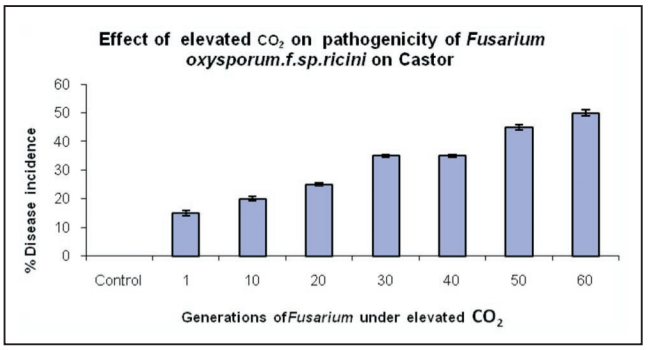


Fig. 25. Similar trends were recorded on pigeonpea inoculated with *Rhizoctonia solani*, *Macrophomina phaseolina* and *Sclerotium rolfsii*. However, the increase was considerably less in *M. phaseolina* as compared to other pathogens

2.2.11 Farmers' perceptions and adaptation measures towards climate variability in different agro-climatic regions of Andhra Pradesh

A study was conducted in Coastal, Rayalaseema and Telangana regions of A.P. with one district each from these regions. From each district three mandals, and from each mandal two villages were selected based on rainfall averages. About 10 farmers were selected from each village for data collection. In Anantapur district the chief perception regarding climate change is change in monsoon patterns viz., advanced onset of rains followed by dry spell during pod formation and flowering stage of groundnut. End of the season witnessed heavy cyclonic rains resulting in damage to the standing and harvested crop rendering it unsuitable even as fodder. Therefore, a shift in the regular sowing window of groundnut from July second week to June end was observed to avoid mid season drought and heavy rains at the end of season. Change in planting dates of groundnut and intercrop with red gram (8:1 or 12:1 ratios) are the major adaptation strategies of farmers to climate change. Crop insurance is another common adaptation followed against climate change. In Mehboobnagar district the chief perception regarding climate change is change in monsoon patterns viz., timely onset of rains followed by dry spell during middle flowering stage. The end of the season witnessed heavy continuous rains resulting in damage to the standing crop as a result of pest and diseases. Castor crop suffered from powdery mildew, while paddy experienced smut disease along with leafhopper infestation.

2.3. Rainwater management

2.3.1. Hydrologic modeling of water yield in a microwatershed and its productivity in oil seed and vegetable production in Alfisols

A software SWYMOD (Surface Water Yield Model) was developed to fix the curve numbers for different land uses in a microwatershed by integrating the SCS curve number method and water balance in a farm pond. The software is user friendly and it has two modules, one with direct runoff measurement at outlet of a watershed and another, pond water levels as output. Model efficiency has been used to refine the curve numbers by comparing the observed and predicted water level depths in a pond. The limit of model efficiency >90% has been considered as tolerance limit for fixing the curve numbers. The model was validated over a microwatershed having an area of 14 .5 ha area with two land uses of forest (7 ha), agriculture (7 ha) and dirt roads (0.5 ha) with rainfed crops sown in the season.

The daily pond water level, rainfall and evaporation data were recorded for calculating the seepage from a farm pond. In the third year of operation of farm pond, the seepage loss was reduced to 20 mm/day as compared to 40-80 mm/day during the first two years. The total runoff collected was 1992 m^3 during the kharif season and there were only 4 events of runoff production over the season. An amount of 219.4 m^3 was used as pre-sowing irrigation to the experimental as well as the plots existing east and west sides of the pond covering an area of 0.9 acre with groundnut (ICGV 350) and 0.74 acre with maize (DHM 107). The evaporation loss was calculated as 14% of the total runoff.

The experiment on water productivity with treatments of Tank Silt (TS) and No Tank silt (NTS) in the block of supplemental irrigation(SI)

and rainfed (RF), was continued during the year 2010. Total rainfall received during the kharif season was 601 mm during present year (Fig. 26) and it was well distributed over the season without any dryspells affecting the crop growth. The sowing of groundnut (ICGV 91114) and Okra (Araka Anamica) was done on 06 June, 2010 and harvested on October 6,2010. The rainfall during the growth period was 406 mm out of which an amount of 140.5 mm rainfall was used by the crop. The maximum rain water productivity of 23.77 kg/ha mm was achieved in groundnut and there was no significant difference between SI and RF blocks with TS application. In the NTS, the rainwater productivity in the ground nut was 20.31kg/ha mm. In case of Okra, the productivity obtained with TS application was 29.15kg/ha mm and it was 24.14 kg/ha mm in case of NTS (Fig. 27).

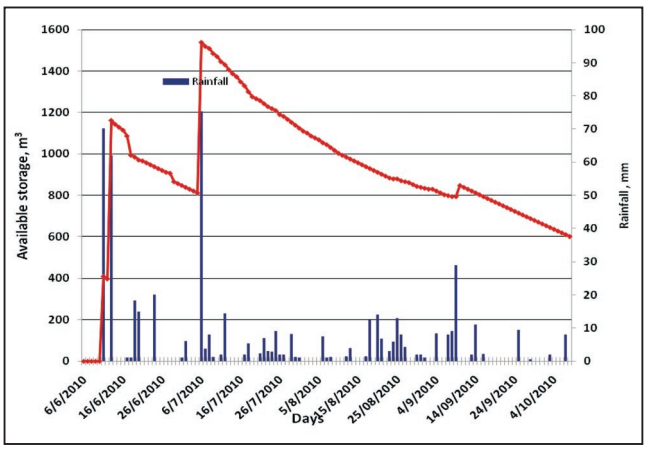


Fig. 26. Available storage of runoff and rainfall distribution during kharif,2010 at the site of farm pond

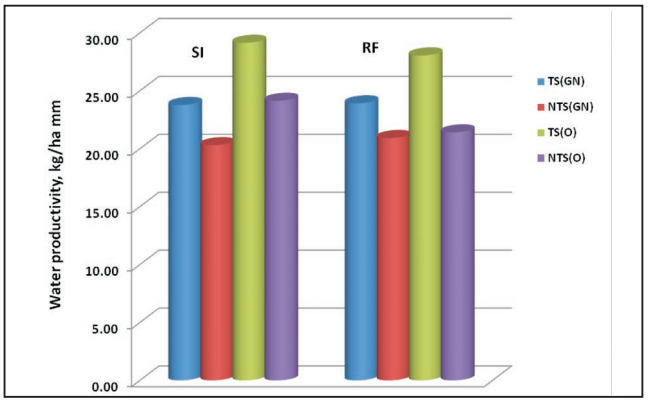


Fig. 27. Water productivity in ground nut and Okra with tank silt and no tank silt application under supplemental irrigation(SI) and rainfed (RF) in alfisols

2.3.2. Water productivity enhancement through In-situ rain water harvesting

The experiments were conducted at Hayatnagar research farm under Castor-Pigeonpea based system for developing suitable in-situ water harvesting mechanisms in rainfed areas. Treatments included Conventional planting, Conventional planting with horsegram as intercrop, Paired row planting (60 cm within pair, 120cm between pair) and paired row planting+ intercrop (2 rows intercrop at 40cm distance) with 3 replications. An existing ridger and furrow making equipment was modified to create larger width furrow of 60 cm and a depth of 25 cm for conservation furrows. Pigeonpea and Castor were sown during 3rd week of June and 1st week of July, respectively. The total rainfall received for the cropping season is about 970 mm out of

Pigeon pea crop sown with ridger in paired row planting mechanism and normal planting

which about 417 mm was the runoff causing rainfall during the season. Runoff was monitored from the plots and is in the range of 8-10% and 1-15% of crop season rainfall for normal planting and paired row planting with ridger, respectively. The threshold rainfall for causing the runoff is increased with conservation furrows thus reducing the runoff from the field. The yields of pigeonpea recorded are in the range of 1700-1900 kg/ha and 2200-2250kg/ha for normal planting and paired row planting with ridger, respectively.

2.3.3. Design and development of cost effective water management system for selected crops in Alfisol

The developed irrigation system includes three broad components namely, solar power generation system, water lifting system and water distribution using water emitting devices operated through gravity; the configuration is presented in figure 28. The developed system operates using low discharge small pump unit. This pump operated from electricity generated from small scale solar power. The low discharge further elevated to the temporary water storage to provide optimum pressure for irrigation system. The elevated water storage provision in this system enables the system to respond to the extreme of less power low discharge conditions which otherwise is not possible with the existing conventional irrigation system. In this system the water applied is equated to the inflow to the storage tank so that it provides a constant hydraulic pressure.

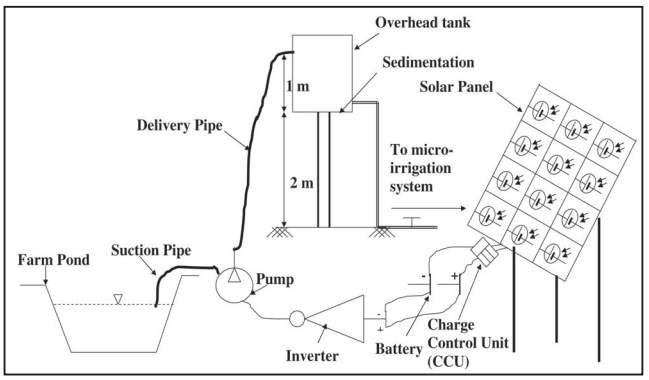
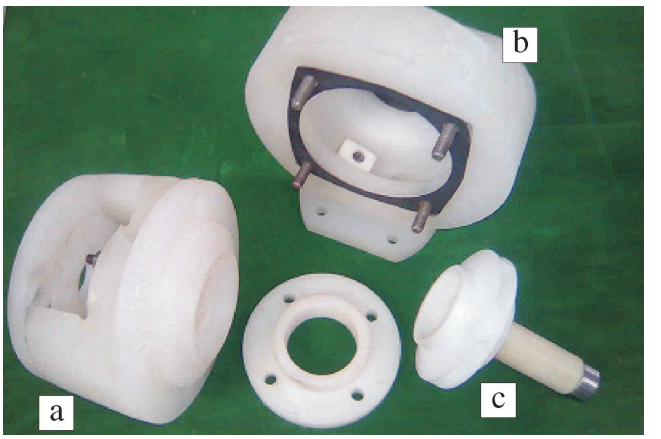


Fig. 28. Schematic diagram of solar based micro-irrigation system

The average discharge of the emitters was 2.92 lph (litre per hour). The emitter discharge was found consistent over the 26 m long laterals. The uniformity coefficient (CUC) of the various laterals was found to be ranging between 90.3 to 94.5% which is within the permissible limit as standardized by ASAE (American society of Agricultural Engineers), 1985. The acceptable limit of the CUC for the drip irrigation system is greater than 85 %. The overall distribution uniformity was found as 90.63 which are also within the permissible limit of ASAE criteria.

2.3.4. Optimization of water lifting and distribution of harvested water

A low weight nylon pump was developed to improve upon portability of existing pumpset. A portable pumpset (Greaves Cotton Limited, Chennai, Engine Model HSMF, MK-12) of 1.5 Hp petrol started diesel engine was selected for the study. It is



Components of Nylon Pump Viz. (a) Coupler (b) Casing (c) Impeller

Monoblock pump of 2" suction size and 2" delivery size. The weight of pumpset along with nylon pump was 23 kg as against 34 kg with existing pumpset. The performance of newly developed pumpset was tested for lifting of farm pond water. The discharge capacity of the nylon pumpset was 5 lps. Though there was no increase in discharge capacity and pressure head with nylon pump the sizable reduction in weight of the pumpset would help greatly to minimize the drudgery of the user while carrying it from one place to another place.

2.4 Crops and cropping systems

2.4.1 Performance of horsegram mutants in AICRP trials

In 2010 late *kharif*, horsegram entries were evaluated in three national trials viz. 1) Advanced Varietal Trial (AVT)-I (8 entries), 2) AVT-II (9 entries) and 3) Initial Varietal Trial (IVT) with 10 entries under All-India Arid Legumes Network Project. The trials were sown during August and evaluated with no inputs (no fertilizer and pesticide) under rainfed conditions. The Entries were coded by the coordinating unit of the Network Project.

In AVT-I trial, the highest grain yield was recorded by HG-31 followed by HG-33 and HG-37 with 848,846 and 842 Kg/ha, and matured in 88, 86 and 90 days, respectively. These entries also gave higher fodder yield (994-1109 kg/ha) with 5-6 branches/plant and 43-47 pods/plant. All the three entries were tolerant to yellow mosaic virus (YMV), powdery mildew (PM) and Anthracnose. In AVT-II trial, HG-23 gave the highest grain yield followed by HG-21 and HG-26 with 894, 864 and 857 Kg/ha and matured in 85, 90 and 83 days, respectively. However, the highest fodder yield was recorded by HG-26 (1243 kg/ha) followed by HG-21 (1190 kg/ha) and HG-23 (1172 kg/ha). All the three entries also showed tolerance to YMV, PM and Anthracnose. In IVT trial, HG-404 recorded highest grain yield (1035 kg/ha) followed by HG-406 (970 kg/ha) and HG-401 (714 kg/ha). These entries matured in 72, 71 and 85 days, respectively. HG-404 produced higher fodder yield (1035 kg/ha) compared to other entries. HG-401 was tolerant to YMV and PM.

Performance of horsegram varieties in different states

CRIDA's Horsegram Varieties CRIDA-18R (Brown Seeded) & CRHG-4 (Black Seeded) Released in 2009 and 2010, respectively by CVRC for South India showed superior performance with a higher grain yield of 33% and also matured by 10 to 25 days earlier than check varieties during 2010-11 in farmers fields of Tamil Nadu (Table 8), Kerala (Table 9) and Andhra Pradesh (Table 10).

Table 8 : Performance of horsegram (CRIDA-18R) in the on-farm trials in Dharmapuri district of Tamil Nadu

Location	Grain yield (Kg/ha)		Superiority over check	
	CRIDA 18R	Paiyur 2/ local check	Grain yield (%)	Maturity (days)
Thonganoor	712	600	18.7	23
Melkullapatti	830	677	22.6	27
Paruvathanahalli	795	686	16.0	23
Salakullathirampatti	845	732	15.4	29
Kottumaranhalli	812	715	13.5	24
Mean	798.8	682.0	17.1	25.2

Table 9. Performance of horsegram (CRIDA-18R) in the on-farm trials in Palakkad district of Kerala

Location	Grain yield (Kg/ha)		% superiority over check
	CRIDA 18R	Paiyur 2/ local check	
Mudavannur	1793	1417	26.5
Mudavannur	720	567	27.0
Uppukarankalam	827	647	27.8
Cheriyakalliyambara	730	583	25.2
Puthenveedu Nellaya	1973	1560	26.5
Pombilaya	827	643	28.0
Pombilaya	1267	990	28.0
Station Trial	973	770	26.4
Mean	1138	897	26.9

Field view of CRIDA 18R at research farm (left) and farmer's field (right)

Table 10. Performance of horsegram (CRHG 4) in the on-farm trials in different districts of Andhra Pradesh

Location	Yield (Kg/ha)		Superiority over local	
	CRHG 4	Local	Yield (%)	Maturity (days)
Guntur district				
Pinniboyinavaripalem	310	245	26	7
Pinniboyinavaripalem	355	265	36	9
Kadapa district				
Utukur	475	225	111	8
Kurnool district				
Location 1	1187	950	25	15
Location 2	1087	860	26	21
Location 3	1125	937	20	12
Location 4	1109	810	28	15
Overall Mean	645	456	56	10

Field view of CRHG-04

2.4.2 Abiotic and biotic stress tolerance in blackgram

Fifteen genotypes of blackgram were evaluated against 4 checks to identify the genotypes tolerant to heat stress, yellow mosaic virus (YMV) and heat stress + YMV. The incidence of YMV was rampant in the whole trial at above 40^0 C. The YMV tolerance was shown by 3 checks viz. Local-1, LBG-20 and T-9. Among the test entries, SK-023 and KARS-157 had lower incidence of YMV than other genotypes.

Heat and YMV tolerance in blackgram genotypes

2.4.3 Enhancing tolerance of sorghum to abiotic stresses through genetic manipulation

Confined field trial by CRIDA for event selection with six individual transgenic events and one untransformed control line of SPV 462 was approved by Genetic Engineering approval Committee (GEAC), Government of India. The experiment was conducted under protective net as per DBT guidelines for

event selection trials. Each event was replicated thrice under irrigated and dryland treatments. PCR and RT-PCR analysis of the transgenics using *mtlD* gene specific primers revealed the presence of 800bp product confirming the carry forward of the integrated *mtlD* transgene while untransformed control did not show such band. As rainfall was uniformly distributed throughout the crop growth period the dryland and irrigated treatments were almost similar in terms of growth and yield parameters. The capacity to retain water upon excision as assessed by Excised leaf water retention capacity was better in *mtlD CRIDA 3-3-18-7-2*, *mtlD CRIDA 1-6-1-8-4*, *mtlD CRIDA 4-7-1-7-4* and *mtlD CRIDA 26-1-11-6-1* than the untransformed control SPV-462. Among different lines, chlorophyll content was highest in *mtlD CRIDA 26-1-11-6-1* and *mtlD CRIDA 3-3-18-7-2* maintained higher root length,

Six transgenic events were grown in a confined field trial along with untransformed line

Untransformed line- cv. SPV462

Transgenic sorghum line - CRM3

Transgenic sorghum under protective net

total biomass and yield when compared to untransformed control and other transgenics. *mtlD CRIDA 26-1-11-6-1* recorded the highest shoot length whereas, *mtlD CRIDA 1-6-1-8-4* and *mtlD CRIDA 3-3-18-7-2* reached anthesis earlier than untransformed control SPV-462.

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

Identification of potentially useful abiotic stress inducible candidate genes and respective stress inducible promoters from tolerant sources of important dryland crops and validating performance of identified promoters and genes in improving stress tolerance is an important objective in managing the abiotic stress tolerance in drylands.

Isolation, cloning and characterization of dehydrin (*DHN*) gene from *Sorghum bicolor* L. Moench

Water-deficit stress is one of the major environmental constraints to crop growth and yield. Dehydrins, a class of LEA proteins play an important role in dehydration tolerance during seed development and in response to dehydration, cold and salinity stress through maintenance of protein or membrane structure, sequestration of ions, binding of water and operation as molecular chaperones. Hence the present study was aimed at the isolation, cloning, characterization and expression analysis of dehydrin gene from *Sorghum bicolor*. Genomic DNA and total RNA isolated from the stressed seedlings of sorghum were used for PCR amplification of *dehydrin* gene. The PCR amplified products were cloned into pTZ57R/T vector designated as pTZ57R-*DHNSb*. Cloning, sequencing and sequence analysis revealed that the isolated *DHN* genomic sequence was 770bp in length and cDNA sequence was 638bp in length. The difference in molecular weights indicated the presence of 132bp intervening region in the genomic sequence. Both genomic and cDNA sequences isolated were deposited in the NCBI Gene Bank with accession # GU137312.1 and HM243499, respectively. BlastX search of genomic and cDNA sequences obtained revealed highest sequence homology with the dehydrin sequences of sorghum as well as with other species available in the database. The ORF encoded a predicted polypeptide of 153 amino acid residues with calculated molecular mass of 15.7 kDa with a pI of 8.81 containing two lysine-rich K-segments and a 7-serine residue S-segment, both characteristic of SK_2-type dehydrins. Expression analysis through semi-quantitative RT-PCR revealed unregulated expression of *DHN* gene under water-deficit, salinity and chilling stresses. For functional validation of dehydrin gene, the plasmid pTZ57R-*DHNSb* was digested with *XbaI* and *BamHI* restriction enzymes and cloned in the corresponding sites of plant expression vector pRT100 that was flanked by CaMV35s promoter and the poly-adenylation signal to create pRT100-*DHNSb*. This expression cassette (1.3kb) was excised with *PstI* digestion and sub-cloned subsequently at *PstI* site in the binary vector pCAMBIA1303 for plant transformation studies aimed at functional validation of the gene.

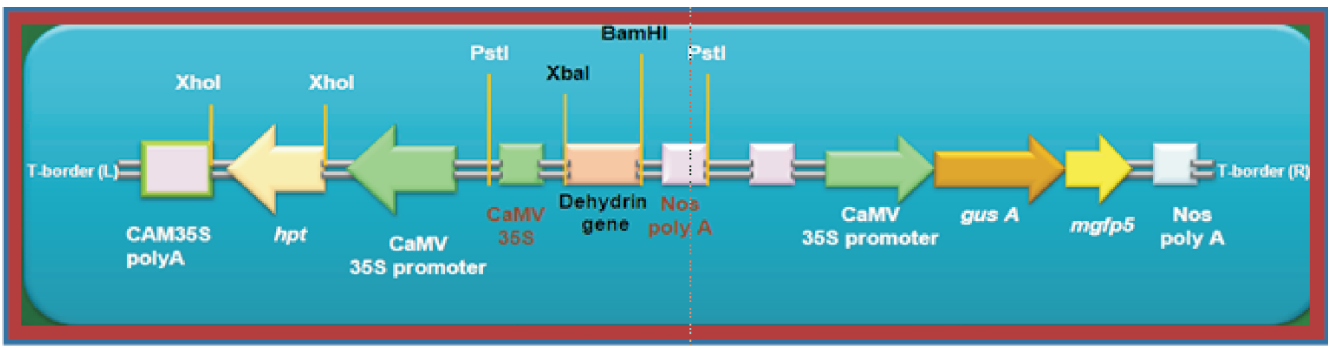


Fig. 29. Recombinant vector map of pCAMBIA1303-dehydrinT-DNA fragment

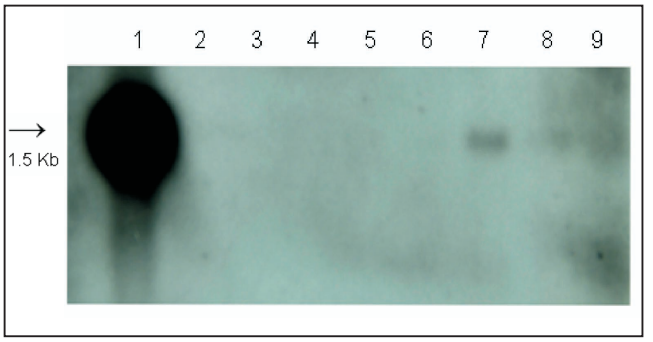
Isolation of water-deficit stress induced genes from *Pennisetum glaucum* by suppression subtractive hybridization

In order to identify novel genes induced under gradual water-deficit stress, a cDNA library was constructed using suppression subtractive hybridization (SSH) from the leaves of a drought tolerant pearlmillet male parent ICMR 356. A total of 528 colonies were randomly selected from the subtracted library to amplify the inserted sequences using M13 forward and M13 reverse primers. Out of the 580 colonies screened from the cDNA library constructed, 380 colonies were found to be positive clones. Further, sequencing of a small subset of 15 positive colonies showed significant sequence similarity to stress-induced signal transduction related and water deficit stress associated genes. The BlastX search of the 15 EST sequences analyzed showed similarity to Bowman Birk proteinase inhibitor, genes involved in proline biosynthetic pathway, C type lectin domains, cytochrome oxidase III, Della protein and opaque-2- like protein etc.

2.4.5 Genetic transformation of greengram (*Vigna radiata* L.) for enhancing abiotic stress tolerance

Drought stress is one of the important abiotic stresses affecting greengram growth and productivity under rainfed situations. Absence of sufficient and satisfactory level of genetic variability is the major hurdle in greengram improvement by conventional breeding. Genes of recognized relevance from alien sources have shown a great promise to enhance tolerance to various biotic and abiotic stresses. In this project, over-expression of *annexin Bj1* is attempted in greengram to enhance its abiotic stress tolerance. Efficient regeneration and genetic transformation of double cotyledonary node explants has been optimized to develop transgenic greengram by using LBA 4404 strain of *Agrobacterium tumefaciens* harbouring pCAMBIA 2301 binary vector containing *annexin Bj1* under the control of CaMV35S promoter. The transformants were selected on shoot regeneration medium containing kanamycin as a plant selection agent.

Agrobacterium mediated transformation of double cotyledonary node explants derived from three-day-old seedlings of variety ML 267 was carried out on regular basis to create more number of independent events. The putative transgenic (T_0) plantlets were selected on kanamycin containing regeneration medium and raised in a containment facility after rooting and hardening. Leaf genomic DNA was isolated from the putative T_0 *annexin* greengram transgenics developed by *Agrobacterium* mediated transformation. Genomic DNA was digested with *Pst I* restriction enzyme which releases 1.5 kb gene cassette containing 954 bp *annexin* gene. The restricted DNA was blotted onto a Hybond N+ membrane. Probe DNA was prepared from the PCR amplified product (941bp) of *annexin* gene. The probe was made hot as per standard procedure with ^{32}P and used for probing for presence of transgene by standard procedure. Detection of hybridizing bands corresponding to the positive control in at least three of the five putative samples tested confirmed transgene integration. DNA isolated from an untransformed control plant was tested for the presence of annexin gene in order to determine if transgene was present. Absence of any hybridization signal indicated that these plants had no inserted transgene. These results indicate very clearly integration of the transgene in the samples tested and hence the success of transformation protocol developed.



Southern blot hybridization of the T_0 putative annexin transgenic green gram plants.
Lane 1: Positive control (pCAMBIA 2301 + annexin digested with *PstI* to release 1.5 kb fragment.
Lane 2-3: Empty; Lane 4: Negative control;
Lane 5-9: T_0 transformants in which 7-9 were positive

2.4.6 Evaluation of chlorophyll fluorescence as an indicator for drought tolerance in selected dryland crops

Of various plant organs, leaf growth is generally more sensitive to water stress. However, reduced leaf growth or senescence and abscission of older leaves under water stress conditions are one of adaptive mechanisms in plants resulting in reduced transpiration. When green plants are illuminated they fluoresce. At physiological temperatures, chlorophylls associated with photosystem II (PS II) are mainly responsible for this fluorescence emission. This chlorophyll fluorescence induction phenomenon has proved to be a sensitive indicator of various reactions of photosynthesis and has been important in the understanding of various photosynthetic processes especially under water stress. This project will be to evaluate chlorophyll fluorescence as an indicator for drought tolerance in selected dryland crops. Upon the application of a saturating flash (about 8000 µmol m^{-2} s^{-1} for 0.6^{-1}s), fluorescence raises from the ground state value (F_o), which is the fluorescence determined in darkness by a weak measuring beam, to its maximum value, namely F_m. This measurement allows the determination of the maximum quantum efficiency of photosystem II (PSII) primary photochemistry, given as Fv/Fm. Ability of a plant to maintain the Fv/Fm ratio at optimum ~ 0.7 under water stress indicates inherent stress tolerating capacity. A study was undertaken to a) elucidate the relationship between chlorophyll fluorescence, carbon assimilation and drought tolerance in selected dryland crops, b) assess the genetic variability in chlorophyll fluorescence in selected dryland crops and c) identify key indices for rapid selection of drought tolerant genotypes.

Various genotypes of Jatropha were taken up this year for studies on gas exchange and chlorophyll fluorescence parameters. Variation in transpiration rate and stomatal conductance was clearly evident from the study. The dendrogram constructed (Fig. 30) is indicative of the relative involvement of gas exchange traits in imparting drought tolerance in terms of growth effects in selected accessions. These characters can be viewed as best gain characteristics for Jatropha improvement because of its strong physiological

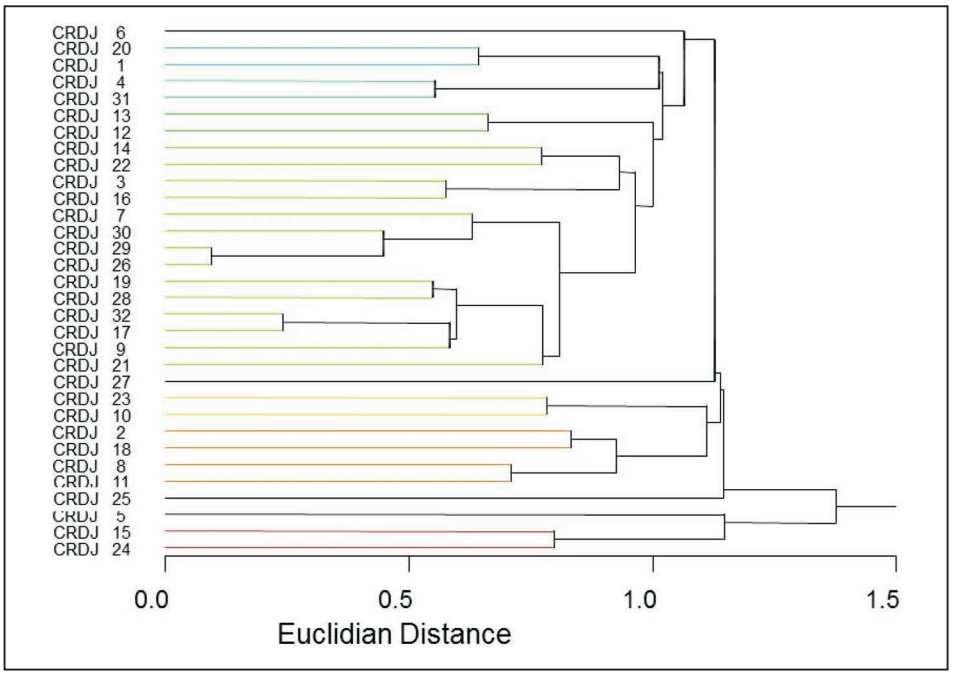


Fig. 30. Average group linlkage (dendrogram) by hierarchical clustering of leaf gas exchange characteristics and growth of *Jatropha curcus* accessions

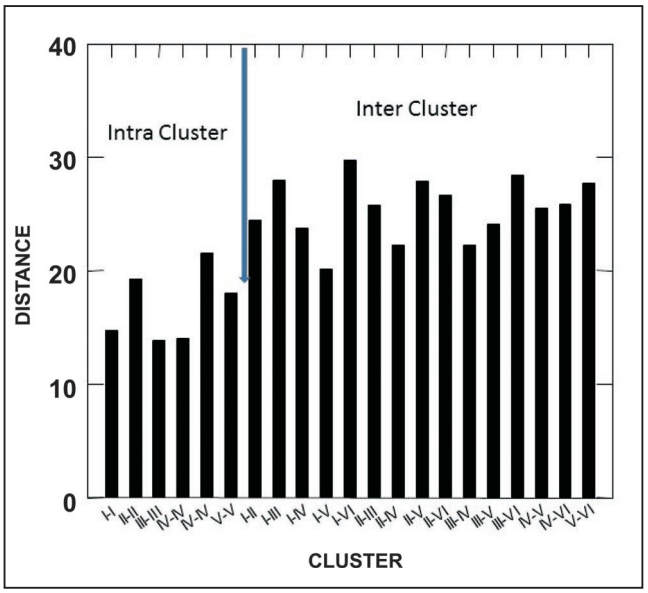


Fig. 31. Estimates of intra cluster and inter cluster distance (six clusters) by K-Means non hierarchical clustering of growth and gas exchange characteristics in selected *Jatropha curcus* accessions

control and a wide range of variability. High intra-cluster distance in gas exchange and growth attributes (Fig. 31) shown by cluster I and IV respectively indicated that selection of parents for improvement in physiological traits should be within these clusters in event of future hybridization programs with expectations for seed yield, as the means for these values were high in these clusters. Among the Chlorophyll fluorescence parameters, the maximum quantum yield of PSII in a leaf (light adapted) which is given by Fv'/Fm' indicated a range of 0.64 to 0.70 in the genotypes studied.

2.4.7 Studies on root characteristics in rainfed greengram and horsegram crop in relation to resource availability

During drought, root system of the plant is the interface between soil and drought. Therefore it is imperative to understand the root dynamics under varied situations of rainfed lands besides realizing the effect of management measures for fine tuning them. Work was undertaken to understand the root growth dynamics in terms of proliferation of horsegram roots under varied resource availability in rainfed lands. Two varieties of horsegram (CRIDA18R and CRHG04) were grown under receding soil moisture conditions during September, 2011. The roots were sampled in trench method.

Horsegram crop received an amount of 205 mm rainfall during its growth period, as a result no significant yield difference between the two cultivars was observed. The horsegram yields ranged between 829-842 kg/ha. However, critical root parameters *viz.*, total root length (TRL), root shoot ratio and root dry weight showed significantly high values with CRHG04 and finer root length ($\leq$ 0.1mm size) and increased TRL at the top soil depth (0-10 cm) with CRIDA18R especially at pod filling stage. Since, significant leaf area, leaf weight and shoot weight at pod filling stage were recorded by CRHG04 over CRIDA18R, more green fodder yields (200-300 kg/ha) were realized from this cultivar. Further evaluation of performance of these two cultivars needs to be carried out in the coming season.

2.4.8 Root proliferation as influenced by soil management for drought and its physiological implications: Short duration pulses (greengram)

The dynamics in the development and distribution of below ground plant parts during the times of moisture stress and after relief play crucial role in understanding their contribution towards the abiotic stress management by plant. A study was initiated in 2009 to understand the root parameters sensitive to moisture stress in greengram crop in order to extract a clue for suitable field management. Profile soil filled acrylic root chambers having dimensions of 30 cm X 15 cm X 45 cm were sown with the greengram plants, retaining one each for the chamber. The sampling was carried out with the help of black pin board and fixed spokes at 2.5 cm grid. The soils in chambers were saturated and left for five days to attain the respective field capacity (FC) and 33.3% available water content (AWC) levels as treatments, with two contrasting greengram varieties (ML267 and WGG37) in a 2 X 2 factorial design.

Both ML267 and WGG37 registered increasing trend in total root length (TRL) up to 69 DAS (pod

filling stage). However, under soil moisture stress (33.3% AWC), though both varieties recorded reduced TRL, the decrease was at a higher rate in case of WGG37 than ML267 up to 42 DAS (flowering stage) and recovered at a later stage. ML267 produced lesser root length under soil moisture stress (33.3% AWC) at pod filling stage than WGG37 (Fig. 32). Further ML267 was a short statured plant compared to WGG37 with maximum root length registering in the range of 0.1-0.5 mm while WGG 37 recorded maximum root length registering in the range of 0.1-0.75 mm indicating the presence of more wider/thicker roots in its root system.

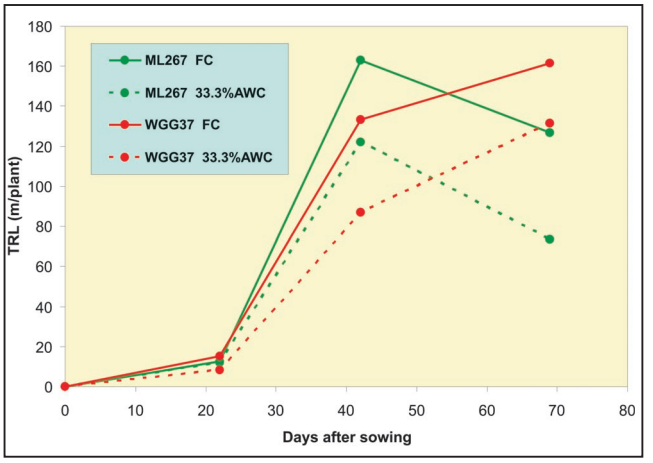


Fig. 32. Effect of water treatments on total root length of ML267 and WGG37 greengram cultivars

Roots architectures of ML267 and WGG37 respectively at flowering stage

2.4.9 Crops yield and quality, soil properties and economic returns under organic management in rainfed agro-ecosystem

Performance of different crops under organic and conventional management

Organic agriculture is one of the fastest growing sectors of agricultural production. A field experiment was conducted during *kharif* 2010, the first year of experiment, at GRF of the Institute to evaluate the comparative performance of sesame, sunflower and pigeon pea under organic and conventional production systems. In general, the performance of sesame was poor in all the treatments due to excessive rains at flowering and pod formation stage. The highest seed yield (392 kg/ha) was obtained under conventional farming. The seed yield reduction under organic farming was 18.7% compared with conventional farming (Fig. 33). About 27% of the crop was affected by phyllody under organic management. Similarly, sunflower performed better under conventional farming (1252 kg/ha) than under organic farming. The latter treatment recorded about 13.2% reduction in seed yield compared with conventional farming. In pigeon pea, conventional management resulted in higher seed yield (1254 kg/ha) compared to other treatments. Organically grown pigeon pea gave about 24.7% reduction in seed yield than its conventional counterpart. Heavy rains during later stages of the crop resulted in more incidence of wilt in the plots under organic management.

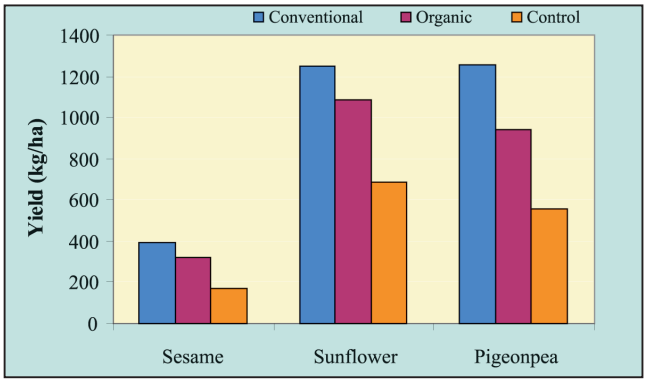


Fig. 33. Comparative performance of crops under different production systems

Performance of sunflower and pigeon pea under different spacing and nutrient management levels

The effects of crop density on the yield of crops are well established under conventional production systems. However, this information is not available for crops grown under organic management. Field experiments were conducted during *kharif* 2010, the first year of experiment, at GRF of the Institute to optimize the plant population of sunflower and pigeon pea under organic management. The experiment included three levels of plant population viz. recommended (P_1), 80% recommended (P_2) and 120% recommended (P_3), and four levels of nutrient management viz. 100 (F_1), 125 (F_2) and 150% (F_3) equivalent of recommended NP through FYM and rock phosphate. In addition, one INM treatment (F_4) was also included as a check. At higher plant population level (120% recommended), the yields of both sunflower and pigeon pea were higher by 7.3 and 2.7%, respectively than that of rec. plant population (Fig. 34). Both the crops gave lower yields (7.8-8.5%) at 80% rec. plant population.

Among different fertility levels, INM gave higher yields of both sunflower and pigeon pea compared to other treatments. In sunflower, application of 100% equivalent of rec. NP through organic amendments gave 16.6% lower seed yield compared to INM treatment. The seed yields increased with increase in application rates of organic amendments. At higher application rate (150%) of organic amendments, the seed yield of sunflower was similar to that of INM treatment. In pigeon pea, the seed yield was 14.5% less in the plots under 100% NP through organic amendments compared with INM treatment. The seed yield increased by 5.5% with increase in application rate (125%) of organic amendments but further increase in application rate (150%) had no effect on seed yield of pigeon pea.

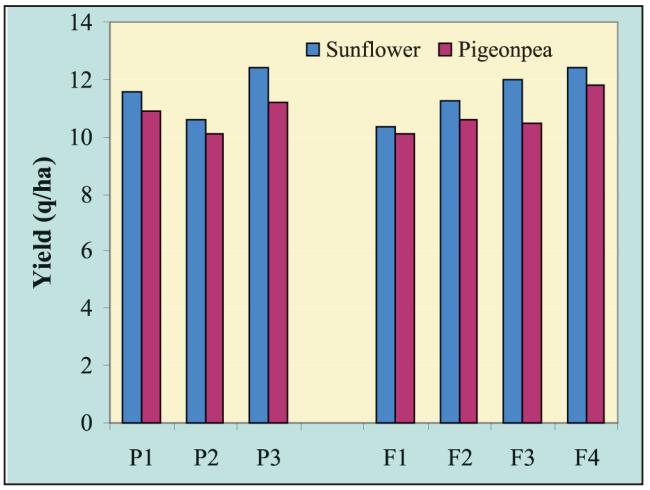


Fig 34. Influence of plant population and fertility levels on yield of sunflower and pigeon pea

2.4.10 Organic cultivation of fruits in drylands

Custard apple: A study was taken to compare the effect of organic and inorganic nutrient management on growth, yield and quality of custard apple. Significantly higher fruit number and fruit yield was recorded by different treatments compared to control (Table 11). Maximum fruit no (215.5) was recorded in organic treatment than other treatments. However, fruit yield was at par in both the organic and inorganic treatments. The physico-chemical

Table 11 : Yield and fruit characteristics of custard apple as influence by organic and chemical fertilizers at HRF

Treatment	Fuits/ plant	Fruit yield (kg/plant)	Fruit wt (g)	TSS (^{0}Brix)	No of seeds	Seed wt (g)	% pulp
Organic	215	51.7	234.8	26.5	43.7	17.3	52.8
Inorganic	165	49.5	296.6	27.9	55.0	21.9	48.7
Control	109	20.7	188.2	22.6	57.9	26.6	42.5
CD (0.05%)	36	8.4	28.8	2.4	9.0	5.4	NS

properties like fruit weight, polar diameter, transverse diameter, ^{0}brix were higher in both the organic and inorganic treatments compared to control. There was significant reduction in number of seeds and seed weight in organically grown fruits compared to other treatments.

Guava: Significantly higher fruit number/plant and fruit yield was observed in organic and inorganic treatments compared to control (Table 12). Similarly, organic treatment recorded significantly higher TSS but lower acidity compared to inorganic and control treatments.

Table 12 : Yield and fruit characteristics as influence by orgnaic and chemical fertilizers in guava at HRF (2010)

Treatment	Fruits/ plant	Fruit yield (kg/plant)	TSS (^{0}Brix)	Acidity (%)
Organic	155.63	15.43	13.2	0.25
Inorganic	112.88	11.78	11.62	0.43
Control	30.5	3.91	8.52	0.47
CD (0.05%)	56.47	5.04	0.637	0.048

Soil chemical properties as influenced by organic and inorganic fertilizers in custard apple, guava and mango

There was reduction in soil pH in the plots under custard apple in both organic and inorganic treatments compared to control and maximum reduction was observed in organic treatment (Table 13). In guava and mango plots. However, maximum reduction in pH was observed in inorganic compared to organic treatment. There was an increase in EC and organic C in both the treatments compared to control in all the plots. The available K was highest in inorganic treatment because of the application of K fertilizers. Among the micronutrients, the Mn and Cu contents were highest in custard apple plots under organic treatment whereas, inorganic treatment recorded highest Mn (both depths) and Cu (15-30 cm) in the plots under guava and mango. Similarly, organic treatment recorded higher Zn content than other treatments in all the crops except in top layer (0-15 cm) of guava plots. Organic treatment also recorded higher Fe content in custard apple and guava plots but higher Fe

Table 13 : Soil chemical properties as influenced by organic and inorganic fertilizers in custard apple, guava and mango

		Custard apple			Guava			Mango		
Constituents	Depth	Control	Organic	In-organic	Control	Organic	In-organic	Control	Organic	In-organic
pH	0-15	8.11	7.13	7.77	7.08	7.46	6.44	7.64	7.23	5.99
	15-30	8.09	6.78	7.84	7.32	7.66	6.15	7.92	7.08	6.37
EC	0-15	0.14	0.34	0.41	0.089	0.283	0.346	0.087	0.273	0.886
	15-30	0.14	0.18	0.46	0.086	0.209	0.293	0.154	0.138	0.66
OC (%)	0-15	0.61	0.99	0.87	0.52	1.33	1.28	0.36	1.1	0.76
	15-30	0.59	0.63	0.72	0.38	0.88	0.93	0.45	0.55	0.68
K(kg/ha)	0-15	172.5	702	1173	166	488	903	194	562	1360
	15-30	132.2	538	1031	125	345	754	217	394	968
Mn(ppm)	0-15	12.71	24.23	19.22	21.6	22.1	35.94	15.7	21.36	36.79
	15-30	12.16	28.12	15.89	22.1	12.61	46.5	17.7	28.43	48.53
Cu(ppm)	0-15	0.88	1.71	0.86	0.96	1.22	1.28	1.04	1.2	1.07
	15-30	1	1.27	0.92	1.36	1.37	1.17	1.06	1.14	1.17
Zn(ppm)	0-15	0.63	2.89	1.3	1.01	1.17	1.45	0.94	0.92	0.63
	15-30	0.46	1.13	0.97	1.26	2.78	2.68	0.94	3.02	1.47
Fe(ppm)	0-15	8.89	67.14	59.2	63	86	66	64	66	108
	15-30	7.84	70.16	62.53	81	56	99	45	78	101

content was observed under inorganic treatments in Mango.

2.4.11 Integrated weed management in reduced/ zero tillage crop production

Weed species shifts and losses in crop yields as a result of increased weed densities have been cited as major reasons why conservation tillage systems have not enjoyed widespread adoption. A field experiment was conducted to evaluate effect of different weed control methods in sorghum + pigeon pea intercropping system, for their weed control efficacy and on crop productivity under conventional (CT), reduced (RT) and zero tillage (ZT) systems. The weed control treatments were herbicide (T_1), hand weeding twice (T_2), herbicide + hand weeding (T_3), and weedy check (T_4).

Adverse effect of pendimethalin on sorghum

The performance of both sorghum and pigeon pea was better under conventional tillage than other tillage treatments (Fig. 35). The yield was reduced by 24.0 and 21.9% in sorghum and 19.1 and 15.4% in pigeon pea under reduced and zero tillage systems, respectively compared to conventional tillage. This was mainly due to more weed infestation under reduced (18.1%) and zero tillage (11.9%) systems. On average, the yields of sorghum and pigeon pea decreased by 81.5% and 86.3%, respectively due to season-long weed-crop competition in weedy check plots. Among the weed control treatments, the highest weed-control efficiency (93.7%) was achieved with hand weeding twice (20 & 40 days after sowing) closely followed

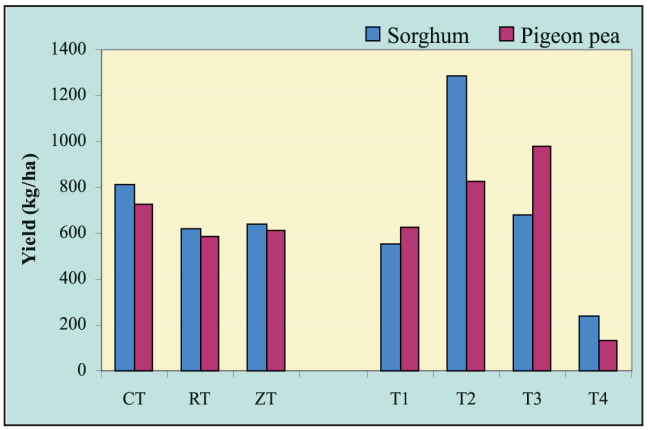


Fig. 35. Yields of sorghum and pigeon pea under different tillage and weed control treatments

by application of pendimethalin + hand weeding (89%). Application of pendimethalin at 1.0 kg/ha severely affected the germination and growth of sorghum. Hence, hand weeding treatment gave higher grain yield of sorghum. On contrary, use of pendimethalin followed by hand weeding gave higher yields of pigeon pea closely followed by hand weeding treatment.

2.4.12 Characterization of biotic stress in rainfed crops using hyperspectral radiometry

Detection of crop stress is one of the major applications of hyperspectral remote sensing in agriculture. Studies were aimed to characterize spectral changes in crops under stress due to pest and disease attack. Identification of bands specific to pest damage and development of hyperspectral indices would be useful in detection of pest damage in large areas using air/space borne remote sensing data. A study was initiated to quantify morphological and chemical changes induced by the pest attack in the plant, identify the narrow band hyperspectral indices specific to the target pest and use of space-borne satellite data to assess the pest damage. Four differential disease infestations of groundnut late leaf spot were created by imposing 7 fungicidal treatments in the plots measuring 4 m^2 at HRF. Each treatment was replicated thrice. Cotton plants with varying levels of leafhopper (LH) severity were selected from three locations across major cotton growing regions of India (Warangal and Coimbatore).

About 57-58 cotton plants from each location exhibiting different levels of LH damage symptoms were selected. Spectral reflectance measurements were recorded using FieldSpec 3 Hi-Res spectroradiometer with a spectral range of 350-2500 nm using the plant probe. Each scan represented an average of 30 reflectance spectra. A minimum of 10 samples were selected for each scale of pest infestation. Simultaneously chlorophyll (Chl) and relative water content (RWC) were also estimated from leaf discs measuring 20 mm dia punched from the uppermost fully expanded leaf of selected plants.

Cotton leafhopper (LH) damage: Reflectance from healthy and LH infested plants showed a significant difference in VIS and NIR regions (Fig. 36). Decrease in Chl *a* pigment was more significant than Chl *b* in the infested plants and the ratio of Chl *a*/*b* showed a decreasing trend with increase in LH severity. Regression analysis revealed a significant exponential relation between LH severity and Chl (R^2 = 0.670**), while a quadratic fit was observed for RWC (R^2 = 0.437**). Plotting linear intensity curves between reflectance at each waveband with infestation grade resulted in six sensitive bands that exhibited maximum correlation at different regions of the electromagnetic spectrum (376, 496, 691, 761, 1124 and 1457 nm). Regression analysis of several ratio indices formulated with two or more of these sensitive bands led to the identification of new indices (LHI 1-4) with potential to detect leafhopper severity. These new indices along with 20 other stress related indices compiled from literature were further tested for their ability to detect LH severity. Two novel indices LHI 2 and LHI 4 proposed in this study consistently showed significantly high coefficients of determination across locations (R^2 range 0.521-0.825**) and hence have the potential use for detection of leafhopper severity in cotton.

Groundnut late leaf spot (LLS) disease: Loss of chlorophyll a, b and relative water content was quantified in all the five grades of the LSS disease. Regression analysis was performed to estimate the slope (R^2 = 0.413, 0.049, 0.327 and 0.765 for Chl a, Chl b, Chl a+b, and RWC, respectively). The observations on spectral reflectance was recorded when the crop was 65 and 90 days after sowing. Ratio analysis of hyperspectral data revealed four sensitive bands centered at 678, 730, 1439 and 1921 nm (Fig. 37). Further work is progress to develop ratio indices using these band combinations. Among different spectral indices tested for their efficacy to predict LLS disease, Simple Ratio (SR), Normalized pigment chlorophyll index (NPCI), red edge vegetation stress index (RVSI), Pigments specific

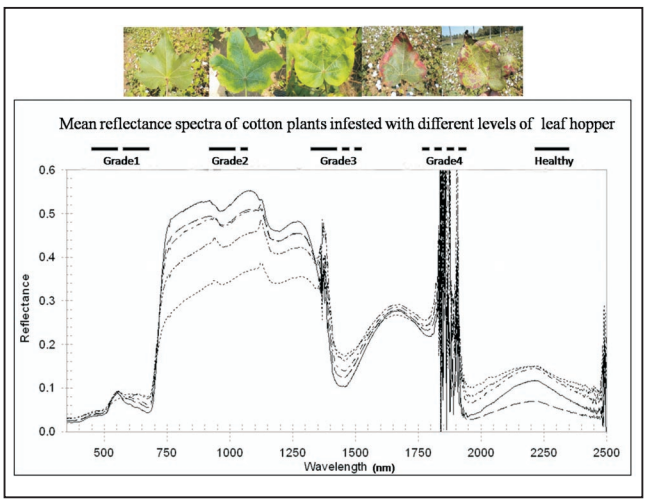


Fig. 36. Mean reflectance spectra of cotton plants infested with different levels of leaf hopper

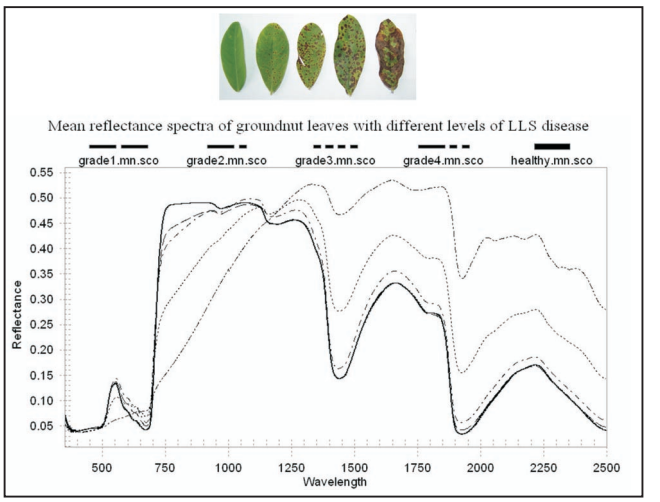


Fig. 37. Mean reflectance spectra of groundnut leaves with different levels of LLS disease

simple ratio (PSSRa) were found to perform well with high co-efficient of determination values of 0.88, 0.85, 0.873 and 0.886, respectively.

2.4.13 Validation of decision support system for groundnut pests and diseases using weather data from wireless sensor networks

The decision support system (DSS) for fungicide spray advisory based on leaf wetness index (LWI) measured by a wireless sensor moat at canopy height developed in collaboration with Centre for Development of Advance Computing (C-DAC), Hyderabad was tested during 2010-11 *kharif* season. Disease initiation was noticed 50 DAS and rose sharply in the next 40 days (Fig. 38). Fungicide spray advisory was issued by the DSS twice at 77 and 94 DAS which were correctly validated. The incidence of leaf miner on groundnut during *kharif* 2010 was contrastingly low due to the well distributed rainfall during the season.

Field view of WSN experiment in groundnut

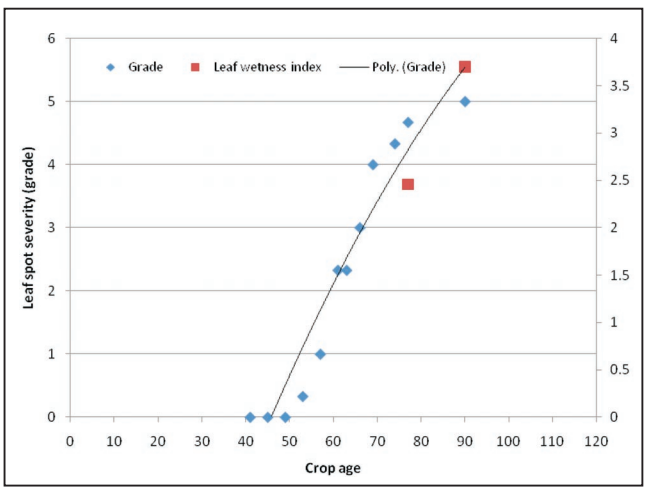


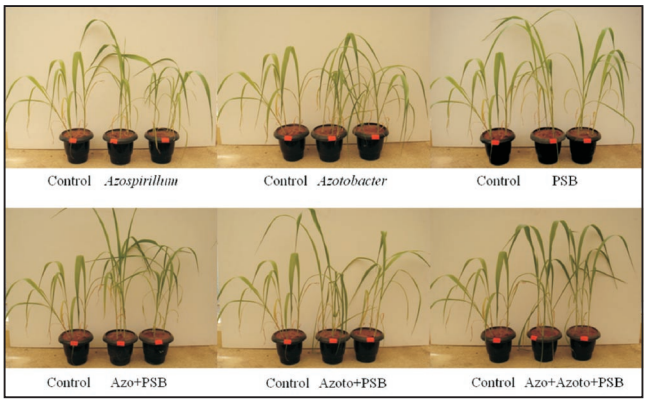
Fig. 38. Incidence of late leaf spot on groundnut during 2010 *kharif* season for validation of WSN based DSS

2.4.14 Development of microorganism consortium to alleviate abiotic stresses like drought and high temperature

Microorganisms have the potential to tolerate abiotic stresses and can also impart tolerance to host plants against abiotic stresses. A study was carried out to develop microorganisms consortia for the management of drought and heat stress in rainfed crops. Based on previous year's studies, abiotic stress tolerant bacterial consortium was developed using *Pseudomonas putida* strain-P7, *Bacillus subtilis* strain-B30 and *Azospirillum* spp. strain-G12. Different ratios of three bacterial strains (1:1:1, 1:2:1, 2:1:1, 1:1:2) were studied for their effect on sorghum under drought and temperature stress under sterile pot conditions. Field studies were also conducted at GRF with two bacterial consortia; P7+B30+G12 for sorghum and P45+B17+G12 for sunflower using six treatments (T1: 75% chemical + inoculation; T2: 50% chemical + FYM 8 t/ha + inoculation; T3: 75% chemical + FYM 4 t/ha + inoculation; T4: 100% chemical + inoculation; T5: 75% chemical + FYM 4 t/ha; T6: 100% chemical). Bacterial consortium with equal ratios (1:1:1) of three strains (P7+B30+G12) showed significant increase in shoot, root and dry biomass of sorghum seedlings compared to single, dual and mixture of three strains with different ratios, under no-stress, drought stress and temperature stress. A significant increase in proline, total sugars and chlorophyll content was also observed in sorghum seedlings inoculated with bacterial consortium (1:1:1) as compared to other ratios tested. In field studies, the results indicated that full dose of chemical fertilizers with consortium inoculation improved plant growth and yield of sorghum and sunflower under rainfed conditions (Table 14).

Table 14 : Effect of different treatments on biochemical parameters and yield of sorghum

Treatment	Chlorophyll (mg/g FW)	Proline (mg/g FW)	Sugars (mg/g DW)	Grain Yield (kg/plot)
T1	113±2.3	46.6±1.1	62.3±1.1	1.6±0.88
T2	115±2.6	47.9±1.3	65.8±1.3	1.5±0.83
T3	117±2.9	48.7±1.8	66.4±1.2	1.7±0.92
T4	128±2.0	49.8±1.7	64.8±1.6	2.1±0.89
T5	112±2.5	45.3±1.2	61.3±1.0	1.5±0.75
T6	125±2.2	45.9±1.0	62.9±1.7	1.9±0.86



Effect of single and multi inoculants on sorghum under drought stress (7th day)

More than 200 new rhizobacteria were isolated from stressed rhizosphere soils using different oligotrophic and selective media. All isolates were screened for tolerance to abiotic stresses viz., temperature, drought and salinity under *in vitro* conditions. From the new isolates, 29 thermotolerant (50º C), 31 drought tolerant (30% PEG) and 18 salinity tolerant (10% NaCl) isolates were selected. Eight isolates could tolerate all the three abiotic stresses tested. Of these, 19 isolates were found positive for P-solubilization, 9 for siderophore production and 15 isolates for IAA production indicating their potential for plant growth promotion.

2.4.15 Diversity of consortia of poly-functional rhizosphere microorganisms for nutrient supply, including tolerance to abiotic stresses in major rainfed production systems and Diversity of Cowpea and Pigeonpea rhizobia

Pot culture experiments were conducted under drought conditions for evaluation of individual stress tolerant isolates for imparting tolerance to sorghum, pigeonpea and sunflower plants. A total 12 isolates (5 *Azotobacter*, 5 *Azospirillum* and 2 PSB) were selected based on pot studies, PGP traits and abiotic stress tolerance capacity. These isolates were further tested under drought stress conditions and best microbial strains from each group *Azospirillum*: ASP1, *Azotobacter*: AZT21 and PSB1 were selected on the basis of plant growth parameters. These selected strains were further tested as individual, dual and multiple inoculants in sorghum and pigeon

Sorghum crop without (a) and with inoculants (b)

pea under non-sterile drought stressed pot conditions and it was observed that dual (Azo+PSB) and multiple (Azo+PSB+Asp) inoculations performed better as compared to single inoculations. A similar experiment was repeated under field conditions at GRF. Application of fertilizers and other farm

practices were followed as recommended. Treatment with three inoculants (Azo+PSB+Asp) showed maximum shoot length i.e. 82.5 inches (control 78.5 inches) whereas single inoculant treatment (*Azotobacter* strain AZT21 alone) showed maximum straw yield (15738 kg/ha) and grain yield (2558 kg/ha) (control straw yield 12205 kg/ha and grain yield 1605 kg/ha).

Rhizobial Diversity

A survey was made in nearby villages of Anantapur and Tandur in August, 2009 and in Chintapalli, Guntur and Jagtial regions of Andhra Pradesh in August, 2010. Soil samples and plants with intact root nodules were collected from the cowpea and pigeonpea growing farmer fields. A total 259 strains of pigeonpea rhizobia and 109 strains of cowpea rhizobia were isolated from the nodules. Most probable number of rhizobia in the soil samples has been estimated. Nodulation studies of isolated rhizobia and other biochemical and PGPR properties are in progress to select best rhizobial strains for pigeonpea and cowpea.

Survival and persistence of stress tolerant PGPR strains in the rhizosphere of dryland crops

The role of microbes in management of biotic and abiotic stresses is gaining importance in the present scenario of climate change. Efficient stress tolerant (heat and drought) strains of *Pseudomonas* and *Bacillus* have been identified at CRIDA. Study of rhizosphere competence of these strains and their stress alleviating potential under field conditions is essential before formulating them as bioinoculants for abiotic stress management. Rifampicin resistant mutants of three *Bacillus* sp. strains (B30, B17 and RP24), three *Pseudomonas* sp. (P7, P52 and P45) and one *Azospirrilum* spp. (G12) were generated by spontaneous mutation and compared for PGP traits with respective wild type strain. Rhizosphere competence of these mutants was studied with sorghum and sunflower under sterile conditions. Inoculation of strains significantly improved the plant growth in terms of shoot, root length and plant dry biomass (Fig. 39). Inoculated seedlings showed higher levels of chlorophyll, total sugars, proline and relative water content as compared to uninoculated control seedlings. Rhizospheric soil was serially diluted and appropriate dilutions were plated on king's B (for *Pseudomonas*), Nutrient Agar (for *Bacillus*) and Rojo congo (for *Azospirrilum*) media supplemented with 50 µg/ml of rifampicin. All the strains could efficiently colonize rhizosphere of sorghum as well as sunflower.

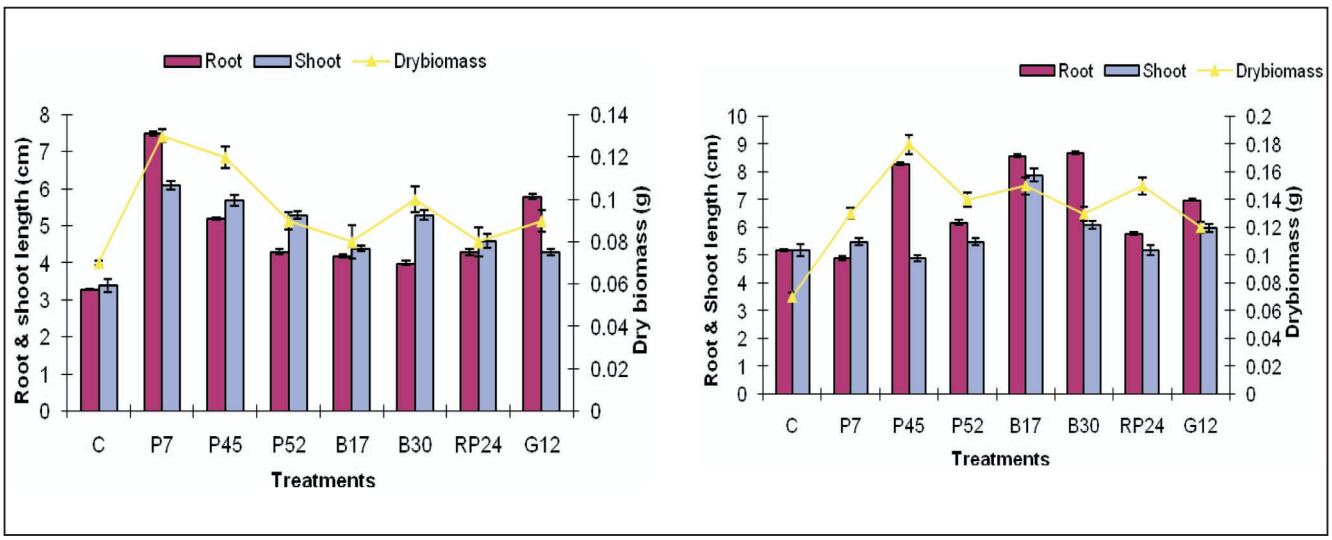


Fig. 39. Plant growth parameters of sunflower and sorghum seedlings under drought stress

2.4.16 PGPRs for nutrient management in sorghum and pigeonpea

Majority of rainfed farmers grow crops with a limited external nutrient supplementation due to shortage of resources. Agriculturally Important Microorganisms (AIMs) are known to supplement the nutrient requirements of plants and also known to promote plant growth. These products not only contribute to enhanced nutrient availability and reduce cost of production for the farmers, but can also give a fillip to certified organic farming in rainfed areas. A project was initiated to identify, characterize and evaluate useful microbial inoculants and develop into a product. During last year, efforts were made to identify promising *Bacillus* and *Pseudomonas* strains that can be used as seed dressers for promoting growth of sorghum and pigeonpea. Among several strains tested, B17 & B38 (*Bacillus* spp.) were superior to other strains (best among the previous studies P1, P22, P28, P67, B38, B53, B93 & B105) in promoting growth of pigeonpea in field. Similarly, P1 & P35 (*Pseudomonas* spp.) were superior to other strains (best among the previous studies P22, P23, P17, B22, B39, B73, B87 & B98) in the plant growth promotion of sorghum in field.

In a process to identify a consortium to promote growth of pigeonpea, B105+P17+*Rhizobium* formulation has shown good growth promotion of pigeonpea in pots, when compared to individual inoculations. Similarly, B87+P17+*Azospirillum* formulation has shown good growth promotion of sorghum in pots, when compared to single and dual inoculations. For the successful deployment of microbial inoculants, it is essential that they are compatible with chemical fertilizers and commonly used seed dressing chemicals so that they can be applied along with basal dose of fertilizers and seed treatment chemicals. Among several strains of *Bacillus* spp. tested, B87, B105 & P17 were compatible with urea (1-5%), murate of potash (1-5%), di-ammonium phosphate (1%) and single super phosphate (1%). Similarly, B87 & P17 were compatible with 2% di-ammonium phosphate. *Pseudomonas* strain P17 was compatible with fungicide carbendazim 50%WP-1%, mancozeb 75% WP-0.5%, metaxyl 35% WP-1%, copper oxychloride (COC) 50% WP-0.5% and captan 50% WP-0.5%. *Bacillus* spp. strains, B87 & B105 were compatable with fungicide Carbendazim 50%WP-0.25%, Mancozeb 75% WP- 0.25%, Metaxyl 35% WP-0.75%, COC 50% WP-0.25% and Captan 50% WP- 0.75%.

2.4.17 Integrated bio-resources centre

Under integrated bioresources centre, various biofertilizers and biopesticides have been produced and sold to farmers. During 2010-11, a total revenue of Rs. 6,00,000 was generated through sale of various bioinoculants such as *Trichoderma*, *Azospirillum*, PSB, *Azotobacter* etc. Farmers were also trained in KVK organized water productivity training programs about use of various bio-inoculants by delivering lectures and also demonstrating the method of use of various products.

2.4.18 Improving the farming systems of small and marginal farmers in selected districts of Andhra Pradesh

There is a need to evolve farming systems approach which minimizes risk while ensuring higher returns to meet the growing needs of the small and marginal farmers. After the analysis of existing farming systems, during second year of the project, suitable interventions were identified for addressing the diagnosed constraints. These interventions were evaluated during *kharif*, 2010 for their performance at selected farmers' fields. At Anantapur, the groundnut + pigeon pea intercropping suffered heavily due to prolonged dry spells during flowering and pod formation. The farmers harvested very low groundnut yields while pigeon pea failed completely. The groundnut yield, averaged across six farmers' fields, was only 140 kg/ha in the plots under farmers' practices (Fig. 40). Application of pendimethalin for weed

control gave about 24% higher yield while use of recommended NPK gave 46% higher yield than farmers' practice. However, the yield increased by more than 2.5 times when both pendimethalin and recommended NPK were applied compared to farmers' practice.

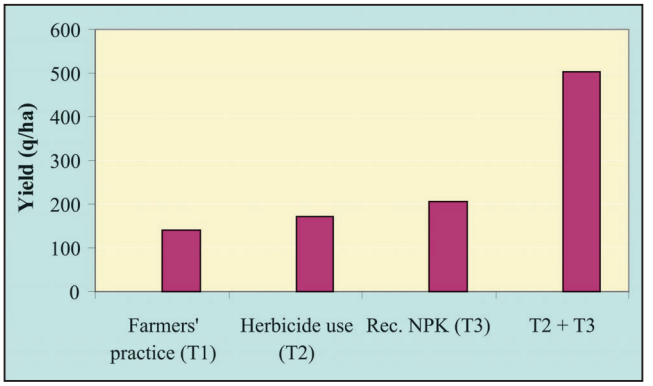


Fig 40. Response of groundnut to different management practices

Similarly, in Seethagondhi cluster of Adilabad district, the interventions identified for addressing the diagnosed constraints were a) use of herbicide for weed control, b) use of recommended NPK, and c) use of both herbicide and recommended NPK in cotton + pigeon pea intercropping. These interventions were evaluated during *kharif* 2010 to test their performance at selected farmers' fields. On average, the yield of cotton + pigeon pea intercropping increased by 25.3% with the use of herbicide for weed control and 36.4% with application of recommended NPK compared to farmers' practice. Use of both herbicide and recommended NPK enhanced the yield of cotton + pigeon pea intercropping by 43.4% compared to farmers' practice.

2.4.19 Sustainable farming System modules for small and marginal farmers in Southern Telangana zone

Studies on farming system modules on microwatershed basis were initiated in a 13,964 m^2 watershed at HRF. A total of 23 crops were grown (4 field crops, 9 vegetables, 2 fruit crops, 3 grasses/fodder, 2 tree crops, 2 bush crops and 1 essential oil yielding crop). Ram lamb (20) rearing was also taken up by utilizing crop byproducts and fodder produced. The total cost of production for crops component was Rs 15,164/ha and net profit from the crops was Rs 31,556/ha. By raising ram lambs, a net profit of Rs 20,800 was realized; thus net profit from the system was Rs 52,356. The economic efficiency of the Farming system module (FSM) was compared with popular cropping systems in the zone i.e. sorghum+ pigeon pea and castor. FSM registered a net profit of Rs 52,356/ ha compared to Rs 12,340/ha & Rs 3,550/ha, respectively. Economics of rainwater harvesting in cement lined farm pond and its utilization was worked out. Cumulative volume of 955 m^3 water was harvested in 500 m^3 farm pond. Crops like pigeon pea, vegetables and leafy vegetables were raised on 0.1785 ha with production cost of Rs 4,500 and a net profit of Rs 12,850.

The main advantage of FSM was production of fodder from diverse sources (Table 15). This fodder was used for raising 20 ram lambs for 250 days with 255 kg gain in body weight along with 1.5 t of faeces. This resulted in an additional net income of Rs 20,800 from the system.

Pigeonpea (PRG-100) was raised in polythene bags for 35 days before onset of monsoon and then transplanted in the main field and compared with direct sown crop. The crop was irrigated using

Table 15 : Area and production of different crops in FSM

Crop	Area (SqM)	Dry fodder (kg/plot)	Kg dry fodder/ day/lamb
Bajra	1,880**	590	0.118
Sorghum	2800**	846	0.170
Sorghum	2560*	2600	0.520
Stylo	256*	320	0.07
Cenchrus	800*	1784	0.357
Glyricidia	368 M	70	0.014
Total	3,616*+4,600**		

* : Land devoted exclusively for fodder production
** : Land devoted primarily for grain production and fodder was a byproduct

harvested rainwater through sprinkler system at critical crop growth stages. Transplanted pigeonpea with life saving irrigations registered 19% more grain yield than rainfed transplanted pigeonpea (970 kg/ha; Table 16). Whereas, direct sown irrigated pigeon pea registered 28% higher grain yield compared with direct sown rainfed crop. Similarly, transplanted crop with life saving irrigation registered 17% more grain yield than direct sown irrigated crop. Furthermore, rainfed transplanted crop recorded 26% more grain yield than rainfed direct sown crop. This technique of transplanting offers opportunity to the farmer to harvest higher yield of pigeonpea even if monsoon rains are delayed by 3-4 weeks. But the process of raising seedlings and their transplanting is labour intensive.

Table 16 : Performance of Pigeon pea under different planting systems and supplemental irrigations

Pigeon pea	Grain yield (kg/ha)	
	Transplanted	Direct sown
Irrigated	1150	980
Rainfed	970	765

2.4.20 Evaluation of forage sorghum varieties

The basic purpose of the experiment was to study the feasibility of forage sweet sorghum for forage purpose, so that forage cultivation can have more options and successes, and nutritious forage is available for draft and milch-cattle. The performance of 7 sweet sorghum varieties (Table 17) was evaluated against 2 forage sorghum varieties (Pusa CHARI and MP CHARI) in rainfed alfislos. Sweet sorghum varieties performed well and were comparable with forage sorghum varieties in terms of fresh forage yield raising the possibility of additional forage varieties as options for forage cultivation. There were significant differences between varieties at all the stages of observations. The yield sequence of varieties at 30DAS was MP CHARI>ICSV 93046>NTJ 2>PC CHARI>ICSV 700>SPV 422>ICSR 93034>SSV 84>SPV 1411. At 60 DAS, the yield sequence was MP CHARI>NTJ 2>ICSV 93046>PC CHARI>ICSV 700>SPV 422>ICSR 93034>SPV 1411>SSV 84. However, the yield sequence at final harvesting was SSV 84>NTJ 2>ICSV 93046>SPV 422>ICSV 700>ICSR 93034>MP CHARI>PC CHARI>SPV1411. The differences in yields of different varieties are due to growth and phenology habits.

Table 17 : Fresh forage yield of different varieties at different growth stages (t/ha)

Varieties	30 DAS	60 DAS	Final harvest
PC CHARI	4.08	21.75	32.25
MP CHARI	5.18	22.75	35.50
ICSR 93034	3.73	20.25	35.75
ICSV 700	4.00	21.75	38.25
ICSV 93046	4.20	22.25	40.25
NTJ 2	4.15	22.25	41.75
SPV 422	3.85	20.75	39.00
SPV 1411	3.50	19.75	30.25
SSV 84	3.50	19.50	43.75
CD 5 %	0.29	0.93	1.70

2.4.21 Development of ready to eat nutrient rich value added products from selected dryland crops

Fortification of coarse millets with fruits and vegetables improves the nutrient profile of the finished product, thereby improves essential nutrients in the finished products. Fortification of Bajra flour was attempted as follows:

Fortified Bajra biscuits: T_1, Bajra flour 50% + Maida 50%, T_2, Bajra flour 65 % + Maida 25% + dehydrated carrot powder 10%, and T_3, T_2 + Egg. The mineral content (Fe and Zn) in these products was compared with that of commercially available Good day biscuits (T_4).

Fortified Bajra fruit pie: 1. Bajra flour 75% + Maida 25% +Pine apple + sapota, 2. Bajra flour 75% + Maida 25% +Pine apple + Guava, 3. Bajra flour 75% + Maida 25% + Pine apple + papaya, 4. Bajra flour 75% + Maida25 % + Pine apple + apple, and 5. Bajra flour 75% + Maida 25% + Apple + sapota + guava.

Four nutrient rich value-added and ready to eat snack products were developed using fortified bajra flour. Carrot powder fortified Bajra biscuits were found to contain significantly higher levels of ash content. Iron content was also significantly higher in bajra based snack products compared to Good day biscuits (Fig. 41).

Ready to eat biscuits and fruit pie prepared using fortified bajra flour

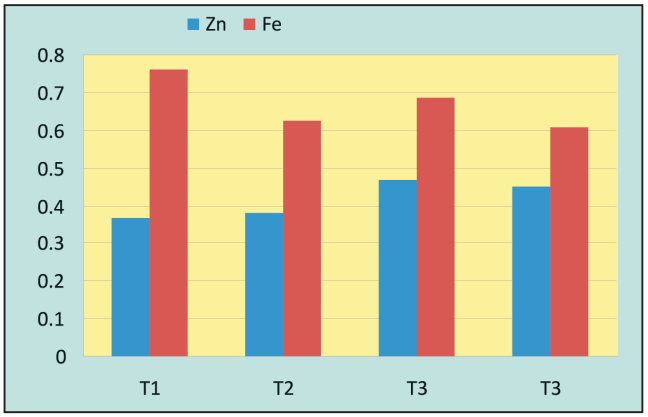


Fig 41. Mineral content (ppm) in fortified bajra products

2.4.22 Effect of bioenrichment on the mineral quality of Spinach crop

A pot experiment was conducted to evaluate the effect of different treatments viz. farmyard manure (FYM), FYM + phosphate solubilising bacteria (PSB), FYM + citrate, FYM + PSB + citrate, chemical Fertilizer and control on bioenrichment of mineral content in spinach leaves. Application of FYM + PSB + citrate resulted in higher Fe (330.1 mg/kg) and Mn (147.7 mg/kg) content in spinach leaves compared with other treatments (Table 18). However, application of FYM + PSB recorded significantly higher N and protein but marginal increase in Zn and Cu content of spinach leaves compared with other treatments.

Table 18 : Mineral content (mg/kg) of spinach crop grown under different treatments

Treatment	Fe	Mn	Zn	Cu
No input (Control)	81.2	28.5	2.2	1.3
Chemical fertilizer	292.1	94.9	25.3	10.8
FYM	247.0	131.8	32.1	16.1
FYM + PSB	273.9	144.3	40.5	16.0
FYM + citrate	224.1	37.8	9.75	6.4
FYM + PSB + citrate	330.1	147.7	36.2	8.3
CD value	24.0	72.2	13.1	7.9
CV %	3.9%	28.8%	20.9%	31.4%

2.5 Soil health and nutrient management

2.5.1 Low tillage and integrated nutrient management strategies for semi-arid tropics

The present study was undertaken to identify low cost integrated nutrient management (INM) treatments using farm based organics for sorghum-mung bean system under conventional and reduced tillage practices. The experiment was conducted at Hayathnagar Research Farm of CRIDA in a strip plot design with two tillage (conventional (CT) and reduced (RT)) and five INM treatments (control (T_1), 40 kg N through urea (T_2), 4 t compost + 20 kg N (T_3), 2 t Gliricidia loppings + 20 kg N (T_4) and 4 t compost + 2 t Gliricidia loppings (T_5)) for sorghum (SPV 462) crop and control (no nitrogen) (T_1), 20 kg N through urea (T_2), 2 t compost + 10 kg N (T_3), 1 t Gliricidia loppings + 10 kg N (T_4) and 2 t compost + 1 t Gliricidia loppings (T_5) for green gram (ML-267) crop. Recommended level of phosphorus @30kg P_2O_5/ha was applied to both sorghum and green gram crops uniformly. The

results in thirteenth year showed both tillage as well as conjunctive nutrient use treatments showed a significant influence on sorghum as well as mung bean yields while their interaction effects were non-significant. The sorghum grain yields varied from 333 to 2271 kg ha^{-1} while the mung bean grain yields varied from 830 to 1579 kg ha^{-1} across the tillage and nutrient management treatments. After 12 year of experiment, on an average, reduced tillage was found superior over the conventional tillage by 10.7 and 1.6 % in terms of sorghum and mung bean yields, respectively. The highest average sorghum grain yields were observed under application of 4 t compost + 20 kg N through urea (2184 kg ha^{-1}) followed by 2 t Gliricidia loppings + 20 kg N through urea (2120 kg ha^{-1}). In case of mung bean, both application of 2 t compost + 10 kg N through urea (1559 kg ha^{-1}) and 2 t compost + 1 t gliricidia loppings (1516 kg ha^{-1}) recorded significantly higher yields. Agronomic efficiency for sorghum crop varied from 40.8 to 47.4 kg grain kg^{-1} N, while it varied from 19.8 to 35.6 kg grain kg^{-1} N for mung bean crop across the treatments. Among the tillage treatments, reduced tillage practice showed significantly higher total hydrolyzable N (6.98%), hydrolyzable NH_4-N (6.01%), hexosamine N (12.9%), available N (9.61%) and total N (4.07%) over conventional tillage (Fig 42). Whereas the conjunctive nutrient use treatments significantly improved all the nitrogen pools over control.

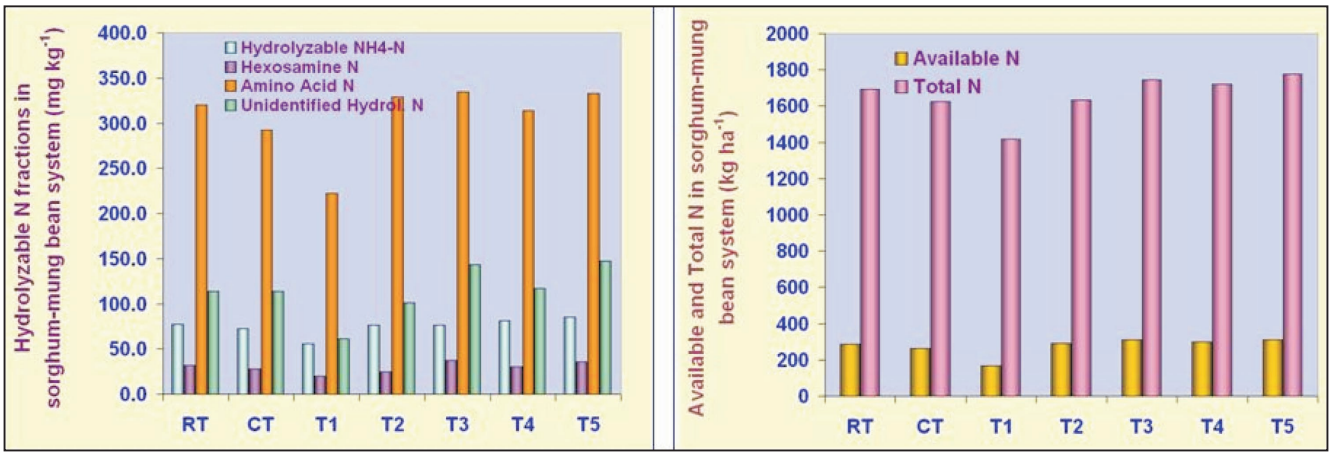


Fig. 42. Effect of tillage and conjunctive nutrient management treatments on different nitrogen pools in sorghum-mung bean system in rainfed Alfisols

2.5.2 Restoration of soil quality through conservation practices

During sixth year of the study in 2010 cowpea (Priya) yield varied from 462 to 870 kg ha^{-1} across the 4 levels of sorghum residue application (Fig. 43). Application of sorghum stover @ 4 t ha^{-1} recorded significantly higher cowpea yields (870 kg ha^{-1}) compared to residue applied @ 6 t ha^{-1} (708 kg ha^{-1}). The percent increase in grain yields with residue application @ 2 (T2), 4 (T3) and 6 (T4) t ha^{-1} was to the tune of 42.9, 88.4 and 53.3 percent, respectively over no residue (T1) application. Residue application significantly influenced

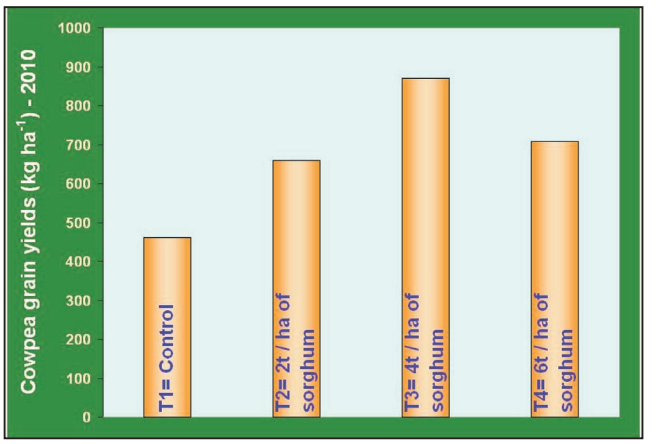


Fig. 43. Cowpea (Priya) yields as influenced by the surface application of crop residue during the year 2010

exchangeable NH_4–N, total hydrolyzable N, hydrolyzable NH_4-N, hexosamine N, amino acid N, available N and total N pools where as no effect was observed on fixed ammonical N and unidentified N.

A field experiment comprising of tillage (conventional (CT) and minimum (MT)), residue (2 t ha^{-1} dry sorghum stover (SS), 2 t ha^{-1} fresh gliricidia loppings and no residue (NR)) and nitrogen levels (0 (N_0), 30 (N_{30}), 60 (N_{60}) and 90 (N_{90}) kg N ha^{-1}) under sorghum (*Sorghum vulgare* (L)) and castor (*Ricinus communis* (L)) system was initiated in a strip split-split plot design at Hayathnagar Research Farm during 1995. During the current year (2010) castor (DCS-9) was the test crop. During the current year (2010), which was 16th year of long-term study,

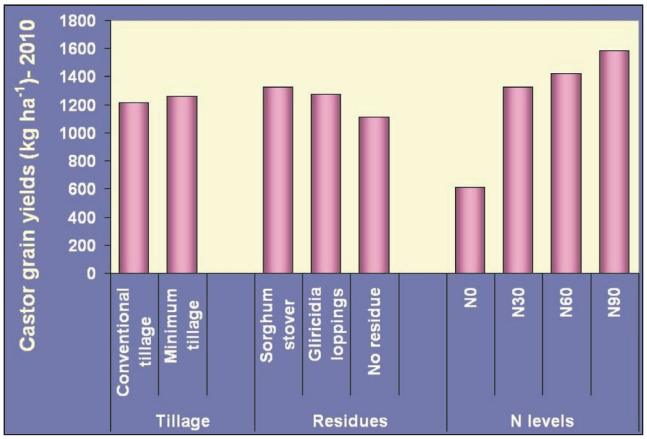


Fig. 44. Castor (DCS-9) bean yields as influenced by tillage, residues and N levels under sorghum-castor system during 2010

castor bean (DCS-9) yield varied from 551 to 1788 kg ha^{-1} across the management treatments. The data showed that residue application and N levels played a significant role in influencing the castor bean yields while tillage did not show any significant effect this year (Fig. 44). The minimum tillage could maintain equal or slightly higher average castor bean yields (1261 kg ha^{-1}) compared to conventional tillage (1211 kg ha^{-1}). Among the residues, application of sorghum stover resulted in higher average castor bean yield (1325 kg ha^{-1}), which was almost at par with application of gliricidia loppings (1273 kg ha^{-1}) compared to no residue application (1111 kg ha^{-1}). Nitrogen levels also played a significant role in influencing castor bean yields which increased with increase in N levels. Application of nitrogen @ 90 kg ha^{-1} recorded significantly highest average yields (1584 kg ha^{-1}) followed by N applied @ 60 kg ha^{-1} (1422 kg ha^{-1}). The interaction effects between tillage, residues and N levels did not show any significant influence on castor bean yields. Residue application and N levels significantly improved available and total N content in soils while tillage could play a significant role in improving available N only.

Two long-term ongoing experiments at Solapur centre (semi-arid vertisols) were adopted for soil quality assessment study. In a long-term manurial experiment, the key soil quality indicators identified along with their percent contributions towards soil quality indices in rainfed rabi sorghum system were: pH (3.97%), EC (1.94%), organic carbon (18.6%), available P (2.80%), available K (6.57 %), exchangeable Ca (7.02%), available S (3.45%), Available Zn (17.9%), dehydrogenase activity (DHA) (16.2%), MBC (microbial biomass carbon) (18.5%) and MWD (mean weight diameter) (3.14%). The soil quality indices varied from 1.77 to 2.36 and were significantly influenced by the long-term manurial treatments. Among all the treatments, the application of 25 kg N ha^{-1}(crop residue) + 25 kg N ha^{-1} (urea) showed the highest soil quality index of 2.36 which was at par with other treatments which received FYM and crop residues along with urea. The treatments viz., 25 kg N ha^{-1} (urea) could achieve a SQI of 1.99 followed by control (1.77).

In a tillage experiment, the key soil quality indicators identified under rabi sorghum system along with their percent contributions towards soil quality indices were: organic carbon (12.8%), available K (10.4%), available Zn (18.2%), available B (27.8 %) and microbial biomass carbon (30.9%). The soil quality indices varied from 1.06 to 1.33 across the tillage and nutrient management

treatments. It was observed that tillage as well as the nutrient management treatments played a significant role in influencing the soil quality indices while their interaction effects were not conspicuous. Among the tillage treatments, order of performance in terms of SQI was: medium tillage (1.28) > low tillage (1.23) > conventional tillage (1.11). Among the nutrient management treatments, application of nutrients through 50 kg N through organics + no P_2O_5 maintained highest soil quality with SQI value of 1.26 followed by 25 kg N (organics) + 25 kg N (urea) + 12.5 kg ha^{-1} P_2O_5 (1.21) and 50 kg N (urea) + 25 kg P_2O_5 ha^{-1} (1.15).

2.5.3 Soil and crop management practices for managing zinc deficiency in maize-based cropping system in rainfed areas

Field experiments were conducted in zinc deficient soils at two locations a) Alfisols of Hyderabad (Andhra Pradesh) and b) Inceptisols of Arija (Rajasthan). The DTPA-extractable Zn at Hyderabad was 0.45 ppm whereas at Arija it was 0.40 ppm. The experiment in both the locations was laid out in randomized block design with three replications and seven treatments viz. 1) Control (No Zn); 2) Soil application of $ZnSO_4$ (@ 25 kg/ha; 3) Seed priming with 1% $ZnSO_4$ solution; 4) Inoculation with P 29 strain of Pseudomonas; 5) Inoculation with P 33 strain of Pseudomonas; 6) Inoculation with B 116 strain of Bacillus and 7) Inoculation with B 41 strain of Bacillus. The test crop used in both the locations was maize. The maize seeds were treated with bio-inoculent @ 10g for 250g of seeds. In Arija, apart from these treatments additional treatment of foliar application of 0.5 % $FeSO_4$ was also evaluated.

Grain yield of maize as influenced by different treatments (Fig. 45) revealed that at Hyderabad soil application with zinc sulphate, inoculation of maize seeds with P 29, P33 and B 116 resulted in significant increase in the grain yield as compared to control. Although other treatments (inoculation with P 41, seed priming) resulted in higher yield as compared to control but the increase was not substantial. At Arija, highest grain yield of 4433 kg/ha was recorded under soil application of zinc sulphate followed by inoculation with P29 and P 33 strains. Higher zinc uptake was also recorded in treatments receiving soil application of zinc sulphate and inoculation with P 29, P33 and B 116 at Hyderabad centre.

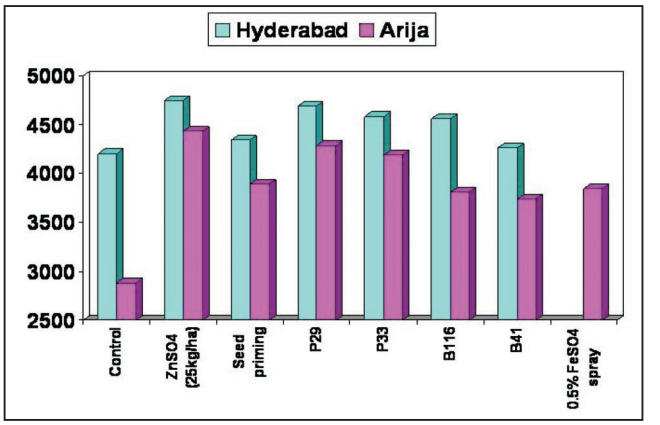


Fig. 45. Grain yield of maize (kg/ha) as influenced by different treatments at Hyderabad and Arija

2.5.4 Carbon sequestration potential of reduced tillage systems under rainfed conditions

Considering the need of reducing the frequency and number of tillage operations in view of the concerns of climate change, soil carbon emissions and the need to increase the soil carbon sequestration the present study was initiated to determine soil carbon pools (active, slow, and passive) as influenced by tillage nutrient application across agro-ecological regions and soil types. Long-term experiments initiated in All India Coordinated Research Project on Dryland Agriculture during 1998-1999 under various tillage practices on the crop productivity and energy conservation are being used for the study. The template of the treatments is as follows:

Tillage treatments

1) Conventional tillage: 1 ploughing+ 2 harrowings+ 2 hoeings + 1 hand weeding
2) Low tillage: 2 harrowings+ 1 hoeing + 1 hand weeding
3) Minimum tillage: 1 harrowing+ 1 hoeing + 1 hand weeding

Nutrient treatments

1) N1- 100% Organic
2) N2- 100% Inorganic
3) N3- 50% Organic + 50% inorganic.

Both the treatments groups were imposed in split plot design. During this year soil samples were collected from Indore and Phulbani center. Crop related parameters were collected from the redgram based system at Bangalore, rice based system from Phulbani, pearlmillet based system from Kovilpatti, sorghum based system from Bijapur. Crop related parameters such as grain and biomass production at harvest, root and litter biomass at the harvest stage of crops in different centers. Soil samples were collected from Phulbani center, which is located in the eastern ghat zone in Orissa with sub humid climate which receives about 1580 mm of rainfall. Rice is the main crop and the predominant soil group is oxisols. Among the treatments the organic carbon was found to be highest in reduced tillage and the carbon content decreased with the increase in depth. In conventional tillage the organic carbon was reduced from 0.35 to 0.27% where as in low tillage the carbon content was reduced from 0.43 to 0.29% and in minimum tillage the carbon content was reduced from 0.40 to 0.31% with the increase in depth. Among the fertilizers treatments the highest carbon content was found to be observed in 50% organic + 50% inorganic fertilizers treatment. Among the tillage treatments the particulate organic matter (POC) was highest in reduced tillage and among the fertilizers treatments POC was highest in 100% organic treatment. Highest microbial biomass carbon was found in reduced tillage treatment and in 100% organic fertilizers treatment. The microbial biomass carbon content is highest in surface layers and gets reduced in deeper layers in the soil. Highest labile carbon was found in the minimum tillage treatment and in fertilizer treatments highest labile carbon was found in 50% organic + 50% inorganic fertilizer treatments and the content was found to reduce with the increase in soil depth from the surface to deeper layers.

2.5.5 Effect of biochar amendment on soil properties and growth of pigeon pea

Crop residues can be carbonized to highly stable carbon compound called as biochar and can be applied as soil amendments for sequestering C and to improve the production potential of crops in rainfed production systems. With this in view, a project was initiated in 2009 at HRF, CRIDA on utilization of crop residues for production of biochar and its subsequent use in rainfed agriculture. Biochar was produced from these residues by partial combustion using the kiln designed and fabricated at CRIDA. Biochar from castor, cotton and pigeon pea stalk were used separately at different rates along with recommended dose of fertilizers (20:50:0 kg /ha of NPK). Pigeon pea (PRG 158) was the test crop during the year 2010.The treatments imposed were, biochar 0.0 t/ha (Control-T_1), biochar 3.0 t/ha (T_2), biochar 6.0 t/ha (T_3) and biochar 0.0 t/ha (no fertilizer, negative control-T_4). Recommended dose of fertilizers was applied equally to all

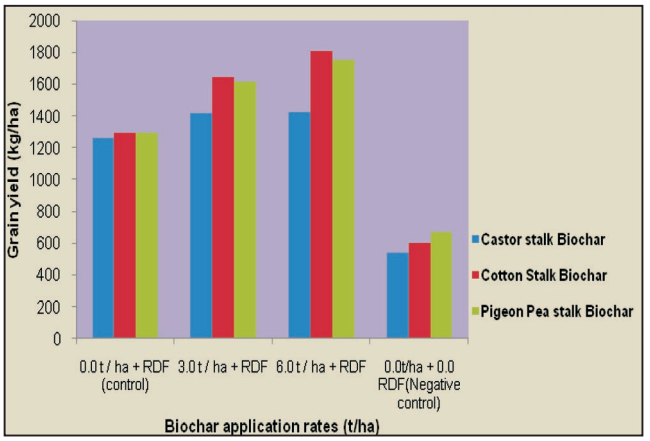


Fig. 46. Pigeonpea grain yields as influenced by the castor, cotton and pigeon pea stalk biochar at different levels of application during the year 2010.

treatments except T_4. During the current year, grain yield response was not significant to the applied castor stalk biochar, however the per cent increase in yield of 12.23 (T_2) and 12.99 (T_3) was observed over control (T_1). Among the biochars amendments, application of cotton stalk biochar at 3.0 and 6.0 t/ha with RDF recorded significantly higher yield showing an increase of 26.9 and 39.8 % over

control (T_1), respectively. Application of pigeon pea stalks biochar at 3.0 and 6.0 t/ha with RDF increased the grain yield by 21.6 and 32.1 % over control(T_1), respectively (Fig 46). In negative control (T_4), grain yield was significantly low compared to all other treatments. In the first year of the study, crop grain yield response to cotton and pigeon pea stalk biochar was effective in registering significantly highest yield at 6.0 t/ha + RDF followed by 3.0 t/ha + RDF and were at par with each other.

2.5.6 On-farm soil health management and livelihood impacts

Soil samples from 1600 farmers' fields covering 50 villages in eight districts of Andhra Pradesh were collected by involving farmers as participants in soil sampling. Most of the soils are low to medium in soil organic carbon, low in available nitrogen, low to high in available P and K. Deficiency of secondary and micro nutrients is also prevalent (Table 19).

Table 19 : Nutrient deficiencies in different clusters of 8 districts of Andhra Pradesh

Cluster	OC	N	P	K	S	Zn	B	Fe	Cu
Adilabad	L-M	L	L	H	D-S	D-S	D-S	S	S
Nalgonda	L-M	L	L-H	L-M	D-S	D	D	D-S	S
Khammam	L-M	L	L-H	L-H	D-S	D	D	S	S
Mahaboobnagar	L-M	L	L-M	M-H	D-S	D-S	D-S	S	S
Anantapur	L	L	M-H	L-H	D	D-S	S-D	S	S
Kadapa	L	L	L-M	L	D	D	D	D-S	D-S
Warangal	L-M	L	M-H	L-M	D-S	D	D	S	S
Rangareddy	L-M	L	L-M	L-H	D-S	D-S	D-S	S	S

L= Low; M= Medium, H= High, D= Deficient, S = Sufficient

2.5.7 Impacts of balanced nutrition on income in participatory soil fertility management

Net income due to balanced nutrition in cotton was upto Rs. 20,000 ha^{-1} while this was around Rs. 16000 ha^{-1} in farmers practice (suboptimal level of nutrients) in Jaffergudem cluster of Warangal district. Since, yield increment in case of balanced nutrition primarily due to higher amount of nutrients used, the B:C ratio was not much higher with balanced nutrition over farmers practice. However, net incomes were much higher in case of cotton with balanced nutrition in Seethagondi cluster of Adilabad district. B:C ratio of balanced nutrition was far ahead to that of farmers practice (Fig 47 and 48).

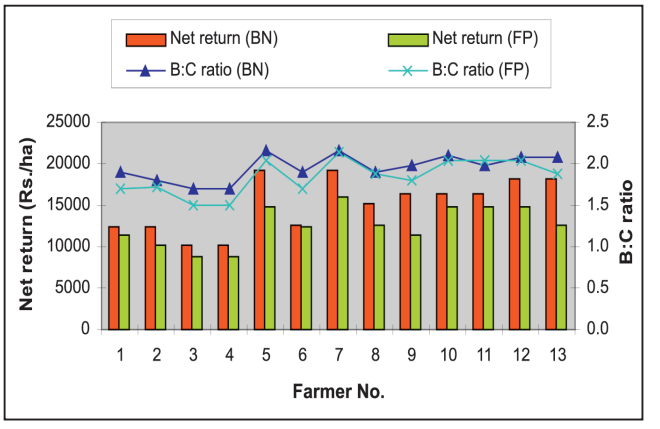


Fig. 47. Impact of balanced fertilization (BN) and farmers' practice (FP) in net return and benefit:cost ratio of cotton cultivation in some selected farmer's field of Jaffergudem cluster of Warangal district, A.P. (2009-2010)

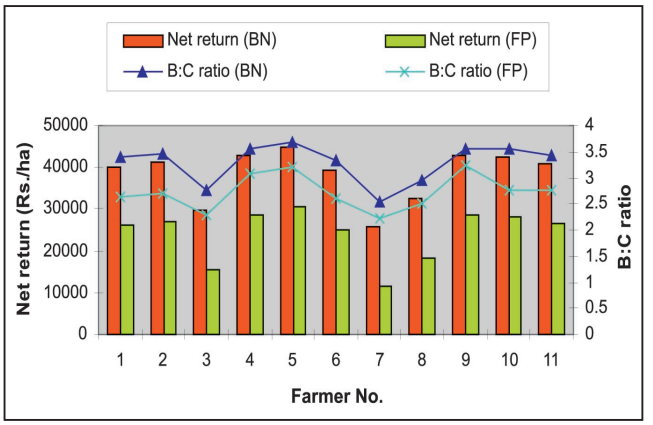


Fig. 48. Impact of balanced fertilization (BN) and farmers' practice (FP) in net return and benefit:cost ratio of cotton cultivation in some selected farmer's field of Seethagondi cluster of Adilabad district, A.P. (2009-2010)

In case of Tummala Cheruvu cluster in Khammam district, net returns of Bt cotton with balanced nutrition were upto Rs. 50000 ha^{-1} and B:C ratio up to 4.5. Net income also increased in groundnut in southern Andhra Pradesh (Kadapa and Anantapur) with balanced nutrition. The net income among farmers showed upto Rs. 6000 ha^{-1} in Kadapa and upto Rs. 5000 ha^{-1} in Anantapur district. The B:C ratio improved in both the districts with balanced nutrition as compared to farmers practice. The economic benefits of nutrient management in cotton and groundnut are presented in Table 20.

Table 20 : Economics of balanced fertilization in cotton and groundnut cultivation in major growing areas of Andhra Pradesh

Name of the cluster	Crop	Mean gross return (Rs./ha)		Mean net return (Rs./ha)		Mean B:C ratio	
		BN	FP	BN	FP	BN	FP
Jaffergudem, Warangal	Cotton	31543	27048	15091	12569	1.95	1.84
Seethagondi, Adilabad	Cotton	54655	38631	37907	23724	3.26	2.72
T. Cheruvu, Khammam	Cotton	55273	43973	38557	29741	3.35	3.05
B. Yerragudi, Kadapa	Groundnut	9647	7290	3977	2885	1.78	1.65
Pampanur, Anantapur	Groundnut	9668	8157	4668	3723	1.82	1.66

2.5.8 Yield sustainability and critical carbon requirement of groundnut-fingermillet rotation on Alfisols of semi-arid tropical conditions

The impact of crop residue carbon (C) inputs on yield sustainability and soil organic carbon (SOC) sequestration was investigated in a 13 year old long-term fertility experiment under rainfed groundnut-fingermillet crop rotation at Bangalore centre (soil type Alfisol, climate semi-arid (moist) type). Critical value of carbon requirement for maintenance of soil organic carbon was also derived. Application of farmyard manure (FYM) alone or integration with chemical fertilizers contributed higher amounts of carbon inputs and subsequently built up higher C in soil. Higher profile soil organic carbon (73.0 Mg ha^{-1}), C buildup (41.2%) and C sequestration (9.3 Mg C ha^{-1}) was observed with

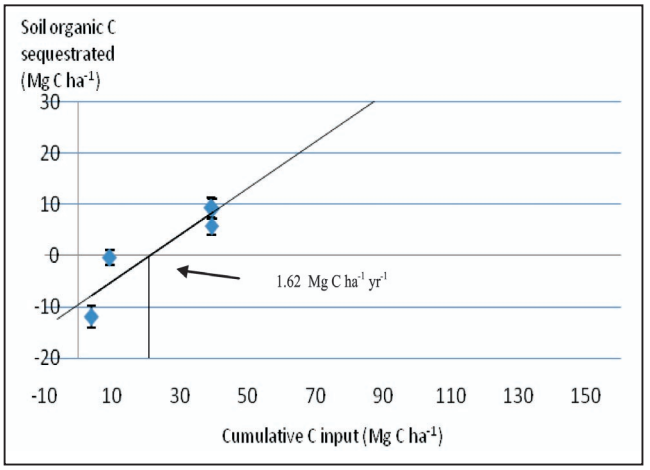


Fig 49. Critical C input value and its influence on C sequestration in groundnut-fingermillet rotation in semi arid condition (error bars represents the standard error of mean for sequestrated C). The relationship between the changes in SOC and the total cumulative C inputs to the soils (external organics plus crop residue) over 13 years (Y=0.454X-9.580; r^2=0.84)

the application of 10 Mg farmyard manure ha^{-1} in wet weight basis along with a recommended dose of chemical fertilizer (25:21.8:20.7 and 50:21.8:20.7 kg N, P, K ha^{-1}) for groundnut and finger millet, respectively. These were positively correlated with cumulative C input and sustainable yield index (SYI) of crops. For sustenance of soil organic carbon level (zero change due to cropping) a minimum quantity of 1.62 Mg C is required to be added per hectare per annum as inputs (Fig. 49). Balanced fertilization with nitrogen, phosphorous, and potassium (NPK) arrested the depletion of soil organic carbon, confirming that balanced fertilization and the inclusion of organic manure is vital to enhancing carbon sequestration in rainfed cereal-legume crop rotation in semi-arid tropical conditions.

2.5.9 Assessment of effects of soil and weather variables on sustainable rainfed agriculture using multivariate statistical and simulation models

Permanent manurial trials conducted at Kovilpatti (sorghum- pearl millet in two years rotation) during 1988 to 2008 under semi-arid Vertisols and Anantapur (groundnut) during 1985 to 2006 under arid Alfisols were studied to evaluate the effects of nutrient management and rainfall on crop productivity; and soil fertility status. In case of pearl millet-sorghum two years rotation at Kovilpatti showed that the treatments 40kg N (urea) + 20kg P per hectare gave maximum available soil N of 121 kg/ha, where as 20 kg N (FYM) + 20 kg N (urea)/ha +10 kg P/ha gave maximum available soil P of 9.8 kg/ha and treatment FYM @ 5 t/ha gave maximum exchangeable soil K of 401 kg/ha. The treatments, 20 kg N (FYM) + 20 kg N (urea)/ ha + 10 kg P /ha gave significantly higher mean pearl millet yield of 766 kg/ha followed by the treatment 40 kg N (urea) + 20 kg P + 25 kg $ZnSO_4$/ha with yield of 754 kg/ha. In case of sorghum the treatment 40 kg N (urea) + 20 kg P + 25 kg $ZnSO_4$/ha gave maximum mean yield of 1516 kg/ha followed by the treatment 20 kg N (FYM) + 20 kg N (urea) /ha + 10 kg P /ha with yield of 1486 kg/ha. The sustainable yield index of sorghum was also superior for the treatment 40 kg N (urea) + 20 kg P + 25 kg $ZnSO_4$/ha (45.3%).

The rain water use efficiency (RWUE, kg/ha/mm) of different treatments was determined in pearl millet with mean rainfall of 520.9 mm (11 years); and sorghum with mean rainfall of 434.9 mm (11 years). The RWUE ranged from 0.83 kg/ha/mm for control to 1.47 kg/ha/mm for 20 kg N (FYM) + 20 kg N (urea)/ha +10 kg P/ha in pearl millet, while it ranged from 1.74 kg/ha/mm for control to 2.91 kg/ha/mm for 40 kg N (urea) + 20 kg P + 25 kg $ZnSO_4$/ha in sorghum.

The regression models of pearl millet yield with monthly rainfall of October to January indicated that January rainfall was negatively related to yield of pearl millet where as for sorghum the October and January rainfall had a negative effect; while December rainfall had a positive effect on the yield.

The study at Anantapur in groundnut indicated that 100% NPK (20–40–40 kg/ha) + $ZnSO_4$ @ 25 kg/ha gave maximum mean pod yield of 926 kg/ha (variation of 46.6%), while control gave minimum yield of 741 kg/ha (variation of 44.6%). However, 100% N (groundnut shells ~ 20 kg N/ha) + 50% NPK (10–20–20 kg/ha) had minimum variation of 41.5%, while 100% NPK (20–40–40 kg/ha) had maximum variation of 47.4%. Highest yield increase of 24.9% was attained by 100% NPK (20–40–40 kg/ha) + $ZnSO_4$ @ 25 kg/ha, followed by 100% NPK (20–40–40 kg/ha) with 23.5%, 50% N (FYM ~ 10 kg N/ha) + 50% NPK (10–20–20 kg/ha) with 23.1%, while 100% N (groundnut shells ~ 20 kg N/ha) gave lowest yield increase of 16.5% over years.

Among the effects of rainfall on yield, the rainfall received in July, September, October and November had a positive influence, while rainfall received in August had negative influence on the yield attained by all treatments (Table 21).

Table 21 : Regression models of groundnut pod yield through monthly rainfall over years

Treatment	Regression model	R^2	SE	SYI
Control	Y = 376 + 1.30* (Jul) – 0.09 (Aug) + 0.58 (Sep) + 1.02 (Oct) + 2.97 (Nov)	0.24	315	27.6 (9)
100% NPK (20–40–40 kg/ha)	Y = 433 + 1.95* (Jul) – 0.04 (Aug) + 0.82 (Sep) + 0.99 (Oct) + 4.01* (Nov)	0.30	397	33.6 (6)
50% NPK (10–20–20 kg/ha)	Y = 423 + 1.76* (Jul) – 0.09 (Aug) + 0.80 (Sep) + 0.96 (Oct) + 4.04* (Nov)	0.32	351	34.2 (4)
100% N (GS ~ 20 kg N/ha)	Y = 473 + 1.03 (Jul) – 0.11 (Aug) + 0.80 (Sep) + 1.16 (Oct) + 3.30 (Nov)	0.18	357	32.7 (8)
50% N (FYM ~ 10 kg N/ha)	Y = 477* + 1.86* (Jul) – 0.46 (Aug) + 1.13 (Sep) + 0.54 (Oct) + 3.23 (Nov)	0.36	330	35.3 (1)
100% N (GS ~ 20 kg N/ha) + 50% NPK (10–20–20 kg/ha)	Y = 527* + 1.11 (Jul) + 0.14 (Aug) + 0.73 (Sep) + 0.72 (Oct) + 3.11 (Nov)	0.18	363	34.0 (5)
50% N (FYM ~ 10 kg N/ha) + 50% NPK (10–20–20 kg/ha)	Y = 432 + 1.97* (Jul) – 0.03 (Aug) + 0.82 (Sep) + 0.99 (Oct) + 3.75* (Nov)	0.32	373	34.9 (3)
100% NPK (20–40–40 kg/ha) + $ZnSO_4$ @ 25 kg/ha	Y = 399 + 1.94* (Jul) + 0.24 (Aug) + 0.88 (Sep) + 0.94 (Oct) + 4.55* (Nov)	0.34	383	35.1 (2)
Farmers practice (FYM @ 5 t/ha)	Y = 366 + 2.08** (Jul) – 0.32 (Aug) + 1.02 (Sep) + 0.84 (Oct) + 3.69* (Nov)	0.43*	315	33.5 (7)

2.5.10 Hydrogel as soil conditioners for improving the productivity of agricultural crops

There has been interest in super water–absorbent gel forming polymers as soil conditioners for improving the water retention of soil, or around seeds, or roots of transplants or seedlings in situations where prolonged or intermittent drought can occur. On an average these hydrogel polymers hold 350-450 times water of its weight and most of the water was released within 15 bar tension. An experiment was conducted to understand the efficacy of hydrogel on tomato crop during *kharif* and *rabi* season at CRIDA research farm. There were four treatments T1 = 25kg hydrogel/ha, T2 = 50kg hydrogel/ha, T3 = 100kg hydrogel /ha, T4 = Control (without hydrogel). Tomato was grown as rainfed crop during kharif season. Fertilizer was applied @ N:P2O5:K2O = 80:50:25kg/ha. Hydrogel was applied at the time of transplanting for each tomato plant as band placement by making hole with a stick at root depth. The highest yield was recorded in T3 treatment (Table 22) followed by T2, T1 and lowest in control T1 treatments. The overall agronomic efficiency of polymers application was 35 kg tomato per kg of Polymer application. During rabi season hydrogel was applied with five irrigation treatments for tomato, T1 = Irrigation every week +hydrogel @100kg/ha, T2 = Irrigation alternate week +hydrogel@100kg/ha, T3 = Irrigation every 3rd week +hydrogel@100kg/ha, T4 = No irrigation + hydrogel@100kg/ha, T5 = Irrigation alternate week +No hydrogel. In case of T1 treatment total 290 mm (16 No.) in T2 and T5 total 160 mm (8 No.) and in T3 total 100 mm (5 No.) water was applied as irrigation. The treatment T4 didn't receive any irrigation except light watering for first three weeks and at the time of fertilizer application. There was bumper yield of tomato in T1 treatment (65.1 t/ha) where hydrogel was applied @ 100kg/ha along with irrigation in every week, but yield was reduced to 50% of T1 when irrigation frequency was reduced to every alternate week. The results

indicated that at least one irrigation in every three weeks can be postponed by applying hydrogel polymers. Three was decrease in nutrient content in soils during the harvesting stage in T1 treatment may be because of higher uptake on nutrients by plants, on the other hand soil nutrients were higher in T4 treatment may be because of less yield and less uptake. When polymer was not effective in increasing yield in case of groundnut and redgram because of good distribution of rainfall during this year, there was yield increase in case of indeterminate type of tomato and cotton crop where flowering occurs in flushes and polymers help in retaining soil moisture towards the maturity stage of crop and increase the number of picking.

Table 22 : Yield, LAI (45 days after transplanting) and nutrient uptake of tomato under different rates of polymer treatment

Treatment	Leaf area Index	Fruit yield	Dry biomass yield	Total N Uptake	Total P Uptake	Total K Uptake	Agronomic efficiency
		kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg yield/ kg polymer
T1	2.5	16500	2387	29.4	21.2	31.0	12.08
T2	2.7	19104	2937	35.2	25.2	37.3	58.12
T3	2.6	19750	3073	36.6	26.2	38.9	35.52
T4	2.2	16198	2323	28.7	20.8	30.2	
CD (5% level)	NS	1292	510	7.1	4.4	8.4	

2.6 Land use diversification

2.6.1 Dryland horticulture

Optimum canopy architecture, need based integrated nutrient management and bio-inputs for rainfed regions in fruit trees

Separate trials were initiated, both on station and on farm, on efficient nutrient management and canopy architecture in custard apple, guava, citrus and mango. Twenty years old guava and custard apple plantations were selected at GRF. The guava plantation was pruned leaving 50% portion of all the existing secondaries during early summer, 2009 in order to promote more fruiting units leaving one to three primaries per pit. The number of secondaries varied from two to six per plant after pruning. The data on tertiaries were recorded after new flush in the next season. The number of tertiaries varied from four to eighty seven per plant in the entire orchard.

By continuous use of inorganic fertilizers, the soil properties are eroding year after year in Indian orchards causing low productivity. No single source of plant nutrients, be it mineral fertilizers or organic manures or crop residues or biofertilizers can meet total requirement for sustainable horticulture. However, by combining them will not only result in optimum crop yields by reduced cost of production but also enhance the orchard fertility for a longer period. In this direction, bio-inputs were applied to tree crops in order to improve orchard health. Early flush, flowering and fruit set, enhanced fruit number and yield/plant were observed with the soil inoculation of different microbes in several fruit crops like guava, custard apple, mango and citrus in the present study. Similarly, microbial inoculation of VAM or PSB or ZSB or K mobilizers along with higher doses of FYM has proved to be effective in early flush growth, flowering and fruit set in sweet orange in an on farm trial.

In another experiment, various combinations of organic and inorganic sources of nutrients along with control treatments were imposed during 2010

following RBD design with four replications. The spacing adopted was 5x5m for guava, custard apple and citrus and 10x10 m for mango. The plants were given uniform cultural operations after imposing the treatments. Custard apple was severely pruned during May 2009 to impart good shape and more fruiting units in the subsequent season.

Growing vegetable crops in the initial four years of orcharding was found beneficial for generating income. When vegetable crops were raised in *rabi*/ summer as intercrops on conserved moisture in a limited area of about half an acre with family labour, it supported their livelihoods during the lean period.

Another experiment was conducted to study the effect of different doses of chemicals and bioinputs on branching pattern (No of primaries, secondaries and tertiaries) and fruit yield in guava cv. Allahabad Safeda. Application of 30 kg FYM + 100% recommended dose of chemical fertilizers was found to impart more no of primaries, secondaries and tertiaries resulting in more number of fruits and yield per plant followed by 15 kg FYM + 50% chemical fertilizers (Table 23). Combinations of all organic and bioinputs imparted significantly more number of tertiaries thereby increasing the fruit yields.

Table 23 : Effect of different doses of fertilizers and bioinputs on fruit yield and quality in guava

Treatment	Yield (kg/plant)	TSS (^{0}Brix)	Acidity (%)
Control 30 kg FYM	11.65	11.47	0.14
100 kg FYM	12.13	10.75	0.13
200 kg FYM	14.93	11.01	0.19
15 kg FYM + 50% chem	22.88	11.51	0.17
30 kg FYM + 100% chem	26.26	11.06	0.22
200 kg FYM + PSB	18.44	11.04	0.16
200 kg FYM + Azo	17.38	13.12	0.13
200 kg FYM + Tricho	18.99	11.03	0.11
S. Em ±	2.185	0.206	0.007
C.D. (0.05)	6.47	0.61	0.02

2.6.2 Jatropha

Germplasm evaluation

During this year (2010-11), the seed yields in all the accessions under evaluation trials of germplasm, in general, were higher compared to last year. The yields could have been much higher had not there been severe infestation of root borer. The three best accessions on the basis of seed yield were:

- Progeny Trial (No. of Progenies-22): Acc.No-36, Acc.No-09 and Acc.No-03
- National Networking Trial (No. of Accessions-16): TNMC-4 (TNAU), TNMC-20 (TNAU) and TNMC-6 (TNAU)
- Zonal Trial (No. of Accessions-8): TNMC-5, TNMC-3, and TNMC-2 (TNAU, Mettupalayam)
- National Trial-III (No. of Accessions-18): MNJ-001 (ICAR RC NEH Region, Manipur), TNCJC-20 (TNAU, Mettupalayam) and LBJJ-23

The data on seed yield in progeny trial during the last five years (planted in 2005) indicated that the top three positions in respect to seed yield were occupied by different accessions in different years, indicating thereby the fact that some more years are required for stabilization of yield (Table 24).

Healthy Jatropha plant and fruiting in National Trial III

Standardization of agro-techniques

Irrigation, spacing & Fertilizer trial: A spacing of 4m x 3m with F1 (N 67.5, P 150 g/plant) under irrigation was found better in terms of seed yield (Table 25).

Pruning: Pruning at 50% height from ground level was the best compared to 25% and 75% with respect to seed yield.

Breeding programme

- Lower percentage of fruit set is observed in geitonogamy / xenogamy study because in this experiment all male flowers from the inflorescences were removed in both the cases, which caused significant injury (Table 26).
- The seed yield in F1s after 1 year 10 months of plantation ranged from 9g to 402.8 g/plant indicating some promise compared to parents. The higher range of relative heterosis and heterobeltosis was found only in RRL-AP-Papum-1 1 05-C-1 x CSMCRI OR-Ganj-1205-C5 (Table 27).

Table 24 : Year-wise best accessions on the basis of seed yield (t/ha)

Second year (2006-07)	Third year (2007-08)	Fourth year (2008-09)	Fifth year (2009-10)	Sixth year (2010-11)
Acc-23 (0.38 t/ha)	Acc-3 (0.50 t/ha)	Acc-20 (0.96 t/ha)	Acc-11 (0.53 t/ha)	Acc-36 (0.95 t/ha)
Acc-24 (0.32 t/ha)	Acc-20 (0.37 t/ha)	Acc-11 (0.90 t/ha)	Acc-29, Acc-24 & Acc-36 (0.40 t/ha)	Acc-09 (0.54 t/ha)
Acc-20 (0.28 t/ha)	Acc-29 (0.34 t/ha)	Acc-2 (0.88 t/ha)	Acc-9 (0.37 t/ha)	Acc-03 (0.43 t/ha)

Table 25 : Effect of irrigation, spacing and fertilizers on growth and yield of Jatropha

Treatment	Plant height (cm)	No. of branches	Collar diameter (cm)	Canopy spread (cm)		Seed yield (g/plant)
				East-west	North-south	
Irrigated conditions						
4 X 3 m						
F1		114.9	11.5	304	321	374.2
F2		82.5	16.9	253	280	288.5
F3		76.5	9.7	242	269	220.2
4 X 2 m						
F1		114.5	12.1	279	312	336.5
F2		99.8	12.2	270	294	254.2
F3		118.1	12.9	286	300	325.2
Rainfed conditions						
3 X 2 m						
F1		100.0	11.1	265	281	176.5
F2		83.3	10.8	252	255	218.0
F3		84.6	11.3	262	275	196.1
2 X 2 m						
F1		85.4	10.2	263	188	298.6
F2		72.7	10.0	246	239	238.2
F3		71.6	9.7	236	244	255.1

F1: N 67.5 + P 150 g/plant; F2: N 135 + P 300 g/plant; F3: control

Table 26 : Floral biology in Jatropha

Floral biology parameters	Range	Average	Overall superior genotypes identified for floral biology parameters
Flowering Duration	6 to 19 days	13.24 days	✓ FRI-UA-The-1005-DD-EL-2 ✓ CSMCRI-OR-Ganj-1205-C5 ✓ CRIDA-JR-06 and PAPL-JPH-108 ✓ CSMCRI-Guj-Banas 1205-C1 ✓ CSMCRI-Guj-Banas 1205-C2 ✓ Excel-Guj-BHV-0105-C1
Female flowers/ nflorescence	0-24	7.1	
Male flowers/ inflorescence	5-275	126.5	
Female : Male Ratio	1:10.4 to 1:53	1:17.56	
Pollen Ovule Ratio (P/O ratio)	21365:1 (per inflorescence) 121.7:1 (per flower)		
Natural Fruit set %	37.5% to 100%	87.61%	
% fruit set through	Geitonogamy 40.52 %	Xenogamy 49.18 %	
Better fruiting season	Oct - Jan		
Reasons for low fruit/seed set in May-Aug	Pollination shortage		

Table 27 : Relative heterosis and heterobeltosis in different accessions (CRIDA evaluation trial)

Hybrid parents			Plant height		Seed yield	
Female parent	X	Male parent	RH	HB	RH	HB
RRL-AP Papum1105 C1	X	CSMCRI-OR-GANJ-1205-C5 (Elite5)	15.56	11.61	38.04	20.27
NBRI-J-05 NBRI (Elite)	X	FRI-UP-Allah-1205-C-15	-27.97	-29.17	-60.74	-64.34
NBRI-J-05 NBRI (Elite)	X	CSMCRI OR-Ganj-1205-C5 (Elite-5)	-16.71	-24.07	-100.00	-100.00
NBRI-J-05 NBRI (Elite)	X	NBPGR (Elite) Hissar local	-19.59	-20.83	-74.70	-76.12
NBRI-J-05 NBRI (Elite)	X	RRL-MNP-Imph-1005-C-1	-0.49	-2.12	5.50	-2.62
NBRI-J-18 (Elite)	X	CSMCRI-OR-GANJ-1205-C5 (Elite5)	7.76	2.29	-70.42	-77.48
Mean			-6.91	-10.38	-43.72	-50.05
Minimum			-27.97	-29.17	-100.00	-100.00
Maximum			15.56	11.61	38.04	20.27

2.6.3 Pongamia

Spacing

The effect of four spacings tried (5mx5m; 6mx4m; 6mx6m and 8mx6m) on kernel yield of pongamia was non significant during 6th year of plantation.

Germplasm evaluation

On the basis of growth and seed yield, the following accessions out of 23, 8 and 8 accessions of pongamia evaluated in progeny trial, national trial and zonal trial, respectively showed superior performance compared to other genotypes at the end of 5th year of plantation.

Progeny trial: Acc-33, Acc-16 and Acc-23
National trial: RAK-22 and RAK-103
Zonal trial: Acc-30, Acc-14 and TNMP-9

Intercrops

Cucumber was sown as intercrop which yielded 645 kg /ha during fifth year of Pongamia trials.

Pongamia + Cucumber

Pongamia-Progeny Trial

Pongamia-Zonal Trial

Pongamia-National Trial

2.7 Livestock management

2.7.1 Studies on *Azolla* and horsegram as lean season protein supplement in small ruminants

Grazed tropical pasture provides a low-cost source of nutrients for small ruminant production, but is characterized by seasonal variations in growth and nutrient composition, both of which can limit animal performance. Supplementation increases nutrient supply during periods of inadequate pasture growth, or to achieve levels of animal performance that are higher than those achievable from pasture alone. The study was conducted to evaluate the effect of supplementation of *Azolla* and horsegram at different levels on the animal response in terms of average daily gain (ADG) and quality of meat under both intensive and extensive systems. Thirty growing lambs with mean body weight of 14.6 ± 0.08 kg, were randomly divided into five comparable groups GI, GII, G III, G IV and G V (BW: mean ± S.E.= 14.6 ± 0.09, 14.6 ± 0.13, 14.5 ± 0.11, 14.6 ± 0.13 and 14.6 ± 0.07 kg) and studied for 120 days. Group I didn't receive any supplement and served as negative control, where as Group II received concentrate mixture @ 1% of the live weight and served as positive control. Group III, IV and V received either horsegram (black: CRHG-4 and brown: CRIDA-18R varieties developed by CRIDA) or *Azolla* on equi-energy and nitrogen basis. Body weight gain was measured at fortnightly intervals.

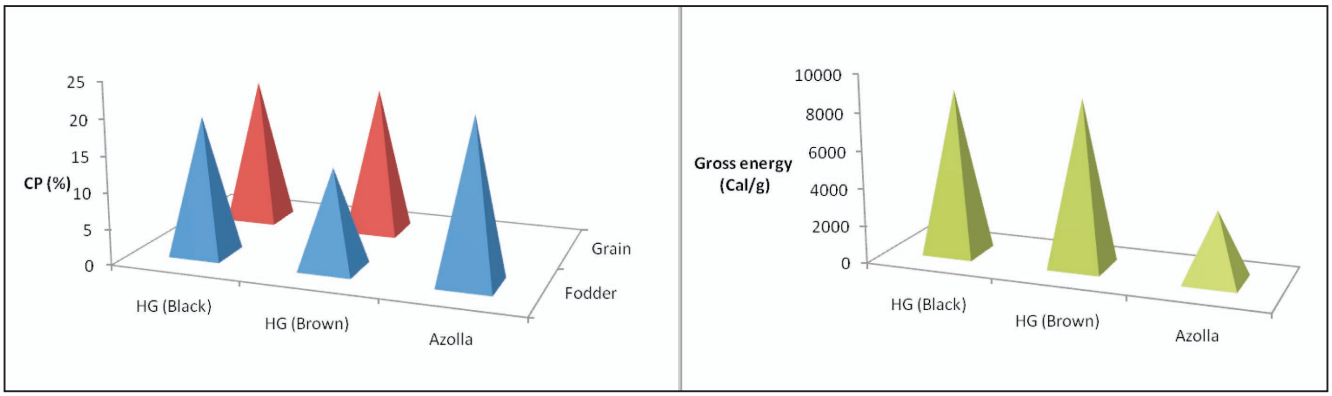


Fig. 50. Crude protein and gross energy value of the horsegram (HG) grain (black: CRHG-4 and brown: CRIDA-18R) and Azolla meal

Crude protein (CP) and gross energy content in grain of horsegram varieties were comparable, however significantly (P<0.01) higher crude protein was observed in fodder of horsegram black (CRHG-4) than brown (CRIDA-18R) variety (Fig. 50). Significantly higher weight gain was observed with supplementation of either horsegram or *Azolla* than concentrate mixture (Fig. 51) on equi-energy and nitrogen basis. Similarly, ADG was also higher with supplementation of horsegram (92.5 g) or *Azolla* (90.0 g) than concentrate mixture (80.8 g). The present study indicates the necessity of feed supplementation in small ruminants under grazing conditions. Further, the difference in weight gain and ADG among different treatment groups indicates the significance of *Azolla* and horsegram as protein supplement in small ruminants.

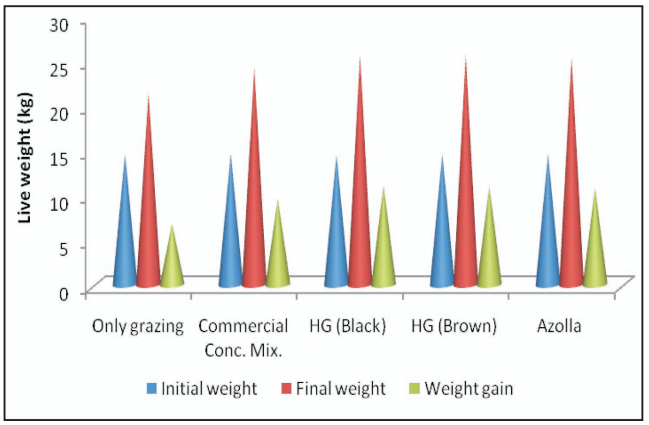


Fig. 51. Performance of growing lambs under grazing conditions fed with different protein supplements on equi-energy and nitrogen basis

2.7.2 *In vitro* evaluation of enteric methane mitigation options for livestock fed with coarse crop residues as basal diet

Ruminants depend on microorganisms to digest plant cell wall polysaccharides present in coarse crop residues. However, microbial digestion in the rumen also results in waste products, such as carbon dioxide (CO_2) and methane (CH_4) and approximately 6% of dietary gross intake energy is lost to the atmosphere as CH_4. Methane represents a loss of energy to the animal and also an important green house gas that significantly contributes to global warming. Any attempt to reduce these emissions from livestock would enhance the productivity of the animal. *In vitro* gas production technique was carried out to assess the cumulative gas pool, organic matter (OM) disappearance and digestibility of coarse crop feed material (sorghum stover). Rumen liquor was collected from the slaughtered sheep at Modern slaughter house, Chengicherla, Hyderabad. The gas pressure and volume were taken at 2 hr interval for 12 hrs and later at 6 hrs intervals. Linear regression equation was plotted and the gas production was corrected with correction factor obtained from the regression equation. Cumulative gas production profiles from the fermentation of sorghum stover alone or with 10% supplementation of *Stylosanthes hamata*, *Leucaena leucocephala*, and *Glyricidia sepium* leaf meal are given in figure 52.

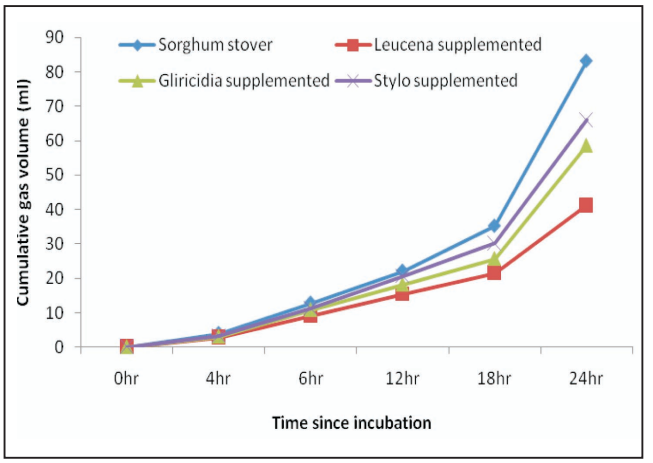


Fig. 52. Cumulative gas production profiles from the fermentation of sorghum stover with or without leaf meal supplementation

Cumulative gas production (ml/g OM fermented) was maximum in sorghum stover alone and minimum in *Leucaena leucocephala* meal supplementation. Organic matter (OM) disappearance and digestibility was maximum with *Leucaena* leaf meal supplementation and minimum in sorghum stover without supplementation (Fig. 53). The results of the present study indicate the possibility of anthropogenic emission reduction by supplementation of locally available leaf meal to the livestock being fed with coarse crop residues.

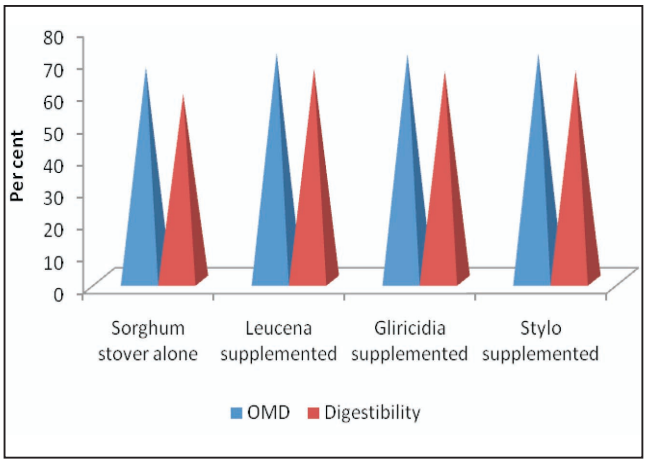


Fig. 53. Organic matter disappearance (OMD) and digestibility of sorghum stover with or without leaf meal supplementation

2.7.3 Study of efficacy of herbal formulations in improving immune response in sheep (Ayurvet sponsored)

Improper immune response especially after vaccination against a particular disease results in severe morbidity and mortality in small ruminants. A study was conducted to assess the efficacy of herbal immunomodulator products (Restobal and Stressomix) in potentiating immune response in Deccani sheep vaccinated with inactivated multivalent blue tongue virus. Eighteen Deccani adult sheep (408 ± 13.7 days old) with mean body weight of 28.3 ± 0.41 kg were randomly divided into three comparable groups (G I, G II and G III) (BW: mean ± S.E.= 28.3 ± 0.26, 28.3 ± 0.38 and 28.3 ± 0.44 kg) to study the efficacy of herbal immunomodulators in potentiating immune response. The test drug Restobal was administered @ 20ml BID for 5 days pre and 5 days post vaccination to adult sheep in Group II. The test drug Stressomix was administered through feed (@ 100g/quintal of concentrate mixture) for 5 days pre and 5 days post vaccination to adult sheep in Group III. The total experimental duration was 40 days [7 days acclimatization + 10 days (5 days pre and 5 days post vaccination) of treatment + blood sampling on 28th day of vaccination (40th day)]. About 6-8 ml blood was collected aseptically from jugular vein of all the experimental adult sheep in standard test tubes before vaccination and on 28th day of vaccination. Antibody titers in serum samples were assessed with competitive enzyme linked immunosorbent assay according to Jochim protocol.

Significantly (P< 0.01) higher antibody titers against blue tongue (BT) were observed on 28th day of vaccination in sheep administered with herbal immunomodulators (Fig. 54). Among the herbal immunomodulators studied, Restobal administered sheep had significantly (P<0.05) higher antibody titers against blue tongue (BT) on 28th day of vaccination. This could be due to minimization of stress and stimulation of immunity in sheep by the administered herbal immunomodulators.

Further, blood biochemical and liver function profiles were comparable among the treatment groups (Fig. 55) in Deccani sheep fed with or without herbal immunomodulators products indicating no stress on vital organs due to the supplementation. The present study shows that administration of herbal immunomodulators would help in potentiating immune response in Deccani sheep at the time of vaccination.

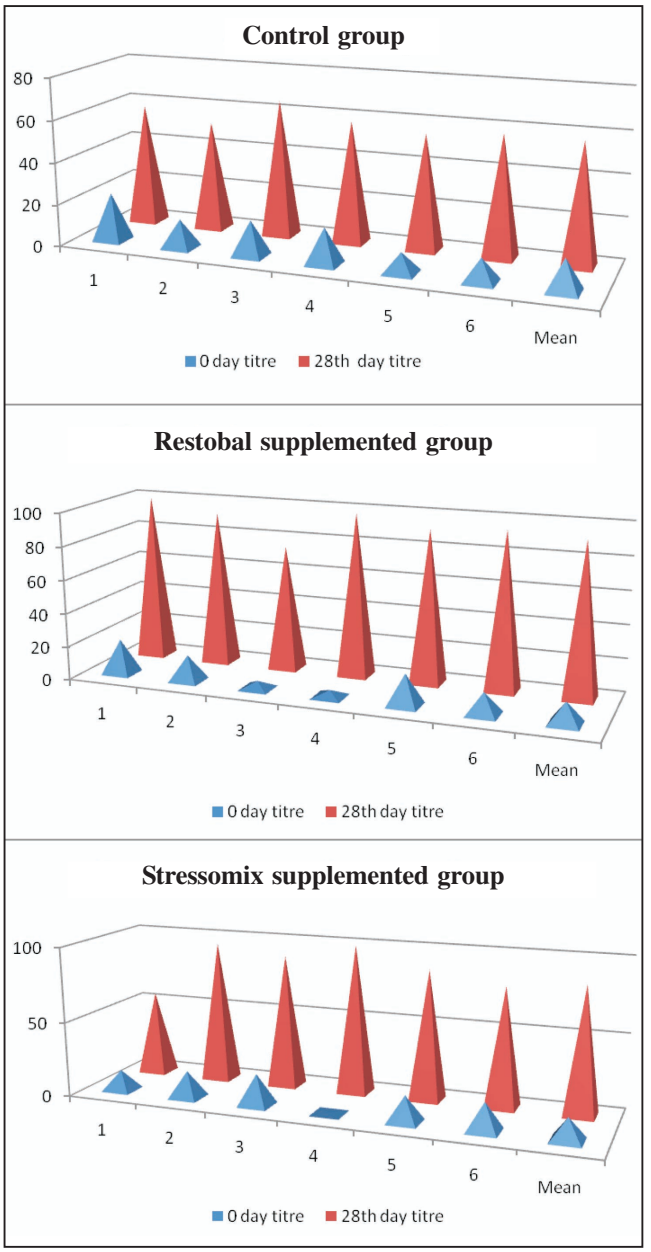


Fig. 54. Competitive ELISA antibody titers in Deccani adult sheep vaccinated with inactivated multi valent blue tongue vaccine (TANUVAS, Chennai)

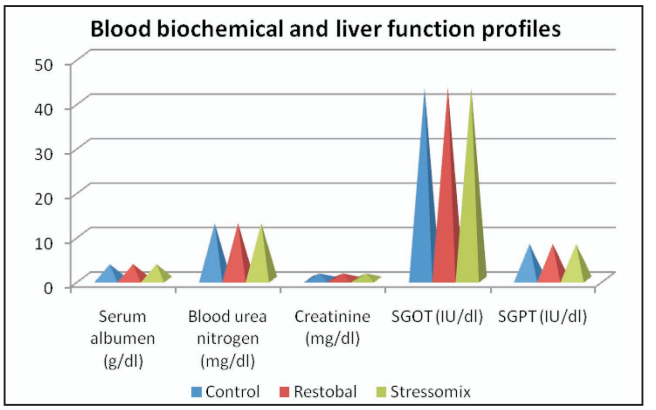


Fig. 55. Blood biochemical and liver function profiles in Deccani sheep fed with or without herbal immunomodulator products

2.8 Energy management

2.8.1 Development and performance evaluation of tractor drawn low-till planter for rainfed maize

Continuous cropping without addition of organic matter is a major threat to sustainable crop production in these areas. The rainfed crops such as maize, cotton, sunflower, castor etc. produces about 2.5 to 6.0 t ha^{-1} biomass. Generally, the crop stalks are removed by either manual pulling or cutting with a sickle upto a height of 75 to 100 mm above the ground surface and burnt later or left on the field bunds in a heap. Instead of resorting to such practices, if managed to slash, shred and spread on the fields evenly using low cost machinery in crop residue management mode, may help in protecting soil and land resources from erosion, conserving soil water, maintaining soil quality and influencing the soil surface environment.

The maize crop was sown using the tractor operated horizontal plate planter and stover management activity taken up with tractor front mounted crop stalk slashing machine. The following are the set treatments for the experiment.

T_1 - Removal of stover after cobs harvest + tillage with cultivator and disc harrow twice each before sowing (conventional practice)

T_2 – Stover slashing, spreading + tillage with disk harrow twice

T_3 – Stover cutting to 50 cm height (stubbles) – No till

T_4 — Stover slashing, spreading on soil surface – No till.

The soil analysis (Table 28) after third year of study showed that, there was sufficient build up of soil carbon and soil phosphorus in low and no till treatments with residue than conventional practice.

The Low till – Horizontal plate Planter was tested for its performance under the set treatments. There was no breakage and blockage of seeds in the planter. In laboratory calibration tests, the set seed metering plate delivered 3-5% higher seed rate than the theoretically calculated rate. Under field conditions, the observed plant stand was 3-7% higher in conventional tillage (T_1) and low till plots (T_2) when compared with theoretically calculated plant stand, on the other hand in no- till plots (T_3 and T_4) the plant stand observed was lower by 5-7% than theoretical value. The present year results showed that (Table 29) lowest dry weed biomass of 223 Kg/ha was recorded in the twice disc harrowed plot (T_2). However, there is no significant difference in weed biomass among various practices. The T_2 treatment recorded highest grain (4797 kg/ha) and biomass (4954 kg/ha) yields whereas the conventional practice (T_1) recorded lowest value (grain yield 3932 and biomass 4016 kg/ha). The tractor front mounted slasher could able to cut the stover to one third of its height and spread evenly. The surface coverage of residue was highest in treatment T_4 followed by T_3 and T_2.

Table 28 : Soil chemical properties after third season crop stalk management activity of experimental Field.

Treatment	Soil Chemical Property											
	Organic Carbon, % Soil depth (cm)			Available N, Kg/ha Soil depth (cm)			Available P, Kg/ha Soil depth (cm)			Exchangeable K, Kg/ha Soil depth (cm)		
	0-10	10-30	30-50	0-10	10-30	30-50	0-10	10-30	30-50	0-10	10-30	30-50
T1	0.48	0.31	0.37	262.4	222.7	190.2	32.2	24.7	32.4	170.8	141.9	157.1
T2	0.54	0.54	0.56	293.7	279.1	211.2	35.1	19.9	32.6	141.7	133.6	128.6
T3	0.51	0.60	0.30	243.5	241.5	223.7	57.9	33.2	37.2	143.5	148.7	146.7
T4	0.55	0.57	0.60	256.1	245.6	189.2	40.6	28.6	32.1	134.2	120.6	105.3

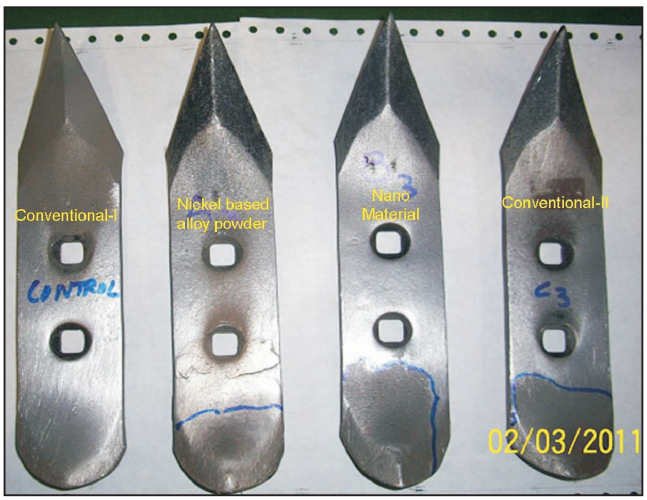
Table 29 : Weed biomass, Grain, Stoover yield and Residue status after stalk management

Parameter	Treatments			
	T_1	T_2	T_3	T_4
Weed biomass, kg/ha	257	224	248	245
Grain yield, kg / ha	3932	4797	3905	4055
Biomass Yield, kg / ha	4016	4954	4101	3930
Stover left in the plot, kg / ha	–	4954	2460	3930
Residue cover on surface after imposition of treatments (% Cover)	—	81	87	93

Low till planter in operation

2.8.2 Use of nano materials to minimize wear in critical parts of selected farm

Nano materials can be used as wear resistance coatings on critical parts of some of the farm implements. As part of the first objective, highly wear prone implement parts were identified viz., rotavator blades and cultivator shovels for which wear tests were conducted in the field to record the wear with the conventional materials like high



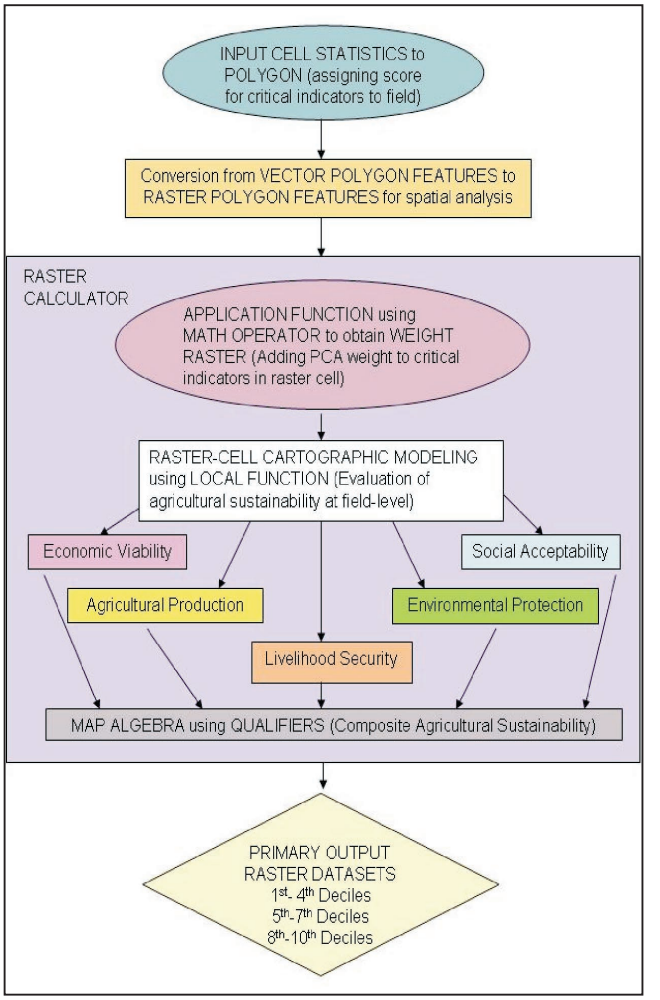
Control and coated Shovels after one hour of field operation

carbon steel etc. Nine cultivator shovels were given to ARCI, Hyderabad for coating them with the nano materials. Ni based fusible alloy powder and other materials were selected as coatings. All the coated shovels were fixed to a tractor drawn cultivator and real time test was conducted in the field for 0.5, 1, 1.5 and 2 hours durations. The observations are recorded and it is found that some of the nano coatings have shown promising effect for further investigations in this regard.

2.9 Socioeconomic studies

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

A multidisciplinary study was initiated in 2005 to assess the impact of watershed development program (WDP) in rainfed regions in order to achieve agricultural sustainability. Tools of geomatics were used in eight treated and untreated micro-watersheds in Rangareddy and Nalgonda representing AESR 7.2 in Andhra Pradesh. An empirical evaluation methodology that was developed last year helped in identifying twelve critical indicators to measure agricultural sustainability at various spatial levels such as household-, field- and watershed-level. The twelve critical indicators for sustainable agricultural development were improvement in availability or encouragement to fodder cultivation, increase in total crop production, increase in gross agricultural income, maintenance of S&WC structures, large-scale adoption of soil moisture conservation measures, availability of gainful employment options, adoption of crop contingency planning, security of tenure, increase



Flow chart of geomatics for evaluating watershed

in crop diversity (no. of crops/cultivated area), improvement in availability of irrigation water and role of extension workers. During the current year, the evaluation methodology was converted into a spatial analyst tool using Raster Calculator in ArcGIS environment and the study shows that the tool can conveniently be used to evaluate and monitor impact of watershed projects on rainfed agriculture.

For development of an evaluation procedure, newer techniques of geographical information system (GIS), remote sensing and differential global positioning system (DGPS) were used along with conventional techniques and methods like soil sampling and analysis for twelve physico-chemical and biological parameters, geo-referencing of sampling sites, transact walk and resource characterization of watersheds, evaluation of S&WC measures, socio-economic survey based on questionnaire developed for the purpose, and database creation in MS-Excel using Dot.Net as front-end. Fifty-one sustainability indicators were constructed to evaluate five aspects of sustainability namely, agricultural productivity, livelihood security, economic viability, environmental protection and social acceptability at three spatial levels within the watersheds. Two statistical techniques – Principal Component Analysis (PCA) and bivariate correlation technique were used to identify critical indicators to assess impact of watershed projects on agricultural sustainability in a region. During the current year spatial analysis was undertaken using Raster Calculator in ArcGIS to evaluate and compare agricultural sustainability across eight treated and untreated micro-watersheds implemented in the two districts by various agencies.

Spatial analysis through Raster Calculator helped to identify the fields that were moving towards sustainable agriculture (Fig. 56). For instance, in case of Pamana treated micro-watershed (TMW) with a spatial extent of 130.2 ha, only 5.2 ha was under sustainable agriculture while 65.8ha was under an agricultural management that was indicated to have only 50-70% probability of sustainable development. Besides this, over 22.2 ha land was under long fallow with proper maintenance that could adversely affect the rest of the watershed (Fig. 56). In untreated micro-watershed in the village, the need for implementation of watershed development program was obvious. In other villages - Chintapatla, Dontanpalli and Gollapalli, poor impact of the watershed program was obvious as the situation in both types of watersheds – treated and untreated was on par. The area under sustainable management was only 3.6 ha out of 46.5 ha in Chintapatla treated watershed, 3.8 ha out of 91.6 ha in Gollapalli and 19.71 ha out of 114.7 ha in Dontanpalli treated micro-watershed. Evidently, impact of watershed development program was seen to be limited which was underlined by the socio-economic survey.

In Pamana TMW, landholding with Survey No. 260 having 5.2 ha was found to be sustainable at present. The landholding accounts for 4% of the TMW and the farmer cultivates maize and cotton besides vegetables like carrot, tomato and beetroot that has earned him a net income of Rs.105,550 (Rs.37,696/ha) during Kharif, 2008. Carrot and tomato contributed towards higher income of Rs. 60,000 and 18,750, respectively. In case of Gollapalli, Survey No. 248 with an area of 3.8 ha being cultivated by seven farm households with castor, chilli, cotton, green gram, paddy and pigeonpea, earned a combined net income of Rs. 90,405 during Kharif season. Although income per family was low, the landholding was assessed to be sustainable as farmers earned an income of Rs. 30,883/ha by cultivating castor and Rs. 4,888/ ha from paddy. In UTMW in the village, Survey No. 280 reported a net income of Rs. 9,056/ha through cultivation of castor, paddy and chilli. In Dontanpalli village, paddy crop dominated both types of watersheds and net income ranged from Rs. 35,856/ha in TMW to Rs. 20,650/ha in UTMW. In Chintapatla village, net income was reported at

Rs. 25,314/ha for paddy, Rs. 4,665/ha for cotton and Rs. 17,175/ha for castor. It may hence be summarized that although watershed program is critical for rainfed regions, it is not being implemented zealously at present resulting in poor returns to agricultural sustainability. Vegetable crops were found to be lucrative for farmers in the districts adjoining urban markets.

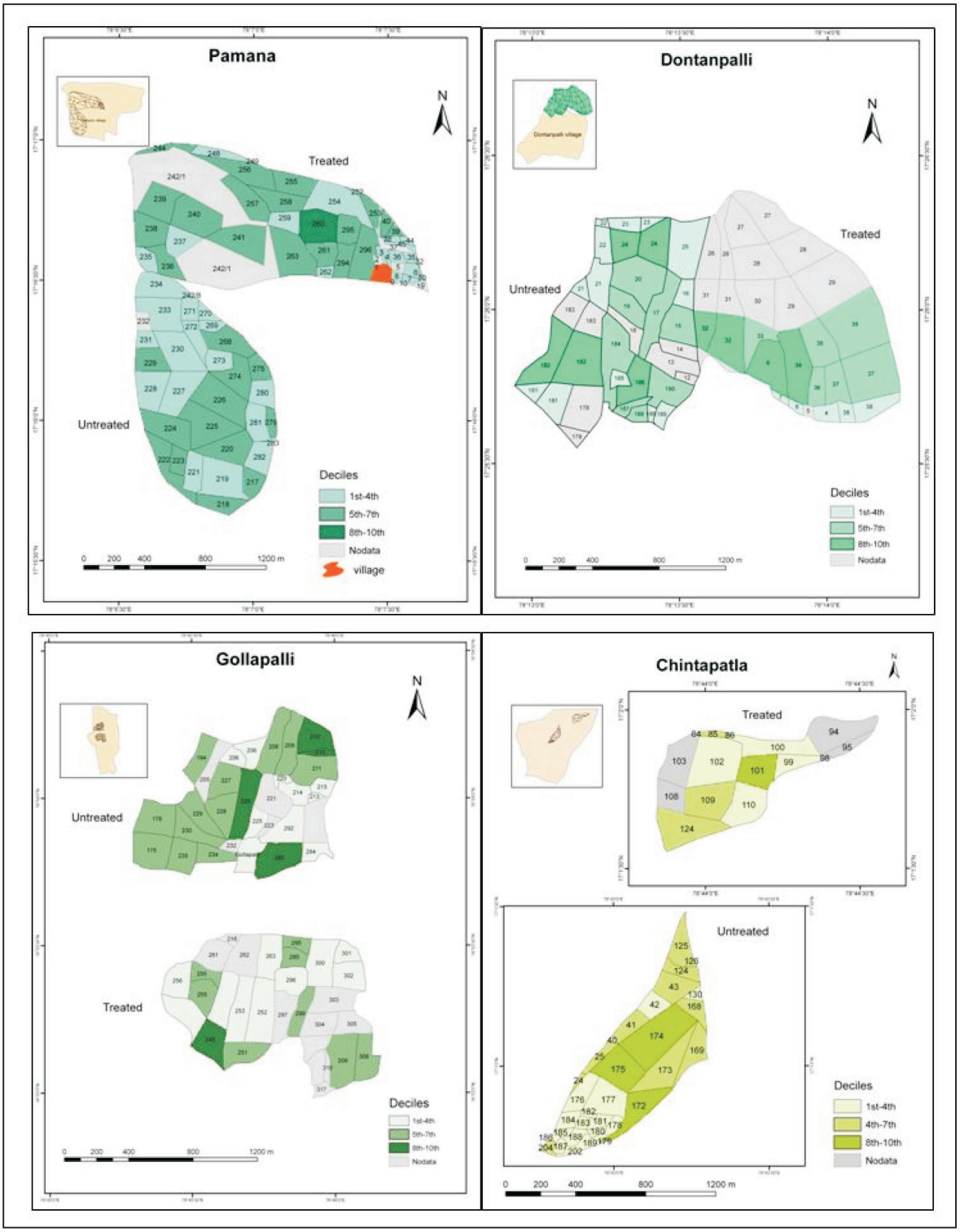


Fig. 56. Composite index of agricultural sustainability at field-level

2.9.2 Gender analysis in watershed development program in Andhra Pradesh and Karnataka

A study was carried out in Rangareddy district of Andhra Pradesh and Bangalore rural district of Karnataka in Government sponsored watershed development of drought prone area program. The study was carried out at two levels: First at project level, the project directors and officials of district water management agency (DWMA) were contacted to get insights on gender related perceptions and gender mainstreaming activities initiated in watersheds (Table 30). Based on gender mainstreaming scores, the districts have been ranked from high to low. At watershed level, one district in each state was selected to identify gender differentials in participation and decision- making.

Table 30 : District-wise gender mainstreaming (GM) in watersheds of AP and Karnataka.

Andhra Pradesh			Karnataka		
District	GM score	Rank	District	GM score	Rank
Chittoor	83	I	Chitrdurga	87	I
Medak	72	II	Shimoga	77	II
Mahabubnagar	68	III	Bellary	71	III
Khammam	62	IV	Bangalore rural	67	IV
West godavari	61	V	Bhagalkot	62	V
Rangareddy	59	VI	Chikamagalur	61	VI
Cuddapah	56	VII	Davangere	55	VII
Krishna	55	VIII	Haveri	58	VIII
			Tumkur	54	IX

Gender issues identified in Andhra Pradesh and Karnataka watersheds

Karnataka

- Major strategic need met through watershed is work, food and creation of asset base for women.
- Developed dairy and horticulture sectors bring livelihood support to women as women form major workforce in these areas.
- Benefits derived from watershed programs are reaching women but women are not made partners in watershed, even though committee representation is seen but they do not participate willingly.

Andhra Pradesh

- Majority of women participated in manual works and SHG related works in watersheds.
- Majority of men participated both in manual and management works equally (Fig. 57)
- Contribution of women in terms of manual labour was significantly more than men. However, men play significantly higher role in decision making than women (Table 31).

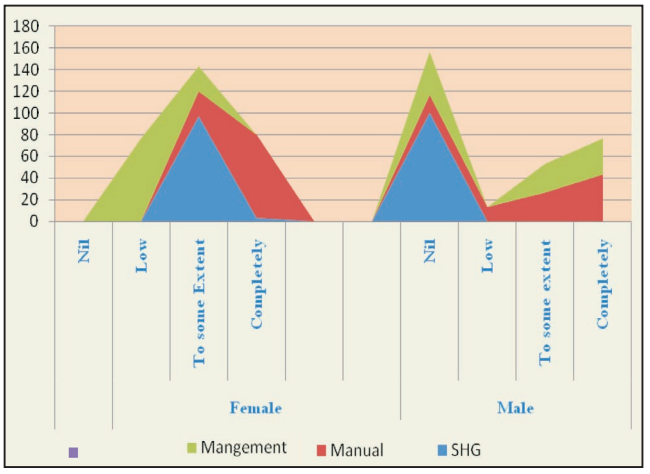


Fig. 57. Gender differentials in participation in watersheds in AP

Table 31 : Gender differentials in participation and decision-making in watershed development programs of AP

Variable	Gender	Mean	S.D	T- value
Decision making	Male Female	22.77 19.67	4.376 3.133	3.154**
Participation (Phase-wise)	Male Female	29.1 29.46	3.122 2.7131	0.485^{NS}
Participation (Work-wise)	Male Female	6.5 8.266	0.731 0.449	11.77**

NS: non-significant; **: significant at 1% level

2.9.3 Economic analysis of rain water harvesting structures – farm ponds

The project was initiated during 2009 with the objective of analyzing the economics and adoption of farm ponds. Farm ponds are considered as important rain water harvesting structures and have been found useful in enabling supplementary or critical irrigation to rainfed crops. During the year, an analysis of farm ponds in Anantapur district of Andhra Pradesh was attempted. An analysis of farm segments where these farm ponds were located was done to examine the changes in cropping pattern and cropping intensity with adoption of farm ponds. It was observed that more area was cultivated after these farms ponds were dug which means that the land which was earlier being left fallow is now brought under cultivation (Fig. 58). Further, the additional land being brought under cultivation is being used to grow bajra, sunflower and rice. The area under these crops increased significantly after the ponds were dug. However, the relative share in the gross cropped area did not change much except in case of bajra where the relative share increased from 21 to 26%. After farm pond was dug, the cultivated area increased by nearly 30% and the cropping intensity increased from 138 to 143%. The effect on cropping intensity would have been much more pronounced had there not been expansion in the cultivated area.

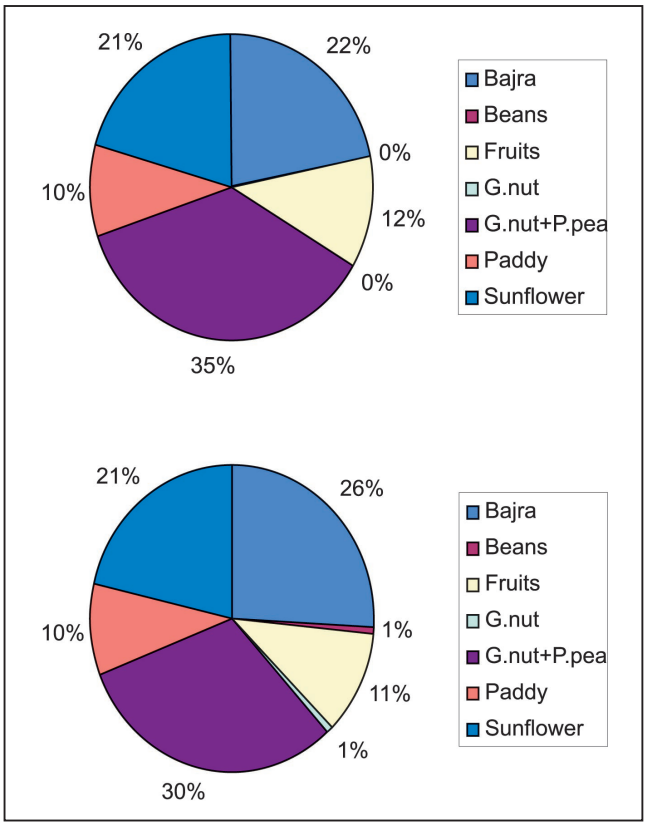


Fig 58. Cropping pattern in selected farm fragments before and after farm pond

The harvested water was either used to give supplemental irrigation to rainfed crops or helped recharge the bore wells in the proximity. This was translated into higher crop yields. The yield-enhancing effect was more visible in case of sunflower and bajra where the yields were reported to increase by 26 to 40%.

2.9.4 Development of a database of rainfed districts

A district database has been developed covering different parameters viz., land use classification (9 fold), net sown area, net irrigated area, source-wise net irrigated area, area sown, area under irrigation, production and yield of major rainfed crops, fund allocated and expenditure made under NREGS, credit flow to agriculture through scheduled commercial banks, consumption of nitrogen, phosphate and potash fertilizers, number of markets (covered by agmarknet), composition of livestock etc.

2.9.5 Performance of major rainfed crops in India during the last decade

Productivity of coarse cereals has significantly increased (30%) during the decade followed by oilseeds (13%). Growth in productivity of pulses (3%) is a bit stagnant in comparison to coarse cereals and oilseeds. Nevertheless the productivity of food grains excluding rice and wheat (coarse cereals + pulses) has recorded a rise of 20% during the decade; whereas growth in productivity of wheat and rice was 9 and 14%, respectively. Coarse cereals, pulses and oilseeds together recorded an 18% rise in productivity. The growth rates in area, production and yield were computed by fitting an

exponential time trend equation for the period 1998-99 to 2008-09. The highest growth rate in yield was observed in cotton (9.6%/year). In case of area sown under a crop, the compound annual growth rate was quite significant for sunflower and soybean. The relative contribution of area and yield to the change in production (between TE 1998-99 and TE 2008-09) was studied by decomposing the total change in production into area effect, yield effect and interaction effect. The contribution of productivity growth to production gain was more in case of chickpea (81.4%) than in case of pigeon pea (65.6%). In case of soybean, about 85% of production change was accounted for by area expansion.

2.9.6 Trends in food consumption and rural household food security in selected dryland cropping systems

Body Mass Index (BMI) is an essential tool to assess basic nutritional status of a community that determines the grade of malnutrition status of population. Nutritional anthropometry of 70 rural women of Kowdipally and Zaheerabad mandals of Medak district was assessed using anthropometric data collected by a structured pre-tested questionnaire. Grading of nutritional status as BMI was calculated using heights and weights of women. The data showed that 60% of rural women in the study area were found to be in normal nutritional status who consumed millets in their daily diets (Table 32). Further, about 17, 9 and 14% of women were found to be in I grade, II grade and III grade of malnutrition, respectively. This can be attributed to calorie insufficiency in the rural women. However, about 80% of women were found to be in normal status in non- millet consuming households without any malnutrition.

Table 32 : Body Mass Index of rural women of millet consuming (MCH) and non-millet consuming households (NMCH) of Medak district

Grade of malnutrition	III (BMI <16)	II (BMI 16-16.9)	I (BMI 17-18.5)	Normal (BMI >18.5)
MCW (%)	14	9	17	60
NMCW (%)	-	-	20	80

2.10 Transfer of technology

2.10.1 Assessment of performance of knowledge share centers in technology dissemination

The formation of knowledge sharing center (KSC) at grassroots level envisages the access to value added information services on latest tools and technologies of agriculture for improving the rural livelihoods. A study was conducted to document the KSC's potential for technology dissemination being operated in 8 NAIP clusters of Andhra Pradesh. The data formats were deployed in the knowledge share centers of different clusters to know the user statistics and assess the performance of KSCs. The current year (April 2010- March, 2011) users statistics of the KSCs revealed that the average number of visitors was maximum (158.5/month) in Nalgonda cluster. The data is being collected regarding the usage of ICT services for touch screen information kiosk and display announcement package are being analysed. The results indicated that among different clusters, the average internet usage (776 mb/month) was more in Ibrahimpur cluster of Rangareddy followed by Kadapa cluster (522 mb/month).

2.10.2 Leveraging access to ICTs for improved rural livelihoods: Development of strategic framework

This project was initiated to study the existing status on needs and utilization of information sources, to sensitize the farmers and formation of user groups on use of ICTs. The interview schedule was administered to farmers, women and rural youth for information services requirement on mobile based SMS services. A preliminary survey for mobile based information services was conducted with 30 farmers from three districts of Andhra Pradesh i.e Warangal, Nalgonda and Khammam using structured questionnaire. The information services

as demanded by the farmers were weather alerts (83%), market based information (92%) and information on outbreak of pests and diseases and their management (63%) etc. In addition to the existing content for 10 crops, content for other crops (medicinal & aromatic crops, oilseeds and spices) was edited and placed in the kiosks. Other activities carried out during the year included review meetings for feedback and performance of KSC, capacity building programme for rural kiosk operators in maintenance of software and hardware, orientation package on ICT, market linkages and agri-risk management for different stake holders in villages in all the clusters of NAIP, content developed by Ikisan was evaluated and edited for placement in the kiosks and mobile based service text messages and voice alerts dissemination to the members of IKU groups. Content for horticultural crops, livestock etc. is being compiled.

3 National Agricultural Innovation Project

The overall objective of the NAIP is to facilitate an accelerated and sustainable transformation of the Indian agriculture so that it can support poverty alleviation and income generation through collaborative development and application of agricultural innovations by the public organizations in partnership with farmers' groups, the private sector and other stakeholders.

The specific objectives envisaged are:

1. To build the critical capacity of the ICAR as a catalyzing agent for management of change in the Indian NARS (Component 1)
2. To promote 'production to consumption systems research' in priority areas/ themes to enhance productivity, nutrition, profitability, income and employment (Component 2)
3. To improve livelihood security of rural people living in the selected disadvantaged regions through technology-led innovation systems, encompassing the wider process of social and economic change covering all stakeholders (Component 3)
4. To build capacity to undertake basic and strategic research in frontier areas to meet challenges in technology development in the immediate and predictable future (Component 4)

Nine subprojects of different components of NAIP are being implemented in CRIDA.

3.1 Policy and institutional options for inclusive agricultural growth (NAIP-Component-1)

It is well known fact the agricultural productivity and income is low in rainfed regions. Technological innovations will continue to be the most important source of agricultural growth however; they need to be supported by appropriate policies and organizational and institutional solutions to make a real dent on productivity growth. This project was initiated under NAIP component-1 to analyze trends and sensitivity of weather induced risks and characterize the existing farming systems in rainfed areas and gaps in technology adoption and growth potential and finally to assess the technological and institutional options to enhance resource/water use efficiency and productivity of different farming systems. The study uses secondary data in order to assess the weather variables on productivity of crops. In-depth primary survey in three districts of Andhra Pradesh and case studies in other districts and states to assess the potential of rainfed technologies are being undertaken.

Prepared a time series dataset (16 years) with district as a unit linking area sown, area under irrigation, area under HYV, production and yield of crops with climatic parameters like rainfall, maximum temperature, wet day frequency etc and management factors like consumption of fertilizers, farm harvest price etc. The districts of the country are made in to two groups viz., rainfed and non-rainfed. The districts with net irrigated area less than 30 % or the districts covered under DPAP or DDP are classified as rainfed districts.

Sensitivities of yield in reference to the above mentioned climatic and management factors have been worked out for Maize crop using multiple linear regression technique. The exercise has been done for rainfed districts separately. Key determinants of yield emanated from the analysis are area under irrigation and area under HYV. The other important determinants were rainfall, fertilizer consumption and technological trend (with time as surrogate). When rainfed districts alone are taken for analysis, the key determinants remained same but the other important determinants turned out to be rainfall, wet day frequency and fertilizer consumption. The annual rainfall was one of the most significant factors affecting productivity of maize. Number of rainy days per annum was another weather variable that had a positive relationship with maize productivity indicating more number of rainy days will result into higher productivity. The coefficient for percent area under irrigation, percent area under high yielding varieties (HYVs) and fertilizer use per ha were positive and significant indicating important contribution of these variables to productivity of maize. Though the coefficient for kharif maximum temperature was negative but it was not significant. It indicates that temperature as such is not negatively affecting the productivity of maize crop.

In further analysis, the crop productivity data was de-trended by subtracting the technological trend fitted with linear model. De-trended residual terms were used in function to ascertain the sensitivity of crop yields against weather parameters. Such analysis was done for all the major sorghum and bajra growing districts in the country. The regression functions were fitted for 65 districts for bajra and 106 districts for sorghum. These estimates were further clustered using Ward method. Kharif season rainfall and wed-day frequency were positively associated with the productivity of both bajra and sorghum in most of the districts. Kharif maximum temperature hardly influenced the yield except in few districts. It may be concluded that the amount and distribution of rainfall which is increasingly becoming more variable significantly affects the crop productivity. Hence there is need to harvest rainwater for groundwater recharging and its recycling, and increase efficiency of water use by using micro-irrigation systems. Convergence with NREGS, RKVY, NSFM, NHM, etc would be the best strategy to undertake such programmes. Time trend was not very significant with rainfed districts.

Examined the yield trends of major crops in rainfed versus non-rainfed districts. The analysis indicated that weather parameters play crucial role in determining yield in non-rainfed districts also. The yield gap between the two groups was studied. Milk productivity of cow and buffalo in rainfed districts were studied with a view to examine their sensitivity to climatic variability. Rainfall has got positive effect on milk productivity of buffalo while maximum temperature and wet day frequency were having inverse relationship. Milk productivity in cow was largely influenced by % of crossbred cows. Maximum temperature has got negative impact on milk productivity of cow. The analysis shows that weather variables like rainfall, temperature and wet day frequency do significantly influence the milk productivity of animals in rainfed regions. Increased frequency of extreme weather events due to global climate change are likely to negatively influence the livestock productivity. Hence, there is need to put in place appropriate adaptation strategies particularly focusing on mitigating feed scarcity situations arising due to climatic variability. In order to assess the potential of rainfed technologies a few case studies were conducted on rainwater harvesting and its recycling in Bhilwara district of Rajasthan. The farm ponds of different sizes viz; 20x20x2.5 m to 70x40x3 m and small Jalkund of 4x2x3 m were observed in the farmers' field. With initial investment from the government, the farm pond could result in additional income of Rs. 4000 to 12000 ha^{-1} by bringing more area under cultivation under high value crops. Small jalkunds were particularly useful to provide water to perennial plants during scarcity period. However

it was observed that technical guidance to decide the location and specification of farm ponds besides financial support would be critical for its successful adoption.

3.2 Enabling small stakeholders to improve their livelihoods and benefit from carbon finance (NAIP-Component 1)

There is a need to reduce the green house gas emissions in view of the growing concerns of climate change and explore opportunities to link such activities to the Clean Development Mechanism (CDM) in view of the benefits associated with the carbon markets. There are many shortcomings in the existing CDM framework which limits its usefulness for community oriented mitigation activities. It is proposed to address some of these limitations by developing a new protocol which is called as "SMART-CDM" developed by ICRAF. The objective of the project is to validate the SMART-CDM frame work and the tool box in the Indian context in four major ecological settings; semi arid, arid, humid and sub temperate ecologies and to pilot test the small holder carbon trading options in different carbon markets. Hence a project under NAIP compononet-1 was initiated. The new protocol is grid based (few km x few km) approach. Both the green house gas emission reduction activities that can be easily adopted by the communities will be tried. Carbon sequestration activities in various land use systems will also be implemented in participatory mode. Following are some of the salient achievements under this project

- After the preliminary survey, identified three broad categories of activities which will result in reducing the green house gas emissions in the selected grid in a participatory manner. Specific green house gas mitigation interventions were identified within the three broad categories. They are energy efficient interventions for lighting, cooking and heating in rural households and through carbon sequestration by planting trees in cultivated lands and degraded common lands.
- In case of energy efficient interventions for lighting the inefficient incandescent lighting was replaced with the energy efficient compact fluorescent lighting (CFL) system. All the existing incandescent lights in the grid were enumerated and replaced with the equivalent lumen output of the CFL bulbs. A total of 287, 15 w bulbs, 345 w bulbs were replaced in the cluster resulting in a reduction of about 40 t of CO^2 emissions per year.
- In the jaffergudem cluster, of the 700 households, 600 households use the traditional stoves as the means of cooking and heating. The fuel used is mostly the wood collected from the common lands, hillocks and the degraded forest lands which can be categorized as non renewable one. We have evaluated about 4 stoves which are low in cost and which uses the locally available wood. The energy efficiency of these stoves ranged from 23 to 30% in comparison to the traditional stoves. The savings in wood is estimated up to 1.3 t/ household/ year due to the adoption of energy efficient stove. These stoves also has low emissions of smoke and have the advantage of portability and result in faster cooking in comparison to the traditional stoves. The possibility of reduction in green house gas emissions due to the improved stoves is about 1260 t/year if all the households adopt energy efficient devises.
- Divided the area available to the tree plantation in the grid in to two categories. The first one is common lands and the private holdings. Communities preferred trees which provide fodder and fuel wood in the common lands and trees which provide timber and fruits in private holdings. The requirement in each category was identified by household survey and also through the survey of common lands and the quality planting material is being developed for taking up the plantation activity in the degraded community lands and also the private holdings.

3.3 AGROWEB - Digital dissemination System for Indian agricultural research (NAIP-Component-1)

This NAIP sub project was initiated in the year 2008 to increase the web presence of Institute's research activities through updated content. Under this project feedback workshop was conducted with participants from AICRPDA scientist and website for CRIDA with Joomla as CMS was developed. Also website for AICRP on Dryland Agriculture Centres was developed. A publication of AICRPDA centres was completed. Facilitated the process of development of websites for partner organizations using Joomla CMS. A GIS databases on watersheds for AP was developed

3.4 Value chain model for bio-ethanol production from sweet sorghum in rain fed areas through collective action and partnership (NAIP- Component-2)

Sweet sorghum crop cultivation should be completely mechanized to make the crop economically viable for biethanol production. To mechanize the sweet sorghum harvesting operation and also to improve the crushing efficiency this project was initiated. Following are the salient achievements under the project during this year

Field trail of CRIDA precision planter cum herbicide applicator

A precision planter cum herbicide applicator developed at CRIDA was tested in a farmer's field at Ibrahimbad. Two acres of areas was sown using the precision planter. It facilitates to apply the seed, fertilizer and pre-germination herbicide at a time. Individually operated spring loaded tyres are fixed to the frame of the planter to sow the seeds even in two way sloppy lands. It has a separate seed cum fertilizer boxes for each row for precise application of seed and fertilizers. Herbicide is sprayed behind the planter along with the width through the hollow cone nozzles. A 150 watt capacity pump get the power from an inverter which is connected to the battery is placed in line with the herbicide tank for facilitating the recommended dose of the herbicide applicator. This machine is highly suitable to the Ibrahimbad cluster soils where the primary tillage is not followed by the farmers.

Precision planter cum herbicide applicator

The precision planter was used for testing purpose at Ibrahimbad in a farmer field where the sowing was done in two acres. Heterozine herbicide was applied to control the weeds. It is observed that the sweet sorghum germination percentage was around 86 % with precise weed control. However, the excess rain during the season and the water stagnation in the field reduced the yield. Hence it is decided to test the machine extensively for the next kharif season.

Introduction of sweet sorghum leaf strippers

A leaf stripper procured recently was tested at Ibrahimbad cluster for its feasibility to use at decentralized cluster unit. It is operated by a 10 h.p. electric motor with stripping capacity of 1000 kg/hour. Two labour were needed for stripping the leaf through the machine. Experiments were conducted to see the leaf stripping effect on the juice recovery in both crushers and the data is presented in the following tables 33 and 34.

Full view of the leaf stripper, Leaf stripper in operation

Table 33 : Juice recovery from the two roller 20 h.p. crusher with leaf stripping

Weight of stems before leaf stripping (kg)	Weight of stems with leaf (kg)	Weight of Juice extracted (kg)	Percentage of juice recovery (%)
72.200	53.400	22.80	31.5
76.400	56.300	23.30	30.49
68.900	50.800	20.10	29.17
Average juice recovery			30.38

Table 34 : Juice recovery from two roller 20 h.p. crusher without leaf stripping

Weight of stems without leaf stripping (kg)	Weight of juice extracted (kg)	% juice recovery
53.400	18.40	34.40
56.300	19.10	33.90
50.800	16.90	33.20
Average juice recovery		33.80

Data showed that there is significant effect of leaf stripping on the juice recovery. Similarly the type of crusher also played a role in increasing the recovery. The lower recovery from the leaf stripped samples may be due to the less friction development during the crushing because of less roughage. It may also be due to the less wastage in the juice when compared to the unstripped samples. However, a detailed study is needed on the quality and quantity of the juice extracted by both the methods.

Development of 3-pass 6-roller crusher for increased juice recovery and energy reduction

A 3- pass 6- roller crusher was designed, fabricated and tested at research workshop to test its feasibility to extract more juice with less energy consumption. This was operated by 10 h.p. electrical motor. During the crushing, the stems pass through different rollers with differently configured flutes for effective shear and compression. Initial trials showed that there is a possibility to increase the juice recovery with less power consumption when compared to the conventional method. However, the strength of the machine and other parameters are yet to be standardized to use in the rabi and next kharif seasons.

Three pass 6 roller crusher and its testing

3.5 Sustainable Rural Livelihoods through Enhanced Farming Systems Productivity and Efficient Support Systems in Rainfed Areas (NAIP- Component 3)

This NAIP component 3 sub project entered the 3rd year of its implementation during which key interventions were consolidated across the clusters. In most of the important crops, farmers were able to achieve a very significant increase in productivity owing to several interventions such as introduction of superior crop varieties, promotion of better plant nutrition, improved rainwater management and plant protection. For instance, the cotton productivity achieved in Jaffergudem cluster, Warangal district during the year (1183 kg/ha) was 3 times higher than the district average (397 kg/ha) for the year 2006 (bench mark year). Similarly, the increase registered in pigeonpea was over 5 times in Mahbubnagar, 5 times in Khammam. Groundnut yields increased by 2 times in Kadapa and by over 35% in Anantapur. A new wave of enthusiasm could be seen among farmers in cropping across the clusters. All the project interventions which aimed at providing a support system for cropping activities peaked during the year and its impact was expressed through higher level productivities of crops across the board. This vindicates the stand taken by the project and its strong belief that farmers need to be supported with building of various systems and sub systems to adopt and benefit from new technologies.

Interventions aimed at improving rainwater harvesting capacity and water productivity gave very significant outputs. The project pursued its interventions of promoting rainwater harvesting and use. A total of 1,76,000 m^3 additional rainwater storage capacity was established during the year by taking up repair of defunct rainwater harvesting structures, farm ponds, percolation ponds, recharge of open wells, networking of bore wells etc. This benefitted about 774 farmers by bringing in nearly 170 acres under protective irrigation regime. Site specific rainwater harvesting interventions thus helped to make best use of a good rainfall year and increased cropping intensity by over 80% on an average. New initiatives in promoting judicious groundwater use were met with immense success in Ibrahimpur cluster, Rangareddy district. The innovation involving sharing of groundwater for building a system of protective irrigation besides encouraging farmers to diversify into less water demanding crops was widely appreciated. This single intervention has made a tremendous impact on the livelihoods of 17 tribal farmers who entered into water sharing agreement with neighbouring farmers who owned bore wells. Realizing the full potential of the Ippalakunta tank in Thummalacheruvu cluster, Khammam was indeed

Ippalakunta tank brought back to life by repairing sluice gate (left)

A successful chickpea crop by using rainwater harvested in farm pond (Adilabad)

a significant event for the farmers of Bheemavaram village. After the faulty sluice gate was replaced through peoples participation, the tank filled to its capacity due to good rains during kharif. For the first time in the past two decades, farmers say, that cropping was possible during rabi with the tank water.

Integrated nutrient management in rainfed crops is crucial to realizing higher yield levels especially during good rainfall years. The project has invested lot of its resources in driving home this point to farmers for the past 3 years. The project has been laying emphasis on improving profitability by mobilizing the farmers for better access to markets. Several measures like formation of commodity interest groups, promotion of good agricultural practices to produce quality product having market demand, promotion of weather based insurance and empowering farmers with regular updates on weather and market related information were promoted during the year. The focus in livestock related interventions was trained on encouraging farmers to produce fodder required to meet the needs of their livestock herds. Hybrid napier, fodder sorghum, lucerne, horsegram and stylo were promoted over 170 acres across the clusters. A total of 376 t of fodder was made available within the clusters. This resulted in improving the overall availability of fodder thereby giving an impetus to livestock activities.

3.6 Modeling the performance of a few major cropping systems in the light of projected climate change (NAIP- Component-4)

Trends in annual rainfall and rainy days over Eastern India

Annual rainfall was computed from daily grid data of eastern India (Bihar, Orissa and West Bengal) and trend analysis was carried out using Mann-Kendall test. Annual number of rainy days (a day with rainfall equal to and more than 2.5 mm) was also computed for the above said states. It is observed from the Fig. 59 that eastern parts of Bihar have shown increasing tendency in annual rainfall where as no significant trend was noticed in other regions. In Orissa, declining trend is noticed in western part and increasing trend in north-

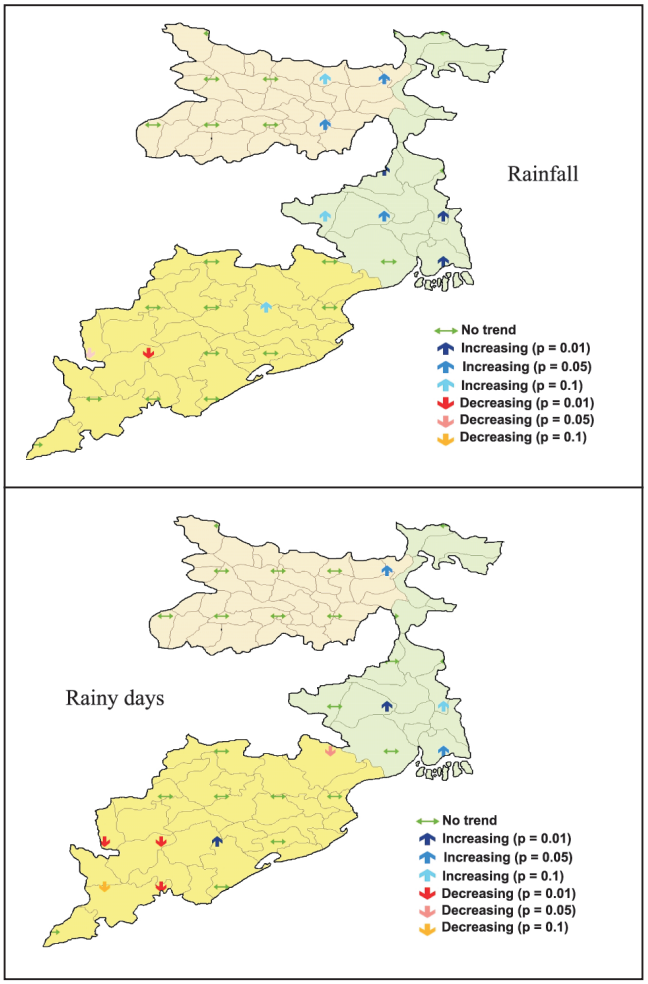


Fig. 59. Trend in annual rainfall and rainy days over Eastern India

eastern part. In case of West Bengal, increasing trend in rainfall is seen in almost all regions except southeast, where no significant trend was observed.

Declining trend was observed in rainy days over south western and north eastern parts of Orissa. Annual rainy days have shown increasing trend in central part of Orissa. In West Bengal, central and south eastern part showed increasing trend in annual rainy days. No significant trend is noticed in Bihar except north eastern part, where increasing tendency is seen.

3.7 Research into Development of Decision Support Systems for insect pests of major rice and cotton based cropping systems (NAIP-Component-4)

At CRIDA, developmental durations of all life stages of cotton mealybug, *Phenacoccus solenopsis*, was completed at 7 constant temperatures viz., at 18, 22, 25, 27, 30, 32, and 36^{0}C. Best fit models were selected based on co-efficent of determination and developmental rate was computed. Degree-days were estimated for each life stage. The total life cycle of the pest takes about 857 degree-days (Table 35).

Table 35 : Developmental rate and thermal constants for all life stages of *Phenacoccus* mealybug

Life stage	Thermal constant (Degree-days)
Nymphs	
I instar	100
II instar	125
III instar	204
Total nymphal	357
Adult	
Pre-reproductive female	204
Ovipositing female	357
Adult longevity	500
Total life cycle (egg to egg)	857

Identification of key mortality factors on cotton mealybug

During 2010-11 season, incidence pattern of *Aenasius bambawalei*, the key natural enemy factor was studied on alternate hosts. Time series data on extent of parasitisation of mealybug on grade 4 (G4) weed hosts occurring on cotton field bunds was recorded for all the months (Aug to Dec). Parasitoid activity was higher (11.3 to 14.8%) initially on the grade 4 weed hosts (*Abutilon indicum, Parthenium hysterophorus and Sida acuta*) in the early season (August) as compared to parasitoid activity on cotton (8.5%), which later shifted gradually to the main host (cotton) during the later part of the season (Fig. 60)

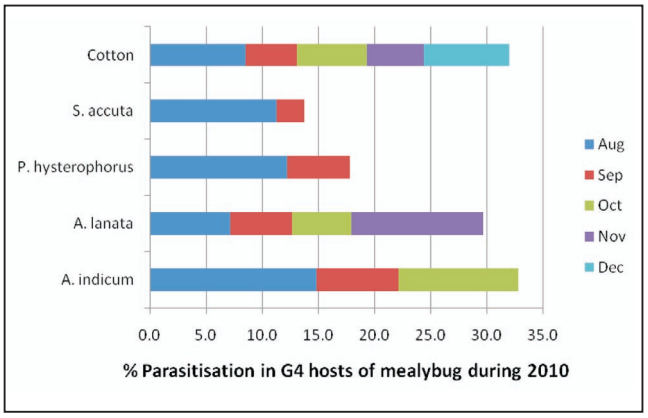


Fig. 60. Parasitoid activity of *Aenasius* on *Phenacoccus* mealybug on cotton and grade 4 weed hosts

3.8 Functional genomics of abiotic stress in *Pseudomonas* (NAIP Component-4)

Pseudomonas spp. are well known as biocontrol agents and plant growth promoting rhizomicroorganims. However, their performance in field is variable due to variations in the introduced environment. These microorganisms are also exposed to abiotic stresses such as high/low temperature, salinity and drought. Strains possessing biocontrol ability coupled with abiotic stress tolerance could be a boon for farmers.

Under NAIP project, "Effect of abiotic stress on natural enemies of crop pests:*Trichogramma, Chrysoperla, Trichoderma* and *Pseudomonas* and

mechanism of tolerance to these stresses", efforts are being made to identify strains possessing tolerance to salinity, drought and high temperature and further understand the mechanisms regulating these tolerances.

HPLC analysis of EPS sugars of temperature tolerant strains P8, P15 and P21 showed raffinose, trehalose in P8, mannose, sucrose, raffinose and mellibiose in P15, fructose, mellibiose, xylose and dextrose in P21 (Table 36). Further studies are in progress to understand metabolic pathways through genomic approaches. About 13 isolates containing GroEL responsible for stress tolerance and 11 isolates with DAPG, 8 with pyoluteorin and 7 with pyrrolnitrin genes all conferring biocontrol ability in *Pseudomonas* were identified among stress tolerant isolates. About 7 isolates with temperature tolerance (P8, P12, P14, P15, P20, P21, P28), 7 shoiwng salinity tolerance (P8, P20, P21, P22, P37, P42, P43) and 14 showing drought tolerance (P6, P17, P30, P59, P60, P62, P64, P65, P67, P68, P69, P70, P73, P74) were identified and their population dynamics under stress conditions was established (Figs 61 and 62). High temperature and salinity tolerant strain P8 and salinity tolerant P43 were selected for whole genome re-sequencing for the identification of genes conferring stress tolerance.

Table 36 : EPS production in promising HT and salinity tolerant *Pseudomonas* isolates

Strain	EPS composition	Quantity of sugar (%)	
		Control	Stress
P15 (Temperature tolerant-50°)	Xylose	0.38	0.32
	Mannose	0.41	0.72
	Sucrose	0.04	0.28
	Raffinose	0.0001	0.21
	Trehalose	0.52	-
	Mellibiose	-	0.07
P8 (Temperature-50° and salt tolerant-1.6 M)	Trehalose	0.14	0.11
	Raffinose	0.04	0.10
	Mellibiose	0.02	-
	Rhamnose	0.40	-
	Sucrose	0.06	-
	Fructose	-	0.63
P21 (Temperature-50° and salt tolerant-1.3 M)	Dextrose	0.14	0.54
	Mellibiose	0.09	0.13
	Raffinose	0.41	0.13
	Fructose	-	0.06
	Xylose	-	0.90
	Rhamanose	0.03	-

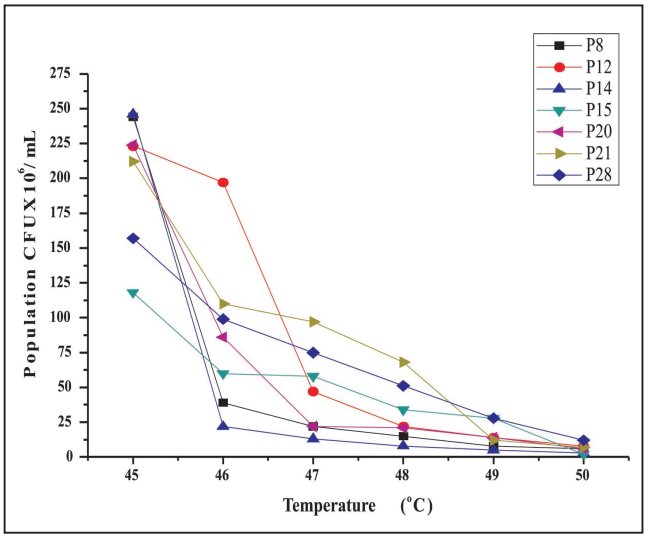


Fig. 61. Temperature tolerance of selected *Pseudomonas* isolates beyond 45°C

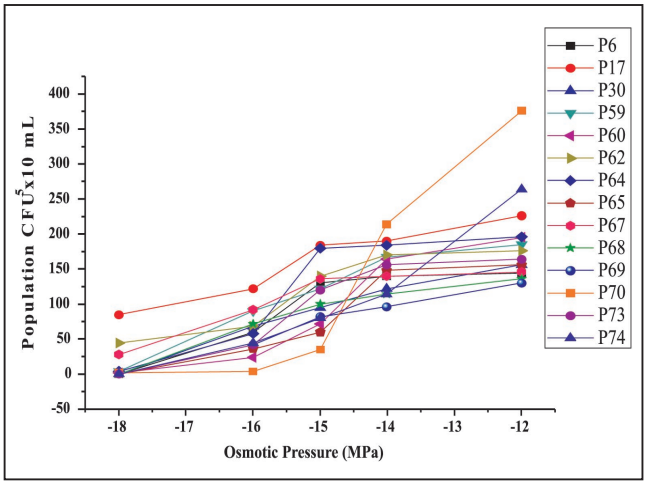


Fig. 62. Drought tolerance in selected *Pseudomonas* isolates

3.9 Assessment of quality and resilience of soils on diverse agro-ecosystems (NAIP Component-4)

A soil quality index (SQI) was determined for soils collected from different land use systems of Nalgonda and Warangal District of Andhra Pradesh. A total 22 physical, chemical and biological properties of soil were analyzed for all the soil samples. The surface map (Fig. 63) of available N, available P and exchangeable K of soils of Warangal district was prepared using the spherical semivariogram parameters through ordinary kriging interpolation techniques using Arc-GIS software.

To determine the SQI, four main steps were followed: (i) defining the goal(s); (ii) selecting a minimum data set (MDS) of indicators that best represent soil function; (iii) scoring the MDS indicators based on their performance of soil function; and (iv) integrating the indicator score into an index of soil quality.

The minimum data set were chosen using two procedures. One is using principal component analysis (PCA) and the other is based on contribution of soil parameters to soil function through expert opinion. For the PCA method, yield information was considered as goal variable and it was collected from the farmers through survey. Yields of all crops were converted to rice equivalent yield by multiplying a factor considering the Indian market price of that crop to that of rice. Soil samples were grouped as Alfisols, Inceptisols, and Vertic Inceptisols and Vertisols as per their respective soil order and three principal component analyses were carried out separately for three soil orders.

For the expert opinion method, minimum data set of indicators were identified that best represent soil function. The indices included only those indicators thought to contribute to the function of interest. Four soil function indices were used for calculating SQI: nutrient cycling, water availability, resistance to degradation and salinity and sodicity. The choice of soil functions to index was also driven by concern voiced by participating farmers. Multiple regression analysis showed significant

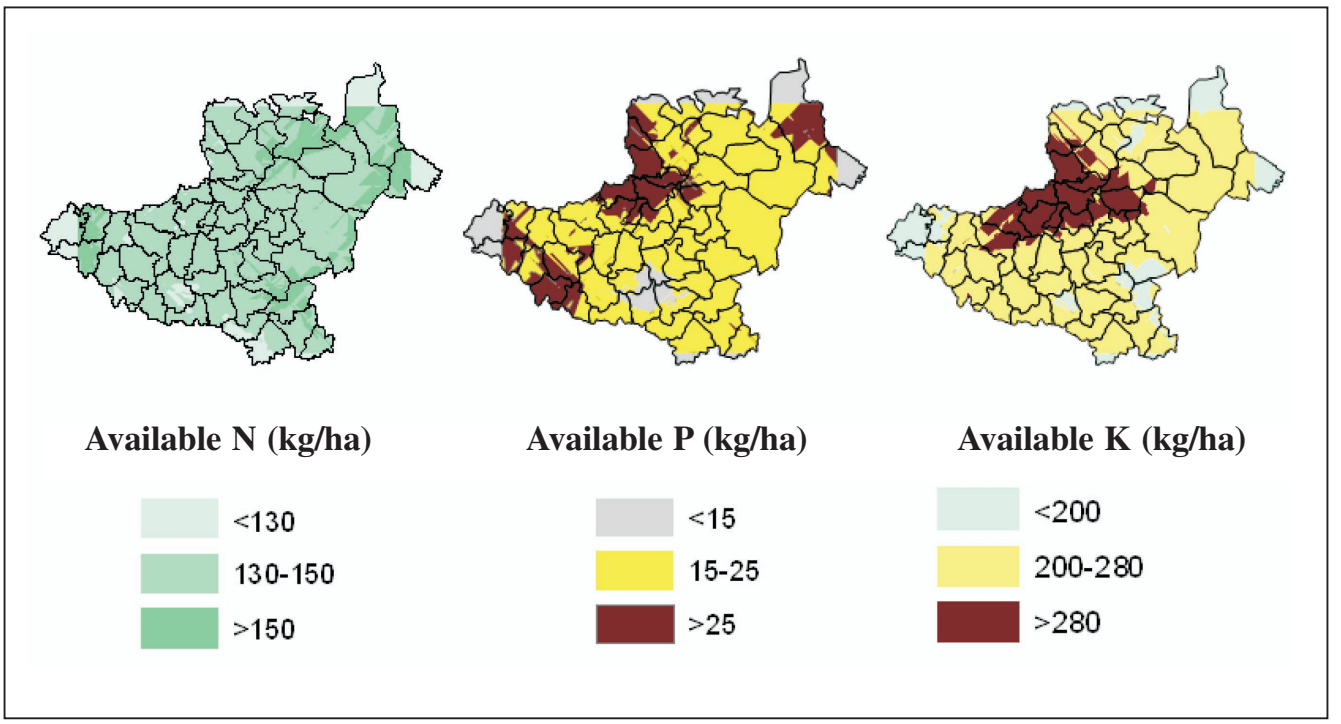


Fig. 63. Kriged map of available N, P, and exchangeable K for Warangal district

dependence of the goal variable i.e., yield, on the four supporting soil functions.

There was good relationship ($r^2 = 0.596$) between the two procedures used for calculating SQI i.,e., by using PCA and by using conceptual framework. The order of calculated SQIs for different land use systems was: castor < intercrop < redgram< sorghum < cotton < maize < fallow < rice. Irrigated systems had better soil quality than areas where rainfed agriculture was practiced. Among the different soil orders, Vertic Inceptisols and Vertisols had the highest SQI followed by Inceptisols and Alfisols. A kriged map of SQI (using soil function) for Nalgonda and Warangal districts is shown in Fig. 64.

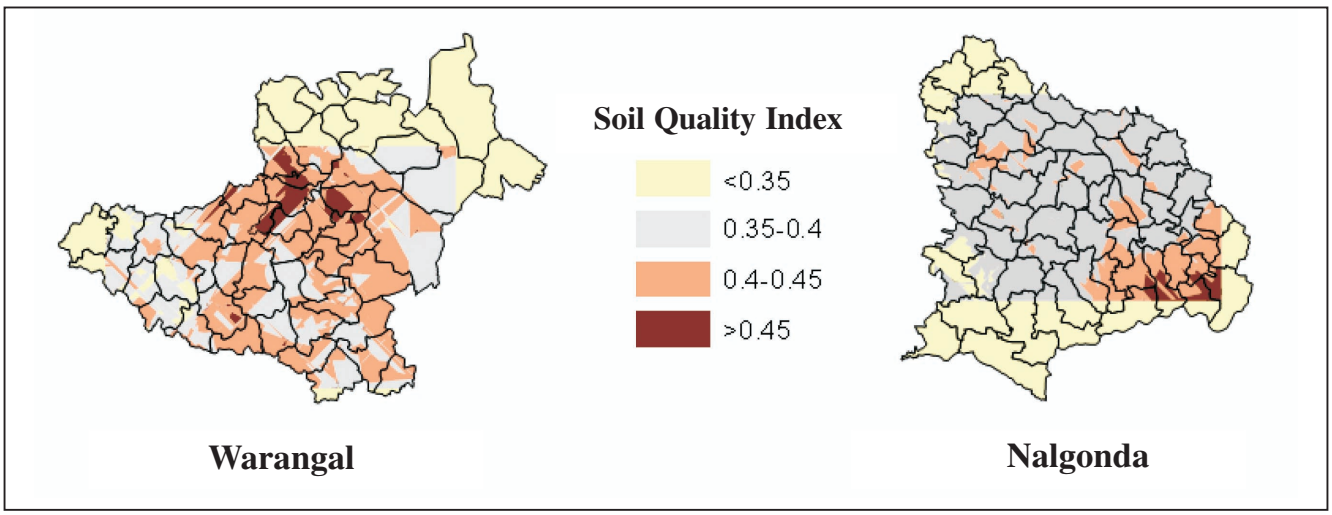


Fig. 64. Thematic map of soil quality index (SQI) for Nalgonda and Warangal districts through kriging interpolation technique

4 National Initiative on Climate Resilient Agriculture (NICRA)

4.1 Background

Climate change impacts on agriculture are being witnessed all over the world, but countries like India are more vulnerable in view of the high population depending on agriculture, excessive pressure on natural resources and poor coping mechanisms. The warming trend in India over the past 100 years was estimated to be 0.60°C. The projected impacts are likely to further aggravate yield fluctuations of many crops thus impacting food security. There are evidences of negative impacts on yield of wheat and paddy in parts of India due to increased temperature, increasing water stress and reduction in number of rainy days.

Significant negative impacts have been projected with medium-term (2010-2039) climate change, eg. yield reduction by 4.5 to 9 percent, depending on the magnitude and distribution of warming. Since agriculture makes up roughly 15 percent of India's GDP, a 4.5 to 9.0 percent negative impact on production implies a cost of climate change to be roughly at 1.5 percent of GDP per year. Hence, maintaining agricultural productivity is critical for all, in particular the resource poor small and marginal farmers that would be affected most. In the absence of rapid and full adaptation, the consequences of long-term climate change could be even more severe on livelihood security of the poor.

4.2 Climate resilient agriculture

There has been a significant rise in the frequency of extreme weather events in recent years affecting farm level productivity and impacting staple food grains availability at the national level. Within a season, severe droughts and floods are being experienced in the same region posing serious problems to the farmers, agricultural scientists and extension staff. Fall in yield leads to shortage of food grains, price rise and inflation affecting the poor most. Therefore, it is of utmost importance to enhance the resilience of Indian Agriculture to climate change. Both application of improved technologies and new policies will contribute to resilience. There is also abundant traditional wisdom among farmers to cope with climate variability which will be captured and documented in the project. Since climate change poses complex challenges like multiple abiotic stresses on crops and livestock, shortage of water, land degradation and loss of bio-diversity, focused and long term research is required to find solutions to the problems specific to our country. The necessary infrastructure to carry out basic and strategic research has to be put in place. At the same time, there is scope to improve the resilience of agriculture by application of existing knowledge and technology on farmers' field as a holistic package. Hence, this integrated proposal is made both to develop improved technologies through short term and long term research and also demonstrate the existing technologies on farmers' fields for enhancing the resilience.

The scheme attempts to develop and promote climate resilient technologies in agriculture which will address vulnerable areas of the country. 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, small and marginal farmers in rainfed, coastal and hill areas will benefit more in view of the focused attention in these regions.

4.3 Objectives

- 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.
- To enhance the capacity of scientists and other stakeholders in climate resilient agricultural research and its application.

4.4 Components

The Scheme will be implemented for the remaining two years (2010-11 and 2011-12) of the XI Plan with the following four components.

1. Strategic research on adaptation and mitigation.
2. Technology demonstration to cope with current climate variability in 100 vulnerable districts.
3. Capacity building
4. Sponsored research to fill critical gaps

The strategic research will be carried out involving 21 Institutes of the Indian Council of Agricultural Research. At seven core institutes, viz., CRIDA, Hyderabad; IARI, New Delhi; NDRI, Karnal; IIHR, Bangalore; CMFRI, Cochin; CIAE, Bhopal; and ICAR Complex for NEH, Barapani, state of the art research infrastructure will be established. Other 14 institutes will contribute to strategic research in specific thematic areas identified. These are CRRI, Cuttack; DRR, Hyderabad; NRCPB, New Delhi; IIVR, Varanasi; IIPR, Kanpur; ICAR-RCER; Ranchi; DWM, Bhubaneswar; NRCAF, Jhansi; PDFSR, Modipuram; NCIPM, New Delhi; IVRI, Izzatnagar; CIFRI, Barrackpore, CIBA, Chennai and NIASM, Baramati. Simultaneously, demonstration of the existing technologies to cope with current climate variability will be carried out in 100 districts through KVKs, Coordinating Centers of the AICRPDA and the TOT Divisions of the above core Institutes. Most of the State Agricultural Universities will be participating in this component through KVKs and AICRP Centers.

4.5 Unique features

- Critical assessment of different crops/zones in the country for vulnerability to climatic stresses and extreme events, in particular, intra seasonal variability of rainfall.
- Installation of the state-of-the-art equipment like flux towers for measurement of green house gases in large field areas to understand the impact of management practices and contribute data on emissions as national responsibility.
- Rapid and large scale screening of crop germplasm including wild relatives for drought and heat tolerance through phenomics platforms for quick identification of promising lines and early development and release of heat/drought tolerant varieties.
- Comprehensive field evaluation of new and emerging approaches of paddy cultivation like aerobic rice and SRI for their contribution to reduce the GHG emissions and water saving.
- Special attention to livestock and fishery sectors including aquaculture which have not received enough attention in climate change research in the past. In particular, the documentation of adaptive traits in indigenous breeds is the most useful step.
- Thorough understanding of crop-pest/pathogen relationship and emergence of new biotypes due to climate change.
- Simultaneous up-scaling of the outputs both through KVKs and the National Mission on Sustainable Agriculture for wider adoption by the farmers

4.6 Technical program

4.6.1 Strategic research

Table 37 : Activities, institutions and deliverables under strategic research component of NICRA

Activity	Institutions	Deliverables	
		2010-11	2011-12
Vulnerability assessment of major food crop production zones to climate variability	**CRIDA** (major rainfed crop zones) **IARI**(with focus on irrigated crops - rice, wheat, chickpea)	Vulnerable crops/cropping systems and zones for respective crops identified.	Vulnerable crops/ zones prioritized and mapped.
Weather based Agro-advisories, contingency plans and identification of best-bet management practices Evaluation of major food and horticultural crops for tolerance to climatic stresses and genetic enhancement of tolerance	**CRIDA** through network of AICRPDA and AICRPAM centres **CRIDA, IIPR** (rainfed crops: maize/ sorghum, pigeonpea and blackgram) **IARI** (irrigated crops: rice, wheat, chickpea) **NRCPB** (thermo tolerant wheat; prospecting of genes for thermo tolerance from microbial & plant resources) **CRRI** (evaluation of key rice germplasm for tolerance to drought and submergence) **DRR** (heat tolerance and nitrogen use efficiency in rice) **ICAR-NEH** (Identification of temperature tolerant rice and maize varieties for north-east) **IIHR, IIVR, ICAR-RCER Ranchi centre** (tomato, banana, mango)	The critical food crop zones identified for strengthening online data collection and equipments installed. Promising material for tolerance to climatic stresses (drought, heat) identified and characterized in selected crops Variation in flowering phenology of mango in relation to temperature variations in different growing areas documented.	Combining weather based agro-advisories with contingency plans and best bet practices field tested. Evaluation testing of promising material in irrigated (wheat, rice, chickpea) and rainfed crops (pigeonpea, maize, blackgram) and horticulture (tomato, banana and mango) initiated. Potentially useful genes for thermo tolerance identified.
Monitoring of GHG emissions through flux towers.	**IARI** (monitoring in large agricultural areas) **CRRI (**onitoring of GHG emissions in rice based production systems)	Flux towers installed and calibrated	Standard system of data recording setup and access to users provided.

Activity	Institutions	Deliverables	
		2010-11	2011-12
Adaptation and mitigation through enhanced water productivity, nutrient use efficiency, conservation agriculture and agro-forestry systems	**CRIDA & DWM** (water productivity in rainfed and irrigated crops, carbon sequestration, water harvesting potential and ground water recharge in relation to rainfall variability **NRCAF & CRIDA** (quantification of carbon sequestration potential in selected agroforestry systems) **PDFSR** (assessment of mitigation potential through farming system approach) **CRRI** (mitigation potential of improved management practices and products in rice cultivation) **ICAR-NEH** (SWM practices for enhancing climatic resilience) **CIAE** (engineering interventions for conservation agriculture and precision farming)	Improved water and nutrient use efficiency parameters identified. Scope of CA practices reviewed and documented. Review & documentation of agroforestry systems for enhanced carbon sequestration suitable for different agro-climatic regions. Identification of potential strategies to reduce GHGs emissions and enhance carbon sequestration from aquaculture. Review and documentation of precision tools for irrigation scheduling, nutrient application and design parameters identified.	Erosivity, water harvesting potential and ground water recharge under high intense rains quantified. Agro-techniques for improved integration of trees in production system to enhance carbon sequestration Efficient strategies identified to reduce GHGs emissions and enhanced carbon sequestration. Work on better designs of SWC structures initiated.
Pest and disease dynamics, changes in crop–pest/ pathogen relationships, changed profile of insect pests and emergence of new bio types due to climate change	**DRR & NCIPM** (initial model on pest dynamics of rice – BPH) **CRIDA & NCIPM** (pest and disease dynamics of pigeonpea, groundnut and forewarning system) **IIHR & NCIPM** (relationships between high temperature and pest and disease on tomato and mango)	Components for improved pest forewarning models identified Climate and pest data collection protocols standardized	The forewarning modules formulated and evaluation initiated

Activity	Institutions	Deliverables	
		2010-11	2011-12
Understanding the unique traits in indigenous livestock which make them resilient to climate change and development of database	**NDRI** (cattle and buffalo) **IVRI** (livestock diseases resistance traits) **ICAR-NEH** (pig and poultry)	Information and data base on genetic adaptation in cattle and buffalo developed. Improved survival parameters of indigenous livestock under climatic stresses identified.	Useful traits in indigenous breeds of cattle, buffalo, pig and poultry in relation to climate change documented and characterized Changes in incidence pattern of livestock diseases documented
Adaptation strategies in livestock to thermal stress through nutritional and environmental manipulations	**NDRI** (cattle and buffalo)	Review and documentation of existing knowledge and gaps identified Environmental and nutritional parameters identified and methodology for adaptation studies standardized	Preliminary evaluation of location specific and cost effective interventions initiated.
Assessment of spawning behaviour of major fish species in marine and inland environments with a view to harness the beneficial effects of temperature	**CMFRI** (marine fish) **CIFRI** (Inland fish)	Studies on spawning behavior of marine and inland fishes initiated	Potential fishing zones in seas identified and breeding strategy for inland fishes in the context of climate change evolved.
Impacts on aquaculture and mitigation options	**CIBA,** Chennai	Impact of climate variables documented and source of GHG emissions identified	Mitigation potential through carbon sequestration quantified

4.6.2 Technology demonstration

Under this component, an integrated package of proven technologies will be demonstrated in one village in each district for adaptation and mitigation of the crop and livestock production systems to climate variability based on the available technologies. The districts to be covered for these demonstrations and list of KVKs are given in Fig.65.

The process of finalizing demonstration package will have the following steps:

1. Analysis of climatic constraints of village based on long term data
2. Assessment of the natural resources status of the village
3. Identification of major production systems
4. Studying of existing institutional structures and identifying the gaps
5. Focus group discussion with the community to finalize the interventions

The interventions will cover the following four modules:

Module I : Natural resources

This module consists of interventions related to in-situ moisture conservation, water harvesting and recycling for supplemental irrigation, improved drainage in flood prone areas, conservation tillage where appropriate, artificial ground water recharge and water saving irrigation methods.

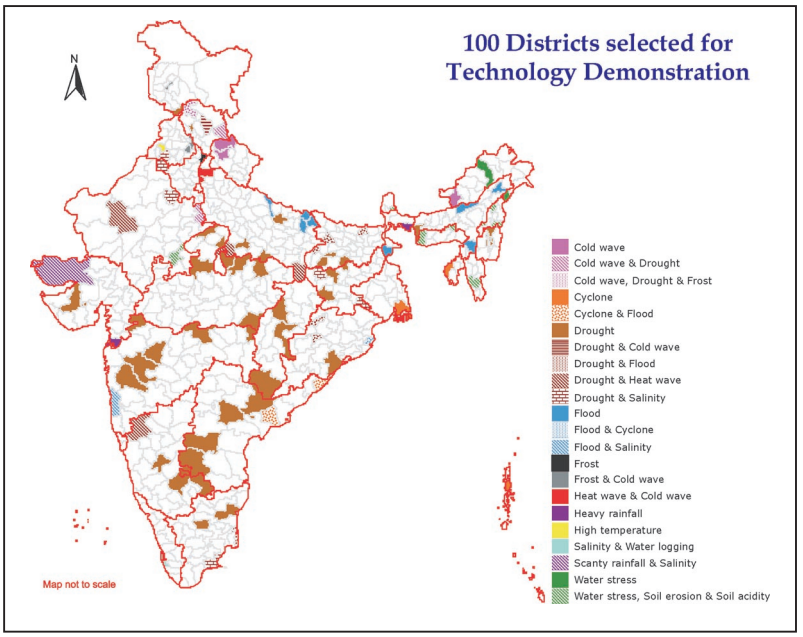


Fig. 65. 100 districts celected for technology demonstration

Module II : Crop Production

This module consists of introducing drought/ temperature tolerant varieties, advancement of planting dates of rabi crops in areas with terminal heat stress, water saving paddy cultivation methods (SRI, aerobic, direct seeding), frost management in horticulture through fumigation, community nurseries for delayed monsoon, custom hiring centres for timely planting, location specific intercropping systems with high sustainable yield index.

Module III : Livestock and Fisheries

Use of community lands for fodder production during droughts/floods, improved fodder/feed storage methods, preventive vaccination, improved shelters for reducing heat stress in livestock , management of fish ponds/tanks during water scarcity and excess water, etc.

Module IV : Institutional Interventions

This module consist of institutional interventions either by strengthening the existing ones or initiating new ones relating to seed bank, fodder bank, commodity groups, custom hiring centre, collective marketing, introduction of weather index based insurance and climate literacy through a village level weather station.

The KVK team for each district will carry out a detailed exercise on the needs of the village, the climatic vulnerability (drought/floods/heat wave/ frost/cyclone) and the available technology options from the concerned Zonal Agricultural Research Stations of the SAU. After a careful study of the gaps, specific interventions from each of the module will be selected and an integrated package from all modules will be formulated. The whole village will be saturated with the above interventions in order to demonstrate a discernible effect. As an outcome of this exercise, location specific climate resilient practices and constraints in their adoption will be documented.

4.6.3 Capacity building

Under this component, need based training will be provided to scientists on the latest tools and methodologies of climate change research at the best of the institutions in the world. Simultaneously, capacity building of senior faculty will be done through short term exposure visits, participation in international symposia, training programs for

extension functionaries of the states and policy makers, NGOs and farmers will be organized to generate awareness on climate change.

4.6.4 Sponsored research

Under this component, research proposals will be invited from identified institutions/ scientists to fill up critical research gaps.

Outputs

- Selection of promising crop genotypes and livestock breeds with greater tolerance to climatic stress.
- Existing best bet practices for climate resilience demonstrated in 100 vulnerable districts.
- Infrastructure at key research institutes for climatic change research strengthened
- Adequately trained scientific man power to take up climate change research in the country and empowered farmers to cope with climate variability

Outcome

- Enhanced resilience of agricultural production in vulnerable regions of the country

Coordination and Monitoring

The Scheme will be implemented with CRIDA, Hyderabad as Lead Institute under over all supervision of NRM Division of ICAR.

4.7 Budget

Table 38 : Componentwise budget (Rupees in crores) of NICRA

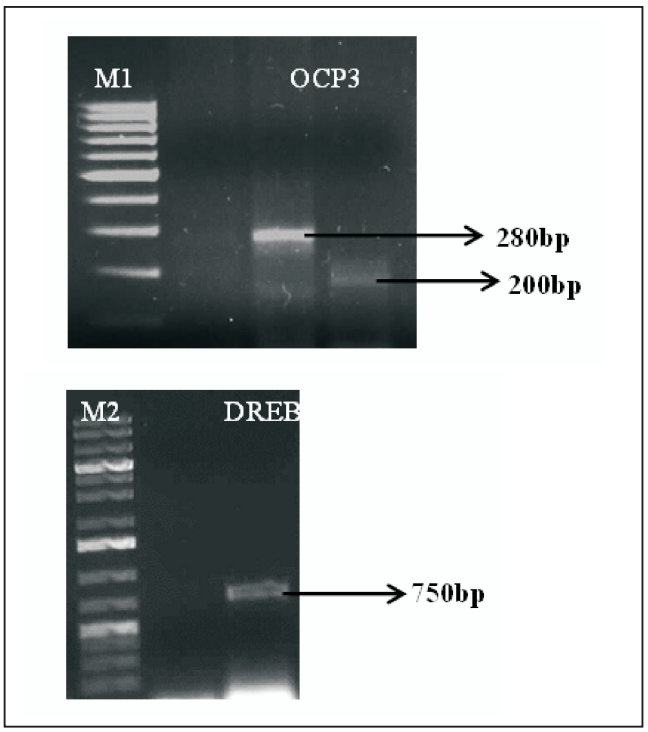
Head/Component	2010-11	2011-12	Total
Strategic Research	147	99	246
Technology Demonstration	40	30	70
Capacity Building Sponsored/Competitive	3	6	9
Research Grant	10	15	25
Total	**200**	**150**	**350**

4.8 Achievements so far

4.8.1 Strategic research

4.8.1.1 Abiotic stress management

Abiotic stresses are major factors limiting plant growth and yield. The response of the plant to each abiotic stress is unique, but in general the plant experiences a combination of two or more stresses which might require a response that is also unique. In view of the global climate change, genotypes which can perform better under multiple stresses is the need of the hour. One of the approaches is to target upstream regulatory master switches rather than 'single-action' genes as these are known to induce the expression of hundreds of genes whose products act both at the transcriptional and translational levels culminating in stress tolerance. Hence efforts have been initiated for the isolation of regulatory master switch genes. The genes such as DREB2A, GRP7 and OCP3 with functional relevance in abiotic stress tolerance have been targeted.



Heterologous amplification of transcription factors using gene specific primers from *Pennisetum glaucum*. M1: 100bp ladder, M2: 1Kb plus ladder

Based on the sequence information available in the public database, heterologous primers have been designed to amplify the highly conserved domain regions. PCR amplification of the cDNA of pearl millet resulted in the amplification of 750bp, 200bp and 280bp products with DREB2A, GRP7 and OCP3 specific primers respectively. Efforts are under way for further characterization and isolation of full length clones.

4.8.2 Technology demonstration component

Activities planned as per the technical programme were taken up immediately after the launch of NICRA in February 2011. Eight workshops were organized to finalize the action plans of 100 NICRA-KVKs during the months of February and March 2011 jointly with the respective Zonal Project Directors in different zones. Action plans for the 100 selected districts, developed based on village–PRA, were critically reviewed by a group of scientists from CRIDA, concerned university and ZPD. In all, 12 KVKs in Zone-I, 15 KVKs in Zone-II, 17 KVKs in Zone-III, 13 KVKs in Zone-IV, 13 KVKs in Zone-V, 7 KVKs in Zone-VI, 14 KVKs in Zone-VII and 9 KVKs in Zone–VIII participated in different workshops. All KVKs were suggested to take up only 4-5 major flagship interventions on a large scale to address the climatic vulnerabilities of the selected village.

A team of scientists from CRIDA, Hyderabad including Dr. B. Venkateswarlu, Director, CRIDA and Dr. Shalander Kumar, Coordinator, NICRA technology demonstration component, participated in all the workshops. The workshops were also attended by respective zonal project directors, director of extension of concerned agricultural university, chief scientists of AICRPDA centers falling in the zone, scientists from nearby ICAR institutes, and programme coordinators and subject matter specialists from NICRA-KVKs of the zone. The NICRA-action plan for each of the 100 selected districts developed based on village–PRA was critically reviewed by the group to make them focused to address the climatic vulnerabilities of the selected districts.

By the end of March 2011, all the 100 KVKs have purchased most of the approved farm implements to be used for custom hiring in the selected village and about 25% of them have organized village level NICRA launch-workshop with participation of line departments, farmers and peoples' representatives.

Action plan finalizing workshop of Zone VIII at Bengaluru

Village level launch workshop

5 Coordinated / Network Projects

5.1 All India Coordinated Research Project for Dryland Agriculture

The All India Coordinated Research Project for dryland agriculture has a network of 25 centers representing arid, semi-arid, sub-humid, humid and per-humid climates with 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 rain water management, integrated nutrient management, energy management, cropping systems, participatory varietal selection, alternate land use and farming systems in rainfed rice, maize, sorghum, pearlmillet, fingermillet, 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 Frontline demonstrations (FLDs) on pulses and oilseeds, on-farm trials are also being undertaken. A total of 361 experiments were conducted with a percentage of 18.3, 22.7, 12.5, 12.5, 21.6, 1.9, 4.2, 3.9 and 2.5 under rain water management, INM, energy management, cropping systems, participatory varietal selection, integrated weed management, alternate land use, integrated farming system and other experiments respectively across the production systems.

These include 90 experiments on rice based production system (Jagdalpur, Jorhat, Faizabad, Phulbani, Ranchi and Varanasi); 46 on maize based production system (Arjia, Ballowal-Saunkri and Rakh Dhiansar); 44 on sorghum based production system (Solapur, Bijapur, Bellary and Jhansi); 43 on pearlmillet based production system (Agra, Hisar and S.K.Nagar); 20 on fingermillet based production system (Bangalore); 37 on soybean based production system (Indore and Rewa); 41 on groundnut based production system (Anantapur and Rajkot); 37 on cotton based production system (Akola, Kovilpatti and Parbhani). Under ORP, there were 133 trials with a percentage of 11.3, 15.8, 11.3, 18.8, 18.0, 2.3, 5.3, 6.8 and 10.5 on rain water management, INM, energy management, cropping system, participatory varietal selection, alternate land use, integrated farming system, demonstrations and other trials respectively. The salient findings from the research conducted at different AICRPDA centres are summarized below:

5.1.1 Rain water management

- In a sub soil tillage study for rice-lentil sequence at Faizabad, sub-soiling at 2 m interval with cross pass at 35 cm depth was superior with rice yield of 1901 kg/ha and lentil yield of 1307 kg/ha, and highest rice equivalent yield of 5632 kg/ha.
- At Jorhat, yield of potato (Kufri Megha) was significantly affected by date of sowing and mulching. The highest yield (12.06 t/ha), BC ratio (1.51) and rain water use efficiency (123.3 kg/ha/mm) were obtained when the seeds were sown on 23rd November, 2009 and grown under mulch. The lowest yield (8.46 t/ha) and BC ratio (1.10) were obtained when it was sown on 14th December, 2009 and grown without mulch. The yield of potato was significantly reduced with delay of sowing. The yield of potato was decreased by 7.54 and 20.6 % when sowing was late by 10 and 20 days respectively.

Mulching with rice straw increased the potato yield by 9.3 to 18.0 %. However, with late sowing, effect of mulching was also reduced. Mulching conserved the soil moisture ranging from 5.7 to 13.3 %.

- At Phulbani, higher tomato yield of 13,321 kg/ha in *kharif* and radish yield of 23,325 kg/ha in *rabi* were attained by providing critical irrigation from a lined pond with soil: cement (6:1) plaster of 8 cm thickness compared to unlined pond. The superior treatment gave a net income of Rs.1,46,380/ha with BC ratio of 2.67 compared to significantly lower net income of Rs.82,021/ha with BC ratio of 2.51 from unlined pond.
- At Arjia, sesame vertical mulch at 10 m interval with deep summer ploughing recorded highest maize stover yield (3000 kg/ha), followed by taramira vertical mulch at 10 m interval with deep summer ploughing over control. This practice recorded lowest runoff (10.13%) and soil loss (3.125 t/ha).
- At Ballowal Saunkhri, among different vegetative barriers, Kannah proved best for yield, rainwater-use-efficiency and economics. Kannah was followed by Napier hybrid bajra, Subabul and Vetivar in maize, sesame and blackgram.
- At Anantapur, the treatment of mulch together with micro-catchments at 45 cm apart for every four lines was superior with maximum groundnut pod yield of 742 kg/ha, net income of Rs.10268/ha, BC ratio of 1.74 and rain water use efficiency of 2.40 kg/ha/mm.
- One supplemental irrigation of 10 mm was given for groundnut using stored water in farm pond at field no 17 of ARS, Anantapur. The yield increase with one supplemental irrigation was 11.2 % compared to rainfed crop. The increase in haulm yield and shelling were 7.8 and 9.6% respectively.
- At Rajkot, maximum groundnut pod yield of 414 kg/ha, net income of Rs.6600/ha and BC ratio of 1.47 were attained when 30 cm distance between rows having 3 rows on broad bed of 90 cm and furrow of 45 cm were maintained. Minimum runoff (26.92 %) and soil loss (454.82 kg/ha) were observed in the treatment having four rows on broad bed.
- At Rajkot, significantly higher pod (950 kg/ha) yield and BC ratio (2.41) were obtained under the treatment with irrigation at soil moisture deficit of about 40%. Crop water use efficiency was highest (23.5 kg/ha/cm) under irrigation at soil moisture deficit of about 40%, where as field water use efficiency was highest (16.2 kg/ha/cm) under irrigation at soil moisture deficit of about 50%.
- At Indore, ridge and furrow system with 60 cm along with a seed rate of 60 kg/ha was superior and gave maximum soybean yield of 1912 kg/ha, RWUE of 2.23 kg/ha/mm, net income of Rs.27502 /ha and BC ratio of 3.13.
- At Rewa, sole soybean gave a yield of 951 kg/ha in *kharif*, while wheat and chickpea recorded a yield of 2756 and 1905 kg/ha respectively in *rabi*. The highest BC ratio was attained by chickpea (5.71) and wheat (4.50) in which pre-sowing irrigation was given. Without pre-sowing irrigation, wheat and chickpea yields of 2460 and 1270 kg/ha were attained.
- At Akola, grain yield of soybean recorded higher in the treatment of thinning of plant population which was at par with remaining *in-situ* moisture conservation practices, except furrow opening after every two rows. BC ratio was maximum in thinning (2.76) treatment.
- At Akola, highest seed cotton (971 kg/ha), stalk yield (3788 kg/ha) and BC ratio of 1.87 were attained under the treatment of opening of furrow after each row together with 50% RDF + FYM @ 5t/ha + PSB + *Azotobactor* compared to opening of furrow after every two rows and flat bed treatments.

- Among *in situ* rainwater conservation techniques tested for sorghum + pigeonpea (4:2), soybean + pigeonpea (4:2) and cotton + soybean (1:1) at Parbhani, soybean + pigeonpea (4:2) with conservation furrow at 2.7 m i.e. after 6 rows was superior with maximum net income of Rs.43144/ha and BC ratio 5.39.
- At Bijapur, in both *kharif* and *rabi* seasons, pebble mulch performed better for runoff and soil loss reduction. However, highest green gram yield (321 kg/ha) was recorded in sand mulch plot during *kharif*, while highest sunflower yield (6.27 kg/ha) was recorded in pebble mulch plot in *rabi*.
- At Bijapur, seed yield of greengram was maximum under planting geometry of 45 X 8 cm with yield of 226 kg/ha. In blackgram, maximum yield was attained under planting geometry of 60 X 6 cm (357 kg/ha). In groundnut, planting geometry of 30-60-30 cm (730 kg/ha) was superior. In cotton, Jayadhar variety with 45-90-45 cm x 13 cm was superior with mean kapas yield of 974 kg/ha.
- At Solapur, pearlmillet + cowpea (6:3) was superior for minimum runoff of 52.2 mm, and soil loss of 0.041 t/ha. However, pearlmillet + pigeonpea (2:1) gave maximum grain yield (pearl millet 720 kg/ha and pigeonpea 1200 kg/ha).
- At Agra, ridge and furrow sowing together with recommended fertilizer in 3 splits (1/3 each) gave significantly higher pearlmillet yield of 3545 kg/ha, net income of Rs. 24952/ha and BC ratio of 3.24.
- At Agra, furrow sowing by ridger seeder in combination with irrigation at 45 DAS (8 cm depth/ha) was superior and gave significantly higher lentil yield of 1387 kg/ha, gross income of Rs. 55460/ha, net income of Rs. 44013/ha and BC ratio of 4.8.
- At Hisar, maximum net returns of Rs. 12890/ha with BC ratio of 1.81 from a yield of 1030 kg/ha were attained when greengram was sown across the slope in *kharif*. In *rabi*, maximum and significantly higher net income of Rs. 18010/ha and BC ratio of 2.08 from a yield of 1780 kg/ha were attained by sowing mustard along the slope. In chickpea also, sowing along the slope gave grain yield of 846 kg/ha, net income Rs.7942/ha and BC ratio of 1.53.
- At Hisar, deep ploughing before the onset of monsoon was superior and gave significantly higher mustard yield of 1580 kg/ha, net income of Rs.14806/ha and BC ratio of 1.86.
- At SK Nagar, highest castor yield of 765 kg/ha and stalk yield of 996 kg/ha were attained with two life saving irrigations + FYM @ 5 t/ha, which were 59.4 and 68.1% higher than control.
- At Bangalore, the green manure incorporator was superior with coverage area of 0.72 ha/hr, incorporation of 85%, working width of 175 cm, working depth of 9 cm and operating speed of 4.5 km/hr with maximum soil moisture storage of 11.06% in fingermillet.
- At Bangalore, tractor drawn deep trencher was superior to conserve maximum rain water with low runoff of 64.7 mm (8.22%) which accounts runoff volume of 448.5 cum and soil moisture storage of 12.9% in orchard crops.
- At Bangalore, Nase grass live barrier plot gave higher fingermillet grain yield of 2448 kg/ha and straw yield of 4028 kg/ha with RWUE of 7.43 kg/ha/mm when grown in the lower plot compared to upper plot. In *khus* grass live barrier plot also, finger millet yield of 2044 kg/ha and straw yield of 3681 kg/ha were attained under the lower plot compared to upper plot.
- At Bangalore, among different vegetable crops grown around farm pond, highest yield (35.4 kg), RWUE (34.6 kg/ha/mm) and income (Rs.354/-) were realized with bottle gourd. Due to this, an additional income of Rs.797/- was realized with effective utilization of harvested water profitably. Harvested water was used to

nourish amla, pomello, papaya, banana, drumstick and curry leaf.

5.1.2 Integrated nutrient management

- At Faizabad, 100% RDF (60 kg N+ 40 kg P + 30 kg K/ha) was superior for maize under maize-chickpea with significantly higher maize yield of 2407 kg/ha. However, significantly higher chickpea yield of 1173 kg/ha was attained by FYM @ 10 t/ha which was at par with treatment vermin-compost @ 3 t/ha. Maximum maize equivalent yield of 6337 kg/ha from both seasons was attained by FYM @ 10 t/ha application.
- At Faizabad, 15 kg N (compost) + 20 kg N (inorganic) was superior with maize yield of 510 kg/ha under maize + pigeonpea block, while 15 kg N (Compost) + 20 kg N (Inorganic) was superior in maize block with yield of 1412 kg/ha and 15 kg N (Compost) + 10 kg N (green leaves) was superior in pigeonpea block with yield of 448 kg/ha.
- In an evaluation of dry aerobic line sowing of rice in midlands at Jagdalpur, dry line seeding by bullock drawn *Nari* plough + 100% RDF + FYM was superior with grain yield of 4237 kg/ha. Under lowlands, dry line sowing by nari plough + 100% RDF + FYM was superior with grain yield of 5933 kg/ha.
- At Jorhat, the grain yield of *kharif* rice ranged from 2630 to 4060 kg/ha. Maximum grain yield, gross income and BC ratio were attained by 50% RDF (inorganic) + 50% N (organic), followed by 50% N (inorganic) + 50% N (organic) +PK (less present in organic).
- At Jorhat, yield of niger (NG-1) grown after *kharif* rice ranged between 48 to 283 kg/ha, the highest yield being attained by 50% RDF (inorganic) + 50% N (organic) and RWUE of 4.61 (kg/ha/mm).
- At Phulbani, application of FYM to supply 15 kg N along with chemical fertilizer (urea) to supply 20 kg N was most effective. This gave 1903 kg/ha under sole rice, 607 kg/ha under sole blackgram and 453 kg rice + 297 kg/ha blackgram under rice + blackgram blocks.
- At Phulbani, application of Ca along with Zn, B and 100% RDF gave highest mean yield (714 kg/ha), followed by treatment with B (Borax @ 10 kg/ha) along with RDF (50-20-20 kg/ha NPK) (676 kg/ha).
- At Chianki, maximum yield of 1520 kg/ha of pigeonpea and 3790 kg/ha of sorghum were attained by application of 100 % NPK treatment.
- For rice-linseed at Chianki, 100% RDF of NPK was superior for attaining maximum rice yield of 3533 kg/ha, followed by 50% N (FYM) + 50% RDF with yield of 3333 kg/ha. In case of linseed also, these two treatments gave yield of 652 and 645 kg/ha respectively.
- For maize at Barkaccha (Varanasi), 100% RDF + $ZnSO_4$ + Manganese @ 25 kg/ha + Boron + Molybdenum @ 10 kg/ha (soil application) was superior with significantly higher grain yield of 1000 kg/ha compared to control yield of 470 kg/ha. The dehusked cob (baby corn) yield was 320 and 510 kg/ha in the respective treatments.
- At Barkachha (Varanasi), highest yield of blackgram was recorded with raised bed system, closely followed by ridge-furrow system. Among fertilizer treatments, 50% RDF + 2% urea spray + 25 kg Zn SO4/ha was superior for attaining maximum yield.
- At Arjia, application of zinc and magnesium with recommended N (50 kg/ha) and P (30 kg/ha) gave highest maize stover yield. This treatment was at par with application of FYM @ 10 t/ha.
- At Ballowal Suankhri, 80 kg N/ha (urea) was superior for maize with maximum grain yield of 4407 kg/ha, net income of Rs.30988/ha and BC ratio of 2.71.

- At Rakh Dhiansar, 100% recommended N (urea) was superior with significantly higher yield of 932 kg/ha, net income of Rs. 1447/ha and BC ratio of 0.13 in maize block and maize equivalent yield of 880 kg/ha, net income of Rs. 1280/ha and BC ratio of 0.12 in maize + blackgram block.
- In a permanent manurial study on maize at Rakh Dhiansar, 100% recommended NPK + Zn SO_4 @ 20 kg/ha was superior and gave significantly higher yield of 875 kg/ha, negative net returns of Rs.1831/ha and negative BC ratio of 0.83.
- At Anantapur, maximum groundnut pod yield of 676 kg/ha with BC ratio 1.28 and rain water use efficiency of 2.19 kg/ha/mm were attained with 100% RDF (20-40-40) + Groundnut shells @ 4 t/ha.
- At Anantapur, sheep penning recorded significantly higher pod yield of 569 kg/ha and haulm yield of 1303 kg/ha with rain water use efficiency of 2.0kg/ha/mm compared to control which recorded lowest pod yield of 428 kg/ha and rain water use efficiency of 1.54kg/ha/mm. Sheep penning significantly increased available soil K.
- At Rajkot, maximum groundnut equivalent main (2046 kg/ha) and by product (1782 kg/ha) yield were recorded under groundnut-sesame and groundnut-groundnut sequence respectively. Maximum gross (Rs.54418/ha) and net (Rs.41088/ha) income were obtained under sesame cultivation after groundnut. Higher gross and net income was recorded from all crops (pearl millet, sesame and castor) when it was rotated with groundnut, followed by cotton rotation, whereas, mono cropping was found less remunerative in all cases under organic farming.
- At Indore, highest soybean yield of 2583 kg/ha, RWUE of 2.45 kg/ha/mm, net income of Rs.93511/ha and BC ratio of 7.76 were attained by application of S @ 60 kg/ha in *kharif*. The chickpea responded well when S was applied to soybean crop only @ 40, 60 and 80 kg/ha with a yield of 2427, 2531 and 2469 kg/ha respectively.
- In a permanent manurial trial of soybean–safflower at Indore, FYM @ 6 t/ha + 20 kg N + 13 kg P/ha was superior with maximum soybean yield 2600 kg/ha, RWUE of 3.03 kg/ha/mm, net income of Rs.30575/ha and BC ratio of 3.34 in the *kharif* and 1351 kg/ha of yield, RWUE of 3.03 kg/ha/mm, net returns of Rs.16736/ha with BC ratio of 2.17 from safflower in *rabi* season.
- At Rewa, with different combinations of N sources for rice–wheat; blackgram - chickpea; and rice + blackgram/wheat + chickpea in separate blocks, 100% N through compost was superior in all the blocks with maximum net income of Rs. 61+18314/ha, Rs.35384 + 16154/ha and Rs.17077 + 20571/ha and BC ratio of 1.01 + 2.96; 3.36 + 2.70 and 3.36 + 2.70 respectively.
- At Akola, significantly higher seed cotton yield (1195 kg/ha) and cotton stalk yield (2403 kg/ha) were attained with application of 100% RDF + 25 kg K/ha + bio-fertilizer.
- At Akola, application of 40 kg N/ha (50% RDN) through FYM/glyricidia lopping in combination with 40 kg N + 40 kg P/ha + 100% K through urea, SSP and MOP respectively gave maximum yield of 392 kg/ha of cotton and 334 kg/ha of green gram in the long term study.
- At Kovilpatti, in the permanent manurial experiment on sorghum, maximum grain yield of 1624 kg/ha and stover yield of 3505 kg/ha, RWUE of 4.87 kg/ha/mm and BC ratio of 2.15 were attained by 40 kg N/ha (urea) + 20 kg P/ha (SSP) + 25 kg $ZnSO_4$/ha.
- In a long term manurial experiment on cotton–sorghum rotation based intercropping at

Kovilpatti, maximum sorghum grain yield of 1574 kg/ha, cowpea yield of 75 kg/ha BC ratio of 2.44 and RWUE of 4.72 kg/ha/mm were attained by application of 20 kg N/ha (urea) + 20 kg N/ha (FYM) + 20 kg P/ha (SSP).

- At Bijapur, ploughing back of *kharif in situ* cowpea or lopping at flowering, followed by application of 50:25 kg/ha of NP was superior with sorghum yield of 2057 kg/ha.
- In the PMT at Solapur, 25 kg N (FYM) + 25 kg/ha N (urea) gave significantly higher grain and stover yield of *rabi* sorghum.
- At Solapur, RDF @ 50 kg N + 25 kg P/ha (50 % through organic + 50 % through inorganic) gave significantly highest safflower grain yield (1464 kg/ha), stover (2190 kg/ha), petals (96 kg/ha), total N uptake (46 kg/ha) and oil content (31 %).
- In a permanent manurial trial on pearlmillet at Agra, 50% N (urea) + 50% N (FYM) was efficient with significantly higher grain yield of 3415 kg/ha, net income of Rs. 23492/ha and BC ratio of 3.07.
- At Agra, 75 kg N + 50 kg P_2O_5 + 50 kg K_2O/ha (soil test based) + zinc + boron + magnesium gave significantly higher pearlmillet grain yield of 4508 kg/ha, net income of Rs. 32222/ha with BC ratio of 3.27.
- At Hisar, 60 kg N + 20 kg P/ha was superior with a significantly higher castor yield of 1066 kg/ha, net income of Rs.8227/ha and BC ratio of 1.54; and 20 kg N + 40 kg P/ha was superior with significantly higher moth bean yield of 932 kg/ha.
- At Hisar, 40 kg N + 20 kg P/ha at sowing time was superior with barley yield of 4153 kg/ha, net income Rs. 22217/ha and BC ratio of 2.12; and 20 kg N + 40 kg P/ha + inoculation with biomix gave significantly higher chickpea yield of 1196 kg/ha net income of Rs. 14393/ha and BC ratio of 1.94.
- At SK Nagar, highest seed yield (1409 kg/ha) was recorded by 100% RDF of NPK (150-100-50%). However, highest straw yield (3837 kg/ha) was attained with 100-100-100% (N-P-K). Maximum net income (Rs.14814/ha) with BC ratio of 3.62 were recorded with 100-100-100% NPK.
- At Bhachau (SK Nagar), highest seed yield (1114 kg/ha), straw yield (3945 kg/ha), gross income (Rs.17949/ha), net income (Rs.11818/ha) and BC ratio (2.93) were attained by 100-100-100% RDF of NPK.
- At SK Nagar, 40 kg N/ha + *Rhizobium* gave significantly higher dry leaves yield of senna (1269 kg/ha), seed yield (124 kg/ha) and BC ratio (2.09). Dry leaves yield was higher in 60 x 20 cm spacing (1565 kg/ha) and BC ratio (2.78).
- At Bangalore, in rotation with groundnut, finger millet grain yield was significantly higher (4004 kg/ha) with FYM @ 10t/ha+ 100% NPK compared to 100% NPK alone (2646 kg/ha) with BC ratio of 2.40. In mono-cropping of finger millet, FYM @ 10 t/ha + 100% NPK recorded significantly higher grain yield (3385 kg/ha) compared to 100% NPK alone (2376 kg/ha) with BC ratio of 2.18.
- At Bangalore, 100% rec. NP (50:40 kg/ha) + 150% rec. K (37.5 kg/ha) as basal gave significantly higher fingermillet (GPU-28) yield (4504 kg/ha) compared to with out K application. In ORP area (Chikkamaranahalli, Nelamangala Tq), application of 100% rec. NP (50:40 kg/ha) + 150% rec. K (37.5 kg/ha) as basal gave fingermillet (MR-1) yield of 4750 kg/ha compared to farmer's practice (2500 kg/ha).

5.1.3 Energy management

- For rice-lentil sequence at Faizabad, conventional tillage + 2 hand weedings at 20 and 40 DAS together with 100% N through

organic source was superior with rice yield of 1180 kg/ha and lentil yield of 822 kg/ha. Low tillage + 50% N (organic) + 50%NPK (inorganic) was the 2nd best with yield of 1092 kg/ha of rice and 761 kg/ha of lentil.

- In an evaluation of dibbler for different upland crops under rainfed conditions at Jagdalpur, dibbling without fertilizer has shown significant result for cowpea with yield of 3670 kg/ha. For Kodomillets, dibbling with 100% RDF placement gave superior and equal yield with line seeding + RDF (3330 kg/ha). For maize, Line seeding + RDF gave superior yield than dibbling treatment.
- At Jorhat, the yield of toria (TS-38) was highest (713 kg/ha) in T_3 treatment (Two harrowing + one pulverization by power tiller) with highest B:C ratio (4.06) and RWUE of 26.41 kg/ha/mm.
- At Phulbani, 50% N organic (FYM) + 50% N (inorganic) recorded maximum rice grain yield of 1390 kg/ha. In horsegram 100% N as organic proved the best with grain yield of 285 kg/ha. The tillage practices did not influence the rice equivalent yield significantly. Maximum rice equivalent yield of 1555 kg/ha was attained by low tillage + herbicide + one interculture.
- In an assessment of effect of sowing by different implements of productivity of groundnut at Chianki, sowing by Dutch hoe was superior with maximum pod yield of 2978 kg/ha, followed by sowing by inclined plate planter with yield of 2725 kg/ha.
- In an assessment of effects of different sowing methods on maize and pearlmillet yield at Varanasi, ridger seeder was efficient for attaining a significantly higher yield of 665 kg/ha of maize and 2016 kg/ha of pearlmillet.
- At Arjia, low tillage + herbicide + one weeding & hoeing gave significantly higher maize yield of 1020 kg/ha, net returns of Rs.10077/ha, BC ratio of 1.90 and rainwater use efficiency of 3.56 kg/ha/mm. Among nutrient management practices, 100% N (compost) was superior with significantly higher yield of 1005 kg/ha, net income of Rs.6998/ha, BC ratio of 0.85 and rainwater use efficiency of 3.51 kg/ha/mm.
- At Ballowal Suankhri, low tillage + interculture + herbicide application together with 100% recommended N through inorganic source was highly efficient with significantly higher maize yield (2503 kg/ha), net income (Rs.13191/ha) and BC ratio (1.87). This practice gave minimum number of weeds/m^2 and lowest weed dry weight/m^2.
- At Rakh Dhiansar, low tillage + interculture + weedicide together with 100% N through urea was superior with significantly higher maize grain yield of 1089 kg/ha, fodder yield of 1668 kg/ha, net income of Rs.3277/ha and BC ratio of 1.41.
- Among different seed drills tested at Anantapur, lowest seed rate of 95 kg/ha was used by Ananta planter compared to maximum of 180 kg/ha under Saathi planter. Ananta planter was efficient with plant population of 30/sq.m, field capacity of 6 to 7 ha/day, depth of planting of 4 to 5 cm with groundnut pod yield of 402 kg/ha.
- At Rajkot, low tillage + interculture + 50% N (organic) + 50% N (inorganic) was superior with a higher yield of 312 kg/ha, net income of Rs.11340/ha and BC ratio of 2.4 in the season.
- At Indore, conventional tillage + recommended fertilizer (+ Off season tillage) + hand weeding gave the highest soybean yield and net returns (yield of 1494 kg/ha, RWUE 1.74, net income of Rs.18374/-, BC ratio of 2.41).
- At Rewa , low till + weedicide + interculture in combination with 50% N (organic) + 50% N (inorganic) was superior with maximum yield of 1730 kg/ha, net income Rs. 27611/ha and

BC ratio of 2.87 for soybean in *kharif*. In case of wheat in *rabi*, the treatment of low till + weedicide + interculture together with 100% (organic) i.e. FYM @ 8 t/ha was superior with maximum yield of 3331 kg/ha, net income of Rs. 41216/ha and BC ratio of 4.92.

- At Akola, tillage and nutrient management practices did not influence cotton seed and stalk yields.
- At Kovilpatti, broad bed and furrow treatment gave significantly higher maize yield of 1544 kg/ha which was 7.8% higher than ridges and furrows (1298 kg/ha) and RWUE of 5.71 kg/ha/mm.
- At Parbhani, reduced tillage + interculture + 100% recommended N (inorganic) was superior with significantly higher seed cotton equivalent yield of 1136 kg/ha, net income of Rs. 18473/ha and BC ratio of 1.34.
- Among four seed-drills tested for sorghum at Bijapur, bullock drawn seed-drill was superior which gave maximum yield of 625 kg/ha.
- At Solapur, conventional tillage (plough once in 3 years + one harrowing + ridges and furrows) + 50% N (organic) + 50% N (inorganic) was superior for sorghum with significantly higher grain yield (2210 kg/ha).
- At Agra, pearlmillet yield of 3280/ha, net income of Rs. 21237/ha ad BC ratio of 2.80 were attained by conventional tillage + interculture + 50% N (organic) + 50% N (inorganic) application.
- At Hisar, significantly higher pearl millet yield of 2116 kg/ha, net returns of Rs.7058/ha and BC ratio of 1.44 were attained by low tillage + two intercultures + 100 % N (inorganic) application.
- At SK Nagar, the highest grain yield (1709 kg/ha) and stalk yield of castor (1376 kg/ha) were recorded under deep ploughing with disc plough which were 45.3 and 57.2% higher than control.
- At SK Nagar, significantly higher cluster bean seed yield (302 kg/ha), straw yield (742 kg/ha), gross return (Rs. 7530/ha) were attained by low till + two intercultures + herbicide + 50 % N (Urea) + 50 % (FYM).
- At Bangalore, conventional tillage + 50% N (organic) + 50% N (inorganic) gave significantly higher finger millet yield of 2624 kg/ha and straw yield of 4588 kg/ha with RWUE (5.45 kg/ha/mm).

5.1.4 Cropping system

- In an assessment of suitability of different crop sequences of *kharif* rice followed by seven crops in *rabi* at Jorhat, rice-pea was superior with rice equivalent yield of 5079 kg/ha. The system gave net returns of Rs. 30348/ha with BC ratio of 2.54. The grain yield of *kharif* rice, rice equivalent yield of different *rabi* crops and the total rice equivalent yield of different crop sequences were highest in rice–pea sequence. The grain yield of *kharif* rice under this sequence remained at par with the rice-linseed sequence.
- Among six different pigeonpea + vegetable intercropping systems tested under bed and furrow planting at Phulbani, pigeonpea + tomato (pigeonpea grain yield of 155 kg/ha, tomato fruit yield of 7078 kg/ha and pigeonpea equivalent yield of 4402 kg/ha) and pigeonpea + cauliflower (pigeonpea grain yield of 261 kg/ha, cauliflower curd yield of 4375 kg/ha and pigeonpea equivalent yield of 4636 kg/ha) intercropping were most remunerative with net returns of Rs.47940/- and Rs.47380/ha respectively.
- At Arjia, HIM-129 variety of maize + 100 % RDF (50 kg N + 30 kg P/ha) + ridging at 30 DAS was superior with significantly higher yield of 1224 kg/ha, net income of Rs11327/ha, BC ratio of 2.5 and rainwater use efficiency of 4.96 kg grain/ha/mm.
- At Arjia, PM-3 variety of maize + RBU-38 variety of blackgram gave maximum maize equivalent

yield of 1757 kg/ha, net income of Rs. 5859/ha, BC ratio of 1.59 and rainwater use efficiency of 7.01 kg grain/ha/mm.

- At Ballowal Saunkhri, greengram and blackgram attained significantly higher maize equivalent grain yield (MEY). When maize was intercropped with blackgram, greengram and sesame, highest MEY was obtained in maize + greengram (two rows), followed by maize + greengram (one row). Maize intercropped with greengram gave maximum BC ratio (1.44).
- At Ballowal Saunkri, IT-38956-1 of cowpea was superior for fodder yield (30833 kg/ha). In pearlmillet fodder, FBC 16 yielded highest fodder (60833 kg/ha). In maize fodder, local race (Harman) was superior (23333 kg/ha). Among fodders of Bajra, teosinte and maize, bajra gave highest fodder yield (21567 kg/ha).
- At Anantapur, pigeonpea gave maximum net returns in the range of Rs.1915/ha (5th DOS : 1st fortnight of October) to Rs.39820/ha (1st DOS : 1st fortnight of June) from a yield of 224 to 1307 kg/ha when sown on the respective dates. Field bean was the 2nd best with net returns in the range of Rs.3330/ha (4th DOS : 2nd fortnight of September) to Rs.32890/ha (2nd DOS: 2nd fortnight of August) from a mean yield of 222 to 961 kg/ha (2nd DOS : 2nd fortnight of August). Highest rain water use efficiency (7.57 kg/ha/mm) was recorded in sorghum with a yield of 1590 kg/ha , when it was sown on 1st fortnight of September.
- At Indore, maximum and significantly higher soybean equivalent yield of 4122 kg/ha, RWUE of 4.80 Kg/ha/mm with a net income of Rs.67160/ha and BC ratio of 6.08 were attained by pigeonpea + soybean system.
- Among different contingency crops tested at Indore, maximum net returns of Rs. 19660/- was recorded by guar with BC ratio 2.79, followed by kulthi with net returns of Rs.11380/- and BC ratio 2.03.
- At Rewa, in an evaluation of suitable *rabi* crops for rice based cropping sequences, lentil was superior with maximum net income of Rs.34033/ha and BC ratio 4.09 from yield of 1217 kg/ha attained by applying with 100% RDF. Chickpea was the 2nd best with net income of Rs.14756/ha and BC ratio of 3.25 from yield of 1452 kg/ha attained with 100% RDF.
- At Parbhani, Bt cotton planted at 90 x 60 cm plant geometry was efficient to produce significantly higher seed cotton yield of 1527 kg/ha with net returns of Rs.29190/ha, BC ratio 2.76 and RWUE of 2.60 kg/ha/mm.
- At Akola, 9:1:1:1 crop geometry of cotton, sorghum, pigeonpea and sorghum gave significantly higher seed cotton (374 kg/ha) and stalk yield (1022 kg/ha), followed by 6:1:1:1 ratio. Fodder yield of (5816 kg/ha) was significantly higher in 6:1:2:1 row proportion. Significantly higher total productivity (2548 kg/ha) was recorded in 3:1:1:1, followed by 6:1:2:1 row proportion which were at par with each other.
- At Parbhani, maize paired row planting (2:2) with 45/75 cm spacing gave significantly higher grain (2509 kg/ha) and fodder (3400 kg/ha) yield. However, maximum maize equivalent yield (3774 kg/ha) and net returns (Rs.17185/ha) were recorded under maize + soybean (1:1) at 60 cm spacing with BC ratio 2.18 and RWUE of 7.55 kg/ha/mm.
- At Parbhani, combination of kaoline spray @ 6%, vegetative mulching 2 t/ha and soil mulching was superior with seed cotton equivalent yield of 1796 kg/ha, net income of Rs.38351/ha and BC ratio of 2.56. Among cropping systems, soybean + pigeonpea (4:2) was superior with seed cotton equivalent yield of 1788 kg/ha, net income of Rs.39864/ha and BC ratio of 3.09.

- In chilli + onion (2:4) at Bijapur, foliar spray of cow pat pit manure (5 g/lit) produced significantly higher gross net returns of Rs.50254/ha and net returns of Rs.41510/ha compared to other organic formulations.
- At Solapur, sole pigeonpea gave highest gross monetary returns of Rs.37914/ha, net returns of Rs.24376/ha and BC ratio 2.80 compared to intercropping systems.
- At Agra, clusterbean + pearlmillet (6:1) was superior with significantly higher clusterbean equivalent yield of 1015 kg/ha, net income of 13067/ha and BC ratio of 2.43.
- At Agra, sowing at 25-30 days delayed condition with ridge and furrow was equally beneficial for all *kharif* crops compared to sowing at normal onset. Among crops, maximum yield of 3212 kg/ha was attained by pearlmillet with net income of Rs. 22029 and BC ratio of 2.95, while greengram gave highest net income of Rs. 47005/ha and BC ratio of 5.23 respectively, when crops were sown on 30th July.
- At Hisar, castor paired rows (60-120-60 cm) + two rows of greengram was superior with maximum castor equivalent yield of 1030 kg/ha, net income of Rs. 7057/ha and BC ratio of 1.45.
- At Hisar, mothbean paired rows (30-60 cm) + one row of clusterbean was superior with significantly higher mothbean equivalent yield of 1154 kg/ha, net income of Rs.11891/ha and BC ratio of 1.81.
- At SK Nagar, sole greengram gave significantly higher cotton equivalent yield (1007 kg/ha), gross returns (Rs.33933/ha) and BC ratio was maximum (6.80). The LER was maximum higher under cotton + blackgram (1.75).
- Among different intercrops tested with nipped castor at Bangalore, castor + fingermillet (1:3) gave significantly higher castor equivalent yield (2910 kg/ha), LER (1.26) and BC ratio (2.98).

5.1.5 Participatory varietal selection

- At Faizabad, Varuna (1480 kg/ha), NDR-1 (1457 kg/ha) and Pusa gold (1330 kg/ha) were superior among different mustard varieties evaluated in the season. NDR-4 gave lowest yield of 1099 kg/ha.
- At Faizabad, T-12 (602 kg/ha) and TC-289 (555 kg/ha) were superior among different sesame varieties evaluated in the season. T-4 gave lowest yield of 370 kg/ha.
- Out of 12 Varieties of safflower tested at Jagdalpur, Variety A 1 gave highest seed yield of 1188 kg/ha, followed by Bhima (982 kg/ha), JSF 1 (974 kg/ha), S 144 (956 kg/ha), Sharda (907 kg/ha) and Manjira (904 kg/ha). A1, Bhima and Manjira out yielded over average experimental mean of 752 kg/ha.
- At Phulani, 'Morden' recorded seed yield of 312 kg/ha. The composite variety 'Bhanu' (501 kg/ha) and the hybrid DRSH-1 (652 kg/ha) gave significantly higher seed yield than the check.
- Among different rice varieties evaluated at Chianki, the varietal differences of grain yield were significantly different. The entry BAU-438-6-2 (2389 kg/ha) recorded higher yield, followed by R-RF-25 (2144 kg/ha). Sabhagi (2000 kg/ha) and Vandana (1989) were at par with Local Check BVD-110(1744 kg/ha) and BVD-111(1744 kg/ha).
- In a sorghum varietal trial at Chianki, the varietal differences for grain yield were significant. The variety SPV-1824 (3999 kg/ha), followed by SPV-462 (3827 kg/ha) performed better. Among different varieties, CSV-17 took a minimum of 95 days for maturity.
- Among 12 varieties of horsegram evaluated at Chianki, AK-21 gave a maximum yield of 1003 kg/h, followed by GHG-19 (944 kg/ha), Madhu (933 kg/ha) and AK-51 (926 kg/ha). These entries were at par with local check Birsa Kulthi-1 (980 kg/ha).

- In another trial of horsegram with 12 varieties at Chianki, the varietal differences for grain yield were significantly superior. The entry VLG-21 (900 kg/ha) recorded significantly higher yield, followed by GHG-13 (819 kg/ha) and AK-21 (808 kg/ha).
- In a trial on linseed with 14 varieties at Chianki, the varietal differences for grain yield were significant. The entry NL-259 recorded significantly higher yield of 349 kg/ha, followed by PKDL (315 kg/ha) and PCL-42-1 (309 kg/ha).
- In a varietal trial of safflower with 10 entries at Chianki, the entry JSI-116 gave maximum yield i.e 467 kg/ha. The entries PBNS-72 (444 kg/ha), AKS-204 (419 kg/ha) and AKS-307 (414 kg/ha) were at par to the National check A-1 i.e 367 kg/ha.
- Among 15 varieties of sesame evaluated for suitability under farmers filed in Mirzapur district, TC-289 (806 kg/ha) gave the highest yield, followed by T12 (805 kg /ha) and TC 25 (800 kg/ha). These varieties were on par with each other and gave highest RWUE.
- In an evaluation of 11 varieties of lentil under farmers field in Mirzapur district , HUL-57 (Malviya Vishwanath) was superior with significantly higher yield of 2133 kg/ha, followed by DPL-15 with 1967 kg/ha and KLS-218 with 1900 kg/ha. PL-5 gave lowest yield of 1500 kg/ha in the season. In general higher RWUE was associated with high yielding lentil varieties.
- At Anantapur, ATPH-11 of horse gram recorded highest yield of 1578 kg/ha with net income of Rs.19092/ha, BC ratio of 7.36 and rain water use efficiency of 5.12 kg/ha/mm.
- At Anantapur, ATPFB-1 of field bean recorded highest yield of Rs.1167 kg/ha with net income of Rs.42680/ha, BC ratio of 11.67 and rain water use efficiency of 3.78 kg/ha/mm.
- At Rajkot, maximum groundnut pod yield was attained by JSSP-35 (2283 kg/ha). The highest haulm yield of 5451 kg/ha was attained by the variety GG-20. The pod and haulm yields were recorded higher due to two life saving irrigations applied on 23rd September and 4th October-09.
- At Rajkot, sesame seed yield was maximum for genotype AT-183 (1382 kg/ha) which was at par with G.Til-10 (1263 kg/ha) and AT-191 (1251 kg/ha). In greengram, GM-06-08 gave maximum yield of 1465 kg/ha, gross income of Rs.58600/-, net income of Rs.48150/- BC ratio of 5.61. In sorghum, SR-1904 was superior with significantly higher fodder yield (13905 kg/ha).
- At Indore, JA 4 08-20 of pigeonpea was superior with significantly higher yield of 4167 kg/ha, RWUE of 4.62 kg/ha/mm, net income of Rs.103042/ha and BC ratio of 7.93. In soybean, NRC-2 was superior with maximum and significantly higher yield of 3469 kg/ha, 4.04 kg/ha/mm of RWUE, net income of Rs.60556/ha and BC ratio of 5.66. In chickpea, JG 226 was superior with maximum yield of 1778 kg/ha, RWUE of 7.90 kg/ha/mm, net income of Rs.32383/ha and BC ratio of 4.60. At Indore, JNS-28 of niger was significantly superior to other test entries recording highest yield of 248 kg/ha, RWUE of 0.58, net income of Rs.10369/ha and BC ratio of 4.46.
- At Rewa, Vandana of rice was superior among early sown varieties with a maximum yield of 3024 kg/ha, net income of Rs.13842/ha and BC ratio of 2.69. Even for medium and late sown conditions, Vandana was superior with yield of 2464 and 2096 kg/ha, net income of Rs.9704/ha and 7169/ha and BC ratio of 2.18 and 1.87 respectively. In blackgram, TU-98-43 was superior with a significantly higher yield of 1050 kg/ha, net income of Rs.34485/ha and BC ratio of 5.79. In soybean, JS 93-05 variety was superior with highest yield of 1567

kg/ha, net income of Rs.23068/ha and BC ratio of 3.59. In chickpea, Shaki was superior with maximum yield of 2700 kg/ha, net income of Rs.57310/ha and BC ratio of 6.21.

- At Akola, maximum seed cotton yield was attained by AKA-5. In castor, GCH-5 (1195 kg/ha) was superior.
- At Kovilpatti, among *G.hirsutum* Bt hybrids in 5 farmers fields, Tulasi-9 and Mallika were superior with mean seed cotton yield of 536 kg/ha. In an evaluation of *G.arboreum* cotton varieties, maximum mean seed cotton yield of 513 kg/ha was attained by PA 255 (58% more than the local K 11). Out of 18 varieties and 8 Bt cotton hybrids, SVPR-3 and G.cot 16 were superior among varieties with mean seed cotton yield of 700 kg/ha, which was 59% more than KC 3. Among Bt hybrids, Brahma BG II recorded highest seed cotton yield of 1194 kg/ha which was 30% more than RCH2 Bt.
- At Parbhani, among 23 genotypes of pigeonpea evaluated, BDN-2009 was superior with maximum grain yield of 1556 kg/ha. Among different *rabi* sorghum genotypes, M-35-1 was superior with significantly higher grain yield of 1558 kg/ha.
- At Bijapur, DNC-08-09 of niger (691 kg/ha); Dwarika of sesame (812 kg/ha); MLT-13 of sunflower (1065 kg/ha); AHT-18 of sunflower (1386 kg/ha); MB-3 of moth bean (644 kg/ha); CRIDA-06-JL of *Jatropha* (1660 kg/ha) were superior.
- At Solapur, RSV-1130 of sorghum (3135 kg/ha); PT-002-25-1 of pigeonpea (852 kg/ha); SHG-0625 of horse gram (1081 kg/ha); MBS 0711 of moth bean (633 kg/ha); CK-09-IVT-01 of castor (1401 kg/ha) were superior.
- At Agra, AVT-09-09 was superior with yield of 276 kg/ha, net returns of Rs. 1399/ha, BC ratio of 1.15 and RWUE of 0.98 kg/ha/mm.
- At Hisar, HHB-197 of pearlmillet (2419 kg/ha), HFC-98-46 of cowpea (588 kg/ha), HT-1 of sesame (156 kg/ha), HG2-20 of clusterbean (1054 kg/ha), Satya of greengram (843 kg/ha), T-9 of blackgram (1129 kg/ha), RMO-225 of mothbean (903 kg/ha), DCH-32 of castor (758 kg/ha), RH 440 of raya (2075 kg/ha) and DSH-5 of sunhemp (632 kg/ha) were superior in *kharif*. In *rabi*, RB-50 of mustard (yield of 1756 kg/ha), HC O212 of *B. carinata* (1218 kg/ha), T-27 of Taramira (687 kg/ha), BH-393 of barley (1814 kg/ha) and HC-5 of chickpea (1317 kg/ha) were superior.
- At SK Nagar, Hybrid GCH-7 of castor (1547 kg/ha); G.Cot.-21 of cotton (988 kg/ha); Gujarat Maize-4 of maize (1504 kg/ha); GG – 2 of chickpea (850 kg/ha) were superior.

* At Bangalore, IT 38956-1 of cowpea gave highest yield of 782 kg/ha when sown in early *kharif*, and 1610 kg/ha when sown in late *kharif*. GPU-28 of finger millet (3040 kg/ha) and hybrid SMLHT-2 of sunflower (3381 kg/ha) were superior.

5.1.6 Alternate land use systems

- At Rakh Dhiansar, highest green fodder yield of 12350 kg/ha was attained by sole fodder crop, followed by *Grewia optiva* + green fodder (8146 kg/ha). The highest yield of green leaves and fuel wood were attained by *Leucaena* (7125 and 5135 kg/ha respectively).
- Among different combinations of agri-horti systems tested at Indore, soybean - chickpea in combination with Ber was superior with maximum net income of Rs. 24021/ha and BC ratio of 2.66 from a soybean equivalent yield of 1851 kg/ha. Soybean - chickpea in combination with aonla gave the 2nd best soybean equivalent yield of 1790 kg/ha, net income of Rs. 22808/ha and BC ratio of 2.85 in the study.
- At Kovilpatti, under sapota based intercropping systems, cotton was superior with highest

sorghum equivalent yield of 2509 kg/ha, gross income of Rs 20070/-, net income of Rs. 13570/ ha and BC ratio of 3.09.

- At Akola, custard apple + greengram system was superior with green gram yield of 635 kg/ ha and gross monetary returns of Rs. 36976/ ha. Under hanumanphal + greengram system, greengram attained grain yield of 338 kg/ha and gross returns of Rs. 19682/ha.

5.1.7 Integrated farming systems

- In an assessment of different cost efficient water conservation structures for establishing rainfed mango orchard under upland farming situation at Jagdalpur, continuous contour trenches was found to be beneficial with an average plant height of 75.49 cm in the first year but was economically not so beneficial with BC ratio of 0.9. U pits showed a significantly high economics value of 9.0 stating that low construction or excavation cost can be incurred for significantly good biometric results of the plant.
- At Arjia, among anola based intercrops, highest maize equivalent grain yield and net returns were obtained with greengram (1807 kg/ha and Rs.14307/ha, respectively). Maximum BC ratio was obtained in greengram (3.48).
- At Rakh Dhiansar, growing of fodder in *Leucaena* in *kharif* was superior with maximum net income of Rs.11443/ha and BC ratio of 3.82 from a yield of 18000 kg/ha of fodder.
- At Kovilpatti, crop + dairy + goat farming system gave highest sorghum equivalent yield of 9171 kg/ha compared to 795 kg/ha under only crop component. The total income under cropping + dairy + goat system was Rs.73369/- compared to Rs. 6358/- under crop component.
- At Solapur, the crop component gave net income of Rs.6280/-, while the horticulture component gave Rs.1923/-. Among animal components, poultry keeping has given better income (Rs.2278/-) with minimum additional expenditure.
- At SK Nagar, integrated farming system gave 30.2% higher gross returns over traditional sole maize. Castor+greengram were superior among intercropping systems for maximum gross returns. Livestock component provided a net income of Rs. 45480/ha.

5.1.8 On-farm trials

- At Faizabad, improved variety of pigeonpea (Narendra Arhar-1) intercropped with maize and grown with recommended dose of fertilizer (20-40-0 kg/ha) was superior and gave maximum pigeonpea equivalent yield (1964 kg/ha), net returns (Rs. 38704/ha) and BC ratio (5.13) in farmers' field.
- At Faizabad, improved variety of chickpea (PG-186) sown in line with recommended dose of fertilizer (20-40-0 kg/ha) gave maximum yield of 1520 kg/ha with maximum net returns of Rs. 24020/ha and BC ratio 2.68 under rainfed condition.
- At Phulbani, 4 short duration rice varieties viz. Vandana, Subhadra, ZHU 11-26 and Saria (local) with fertilizer dose of 40:20:20 kg NPK/ha were tested in two farmers' fields under rainfed upland situation in Ghoda pathar village under Khjuripada block of Kandhamal district. Highest mean grain yield of 1772 kg/ha was realized from variety Vandana.
- At Phulbani, out of 7 varieties of greengram viz. K-851, Pusa 9531, Sujata, PDM-54, OBGG-52, Dhauli and Boudh Local tested under rainfed upland situation in two farmers' fields of Ghoda pathar village, Pusa-9531 (67 days) gave highest seed yield of 680 kg/ha.
- At Phulbani, out of 6 sesame varieties viz. Nirmala, Prachi, OSSel-84, Uma, Kanak and 'Maghi Local' evaluated in a farmer's field under rainfed upland situation in Ghoda pathar village, Prachi (75 days) gave highest seed yield of 375 kg/ha.

- At Phulbani, Yam cv. Hatikhoj was tested in two farmers' fields in village Ghoda pathar under Khajuripada Block. The crop was planted in ridge method with fertilizer dose of 80:60:80 kg N-P_2O_5-K_2O/ha. Mean tuber yield of 10060 kg/ha was realized from the crop with net returns of Rs 37100 /ha.

5.1.9 Operational Research Project

5.1.9.1 Rain water management

- At Anantapur, shelling (%) in groundnut was improved by 5% with supplemental irrigation. There was 32-35% increase in pod yield with supplemental irrigation compared to no irrigation.
- At Bengaluru, higher fingermillet grain yield of 2350 kg/ha, straw yield of 5523 kg/ha and pigeonpea grain yield of 180 kg/ha were attained by staggered moisture conservation furrow. The improved system gave BC ratio of 2.38, while the farmers' practice registered a BC ratio of 1.57.
- At Ballowal Saunkhri, 1st post-sowing irrigation was applied 30 DAS and 2nd at grain filling stage in wheat (PBW-175). Application of supplemental irrigation gave grain yield of 1953 kg/ha and net returns of Rs.27117/ha with BC ratio of 3.91.
- At Ballowal Saunkhri, maximum grain yield of 2939 kg/ha, RWUE of 4.87 kg/ha/mm, net returns of Rs.18770/ha and BC ratio of 2.33 were attained by ridge sowing of maize.
- At Solapur, maximum *rabi* sorghum grain yield of 1268 kg/ha, fodder yield of 3290 kg/ha and BC ratio of 2.36 were attained under ridges and furrows.
- At Solapur, a higher pigeonpea grain yield of 800 kg/ha, stalk yield of 2008 kg/ha and BC ratio of 2.47 were attained with ridges and furrows.

5.1.9.2 Integrated nutrient management

- At Anantapur, mean groundnut pod yield of 525 kg/ha, net returns of Rs.4758/ha and BC ratio of 1.55 were attained when fertilizers were applied based on soil test values.
- At Arjia, 50 kg N+ 30 kg P/ha Spray of $ZnSO_4$ @ 0.5% gave negative net returns of Rs. 1771/ ha, BC ratio of 0.74 and maize yield of 205 kg/ha.
- At Arjia, spray of thiourea @ 0.05% at knee height and tasseling stage gave negative net returns of Rs.1663/ha, BC ratio of 0.77 from maize yield of 217 kg/ha.
- At Bengaluru, groundnut (TMV-2) + pigeonpea (TTB-7) in 8:2 row ratio with 100% RDF + 12.5 kg/ha of $ZnSO_4$ + 10 kg/ha of Borax + bio-fertilizers gave maximum net returns of Rs.26295/ha and BC ratio of 2.43 from groundnut pod yield of 827 kg/ha and pigeonpea grain yield of 625 kg/ha.
- At Bengaluru, 50% N (organic) + 50% NPK + 12.5 kg/ha $ZnSO_4$ + 10 kg/ha Borax gave maximum net returns of Rs.24324/ha with BC ratio of 2.44 from fingermillet yield of 2520 kg/ha and pigeonpea yield of 330 kg/ha.
- At Ballowal Saunkhri, reduced tillage (2 ploughings) + 100% N (inorganic) gave maize grain yield of 2056 kg/ha, higher net returns of Rs.18300/ha, BC ratio of 1.88.
- At Hisar, application of 20 kg N/ha + Azotobacter gave maximum mustard seed yield with net returns of Rs.10065/ha and BC ratio of 1.71.
- At Indore, 100% recommended NP gave the maximum soybean yield of 1726 kg/ha, net income of Rs.17135/ha and BC ratio of 2.49.
- At Solapur, maximum sorghum grain yield of 914 kg/ha and fodder yield of 2233 kg/ha were attained as per soil test value (N:P 75:31 + 15 kg zinc/ ha).

5.1.9.3 Energy management

- Mechanical seed drill was superior for groundnut at Anantapur with pod yield of 577 kg/ha, net returns of Rs. 6613/ha, and BC ratio of 1.74 were recorded.
- At Solapur, *Solapur Sheti Yantra* was superior with maximum effective field capacity (2.1 ha/day), lower power requirement of 3.8 hr/ha of machine, 3.8 hr/ha of human labour and 7.6 hr/ha of bullock with a cost of operation of Rs.595/ha. The improved drill gave highest grain yield of 1210 kg/ha and fodder yield of 2885 kg/ha.
- At Chianki, after harvest of paddy, cultivation of wheat under zero tillage condition was highly profitable with a grain yield of 2712 kg/ha in Sua village and 2956 kg/ha in Thakurai Dhabra village at Chianki with net returns of Rs.24786/ha and BC ratio of 2.62.

5.1.9.4 Cropping system

- At Arjia, maximum groundnut equivalent yield of 368 kg/ha, negative net returns of Rs.1424/ha and BC ratio of 0.83 were attained in groundnut+ sesame (6:2).
- In maize + blackgram (2:2) at Arjia, maximum grain yield of 340 kg/ha of maize and 50 kg/ha of black gram, net returns of Rs.-356/ha and BC ratio of 0.96 with maize equivalent yield of 618 kg/ha were attained with supplemental irrigation.
- At Bengaluru, fingermillet (MR-1) + pigeonpea (TTB-7) in 10:2 ratio was superior with fingermillet yield of 2210 kg/ha, pigeonpea yield of 210 kg/ha, net returns of Rs.19095/ha and BC ratio of 2.34.
- At Bengaluru, groundnut (TMV-2) + pigeonpea (TTB-7) in 8:2 row ratio gave 710 kg/ha of groundnut pod yield, 3905 kg/ha of haulm yield and 550 kg/ha of pigeonpea yield, net returns of Rs.21962/ha with BC ratio of 2.29.
- At Ballowal Saunkhri, Ash gourd–taramira gave highest net returns of Rs.51209/ ha and BC ratio of 4.44.
- At Hisar, chickpea + Chinese cabbage was profitable with net returns of Rs.7430/ha and BC ratio of 1.47.
- At Solapur, blackgram–sorghum sequence was superior with maximum BC ratio of 2.08 from yield of 1450 kg/ha of grain and 3540 kg/ha of fodder sorghum.

5.1.9.5 Participatory varietal selection

- At Anantapur, local bunch gave maximum groundnut pod yield of 724 kg/ha, while Kadiri-6 gave maximum haulm yield of 1596 kg/ha.
- At Arjia, PM-3 of maize (186 kg/ha); AK-49 of horsegram (157 kg/ha); TAU-1 of black gram (73 kg/ha); TG–37A of groundnut (193 kg/ha); SU-1080 of sorghum (558 kg/ha) were superior. Similarly, RT-125 of sesame; T-9 of mustard were superior
- In fingermillet at Bengaluru, maximum grain yield of 2872 kg/ha was attained by ML-365, while straw yield of 5837 kg/ha was attained in MR-1. The improved Samrudhi variety gave a maximum green chilli yield of 4800 kg/ha at Bengaluru. In a pigeonpea at Bengaluru, BRG-1 was superior with maximum grain yield of 1788 kg/ha, stalk yield of 6850 kg/ha and BC ratio of 5.62.
- At Ballowal Saunkhri, Parkash variety of maize gave maximum productivity of 2504 kg/ha, net returns of Rs.11 392/ha, BC ratio of 1.93 and RWUE of 4.15 kg/ha/mm.
- At Ballowal Saunkhri, RLM 619 of raya was superior with maximum yield of 622 kg/ha, net returns of Rs.5325/ha, RWUE of 19.0 kg/ha/mm and BC ratio of 1.55.
- At Hisar, RH-30 of mustard (1260 kg/ha); BH-393 of barley (3050 kg/ha); HC-1 of chickpea (1080 kg/ha) were superior.

- At Indore, JS-9560 was superior with maximum grain yield of 2224 kg/ha, net income of Rs. 35491/ha and BC ratio of 3.22. JG-412 of chickpea was superior with highest grain yield of 2218 kg/ha with net returns of Rs.3835/ha and BC ratio of 4.52.
- At Solapur, M 35-1 of sorghum gave higher monetary returns (Rs.18908/ha) under medium soils. Phule Vasudha gave higher monetary returns (Rs.23380/ha) under medium deep soils. M35-1 gave a yield of 1191 kg/ha, while Phule Vasudha gave yield of 1396 kg/ha. At Solapur, Vipula of pigeonpea was superior with grain yield of 711 kg/ha and BC ratio of 2.16.
- At Chianki, HPQM-1 of maize (3474 kg/ha); ICPH-2671 of pigeonpea (2004 kg/ha); Gajendra variety of OL (EFY) + recommended package of practices (56000 kg/ha) were superior. HUDP-15 of field pea gave grain yield of 1298 kg/ha, net income of Rs.11508/ha with BC ratio of 1.7. K-75 of lentil attained maximum yield of 1253 kg/ha with net income of Rs.10563/ha and BC ratio of 1.7. Under minimum tillage condition, KAK-2 of chickpea gave highest grain yield of 1393 kg/ha, net income of Rs.17913/ha with BC ratio of 2.1; and T-397 of linseed gave maximum yield of 545 kg/ha, net income of Rs.4385/ha and BC ratio of 1.7.

5.1.9.6 Integrated farming system

- At Anantapur, in a farming system model, 5 sheep were introduced in two sweet orange orchards. The increase in weight of sheep ranged from 42 to 65% and overall improvement in weight was 53% at 110 days after introduction of sheep in sweet orange orchards. The net returns were Rs.1446/month/farmer.
- In a 1.0 ha farming system model at Chikkamaranahalli, Nelamangala taluk of Bengaluru, pigeonpea + field bean was superior with maximum net returns of Rs.5518/ha and BC ratio of 4.72 in an area of 0.12 ha. The diary component effected a net returns of Rs.28750/ha and BC ratio of 2.10. There was a total net returns of Rs.50211/ha and BC ratio of 2.21.

5.1.10 Demonstrations

- Under farmers participatory approach in watershed basis at Anantapur, the improved practice gave a higher mean yield of 762 kg/ha, net returns of Rs.13674/ha and BC ratio of 2.43, compared to the farmers' practice with a yield of 699 kg/ha, net returns of Rs.10131/ha and BC ratio of 1.90.
- At Arjia, maximum net returns of Rs.17575/ha with BC ratio of 3.15 were attained with tank silt application for maize.
- At Ballowal Saunkhri, in a demonstration of maize, the improved practice gave net returns of Rs.17545/ha and BC ratio of 2.36 from a yield of 2688 kg/ha. In toria, the improved practice gave a yield of 564 kg/ha, net returns of Rs.2800/ha and BC ratio of 1.29. In raya, the improved practice gave net returns of Rs.5229/ha and BC ratio of 1.54 from yield of 618 kg/ha. In case of taramira, the improved practice gave yield of 516 kg/ha, net income of Rs.4882/ha and BC ratio of 1.65.
- At Hisar, net returns of Rs.8580/ha with BC ratio of 1.58 were attained from mustard with improved practice. In chickpea, net returns of Rs.9800/ha with BC ratio of 1.71 were attained under the improved practice. In barley, net returns of Rs.3960/ha with BC ratio of 1.30 were attained under improved practice.

5.1.11 Linkages and collaborations

AICRPDA Network centers worked in close collaboration with the respective State Agricultural Universities (research, teaching and extension), ICAR/National Institutes (DOR, DMR, NRC on sorghum, CPCRI for breeding programs, evaluation trials etc.) State and Central Govt. Departments, ATMA, KVKs, NGOs and other stakeholders in the areas of research, training, extension and education

and also providing the technical support on rainfed farming and watershed development etc. with national agencies. The centers also established linkages with Medicinal Plant Board, local institutions for training programs and Ministry of Water Resources, GOI for implementing adhoc projects.

5.1.12 Publications

Overall 484 publications were contributed by AICRPDA team comprising of 12 research papers, 191 papers in conferences, 231 books/bulletins/ reports and 50 popular articles during the year. The scientists gave 88 Radio talks and 52 Television talks and 128 lectures delivered during 2010-11.

5.1.13 HRD, impact and upscaling of rainfed technologies

There were also few human resource development activities by the Project Coordination Unit at CRIDA and network centers for capacity building for the scientists, stake holders and farming community. Various outreach programs like on-farm trials/ demonstrations, pre-seasonal trainings, Farmers' Days, Radio/TV talks etc., could impact the upscaling of rainfed technologies. Few scientists also were recognized/ appreciated for their valuable contribution.

5.1.14 Scientific events like workshops/seminars

XIII Working Group Meeting of AICRPDA was organized at CRIDA during 24th to 27th November, 2010. Scientists from 22 Main centers and 8 ORPs under AICRPDA, CRIDA and AICRPAM and PC Unit participated. The Technical Program of component II i.e. Technology demonstration / Action Research under the new program on National Initiative on Climate Change Resilient Agriculture (NICRA) was discussed and finalized. The Technical program of 2010-11 and 2011-12 was also discussed. The common research programs of AICRPDA with CRIDA and AICRPAM was also reviewed. Dr. D. M. Hegde, Director of DOR, Hyderabad was Chief Guest of the inaugural session and Dr. B. Venkateswarlu, Director, CRIDA presided over the plenary session.

XIII Working Group Meeting of AICRPDA

5.1.15 Technologies for adoption

5.1.15.1 Compartmental bunding for moisture conservation in Northern dry Zone of Karnataka

Recommendation Domain

Bijapur, Bagalkot, Gadag, Koppal, Bellary, part of Dharwad, Belgaum, Raichur and Davangere districts in medium to deep black soils of Northern dry zone of Karnataka.

Existing Practice

In northern dry zone of Karnataka, *kharif* cropping is not possible due to workability and tillage related constraints in medium to deep black soils. Further, infiltration rate is low resulting in more runoff. Farmers generally do not practice any *in situ* moisture conservation practices during *kharif* resulting in soil erosion and low yield of *rabi* crops.

Improved Technology

It involves making square compartments on the field to retain rainwater and arrest soil erosion. After receipt of early rains in June and July, land is harrowed to remove germinating weeds. Then compartment bunds (0.15 m height) are formed using bullock drawn bund former. The size of the bunds varies from 3 m x 3 m to 4.5 m x 4.5 m depending on the slope. The cost of compartmental bunding is Rs.150/ha. These bunds are retained

till the sowing of *rabi* crops, which are sown with seed cum ferti drill during second fortnight of September to first fortnight of October. Compartment bunds provide more opportunity time for water to infiltrate into the soil and help in conserving soil moisture.

Bund former

Compartment bunding in medium deep black soils

Performance

Rabi sorghum, sunflower, safflower and chickpea gave seed yields of 870 kg/ha, 675 kg/ha, 620 kg/ha and 450 kg/ha, respectively with an yield advantage of 40, 35, 38 and 50% respectively with additional net returns of Rs. 2475, Rs.3700, Rs. 3250 and Rs.2850 with compartment bunding over flat planting .The impact of the practice is more during sub-optimal rainfall years. It also significantly controls run off.

Impact and up scaling

This practice is adopted on 800 ha in Bijapur, Bagalkot and Raichur districts of northern Karnataka. Further upscaling in the region can be done through demonstrations by line departments, KVKs, ATMA, and NGOs etc. There is large scope to implement this through NREGS where land development works can be undertaken on private lands also. Each year this activity can be included in the shelf of works of the Gram Panchayath.

5.2 All India Coordinated Research Project on Agrometeorology

The agrometeorologial research carried out at 25 centers of All India Coordinated Research Project on Agrometeorology (AICRPAM) is mainly focused on agro-climatic characterization, crop weather relationships, crop growth modeling and weather influence on pests and diseases. The salient achievements of the project are:

5.2.1 Agro-climatic characterization

- Long-term (140 Years) rainfall analysis of Vidharba region showed decrease of both annual and southwest monsoon's rainfall below their long-term averages, since the year 1960 and beyond. Further, declining trends of high rainfall events of 75-100 mm and more than 100 mm during the last four decades were observed.
- At Anand, year-wise categorization of meteorological droughts in past 30 years (1980-2009) showed occurrence of mild, moderate and severe droughts, respectively, in 20, 23 and 7 percent of years.
- From the long-term (1976-2000) analysis of monthly maximum and minimum temperatures at Bangalore, significant increasing trends in minimum temperature of monsoon months (June to September) and decreasing trend in maximum temperature of pre-monsoon (April-May) and post-monsoon (October) months were observed.

- Bijapur centre analyzed taluk-wise rainfall of six districts of north Karnataka and worked out start, end and duration of rainy season in each district. Mean duration was found to be longer in Haveri (22 weeks) district situated in transition zone and it was shorter by two weeks in Bijapur, Bagalkot and Koppal districts situated in dry zone of Karnataka. Standard deviations of start, end and durations were higher in districts of dry zone compared to districts of transition zone.
- Analysis of 38 years weather data of Dapoli and Venegurla brought out that the occurrence of drought is more frequent (47%) at Dapoli than at Venegurle (35%). It was further observed that number of days with maximum temperature more than 35°C is increasing significantly with a rate of increase of 4 days per decade at Dapoli.
- Analysis of last 25 years zone-wise rainfall data of eastern Uttar Pradesh at Faizabad centre, showed the frequency of occurrence of terminal droughts to be highest (80%) in Vindhyan region compared to the frequency in eastern plain zone (72%) and north eastern plain zone (70%).
- At Ludhiana, analyzing average rice yield over last 10 years in relation to monthly and seasonal climatic conditions of Amritsar, Ludhiana and Patiala, seasonal maximum temperature of 34.8°C, minimum temperature of 25°C and rainfall of 589 mm were identified to be optimum weather conditions for obtaining higher rice yield.

5.2.2 Crop-weather relationships

- At Jabalpur, higher day temperatures during reproductive period were found to be detrimental for productivity of chickpea (decline of 199 kg/ha per 1°C) than high night temperature (decline of 172 kg/ha per 1°C).
- Yield of chickpea at Solapur showed significant positive relationship with cumulative moisture use and heliothermal units during the crop growing period.
- At Ludhiana, interception of PAR in wheat canopy was observed to be highest at booting stage (84 to 85%) in early sowing and at flag leaf initiation stage in normal and late sown conditions.
- Higher average temperature during total growing period and lower soil moisture during boot to milking stage of wheat were found to be responsible for lower yield and yield attributes in late sown crop at Ranchi.
- Pooled analysis of wheat yield in relation to temperature at Udaipur, identified average temperature of 17.5 to 19°C during reproductive period to be optimum for achieving higher yield.
- Seed yield (Y) of mustard at Udaipur showed the following significant negative relationship with temperature (X) during 90 to 105 days of the crop.

$$Y = 2817 - 391.8\ X \quad (R^2 = 0.91)$$

- At Dapoli, high rainfall and minimum temperature advanced the occurrence of vegetative and reproductive flushes of mango and the following equation for predicting week of vegetative flush (Y) based on minimum temperature (Tmin), morning relative humidity (RH1) and rainfall explained 99 percent of variation in occurrence.

$$Y = -135.3 - 1.69*Tmin + 2.21*RHI - 0.03*\ Rain \quad (R^2 = 0.99)$$

- Lower rainfall and low minimum temperature during growing period were found to be limiting factors for maize yield at Kovilpatti.
- The influence of meteorological parameters at different growth stages, viz., panicle initiation, flowering and maturity in Sali rice at Jorhat revealed that accumulated mean temperature during maturity stage, maximum temperature and relative humidity during flowering stage

and rainfall during maturity and panicle initiation were found to be positively related with crop yields.

- At Samastipur, the rice yields of three varieties, viz., Rajendra Suhasini, Rajendra Bhagawati and Rajendra Kasturi grown under four dates of sowing were related with the weather at different growth stages. It was found that rainfall from transplanting to dough stage and temperature during reproductive period was found to influence the yields significantly.
- At Parbhani, the pooled yield data of soybean for the years 2003 to 2009 with weather parameters at different phenological stages revealed that rainfall and rainy days during pod and seed development stages had significant positive relationships with yield. Higher maximum and minimum temperature during pod development to seed development showed highly significant negative relationship with the yield.

5.2.3 Crop growth modeling

- Validation of crop simulation model DSSAT 4.0 for chickpea at Faizabad showed that simulated yields were closer to observed yield at all three sowing dates.
- To validate DSSAT model for chickpea, simulated and measured values of number of days taken for anthesis and maturity under 12 dates of sowing over four years were compared. They were predicted accurately in November 2002 sowing only.
- At Hisar, lesser allocation of dry matter towards stem in dwarf variety, facilitates in increasing the dry matter allocation to spike significantly (54%) compared to the allocation in tall variety (44.1%). At this centre, WOFOST model simulated phenology, yield and other crop parameters (except LAI) accurately and the model over-estimated leaf area index (LAI) by 11.7 percent.
- Comparison of actual and predicted grain yield of wheat (using regression models) at Udaipur showed that prediction of grain yield was more accurate using average temperature during milking to dough stage, in crop sown on normal dates.

5.2.4 Weather effects on pests and diseases

- Lower mean relative humidity (MRH) and higher mean temperature were found to be congenial for aphids and sawfly infestation in mustard at Anand.
- Incidence of aphids and powdery mildew were found to be negatively correlated with minimum and mean temperature and positively correlated with relative humidity and maximum temperature at Udaipur.
- At Faizabad, higher maximum temperature and low relative humidity were identified as the factors for high incidence of pod borer in chickpea.
- Low morning relative humidity and higher sunshine hours were found to be responsible for flare up of *Helicoverpa armigera* egg population in chickpea at Jabalpur.
- At Jabalpur, correlation of mango hopper population with weather factors, revealed that maximum and minimum temperature exhibited significant positive effect (r = 0.86 and 0.87) and morning and evening relative humidity exhibited significant negative effect (r = -0.88 and -0.64).
- At Hisar, rainfall and minimum temperature during 6th SMW positively influenced Karnal bunt infection in wheat.
- At Kovilpatti, maximum and minimum temperature showed significant positive and negative relationship with PDI of bacterial blight and unit increase in maximum temperature increased PDI by 6.1 percent and in minimum temperature decreased PDI by 3.9 percent.

- At Ludhiana, congenial weather parameters identified for the following pests on cotton

Aphids

- Fall in maximum temperature from 34.8 to 31.3°C
- Fall in minimum temperature from 26.9 to 26.1°C
- Decrease in sunshine hours from 7.7 to 6.9 hrs
- Increase in morning RH from 87 to 93 percent and evening RH from 70 to 83 percent

Thrips

- Maximum and minimum temperature above 38 and 25°C, respectively
- Morning and afternoon RH below 70 and 55 percent, respectively
- More than 9 hours of sunshine

5.2.5 Training programs/sorkshops/seminars

5.2.5.1 Training program on analysis of crop - weather relationships

A training program on analysis of crop -weather relationships was organized by AICRPAM Unit to impart the knowledge / techniques regarding crop – weather relationships to the scientists of the AICRPAM centres during 23 – 26 June, 2010.

5.2.5.2 AICRPAM XI biennial workshop

To review the progress made in the AICRPAM Project during 2009 and to finalize the Technical Program of the Cooperating Centres for the years 2010-12, the XI Biennial Workshop of AICRP on Agrometeorology was organized at CRIDA, during 27-29 August 2010. The Workshop was inaugurated by the Chief Guest, Dr. A.K. Singh, DDG (NRM), ICAR, New Delhi and session was presided over by Dr. B. Venkateswarlu, Director, CRIDA. About 42 scientists from 25 AICRPAM network centres attended this workshop. About 11 publications including "25 years research of AICRP on Agrometeorology" from Coordinating Centre were released by Dr. A. K. Singh. 'Best performing Centre' awards were given to Bijapur, Hisar and Palampur. Similarly, the 'Best Information Dissemination Award' was given to Akola, Bangalore, Dapoli, Raipur and Solapur centres for updating the www.cropweatheroutlook.ernet.in website regularly and providing vital information on Crop Contingency Plans and Agromet Advisories during the years 2008-09 and 2009-10.

5.2.5.3. SERC School on Agricultural drought: climate change and rainfed agriculture

AICRPAM Unit of CRIDA conducted fifth series of SERC School on "Agricultural Drought: Climate Change and Rainfed Agriculture" during January 20 – February 9, 2011 at CRIDA under Directorship of Dr. V.U.M. Rao, Project Coordinator (Agrometeorology). Dr. A.K. Singh, DDG (NRM), ICAR has inaugurated the SERC School and delivered a lecture on "Climate Change Strategies: ICAR Initiatives". About 30 participants from different parts of country participated in the SERC School.

5.2.5.4. Action plan workshop on Strengthening of agromet advisory services and weather indices

The action plan workshop on strengthening of agromet advisory services and weather indices under NICRA Project was organized for the Agrometeorologists of AICRPAM centres during 18 - 19th February 2011 at CRIDA. During these two days deliberations lead to identification of areas for strengthening agromet advisory services in the country.

5.3. Network Project on Climate Change

To meet the challenges posed by climate change on agriculture, ICAR initiated a network project on climate change (NPCC) in the X plan. The budget during X Plan was Rs. 9.11 crore with 15 network centres. In the XI Plan, the number of centres was increased to 23 and the budget was enhanced to Rs.15.15 crore. The project has three main objectives: (i) To identify the regions experiencing

significant climate change and variability, (ii) To develop methodologies for assessing the impacts of climate change on agricultural productivity in various agro-ecological regions, and (iii) To suggest suitable interventions for reducing the impacts of climate change on agricultural productivity. Significant achievements and findings of the network project for the year 2010-11 are given below.

- The impacts of climate change on major crops, horticulture, plantations, dairy, fish, and natural resources were quantified.
- Adaptation options that minimize the adverse effects and maximize beneficial effects were identified.
- The inventory of GHG emissions from Indian agriculture was updated and options for reduced GHG emissions were identified. Carbon sequestration potential of plantations and agroforestry was quantified
- Inputs were provided to NATCOM for communication to UNFCCC
- In the predicted climate scenario of 2030, irrigated wheat production may decrease by 6%. Adaptation strategies can not only offset the production losses but can increase the yields
- In the A1b 2030 scenario, potato productivity in Punjab, Haryana and Western and Central UP could increase by 3.46 to 7.11%, but in rest of India particularly West Bengal and plateau region potato production may decline by 4 to 16%.
- An increase of 0.5 °C in average temperature in 2006 in Delhi caused a slight decrease in brown plant-hopper population while 1-3 °C rise resulted in significant decline.
- Temperatures of 30 °C inhibited the growth of ancestral range of *Pseudomonas fluorescence*, whereas evolved lines could tolerate the higher temperatures of 40 °C.
- Changes in the quality of the castor and groundnut foliage under elevated CO_2 conditions caused leaf eating caterpillar sp (*A. janata* on castor and *S. litura* on groundnut) to cause increased consumption over generations.
- Extension of northern boundary of oil sardine due to rise in sea surface temperature.
- Change in spawning season of threadfin breams (*Nemipterus japonicus* and *N. mesoprion)* off Chennai: Possible responses of marine fishes to climate change. Extension of distributional boundary of small pelagics; Extension of depth of occurrence – Indian mackerel; and Phenological changes.
- Rise in sea surface temperature (2-2.5°C) in May 1998 led to bleaching in 85% coral reefs.
- Animal distress due to heat effects on reproduction could result in loss of 1.5 million tons of milk by 2020 in business as usual scenario
- Body temperature of lactating buffaloes and cows producing milk is 1.5 - 2 °C higher than their normal temperature, therefore more efficient cooling devices are required to reduce thermal load of lactating animals as current measures are becoming ineffective.
- In poultry, increase in temperature from 31.6 °C to 37.9 °C reduced feed consumption by about 36% and egg production up to 7.5% in broiler breeders and up to 6.4% in commercial layers.
- The critical body temperature at which the birds succumb to death was 45 °C which was observed at the shed temperature of 42 °C.
- Feed additives like fenugreek and mustard were able to decrease the methane emissions from livestock.
- The annual C sequestration in coconut above-ground biomass varied from 15 Mg CO_2/ha/year to 35 Mg CO_2/ha/year out of which 2-3 Mg CO_2/ha/year is stocked into stem (about 2.7 million t/year in 4 major coconut growing states). The carbon sequestration potential of arecanut plantations ranged from 5.14-10.94 Mg CO_2/ha/year while that of cocoa plantation ranged from 2.02-3.89 Mg CO_2/ha/year. Carbon sequestration potential of agroforestry in Bundelkhand region was quantified.

6 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 programmes 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. The following activities were accomplished during the year 2010-11.

6.1 Frontline demonstrations

During kharif 2010 Frontline demonstration (FLD) of maize (100), cotton (25), pigeonpea (25), inter cropping (5), paddy (10), brinjal (5), fodder crops (25) were conducted on farmers fields of

Table 39 : Results of Frontline Demonstrations conducted by the KVK during 2010-11

Crop	Component (Intervention)	No. of farmers	Area (ha)	Yield (kg/ha)		% increase over control
				IP	FP	
Kharif						
Pigeonpea	Varietal (PRG-158)	25	10	1082	805	34
Maize- Pigeonpea	Inter cropping 2:1	5	2	794	650	22
Maize	Production technologies	100	40	4440	3680	21
Paddy	IPM	10	2	3875	3250	19
Cotton	Sucking pests management	25	10	1450	800	81
Brinjal	IPM	10	9	26250	35000	33
Fodder crops	APBN1	27	5.4	128000	25000	412
Rabi						
Sunflower	Spacing & thinning	10	4	1022	620	65
Chickpea	Variety JG-11	10	4	1739	1336	30
	IPM	10	4	1760	1348	30
	CRIDA 6 row planter	10	4	1755	1360	29
Maize	Production technologies	100	40	7850	6040	30

IP – Improved Practice; FP – Farmers Practice

FLD in maize

FLD in chickpea

Ranga Reddy District, Andhra Pradesh. These FLDs were supported by Zonal Project Directorate (ZPD) - Zone V, Hyderabad and Directorate of Maize Research (DMR), New Delhi. During rabi 2010-11, KVK conducted FLDs of Maize (110) and chickpea (30) in different villages of Ranga Reddy district and Nizamabad district of Andhra Pradesh. The details of FLDs are given below:

6.2 Backyard poultry for livelihood enhancement

Under FLD programmes, livelihood based income generation from backyard poultry was introduced in Thimmareddyguda village. About 56 farmers and farm women were given 6 weeks old Rajasri variety breeds of poultry. Their body weight and egg laying capacity are being monitored regularly.

Backyard poultry

6.3 Training programmes

The Krishi Vigyan Kendra has organized 58 need based and skill oriented training programmes on various aspects of improved technologies to 1786 clientele (farmers, farm women, rural youth and field level extension workers). Of the total programmes 10 were sponsored by outside agencies/ schemes the details are shown below.

Table 40 : Training programs by KVK during the year 2010-11

Discipline	No. of programmes			No. of Participants		
	On campus	Off campus	Total	Male	Female	Total
Agronomy	-	9	9	188	22	210
Plant Protection	3	6	9	143	33	176
Home Science	3	9	12	-	431	431
Veterinary Science	-	8	8	195	15	210
Agricultural Extension	1	9	10	279	35	314
Agricultural Engineering (Sponsored)	1	-	1	33	7	40
Watershed (sponsored)	9	-	9	355	50	405
Total	17	41	58	1193	593	1786

6.4 Extension activities

The KVK organized several extension activities for the benefit of farmers.

Table 41 : Extension activities by KVK during the year 2010-11

Activity	Date
Parthenium awareness week	07 June, 2010
Raitu sadassulu at Maheswaram, Parigi, Peddamul villages of Ranga Reddy Dt.	08-10 June, 2010
Technology week at KVK, HRF, CRIDA	20 – 25 August, 2010
Field day on maize at Mandanpalli, Nawbpet Mandal, R.R.Dist	12 October, 2010
Animal health camp at Mandanpalli, Nawabpet Mandal, R.R.Dist.	3 November, 2010
Backyard poultry – Thimmareddyguda, Shabad Mandal (R.R.Dist.)	11 November, 2010
Women in Agriculture Day	04 December, 2010
Field day on maize at Bazar Kotur, Nandipet Mandal, Nizamabad Dist.	18 January, 2011
Animal health camp at Thimmareddyguda, Shabad Mandal, R.R.Dist	23 February, 2011
Exhibition at DOR, Rajendranagar NIRD, Rajendranagar RTP, Rajendranagar	05 September, 2010 12-13 November, 2010 2-4 February, 2011

Animal health camp

6.5 On-farm evaluation trials

Maize hybrid- DHM 117

Maize hybrid DHM-117 was tested in five farmers' fields in KVK adopted villages of Thimmareddyguda and Jalaguda villages. The average yield obtained was 3050 kg/ha compared to 2735 kg/ha of local practice even under excess rainfall (flooded) conditions during the kharif 2010-11. The farmers benefited with net returns of Rs.13717/ha and benefit cost ratio of 2.04.

Castor Hybrid- PCH-111

High yielding castor hybrid (PCH-111) developed by ANGRAU was tested in four farmers' fields of Thimmareddyguda Village. The average yield obtained by the farmers was 1226 kg/ha compared to 880 kg/ha in local practice (GCH-4). The net profit was Rs.29,358/ha with benefit cost ratio of 3.64

New Rice variety- RNR-2458

The new rice variety RNR 2458 developed by ANGRAU was tested in five farmers' fields of KVK adopted villages of Thimmareddyguda and Jalaguda. This activity was taken up under the minikit trial. The yields recorded higher in RNR 2458 (5336 kg/ha) as against the local check i.e. BPT -5204 (5160 kg/ha). The results revealed that 85.6 per cent of filled grain per panicle in the new variety and the 1000 grain weight was 19.60 g.

Soil Test Based Fertilizer application (STBF) on Rice

The refined treatment with STBF gave crop yield of 4548 kg/ha compared to 4206 kg/ha in farmers practice with 8.05 per cent increase in yield. An additional input of Rs.480/ha gave additional returns of Rs.3420/ha with additional benefit cost ratio of 7.12:1 over farmers practice.

Herbicide assessment in carrot

Metribuzin applied at 300 g/ac as post emergence herbicide in carrot at 15-20 DAS followed by one manual weeding gave an additional yield of 2900 kg/ha with 18.43 per cent increase over control where manual weeding (thrice) was taken up.

Wilt management in Castor

Based on the refined practice (Pre soaking seed in carbendazim + seed treatment with Trichoderma) conducted in five farmers field of Kandukur Mandal, highest yield (650 kg/ha) was recorded against the farmers practice (450 kg/ha) with 44.44% increase in yield and also no incidence of wilt in demo plots.

Supplementation on growth of sheep – lean period

Semi intensive grazing i.e. supplementation of concentrate feed and mineral mixture to sheep carried out with five farmers showed average body weight of 19.30 kg with 25.73 % increase over the farmers practice of extensive system of grazing (15.35 kg)

Vit- E and mineral mixture supplementation in anoestrous condition in cattle

Concentrate feed supplementation of Vit - E and mineral mixture in cattle carried out with five farmers resulted in timely heat and proper conception in cattle compared to the farmer's practice of natural grazing where lack of balanced nutrition showed silent heat and poor conception.

7 Human Resource Development

7.1 Deputation within India

Name	Title	Duration	Venue
U. K. Mandal	Geostatistical Analysis of Environmental Data	5-9 April, 2010	ICRISAT, Patancheru
Minakshi Grover	Blue Green Algae in Agriculture and Industry	12-18 May, 2010	CCUBGA, IARI, New Delhi
P. K. Mishra	Climate Change and its Impact on Water Resources	16-22 May, 2010	NIH & IIT, Roorkee
B. M. K. Raju	SAS Installation	16-17 June, 2010	NAARM, Hyderabad
B. M. K. Raju	SAS	28 June to 02 August, 2010	NAARM, Hyderabad
G. R. Rao	Science Administration and Research Management1	6-17 September, 2010	ASCI, Hyderabad
P. Vijaya Kumar	Cropping System Models – Applications in Land Resource Management	18-22 October, 2010	ICRISAT, Patancheru
P. K. Mishra	Management Development Program in Agricultural Research	02-07 December, 2010	NAARM, Hyderabad
G. R. Rao M. Prabhakar	Data Analysis Using SAS	21-26 March, 2011	NAARM, Hyderabad

7.2 Deputation outside India

Name	Title	Duration	Venue
N. Jyothi Laxmi	Marker assisted selection, mapping QTL's in sorghum for transpiration efficiency	24 March to 18 June, 2010	USDA, Lubbuck, Texas
G. Ravindra Chary	Agriculture in Transition: analyis, design and management of sustainable farming.	20-29 May, 2010	Wagenengin University and Research Centre for Development of Innovation, Wagenengin
Minakshi Grover	Nanoencapsulated Iturin A and its efficacy as antifungal compound	01 September - 30 November, 2010	Alabama State University, USA
P. K. Mishra	Flow regulation and energy loss characteristics of Baffle-sluice irrigation modules	14 September to 29 October 2010	Karlsruhe Institute of Technology (KIT), Germany

7.3 Academic qualification obtained

Ravikat Adake, Scientist Senior Scale was awarded Ph.D in Mechanical Engineering by Jawaharlal Nehru Technological University, Hyderabad, on 14th March, 2011, for the thesis entitled 'Theoretical and Experimental Analysis of Mechanical Incorporation of Biomass for Soil fertility Improvement".

7.4 Under graduate and post graduate research and training provided

Scientist	Student	Degree	Discipline	Institute/University
B.Venkateswarlu	Venkatesh G	Ph.D	Environmental Sciences	JNTU, Hyderabad
K. S. Reddy	R Nagarjuna Kumar	Ph.D	Computer Science	BITS, Ranchi
U. K. Mandal	K. Venkanna	Ph.D	Environmental Science	Andhra University, Visakhapatnam
S. Desai	Praveen Kumar Mir Hassan Ahmed Sk. Shaik Naseeruddin	Ph.D Ph.D Ph.D	Microbiology Microbiology Microbiology	Osmania University, Hyderabad Osmania University, Hyderabad Osmania University, Hyderabad
M. Vanaja	Babu Abraham G. Vijay Kumar Y. Anitha	Ph.D Ph.D Ph.D	Botany Genetics Genetics	Osmania University, Hyderabad Osmania University, Hyderabad Osmania University, Hyderabad
K.A. Gopinath	K. S. Sudhakar	Ph.D	Agronomy	ANGRAU, Hyderabad
M Srinivasa Rao	Sunitha Devi D. Manimanjari K. Teju Singh Chavan	Ph.D Ph.D M.Sc. (Ag)	Agricultural Entomology Zoology Agricultural Entomology	ANGRAU, Hyderabad Osmania University, Hyderabad ANGRAU, Hyderabad
V.U.M. Rao	R. Sudhakar	M.Sc	Satellite Meteorology & Weather Informatics)	JNTU, Hyderabad
P. Vijaya Kumar	K. Venkanna	M.Sc	Satellite Meteorology & Weather Informatics)	JNTU, Hyderabad
A.V.M. Subba Rao	G. Kishore Kumar	M.Sc	Satellite Meteorology & Weather Informatics)	JNTU, Hyderabad
S. Desai	Bharat Gayatri K.	M.Sc M.Sc	Biotechnology Biotechnology	Telangana University, Dichpally Telangana University, Dichpally
Minakshi Grover	R. Raja Srinath Prashanth Nayak Ramavath	M.Sc M.Sc	Microbiology Microbiology	Palamuru University, Mahabubnagar JNTU, Hyderabad
K.Nagasree	K.Surender Rao	M.CJ	Communication and Journalism	Telugu University, Hyderabad
Kaushalya Ramachandran	N. Thilagavathi	M.Tech	Remote Sensing and GIS	Bharathiar University, Coimbatore
K. Sreedevi Shankar	Ch. Anjani	M. Tech	Biotechnology	JNTU, Hyderabad
S.K.Yadav	D. Nanda Kumar	M. Tech	Biotechnology	Vignan University. Guntur
K. S. Reddy	Vijayalaxmi	M. Tech	Soil and water engineering	UAS, Raichur
I. Srinivas	B. Jail Singh B. Palender C. Bharadwaj G. Jeevan M. Karam Sagar A. Nagabharadwaj Rupam Dewan K. Tanuj Kumar	B.Tech B.Tech B.Tech B.Tech B.Tech B.Tech B.Tech B.Tech	Mechanical Engineering Mechanical Engineering Mechanical Engineering Mechanical Engineering Mechanical Engineering Mechanical Engineering Mechanical Engineering Mechanical Engineering	MIST, Hyderabad MIST, Hyderabad MIST, Hyderabad MIST, Hyderabad MIST, Hyderabad MIST, Hyderabad MIST, Hyderabad MIST, Hyderabad

8 Women in Agriculture

KVK under CRIDA carried out many training programmes and exposure visits for farm women for skill development and extra income generation. Seventeen programmes were conducted, in which 720 farm women were trained in various aspects.

8.1 Training programmes for farm women

Title of the course	Duration (days)	Venue On/Off campus	Number of parti-cipants
Value addition to Mango	5	On	20
Personality development and communication skills	2	On	30
Bakery	2	On	30
Nutrition garden	1	Off	50
Adda leaf making	1	On	20
Prevention of anaemia	2	Off	60
Detergents preparation	1	Off	60
Advanced garment making	3	Off	40
Dyeing and printing	2	Off	40

8.2 Training programmes for rural adolescent girls

Title of the course	Duration (days)	Venue On/Off campus	Number of parti-cipants
Tailoring	90	Off	30
Maggam works (REDP sponsored by NABARD)	90	Off	30
Maggam works (REDP sponsored by NABARD)	90	Off	30
Detergents preparation	7	Off	50
Leaf plate making	7	Off	30

Training on value addition

Training on Maggam works

Training on prevention of anaemia

8.3 Collaboration with line departments

Title of course	Duration (Days)	Collaboration	Number of participants
Anaemia- iron rich recipes	1	Food and Nutrition Board	60
Vitamin A deficiency	1	Food and Nutrition Board	60
Income generating activities (washing powder, pain balm, vaseline, phenyl)	1	DAAT centre	60
Watershed approach for sustainable development.	7	GOI	50

8.4 Exposure visits

Women farmers were taken on exposure visits to

- AICRP Poultry, Sri Venkateshwara Veterinary University
- Fodder Research Station, Mamidipally
- Leaf plate making machine unit
- Annapurna cottage industries, Hyderabad
- Vermicompost unit by progressive farmer, Pasumamula
- Centre for Medicinal and Aromatic Plants (CIMAP), Regional centre.

8.5 Events for farm women

Women in Agriculture Day

Women in Agriculture Day was organized on 4th December, 2010. About 200 farm women attended the event. They were enlightened on different aspects of nutrition, minor millets utilization in the diet, and income generating activities.

Technology week

In the Technology Week organized during 20-25 August, 2010, one day, i.e., 23rd August, was exclusively devoted to women. About 150 women attended the event.

International Women's Day

Centenary celebration of International Women's Day was organized in CRIDA on 8th March, 2011. The function was chaired by the Director Dr. B. Venkateswarlu. The Women's Cell in CRIDA arranged a staff get-together with a poster show highlighting the role of women in the past and at present. A few extempore talks were delivered by the scientific staff and young research scholars on various aspects of women's life, her multiple roles and aspirations in present times. It was interesting to hear the young women for whom the concerns of yesteryears have been replaced by present day issues concerning job, economic independence, equality and the need to be heard in matters of education, matrimony and life goals. The celebration concluded with high tea.

Women in Agriculture Day

Women day during Technology Week

International Women's Day

9 Awards and Recognition

- The All India Coordinated Research Project for Dryland Agriculture (AICRPDA), Hyderabad received the Chaudhary Devi Lal Outstanding All India Coordinated Research Project (AICRP) Award 2009 for the research work on location specific technologies focusing on rainwater management, cropping systems, contingency plans, integrated nutrients management, farm mechanization and alternate land use systems carried out by the centres of AICRP on Dryland Agriculture. The award carries a cash prize of Rs.1.00 lakh, a citation and a plaque.

Dr. P. K. Mishra, Project Coordinator (AICRPDA), receiving the Chaudhary Devi Lal Outstanding AICRP Award

- Dr.B.Venkateswarlu (Director), Dr. M. Osman (Principal Scientist), Dr. P.K. Mishra (Project Coordinator), Dr. D.H. Ranade (Senior Scientist, RSKVV), Dr. K.V. Rao (Senior Scientist), Dr. S. Dixit (Principal Scientist) and Dr. Ch. Srinivasa Rao (Principal Scientist) of Central Research Institute for Dryland Agriculture received the prestigious Vasantrao Naik Award 2009 for Research Applications in Dryland Agriculture. This award was given by ICAR in recognition of the research carried out by the scientists in the area of water harvesting and recycling. The award carries a cash prize of Rs.1.00 lakh and a citation.

Dr.B.Venkateswarlu, Director, CRIDA, receiving the Vasantrao Naik Award

- Dr. M. Osman (Principal Scientist), Dr. G.Ravindra Chary (Principal Scientist), Dr. S.K. Sharma (Senior Scientist, MPUA&T), Dr. P.K. Mishra (Project Coordinator), Dr. B. Venkateswarlu (Director), Dr. D.B. Bhanavase (Principal Scientist, MPKV), Dr. Shaik Haffis (Technical Officer), Shri R. Murali (MARI, Warangal), Shri B.V. Joshi (AME, Bengaluru), Shri K. Khasimpeera (MEOS, Anantapur) and Shri K. Nimmaiah (PEACE, Nalgonda) received the prestigious Groundwater Augmentation Award 2009 in the category of Institutions implementing the Farmers' Participatory Action Research Programme (FPARP), instituted by Ministry of Water Resources, Government of

India. The award was for modernizing the indigenous technical knowledge of tank silt application using science based tools across four States and six districts of the country.

Dr.B.Venkateswarlu, Director, CRIDA receiving the Groundwater Augmentation Award

- Dr.B.Venkateswarlu, Director, CRIDA was conferred the fellowship of National Academy of Agricultural Sciences by the President of NAAS, Dr. Mangala Rai during Annual General Meeting held on June 5, 2010 at New Delhi.

Dr. B. Venkateswarlu, Director, being conferred NAAS Fellowship

- Dr. Gopinath, K.A., Senior Scientist (Agronomy) was awarded 'ISA P.S. Deshmukh Young Agronomist Award' by Indian Society of Agronomy during National Symposium of the Society at Bangalore, Karnataka on 02 December, 2010.

Dr. K. A. Gopinath receiving the P.S. Deshmukh Young Agronomist Award

- Dr. Ch. Srinivasa Rao, Principal Scientist (Soil Science) received the FAI award for his significant work on watershed based nutrient management strategies in December, 2010.

Dr. Ch. Srinivasa Rao, receiving the FAI Award

- Dr. I. Srinivas, Senior Scientist received the Jawaharlal Nehru Award for Outstanding Post-Graduate Agricultural Research 2009 from Indian Council of Agricultural Research for his work on 'Energy saving in modified oil expeller – Influence of pretreatment on biodiesel production and usage'.

- Dr. J. Kusuma Grace, Research Associate, received the Jawaharlal Nehru Award for Outstanding Post-Graduate Agricultural Research 2009 from Indian Council of Agricultural Research, for her work on 'Assessment of soil quality under different land use treatments in rainfed Alfisols'. Done under the Supervision of Dr K. L. Sharma, Principal Scientist and ICAR National Fellow.

- Dr. S. Desai was nominated as Member, Scientific Panel on Biological Hazards, Food Safety and Standards Authority, Govt. of India

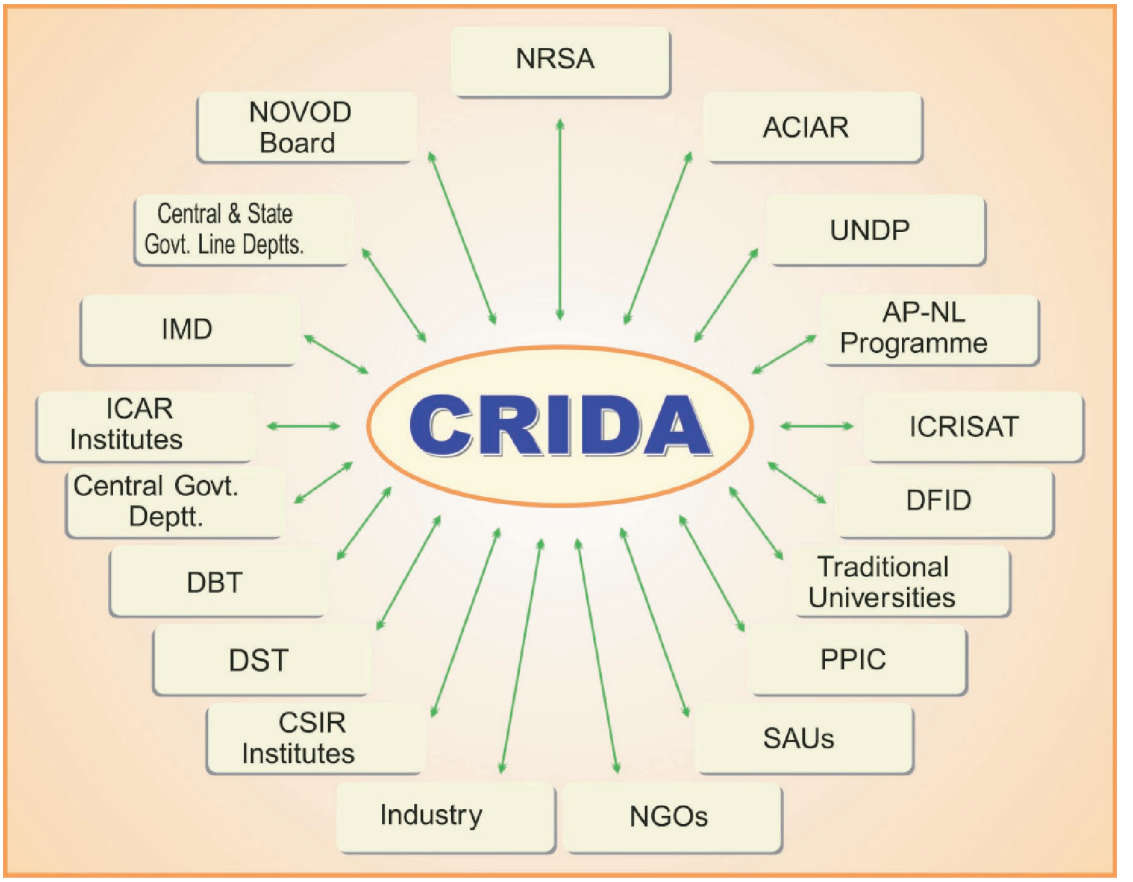
- NAIP SRL3 project ICT initiative " Knowledge share centres " has been awarded as citizen choice # 2 for the best ICT enabled agriculture initiative of the year during India 's largest ICT event **eIndia 2010** conducted at HICC, Hitex, Hyderabad during August 4 to 6, 2010. The details can be seen at http://www.eindia.net.in/2010/awards/award-winners.asp.

- The paper 'B.M.K. Raju, V.K. Bhatia and L.M. Bhar 2009. Assessing Stability of Crop Varieties with Incomplete Data. Journal of the Indian Society of Agricultural Statistics. 63:139-150' received the best paper award in the field of 'Statistical Genetics' at the 64th annual conference of Indian Society of Agricultural Statistics held at Kalyani, West Bengal from Dec 3-5, 2010.

- The poster, 'Yield and HI response of sunflower hybrid (KBSH-1) to elevated CO_2 under two temperature regimes' by M. Vanaja, P. Raghu Ram Reddy, N. Jyothi Lakshmi, S.K. Yadav, A. Narshimha Reddy, M. Maheswari and B. Venkateswarlu was adjudged as Best Poster in the International Conference on Climate Change Perspectives and Projections: A Systems Approach organized by Osmania University at Hyderabad from December 9-11, 2010.

10 Linkages and Collaborations

CRIDA constantly endeavours to forge new linkages and collaborations 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, ILRI, IWMI, ANGRAU and other SAUs, JNTU, University of Delhi, Osmania University and other 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 to develop suitable policies for implementing programmes 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, NOVOD Board, PPIC, Govt. of Andhra Pradesh and the like. CRIDA also undertakes consultancy programmes for specific tasks from Government of Andhra Pradesh, Madhya Pradesh, WWF, etc. CRIDA takes inputs from IMD and NCMRWF and generates value added outputs for the benefit of rainfed farmers.



11 Publications

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12 Ongoing Projects

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
DIVISION OF RESOURCE MANAGEMENT				
1. RM/LU/12	Low till farming strategies and integrated plant nutrient supply for rainfed semi-arid tropics	**K.L. Sharma** K. Srinivas G.R. Korwar B. Venkateswarlu G.R. Maruthi Sankar V. Maruthi K.V. Rao U.K. Mandal	1998	2012
2. RM/RM/04	Soil and crop management strategies for resource conservation, weed control and carbon sequestration in pigeonpea-castor system	**G. Pratibha** G.R. Korwar K.V. Rao K. Srinivas I. Srinivas M. Srinivasa Rao K.L. Sharma Arun Kumar Shanker	2008	2013
3. RM/RM09	Carbon sequestration through conservation agriculture	**G. Pratibha** G.R. Korwar I. Srinivas K.V. Rao K. Srinivas	2009	2013
4. RM/NM/06	Response of rainfed crops to Boron	**K. Srinivas** K.L. Sharma	2009	2010
5. EF033 (NABARD)	Prospects of Land Use Diversification Opportunities in distressed districts of Telangana Region	**M. Osman** G. Ravindra Chary Shaik Haffis	2009	2010
6. EF006 (NOVOD BOARD)	National Network project on integrated development of Jatropha and Pongamia	**G. Rajeshwar Rao** G.R. Korwar M. Prabhakar	2004	2011
7. EF007 (CSIR)	Genetic improvement of Jatropha for oil yield and adaptability	**G. Rajeshwar Rao** G. Ravindra Chary Y.G. Prasad D.P. Dubey M.P. Jain P.R. Reddy	2005	2012

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
8. EF009 (DST)	Carbon sequestration potential of reduced tillage system under rainfed conditions	**J.V.N.S. Prasad** K. Srinivas G. Ravindra Chary K.L. Sharma G.R. Korwar P.K. Mishra Ch. Srinivasa Rao G. Pratibha	2009	2012
9. EF034 (NAIP)Comp-I	Enabling small stakeholders to improve livelihoods and benefits from carbon finance	**J.V.N.S. Prasad** K. Srinivas G.R. Korwar Ch. Srinivasa Rao C.A. Rama Rao K.V. Rao	2009	2012
10. RM/NM/05	GHG emissions and global warming potential of crop production systems under rainfed conditions	**J.V.N.S. Prasad** G.R. Korwar Ch. Srinivasa Rao K. Srinivas	2010	2012
11. RM/RM/05	Hydrologic modeling of water yield in a micro watershed and its productivity in vegetable and oilseed production in Alfisols	**K. Srinivas Reddy** K.V. Rao B.Sanjeeva Reddy B.M.K. Reddy V. Maruthi K. Kareemulla	2008	2011
12. RM/RM/06	Rainfall –Runoff and water use characterization of different crop/ cropping systems	**K.V. Rao** K. Srinivasa Reddy G. Pratibha M. Osman U.K. Mandal	2008	2012
13. RM/RM/10	Water Productivity enhancement through in-situ Rainwater Harvesting	**K.V. Rao** G. Pratibha I. Srinivas Y.G. Prasad	2008	2012
14. EF003 (NAIP)Comp.I	Agroweb-Digital Dissemination System for Indian Agricultural Research (ADDSIAR)	**K V Rao** V.U.M. Rao G. Ravindra Chary Sreenath Dixit	2008	2010
15. RM/FM/07	Development and Performance evaluation of Tractor drawn Low till Planter for Rainfed Maize	**B. Sanjeeva Reddy** Ravikanth V. Adake U.K. Mandal	2008	2011
16. RM/FM/10	Development of an Electronic sensors based Instrumentation system to Evaluate Seed planter Performance	**B. Sanjeeva Reddy** Ravikant V. Adake G.R. Korwar	2010	2013

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
17. EF005 (NAIP) Comp.V	Assessment of Quality and Resilience of Soils in Diverse Agro-ecosystems	**U.K. Mandal** K.L. Sharma K. Srinivas Ch. Srinivasa Rao	2008	2012
18. RM/FM/08	Optimization of water lifting and distribution of harvested water	**Ravikant V. Adake** C.R. Thyagaraj I. Srinivas B.S. Reddy K.V. Rao M. Osman Sreenath Dixit Manoranjan Kumar B.M.K. Reddy	2009	2011
19. RM/FM/09	Use of Nano materials to minimize wear in critical parts of selected farm implements	**I. Srinivas** C.R. Thyagaraj R.V. Adake	2009	2012
20. EF030 (NAIP) Comp.2)	Value chain Model for Bio-ethanol production from Sweet Sorghum in rainfed areas through collective action and partnership	**I. Srinivas** G.R. Korwar B. S. Reddy Ravikant V. Adake	2008	2012
21. RM/RM/08	Effect of Biochar amendment on soil properties and growth of crops	**G. Venkatesh** G.R. Korwar U.K. Mandal Ch. Srinivasa Rao K.A. Gopinath Minakshi Grover Dhanpal, AICRPDA Bangalore centre	2009	2012
22. RM/RM/11	Assessment of performance of sorghum and maize in the Dryland areas of Andhra Pradesh, Maharashtra and Rajasthan in the light of climate change	**U.S. Saikia** A.V.M. Subba Rao G.R. Maruthi Sankar	2009	2011
23. RM/MET/1	Modelling mean weekly diurnal patterns of air temperature and dew point temperature and/or relative humidity from daily values thereof-A case study for Hyderabad	**N.N. Srivastava** V.U.M. Rao U.S. Saikia	2009	2011
24. RM/RM/12	Design and development of cost effective water management system for selected crops in alfisol (red soil)	**Manoranjan Kumar** K.S. Reddy K.A. Gopinath	2010	2013

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
DIVISION OF CROP SCIENCE				
25. EF017 (DBT)	Genetic transformation of greengram for enhancing abiotic stress tolerance	**S.K. Yadav** M. Maheswari B. Venkateswarlu N. Jyothi Lakshmi M. Vanaja P.R. Reddy	2004	2011 (merged with DBT project)
26. CS/CP/26	Metabolic indices for heat tolerance in short duration grain legumes	**S.K. Yadav** M. Maheswari M. Vanaja N. Jyothi Lakshmi Arun Kumar Shanker	2010	2013
27. CS/CP/21	Impact of elevated CO_2 on plant nitrogen use efficiency	**N. Jyothi Lakshmi** M. Maheswari M. Vanaja S.K. Yadav Ch. Srinivasa Rao	2009	2012
28. EF011 (ICAR Network Project)	Impact of elevated CO_2 on important rainfed crops	**M. Vanaja** M. Maheswari P.R. Reddy S.K. Yadav N. Jyothi Lakshmi B. Venkateswarlu	2004	2012
29. EF012 (NPCC)	Physiological responses of crop plants to water deficit under elevated CO_2	**M. Vanaja** M. Maheswari P.R. Reddy S.K. Yadav N. Jyothi Lakshmi B. Venkateswarlu	2007	2010
30. CS/CP/16	Evaluation of chlorophyll fluorescence as an indicator for drought tolerance in selected dryland crops	**Arun Kumar Shanker** M. Maheswari G. Rajeshwar Rao	2007	2012
31. CS/CP/18	Evaluation of horsegram mutants in multi-locational AICRP trials	**P.R. Reddy**	2007	2012
32. CS/PP/12	Utilization of candidate microbial isolates for management of dryland insect pests	**Y.G. Prasad** M. Prabhakar B. Venkateswarlu G. Rajeshwar Rao I. Srinivas Sreenath Dixit	2007	2010

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
33. EF014 (NAIP) Comp.4	Development of Decision Support Systems for insect pests of major rice and cotton based cropping systems	**Y.G. Prasad** M. Prabhakar K.V. Rao G.R. Maruthi Sankar K. Nagasri A.V.M. Subba Rao B.M.K. Raju	2008	2012
34. EF035 (CDAC)	Wireless sensor networks – application for pest decision support in agriculture (CDAC – CRIDA collaborative project)	Y.G. Prasad S. Desai	2008	2010
35. CS/CP/20	Sustainable farming systems modules for small & marginal farmers in southern Telangana zone	**B.M.K. Reddy** V. Maruthi S.S. Balloli D.B.V. Ramana K.S. Reddy K. Kareemulla	2008	2011
36. EF016 (NPCC)	Impact of elevated CO2 and temperature on host herbivore interaction	**M. Srinivasa Rao** K. Srinivas M. Vanaja	2004	2012
37. CS/CP/25	Studies on Root characteristics in rainfed greengram and horsegram crop in relation to resource availability	**V. Maruthi** K. Srinivas K. Srinivas Reddy	2007	2012
38. EF023 (DST)	Root proliferation as influenced by soil management practices for drought and its physiological implications short duration pulses	**V. Maruthi** K. Srinivas Arun Kumar Shanker K.S. Reddy	2009	2012
39. CS/SS/03	Soil & Crop Management options for managing Zn deficiency in rainfed areas	**S.S. Balloli** P.K. Mishra G.R. Korwar K.L. Sharma and AICRPDA scientists	2008	2012
40. CS/CP/19	Candidate gene approach for improvement of drought tolerance and yield in drylands	**M.M. Maheswari**	2008	2013
41. EF010 (APNL)	Enhancing tolerance of sorghum to abiotic stresses through genetic manipulation	**M.M. Maheswari** S.K. Yadav B. Venkateswarlu M. Vanaja N. Jyothi Lakshmi	2001	2012
42. CS/ALU/05	Evaluation of forage sorghum cultivars for different soil conditions	**G. Jayaram Reddy**	2009	2012

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
43. CS/Hort/08	Organic Cultivation of Fruits in Drylands	**V.S. Rao** N.N. Reddy M. Srinivasa Rao C.A. Rama Rao K. Sreedevi Shankar G.R. Maruthi Sankar	2008	2013
44. EF020 (AMASS)	Application of micro-organisms in agriculture and allied sectors (Nutrient Management, PGPR) (AMAAS)	**S. Desai** Minakshi Grover S.S. Balloli	2006	2012
45. EF021 (NAIP) Comp.4	Effect of abiotic stresses of the natural enemies of crop pests, Trichogramma, Chrysoperla and pseudomonas and mechanism of tolerance to these stresses	**S. Desai**	2009	2012
46. CS/CP/22	Survival and persistence of stress tolerant PGPR strains in the rhizosphere of dryland crops	**Minakshi Grover** S. Desai	2009	2012
47. EF015 (ICAR Network Project)	Application of micro organisms in Agriculture and allied sectors (AMAAS) – abiotic stress management (Management of Abiotic stresses)	**Minakshi Grover** S.K. Yadav	2006	2012
48. EF031 (ICAR Network Project)	Diversity of consortia of poly-functional rhizosphere microorganisms for nutrient supply, inducing tolerance to abiotic and biotic stresses in major rainfed production systems	**Minakshi Grover**	2009	2012
49. CS/CP/23	Improving the farming systems of small and marginal farmers in selected districts of Andhra Pradesh	**K.A. Gopinath** G. Ravindra Chary K. Kareemulla M. Osman Ch. Srinivasa Rao D.B.V. Ramana B.M.K. Raju	2009	2012
50. CS/CP/24	Integrated weed management in reduced/zero tillage crop production	**K.A. Gopinath** G.R. Korwar K.L. Sharma B. Sanjeeva Reddy G.R. Maruthi Sankar U.S. Saikia	2009	2012
51. EF036 (Lal Bahadur Shastri Young Scientist Award)	Crop yield and quality soil properties and economic returns under organic management in rainfed agro-ecosystem	**K.A. Gopinath**	2009	2012

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
52. CS/FN/02	Trends in food consumption and rural household food security in selected Dryland production systems of Andhra Pradesh	**K. Sreedevi Shankar** G. Nirmala N.N. Reddy	2008	2011
53. CS/FN/03	Development of Ready-to-eat Nutrient rich Value added products with extrusion process technology from selected Dryland crops	**K. Sreedevi Shankar** I. Srinivas C.R. Thyagaraj	2008	2012
54. CS/PP/13	Characterization of Biotic Stress in Rainfed Crops Using Hyperspectral Radiometry	**M. Prabhakar** Y.G. Prasad S. Desai Arun Kumar Shanker P. Vijay Kumar	2010	2013
55. CS/Horti/09	Integrated nutrients & bio-inputs as components of horticultural crop production in dryland regions	**N.N. Reddy** B. Venkateswarlu V.S. Rao Minakshi Grover K.S. Reddy	2010	2014
SECTION OF TRANSFER OF TECHNOLOGY				
56. TOT/AE/24	Leveraging access to ICTs for improved rural Livelihoods : Development of strategic framework	**K. Nagasree** Sreenath Dixit K.V. Rao K. Ravi Shankar B. Venkateswarlu G. Ravi Kumar	2008	2011
57. TOT/AE/27	Assessment of Performance of Knowledge share Centers in technology dissemination	**K. Nagasree** K. Ravi Shankar Sreenath Dixit B.M.K. Raju	2009	2012
58. TOT/AE/26	Farmers' Knowledge Perceptions and Adaptation Measures towards Climate Variability in different Agro-climatic Regions of Andhra Pradesh	**K. Ravi Shankar** A.V.M. Subba Rao G. R. Maruthi Sankar K. Nagasree	2008	2011
59. TOT/AE/28	Evaluation of water productivity under different types of micro irrigation systems	**M.V. Padmanabhan** K. Srinivas Reddy K. Nagasree K. Ravi Shankar N.N. Reddy	2009	2014

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
60. EF029 (ICAR/DARE)	Scaling up of water productivity in Agriculture for Livelihoods through Teaching-cum-Demonstrations, Training of Trainers and Farmers	**M.V. Padmanabhan** C.R. Thyagaraj M.S. Prasad K. Nagasree K. Ravi Shankar D.B.V. Ramana G. Nirmala M. Osman	2007	2012
61. TOT/LM/04	Invitro evaluation of enteric methane mitigation options for livestock fed with coarse crop residues as basal diet	**D.B.V. Ramana** S.K. Yadav P. Basava Reddy (NRCM)	2010	2013
62. TOT/LM/05	Studies on Azolla and horsegram as lean season protein supplement in small ruminants	**D.B.V. Ramana** P.R. Reddy M. Muthukumar (NRCM)	2010	2013
SECTION OF DESIGN & ANALYSIS				
63. D&A/AE/10	Impact Assessment of Rainfed Agriculture Technologies	**K. Kareemulla** Sreenath Dixit Shalander Kumar C.A. Rama Rao G. Ravindra Chary P.K. Mishra	2010	2013
64. EF037 (NCAP)	A study on Impact of NREGS (EGS) on Rainfed Agriculture in India	**K. Kareemulla**	2009	2012
65. D&A/AE/09	Economic Analysis of Rain Water Harvesting Structure – Farm Ponds	**C.A. Rama Rao** K. Kareemulla Shalander Kumar P.K. Mishra K.V. Rao	2009	2012
66. D&A/AS/01	Development of a database of rainfed districts	**B.M.K. Raju** K.V. Rao K. Kareemulla A.V.M. Subba Rao	2009	2011
67. EF039 NAIP (COMP.1)	Policy and Institutional Options for Inclusive Agricultural Growth	**Shalander Kumar**	2009	2012
68. EF028 (NAIP) Comp.3	Sustainable Rural Livelihoods through enhanced farming systems productivity and efficient support systems in rainfed areas	**Sreenath Dixit** CRIDA, ICRISAT, ANGRAU Scientists and NGOs	2007	2012

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
KVK				
69. KVK/AE/01	Gender analysis in watershed development programmes of Andhra Pradesh	**G. Nirmala** Sreenath Dixit	2007	2009 (on deputation)
70. KVK/AE/03	Assessment of factors of farm productivity based on modeling of socio-economic variables of rainfed farmers	**M.S. Prasad** G.R. Maruthi Sankar K. Ravi Shankar C.R. Thyagaraj	2008	2011
AICRPDA				
71. PC(D)/1	Assessment of effects of soil and weather variables on sustainable rainfed agriculture using multivariate statistical and simulation models	**G. R. Maruthi Sankar** P.K. Mishra M. Osman K.L. Sharma G.G.S.N. Rao	2008	2014
72. PC(D)/2	Assessment of impact of regional climate variability/change on agricultural land use in rainfed regions	**G. Ravindra Chary** P.K. Mishra G.G.S.N. Rao V.U.M. Rao K.V. Rao M. Osman G. Pratibha Ch. Srinivasa Rao A.V.M.S. Rao B.M.K. Raju Arun Kumar Shanker & Scientists from AICRPDA & AICRPAM	2009	2012
AICRPAM				
73. EF024 (ICAR Network Project)	Network Project on impact, adaptation and vulnerability of Indian Agriculture to climate change	**G.G.S.N. Rao** V.U.M. Rao M. Srinivasa Rao M. Vanaja A.V.M. Subba Rao	2004	2012
74. EF025 (NAIP) Comp.4	Modeling the performance of a few major cropping systems in Eastern India in the light of projected climate change	**S. Pasupalak** G.G.S.N. Rao V.U.M. Rao A.V.M. Subba Rao	2008	2012
75. AGMET/01	Agroclimatic resource characterization of Andhra Pradesh	**V.U.M. Rao** G.G.S.N. Rao A.V.M. Subba Rao K.V. Rao K. Srinivas	2007	2011

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
76. AGMET/02	Validation of High resolution model forecasting and utilizing them in pest/disease forewarning and contingency planning for Andhra Pradesh	**A.V.M. Subba Rao** G.G.S.N. Rao V.U.M. Rao Y.G. Prasad S. Desai K.V. Rao G. Ravindra Chary K. Ravi Shankar	2008	2012
77. AGMET/03	Value addition to the Agromet Database of AICRP on Agrometeorology	**P. Vijay Kumar** G.G.S.N. Rao B.M.K. Raju B. Venkateswarlu	2010	2015
NATIONAL FELLOW				
78. 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	**Kausalya Ramachandran**	2005	2015
79. EF027 (National Fellow Scheme)	Restoration of soil quality through conservation agricultural management practices and its monitoring using Integrated Soil Quality Index approach in rainfed production system(s)	**K.L. Sharma**	2005	2015

13 Consultancy, commercialization and intellectual property management

13.1 Consultancy

- A multidisciplinary team of CRIDA scientists consisting of Drs. P. K. Mishra, K. Kareemulla, M. Osman, K.V.Rao, D.B.V.Ramana,.C.A. Rama Rao, G. Ravindra Chary, Shalander Kumar, K. Srinivas, Manoranjan Kumar and K. Nagasree carried out a NABARD sponsored mid-course evaluation of two WDF watersheds, ie., Thimmapur and Fazulnagar in Karimnagar district and one Indo-German Watershed, Veeraram, in Warangal district of Andhra Pradesh. The studies brought out the critical role of project facilitating agencies and community involvement in bio physical interventions. The team made suggestions on the administrative, institutional, technical and policy measures that are required for effective implementation of such projects and for sustaining the gains.
- A multidisciplinary team of CRIDA scientists consisting of Drs. B. Venkateswarlu, M. Osman, Y.G. Prasad, K. Kareemulla, M.V. Padmanabhan, Ch. Srinivasa Rao, S. Desai, C.A. Rama Rao, K.S. Reddy, G. Rajeshwar Rao, M. Srinivasa Rao, S. Dixit, G. Pratibha, K. Srinivas, Shalandar Kumar, K.V. Rao, G.Nirmala, G. Ravindra Chary, M. Prabhakar, Manoranjan Kumar, J.V.N.S. Prasad and K.Sreedevi Shankar carried out an evaluation of "Community Managed Sustainable Agriculture" project being implemented by Society for Elimination of Rural Poverty (SERP), Govt. of A.P. The evaluation brought out that the programme is well intended with focus on sustainable agriculture using Self Help Groups (SHGs) as the vehicle of technology transfer and development of lands assigned to the poor. However it suffered from some technical flaws. Most of the interventions were not based on validated information. Though Non-Pesticidal Management (NPM) programme is eco-friendly, its implementation and upscaling are extremely difficult. The Rainfed Farming for Sustainable Agriculture (RFSA) programme, which is also a part of CMSA, commenced recently (summer 2010) and therefore it was too early to gauge its success. The interventions (conservation furrows, trenches, farm ponds and cropping systems) were implemented on uniform basis across the state without regard to the rainfall and soil type of the location. Adoption of improved agronomic practices was not evident in many clusters. Technical backstopping was weak particularly from R and D organizations. Overall, the programme needed considerable modification, for which specific suggestions were made by the CRIDA team.
- Dr. P. K. Mishra acted as Team member in the consultancy project of National Rainfed Area Authority for Prioritizing the Districts of India for taking up developmental activities including livelihood improvements.

- Dr. D. B. V. Ramana carried out a consultancy project entitled "Study of efficacy of herbal formulations in improving immune response in sheep" for Ayurvet Limited

13.2 Commercialization

- MoA has been signed with M/s Jain Irrigation Systems, Jalna for collaborative research and product development in rain water management systems for rainfed crops.
- MoA has been singed with M/s Mahindra and Mahindra Ltd., Mumbai for transfer of technology of CRIDA Ridger planter

Signing of MoA with M/s Mahindra and Mahindar Ltd.

- MoA has been singed with M/s MicroEnsure for developing weather based insurance products for rainfed farmers.
- MoA has been drafted with AIC for developing weather based insurance products for rainfed farmers.

13.3 Intellectual property management

Two applications have been submitted for copy right protection with Registrar, Copyrights, New Delhi.

14 Meetings of RAC/SAC/IMC/IRC

14.1 IRC Meeting

The annual Institute Research Council (IRC) meeting was held on 4, 5, 6, 26 May and 1st June 2010. The main agenda was to cut down large number of experiments and focus on a few major themes. In all, 79 projects including externally funded ones were reviewed and 8 new projects were approved. Director appreciated the efforts of the scientists in the past year in terms of external projects sanctioned, funds mobilized and additional responsibilities assigned by the council in recognition of the institute's contribution.

14.2 SAC Meeting of KVK

The Scientific Advisory Committee (SAC) meeting of KVK Ranga Reddy district was organized on 4th August, 2010 at KVK, HRF, CRIDA. The meeting was chaired by Dr.B.Venkateswarlu, Director, CRIDA and was attended by all members including progressive farmers, officials from line departments, scientists from ANGRAU and CRIDA. The progress achieved during 2009-10 rabi crop season was reviewed and action plan proposed for rabi 2010-11 was discussed.

14.3 RAC Meeting

The Nineteenth Research Advisory Committee (RAC) Meeting under the Chairmanship of Dr. R. Dwarakinath was held on 20th November, 2010. RAC members Dr S. M. Virmani, Dr A. T. Rao, Dr D. C. Upreti, Shri.Vijay Borade and Dr K. Palanisamy attended the meeting. The Committee reviewed the progress under the on-going projects and offered suggestions for improvement. The chairmen suggested several points regarding upscaling of rainfed agriculture technologies and particularly appreciated the new initiative on climate resilient agriculture and recommended that KVK's should be strengthened to take up this programme in all drought prone districts of the country.

14.4 IMC Meeting

The 41st Management Committee Meeting of CRIDA was held on 6th December, 2010 under the Chairmanship of Director, CRIDA. The meeting was attended by IMC members Dr.B.K.Ramachandrappa, Shri.Vijay Borade, V.Vibhishan Reddy, Dr.(Mrs.) Sobha Rani, and special invitees from CRIDA. Besides regular agenda items, the major research achievements were also discussed. The major achievements and replicable case studies from NAIP livelihood project were presented through a film. Progress of expenditure, procurement of equipments and execution of works were reviewed.

15 Participation of Scientists in Conferences, Meetings, Workshops and Symposia

Scientist	Topic	Period	Venue
K.A. Gopinath	One-day Consultation Meeting on Organic Farming in India	23 April, 2010	NASC Complex, New Delhi
V. Maruthi	Workshop for reviewing Action Plan of the KVKs under ANGRAU	26 April, 2010	ANGRAU, Hyderabad
B. Venkateswarlu	Workshop on Climate Change Action Plan for Bundelkhand	27-28 April, 2010	Jhansi
V.U.M. Rao	Annual Review and Planning Meeting of Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience	3-4 May, 2010	Dhaka, Bangladesh
V. Maruthi	State level workshop for finalizing Strategy for Pulses Development in the State	5 May, 2010	MANAGE, Hyderabad
J. V. N. S. Prasad	Carbon Bazaar (organized by the GTZ and MOEF	9-10 May, 2010	New Delhi
Kaushalya Ramachandran	Workshop on Digital Governance & Surveillance Geo-informatics for Integrated NRM & Sustainable Livelihoods	8-9 June 2010	CEFNARM - AP Forest Academy, Hyderabad
Kaushalya Ramachandran	6th UGC Refresher Course on Environmental Management	22-24 June, 2010	Academic Staff Council, Osmania University, Hyderabad
B.Sanjeeva Reddy	Consultation Workshop on Women Friendly Tools and Rural Women Workers	29 -30 June, 2010	NIRD, Hyderabad
K. Ravi Shankar	2010 International Climate Change Adaptation Conference	29 June – 1 July, 2010	Gold Coast, Queensland, Australia
M. Vanaja	National Workshop on Climate Change Actions in Semi-Arid Areas – Linking Grassroots Experiences and Perspectives to Policies and Programmes	1-2 July, 2010	Pune
B. Venkateswarlu	Stakeholders Meeting on Integrated Agriculture Systems for the Poor and Vulnerable	8-9 July, 2010	Nairobi, Kenya
G. R. Rao	AICRPAF Annual Workshop	10-12 July, 2010	BSKKV, Dapoli

Scientist	Topic	Period	Venue
Kaushalya Ramachandran	National Consultation on Urban Agriculture	28-30 July 2010	MANAGE, Hyderabad
B. Venkateswarlu	ICRISAT Stakeholders Workshop on Water Management for CG Project	2 August, 2010	New Delhi
G. Nirmala	Workshop on Gender Analysis and its Application in Sustainable Livelihood Security	2-5 August,2010	DWA, Bhubaneswar
K.Nagasree	e India 2010	4-6 August, 2010	HICC, Hyderabad
B. Venkateswarlu	SAARC Regional Workshop on Drought Risk Management in South Asia	8-9 August, 2010	Afghanistan
B. Venkateswarlu	Meeting with President of India at Rastrapathi Bhawan on Dryland Farming.	11 August	New Delhi
Shalander Kumar	Workshop on Quantitative Modelling Approaches for Economic Policy Analysis in Agriculture	12-13 August, 2010	NCAP, New Delhi
J. V. N. S. Prasad	Workshop on Climate Change, Extreme Events, Adaptation Practices and Technology Solutions	16-18 August 2010	NASC Complex, New Delhi
K.A. Gopinath	National Symposium on Integrated Weed Management in the Era of Climate Change	21-22 August, 2010	NASC Complex, New Delhi
K. V. Rao	ICAR-IWMI Steering Committee Meeting	25 August, 2010	NASC Complex, New Delhi
V.U.M. Rao P. Vijaya Kumar A.V.M. Subba Rao	XI Biennial Workshop of AICRP on Agromteorology	27-29 August, 2010	CRIDA, Hyderabad
K. Kareemulla	National Workshop on Livelihood Opportunities for Smallholders: Challenges & Opportunities	7-8 September 2010	NAARM, Hyderabad
V. S. Rao K. Sreedevi Shankar	National Seminar in Commemoration of the Bicentenary of Nicholas Appert's Invention of Thermal Processing of Foods	18-19 September, 2010	IICT, Hyderabad.
B. Venkateswarlu K. S. Reddy Ravikant Adake B. Sanjeeva Reddy I. Srinivas K. Sreedevi Shankar	National Seminar on Engineering Agriculture for Evergreen Revolution	24-25 September, 2010	Tirupati
B. Venkateswarlu	National Seminar on Land Degradation	9 October, 2010	NBSSLUP, Nagpur
K.L. Sharma	Pilot Planning Workshop on Soil Fertility Improvement Programme Tarnaka, Secunderabad.	20-21 October, 2010	Tarnaka, 20-21 October, 2010

Scientist	Topic	Period	Venue
M. Prabhakar M. Vanaja	National Symposium on Research and Development in Castor: Present Status and Future Strategies	22-23 October 2010	Directorate of Oilseeds Research, Hyderabad
J. V. N. S. Prasad	Brain Storming on Carrying Capacity of Indian Agriculture	28 October, 2010	NASC Complex, New Delhi
G. R. Korwar	Curtain Raiser Meet on Research Needs Arising due to Abiotic Stresses in Agriculture: Management in India under Global Climate Change Scenario	29-30 October, 2010	NIAM, Baramati
V. U. M. Rao M. Vanaja	National Symposium on Food Security in Context of Changing Climate	30 October - 1 November, 2010	CSUAT, Kanpur
K.Nagasree	Interactive Meet on Information and Communication Technology in ICAR	3-4 November, 2010	NASC Complex, New Delhi
Minakshi Grover	96th South Eastern Branch of American Society of Microbiology Annual Meeting	4-6 November, 2010	Alabama State University, Montgomery, USA
M.Maheswari	Discussion on the Status and Perspectives of Phenomics Research in Indian Agriculture	6 November, 2010	NRCPB, New Delhi
G. R. Korwar	Seminar on New Dimensions of Enhancing Production & Productivity of Seed Spices in Andhra Pradesh	11-12 November, 2010	CRIDA, Hyderabad
C A Rama Rao	Annual Conference of Agricultural Economics Research Association	12-14 November, 2010	NAARM, Hyderabad
G. R. Korwar	National Brainstorming Workshop for Promoting MILLETS	13 November, 2010	NIRD, Hyderabad
K. Sreedevi Shankar	Issues and Challenges in Sustainable Agriculture and Rural Development	15-19 November, 2010	MSSRF, Chennai
K. Kareemulla Shalander Kumar	Annual Conference of Agricultural Economics Research Association	18-20 November, 2010	NAARM, Hyderabad
M. Vanaja	National Conference of Plant Physiology Physiological and Molecular Approaches for Crop Improvement under Changing Environment. 2010	25-27 November,	BHU, Varanasi
K. V. Rao	NAAS Brain Storming Session on Drought Preparedness and Mitigation	26 November, 2010	NASC Complex, New Delhi
B. Venkateswarlu	Workshop on ICT in Technology Dissemination Organized by MSSRF	28 November, 2010	Mumbai
J. V. N. S. Prasad K.A. Gopinath	National Symposium on Resource Management Approaches Towards Livelihood Security	2-4 December, 2010	UAS, Bangalore

Scientist	Topic	Period	Venue
B. Venkateswarlu	Annual Conference of Indian Society of Agronomy	3 December	UAS, Bengaluru
B. M. K. Raju	64th Annual Conference of Indian Society of Agricultural Statistics	3-5 December, 2010	Kalyani, West Bengal
Minakshi Grover	Symposium on Instrumentation for Global Climate Research	7-8 December, 2010	CRIDA
G. R. Rao	National Workshop on Innovations and Better Management Practices for Climate Resilient and Sustainable Cotton Production	8-9 December, 2010	CRIDA, Hyderabad
G. Nirmala	National Seminar on Role of Extension in Integrated Farming Systems for Sustainable Rural Livelihood	9-10 December, 2010	Bombay Veterinary College, Mumbai
M. Srinivasa Rao M. Vanaja S.K.Yadav	International Conference on Climate Change – Perspectives and Projections A Systems Approach	9-11 December, 2010	Osmania University, Hyderabad, A.P.
M.Maheswari	Meeting the Challenges in Banana and Plantain for Emerging Biotic and Abiotic Stresses	11-12 December, 2010	National Research Centre for Banana, Trichy
Minakshi Grover	FICCI Workshop on Commercialization Strategies under DST-Lockheed Martin India Innovation Growth Programme 2011	14 December, 2010	Hotel Taj Krishna, Hyderabad
K. Nagasree	Workshop on Knowledge Management Tools	14 -15 December, 2010	ICRISAT, Patancheru
Venkatesh G	National Workshop on Innovations and Better Management Practices for Climate Resilient and Sustainable Cotton Production.	15-16 December, 2010	CRIDA, Hyderabad
B. Venkateswarlu	International Conference on Dryland Farming Sponsored by ICARDA	17-20 December, 2010	Kabul, Afghanisthan
D. B. V Ramana	Vetting Workshop on Preparation of District Contingency Plans for AP	5-6 January, 2011	Agromet Cell, Rajendrangar, ANGRAU, Hyderabad
S S Balloli	Potassium Nutrition in Enhancing Yield and Quality of Crops	17-18 January 2011	UAS Dharwad
Kaushalya Ramachandran	Dimensions & Directions of Geospatial Industry - Geospatial World Forum	18-21 January, 2011	HITEX, Hyderabad
D. B. V Ramana	Project Development Workshop for KVK, Chintamani, Kolar-Chikballapur District	19-20 January, 2011	UAS, Bangalore
Ravikant Adake	National Seminar on Technological Intervention for Evergreen Revolution	24-25 January, 2011	Hyderabad

Scientist	Topic	Period	Venue
B. Venkateswarlu M. Maheswari M. Srinivasa Rao C. A. Rama Rao P. K. Mishra	Pre launch Technical Workshop- NICRA	1-2 February, 2011	NASC, New Delhi.
Kaushalya Ramachandran	Workshop on Success Stories in Watershed Management, DoLR, MoRD	2-3 February, 2011	CGO Complex, New Delhi
B. Venkateswarlu	X Agricultural Science Congress	11-12 February,2011	NBFGR, Lucknow
K. V. Rao	Indo-US Workshop on Managing Water Resources for Food Security and Sustainability	4-6 March, 2011	MSSRF, Chennai
P. Vijaya Kumar	First Indo-German Workshop on Hydrological Optimization of Rice Production Technologies: Evaluation and Decision Support for Efficient Resource Use and Reduced Emission in India	9-10 March, 2011	IIT, Khargpur
P. Vijaya Kumar	Indo-US Workshop on “Agro-climatological and Water Resource Availability Modeling for Agriculture Management	22-23 March, 2011	IHC, New Delhi
Kaushalya Ramachandran	Geospatial Database for Natural Disaster Management and Planning, UGC-Special Assistance Program	25-26 March, 2011.	Osmania University, Hyderabad

16 Workshops, Seminars, Trainings and other Activities Organized by the Institute

16.1 Workshops, seminars and trainings

CRIDA organized several training programmes, seminars and workshops during the year.

Programme	Period	Venue
Training Program on 'Analysis of Crop -Weather Relationships'	23-26 June, 2010	CRIDA, Hyderabad.
Orientation workshop for KVKs on Climate Resilient Technology Demonstration'	1 July, 2010	CRIDA, Hyderabad
Training Course on 'Agricultural Mechanization for Enhancing Water Productivity in Dryland Crops'	July 15-28, 2010.	CRIDA, Hyderabad.
Model Training Course on "Impact of Climate Change in Rainfed Agriculture and Adaptation Strategies"	3-10 August, 2010	CRIDA, Hyderabad
XI Biennial Workshop of AICRP on Agromteorology	27-29 August, 2010	CRIDA, Hyderabad.
Training Course on 'Climate Change and Water Productivity in Rainfed Areas'	16-29 September, 2010	CRIDA, Hyderabad
National Seminar on 'Engineering Agriculture for Evergreen Revolution'	24-25 September, 2010	S.V.Veterinary University, Tirupati
Model Training Course on 'Integrated Nutrient, Pest and Disease Management in Dryland Crops'	26 October - 2 November, 2010.	CRIDA, Hyderabad.
Training Course on 'Livestock Production Enhancement Strategies for Rainfed Areas'	3-16 December, 2010	CRIDA, Hyderabad
Model Training Course on 'Mechanization of Dryland Agriculture'	4-11 January, 2011.	CRIDA, Hyderabad.
5th SERC School on 'Agricultural Drought: Climate Change and Rainfed Agriculture'	20 January - 11 February, 2011	CRIDA, Hyderabad.
Training programme on 'Tools for Technology Access of Agriculture & Allied Sectors in Rainfed areas'	4-10 February, 2011	CRIDA, Hyderabad
Training Course on 'Farm Implements for Mechanizing Small Farms"	14-15 February, 2011	CRIDA, Hyderabad
Training Course on 'Livelihood Enhancement through Sustainable Natural Resource Management in Drylands'	17 February – 2 March, 2011	CRIDA, Hyderabad
Action Plan Workshop on 'Strengthening of Agromet Advisory Services and Weather Indices'	18-19 February 2011	CRIDA, Hyderabad.
Thematic Workshop on 'Strategic Research for Pest and Disease Dynamics in Relation to Climate Change' under NICRA project	26-27 February, 2011	CRIDA, Hyderabad

16.2 Other Activities

Silver Jubilee Foundation Day of CRIDA

The Silver Jubilee Foundation Day of CRIDA was celebrated on 12th April, 2010, in a befitting manner. The Institute's achievements during the past 25 years were highlighted by the Director. Chief Guest, Shri Shiti Kanthananda Swamiji of Ramakrishna Math, Hyderabad, gave a motivational speech relating science, divinity and duty. Scientists who received awards during the last one year were felicitated on this occasion.

Technology week

CRIDA KVK organized Technology Week and Field Day at Hayathnagar Research Farm during 20-25 August 2010 with an aim of disseminating information on latest technologies. Dr. Dana Kishore, IAS, District Collector, Ranga Reddy District, Shri Rama Krishna Goud, Manager, Implements Division, Agro-Industries Corporation, A.P, Ms. V. Usha Rani, IAS, Director, Women & Child Welfare Department, A.P., Dr. Manik Reddy, Deputy Director (Ranga Reddy East Division), Dr. N. Sudhakar, Zonal Project Director, graced the occasion on different events. About 1000 persons including farmers, farm women and extension officials participated in the technology week.

Field IRC

A field IRC was conducted at GRF on 26th August, 2010. Director reviewed the progress of field experiments on water productivity, rain water harvesting, and micronutrient use, organic farming and made several suggestions on data collection.

Hindi fortnight

Hindi fortnight was celebrated at CRIDA from 14-30 September, 2010. On this occasion Hindi noting & drafting, Hindi-English terminology, Hindi essay (for Hindi speaking and non-Hindi speaking), Hindi elocution & Hindi sulekh competitions were conducted. The winners were awarded prizes by the Director on the concluding day.

17 Distinguished Visitors

- Technical staff from 30 project facilitating agencies (PFAs) of NABARD Watershed Programme in Nizamabad district of AP visited CRIDA on 27th January, 2010. Shri. G.Ramasubramanyam, AGM, NABARD facilitated the visit. The team visited Hayathnagar Research Farm to gain knowledge on rainfed agriculture technologies and interacted with Scientists.

- Senior Officers of the district administration, Bhilwara district, Rajasthan, visited NAIP SRLS project sites in AP on 24th April, 2010 and discussed the project interventions, institutional set up and innovations. They expressed keen interest to formulate a project on similar lines for Bhilwara. Dr S.K. Sharma of the AICRPDA, Bhilwara centre coordinated the visit.

- Five scientists from Australian PhytoFuel Company visited CRIDA on 29th April, 2010, to learn about our work on biofuels

- A twelve member official delegation from Ethiopia, led by Ato Sileshi Getahun, Director, Natural Resources Management Directorate, Ministry of Agriculture and Rural Development (MoARD), Ethiopia, visited CRIDA on 4th June, 2010. The team interacted with heads of divisions and senior officers and evinced keen interest on our work on NRM in relation to livelihoods.

- Dr. Amit Aradhey, Agricultural Specialist, American Embassy, New Delhi visited CRIDA on 17th June, 2010 to discuss the recent developments in biofuel crops.

- A team of 22 scientists from Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) countries visited CRIDA on 19th November, 2010 under ICAR – GOI collaborative programme. CRIDA scientists interacted with the visitors on key technologies of the Institute. A visit to laboratories & Hayathnagar Farm was organized to show ongoing experiments on dryland technologies. The team felt that technology transfer through KVK and low cost farm implements are quite useful for adoption in their countries.

- RAC members Dr D.C. Uprety and Dr A.T. Rao visited Ibrahimpur cluster, Ranga Reddy District where NAIP Component 3 sub-project on "Sustainable Rural Livelihoods" is implementing the water sharing intervention on 19th November, 2010. The members saw the demonstration of the ICT kiosk established at the village resource centre under the project and interacted with several farmers and farm women involved in other interventions such as value addition.

- Mr.Sanjeev Kumar, Consultant from NDDB & FAO visited Ibrahimpur and Jamistapur clusters on 22 and 23 December, 2010 to document good practices of sheep rearing implemented under NAIP project. He interacted with members of women SHGs practicing improved sheep rearing practices. He was particularly appreciative the institutional innovations for up scaling the interventions on small ruminants through revolving fund mechanism. His visit was in response to the submission of a case study on institutional innovations for small ruminant rearing from the project clusters which has scope for replicability in several countries of South Asia.

18 Personnel

(As on 31 March, 2011)

Dr. B. Venkateswarlu	**Director**

Division of Resource Management

Dr. G.R. Korwar	Principal Scientist (Agronomy) & Head
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Dr. M. Osman	Principal Scientist (Agronomy)
Dr. G. Rajeshwara Rao	Principal Scientist (Forestry)
Dr. Ch. Srinivasa Rao	Principal Scientist (Soil Science)
Dr. G. Pratibha	Senior Scientist (Agronomy)
Dr. K. Srinivas	Senior Scientist (Soil Science)
Dr. K.V. Rao	Senior Scientist (Soil and Water Conservation Engineering)
Dr. J.V.N.S. Prasad	Senior Scientist (Agronomy)
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Dr. B. Sanjeeva Reddy	Senior Scientist (Farm Machinery and Power)
Dr. U.K.Mandal	Senior Scientist (Soil Physics)
Dr. I. Srinivas	Senior Scientist (Farm Machinery and Power)
Dr. Ravikanth V. Adake	Scientist (Senior Scale)(Farm Machinery and Power)
Dr. U.S. Saikia	Senior Scientist (Agricultural Meteorology)
Dr. Manoranjan Kumar	Senior Scientist (Soil and Water Conservation Engineering)
Sri. G. Venkatesh	Scientist (Forestry)
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Sri. Ram Kumar	Technical Officer (T-6)
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Dr. N. Jyothi Lakshmi	Senior Scientist (Senior Scale) (Plant Physiology)
Dr. Minakshi T. Grover	Senior Scientist (Microbiology-Plant Science)
Dr. K.A. Gopinath	Senior Scientist (Agronomy)
Dr. G. Jayaram Reddy	Scientist (Senior Scale) (Agronomy)
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Dr. Shalander Kumar	Principal Scientist (Agricultural Economics)
Dr. B.M.K. Raju	Senior Scientist (Agricultural Statistics)
Shri I. Syam Prasad	Technical Officer (T-7/8)

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Dr. M.S. Prasad	Principal Scientist (Agricultural Extension)
Dr. D.B.V. Ramana	Senior Scientist (Livestock Production and Management)
Dr. K. Ravi Shankar	Senior Scientist (Agricultural Extension)
Dr. K. Nagasree	Scientist (Senior Scale) (Agricultural Extension)
Sri. K. Surender Rao	Technical Officer (T-6)
Sri. K.V.G.K. Murthy	Technical Officer (T-6)
Sri. B. Dhanunjaya	Technical Officer (T-5)
Sri. S. Yadagiri	Technical Officer (T-5)
Sri. V.L. Savithri	Technical Officer (T-5)

All India Coordinated Research Project for Dryland Agriculture

Dr. P.K. Mishra	Principal Scientist (Soil and Water Conservation Engineering) & Project Coordinator
Dr. G.R. Maruthi Sankar	Principal Scientist (Agricultural Statistics)
Dr. G. Ravindra Chary	Principal Scientist (Agronomy)
Smt. A. Prema Kumari	Assistant Administrative Officer
Sri. R.V.V.S.G. Krishnam Raju	Technical Officer (T-7/8)
Dr. A. Girija	Technical Officer (T-7/8)
Sri. G. Prem Kumar	Technical Officer (T-6)
Sri. L. Sree Ramulu	Technical Officer (T-5)

All India Coordinated Research Project on Agrometeorology

Dr. G. G. S. N. Rao	Principal Scientist (Agricultural Meteorology) & Project Coordinator (up to 31 August, 2010)
Dr. V.U.M. Rao	Principal Scientist (Agricultural Meteorology) & Project Coordinator
Dr. P Vijay Kumar	Senior Scientist (Agricultural Meteorology)
Dr. A.V.M. Subba Rao	Scientist (Senior Scale) (Agricultural Meteorology)
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Dr. S.S. Balloli	Principal Scientist (Soil Science)
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S. Deasi	Principal Scientist (Plant Pathology)
G. Rajeshwara Rao	Principal Scientist (Forestry)
K. Srinivas Reddy	Principal Scientist (Soil and Water Conservation Engineering)
M. Srinivasa Rao	Senior Scientist (Entomology)
K. A. Gopinath	Senior Scientist (Agronomy)

Hayathnagar Research Farm

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Sri. S. Srinivasa Reddy	Technical Officer (T-7/8)
Sri. Ganesh Ramji Hedau	Technical Officer (T-6)
Sri. Y. Venkatesha Reddy	Technical Officer (T-6)
Sri. T. Laxmaiah	Technical Officer (T-5)

Gunegal Research Farm

Sri. V. Sree Ramulu	Technical Officer (T-7/8)

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Sri. S. K. C. Bose	Senior Finance & Accounts Officer
Smt. A. Prema Kumari	Assistant Administrative Officer
Sri. P. Pushpakar	Assistant Administrative Officer
Sri. Narsingh Singh	Assistant Administrative Officer
Sri. G. Jaganmohan Rao	Asssistant Finance & Accounts Officer
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Sri. P. Nagendra Rao	Technical Officer (T-5) (Driver)
Sri. T. Ravi Kumar	Technical Officer (T-5) (Driver)

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Landscaping

Sri. P. Yadagiri	Technical Officer (T-5)
Sri. M. Ramulu	Technical Officer (T-5)

19 Acronyms

AAS ..... Agro-Advisory Services
ACU ..... Adult Cattle Unit
AD ..... Approximate Digestibility
AICRPAM ..... All India Coordinated Research Project on Agrometeorology
AICRPDA ..... All India Coordinated Research Project for Dryland Agriculture
AU ..... Andhra University
BC ..... Benefit Cost
BD ..... Bulk Density
Bt ..... *Bacillus thuringiensis*
CAZRI ..... Central Arid Zone Research Institute
CICR ..... Central Institute for Cotton Research
DAS ..... Days After Sowing
DRR ..... Directorate of Rice Research
DST ..... Department of Science and Technology
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
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
IRC ..... Institute Research Council
JNTU ..... Jawaharlal Nehru Technological University
KVK ..... Krishi Vigyan Kendra (Agricultural Sciences Centre)
LAI ..... Leaf Area Index
LER ..... Land Equivalent Ratio
LGP ..... Length of Growing Period
MANAGE ..... National Institute of Agricultural Extension Management
MBC ..... Microbial Biomass Carbon
MBN ..... Microbial Biomass Nitrogen
MSAVI ..... Modified Soil Adjusted Vegetation Index
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
NASC ..... National Agricultural Science Complex
NBAIM ..... National Bureau of Agriculturally Important Microorganisms
NBSS&LUP .. National Bureau of Soil Survey and Land Use Planning
NCAP ..... National Center for Agricultural Economics and Policy Research
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
NR ..... Nitrate Reductase
NRAA ..... National Rainfed Area Authority
NRCS ..... National Research Center for Sorghum
NRCWA ..... National Research Center for Women in Agriculture
NRM ..... Natural Resource Management
NRSA ..... National Remote Sensing Agency
NWDPRA ..... National Watershed Development Program for Rainfed Areas
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
RCR ..... Relative Consumption Rate
RDF ..... Recommended Dose of Fertilizer
RH ..... Relative Humidity
RSQI ..... Relative Soil Quality Index
RUE ..... Radiation Use Efficiency
SAU ..... State Agricultural University
SAVI ..... Soil Adjusted Vegetation Index
SMW ..... Standard Meteorological Week
TAR ..... Technology Assessment and Refinement

CRHG-04 - a new variety of horsegram released by CRIDA

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