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वार्षिक प्रतिवेदन
Annual Report
2008-09

Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad - 500 059

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Some of the interventions being implemented by CRIDA for improving rural livelihoods

Back Cover
Rainwater harvesting and recycling through farm pond

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केंद्रीय बारानी कृषि अनुसंधान संस्थान

संतोषनगर, हैदराबाद - 500 059

Central Research Institute for Dryland Agriculture

Santoshnagar, Hyderabad - 500 059

Preface

Adoption of improved technologies emanating from rainfed agriculture research is an important contributor for sustained growth in agriculture and livelihood security of small and marginal farmers. In spite of the significant investments made in expansion of irrigation, Indian agriculture is still rainfed with all attendant risks. The concentration of poverty in rainfed regions further underlines the need for increased attention to these areas. Rainfed regions are also more vulnerable to 'climate change'. CRIDA is taking up these challenges with a long term vision, medium term programme planning and short term project execution. We at CRIDA are striving hard to take forward the mandate of the institute with support from ICAR. This annual report presents the detailed progress made in various research activities at the institute, including the summary reports of two coordinated projects, All India Coordinated Research Project on Dryland Agriculture (AICRPDA) and All India Coordinated Research Project on Agrometeorology (AICRPAM), and one Network Project on Climate Change (NPCC). The report also covers human resource development, infrastructure creation, linkages, research publications and other communications, etc.

During the year, significant progress was made in understanding the potential impact of climate change on water availability and water requirements of major rainfed crops, response of crops and pests to climate change and enhancement of drought tolerance of rainfed crops viz., sorghum, green gram and black gram using biotechnology tools. A new variety of horse gram resistant to drought is now ready for release from the institute. There was also significant progress in standardizing agronomic practices for maximizing the yield of biofuel crops like jatropha and pongamia and optimizing the yield and quality of some medicinal and aromatic plants that can be profitable alternatives to the traditional rainfed crops. The institute made new strides in understanding the rainwater harvesting potential in different parts of the country including pond design, recycling water and opportunities for convergence with NREGA. CRIDA identified a new strain of *Pseudomonas putida* which helps plants cope with heat and drought stress. The NAIP subproject on sustainable rural livelihoods has been firmly grounded and has already shown promise in terms of bringing out new models and important lessons in livelihood enhancement, which is the key goal of the project. Besides this, five more NAIP subprojects covering different components have also been launched during the year. These projects are addressing issues such as pest forewarning, mechanization of sweet sorghum cultivation, disease management, soil quality mapping, and digitizing the data on rainfed agriculture and making available to all stakeholders. The institute has also contributed to human resource development significantly and trained a large number of senior and middle level staff from state line departments from all over India. The efforts and contributions earned the Institute and its staff a few awards. CRIDA also played a key role in developing the National Action Plan on Climate Change (NAPCC).

Finally, I present this annual report with a deep sense of gratitude to all those who helped us directly or indirectly during the year. I compliment our editorial committee for their painstaking efforts in bringing out this report.

Hyderabad

Date: September 19, 2009

B. Venkateswarlu

(B Venkateswarlu)

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- आंध्र प्रदेश के लिए वर्षा वितरण एवं मंडल स्तर पर फसलों के अंतर्गत विभिन्न क्षेत्रफल आंकडों का विश्लेषण किया गया । भौगोलिक सूचना प्रणाली का उपयोग कर वार्षिक एवं मौसमी वर्षा के विषयक मानचित्रों को तैयार किया गया । ज्वार एवं मक्का उगाने के लिए उपयुक्त वातावरण का पता लगाया गया। वर्षा का पूर्वानुमान लगाने में भारी वर्षा एवं सूखे के लिए उच्च दृढता वाले मौसम पूर्वानुमान मॉडल के मान्यकरण ने असंगति दर्शाई।
- उष्णकटिबंधी भारत में विभिन्न वर्षा आधारित उत्पादन प्रणालियों के अंतर्गत मृदा कार्बन भंडारणों पर किए गए अध्ययनों से ज्ञात हुआ कि वर्टीसोल्स में जैविक, अजैविक एवं कुल कार्बन भंडारण अधिक थे । उत्पादन प्रणालियों में, सोयाबीन, मक्का एवं मूंगफली आधारित प्रणालियों में बेहतर जैविक कार्बन का भंडारण था ।

जलवायु परिवर्तन

- 1990 (आधार वर्ष), 2020 एवं 2050 के लिए क्रॉपवैट का उपयोग कर 11 राज्यों में कुल गेहूं उत्पादन क्षेत्रों के लिए गेहूं फसल की जल संबंधी आवश्यकता का आकलन किया गया। वर्ष 2020 के लिए 2-4 प्रतिशत एवं वर्ष 2050 के लिए 4-6 प्रतिशत अधिक जल आवश्यकता का अनुमान लगाया गया ।
- विभिन्न CO_2 स्तरों एवं बोवाई की तारीखों से 2020, 2050 एवं 2080 *HadCM3* जलवायु परिस्थितियों के लिए इंफो-फसल ज्वार मॉडल के निर्धारण ने क्रमशः तीन परिस्थितियों के लिए अनंतपुर में 8, 18 एवं 30 प्रतिशत तथा पालेम केंद्र में 2.2, 5.1 और 9.7 प्रतिशत फसल में कमी का पूर्वानुमान लगाया।
- खुला आच्छादित प्रकोष्ठों में दो ज्वार किस्म एस.पी.वी. 1616 (खरीफ किस्म) एवं एम35-1 (रबि किस्म) को परिवेश(365 पीपीएम) एवं उत्थित (550 तथा 700 पीपीएम) CO_2 की स्थिति में प्रतिक्रिया का अध्ययन किया गया । CO_2 सांद्रता से दोनों किस्मों के बायोमॉस एवं बीज उत्पादन में वृद्धि हुई । जबकि, एस.पी.वी. में वृद्धि केवल 17 प्रतिशत थी जबकि एम 35-1 में यह 133 प्रतिशत थी । इससे यह सुझाव मिलता है कि उत्थित CO_2 से रबि किस्मों को अधिक लाभ मिल सकता है ।
- उत्थित CO_2 से सूरजमुखी पौधों में नाईट्रेट रेडेक्टेज क्रिया नाईट्रेट को ग्रहण करने वाले पर्ण क्षेत्र एवं कुल शुष्क पदार्थ में वृद्धि हुई।
- उत्थित परिवेश एवं उत्थित CO_2 के अंतर्गत उगाए गए मूंगफली पर्णों पर पाले गए स्पोडेप्टेरा लिटुरा की चार क्रमिक पीढ़ियों की वृद्धि, विकास एवं उपभोग का अध्ययन किया गया। उत्थित CO_2 परिस्थितियों के अंतर्गत पर्ण उगाऊ से पोषित लार्वों के विकास की अवधि में वृद्धि हुई। बेहतर पोषण एवं बेहतर शरीर भार देखा गया, लेकिन यह परिवर्तन सभी पीढियों में एक समान नहीं था।
- सामान्य CO_2 की परिस्थिति की अपेक्षा उत्थित CO_2 की परिस्थिति में उगाई गई बीटी कपास में *हलिकोवेरपा आरमिगेरा* के लार्वे अधिक देखे गए जिससे ज्ञात होता है कि उत्थित CO_2 की स्थिति में बी.टी. कपास की पत्तियों में विषैले प्रभाव में कमी आई।

वर्षाजल प्रबंधन

- फसल वृद्धि के क्रांतिक स्तर पर कृषि तालाबों में संचित वर्षा जल से अतिरिक्त सिंचाई देने से मूंगफली एवं भिण्ड़ी की उत्पादकता में विशेष वृद्धि हुई । 60 टन प्रति हेक्टेयर टैंक सिल्ट के उपयोग से मृदा को संशोधित करने के बाद इन फसलों की उत्पादकता में और अधिक वृद्धि हुई ।
- परंपरागत अरहर (90 सेंटीमीटर दूरी की पंक्तियां, संरक्षण गड्ढे रहित) की तुलना में संरक्षण गड्ढ़ों सहित अरहर के जोडी पंक्ति रोपण (60 सेंटीमीटर की दूरी से जोडी पंक्ति, जोड़ी के बीच 120 सेंटीमीटर) से जल बहाव में कमी आई, परिणामस्वरूप लोबिया का अंतरासस्यन किया जा सका तथा अरहर के समकक्ष उत्पादन में 50 प्रतिशत की वृद्धि हुई ।

फसल एवं फसल प्रणालियां

- फरवरी 2009 में कुलथी की किस्म क्रीड़ा-18आर का विमोचन कर उसे अधिसूचित किया गया । यह किस्म भूरे बीज, शीर्घ परिपक्व होने वाली, *पीत मोसाइक वायरस* के प्रति सहीष्णु एवं बेहतर दाल गुणवत्ता वाली है । इस किस्म ने स्थानीय किस्मों की तुलना में 40 प्रतिशत अधिक पैदावार दर्ज की ।
- ट्रांसजेनिक ज्वार के आणविक एवं पादप क्रिया लक्षणों तथा पीढियों का अग्रेषण किया गया। कुछ ट्रांसजेनिक वंशावलियों के टी-4 पौधों ने सूखे के प्रति सहिष्णुता में वृद्धि दर्शाई। इस लक्षण का पता एक्साइजड पर्ण जल धारिता क्षमता से प्रमाणित हुआ ।
- एग्रोबेक्टेरियम मध्यस्तता दृष्टिकोण का उपयोग कर एन्नेक्सिन बीजे जीन (किस्म एमएल 267) से ट्रांसजेनिक मूंग का विकास करने के लिए दोहरे कोटिलेडोनरी नोड (डी.सी.एन) एक्सप्लांटों का जननिक रूपांतरण किया गया । ट्रांसजीन के

एकीकरण एवं एक्सप्रेशन की स्थापना के लिए ट्रांसजेनिक पदार्थ का आणविक विश्लेषण किया गया । उत्कृष्ट सिद्ध सस्य महत्व वाले जीनों को उर्द जीन रूपों में संघटित करने के लिए बेहतर रूपांतरण प्रोटोकॉल का विकास किया गया ।

- चार वर्षों के प्रयोगों के बावजूद भी तिल में पारंपरिक रसायन आधारित प्रक्रियाओं की तुलना में जैविक प्रक्रियाओं में उत्पादन कम था । जबकि, कुछ वर्षों से इन प्रक्रियाओं के उत्पादन के अंतर में कमी आई । रसायन की तुलना, एकीकरण एवं जैविक उत्पादन प्रक्रियाओं ने दर्शाया कि रासायनिक प्रक्रिया से ज्वार का निष्पादन बेहतर था जबकि एकीकरण एवं जैविक प्रक्रिया से अरहर का प्रदर्शन बेहतर था ।
- एक क्षेत्रीय सर्वेक्षण ने स्पष्ट किया कि वरंगल जिले में खरीफ 2008 के दौरान कपास पर मीलीबग(फेलोकोक्कस मेलोनोपसी) को प्रमुख नाशीजीव माना गया एवं किसानों ने इसके नियंत्रण के लिए 2-4 कीटनाशी छिडकावों के प्रयोगों पर ही भरोसा किया । सर्वेक्षण ने पहली बार वरंगल जिले में कपास पर मीलीबग का प्राकृतिक पैरासिटाइजेशन का स्तर दर्ज किया ।
- अंतरासस्यन अरहर पर वनस्पतिक सारों एवं तेलों से युक्त कम वाह्य निवेश वाले समेकित नाशीजीव प्रबंधन पैकेज का तना बेधक नियंत्रण में काफी प्रभावी था और यह परंपरागत समेकित नाशीजीव प्रबंधन पैकेज के लगभग समान पाया गया । यह कम वाह्य नाशीजीव प्रबंधन पैकेज बेहतर न्यूनतम आमदनी उपलब्ध करवाने में भी सक्षम रही ।
- सेंटर फॉर एडवांस कंप्यूटिंग, हैदराबाद द्वारा अनुसंधान फार्म पर एक बेतार सेंसर नेटवर्क की स्थापना की गई। इससे मौसम सहित खरीफ एवं रबि मौसम के दौरान पर्ण सुरंगी का आपतन एवं देर से आने वाले पर्णचित्ती रोग को मॉनीटर किया गया। मूंगफली की फसल में पर्ण सुरंगी के प्रकोप का पूर्वानुमान लगाने हेतु फील्ड-डे-डिग्री-मॉडल का विकास किया गया।
- उच्च तापमान, लवणता एवं/या सूखा के प्रति सहनशीलता दर्शाने वाले *स्युडोमोनॉस* की तेईस नस्लों को अलग किया गया तथा इनको दबावों के अंतिम स्तरों के लिए जांचा गया । आगे, कई नस्लों ने कई कवकीय रोगजनकों के विरूद्ध जैव नियंत्रण योग्यता दर्शाई। जैव नियंत्रक, फासफोरस सांद्रीकरण, जिंक सांद्रीकरण एवं पादप वृद्धि के योग्य सूक्ष्म जीवाणुओं की नस्लों को अलग कर जांचा गया।
- पादप वृद्धि गुणों को प्रदर्शित करने वाले *स्युडोमोनॉस* एवं *बैसिलस* के चयनित दबाव-सहिष्णु नस्लों का संघ स्थापित किया गया तथा तापमान दबाव सहिष्णुता के लिए ज्वार में बीज निवेश द्रव्य के रूप में जांचा गया । एकल निवेश द्रव्यों की तुलना में तापमान दबाव परिस्थितियों के अंतर्गत बैक्टि रियल संघ ने जीवक्षम, पादप बायोमॉस एवं ज्वार पौधों के जैव-रसायन स्तर में बेहतर परिणाम दिया ।
- अरंड पर *स्पोडोप्टेरा लिटुरा* के विरूद्ध सूक्ष्मजीवी विगलकों के मूल्यांकन ने दर्शाया कि एंडोसलफान से 99 प्रतिशत कमी की तुलना में *बेयवेरिया*, बीटी 48बी एवं एस.आई.एन.पी.वी. 0.2 प्रतिशत से नाशीजीव संख्या में 70-78 प्रतिशत की कमी आई। जबकि, एस.आई.एन.पी.वी. में अत्यधिक प्राकृतिक पारासिटायड संख्या (42 प्रति क्षेत्र) एवं कीटनाशी उपचार में न्यूनतम थी।
- छोटे किसानों के लिए केंद्र पर कृषि प्रणाली मॉड्युलों पर अध्ययन जारी है । वर्ष के दौरान, मॉड्युल के उप-अवयवों में मोटे अनाज, दलहन एवं चारा फसलें 1.4 हेक्टेयर क्षेत्र पर शामिल थी। भेड़ पालन के लिए उपयोग किए गए चारे से कुल 31,309 रुपए की आमदनी हुई । देरी से की गई बोवाई को छोड़ यह अच्छा सामान्य वर्षा वाला अनुकूल वर्ष था ।

मृदा एवं पोषण प्रबंधन

- कर्षण एवं पोषण प्रबंधन उपचार दोनों ने ज्वार के अनाज उत्पादन को महत्वपूर्ण रूप से प्रभावित किया । कम कर्षण (1188 किलोग्राम प्रति हेक्टेयर-1) की तुलना में पारंपरिक कर्षण में महत्वपूर्ण रूप से बेहतर अनाज उत्पादन (1339 किलोग्राम प्रति हेक्टेयर-1) दर्ज किया गया। 2 टन ग्लैरीसीडिया कर्तन + 20 कि.ग्रा. नाइट्रोजन के प्रयोग से अधिकतम (1485 कि.ग्रा. प्रति हेक्टेयर -1) उत्पादन दर्ज किया गया । अरंड में ग्लैरीसीडिया कर्तन एवं ज्वार कड़बी प्रत्येक 2 टन प्रति हेक्टेयर के प्रयोग से, बिना कड़बी के उपयोग की तुलना में क्रमशः 14.7 प्रतिशत एवं 13.7 प्रतिशत अधिक अरंड बीन का उत्पादन प्राप्त हुआ । नाइट्रोजन के प्रयोग के प्रति अरंड की प्रतिक्रिया महत्वपूर्ण थी और 90 कि.ग्रा. नाइट्रोजन प्रति हेक्टेयर से अधिकतम अरंड उत्पादन (913 कि.ग्रा. प्रति हेक्टेयर) प्राप्त हुआ ।
- क्रिगिंग इंटरपोलेशन तकनीकों का उपयोग कर आंध्र प्रदेश में नलगोंडा जिले के चिंतापल्ली गांव में सकलिसेरीपल्ली सूक्ष्म जलग्रहण के चयनित मृदा प्राचलों के लिए विषयक मानचित्र तैयार किए गए । मृदा गहराई एवं गठन दो अंतर्निहित मृदा गुण हैं जो भूमि उपयोग योजना के लिए अत्यंत महत्वपूर्ण माने जाते हैं। नए मार्गदर्शनों के अंतर्गत समेकित जलग्रहण विकास योजना (IWDP) कार्यक्रम में इस तकनीक का उपयोग किया जा सकता है ।
- छः केंद्रों की 50 जगहों पर तालाब-गाद के उपयोग पर किसान भागीदारी द्वारा अनुसंधान का आयोजन किया गया। सभी जगहों की सभी फसलों में तालाब गाद से महत्वपूर्ण रूप से बेहतर फसल उत्पादन एवं आर्थिक लाभ हुआ।
- एक अन्य अध्ययन में, भारत में दो मक्का उगाने वाले जिलों, करीमनगर (आंध्र प्रदेश), भीलवारा (राजस्थान) से मृदा नमुनों को एकत्र किया गया । अत्यधिक मृदा नमूनों में जिंक की कमी पाई गई। लंबी अवधि के प्रयोगों से एकत्रित मृदा नमूनों के

विश्लेष्ण से भारत में वर्षा आधारित उत्पादन प्रणालियों से मृदा में कार्बन की बढ़ोत्तरी हेतु प्रबंधन प्रक्रियाओं की पहचान की गई।

भूमि उपयोग विविधता

- *ए. सेनेगल* में अंतर सस्ययन के रूप में उगाया गया *सेटारिया*, एकल *सेटारिया* के समान पाया गया। जब सेट ारिया का अंतरासस्ययन आमला एवं इमली के साथ किया गया तो इन उपचारों में सेटारिया का उत्पादन महत्वपूर्ण रूप से बेहतर था । गोबर की खाद एवं अजैविक उर्वरकों के संयोग से, आमला में महत्वपूर्ण रूप से बेहतर फल उत्पादन प्राप्त किया गया ।
- संरक्षण सिंचाई से सभी फल प्रजातियां लंबे समय तक बनी रही जबकि बिना सिंचाई के कारण काफी संख्या में पौधे सूख गए । संपूर्ण वर्षा आधारित परिस्थितियों के अंतर्गत आम एवं ओनला काफी संख्या में नष्ट हो गए जबकि इमली ने बेहतर प्रदर्शन किया। स्थापित पौधों पर सिंचाई 0.25 ई.पी. उपचारों की तुलना में 0.75 ई.पी. एवं 0.50 ई.पी. में बेहतर रूप से उगने में सहायक पाई गई । अनुसंधान एवं तकनीकियों को अपनाने में हुए अंतराल को दर्शाते हुए सूक्ष्मपोषक तत्वों के प्रयोग से एवं अतिरिक्त सिंचाई जैसी बेहतर प्रक्रियाओं को अपनाने से किसानों के खेतों पर सब्जियों की उत्पादकता में 62 से 366 प्रतिशत की वृद्धि हुई ।
- बागवानी उत्पादों के मूल्य वृद्धि उत्पादों पर किए गए अध्ययनों ने दर्शाया कि व्यावसायिक उत्पाद विकास के लिए पपीता, अनन्नास, आम एवं अमरूद की गुदा को 20-40 प्रतिशत के सम्मिश्रण से बनाए गए फल उत्पाद उपयुक्त पाए गए । पलमिरा स्क्वॉश में जब रोसल्ले-सार मिलाया गया तो उससे उत्पाद को उत्कृष्ट रंग प्राप्त हुआ ।
- *ल्युकेना* पेडों के बीच उगाए गई घासों की उत्पादकता का क्रम इस प्रकार था : गुनिया घास किस्म रिवर्सडेल>गुनिया घास किस्म मकुनी>कांगों सिगनल घास>सेंचोरस सिल्लरिस>गुनिया घास किस्म ग्रीन पैनिक। घासों के कारण पेड की वृद्धि पर प्रतिकूल प्रभाव पडा ।
- तीसरे वर्ष के अंत तक जेट्रोफा की आशाजनक किस्मों का बीज उत्पादन 0.98 से 1.30 टन प्रति हेक्टेयर था। प्रथम वर्ष में भूमि स्तर से 45 सें.मी. तक पौधों की कटाई एवं द्वितीय वर्ष में प्रत्येक शाखा की आधी कटाई से अधिकतम उत्पादन प्राप्त हुआ।
- *पोंगामिया* के रोपण के पांचवें वर्ष के दौरान कलमी पौधों में कारनेल उत्पादन 0.7 से 2.9 कि.ग्रा. प्रति हेक्टेयर तक था। पांचवें वर्ष के दौरान बीज से उगाए गए पौधों में पुष्पण शुरू हुआ एवं कारनेल का उत्पादन 0.4 से 0.9 कि.ग्रा. प्रति हेक्टेयर था।
- हारमोनल एवं रासायनिक परिचालनों के उपयोग से पोंगामिया में बढ़ते आर्थिक उत्पादन एवं बीज तेल की गुणवत्ता पर किए गए अध्ययन ने दर्शाया कि ब्रासिनोलाइड (बी.आर.आई), पैक्लोबुट्रोजोल एवं युरिआ के उपयोग से प्रति शाखा फली संख्या एवं फलियों की कुल संख्या में वृद्धि हुई।
- सिमराउबा में, रोपण के पांचवें वर्ष के अंत में, फलों का शुष्क उत्पादन 6.59 से 13.2 कि.ग्रा.प्रति पेड था। सिमराउबा के बीच की जगह (6X6 मी.) को पेड वृद्धि पर किसी प्रकार के नकारात्मक प्रभाव के बिना अरंड एवं लोबिया को उगाने के लिए प्रयोग किया जा सकता है ।
- सनई, एण्ड्रोग्राफिस एवं अश्वगंधा के अधिकतम उत्पादन एवं गुणवत्ता हेतु पोषण प्रबंधन प्रक्रियाओं का मानकीकरण किया गया ।

पशुधन प्रबंधन

- पशुओं एवं भैसों में गर्भधारण दर में वृद्धि करनें एवं पोस्टपारटम विसंगतियों को कम करने के लिए तापमान दबाव प्रबंधन सहित ओएसटरस तकनीक का सिंक्रानाइजेशन बेहतर पाया गया।
- माँस के लिए उपयोग में लाई जाने वाली भेडों को अलग प्रबंधन प्रणालियों के अंतर्गत पाला गया जिनका अध्ययन करने पर पता चला कि सेमी इंटेनसिव एवं एक्सटेनसिव प्रणालियों की तुलना में इन्टेन्सिव प्रणालियों में बेहतर कारकस भार एवं ड्रेसिंग प्रतिशत पाया गया । आगे यह भी देख गया कि बेहतर सजीव भार वृद्धि, कारकस भार एवं ड्रेसिंग प्रतिशत के लिए प्रबंधन के गहन प्रणाली के अंतर्गत मोटा चारा आधारित आधार पोषण (कटा हुआ ज्वार की कडबी) के साथ दक्कनी भेडों को स्टाइलो+ग्लैरीसीडिया पत्तों को वैकल्पिक सांद्रता मिश्रण के रूप में दिया जा सकता है ।

ऊर्जा प्रबंधन

- एम.बी.हल से 0.18 हेक्टेयर प्रति घंटा की तुलना में क्षेत्रीय क्षमता का रोटरी टिल्लर 0.26 हेक्टेयर प्रति घंटा बेहतर पाया गया। एम.बी. हल (1321 रुपए प्रति हेक्टेयर) की तुलना में रोटरी टिल्लर से किया गया परिचालन खर्च (962 रुपए प्रति हेक्टेयर) कम था । बेहतर बायोमॉस स्थापना एवं कम परिचालन लागत के लिए एम.बी. हल की तुलना में रोटरी टिल्लर बेहतर उपकरण है । वर्षा आधारित मक्का के लिए ट्रेक्टर चालित लो-टिल प्लांटर के कार्य निष्पादन का मूल्यांकन किया गया ।
- हस्त चालित मोटरयुक्त कट्टर का उपयोग कर कड़बी को 50 सें.मी. तक काटने के बाद ट्रेक्टर चालित स्लैशर ने एक समान कटाई कर खेत में समान रूप से फैला दिया ।

सामाजिक-आर्थिक अध्ययन

- जलग्रहण विकास कार्यक्रमों के टिकाऊपन के विश्लेषण से ज्ञात हुआ कि इन कार्यक्रमों की सफलता के लिए जीविकोपार्जन

सुरक्षा, विकास एवं मृदा तथा जल संरक्षण संरचनाओं का उचित रख-रखाव, भू-धारण सुरक्षा, ऋण की उपलब्धता आदि आवश्यक हैं ।

- आंध्र प्रदेश में राष्ट्रीय ग्रामीण रोजगार गारंटी योजना पर प्रायोगिक अध्ययन ने सूचित किया कि मज़दूरों एवं किसानों दोनों के द्वारा राष्ट्रीय ग्रामीण रोजगार गारंटी योजना से रोज़गार लाभ प्राप्त किया गया । इस योजना ने महत्वपूर्ण रूप से प्रवास को रोका है । कुछ मंडलों में, इस योजना से की गई कमाई करीब पूरे परिवार की आय का एक तिहाई थी ।
- आंध्र प्रदेश के महबूबनगर जिले के विभिन्न मंडलों में फसल विविधता की सिंपसंस सूची 0.62 एवं 0.86 के बीच पाई गई जो यह सूचित करता है कि यह अपेक्षाकृत उच्च स्तर की विविधता है। पूरे जिले के लिए विविधता की सूची 0.84 पाई गई । सिंपसंस सूची के आधार पर, अधिकतम विविधता एवं न्यूनतम विविधता वाले मंडलों की पहचान की गई ।
- रंगा रेड्डी जिले में ग्रामीण लोगों के पोषण पर किए गए अध्ययन ने सूचित किया कि विभिन्न खाद्य पदार्थ विशेषकर 'संरक्षी आहार' जैसेकि हरी पत्ते वाली सब्जियां, अन्य सब्जियां, दूध तथा दूध से बने उत्पादों का औसत दैनिक ग्रहण आर. डी.ए. से कम था । विभिन्न खाद्य ग्रूपों की न्यूनतम ग्रहण कमी इस प्रकार है :दूध एवं दूध से बने उत्पाद (77-83 प्रतिशत), हरे पत्ते वाली सब्जियां (25-67 प्रतिशत) एवं अन्य सब्जियां (33-41 प्रतिशत) ।

प्रौद्योगिकी हस्तांतरण

- बारानी किसानों द्वारा अपनाने योग्य प्रौद्योगिकियों पर किए गए अध्ययन से पता चला कि प्रौद्योगिकियां जैसेकि पंक्ति अनुपातों, उर्वरक सिफारिशें, गड्ढों का संरक्षण एवं बीटी कपास की किस्म को कृषि में बेहतर रूप से अपनाने योग्य पाया गया। क्षेत्रीय स्तर पर सूचना एवं संचार प्रौद्योगिकी की संचार पद्धतियों के कार्यान्वयन में आने वाले अवरोधों की पहचान की गई । इन अवरोधों में अपर्याप्त क्षमता निर्माण, अधिक लागत का रख-रखाव, आधार संरचना(कंप्यूटर, सॉफ्टवेअर एवं हार्ड वेअर) का लगातार खराब होना, शिक्षित कर्मचारियों का लगातार बदलना, सूचना एवं संचार प्रौद्योगिकी से कृषि प्रसार सेवाओं के बीच समन्वयन का न होना, विभागों द्वारा पारंपरिक प्रसार सेवाएं, संबंधित विभागों के बीच असहयोग, किसानों द्वारा परिवर्तन का विरोध(उनके समक्ष उपलब्ध सूचना के वैकल्पिक स्रोतों के उपयोग में सुविधा) आदि शामिल हैं ।

राष्ट्रीय कृषि नवोन्मेषी परियोजना (एन.ए.आई.पी.)

- वर्ष के दौरान विभिन्न विषयों से जुडी एन.ए.आई.पी. की छः उप-परियोजनाएं कार्यरत हैं । ये परियोजनाएं टिकाऊ ग्रामीण रोज़गार, नाशीजीव प्रबंधन के लिए पूर्वानुमान एवं निर्णय सहायक प्रणालियां, मीठी ज्वार की कृषि की तैयारी, दबाव सहीष्णु माइक्रोब, मृदा गुणवत्ता मानचित्रण एवं एग्रो वेब प्रणाली के लिए डेटा डिजीटीकरण जैसे मुद्दे शामिल हैं ।
- अवयव 3 के अंतर्गत टिकाऊ ग्रामीण रोज़गार पर एन.ए.आई.पी. की उप-परियोजना को मूर्त रूप दिया गया है और प्रौद्योगिकी हस्तांतरण के कुछ मानदंडों के साथ आगे आया है और सशक्त रूप से कार्य कर रहा है ।

कृषि विज्ञान केंद्र

- खरीफ 2008 के दौरान, रंगा रेड्डी जिले में मक्का, कपास, सूरजमुखी, अरंड, अरहर एवं भिंडी की बेहतर प्रक्रियाओं पर 381 अग्रिम प्रदर्शनों का आयोजन किया गया । इसके अलावा, समेकित नाशीजीव प्रबंधन(50 हेक्टेयर) पर एवं कपास की फसल पर यांत्रिकीकरण(25 हेक्टेयर) पर खंड प्रदर्शनों का आयोजन किया गया । कृषि विज्ञान केंद्र द्वारा 1784 ग्राहकों को बेहतर प्रौद्योगिकी के विभिन्न पहलुओं पर 70 आवश्यकता आधारित एवं कौशलोन्मुख प्रशिक्षण कार्यक्रमों का भी आयोजन किया गया ।

मानव संसाधन विकास

- वर्ष के दौरान, कई वैज्ञानिकों ने देश के भीतर एवं बाहर विभिन्न प्रशिक्षण कार्यक्रमों में भाग लिया। इसके अलावा, विभिन्न विश्वविद्यालयों के कई विद्यार्थी संस्थान में लघु स्नातकोत्तर अनुसंधान की शिक्षा ग्रहण कर रहे हैं ।

पुरस्कार एवं मान्यताएं

- संस्थान के कई वैज्ञानिक पुरस्कार एवं मान्यताएं प्राप्त कर चुके हैं। डॉ. सी.एच.श्रीनिवास राव, प्रधान वैज्ञानिक (मृदा विज्ञान) को प्राकृतिक संसाधन प्रबंधन के क्षेत्र में उत्कृष्टकार्य के लिए, वर्ष 2008 के लिए राष्ट्रीय कृषि विज्ञान अकादमी (एन.ए.ए.एस.) के अध्येता के रूप में चुना गया । डॉ. जी. रविंद्रा चारी, वरिष्ठ वैज्ञानिक (सस्यविज्ञान) को भारतीय दलहन अनुसंधान एवं विकास सोसाइटी का अध्येता पुरस्कार प्रदान किया गया । संस्थान को श्रेष्ठ गुलाब उद्यान एवं लॉन का प्रथम पुरस्कार प्राप्त हुआ।

प्रकाशन

- अभिजात समीक्षा पत्रिकाओं में 66 अनुसंधान लेख प्रकाशित किए गए ।

संगोष्ठियां, कार्यशालाएं, सम्मेलन, सेमिनार, प्रशिक्षण कार्यक्रम आदि

- संस्थान में सत्ताइस कार्यशालाएं, सेमिनार एवं प्रशिक्षण कार्यक्रम आयोजित किए गए ।

संपर्क

संस्थान राष्ट्रीय एवं अंतर्राष्ट्रीय संगठनों जैसे इक्रीसेट, आई. पी.ई., भा.कृ.अनु.प. के संस्थानों, विभिन्न सरकारी विभागों, राज्य कृषि विश्वविद्यालयों एवं गैर सरकारी संगठनों से सक्रिय सहयोग बनाए हुए है।

Executive Summary

Resource characterization

- Historical data in respect of rainfall and area under crops at mandal level for the state of Andhra Pradesh was analyzed and thematic maps of annual and seasonal rainfall were prepared using GIS. Crop growing environments for sorghum and maize were delineated.Validation of a high resolution weather forecast model for heavy rainfall and dryspell events showed inconsistencies in prediction of rainfall.
- Studies on soil carbon stocks under diverse rainfed production systems in tropical India indicated that organic, inorganic and total carbon stocks were larger in Vertisols. Among production systems, soybean, maize and groundnut based systems had higher organic carbon stocks.

Climate change

- The crop water requirement of wheat crop was calculated for the entire wheat growing area in 11 states using Cropwat 4 for 1990 (base year) and for 2020 and 2050. Water requirements increased by 2-4% for 2020 and by 4-6% for 2050.
- Validation of Info-crop sorghum model for 2020, 2050 and 2080 *Had CM3* climate scenarios with different CO_2 levels and dates of sowing predicted a yield decrease of 8, 18 and 30% at Anantapur and 2.2, 5.1 and 9.7% at Palem stations for the three scenarios respectively.
- Response of two sorghum varieties, SPV 1616 (*kharif* var) and M35-1(*rabi* var) to ambient (365 ppm) and elevated (550 and 700 ppm) CO_2 was studied in open top chambers. Biomass and seed yields of both the varieties increased with CO_2 concentration. However, the increase was only 17% in SPV 1616 where as it was 133% in M35-1.This suggests that rabi varieties may benefit more from elevated CO_2
- Nitrate reductase activity, nitrate uptake, leaf area and total dry matter of sunflower seedlings increased with elevated CO_2.
- Growth, development and consumption of four successive generations of *Spodoptera. litura* reared on groundnut foliage grown under ambient and elevated CO_2 conditions were studied. Significantly longer larval development duration, increased feeding and increased body weight were observed in larvae fed with foliage grown under elevated CO_2 condition but these changes were not uniform across generations.
- The toxic effect of Bt in cotton leaves was diluted when plants were grown under elevated CO_2 conditions as evidenced by increased larval survival (*Helicoverpa armigera*) than Bt cotton plants gown under ambient CO_2 condition.

Rainwater management

- The productivity of groundnut and okra was considerably enhanced when supplemental irrigation with rainwater harvested in farm pond was given at the critical stages of crop growth. The productivity of these crops was further enhanced when the soil was amended with tank silt@60 ton/ha.
- Paired row planting (60 cm between rows within a pair, 120 cm between pairs) of pigeonpea combined with conservation furrows reduced the runoff, enabled raising of cowpea intercrop and increased the pigeonpea equivalent yields by up to 50% compared to conventional pigeonpea (90 cm between rows, no conservation furrow)

Crops and cropping systems

- A horse gram variety CRIDA 18R, was released and notified in February 2009. It is a brown seeded, early maturing variety, tolerant to yellow mosaic virus and has superior grain quality. The variety recorded up to 40 per cent higher yield over local checks.
- Molecular and physiological characterization of transgenic sorghum and advancement of generation was carried out. T4 plants of some transgenic lines exhibited enhanced drought tolerance as evidenced by improved excised leaf water retention capacity (ELWRC).
- Genetic transformation of double cotyledonary node (DCN) explants to develop transgenic greengram (cv. ML 267) with *annexin bj* gene was carried out using *Agrobacterium* mediated approach. Molecular analyses of the transgenic material was undertaken to establish

integration and expression of the transgene. An efficient transformation protocol was developed to mobilize genes of proven agronomic importance into the elite background of black gram genotypes.

- Organic production was found to yield less than conventional chemical based practices in sesame even during the fourth year of experimentation. However, the yield differences narrowed over years. Comparison of chemical, integrated and organic production practices showed that the performance of sorghum was better with chemical practices whereas that of pigeonpea was better with integrated and organic practices.
- A field survey revealed that mealybug (*Phenococcus melonopsi*) assumed major pest status on cotton during *kharif* 2008 in Warangal district and that farmers relied solely on application of 2-4 insecticide sprays for its control. The survey for the first time reported the extent of natural parasitization of mealybug on cotton in Warangal district.
- Low external input IPM package consisting of botanical extracts and oils on an intercropped pigeonpea was effective in controlling pod borers and was found comparable with conventional IPM package. The low external IPM package was also found to be viable in terms of higher marginal rate of returns.
- A wireless sensor network was established at the research farm by the Centre for Development of Advance Computing (CDAC), Hyderabad. Incidence of leaf miner and late leaf spot disease were monitored during *kharif* and *rabi* seasons along with weather. Field based degree-day model with first trap catch as 'bio-fix' (starting) date for forecasting the peak adult moth emergence of groundnut leaf miner was calculated.
- Twenty three strains of *Pseudomonas* spp. showing high temperature, salinity and/or drought stress were isolated and tested for their threshold levels of these stresses. Further, many of the strains showed biocontrol ability against a number of fungal pathogens. Strains of microorganisms with ability for biocontrol, phosphorous solubilization, zinc solubilization and plant growth promotion were isolated and tested.
- A consortium of selected stress tolerant strains of *Pseudomonas* and *Bacillus* exhibiting plant growth properties was formulated and tested as seed inoculants in sorghum for heat stress tolerance. The bacterial consortium resulted in better survival, plant biomass and biochemical status of sorghum seedlings under heat stress conditions, as compared to single inoculants.
- Evaluation of microbial isolates against *Spodoptera litura* on castor showed that 70-78% reduction in pest population was achieved with *Beauveria*, Bt 48b and SlNPV 0.2% as against 99% reduction with endosulfan. However, natural parasitoid population (42 per plot) was highest with SlNPV and lowest in the insecticide treatment.
- Studies were continued on the on-station model farming system module for small farmers. During the year, the sub-components of the module including cereal, pulse and fodder crops on 1.4 ha of land and fodder used for growing sheep generated a net income of Rs.31309.This was a favorable year with good rainfall distribution except delayed sowing.

Soil and nutrient management

- Both tillage and nutrient management treatments significantly influenced sorghum grain yields. Conventional tillage showed significantly higher grain yield (1339 kg ha^{-1}) compared to reduced tillage (1188 kg ha^{-1}). Application of 2 t *Gliricidia* loppings + 20 kg N through urea/ha recorded highest grain yield of 1485 kg ha^{-1}. Application of gliricidia loppings and sorghum stover each @ 2 t ha^{-1} to castor proved superior over no residue application and increased the castor bean yield by 14.7% and 13.7% respectively. Response of castor to N application was significant and highest castor yield (913 kg ha^{-1}) was observed with 90 kg N ha^{-1}
- Thematic maps for selected soil parameters of Sakaliseripalli micro-watershed in Chintapalli Mandal of Nalgonda district in Andhra Pradesh were prepared using krigging interpolation techniques. Soil depth and texture are two inherent soil properties considered most important for land use planning. This technique has a potential to be used in IWDP programme under new guidelines.
- Farmer participatory action research was conducted on tank silt recycling on 50 sites at six centres. Crop yields and monetary returns were significantly higher with tank silt application at all the sites in all the crops.
- In another study, soil samples were collected from two maize growing districts of India, Karimnagar (AP) and Bilwarah (Rajasthan) and analyzed for Zinc. Majority of soil samples were deficient in Zinc.

- Management practices contributing to soil carbon sequestration across rainfed production systems in India were identified from analysis of long term experiments.

Land use diversification

- Setaria as an intercrop with *A. senegal* was on par with sole setaria. Yields in these treatments were significantly higher than setaria intercropped with amla and tamarind. In amla, significantly higher fruit yields were obtained with a combination of FYM and inorganic fertilizers.
- Highest survival of all the fruit species was observed with protective watering while no irrigation led to high mortality. Mango and aonla recorded high mortality under complete rainfed conditions while tamarind was able to show better performance. On established plants, irrigation at 0.75 Ep and 0.50 Ep was found to support better growth than 0.25 Ep treatment.
- The productivity of vegetables on farmers fields increased by 62 to 366 per cent with adoption of improved practices like micronutrient application and supplemental irrigation indicating the gaps in research and adoption.
- Studies on value addition to horticultural commodities showed that the fruit products prepared with blends of 20%-40% of papaya, pineapple, mango and guava pulp were found suitable for commercial product development. Palmyra squash when fortified with roselle extract imparted excellent colour to the product.
- The productivity of grasses planted between leucaena trees was in the order guinea grass var. riversdale > guinea grass var. makuni > congo signal grass > *Cenchrus ciliaris* > guinea grass var. green panic. Tree growth was adversely affected by grasses.
- The seed yield of the promising accessions of Jatropha ranged from 0.98 to 1.30 t/ha at the end of 3rd year. Pruning schedule consisting of cutting back the plants to 45 cm from ground level in the first year and removing 1/2 of each branch in the second year, maximized yields.
- During fifth year of plantation of pongamia, kernel yield in grafted plants ranged from 0.7 to 2.9 kg/plant. Seedling originated plants started flowering during fifth year and the kernel yield ranged from 0.4 to 0.9 kg/plant.
- A study on increasing the economic yield and quality of seed oil in pongamia using hormonal and chemical manipulations showed increased pod number per branch and total number of pods with brassinolide (BR1), paclobutrazol and urea.
- In simarouba, at the end of fifth year of plantation, the dry yield of fruits was in the range of 6.59 to 13.2 kg per plant. The inter spaces of simarouba (6 X 6 m) could be used for raising castor and cowpea without any negative effect on tree growth.
- Nutrient management practices maximizing the yield and quality of senna, andrographis and aswagandha were standardised.

Livestock management

- Synchronization of oestrus along with management of heat stress was found to improve conception rate and reduce postpartum disorders in cattle and buffaloes.
- The slaughter characteristics of lambs reared under different management systems indicated significantly higher carcass weight and dressing per cent with intensive followed by semi-intensive and extensive systems. It was further observed that Stylo + Gliricidia leaf meal could be used as alternative to concentrate mixture to feed growing Deccani lambs along with the roughage basal diet (chopped sorghum stover) under intensive system of management for higher live weight gain, carcass weight and dressing per cent.

Energy management

- Field capacity of rotary tiller was higher at 0.26 ha/hr as against 0.18 ha/hr with MB plough. Cost of operation with rotary tiller was lower (962 Rs/ha) as compared to MB plough (1321 Rs/ha). Thus, rotary tiller is a superior implement than MB plough for efficient biomass incorporation and low cost of operation.
- The performance of tractor drawn low till planter for rainfed maize was evaluated. Cutting stover to 50 cm height using manually carried motorized cutter followed by operating tractor rear mounted slasher gave uniformly cut material and uniform spread through out the field

Socioeconomic studies

- An analysis of sustainability of watershed development programmes indicated that in case of livelihood security, development and proper maintenance of soil and water conservation structures, security of tenure, availability of credit were essential for success.

- A pilot study on NREGA in Andhra Pradesh indicated that the employment benefit was obtained from NREGA both by labour and by farmers. The scheme significantly reduced the migration. In some mandals, the NREGA earnings formed almost one third of the family income.
- The Simpsons's index of crop diversification was found to vary between 0.62 and 0.86 in different mandals of Mahabubnagar district of Andhra Pradesh, indicating relatively high degree of diversification. The index of diversification for the district as a whole was found to be 0.84. Based on the Simpson's index, mandals which are most diversified and least diversified were identified.
- A study on nutrition of rural population in Rangareddy district found that the average daily intake of various foodstuffs especially protective foods such green leafy vegetables, other vegetables and milk and milk products, were lower than the RDA. The extent of deficit in mean intake of different food groups was higher for milk and milk products (77-83 percent), green leafy vegetables (25-67 percent) and other vegetables (33-41 percent).

Transfer of technology

- In a study on adoption of technologies by dryland farmers, technologies such as row ratios, fertilizer recommendations, conservation furrows and cultivation of *Bt* cotton varieties were found to be better adopted.
- The bottlenecks in implementation of ICT - enabled communication methods at field level were identified. These bottlenecks included inadequate capacity building, high cost of maintenance, frequent repairs of infrastructure (computer software and hardware), frequent change of trained personnel, lack of coordination between agricultural extension services from ICTs and traditional extension services by departments, non cooperation from line departments, farmers' resistance to change (convenience in using alternative sources of information available at their doorsteps) etc.

National Agricultural Innovation Project

- Six NAIP subprojects covering different components are in progress during the year. These projects are addressing issues such as sustainable rural livelihoods, pest forewarning and decision support systems for pest management, mechanization of sweet sorghum cultivation, stress tolerant microbes, soil quality mapping and digitizing data for agroweb system.
- The NAIP subproject on sustainable rural livelihoods under component 3 has been firmly grounded and has come up with modules of technology transfer which showed potential for up scaling.

Krishi Vigyan Kendra

- During *kharif* 2008, KVK conducted 381 frontline demonstrations on improved practices of maize, cotton, sunflower, castor, pigeonpea and lady's finger in Rangareddy district. Besides these, block demonstrations of IPM (50 ha) and mechanization (25 ha) on cotton crop were conducted. The KVK also organized 70 need based and skill oriented training programmes on various aspects of improved technologies to 1784 clients.

Human resource development

- During the year, many scientists participated in different training programmes within and outside the country. Further, a number of students from different universities pursued short term post graduate research in the Institute.

Awards and recognition

- The Institute scientists won several awards and recognition. Dr Ch Srinivasa Rao, Principal Scientist (Soil Science) was elected as Fellow of National Academy of Agricultural Sciences (NAAS) for the year 2008 for best work done in the field of Natural Resource Management. Dr. G. Ravindra Chary Senior Scientist (Agronomy), was awarded Fellowship of Indian Society of Pulses Research and Development by Indian Society of Pulses Research and Development. CRIDA won the first prize for Best Rosary and Lawns.

Publications

- Sixty six research papers were published in peer reviewed journals.

Symposia, workshops, conferences, seminars and training programmes

- CRIDA conducted twenty seven workshops, seminars and training programmes.

Linkages

- The Institute maintained close functional collaboration with national and international organizations and several government departments, SAUs and NGOs during the year which enabled effective implementation of its technical programme.

1. Introduction

Agriculture is the single largest livelihood source in India with nearly two thirds of people dependent on it. Out of 142 m ha of net sown area, about 85 m ha is rainfed and it is estimated that about half of the cultivated area will remain rainfed even after realizing the full irrigation potential in the country. There are a number of factors behind the significant growth observed in Indian agriculture since independence. Among these are the National Agricultural Research System that successfully introduced the HYVs, investments in irrigation, favourable price and procurement policies (especially for rice and wheat). Such a significant growth however did not go unaccompanied by economic and ecological costs in terms of indiscriminate use of chemical fertilizers and insecticides resulting in resource degradation and widening gap between the standards of living of people dependent on irrigated and rainfed farming. The green revolution, that dramatically changed the face of irrigated agriculture, largely bypassed the rainfed agriculture. On the other hand, the productivity levels of rainfed crops remain much below the levels of irrigated crops as well as below the achievable yield levels. Further, the poverty levels in the regions dominated by rainfed agriculture are higher than the all India average as well as in the irrigated regions. In order to bring the millions of people (about 81% of 147.5 million rural poor live in rainfed agriculture dominated regions) in these rainfed regions out of poverty and enable them for a better standard of living, it is imperative that the productivity and profitability of rainfed agriculture be improved considerably for output growth and agricultural wages were found to have a negative relationship with incidence of poverty. It was also proved that investments in rainfed agricultural regions were more paying than those in irrigated/developed regions.

1.1 Rainfed Farming - Historical

Rainfed agriculture constitutes a major part of Indian agriculture that it necessitates 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 since the 1950s more 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 the leadership in basic and strategic research in dryland agriculturewhile continuing research location-specific ORP's at AICRPDA centres. To give fillip and further strengthen the activities in this field, the All India Coordinated Research Project on Agrometeorology (AICRPAM) was launched in 1983, also at CRIDA Hyderabad, with 10 cooperating centres under different SAUs. Presently the strength of AICRPDA and AICRPAM is placed at 25 centres each.

1.3 Mandate

The mandate of CRIDA is:

- To conduct basic and applied research for improving the productivity of natural resources in drylands.
- To develop techniques and systems for long-term conservation and efficient utilisation of dryland environmental resources.

- To understand crop growth process and yield management more specifically under moisture-stress.
- To carry out economic evaluation of technologies, to study the constraints, and to develop suitable resource base models for adoption.
- To evolve appropriate extension, training and communication methodologies for accelerating transfer of technology.

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

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

1.4 Current Thrust Areas

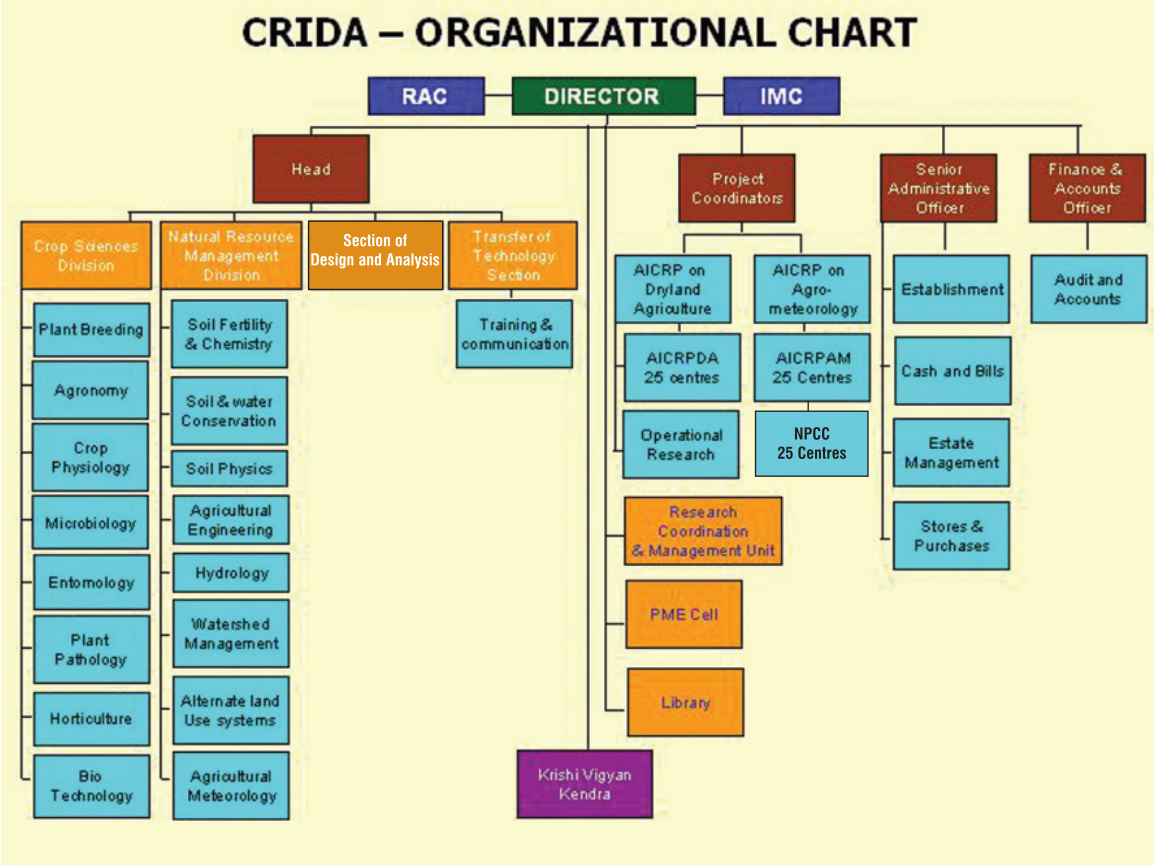
Along with the key programme areas mentioned above, the Institute is also giving due importance to understand the nature of climate change and its potential impacts on the behaviour of rainfed crops, insect pests and microbes. Efforts are also on to identify the potential options such as carbon sequestration for mitigating the 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 apace to evolve transgenic crop varieties that are tolerant to drought. Renewed emphasis is now placed as on- farm water harvesting in view of increased extreme rainfall events and greater run off.

The following programmes have been identified to address the mandate:

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

1.5 Organogram

The organizational setup of CRIDA is given below:



1.6. Past Achievements

Some of the accomplishments of the institute are as follows.

- Characterization and inventorisation of natural, bio-physical and socio-economic resources at micro-level.
- Probabilities of occurrence of drought in different regions in India.
- Studied the water requirement of crops in the 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 crops' pests and diseases and value added agromet advisory service through added advisory service 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, which is the hub of national and international activities in agricultural research. 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 most 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 crop sciences and natural resources management.

Soil physics: The laboratory, besides basic facilities, has excellent instruments to measure physical properties of soil and special equipments 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. The laboratory is equipped with six open top field chambers for quantifying the effect of increased carbon dioxide on the productivity of rainfed crops.

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 tolerance in rainfed crops. The researchers employ 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 in the fields of insect rearing, bio-pesticide evaluation, testing of pesticides, studies on pest development and assessing the effect of climate change on insect's 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 complex: Besides the discipline-wise research facilities highlighted above, the Institute has also established a Central Laboratory facility, which has state-of-the-art instruments. These include Inductivity Coupled Plasma (ICP) analyzer, atomic absorption spectrophotometer, auto analyser and CNS analyzer. This laboratory not only supports research at CRIDA but also assists the entire research network on rainfed agriculture in the country.

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' 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: The Agroforestry research is in progress at this Institute for more than two decades. There is a strong Agroforestry laboratory with several facilities like soil, plant and chemical analysis, aromatic oil estimation, secondary metabolite estimation 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 products for evaluation of components pertaining to horticultural aspects. There is also a cool chamber for storage of fruits and vegetables and their value added products to avoid spoilage.

Animal science laboratory: 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 feed 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 mapping and analysis of watershed programme, land use, cover change analysis besides mapping of soil erosion, drought incidence, and land degradation. The laboratory is also equipped with advanced softwares like ArcGIS Package (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 for collection of accurate geographical locations.

Transgenic glasshouse and green house: A transgenic glasshouse conforming to the 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) for study the impact of elevated carbon dioxide on crops.

Bio-resource centre: A bio-resource centre to produce and make available biological pesticides and biofertilizers was set up at HRF.

Farmers' service laboratory: A research and farmer's service laboratory was set up 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 ARIS Cell trained all the administrative staff on efficient utilization of computer system and MS Office. http://search.apnet.com provides world wide web access to on-line publications of full length articles/papers or data bases to Academic Search Premier. The database is completely researchable.

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 as on March 2009. It subscribes to 132 Indian and 21 International Journals, and is equipped with AGRICOLA, AGRIS, CROP – CD and SOIL – CD Databases. The 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 broad 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. Data input of each book in the software is under completion and will be made available to the users.

Research farms

The Institute has two well laid-out research farms at Hayathnagar (HRF)(280 ha) and Gunegal (GRF) (80 ha) about 15 and 45 km from the main campus, respectively. Both these farms sufficiently represent the predominant soils of the rainfed regions of the country. The mean annual rainfall received at Hayathnagar farm 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 include 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.

Residential quarters

A total of 33 residential quarters (Type-A 12; Type-B 8; Type-C 4; Type-D 6; and Type-E3) are also located at the headquarters.

1.8 Staff Position (as on 31 March, 2009):

Staff	Positions	
	Sanctioned	Filled
Scientific	68	56
Technical	82	74
Administrative	49	46
Supporting	65	50
TOTAL	**264**	**226**

1.9 Financial Outlay for 2008- 09 (as on 31 March, 2009): (rupees in lakhs)

	CRIDA		AICRPDA		AICRPAM		NPCC	
	Sanctioned	Utilized	Sanctioned	Utilized	Sanctioned	Utilized	Sanctioned	Utilized
Non-Plan	1440.90	1273.9	28.01	25.01	44.78	39.64	-	-
Plan	200.00	197.58	1040.00	1040.0	280.00	280.00	210.00	210.00
Total	**1640.90**	**1471.48**	**1068.01**	**1065.01**	**324.78**	**319.64**	**210.00**	**210.00**

2. Research Achievements

2.1. Resource Characterization

2.1.1. Weather conditions at Hayathnagar Research Farm

The southwest monsoon set in on June 9 as a very weak system. Light rainfall occurred only on 12 and 13th June. The annual rainfall received at Hayathnagar Research Farm (HRF), Hyderabad was 1088 mm as against long term (1971-2007) average of 740 mm. Sowing of most crops commenced during 26 SMW only, due to low activity of monsoon. Sowings were completed during 30th SMW. Rainfall of 90 mm received during July was deficient (-32%). The 400 mm rainfall received during August was 168% excess over normal, with two consecutive very heavy rainfall events. The rainfall of 157 mm during September was confined to the first fortnight. Crops like sorghum experienced early as well as terminal drought. Long duration crops of castor and pigeonpea also experienced stress conditions due to below normal (-43%) rainfall during October. Rainfall of 50 mm during November mitigated stress conditions to some extent. The southwest monsoon withdrew by about one week in advance. The weekly weather data are given in Table 1. The actual (2008) and long term average (1971-2007) rainfall and number of rainy days are presented in Table 2, Fig. 1 and Fig. 2.

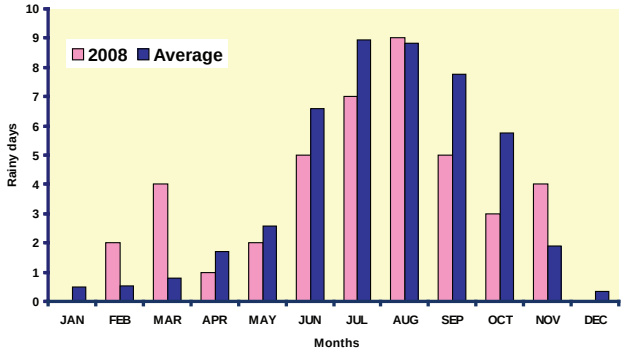


Fig. 1. Actual (2008) and average (1971-2007) number of rainy days at HRF, Hyderabad

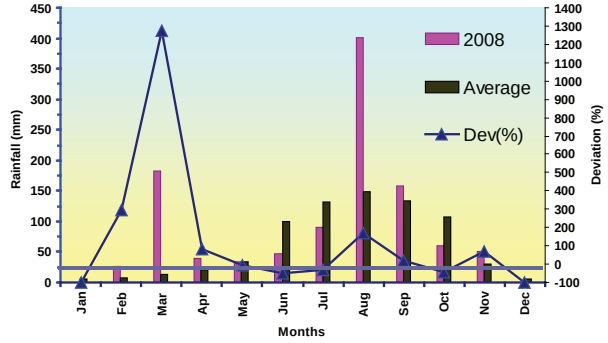


Fig. 2 Monthly actual (2008) and average (1971-07) rainfall along with deviation (%) at HRF

Table 1. Weekly meteorological parameters recorded at HRF during 2008

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	21.0	29.1	28.6	12.1	82	38	8.7	3.8	4.2
2	0	21.0	29.4	29.9	12.0	83	32	9.6	3.4	4.8
3	0	21.2	30.1	30.8	12.0	80	30	9.6	3.3	4.8
4	0	22.6	30.2	29.8	14.2	77	37	7.8	4.9	4.5
5	0	21.5	30.4	30.3	13.8	61	39	6.9	4.0	4.7
6	2.0	24.0	28.7	28.5	17.0	85	61	3.7	4.8	3.9
7	24.4	22.6	30.4	29.1	16.3	92	61	6.8	5.3	3.9
8	0.0	24.6	33.0	32.2	16.2	86	53	8.8	4.4	5.3
9	0.0	24.5	34.0	33.1	14.7	76	32	9.5	4.5	6.7
10	0.0	25.2	34.4	35.1	14.5	66	41	8.7	4.6	8.2
11	0.0	27.6	35.0	34.3	18.8	82	46	8.2	6.3	7.7
12	168.5	25.9	31.4	31.1	19.2	91	67	4.2	5.8	6.6
13	13.8	25.0	32.7	32.4	19.9	84	57	6.1	4.0	4.5

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			
15	0.0	27.0	36.5	34.9	20.0	84	39	9.1	3.4	5.7
16	0.0	30.1	38.2	37.9	21.3	67	27	9.8	3.5	7.1
17	0.0	30.4	39.5	38.4	20.3	65	29	8.9	3.8	7.8
18	0.0	32.1	40.7	39.6	24.2	56	32	9.0	5.5	9.7
19	0.0	32.6	40.6	39.2	24.2	49	24	8.9	5.5	11.3
20	0.0	33.0	40.6	39.7	25.5	48	26	8.8	6.9	11.6
21	31.4	29.6	36.7	37.1	22.4	62	35	6.9	5.9	8.1
22	1.8	33.4	38.6	38.3	25.2	58	33	4.5	6.1	9.4
23	1.0	33.4	38.5	35.9	23.8	66	40	7.3	9.2	9.5
24	11.2	28.8	34.0	32.9	22.4	75	47	0.7	12.2	8.1
25	1.2	30.4	35.6	34.5	23.4	67	40	1.9	9.9	9.1
26	34.4	26.2	32.3	31.5	21.2	80	51	2.8	8.9	5.9
27	1.8	29.0	35.9	33.6	22.6	75	45	5.1	10.1	8.4
28	7.5	29.3	35.4	33.8	22.7	71	41	5.1	8.3	7.4
29	4.8	29.7	36.0	33.9	22.9	73	49	2.8	5.7	6.3
30	67.8	25.6	28.7	29.0	20.0	89	74	1.2	7.2	3.1
31	89.2	24.9	29.0	29.1	20.3	85	70	2.4	7.9	4.1
32	231.2	24.1	26.7	26.4	19.9	77	77	1.0	7.5	3.4
33	38.8	25.8	31.5	28.7	20.8	86	69	2.5	7.3	4.2
34	47.0	26.1	33.6	30.4	20.8	83	61	4.4	4.9	4.7
35	2.0	28.3	36.1	31.3	21.4	89	61	6.7	2.9	4.4
36	23.1	28.1	35.6	31.7	20.7	87	60	4.6	4.1	4.7
38	2.8	25.5	33.4	29.6	20.1	84	61	4.0	6.5	4.2
39	0.0	26.8	35.1	30.9	19.3	81	50	6.4	3.3	4.3
40	35.2	28.8	35.6	32.1	19.4	83	56	6.3	2.9	4.7
41	23.7	25.4	33.7	30.9	18.5	88	53	8.4	2.4	4.1
42	1.8	26.1	34.7	30.8	18.1	82	53	7.6	3.5	4.3
43	0.4	25.5	33.8	30.4	15.8	78	45	7.5	4.0	5.0
44	0.0	23.8	32.9	31.3	13.1	77	26	9.6	2.8	5.1
45	0.0	23.8	32.4	30.6	13.2	82	38	8.9	2.4	4.7
46	29.8	24.1	30.1	28.2	13.8	86	51	4.1	4.8	3.5
47	0.0	24.3	30.5	28.9	16.7	91	54	6.1	2.9	2.9
48	20.6	23.1	27.0	28.2	14.8	89	65	3.6	3.9	3.3
49	0.0	20.5	28.5	28.5	12.6	88	45	8.4	2.5	3.5
50	0.0	22.5	29.1	29.2	13.6	91	57	8.5	3.0	3.5
51	0.0	22.0	27.6	29.1	11.7	85	53	8.0	3.1	3.0
52	0.0	21.1	28.5	29.1	20.4	83	38	8.7	2.2	3.7

Rainfall is weekly total. Other parameters are weekly mean values. Week nos. 9 (leap year) and 52 are of 8 days.

Table 2. Rainfall (mm) pattern during 2008 in comparison with normal

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall in 2008	0	26.4	182.3	39.2	33.2	7.8	89.8	400.3	157.5	61.1	50.4	0	1088.0
Average (1971-07)	5.7	6.7	13.3	21.5	34.3	99.6	132.6	149.5	134.2	107.5	29.6	5.3	739.6
% Deviation from average	-100	294	1272	82.1	-3	-52	-32	168	17	-43	70	-100	47
Rainy days in 2008	0	2	4	1	2	5	7	9	5	3	4	0	42
Average rainy days	0.5	0.5	0.8	1.7	2.6	6.6	9.0	8.8	7.8	5.8	1.9	0.3	46.3

2.1.2. Agro-climatic Atlas of Andhra Pradesh

Rainfall analysis

Historical data in respect of rainfall and area under crops at mandal level was analyzed for the state of Andhra Pradesh. Thematic maps showing the CV (%) of annual and seasonal rainfall and delineation of crop growing environments of sorghum crop prepared using GIS are shown in Fig. 3. The distribution of annual rainfall in the state as a whole in different seasons is about 65% during southwest monsoon, 24% during northeast monsoon and 9% during summer and 2% in winter season. Region-wise rainfall data indicates that Telangana, Coastal Andhra and Rayalaseema regions of the state receive 76, 59 and 56% of the annual rainfall respectively during Southwest monsoon. The Northeast monsoon contributes more than 30% of the annual rainfall over Rayalaseema region followed by 29% in Coastal region and a mere 13% in Telangana.

In general, annual rainfall variability is low (20-30%) in coastal and parts of Telangana districts and high (30-40%) in Rayalaseema and north Telangana districts (Fig. 3). During southwest monsoon season, high variability (>50%) is seen in Anantapur district and certain pockets of Prakasam and Nellore districts. On the other hand, during northeast monsoon season, variability is more (>50%) in north Telangana districts than other parts of the State. During winter and summer, coefficient of variation for rainfall is more than 50% throughout the State indicating high variability.

Occurrence of heavy rainfall events in Andhra Pradesh State at mandal level for all districts for different rainfall ranges viz., 25-50mm, 50-75mm, 75-100mm and >100mm, were worked out for annual and south west monsoon period for all the districts. As an example, results for Visakhapatnam and Chittoor districts are shown in Table 3. A non-parametric statistical trend test, Mann-Kendall was used for trend analysis. Except in two or three mandals no specific trend is noticed in the mandals of both the districts. However, in Araku valley mandal, increasing trend is noticed for all rainfall categories during annual and southwest monsoon period except for more than 100 mm rainfall/day on annual basis. Decreasing trend is seen in Vishakapatnam mandal for 25-50 mm and 50-75 mm rainfall category for both annual and southwest monsoon period.

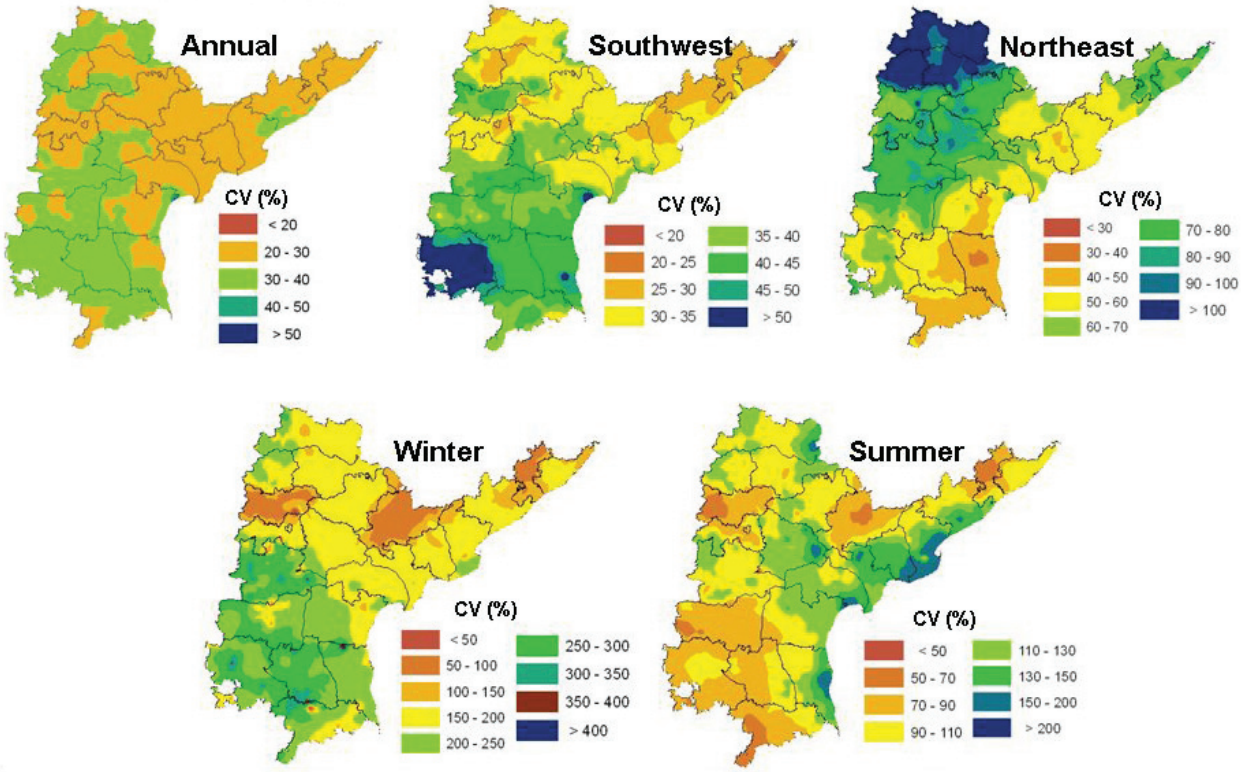


Fig 3. Annual and seasonal coefficient of variation (%) of rainfall over AP

Table 3. Trend in heavy rainfall in different mandals of Visakhapatnam district

Mandal Name	Rainfall categories							
	25-50 mm		50-75 mm		75-100 mm		>=100 mm	
	Annual	SWM	Annual	SWM	Annual	SWM	Annual	SWM
Anakapalle	NS	NS	IT S (0.05)	IT S (0.1)	NS	NS	NS	NS
Arakuvalley	IT S(0.01)	IT S (0.05)	IT S (0.05)	IT S (0.05)	IT S (0.05)	IT S (0.1)	NS	IT S (0.1)
Bheemunipatnam	NS	NS	NS	NS	NS	NS	NS	NS
Chintapalle	NS	NS	NS	NS	NS	NS	NS	NS
Chodavaram	NS	NS	NS	NS	NS	NS	NS	NS
Madugula	NS	NS	NS	NS	NS	NS	NS	NS
Narsipatnam	NS	NS	NS	NS	NS	NS	NS	NS
Paderu	NS	NS	NS	NS	NS	NS	IT S (0.05)	NS
Visakhapatnam	DT S (0.05)	DT S (0.05)	DT S (0.05)	DT S (0.1)	NS	NS	NS	NS
Yelamanchili	NS	IT S (0.1)	NS	IT S (0.05)	NS	NS	NS	NS

IT = Increasing Trend
DT = Decreasing Trend
NS = Non-significance

Level of Significance: 0.01 – Significant at 99 %
0.05 - Significant at 95 %
0.10 - Significant at 90 %

Delineation of crop growing environment for major crops

District-wise data on area of major crops of Andhra Pradesh state published by CMIE has been used to delineate crop production zones. The total area under a crop was classified into three production zones, namely, primary, secondary and tertiary based upon the area under the crop in each district. To classify districts into various production zones for a crop, all the districts of Andhra Pradesh growing the particular crop were arranged in a descending order based on the area under the crop. The top districts covering 50% of the total cropped area were taken as primary production zone and next group of districts covering 35% (51-85%) of the total area were considered as secondary zone. Remaining districts were categorized into tertiary production zone. Using this data, GIS maps were prepared for sorghum (Fig. 4) and maize crops. The spatial distribution of weather parameters like rainfall, temperature (maximum and minimum) and relative humidity (RH) were superimposed on the production zones to delineate the crop growing environments (Fig. 4). It was observed that the amount of rainfall is differing from the primary to secondary zone whereas it did not differ much in and tertiary zones. In the case of temperatures both primary and secondary zones are having the same range of minimum and maximum temperatures 23 to 24°C and 32 to 33°C, respectively. The minimum temperatures are increasing in the tertiary zone. The RH range is low in case of the secondary zone and high in the tertiary zone compared to primary zone.

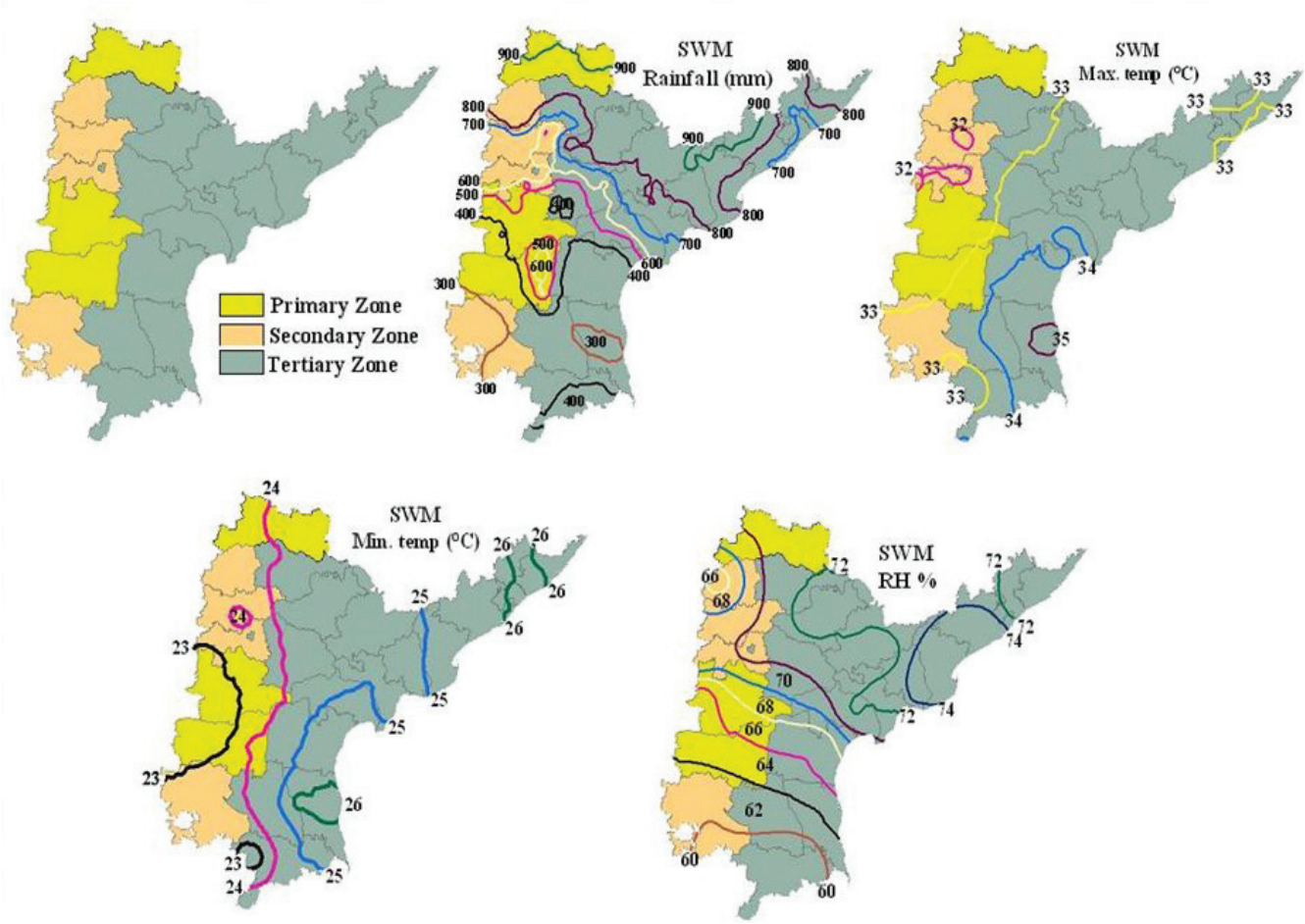


Fig 4. Crop growing environment of sorghum in Andhra Pradesh

2.1.3. Validation of high resolution weather forecast model output

For any weather based agriculture operation, a field level forecast is essential. Recent advances in numerical weather prediction paved way to develop the models such as Meso scale Model (MM5) and Weather Research Forecast model (WRF) which enable to forecast the weather at a high resolution (10 X 10 km^2) grid with certain accuracy level. In order to validate the model forecast output at Mandal level in Andhra Pradesh for the year 2008, mandal-wise daily rainfall data was collected from Department of Economics and Statistics, Government of Andhra Pradesh and temperature data from 29 stations located in Andhra Pradesh from IMD website for 2008 to compare the forecasted and observed data through spatial analysis using GIS.

Majority of the stations showed good correlation coefficients for maximum and minimum temperature with a R^2 values of 0.48 and 0.63 respectively. However, low correlation values were found for stations nearer to coastal region.

The GIS maps for rainfall were generated with the simulated data and observed rain gauge data. It was noticed from the maps that the overall model prediction of rainfall is good but in some cases it is overestimated and in some areas it is under estimated. However, the overall forecast showed good potential for giving accurate agro advisories even at village level.

Two specific case studies are illustrated to assess see the location specific performance of model prediction of rainfall and the results are presented below.

Case study 1 *(Heavy rainfall event)*

A Heavy rainfall event occurred during March 23 – 25, 2008. This period is coincided with the harvesting of *rabi* crops. Due to this event, crop damage was noticed. Mesoscale model predicted heavy rainfall pattern correctly. Moderate (7.6 –35.5 mm) and rather heavy rainfall (35.6-64.5mm) intensity prediction was good on March 23, 2008. Further improvement was observed on the second day forecast (March 24, 2008) for rainfall (Fig.5). Moderate rainfall conditions predicted by model were very good. Third day forecast (March 25, 2008) was not as good as first and second day forecast. However, model could not predict very heavy rainfall (124.5-244.4 mm) conditions during first and second day of the forecast.

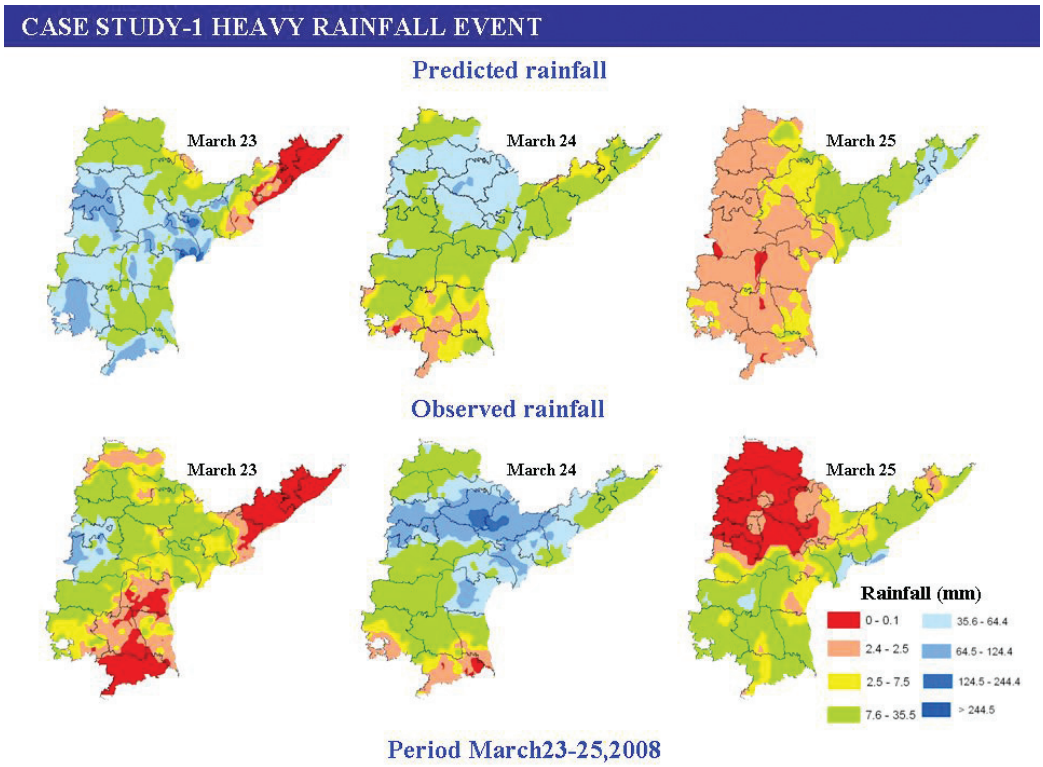


Fig 5. MM5 model forecast of heavy rainfall event

Case study 2 *(Dry spell condition)*

In Andhra Pradesh, climatologically, onset of southwest monsoon and good rainfall would occur during second week of June. But, in most of the places no rainfall was received during June 18-20, 2008. This is an important period for agricultural operations, especially sowing. The model predicted no rainfall conditions at most of the locations. During day 1, forecast also predicted very light rainfall conditions well. Light and moderate rainfall conditions predicted by model in third day forecast did not coincide with observed rainfall conditions (Fig 6).

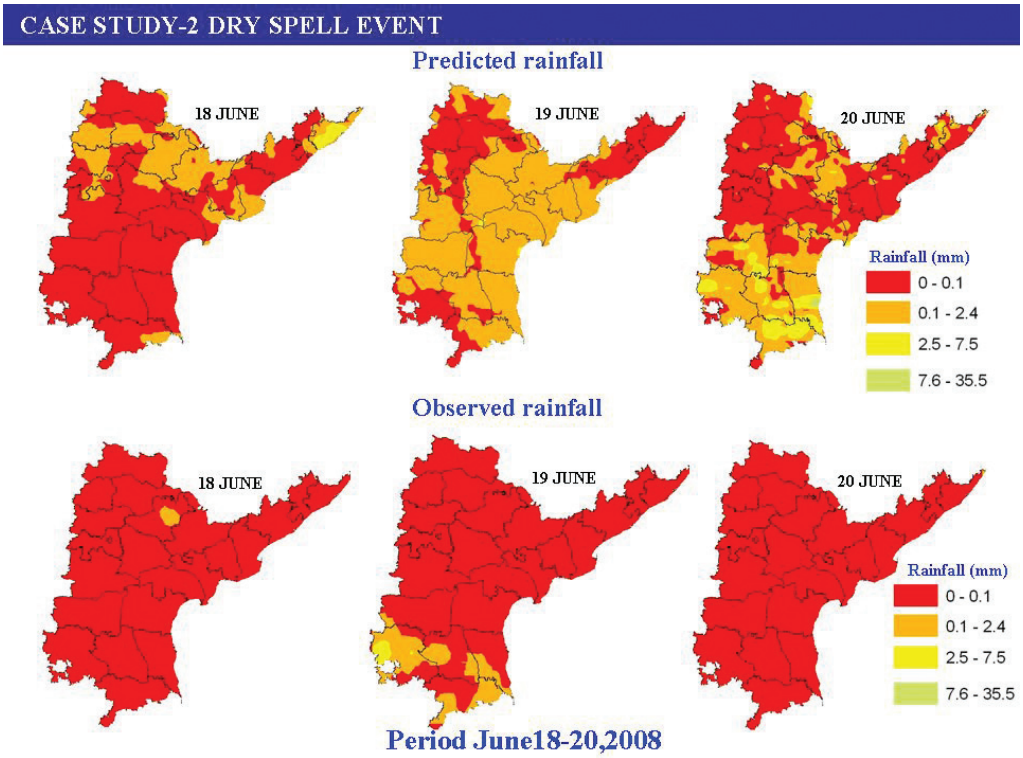


Fig 6. MM5 model forecast of dry spell event

2.1.4. Soil carbon stocks under diverse rainfed production systems in tropical India

Soil carbon pool plays a crucial role in soil quality, availability of plant nutrients, environmental functions and the global carbon cycle. Drylands are generally low in fertility, low in organic matter, and hence ideal for carbon sequestration. Carbon storage in the soil profile not only improves fertility but also abates global warming. Several soil, production and management factors influence carbon sequestration and it is important to identify production and management factors that enhance carbon sequestrations in dryland soils. To examine carbon stocks in predominant dryland soils, samples were collected from twenty one sites covering a range of climatic conditions in India under different rainfed production systems and management regimes for the last 25 years, and analyzed for carbon content. Organic carbon stocks in the soil profiles across the country showed wide variations and followed the order Vert isols>Inceptisols>Alfisols>Aridisols (Fig.7). Inorganic carbon and total C stocks were larger in Vertisols than in other soil types. Soil organic carbon stocks decreased with depth in the profile, while inorganic carbon stocks increased with depth. Among the production systems, soybean, maize and groundnut based systems showed higher organic carbon stocks than other production systems (Fig.8). The highest contribution of organic carbon to total carbon stock was found in upland rice system. Organic carbon stocks in surface layer of the soils increased with rainfall (r=0.59) while inorganic carbon stocks in soils were found to be more in the regions with less than 550 mm annual rainfall (Fig.9). Cation Exchange Capacity (CEC) showed better correlation with organic carbon stocks than with clay content in soils. These results suggest that Indian dryland soils are low in organic carbon but have potential to sequester.

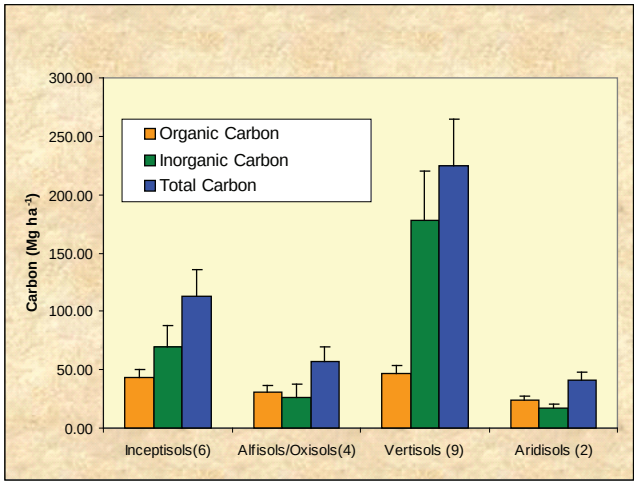


Fig 7. Carbon stocks in different soil types under diverse rainfed production systems

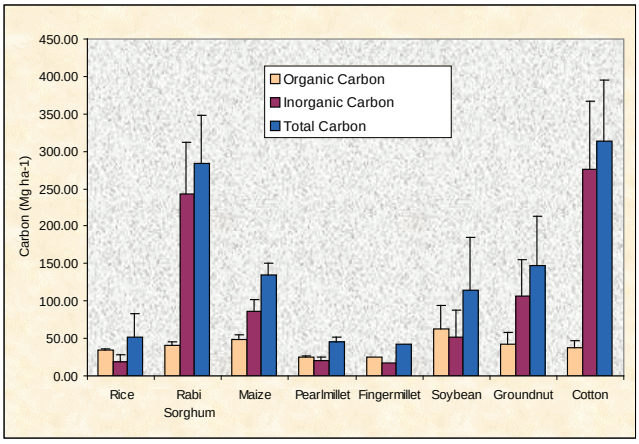


Fig 8. Carbon stocks in soils under diverse rainfed production systems

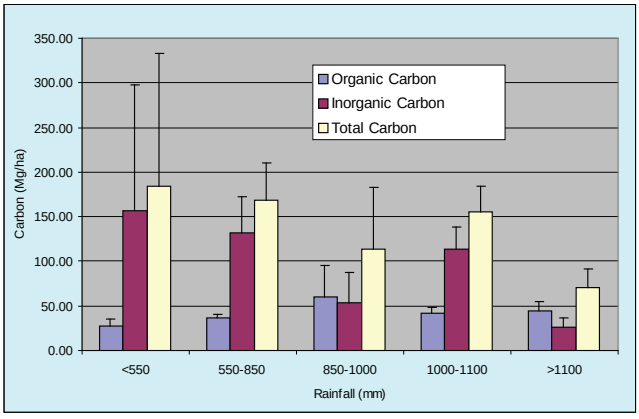


Fig 9. Carbon stocks in soils under diverse rainfed production systems in relation with rainfall

2.2. Climate Change

2.2.1. Impact of climate change on crop water requirements of wheat growing areas

Crop water requirement (CWR) is an important parameter in agriculture for selection of a crop in a given location. The crop water requirement CWR of wheat crop was calculated for the entire wheat growing areas in 11 states viz. J&K, Himachal Pradesh, Punjab, Haryana, UP, Bihar, West Bengal, Gujarat, Rajasthan, Madhya Pradesh and Maharashtra using Cropwat 4 Windows Version 4.3. Crop coefficients (Kc) were used to calculate CWR from ET. ET crop or CWR can be determined in mm per day as mean over the total crop period. The Kc values were taken from FAO (1998) and also collected from different AICRPAM centers where available.

District wise total water requirement in million cubic meters (mcm) was calculated by multiplying the district wise wheat growing area and crop water requirement for the baseline year 1990 and from climate projections of Had CM3 model the ETo and subsequently the CWR for 2020 and 2050 have been computed with an assumption that the cropped area remains the same for the projected years. The percentage deviation from the baseline year (1990) to total water requirement of 2020 and 2050 were computed and maps were generated for all the study area. State wise estimates of water requirements for the base year 1990 and the deviations for the 2020 and 2050 are given in Table 4.

In general, increase in water requirements is marginal among all the states for the year 2020 and for the year 2050 it is around 6 percent. As expected, UP is having the larger area under wheat the water requirements are also high.

Table 4. Water requirements of wheat crop in different states of India

States	Area (ha)	Crop water			water requirement (mcm)			%Deviation	
		1990	2020	2050	1990	2020	2050	2020	2050
J&K	253023	217	224	230	824	852	875	3	5
HP	367770	452	467	481	1051	1090	1119	4	6
Punjab	3468000	359	372	381	12554	13003	13318	4	6
Haryana	2316674	282	292	299	10475	10825	11158	3	6
UP	9443104	424	435	448	39718	40750	41990	3	6
Bihar	2076727	439	449	465	9046	9271	9594	2	6
WB	366729	400	407	425	1449	1480	1543	2	6
Rajasthan	2010241	485	499	512	9924	10208	10480	3	5
Gujarat	727400	605	615	631	4603	4683	4807	2	4
MP	4188248	502	513	526	21177	21655	22200	2	5
Maharashtra	932800	606	618	633	5614	5718	5859	2	4

Climate change impact and adaptation studies on sorghum

Info-crop Sorghum model was validated for Anantapur and Palem stations with an overall error percentage of 8.6 and 11.8 respectively. The predicted and actual yield showed good correlation with the R^2 values of 0.84 at Anantapur and 0.64 at Palem respectively.

After the validation of the model the crop was subjected to climate change by imposing the 2020, 2050 and 2080 Had CM3 scenarios generated by the model for different dates of sowings and different levels of CO_2 at Anantapur and Palem. The results showed that on average decrease in sorghum yield under climate change scenarios are in the order of 8%, 18% and 30% at Anantapur (Fig.10) and 2.2, 5.1 and 9.7% at Palem during the years 2020, 2050 and 2080 respectively (Fig. 11).

Later a simulation study was conducted to see how the crop behaves under changed dates of sowing as an adaptation strategy in view of delayed season sowing operations due to delayed onset of rainy season. It is observed from the results of the simulations, that to obtain atleast current level of production rates in the year 2020 (Fig.12), the sowing of the crop to be taken up after 2 weeks to match with the rainfall distribution time during the year 2020. Similarly, for attaining current level production under normal dates of sowing in the year 2020, 2050 and 2080 application of one irrigation at 45

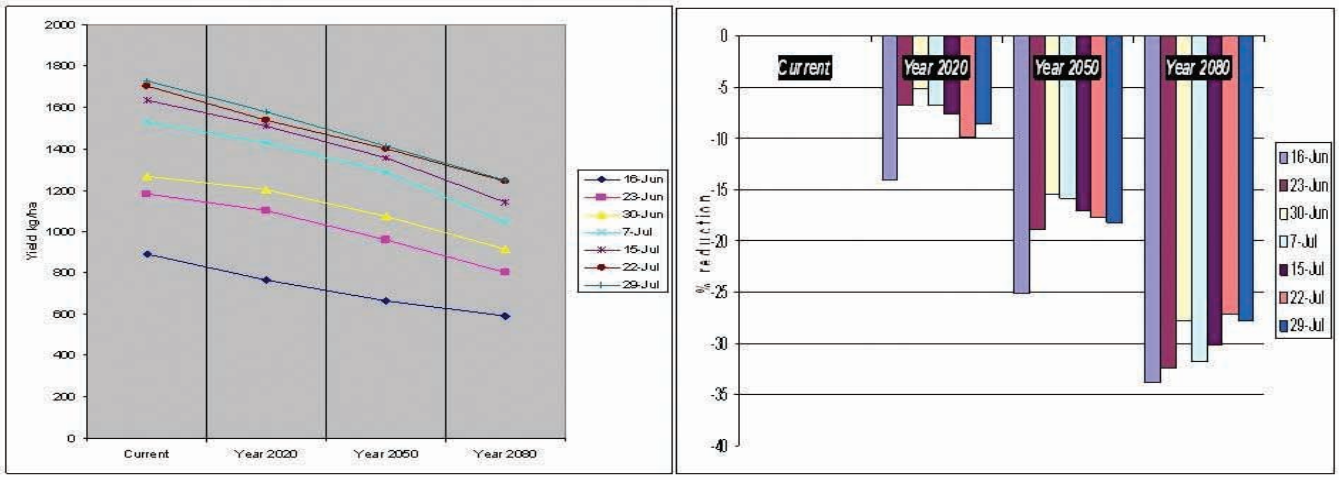


Fig 10. Impact of climate change on the yield of sorghum (kg/ha) at Anantapur

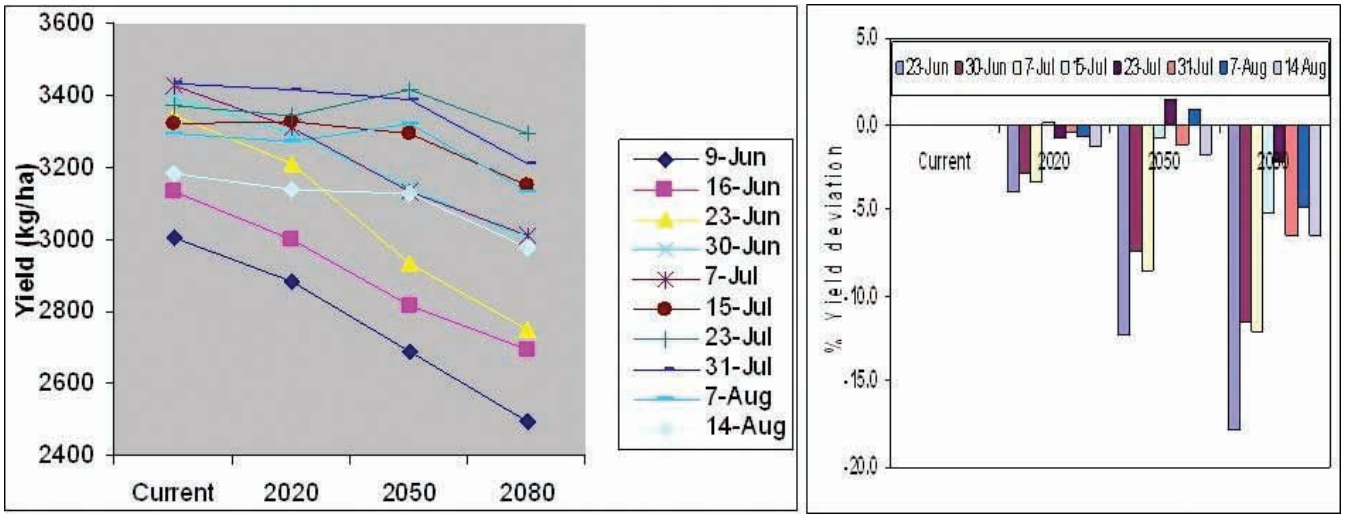


Fig 11. Impact of climate change on the yield of sorghum (kg/ha) at Palem as assessed by modeling studies

DAS has incorporated and it has improved the yields by 15 to 25% over the normal yield in 2020, while it is 5 to 10 percent over the normal yield at 2050 and is 5 to 12% over normal yield of 2050.

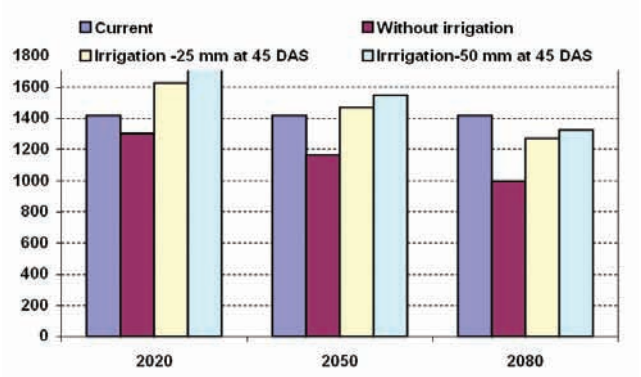


Fig 12. Percent change in the yields of sorghum after applying the irrigation at 45 DAS at Anantapur and Palem

2.2.2. Effect of elevated CO_2 on rainfed crops

Sorghum varieties *viz.,* SPV-1616 recommended for *kharif* season and M 35-1- recommended for *rabi* season were evaluated for their response to two elevated CO_2 levels (550 & 700ppm) along with ambient level (365ppm) in terms of biomass and seed yield during *rabi* 2007 and *kharif* 2008. Differential response of two sorghum varieties to elevated CO_2 was observed. With increase in CO_2 concentration, the days to flower initiation and maturity decreased in both the varieties. With doubling of CO_2, the total biomass of M 35-1 increased by 279% and seed yield by 133% as compared with ambient chamber control. Under similar conditions, the total biomass of SPV-1616 increased by 14% and seed yield by 17% (Table 5). The study revealed that increased CO_2 levels may have positive impact on *rabi* genotypes/varieties such as M 35-1 that are less efficient at present at ambient CO_2 levels as compared to more efficient varieties like SPV-1616.

Table 5. Yield and yield components (g/plant) of SPV-1616 (*kharif* sorghum) and M 35-1 (*rabi* sorghum) under elevated and ambient CO_2

	Ambient CO_2		Elevated CO_2	
	Chamber Control	Open Control	700 ppm	550 ppm
SPV-1616				
Total biomass	129.22	97.12	147.64 (14.3)	104.98 (-18.8)
Cob dry weight	60.28	33.72	71.84 (19.2)	50.36 (-16.5)
Fodder weight	68.9	63.4	75.8 (10.0)	54.62 (-20.8)
Number of seeds	1552	809	1804 (16.3)	1367 (-11.9)
Seed weight	52.02	28.44	61.04 (17.3)	43.60 (-16.2)
100 Seed weight	3.37	3.55	3.37 (0.03)	3.18 (-5.5)
Husk weight	8.26	5.28	10.80 (30.8)	6.76 (-18.2)
Harvest Index (%)	40.26	29.28	41.34 (2.7)	41.53 (3.2)
M 35-1				
Total biomass	24.0	105.1	90.84 (279)	53.34 (123)
Cob dry weight	10.6	49.3	25.66 (142)	20.22 (91)
Fodder weight	13.4	55.8	65.18 (388)	33.12 (148)
Number of seeds	277	1068	512 (85)	463 (67)
Seed weight	8.6	41.2	20.14 (133)	15.29 (77)
100 Seed weight	3.3	3.9	3.92 (20)	3.36 (3)
Husk weight	1.9	8.1	5.52 (181)	4.93 (151)
Harvest Index (%)	36.1	39.2	22.17 (-39)	28.66 (-21)

*Values in parenthesis are the percentage change over chamber control

2.2.3 Effect of elevated CO_2 on nitrate uptake and assimilation in rainfed crops

Nitrogen assimilation by plants requires carbon skeletons derived from photosynthesized carbohydrates for the synthesis of amino acids. Photosynthesis and leaf N assimilation are mutually dependent processes. Since elevated CO_2 increases photosynthesis and biomass production, it also affects the nitrogen metabolism. To examine this, nitrate uptake and assimilation studies were taken up in sunflower *(Helianthus annum)* at ambient (365 ppm) and elevated CO_2 (550ppm) levels. Sunflower *(Helianthus annum)* hybrid KBSH-1 was sown in plastic pots containing acid washed sand. These pots were placed in open top chambers (OTC) maintained at 550 ppm and ambient CO_2 conditions. The seedlings irrigated with full strength Hoagland solution without nitrate and with different concentrations of nitrate (as KNO_3) were observed for growth and dry matter production for 15 days. Seedlings grown with 5m M NO_3^- were used for induction potential for Nitrate Reductase (NR) activity. Shoots of 10 day old plants were cut 1 cm above the root-shoot junction under water and placed in 10 ml incubation medium of 0.25 Hoagland solution with 0,5,15,30 and 100 mm NO_3^-. The effect of inclusion of carbohydrate (0.2% sucrose) on induction potential was also determined. Incubation was carried out in light for 24 hours after which *invivo* NR activity was assayed.

Nitrate uptake was determined in 8 day old sunflower seedlings by ambient depletion technique at various concentrations of nitrate viz; 0.025,0.05, 0.075, 0.1, 0.2, 0.5, 1.0 and 2.0 mM. The seedlings grown under elevated CO_2 (550 ppm) had significantly higher NO_3^- uptake rates compared to ambient (365 ppm) grown seedlings (Fig 13).

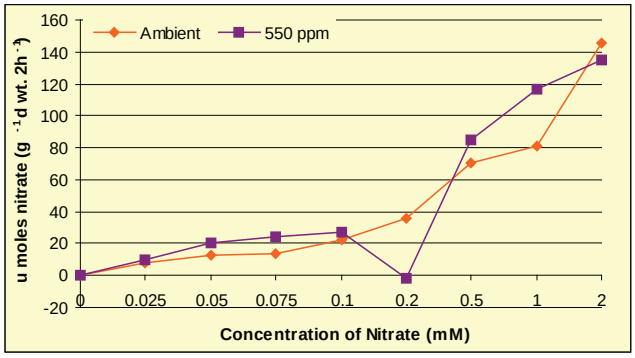


Fig 13. Nitrate uptake (µ mole g^{-1}d wt. 2 hr^{-1}) in sunflower seedlings grown under ambient and elevated CO_2 conditions as a function of the concentration of NO_3^- in the medium.

Induction potential for NO_3^- reduction by direct feeding of the excised plants with NO_3^- and energy source (0.2% sucrose) showed that plants grown under elevated CO_2 had higher potential for enzyme induction. Inclusion of NO_3^- up to 30 mM, increased the inducible activity, beyond which it decreased in both ambient and elevated CO_2 conditions (Fig 14).

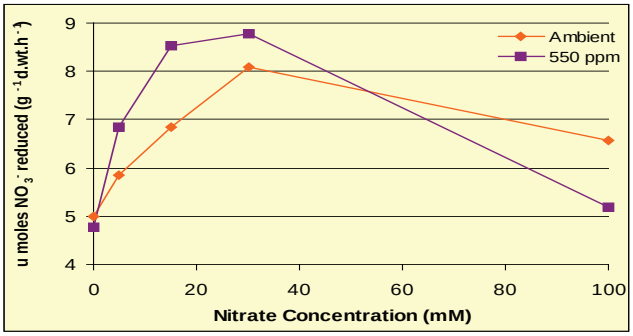


Fig 14. Inducible NR activity (µ moles NO_3^- reduced g^{-1} d. wt. h^{-1}) in sunflower grown at ambient and elevated CO_2 conditions as a function of concentration of nitrate in the medium.

Leaf area and total dry matter of 15 day old seedlings grown with 0, 5, 15 and 30 mM NO_3^- was significantly higher under elevated CO_2 compared to ambient conditions at all levels of nitrogen applied (Table 6). Increase in the dose of applied NO_3^- significantly increased the total dry weight of plants upto 15 mM and decreased there after. These results indicate greater induction potential for NR along with better uptake in sunflower plants grown under elevated CO_2 is likely to favour higher nitrate assimilation leading to more leaf area and higher dry matter production.

Table 6. Effect of elevated CO_2 and nitrogen on sunflower growth (15 DAS)

NO_3^- levels (mM)	Leaf area (cm^2/10 plants)		Total plant dry wt. (g/10 plants)	
	Chamber control (365ppm)	Elevated CO_2 (550pm)	Chamber control (365ppm)	Elevated CO_2 (550pm)
0	169.2	184.1	1.57	1.84
5	222.5	280.2	1.83	2.08
15	270.6	289.5	2.31	2.51
30	265.5	285.0	2.39	2.60
Mean	**232.4**	**259.7**	**2.02**	**2.26**
LSD at 0.05				
CO_2(C)	13.26		0.093	
NO_3^-(N)	18.76		0.132	
C x N	NS		NS	

2.2.4. Impact of elevated CO_2 on insect herbivore and host interactions

Experiments were conducted to study the impact of elevated CO_2 on insect pests of groundnut. Feeding trials using neonate larvae of *S. litura* on groundnut were performed. Groundnut plants were grown in three conditions, two elevated CO_2 concentrations 700±25, 550±25 ppm inside open top chambers (OTCs) and ambient CO_2 (350±25ppm) in the open outside the OTC.

Adaptation of insect pests under elevated CO_2 conditions

The growth, development and consumption of four successive generations of *S. litura* reared on groundnut foliage grown under elevated CO_2 (elevated and ambient) in open top chambers were examined. The life history parameters of successive second, third and fourth generations of *S. litura* were measured. The larval life span of *S. litura* fed on groundnut grown under elevated CO_2 varied significantly among the four successive generations. Significantly longer larval development duration was found under elevated CO_2 conditions. The larval duration increased over four generations from 15.5±0 in ambient to 18.5±0.7 in 550 ppm and 19.0±0 in 700 ppm. Under each CO_2 condition, gradual increase of larval duration over four generations was observed. Significantly longer larval life span for third and fourth generations was observed. (Fig. 15). Significantly lower pupal weights (0.24±0.003 to 0.22±0.003g) were observed in the second to fourth generations of the *S. litura* fed on groundnut under elevated CO_2. However, pupal weight did not significantly vary among *S. litura* generations within each CO_2 treatment. The weight of leaf ingested was reduced over generations in elevated CO_2 conditions. The ingestion was more in second generation (2.36±0.04 g.) and was gradually reduced in third (2.13±0.06) and fourth generations (1.99±0.06) (Fig. 16)

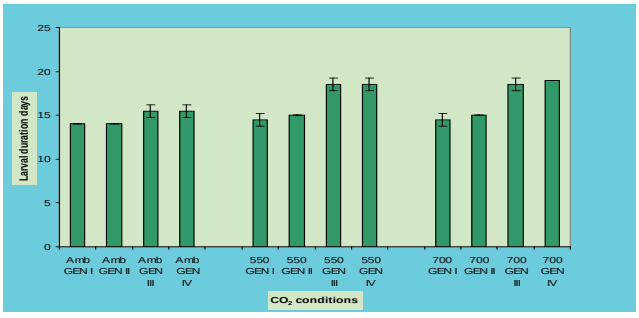


Fig 15. Larval duration in four successive generations of *S. litura* fed on groundnut under different CO_2 concentrations

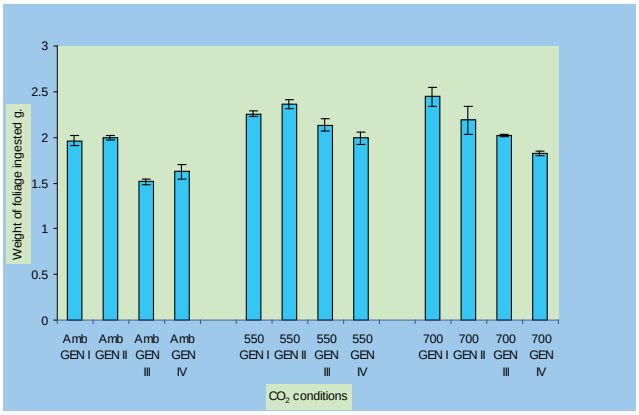


Fig 16.Weight of foliage ingested in four successive generations of *S. litura* fed on groundnut

Relationship of larval and biochemical parameters

The data on two larval parameters i.e., larval weight and weight of foliage consumed by larva were analysed in relation to biochemical constituents *viz.,* (carbon, nitrogen, C: N ratio and polyphenols of each of the foliage obtained from each treatment.

The sequential sum of squares associated with each of the independent variables indicated that nitrogen (0.025-4.744) had a relatively more contribution to the explained variation in the dependent variable. When these results are seen together with the regression coefficients, it becomes evident that nitrogen is more important in determining consumption and weight gain of the larvae. Nitrogen was found to contribute to 75 to 96 per cent of the explained variation. The contribution of carbon was found to be ranging between 3-20 per cent and that of polyphenols between 0 – 2.9 (Table 7).

Table 7. Sequential sum of squares (SSS) and percentage contribution of biochemical parameters to explained variation in larval parameters

Variable	*Spodoptera litura* on Groundnut			
	Weight consumed		Larval weight	
	SSS	%	SSS	%
Nitrogen	0.244 (86.76)	75.1	0.041 (50.46)	89.1
Carbon	0.077 (27.38)	23.7	0.004 (4.93)	8.7
Polyphenols	0.004 (1.42)	1.2	0.001 (1.23)	2.2
Regression sum of squares	0.325	100	0.046	100

2.2.5. Impact of elevated CO_2 on Bt cotton and bollworms

The project was initiated in 2007 to study the impact of elevated CO_2 on Bt cotton and bollworm *(Helicoverpa armigera)*. For this purpose Bt and Non Bt cotton were raised in OTC and different levels of CO_2 and bollworms were reared on leaf material from each treatment. Both Bt cotton and elevated CO_2 resulted in variation of body mass of the bollworm larvae and different insect performance indices. Larval life span of bollworm larvae fed with Bt cotton foliage under elevated CO_2 conditions was longer (13.5±0.07 days for 550ppm & 13.35±0.07 days for 700ppm) than larvae fed with ambient CO_2 foliage (8.75±0.07 days) (Table 8).

Significantly reduced larval weight (0.40 g for 550ppm & 700ppm) (Fig.17) and weight of leaf consumed (3.16g for 550ppm & 3.20g for 700ppm) (Fig.18) were observed in *H armigera* fed with elevated CO_2 grown transgenic Bt cotton leaf compared with non-transgenic cotton regardless of the CO_2 level.

Table 8. Impact of elevated CO_2 on larval duration of *H.armigera* in B and Non Bt cotton

Genotype	Elevated CO_2		Ambient CO_2	
	500 ppm	700 ppm	Chamber	Ambient
Bt cotton	13.55±0.07	13.35±0.07	8.8±0.28	8.75±0.07
Non Bt cotton	15.05±0.26	14.75±0.37	13.25±0.12	13.55±0.14

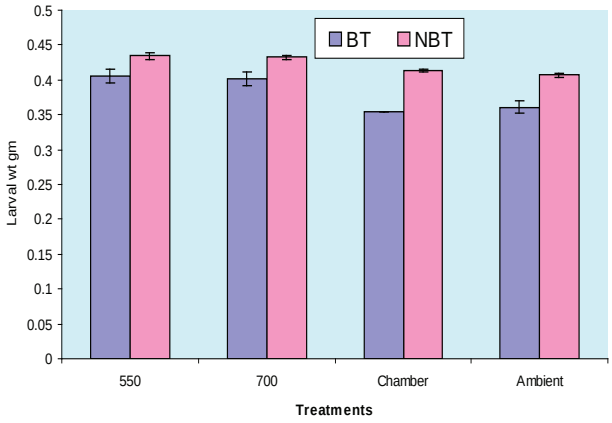


Fig 17. Impact of elevated CO_2 on larval weight of *H. armigera* on Bt and Non Bt cotton

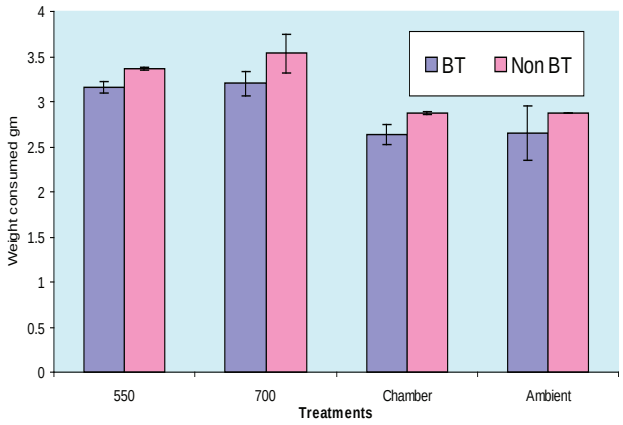


Fig 18. Impact of elevated CO_2 on consumption by larvae of *H. armigera* in Bt and Non Bt cotton

2.3. Rainwater Management

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

Availability of water yield in farm ponds in micro watersheds and its efficient utilization for crop production has gained importance to increase the water productivity and to sustain the production system in Alfisols. A study was taken up in 2008 to develop a model for prediction of water yield in a micro watershed and its efficient utilization through sprinklers with tank silt and no tank silt applications as soil amendments under supplemental irrigation and rainfed control. A micro watershed having two different land uses namely forest (5 ha) and agriculture (7 ha) was developed with drainage network to collect the rainwater into a farm pond at Gunegal Research Farm. The maximum capacity of the pond is 1500 m^3 with maximum depth of 3.5 m. Productivity of rainwater in groundnut (ICGV 91114) and Okra (Arka Anamika) with and without tank silt @ 60 t/ha was studied using two blocks of land close to the pond. One block was irrigated with harvested water through sprinklers at critical stages of crops and other block was rainfed. A 5 hp diesel engine coupled with water meter was used for operating the sprinklers and amount of diesel used for lifting water was recorded. Data on soil moisture (gravimetric method), daily rainfall, evaporation, depth of water in pond, amount of water used for crops as supplemental irrigation with 50 mm depth of application were recorded. The rated curves of the depth vs. volume and depth vs. water spread area (Fig 19) were developed to calculate the water balance components in the pond.

Sprinkler irrigation of vegetables with pond water

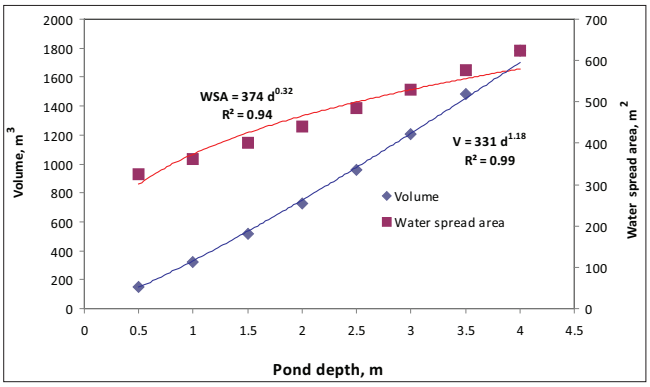


Fig 19. Depth vs volume and depth vs water spread area relationships of a water harvesting pond

Water balance in the pond

Eight runoff producing events were observed during *kharif*, 2008. Total water yield from the micro watershed was 1179 m^3 in the season. The maximum inflow of 640 m^3 was received in the month of August with 56 mm rainfall on Aug 10, 2008. The total evaporation loss was 167 m^3 and the seepage loss was 968 m^3 in the pond. The pond was not lined. The remaining 54 m^3 was used as irrigation water supplemented to the crops with sprinklers at critical stages of pod development in groundnut and after initial picking in okra.

Crop water productivity

The yield of ground nut and Okra was calculated from different treatments for the *kharif* season, 2008. The yields obtained from three replications were averaged for both the crops and the shelling percentage in groundnut was calculated. The maximum yield was obtained in the supplemental irrigation (SI) (50 mm) with tank silt application (TS) in groundnut (1147 kg/ha) and in Okra (2610 kg/ha) respectively. It was followed by no tank silt application with SI (Table 9). The maximum shelling (60%) of groundnut was obtained in SI block with TS application as compared to rainfed (54%) with the same treatment. It was 56% with no tank silt (NTS) with SI and only 48% with rainfed and no tank silt.

The effective rainfall in *kharif* 2008 was calculated as 188 mm out of the total rainfall of 397 mm received during the crop growing period. Water productivity was calculated for both the crops under different treatments. Water productivity in groundnut was maximum in SI with TS (6.10 kg/ha mm) as compared to NTS (4.49 kg/ha mm) (Fig 20). It was 3.37 kg/ha mm under rainfed condition with TS application as compared to 2.66 kg/ha mm with NTS in rainfed. In okra, the productivity (13.88 kg/ha mm) was maximum with TS in SI followed by NTS (12.61 kg/ha mm) in SI. Under rainfed conditions, water productivity of okra was 7.93 kg/ha mm as compared to 4.76 kg/ha mm with NTS.

Table 9. Average Yield and shelling of ground nut (ICGV 91114) and average yield of okra (Arka Anamika) under different treatments

Crop	Yield (kg/ha)				Shelling percentage			
	SI		RF		SI		RF	
	TS	NTS	TS	NTS	TS	NTS	TS	NTS
Ground nut *(ICGV 91114)*	1147	844	633	500	60	56	54	48
Okra *(Arka Anamica)*	2610	2370	1490	895	-	-	-	-

SI: Supplemental irrigation; RF: Rainfed; TS: Tank silt; NTS: No tank silt

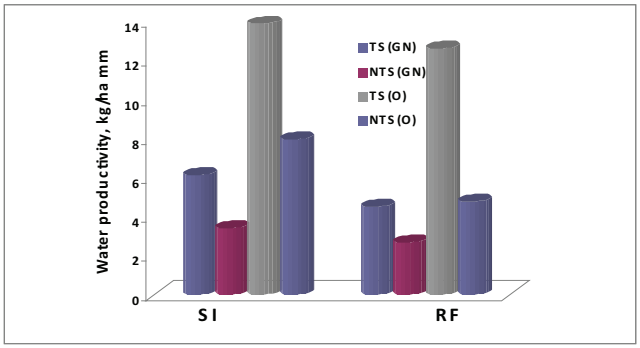


Fig 20. Water productivity in ground nut and okra with tank silt and no tank silt application under supplemental irrigation and rainfed conditions in Alfisols

2.3.2 Water productivity enhancement through in situ rain water harvesting

Development of suitable in-situ water harvesting mechanisms is important for improving the productivity of rainfed areas. Experiments were conducted in castor-pigeonpea based system. Treatments included conventional planting, conventional planting with cowpea as intercrop, paired row planting (60 cm within pair, 120 cm between pairs) and paired row planting + intercrop (2 rows intercrop at 40 cm distance) (Fig. 21). An existing ridge and furrow making equipment was used after making adjustments for sowing in the paired rows with conservation furrows.

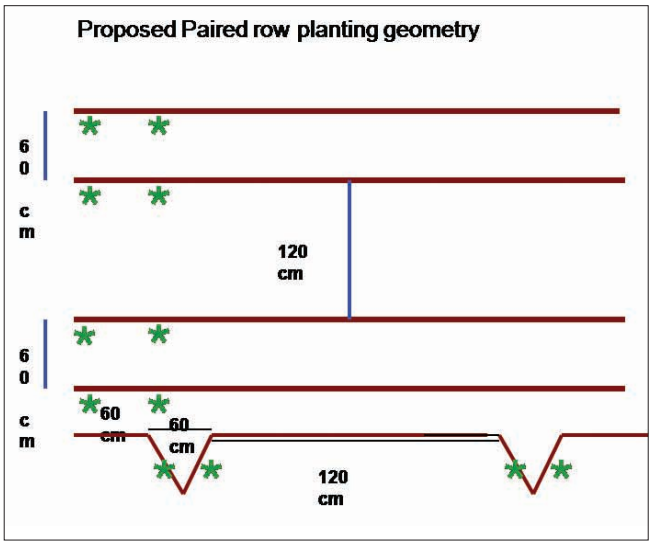


Fig 21. Crop geometry followed for paired row planting in pigeonpea system

With the paired row planting system, the threshold rainfall for causing runoff increased due to the conservation furrows, thus reducing the runoff from the field. A few problems such as limited width of furrow and compaction of surface layer due to furrow maker/ guiding mechanism were identified, which need modification of the equipment. Equivalent yields of the paired row system with pigeonpea and cowpea as intercrop indicated that there was a 30-50% increase in yield over conventional sole pigeonpea system.

2.3.3. A critical evaluation of conservation furrows in Alfisols

Conservation furrows are being recommended in cropped areas of Alfisols to intercept occasional runoff and thus enhance rainwater retention in drylands. However, earlier studies conducted at CRIDA indicated that the effect of such conservation practices may not be significant due to the limitations imposed by the low water holding capacity of the soil. Moreover, runoff generally occurs when antecedent moisture content is high and therefore any further retention of runoff may result in deep percolation only. A study was therefore initiated in 2003-04 to critically evaluate the performance of conservation furrows in terms of their effect on soil moisture and crop yield. In *kharif* 2008, different treatments viz., conservation furrows with spacings of 0.9 m, 1.8 m, 2.7 m and 3.6 m and control (i.e.. without conservation furrows) were tested in castor (variety DCS-9) crop.

The treatment differences in the yield of crop were not statistically significant (Table 10). There was no trend in the spacing of conservation furrows *vis-à-vis* crop yield. Conservation furrows at 2.7 m spacing recorded the highest castor yield of 448 kg/ha, which in itself was low because of untimely rains. In the case of mean soil moisture also, the treatment differences were not statistically significant.

Table 10. Yield of crops as influenced by conservation furrows with different spacings at GRF

Treatments	Crop Yield (kg/ha) (Castor)
Conservation furrow at 0.9 m spacing	345
Conservation furrow at 1.8 m spacing	278
Conservation furrow at 2.7 m spacing	448
Conservation furrow at 3.6 m spacing	431
Control	358

2.4. Crops and Cropping Systems

2.4.1. Varietal development

2.4.1.1. Performance of horsegram mutants in AICRP trials

Efforts are being made since 2007 to develop superior genotypes of horsegram with high yield and quality, tolerant to pests and diseases. During 2008 late *kharif*, CRIDA horsegram mutants were evaluated in two national trials by National Network Project on Arid Legumes at multiple locations in the country viz., a) Advanced varietal trial-II (AVT-II) and b) Advanced varietal trial-I (AVT-I). In AVT-II, seven entries and in AVT-I ten entries of horsegram were grown under rainfed conditions with a spacing of 30cm between rows and 10 cm between plants within the rows. The crop was grown purely under rainfed conditions without any fertilizer. Data on yield

and its components are given in Table 11. In AVT-II, HG-9 was the highest yielder with highest number of branches per plant. HG-14 was earliest to mature but had lower values for grain yield, fodder yield, branches per plant and pods per plant. In AVT-I, HG-31 recorded highest grain yield as well as fodder yield and had the highest no of seeds per pod along with high (100 seed) test weight. HG-35 was the earliest to flower and maturity.

Table 11. Range and averages of the characteristics in each of the two trials at the CRIDA Centre

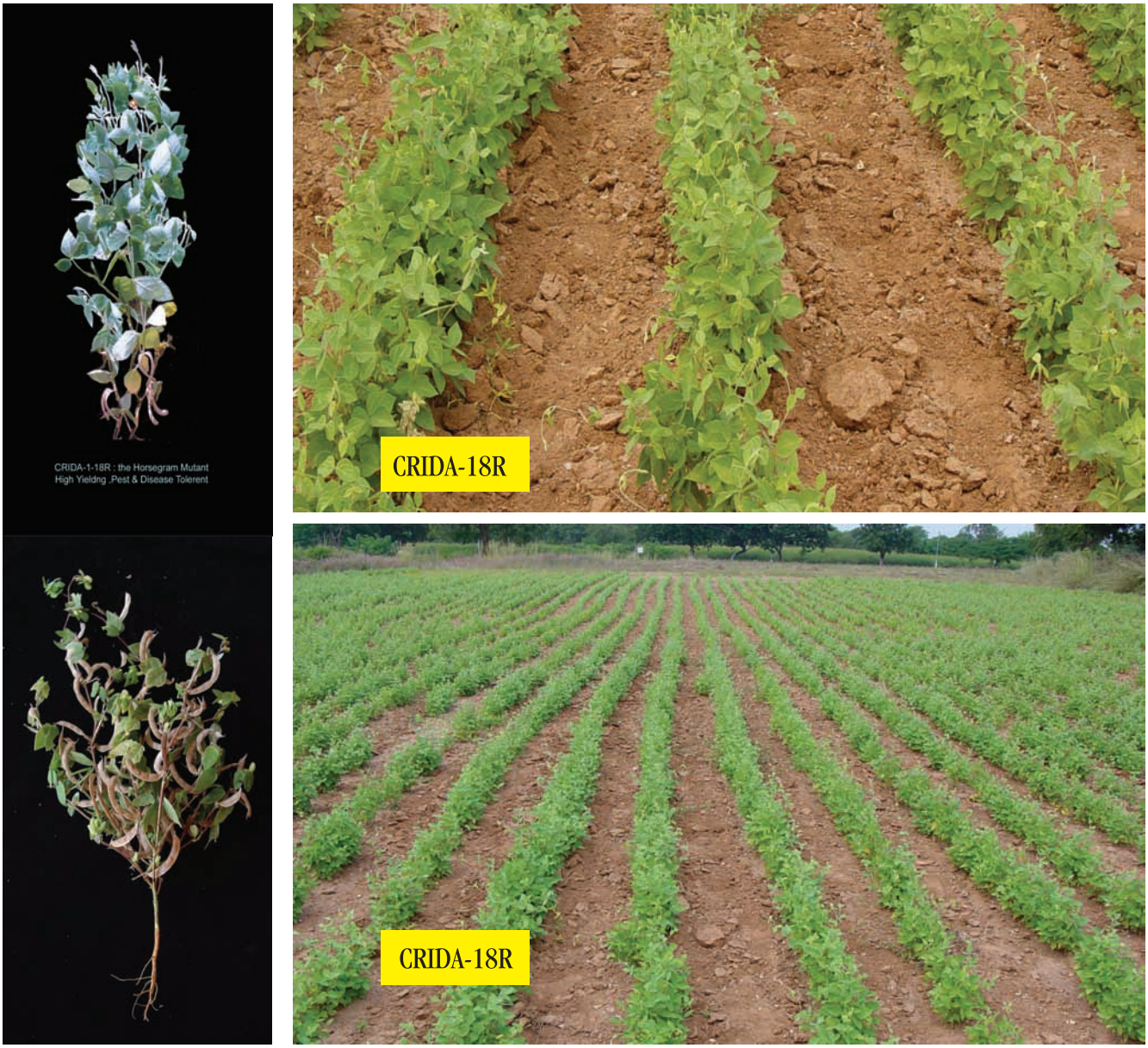
Characteristic	AVT-II					AVT-I				
	Highest genotype value		Lowest genotype value		Average value	Highest genotype value		Lowest genotype value		Average value
Grain yield (kg ha^{-1})	953.1	HG-9	359.6	HG-14	693.1	977.0	HG-31	373.4	HG-33	663.8
Fodder yield (kg ha^{-1})	919.0	HG-11	255.7	HG-14	659.6	749.7	HG-31	250.2	HG-34	501.8
Days to 50% flowering	62.0	HG-13	39.0	HG-12	50.0	62.0	HG-34	38.0	HG-35	49.5
Days to maturity	101.0	HG-13	74.0	HG-14	84.1	102.0	HG-34	72.0	HG-35	82.7
Plant height (cm)	30.8	HG-8	21.5	HG-12	25.4	33.7	HG-26	19.3	HG-33	25.8
Branches per plant (no.)	6.5	HG-9	3.3	HG-14	5.12	4.4	HG-34	2.4	HG-30	3.5
Pods per plant (no.)	28.2	HG-10	7.0	HG-14	20.3	38.4	HG-29	7.0	HG-30	25.4
Seed per pod (no.)	4.3	HG-14	3.6	HG-13	3.91	4.9	HG-31	3.9	HG-28 HG-33 HG-34	4.1
100 Seed weight (g)	3.1	HG-10 HG-11	2.9	HG-13	3.01	3.1	HG-27 HG-28 HG-31	2.6	HG-35	2.9

Horsegram mutant CRIDA-18R released

CRIDA's first ever variety released and notified: The Central Government, after consultation with the central seed committee, notified CRIDA 18R for whole of India through Extraordinary Gazette of India-S.O. 454(E) on 11th February 2009. Salient features of this variety are:

- Suited to Southern states under rainfed conditions
- Early maturing (85-95 days)
- Large pod number (up to) 45 per plant
- Brisk and more synchronized podding behavior
- Tolerant to Yellow Mosaic Virus, Powdery Mildew and Mites
- Brown seeded
- Tolerant to shattering of pods
- Superior quality with 29.01% crude protein
- Responds to fertilizer up to 20N+40P2O5
- Seed rate: 20-25 kg ha-1
- Sowing in south India: September
- Spacing of 30x10 cm

In farmers fields, CRIDA-18R recorded a mean grain yield of 912.0 kg/ha in various districts of AP and recorded an increase of 40.43% (Range of 26.6 to 74.7%) over the local varieties during 2006-07 to 2008-09.

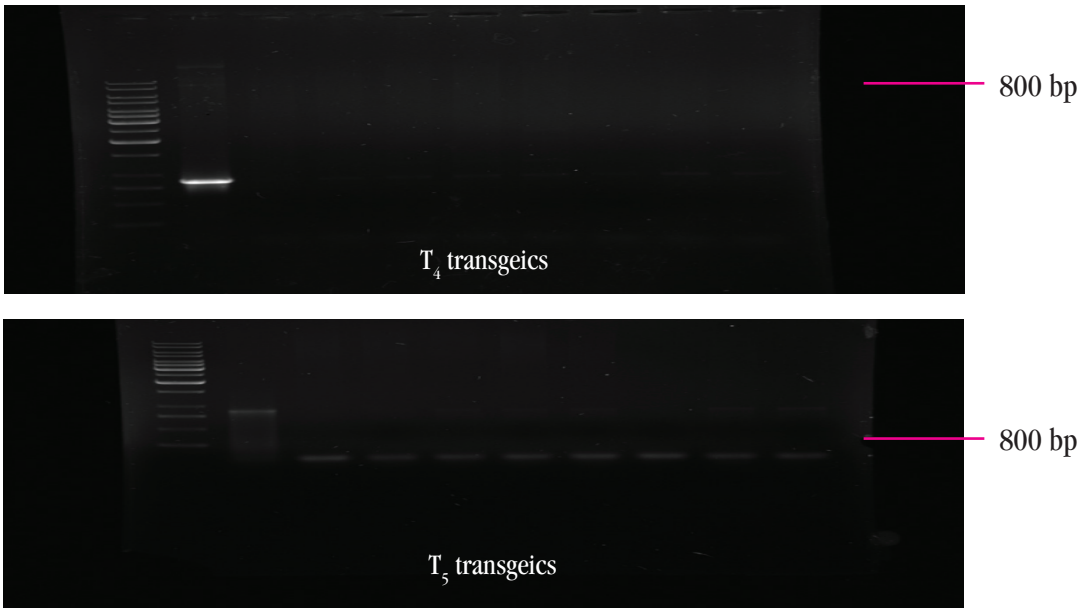


CRIDA-18R, single plants (vegetative & dry pod stages), field view (close up and distant)

2.4.2. Enhancing drought tolerance through transgenic approach

2.4.2.1. Enhancing tolerance of sorghum to abiotic stress

Development of stress tolerant genotypes in sorghum, an important staple food crop of drylands is of immediate priority. In this research project, transformation of sorghum cv. SPV 462 with *mtlD* gene (mannitol-1-phosphate dehydrogenase which catalyses the conversion of mannitol-1-phosphate to mannitol) for biosynthesis of mannitol was attempted. During this year, molecular and physiological characterization of the transgenics and advancement of generation was carried out. Total genomic DNA was isolated from T_4 and T_5 transgenic plants raised in transgenic glass house. PCR analysis carried out using *mtlD* gene specific primers showed the amplification of a product of 800 bp and confirmed the presence of the transgene in most of the T_4 and T_5 plants.



PCR confirmation of transgenics (mtlD) with gene specific primers

T_4 seed of transgenic plants was collected for advancement of generation. These seeds were germinated on hygromycin selection pressure. The selected progeny of T_4 seeds (T_5 plants) were then transferred to pots and were raised in transgenic glass house. They were subsequently selfed and the seed of individual ear heads were harvested on maturity for further advancement of generation.

***mtlD* transgenics (T_4) at reproductive stage**

One month old pot grown plants of untransformed control and four independent transgenic lines were subjected to water deficit stress for 15 days. Observations were recorded on relative water content (RWC), proline content, total soluble sugars, chlorophyll content and activity of nitrate reductase (NR), the rate-limiting enzyme in the nitrate assimilation pathway, at peak stress and 48 h after re-watering. The results indicated the relatively superior performance of some of the transgenic lines compared to untransformed controls when challenged with water deficit stress. Native polyacrilamide gel electrophoresis (PAGE) analysis was also conducted for activity of RUBP carboxylase/oxygenase (RUBISCO). Rubisco activity on native PAGE indicated relatively better retention of enzyme activity under stress as well as better recovery upon re-watering in transgenics as compared to the untransformed plants. Fully expanded leaves from T_4 plants of *mtlD* transgenics and SPV 462 were also assessed for the excised leaf water retention capacity (ELWRC), as this is an important criterion for drought tolerance in sorghum. Results indicated that the ELWRC was higher in transgenics than in untransformed controls (Fig. 22).

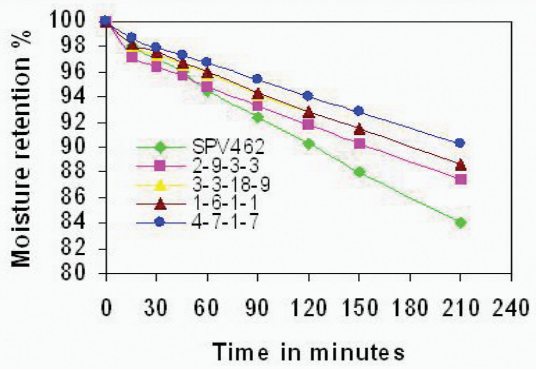


Fig. 22. Excised leaf water retention capacity (ELWRC) in *mtlD* transgenics at vegetative stage.

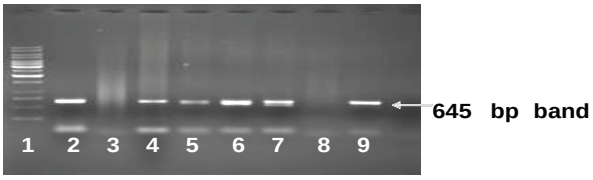
2.4.2.2. Genetic transformation of greengram *(Vigna radiata L.)* for enhancing abiotic stress tolerance

Drought is single most important abiotic stress limiting greengram productivity under rainfed situations. Due to the narrow genetic resource base for desirable traits in the available germplasm, direct introduction of alien genes of useful triats through transgenic approach offers a practical solution to combat drought stress. To this effect, various explants were tested to evolve an efficient regeneration system using different concentrations of plant growth regulators. Genetic transformation of double cotyledonary node (DCN) explants to develop transgenic greengram with *annexin bj* gene (cv. ML 267) was carried out by using *Agrobacterium* mediated approach. Molecular analyses of the transgenic material was undertaken to establish integration and expression of the transgene.

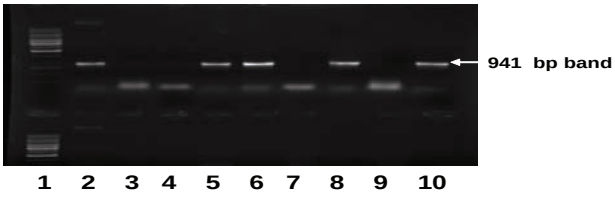
Development of transgenic greengram with *annexin bj* gene and molecular characterization of transgenic plants

The conditions optimized earlier for best regeneration and transformation response were used to develop transgenic greengram with *annexin bj* gene by *Agrobacterium* mediated approach. The transformation of DCN explants was carried out by using LBA 4404 strain of *Agrobacterium tumefaciens* harbouring pCAMBIA 2301 binary vector containing *annexin bj* gene under the control of CaMV 35 S promoter. The transformants were selected on 100mg/l kanamycin in multiple shoot induction medium (MS B_5 containing BAP and NAA) for first 30 days of culture. Subsequently, the kanamycin concentration was reduced to 50 mg/l for next cycle of 30 days in shoot elongation and proliferation medium (MS B_5 containing reduced levels of BAP and NAA). The regenerated shoots were rooted on ½ MS B_5 medium and were taken to maturity in a transgenic glass house after primary hardening. The leaf genomic DNA of these T_0 plants was analyzed by PCR using *npt II* primers. Thirteen T_0 plants that showed amplification of 645 bp band, thus confirming the integration of transgene, were taken to maturity. T_0 seed from these plants was collected and sown in pots to raise T_1 plants. The leaf genomic DNA from the T_1 plants was analyzed by PCR using gene specific primers. Out of the 70 T_1 plants tested, 33 showed amplification of 941 bp band, thus confirming the transgene integration. Constitutive GUS expression was also observed in T_0 seeds, young T_1 leaves and flowers.

Rooting and primary hardening of a transgenic shoot of green gram



PCR verification of T_0 putative transgenics in greengram using npt II primers. Lane 1:MW Marker, 2: Positive Control, 3: Negative Control, 4-9: T_0 putative transgenic plants



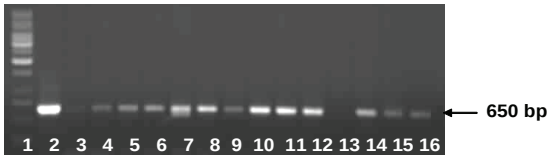
PCR verification of T_1 putative transgenics in green gram using gene specific primers Lane 1:MW Marker, 2: Positive Control, 3: Negative Control, 4-10: T_1 putative transgenic plants

2.4.2.3. Standardization of Agrobacterium mediated transformation conditions for blackgram

To mobilize genes of proven agronomic importance into the elite background of blackgram genotypes, there is an urgent need to develop robust transformation protocols. An efficient transformation protocol was developed and the details are described below: The seeds were soaked in water and kept in dark for 18 hrs. The water imbibed seeds were decoated and the cotyledons were separated very carefully. The cotyledon along with embryonal axis placed on MSB_5 medium containing 4.00 mg/l BAP. Ten day old cotyledon derived callus explants of

cultivar T 9 of blackgram were inoculated with *Agrobacterium tumefaciens* strain LBA 4404 harbouring binary vector pCAMBIA 2301. The vector had *nptII* for plant selection and *uid A* gene for GUS activity. The *uidA* gene had a intron to prevent expression of GUS by the bacterial cell culture. A transformation frequency of 3.8% was achieved by manipulating concentration of bacterial cells (10^8), acetosyringone (100µM) and cysteine (330µM).

The infected explants were initially cultured on MSB_5 medium containing 4.00 mg/l BAP for first 15 days. The regenerated shoots appearing were now elongated on ½ MS medium for 10 days. The elongated shoots were successfully rooted by IBA pulse treatment. The leaf genomic DNA isolated from T_0 plants was tested by PCR for transgene integration using *npt II* primers. Amplification of 650 bp band confirmed integration of transgene. Only the PCR positive T_0 plants were taken to maturity and T_0 seed was collected. Constitutive GUS expression was also observed in T_0 seeds and T_1 flowers. Segregation of progeny of T_0 seed based on inheritance of *nptII* gene was analyzed by PCR. A segregation ratio of 3:1 confirmed the Mendelian inheritance.



PCR verification of T_1 transgenics lines in blackgram using npt II primers. Lane 1: MW Marker, 2: Positive Control, 3: Negative Control, 4-16: T_1 segregating transgenic plants

2.4.3 Studies on root characteristics in rainfed crops

Roots play critical role during drought response management measures. Roots interact closely with soil depth and environmental factors like texture and moisture holding capacity. Therefore, it is imperative to study and understand root morphology and architecture in the soil profile and fine-tune some of the drought management measures. A study was initiated in 2007 to understand the root growth dynamics in terms of proliferation of roots of greengram and horsegram under varied resource use with suitable root chambers. Greengram (WGG-37) was grown in a net house in fabricated root chambers with dimensions of 30X15X15 cm. Soil from Hayathnagar Research Farm was filled to capacity in the root chambers, simulating the soil profile of top three soil depths. A small drainage hole was made at the bottom. Treatments consisted of 50% Field capacity (FC) and 100% FC. In addition to the increased rooting depth of the greengram tap root under moisture stress, when subjected to water deficits only at flowering stage, the number of primary lateral roots were affected at 50% FC. It was observed that not only the number of primary lateral roots was reduced in the topsoil depth (0-15 cm) but also the primary lateral root length, while increased number of primary laterals but reduced root length was recorded in the second soil depth (15-30 cm).

2.4.4. Organic crop production

2.4.4.1. Organic production of sesame

A long-term field trial is under progress at Gunegal Research Farm(GRF) since *kharif* 2005 for studying the feasibility of organic sesame production and also to compare organic and conventional production practices on yield and oil quality besides other parameters like soil health and nutrient loss. Sesame - pigeonpea rotation was followed in the trial. The treatments imposed for sesame (cv. Swetha) in *kharif* 2008 were (a) control (no inputs), (b) organic (meeting the requirements through permitted organic inputs on nutrient equivalent basis) and (c) conventional or inorganic (recommended package of practices for the area).

Crop performance

The number of days taken for flowering was similar under both organic and conventional production systems (Table 12). The number of pods/m^2, the grain and stalk yields were higher under conventional production compared to other treatments. In the first three years, organic sesame yield was about 20% less compared to conventional. However, in the fourth year, the grain yield reduction under organic production was only 7.7% compared with conventional production indicating that the yield levels under organic farming may further improve over the years.

Table 12. Performance of sesame under different production systems (GRF, *kharif* 2008)

Treatment	Days to 50% flowering	No. of pods/m^2	Seed yield (kg/ha)	Stick yield (kg/ha)
Control (No input)	50	144	141	563
Organic	46	384	285	977
Conventional	45	441	309	1206

Soil fertility

Analysis of the soil samples collected after the harvest of sesame are presented in Table 13. Organic cultivation of sesame resulted in the build up of soil organic carbon (0.81%) as compared to conventional (0.76%) and control (0.72%) treatments. The electrical conductivity (EC) was also highest (0.393 dS/m) in the soils under organic management compared to other treatments. Similarly, the available potassium content was highest (255 kg K/ha) under organic management as compared to conventional and control treatments, which might be due to addition of potash-rich ash for meeting the nutritional requirement. However, no definite trend was found with respect to DTPA-extractable micronutrients among different production systems even after four years of experimentation.

Table 13. Soil properties under different production systems after four years of experimentation

Soil property	Production system		
	Control	Organic	Conventional
pH	6.12	6.10	6.20
EC (dS/m)	0.116	0.393	0.127
Organic C (%)	0.72	0.81	0.76
Available P (kg/ha)	34	37	38
Available K (kg/ha)	177	255	208
DTPA-Zn (ppm)	0.65	0.67	0.67
DTPA-Cu (ppm)	0.77	0.73	0.78
DTPA-Mn (ppm)	10.95	10.44	12.11
DTPA-Fe (ppm)	27	27	29

2.4.4.2. Organic production of pigeonpea

The project was initiated in 2005 to examine the feasibility of producing pigeonpea and sorghum in drylands using approved organic production inputs and practices and to compare organic, integrated and chemical production packages in terms of crop productivity, production costs and returns. This was the fourth year of the experiment. Pigeonpea (PRG 158) and sorghum (SPV 462) were grown with six production packages: 1. High input chemical (HIC), 2. Low input chemical (LIC), 3. Integrated (INT), 4. Zero input (ZIP), 5. Low input organic (LIO) and 6. High input organic (HIO). The packages differed in respect of inputs and practices used for supplying nutrients to the crops and for controlling crop pests and diseases. The highest grain yield of sorghum (Fig 23) was obtained with the high input chemical package (2853 kg/ha) followed by the low input chemical package (2663 kg/ha). The organic packages gave lower yield compared to chemical and integrated packages. Considering only package specific labour and inputs, the high input chemical package (Table 14) was the most labour intensive (6 person days/ha) and input intensive (Rs. 1732/ha) followed by the high input organic package (5 person days labour and 1600 Rs inputs/ha).

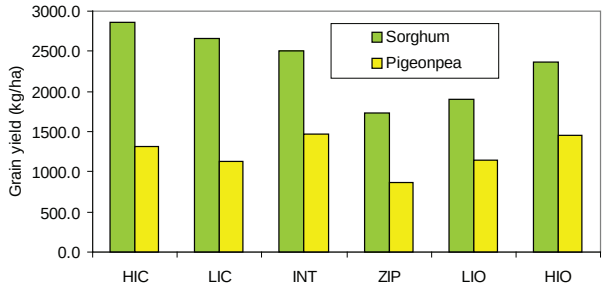


Fig 23. Grain yield of sorghum and pigeonpea with different production packages

In case of pigeonpea, the highest grain yield (1468 kg/ha) was obtained with the integrated package (Fig 23), followed by the high input organic package (1447 kg/ha). Marked differences in grain damage were observed between production packages. The lowest combined grain damage (13%) by lepidopterans and pod fly was observed with the high input chemical package, followed by the integrated package (14.67%). The high input organic package (Table 14) was most labour and cost intensive, requiring 12 persondays additional to routine crop production requirements, and Rs. 3312 for package related inputs per hectare. The integrated package, which gave the highest seed yield was far cheaper in terms of inputs (Rs 1206/ha), although the labour requirement was high (11 persondays/ha).

Table 14. Labour requirement and input costs with different production packages in sorghum and pigeonpea

Production package	Sorghum		Pigeonpea	
	Labour (persondays/ ha)	Input costs (Rs./ha)	Labour (person-days/ ha)	Input costs (Rs./ha)
HIC	6	1732	3	1994
LIC	2	1153	2	1338
INT	3	877	11	1206
ZIP	0	0	0	0
LIO	1	300	11	562
HIO	5	1600	12	3312

2.4.5. Integrated pest management

2.4.5.1. Population dynamics of cotton mealy bug in Andhra Pradesh

Mealybug *(Phenococcus melonopsis)* is an important emerging pest on cotton with a low but wide spread occurrence observed for the first time during 2007 season in Andhra Pradesh. Field surveys were conducted during 2008 *kharif* (August to November) in 18 intensively cultivated villages of Warangal district to quantify the extent of infestation and its natural parasitization. Initially, mealybug incidence was confined to 15-20 plants (>1 branch infested) per acre during August, which later assumed a more uniform distribution by mid-October with a mean plant infestation of 35% and a range of 21 to 61% across villages. Both Bt- and non Bt-cotton cultivars were similarly infested.

Mealy bug infested plant

Field parasitized mealybugs were identified by the presence of exit hole on mummified bodies of mealybugs. Two Hymenopteran parasitoids emerged from field-collected mealybug samples. Solitary endoparasitoid, *Aenasius* sp. (Family: Encyrtidae) emerged from reddish brown cocoons by making a round exit hole. Another unidentified parasitoid (0.4mm in size) emerged from mummified mealybugs. The extent of natural parasitisation was between 8 to 26% and the dominant parasitoid was the Encyrtid.

The survey revealed that mealybug assumed pest status on cotton in Warangal during *kharif* 2008 season and farmers relied solely on application of 2-4 insecticide sprays for its control. The field survey for the first time reports the extent of natural parasitization of mealybug on cotton in Warangal district.

Exit hole on mummified bodies of mealy bugs

Exit hole of *Aenasius* sp. On cocoons

2.4.5.2. Development and evaluation of low external input IPM modules in pigeonpea and castor

The project was initiated in 2007 to find out low external input IPM (LEIIPM) measures as modules for the control of insect pests of dryland crops *viz.,* pigeonpea and castor. Two low external input IPM modules were evaluated along with integrated and chemical modules in effective diversified crop systems identified in earlier studies. The sequential application of various components was adopted in different ways. The low external input IPM modules in pigeonpea were, 1. High chemical pest control: Application of monocrotophos 0.05%, Endosulfan 0.075%, Dimethoate 0.05%, 2. Integrated: NSKE 5%, Endosulfan 0.075%. Ha NPV 500 LE/ha, 3. Low external input IPM I: Neem Seed Kernel Extract (NSKE) 5%, extract of *Vitex negundo* 1/10 w/w, NSKE 5% and extract of custard apple 5%, 4. Low external input IPM II: Neem oil 5%, Pongamia oil

Table 15. Impact of LEI IPM on Cumulative Pest Units in Pigeonpea, 2008-09

Treatments	Gram pod borer		Jassids	
	CPU	Mean	CPU	Mean
High chemical	4.33±1.15	0.54 ±0.14	36.67 ±2.52	4.58 ±0.31
Integrated	2 ±1.0	0.25 ±0.13	41 ±3.06	5.12 ±0.38
LEIIPM I	3 ±1.53	0.37 ±0.19	41 ±4.58	5.12 ±0.57
LEIIPMII	7.66 ±1.0	0.95 ±0.13	40.67 ±4.62	5.08 ±0.58
Zero input	10.66 ±1.53	1.33 ±0.19	50 ±8.72	6.25 ±1.09

5%, Jatropha oil 5%, 5. Zero input - untreated check without any applications. All modules excepting high chemical and zero input included bird perches and mechanical collection of larvae by shaking of the plants. Modules for castor were same as those for pigeonpea except that in integrated package, instead of Ha NPV, Bt @ 0.5kg ai/ha was included and there was no mechanical collection of larvae in any of the modules.

Population of jassids both interms of CPU (Cummulative Pest Units) and mean population) on pigeonpea was highest with zero input module and lowest with high chemical module (Table 15). Both the LEIIPM modules reduced the intensity of jassids. Gram pod borer *(Helicoverpa)* population was least with integrated module followed by LEIIPM I module. Grain damage by lepidopteron borers was pooled and was significantly lower in integrated (7.56±0.40%) and high chemical treatments (8.07±1.62%) as against 19.98±2.14% with zero input module (Fig 24). The best yields (8.75 and 8.81 q/ha) were obtained with integrated and high chemical modules respectively as against 5.64 q/ha with zero input. The low external input IPM modules in pigeonpea and castor-intercropping systems were found to be economical. Higher marginal rate of returns of 6.35± 1.74 & 6.35±1.58 in pigeonpea and 4.47±0.46& 4.06±0.84 in castor were observed with LEIIPM modules I and II respectively.

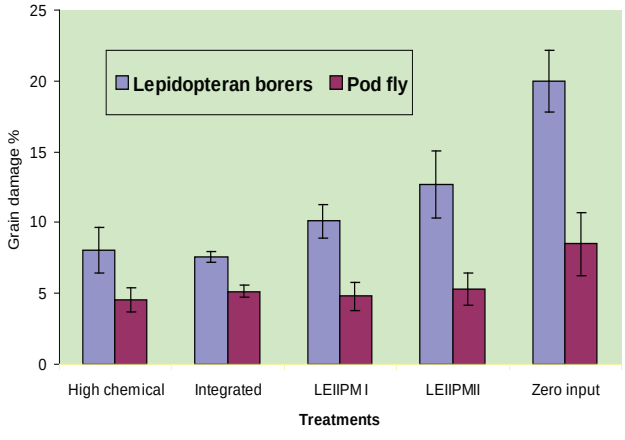


Fig 24. Grain damage in pigeonpea with different pest management modules

2.4.5.3. Application of wireless sensor networks for development of decision tools for crop pest management

A wireless sensor network was established at the research farm by the Centre for Development of Advance Computing (CDAC), Hyderabad. Incidence of leaf miner and late leaf spot disease were monitored during *kharif* and *rabi* seasons along with weather. Triggering weather factors in association with crop age for disease appearance and progress were identified. Field based degree-day model with first trap catch as 'bio-fix' (starting) date for forecasting the peak adult moth emergence of groundnut leaf miner was calculated.

Monitoring groundnut leaf miner using delta-sticky traps with pheromone lure

2.4.6. Agriculturally important microorganisms in crop management

2.4.6.1. Isolation and characterization of agriculturally important microorganisms

Collection of isolates from different stressed agro-ecosystems

Following a Rover's method of survey and sampling, 152 soil samples have been collected from rhizosphere regions of crops grown in saline and high temperature areas (Fig 25) for isolation of *Pseudomonas.* One hundred and twenty strains have been isolated using *Pseudomonas* selective media.

Fig 25. Strains of agriculturally important microorganisms collected from different agro-ecological regions

Abiotic stress tolerance in Pseudomonas strains

Out of the 75 strains of *Pseudomonas* spp., 23 strains showing high temperature, salinity and/or drought stress were further tested for their threshold levels for these stresses (Table 16). At 50ºC, P28 strain could grow with a population of $12X10^6$ cfu mL^{-1}. Similarly, P21 was tolerant of $163X10^3$ dS m^{-1} where as P20 and P22 could tolerate up to $143X10^3$ dS m^{-1}. At $23.2X10^2$ dS m^{-1}, P37 and P43 showed a viable count of $22X10^4$ and $44X10^5$ cfu mL^{-1}, respectively. P42 could tolerate $166.6X10^3$ dS m^{-1} salt concentration with a viable count of $8X10^5$ CFU mL^{-1}. At–1.8 MPa, P62, and P17 showed higher colony counts followed by P67, P59, P64 and P70. *Pseudomonas* strains P62, P17 were found to be tolerant of higher drought stress (-1.8 MPa), P42 and P43 strains were tolerating $22X10^2$ dS m^{-1} salt concentration. P17 *Pseudomonas* strain which promoted the growth of both sorghum and pigeonpea in all respects was tolerant of drought (40% PEG or–1.8 MPa). The tolerance limits of strains of *Pseudomonas* spp. to various abiotic stresses are presented in tables 1.

Biocontrol ability

Biocontrol ability of all strains of *Pseudomonas* was evaluated using dual culture method. Among these, thirty strains were characterized with biocontrol potential. Four strains (PI 20, 21, 59 and 43) could inhibit the growth of all the five test phytopathogens. Apart from these, 13 strains were effective against *Botrytis ricini,* five strains against *Fusarium ricini,* six strains against *Rhizoctonia solani,* and 11 strains against *Macrophomina phaseolina* while three strains were effective against *Sclerotium rolfsii.*

Table 16. Tolerance limits of strains of *Pseudomonas* spp. to increasing salt concentrations *in vitro*

Salinity		Drought		High temperature	
Salt conc. (M)	Surviving strains	Drought (MPa)	Surviving strains	Temperature (°C)	Surviving strains
1.2	PI 20, PI 21, PII 77, PII 35	-1.2	PI 67, PI 65, PI 64, PI 73, PI 77, PI 76, PI 78, PI 79, PI 80, PI 82, PI 83, PII 57, PII 26	47	PI 78
1.36	PI 42, PI 80, PI83, PII 39, PII57	-1.4	PI 74, PI 81, PI 84, PII 72, PII 62, PII 70, PII 14	48	PI 84, PII 26, PII22
1.54	PI 8, PI 78, PII 70, PII 48, PII 4	-1.5	PI 70, PII 35	50	PI 12, PI 14, PI 15, PI 20, PI 21, PI 8, PII 70, PII 35, PII 30, PII57
1.71	PII 88, PII 26, PII 22			52	PII 34
1.88	PI 37, PI 43, PI 79, PII 34, PII 14				
2.05	PI 84				

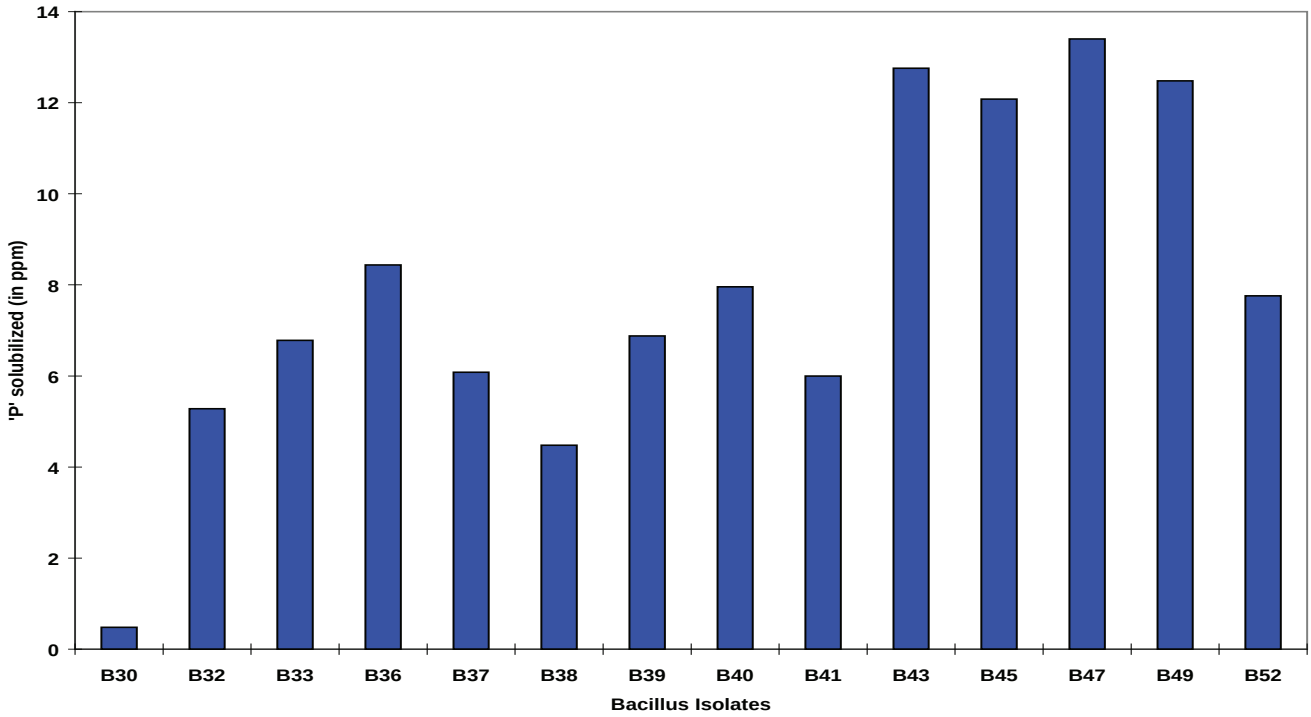


Fig 26. Phosphate solubilization by 14 *Bacillus* isolates

2.4.6.2. Phosphate solubilization by *Bacillus* strains

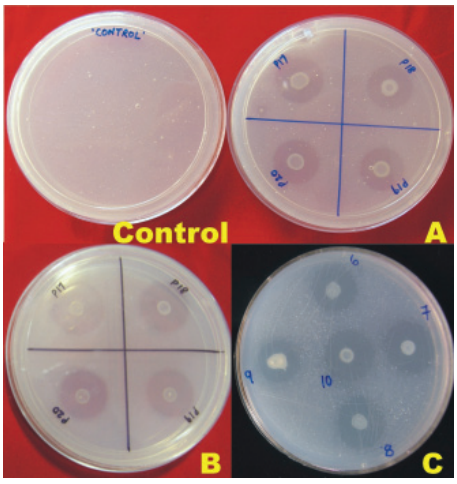
Out of 14 *Bacillus* spp. isolates, B47 solubilized up to 13 ppm phosphorus followed by B43, B49 and B45 showing 12.7, 12.2 and 12.1 ppm, respectively. Of all the isolates, B30 solubilized least phosphorus i.e., 1 ppm. In all the remaining isolates, solubilization ranged between 4-9 ppm (Fig 26). Similarly, out of 24 strains of *Azospirillum*, six were able to solubilize Tricalcium-phosphate. B43 isolated from rhizosphere of pearl millet showed maximum P- solubilization with 26% efficiency.

2.4.6.3. Characterization of PGPR traits

Out of 108 isolates of *Bacillus,* 80 were cellulase-producers, 88 were protease-producers, none were HCN-producers, 48 isolates were positive for IAA, 28 isolates were positive for Gibberellic acid production and 80 isolates were positive for ammonia production. Similarly, out of 24 strains of *Azospirillum,* 14 isolates were positive for HCN production and all isolates were positive for IAA, gibberellic acid and ammonia production.

Zinc solubilization

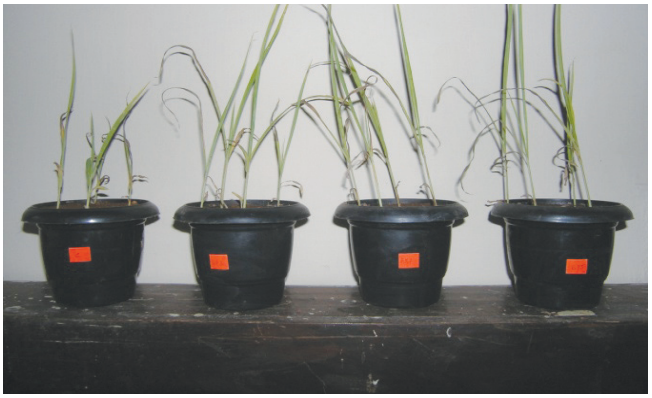
All the *Pseudomonas,* and *Azospirillum* strains were characterized for their ability to solubilize unavailable form of zinc like zinc oxide (ZnO) and zinc carbonate ($ZnCO_3$) *in vitro.* Twenty-five strains showed potential for solubilizing both forms of Zinc. P17 and P21 showed a zone of 21 mm. All 24 strains of *Azospirillum* were able to solubilize ZnO & $ZnCO_3$.



Solubilization of zinc (A. $ZnCO_3$ B. Zn_0) by Pseudomonas strains and Azospirillum strains (c)

Plant growth promotion (PGP) in sorghum and pigeonpea

Twenty-four strains of *Azospirillum* Strains were evaluated for their PGP towards sorghum. Strains AS12, AS13 and AS3 showed 21, 19 and 16% increase in dry matter compared to un-inoculated control, and fixed 54%, 29% and 29% N_2, respectively. Fifteen strains of *Bacillus spp.* were evaluated for their PGP towards sorghum and 15 strains towards pigeonpea. The promising strains for growth promotion were selected for pot studies. B87, B22, B39 strains for sorghum and B105, B38 and B93 strains for pigeonpea were the best among the treatments for plant growth promotion. P22 strain of *Pseudomonas,* which was a good PGP of sorghum was tolerant to salinity ($14X10^2$ dS m^{-1}). *Pseudomonas* strain P28, a plant growth promoter of pigeonpea, was tolerant to high temperature (50°C).



C B22 B24 B36

C B73 B87 B95

PGP activity of promising Bacillus strains on sorghum (30 DAS)

C B38 B39 B43

C B93 B101 B105

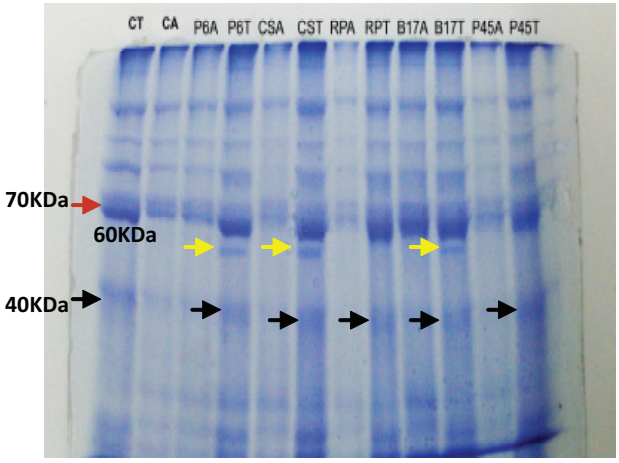
PGP activity of promising Bacillus strains on pigeonpea (30 DAS)

Fourteen strains of *Pseudomonas* were evaluated for their PGP towards sorghum and 17 strains towards pigeonpea that promoted more than 50% growth of seedlings were selected for pot studies. P17, P22, P23 strains for sorghum and P17, P1 and P28 strains for pigeonpea were the best among the treatments for plant growth promotion. Interestingly, no single strain of *Pseudomonas* could enhance all the parameters of the plants studied. Three strains of *Pseudomonas*, P17, P22, P23 and P1, P17, P28 were found to be the best strains for PGP of sorghum and pigeonpea, respectively. Three strains of *Bacillus*, B87, B22, B39 and B105, B38 and B93 were found to be the best strains for PGP of sorghum and pigeonpea, respectively.

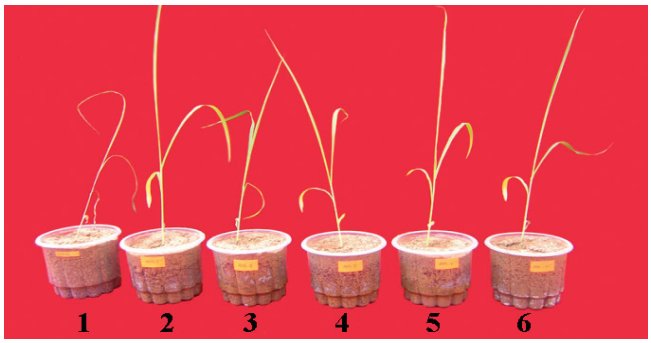
2.4.6.4. Management of abiotic stresses through microorganisms

During the year 2009-09, a consortium of selected stress tolerant strains of *Pseudomonas* and *Bacillus* exhibiting plant growth properties (production of IAA, siderophores and HCN and P-solubilization) was formulated and tested as seed inoculants in sorghum for heat stress tolerance. The bacterial consortium resulted in better survival, plant biomass and biochemical status of sorghum seedlings under heat stress conditions, as compared to single inoculants. Protein profiling by SDS-PAGE revealed the induction of heat shock proteins under high temperature in the seedlings given bio-inoculants

treatments. The selected stress tolerant strains were identified as *Pseudomonas aeruginosa* (P6), *P. stutzeri* (P4), *P. putida* (P46) and *Bacillus amyloliquefaciens* by using 16SrRNA gene amplification technique (B17) and the sequences obtained were submitted to database of NCBI. Five mycorrhizal strains



Induction of HSPs in sorghum at ET



Mycorrhizal application for drought tolerance in sorghum seedlings (1- Control, 2 - *G. fasciculatum*, 3 - *G. mosseae*, 4 - *Sclerocystis* sp., 5 - *G. rubriforme*, 6 - *Entrophospora* sp)

G. fasciculatum, G. mosseae, Sclerocystis sp, *G. rubiforme, Entrophospora* sp. tested for drought tolerance in sorghum seedlings. The strain *Entrophospora* sp. was found to be the best in terms of survival of sorghum seedlings, biochemical status and levels of antioxidative enzymes in the seedlings (Table 17) under drought stress conditions.

2.4.6.5. Utilization of candidate microbial isolates for management of insect pests

Microbial based pest control is an eco-friendly approach for pest management in dryland crops. Potential microbial isolates belonging to insect pathogenic bacteria and fungi have been isolated from dryland soils for use in pest management. The project aims at characterization of isolates, developing cost effective and standardized mass production techniques for wide spread availability and testing their potential under field conditions in castor, groundnut and pigeonpea.

Field efficacy of candidate microbial isolates against *Spodoptera litura* on castor

Castor (DCS-9) was sown during *kharif* 2008, the second year of the project for evaluating the efficacy of candidate microbial isolates of *Bacillus thuringiensis* (Bt) 29b and 48b at 0.05%; *Metarhizium* and *Beauveria bassiana* at 2g/3l, and *Spodoptera litura* NPV (SlNPV) at 0.1 and 0.2% against *S. litura*. These were compared with untreated control and endosulfan 2ml/l spray. One spray was applied during the peak incidence of pest (30-50 larvae/plant).

Among the isolates tested, 70-78% reduction in pest population was achieved with *Beauveria*, Bt 48b and SlNPV 0.2% as against 99% reduction with endosulfan. However, natural parasitoid population (42 per plot) was highest with SlNPV and lowest in the insecticide treatment (Fig 27).

Table 17. Effect of mycorrhizal inoculation on biochemical parameters in sorghum

Isolates	Total sugars (mg/g FW)	Proline (mM/g FW)	Total free AA (mg/g FW)	Total Chlorophyll (mg/g FW)	RWC (%)	Membrane injury (%)
Control	105.7	21.89	1.213	0.745	79.4	85.2
G. fasciculatum	127.6	10.33	1.083	1.627	80.6	72.4
G. mosseae	116.1	10.97	0.753	1.261	84.2	59.8
Sclerocystis sp.	81.9	6.61	1.300	1.236	81.4	71.6
G. rubiforme	198.0	2.62	0.526	1.12	83.6	62.7
Entrophospora sp.	138.0	14.49	1.18	3.276	94.2	49.4
LSD (0.05%)	5.17	0.431	0.149	0.032	1.34	0.144

AA : Aminoacid ; FW : Fresh weight

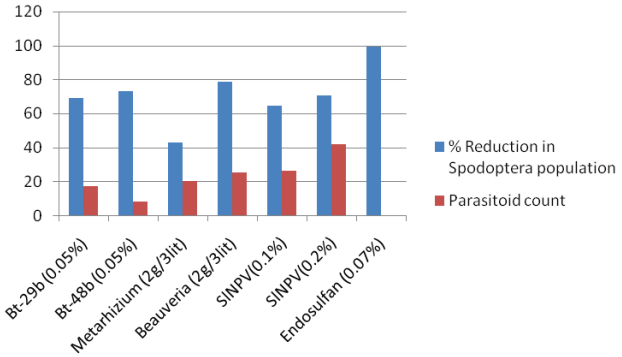


Fig 27. Field efficacy of candidate microbial isolates of Bt, *Metarhizium*, *Beauveria* and SlNPV against *Spodoptera litura* on Castor

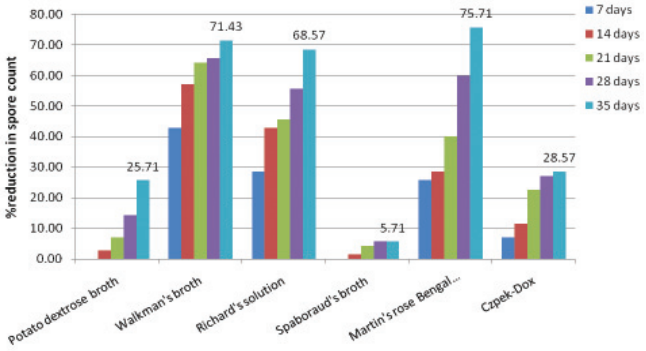


Fig 28. Viable spore count of *Beauveria bassiana* storable liquid formulations under storage at room temperature up to 35 days

Storable liquid formulations of *Beauveria bassiana* and *Verticilium lecanii*

Six media (Czapekdox, Martin's rose bengal, potato dextrose broth, Walkman's, Saboraud's and Richard's broth) were prepared. About 200 ml of each media was taken in a 1L capacity conical flask and sterilized. All the sterilized media were aseptically inoculated with 5% of *Verticillium lecanii* or *Beauveria bassiana* and transferred to the orbital shaker @ 160 RPM and kept for 5 days for multiplication. Initial cell population was adjusted to 70 x 10^5 CFU/ml and transferred 100 ml into the sterilized glass bottles. To each 100 ml of broth media 10% glycerol 10 ml and 2 g PVP (polyvinyl pyrrolidone) were added. Glycerol was used as a cell protectant and PVP as dessicant to reduce the available water. The flasks were again kept in shaker up to one hour for uniform mixing. Later 10 ml of sterilized soybean oil was added to each bottle and kept at room temperature. Shelf life study was conducted at every 5 days interval by standard plate count method. Control was maintained without the formulating agents.

Among six liquid media screened, potato dextrose broth was found to be the best medium for mass multiplication of *Beauveria bassiana* with a spore count of 7.5x 10^7cfu/ml and *Verticillium lecanii* with a spore count of 7.9 x 10^7 cfu/ml at 72 h after inoculation. However, Sabouraud's dextrose broth was found to the best liquid medium for developing the liquid formulation with only 5.7% reduction in spore count 35 days after formulation (Fig 28). In case of *Verticillium lecanii,* Czapekdox broth was found to the best medium for formulation with only 6.4% reduction in spore count 35 days after formulation.

2.4.6.6. Integrated bioresouce centre

An integrated bio resource centre (IBRC) with capacity to produce 3 metric ton of biofertilizers, 5 metric ton of biopesticides per month and tissue culture planting material was commissioned on 16th October 2007. The centre has production facility for Biofertilizers (PSB, *Azospirillium, Azotobacter, Rhizobium* & VAM); Biofungicides (*Trichoderma viride & Pseudomonas fluorescens*); Bioinsecticides (BT, *Beauveria, Metarhizium, Verticillium* & NPV) and planting material (teak and neem). The facilities created are for solid and liquid fermentation of microbes to produce about 4.5 tonnes of a given product per month. Marketing license for biofertilizers and registration of Trichoderma with trade name "Trichoraksha" was received from CIB.

Value added tax (VAT) registration certificate for biofertlizers and manufacturing and marketing license for the production and sale of biofertilizers (PSB, *Azotobacter, Rhizobium* and *Azospirillum*) vide no: 80/2008 validity up to 2011, from Government of Andhra Pradesh was obtained. Similarly, all formalities of *Trichoderma* registration with Central Insecticide Board, Government of India were completed and the registration certificate is expected.

An amount of Rs. 1, 14,355 was generated through sale of various bio-products and also conducting quality analysis of various organic products. In addition, some income was also generated through imparting project work training programs to students. So far, about Rs. 6, 00,000 has been generated as revenue through sale of products.

In-house research

For upgrading the technology, in-house research is also conducted at the IBRC. The salient research findings during 2008-09 were.

i. A method was optimized and standardized for liquid inoculants (LI) production system for biofertilizers. Addition of 0.3 % butanol enhanced the encystment in *Azospirillum* and *Azotobacter* by 26.5% followed by sucrose 11.2%.

ii. Adding 2% PVP and 1% glycerol to Soy peptone broth resulted in 16 months shelf life for the indigenous formulation of PSB, *Azospirilum* and *Azotobacter*.

iii. Six isolates were selected for the quantification of spore and toxin levels in *Bacillus thuringiensis* through liquid culture.

iv. Attempts were made to formulate *Metarrhizium* sp. in oil-based liquid formulations for enhanced shelf-life and easy transport.

v. Among six isolates of *Bacillus thuringiensis* quantified for spore production and toxin levels *in vitro*, toxin production ranged between 8.19 to 29.97 mg/g with the highest productivity with isolate 50c followed by 48b.

vi. PSB, *Azotobacter* and *Azospirillum* were compatible with each other *in vitro*. However, in a liquid formulation consortium PSB inhibited the growth of others.

vii. *Azospirillum* and PSB LI combination enhanced the growth of sorghum seedlings by 13.4% when compared to control. In pigeonpea, PSB and *Rhizobium* combination enhanced growth by 9.5% over control.

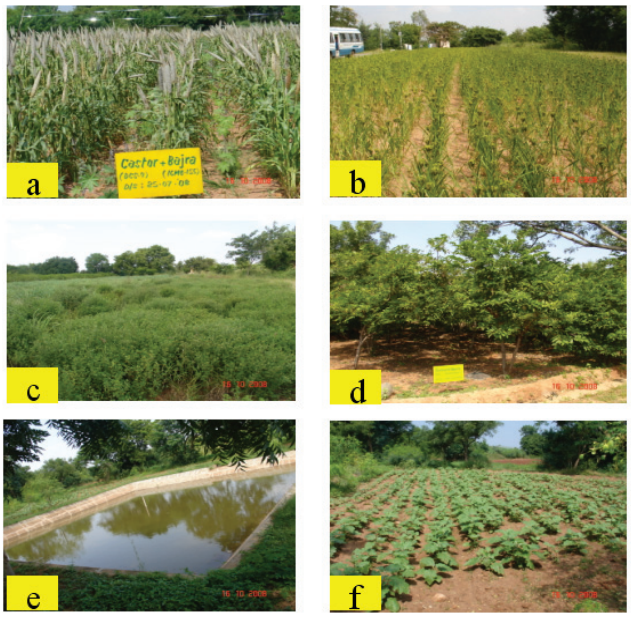
viii. Among 18 strains of *Trichoderma* spp., *Trichoderma* KN could withstand –1.18 MPa osmotic pressure and showed 77% growth. *Trichoderma* 115 recorded the maximum salt tolerance with 27.06% growth @ 2 M Nacl followed by *T. viride* -071 with 24.7% growth. None of the strains could grow at 2.5M NaCl. *Trichoderma* 391 shown highest temperature tolerance with 5.6×10^7 cfu/g at 50^0 C followed by *Trichoderma* 71 with 3×10^7 cfu/g.

ix. *T. viride* KN strain inhibited growth of *P. oryzae* and *R. solani* by 84% over control. Similarly, strain CRIDA-3, 071 and 115 inhibited 90% growth of *P. oryzae*.

2.4.7. Farming systems module for small and marginal farmers

To develop a suitable farming system for small and marginal farmers in Southern Telangana zone of AP, an area of 1.40 ha was selected and cultivated with different crops in *kharif* 2008. Two pulses, horse gram and pigeonpea, and two nutritive cereals, bajra and ragi were cultivated along with one commercial oilseed crop, ie., castor. Four fodder crops were grown viz stylo, cenchrus, gliricidia and sorghum to support animal component i.e., sheep. Yields of different crops in the system are shown in Table 18. Delay in onset of monsoon up to 3rd week of July resulted in poor performance of castor (cv DCS-9). Poor performance by castor was offset by intercropped bajra (825 kg/ha) and sole bajra (1550 kg/ha). Bajra served as insurance against failure of castor. About 500 cubic meters of rainwater was harvested into pond and used for raising vegetables like okra, brinjal, cluster bean and leafy vegetables.

A total of 21 different crops were grown either sole or intercropped on 1.4 ha land realizing gross returns of Rs 22,212 from crops and Rs 17570 by raising lambs. Net cost of production of different crops is Rs.7,269/ha and net profit was Rs.15,739/ha. A total of 8 lambs of three months age were fed with fodders grown in the experimental block on 2,414 Sq m for 258 days. A total of 169.9 kg mutton (live wt gain) and 1.14 t of faeces were produced. The system as a whole resulted in a net return of Rs. 31309.



Components of the farming system a. Castor + Bajra, b. Ragi, c. Stylosanthes, d. Custard apple, e. Farm pond, f. Vegetables around farm pond

Table 18.Yield Performance of different crops in the system

Crop and Variety	Yield (kg/plot)	Byproduct (kg/plot)	Yield (Kg/ha)	Byproduct (kg/ha)
Castor (DCS-9)	47.8	38.5	532	428 (shells)
Castor+Bajra (PBH-207)	37.0+85	26+196	355 (Cas)+825 (Baj)	253 (Cas)+1900 (Baj)
Bajra (PBH-207)	160	299	1550	2900
Bajra (ICMB 155) + Ppea (PRG100)	75+29	141+71	850 (Baj)+330 (Ppea)	1600+800
Ragi (IE2052)	108	250	1100	2550
Horsegram CRIDA18R	81	168	530	1100
Okra(Mahyco hybrid)	100	13	1,850	230
Brinjal (Mahyco Ravaiya)	231	11	7,950	375
Clusterbean (Pusa Navbahar)	195	23	6,964	820
Leafy vegetables (Palak,Coraiander)	9+11	----	4500+5500	-----
Amla+Clusterbean	90 (clusterbean)	47 (clusterbean)	1,800	930 haulms
Curryleaf	248	-------	4,600	-----
Henna 1 (Teak+Hennah-152 M) 2.138M (along Pongamia)	165	230	--------	-----
Lemongrass	142	130	7,100	Dry Leaf after oil extraction
Gliricidia	160 dryleaf	227 decomposable sticks	3,653 sun dried leaf	5,183
Jatropha (95plants)	47	32	940	638
Stylo hamata	289	-------	11,300	Stubbles on ground
Cenchrus	1,240	--------	15,500	Stubbles on ground
Sorghum	-------	1711	----	18,600 green fodder
Pongamia	-------	-------	Not yet yielding	Leaf fall
Custard apple (59 trees)	43,712 fruits	-------	3,497 fruits	Leaf fall

2.4.8. Sustainable cotton production initiative

Work was begun in 2006 in farmer fields in 10 madals of Warngal district to promote better management practices (BMPs) in cotton cultivation. The BMPs were aimed at optimizing use of resources particularly water and nutrients, and reducing the pesticide usage. During the year 2008-09, about 950mm of total rainfall was received during the season out of which 725mm occurred during effective crop growing season. While the rainfall received during crop growth was close to the normal, there was a prolonged dryspell from 3rd week of September onwards and farmers resorted to irrigation wherever it was possible.

During the year 08-09, about 36 farmers were monitored for water use. The predominant source of water was a dug well. Practices suggested for adoption by farmers include irrigating alternate furrows, increasing the frequency of irrigations by reducing the depth of irrigation, shortening the length of furrows etc. However, only a few farmers adopted the method of alternate furrow irrigation. Water productivity and amount of irrigation as percent of effective rainfall for each category is given in Table 19.

Table 19. Water productivity and amount of irrigation as percent of effective rainfall for each category

Irrigation method	BMP/FFS/ Control	WUE (kg/ha per 10 cubic meters of water)	WUE, range (kg/ha per 10 cubic meters of water)	Applied quantity of irrigation as percent of effective rain fall
Alternate	BMP	2.59	2.35-2.72	16-19
Alternate	Control	1.99	1.72-2.18	18-24
Alternate	Other FFS	2.86	1.81-3.73	12-43
Conventional	BMP	2.53	2.02-3.47	17-61
Conventional	Control	3.1	-	31
Conventional	FFS	2.68	1.82-3.17	19-44

The average water use efficiency (WUE) for all categories of ranged from 1.99 to 2.86 with higher value being recorded for other FFS farmers with alternate furrow irrigation method. Quantity of irrigation applied was generally lower for farmers who adopted alternate irrigation method and with less variability among farmers. The number of irrigations was also marginally high, resulting in better water utilization and reduction of deep percolation losses. BMP farmers with alternate furrow irrigation improved their water productivity to 2.59 kg/ha per very 10 cubic meters of water applied in comparison to control farmers who could achieve a WUE of 1.99 only. In case of conventional irrigation methods, quantity of irrigation applied was higher coupled with fewer irrigations, which could result in higher percolation losses.

2.5. Soil and Nutrient Management

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

Rainfed Alfisols are poor in organic carbon and fertility. Farmers cannot afford to add recommended level of fertilizers, therefore it is essential to supplement part of the plant nutrient requirement, especially N, through low cost farm based organic sources. Simultaneously, reduction in intensity of tillage is desirable to improve soil quality in the long run. A study was begun in 1998 at HRF to identify low cost INM treatments using farm based organics for sorghum-green gram rotation under conventional and reduced tillage system. In 2008, the eleventh year of the study, sorghum (SPV 1616) and green gram (ML-267) were grown with different tillage and nutrient management treatments.

Sorghum grain yield was relatively low and varied from 604 to 1578 kg ha^{-1} across the tillage and INM treatments (Fig 29). Both tillage as well as integrated nutrient management treatments significantly influenced sorghum grain yields. Conventional tillage showed significantly higher grain yield (1339 kg ha^{-1}) compared to reduced tillage (1188 kg ha^{-1}), which was 12.7% higher. Application of 2 t Gliricidia loppings + 20 kg N through urea recorded highest grain yield of 1485 kg ha^{-1}. This could be a better alternate INM option to save fertilizer nitrogen upto 50%. In case of green gram, the seed yields varied from 624 to 1089 kg ha^{-1} across the management treatments and were significantly influenced by INM practices but not tillage practices (Fig 30). On an average, among the INM treatments, application of 1 t Gliricidia loppings + 10 kg N through urea recorded highest green gram grain yield of 1086 kg ha^{-1}.

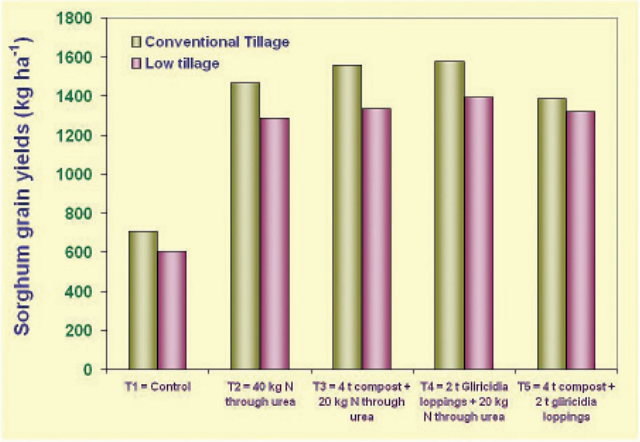


Fig 29. Sorghum (RSH-99) grain yield as influenced by tillage and integrated nutrient management treatments during 2008

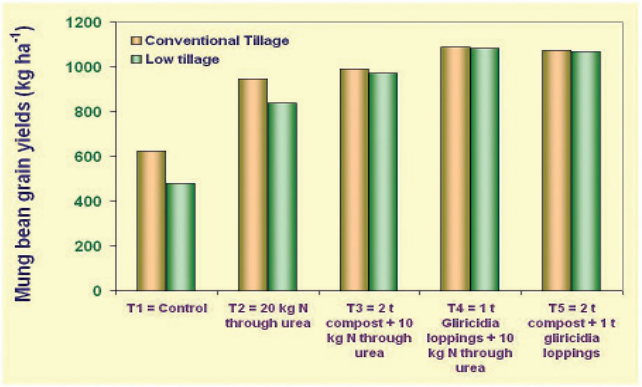


Fig 30. Green gram (ML-267) grain yield as influenced by tillage and integrated nutrient management treatments during 2008.

2.5.2. Restoration of soil quality through conservation agriculture practices and its monitoring using Integrated Soil Quality Index (ISQI)

Severe land degradation has led to deterioration of physical, chemical and biological soil properties in rainfed Alfisols, leading to low crop yields. In order to restore the quality of these soils and to improve the crop productivity, it is important to look for restorative soil and nutrient management practices, which could ensure adequate crop nutrition, enhance organic carbon and improve physical, chemical and biological soil quality attributes. A project was initiated in 2005 to study 1) the response of graded level of surface residue application to cowpea under minimum tillage in Alfisol, 2) to study the influence of tillage practices, residue application and graded levels of N on castor bean yield and long-term influence of predominant N pools under sorghum-castor system.

To achieve the first objective, an experiment comprising of surface application of 4 levels of sorghum residues @ 0, 2, 4, 6 t ha^{-1} in combination with uniform dose of 30 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} with minimum tillage, was initiated during 2005 at HRF, CRIDA. In 2008, cowpea (C 152) was grown as the test crop. To achieve the second objective data is being collected from a field experiment being conducted at HRF, CRIDA since 1995 treatments comprised of tillage (conventional and minimum), residue (2 t ha^{-1} dry sorghum stover, 2 t ha^{-1} fresh gliricidia loppings and no residue) and nitrogen levels (0, 30, 60 and 90 kg N ha^{-1}) under sorghum - castor rotation. Results showed that application of sorghum crop residue as surface mulch in combination with N @ 30 kg ha^{-1} and 30 kg P_2O_5 ha^{-1} under minimum tillage significantly increased the cowpea (C 152) grain yield with sorghum residue applied as surface mulch @ at 4t ha^{-1}. The increase in grain yield of cowpea with residue application @ 2, 4 and 6 t ha^{-1} was to the tune of 20.7, 56.0 and 33.9% respectively over control. Castor (DCS-9) grain yields varied from 367.9 to 1017.8 kg ha^{-1} across the management treatments. Tillage, residues and N levels played a significant role in influencing castor bean yields, while their interaction effects, except the interaction between tillage x treatments, did not show any significant influence. Conventional tillage recorded significantly higher castor bean yield of 720 kg ha^{-1} while minimum tilled plots recorded 625 kg ha^{-1} of castor bean yields. The yield levels in general, were relatively low due to delayed sowing and erratic rainfall pattern during this year.

Application of gliricidia loppings and sorghum stover each @ 2 t ha^{-1} to castor proved superior over no residue application and increased the castor bean yield by 14.7% and 13.7% respectively. Response of castor to N application was significant and highest castor yield (913 kg ha^{-1}) was observed with 90 kg N ha^{-1}. Averaged over years, conventional tillage was superior, maintaining 30.4 and 57.0% higher sorghum and castor yields respectively over minimum tillage. Among the residues, 2 t $ha^{-1}$of fresh gliricidia loppings (leaves + twigs) was better in both the crops on long-term basis. Throughout the study, both sorghum and castor crops responded remarkably to N levels.

Regarding soil N, among the inorganic fractions, exchangeable ammonical nitrogen varied from 17.1 to 42.1 mg kg^{-1} while the nitrate-N varied between 3.89 to 13.4 mg kg^{-1} across the management treatments. Higher ammonical N was observed under conventional tillage (35.5 mg kg^{-1} of soil) than minimum tillage (26.8 mg kg^{-1} of soil). Residue application significantly improved inorganic N fractions over 'no residue' application. Fertilizer N also significantly increased ammonical and nitrate N in soil. Total hydrolyzable N significantly increased with residue application and varied from 333.6 to 648.9 mg kg^{-1} across the management treatments. On an average, total hydrolyzable N was 508.5, 481.6 and 440.4 mg kg^{-1} in sorghum residues, gliricidia loppings and 'no residue' plots respectively. Fertilizer N also played an important role in improving the total hydrolyzable N pool and it was highest (577.2 mg kg^{-1}) with 90 kg ha^{-1}. The order of contribution of different hydrolyzable fractions towards total hydrolyzable N was: amino acid N (51.5%) > unidentified N (21.4 %) > hydrolyzable ammonical N (13.01%) > hexosamine N fraction (8.41 %). Tillage, residues as well as N levels significantly influenced the amino acid N fraction. On an average, significantly higher amino acid N content was observed under minimum tillage (265.0 mg kg^{-1}) followed by conventional tillage (225.7 mg kg^{-1}). Fixed

ammonical N, which represents the nitrogen retained in the clay lattices, varied between 97.8 to 183.8 mg kg^{-1} across the management treatments and was significantly influenced by tillage, residue application as well as varying N levels. This finding helps in building up the nitrogen pools in soil for sustained supply of available N to crops, which otherwise is the main limiting factor in semi-arid tropics.

2.5.3. Assessment and improvement of soil quality and resilience in a watershed under rainfed agroecosystem using GIS and remote sensing

An investigation was carried out to assess the soil quality in a watershed scale considering the spatial variability of soil for optimizing land use. Thematic map for selected soil parameters of Sakaliseripalli micro-watershed in Chintapalli Mandal of Nalgonda district in Andhra Pradesh were prepared using krigging interpolation techniques. Soil depth and texture are two inherent soil properties considered most important for land use planning. Thematic map for combining soil depth and soil texture was also delineated (Fig. 31). Majority of the area has soil depth more than 70cm and depth of soil is not considered as constraint for cultivating any high value, deep-rooted crops. A rock-out with very shallow soil area of 8696.65m^2 (1.11% of total area) was delineated as not suitable for cultivation. Soil quality index map (Fig. 32) showed that the area occupied by paddy and vegetables, which receive regular fertilizer additions, had highest soil quality index.

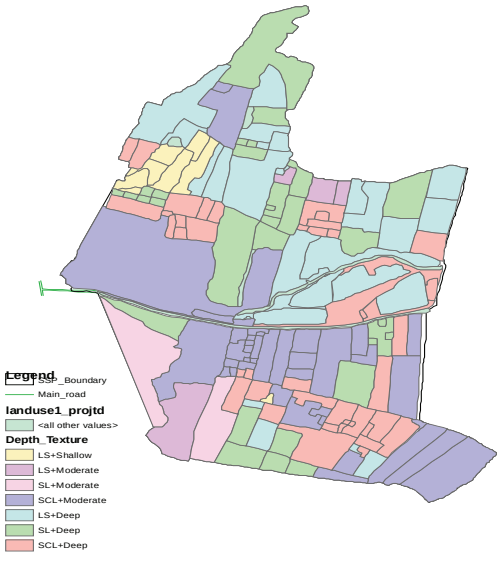


Fig 31. Soil depth and texture for each field boundary (ls= loamy sand, sl=sandy loam, scl=sandy clay loam, shallow<50cm, moderate<100cm, deep>100cm soil depth

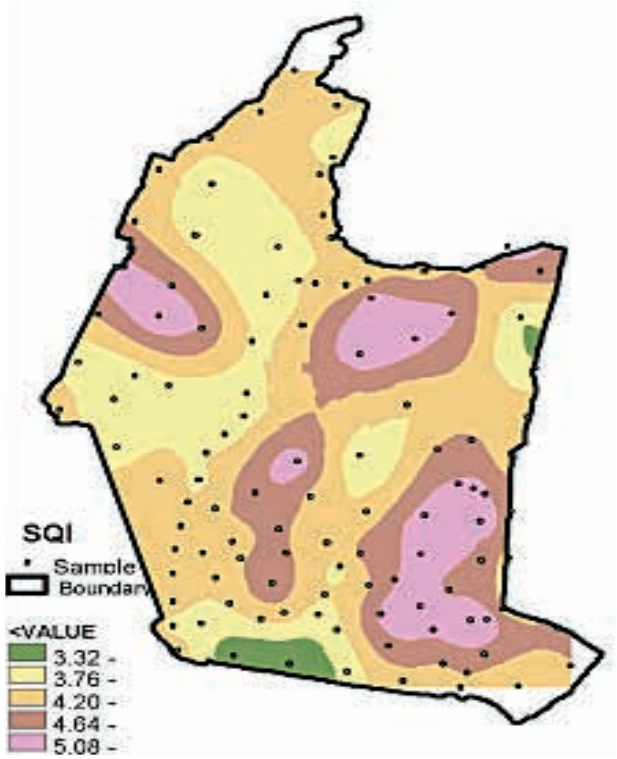


Fig 32. Thematic map for soil quality index

Ground water samples from 13 bore wells were analyzed for different parameters such as Carbonates (CO_3^{-2}), bicarbonates (HCO_3^-) Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Sodium (Na^+), pH, EC. All water quality parameters were in permissible range except for parameters like residual sodium carbonate (RSC) and Mg/Ca ratio for a few wells. Magnesium deteriorates soil structure particularly when waters are sodium dominated and highly saline. High level of Mg usually promotes higher development of exchangeable Na in irrigated soils. The development of alkali soils may be expected when water containing CO_3^{2-} + HCO_3^- higher than Ca^{2+} + Mg^{2+} is used for irrigation and little leaching occurs.

Considering the soil related constraints in the watershed, four on farm experiments were conducted by selecting four farmers for five different cropping systems, maize, sorghum, pigeonpea, sorghum+pigeonpea (3:1), and castor+pigeonpea (4:1). Cropping system was decided based on the choice of the farmers. Gypsum was applied @2.5t/ha considering the level of sodicity in soils. Also gypsum was applied to castor as source of sulphur. Fertilizer were applied @ 60, 30 kg N and P/ha, respectively. Zn as $ZnSO_4$ @20 kg/ha was applied to maize at the time of sowing. FYM was applied @ 2t/ha to all the crops. With appropriate management practices, it was possible to increase

the yield of maize, sorghum, castor and pigeonpea to 3.6, 2.5, 1.6 and 1.6 t/ha respectively, yield levels that were considerably higher than those normally obtained in the watershed. In order to use the residual soil moisture as well as to use off-season rainfall, trials were conducted in four farmers' fields with four *rabi* crops (safflower, chickpea, horse gram and cowpea). In leguminous crops, sowing was done with and without rhizobium culture. Nitrogen @ 10 kg/ha was applied at the time of sowing. Safflower failed to establish. Yields of chickpea (284 kg/ha) and cowpea (259 kg/ha) were low. No yield difference was recorded with and without rhizobium culture. Horse gram performed well and a yield of 7 q/ha with a biomass of 2 t/ha was obtained.

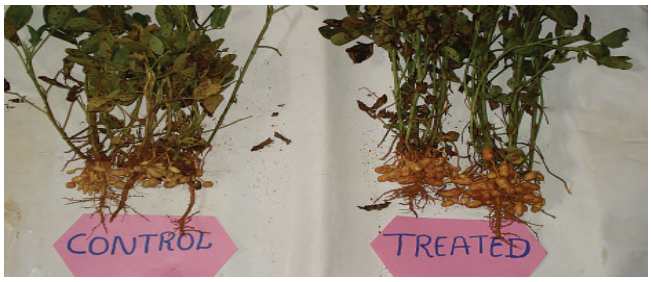
A 30 m long, 7 m wide, 2 m deep gully formed in the watershed due to unabated soil erosion. To alleviate this problem, a two-stepped gabion was constructed for stabilizing the grade of channels. Stone pitching was done for stabilizing the bund. Sand bag structure was constructed by filling empty fertilizer/cement bags with sand and piling one above the other in rows in the upper reaches the gully. The impact is being monitored.

Two-stepped gabion structure

2.5.4. Tank silt as an organic amendment for improving soil and water productivity

Farmer participatory action research was conducted on tank silt recycling on 50 sites at six centres namely Anantapur, Nalgonda, Warangal, Kolar, Solapur and Bhilwara during 2008-09. The beneficiaries (sample farmers) identified for these centers were 20, 20, 22, 20, 10 and 10, respectively and the study was confined to the dominant crops of the region, viz. groundnut, castor, cotton, mulberry, *rabi* sorghum and maize, respectively. The rate of silt application was decided based on the textural properties of tank silt and soil of the farmer's field. Data were collected from treated versus untreated plots/crops in these centers in respect of yields and gross returns accrued per ha (**Tables 20, 21**). The yield and returns were high on all the sites and in all the crops. The response was low in case of cotton and mulberry as they were grown on better sites.

Tank silt application - Solapur



Impact of silt on groundnut - Kolar

Table 20. Comparative yields of different crops in treated vs. untreated plots

Sl. No.	Centre	Crop	Yield (q/ha)					
			Treated			Untreated		
			Min	Max	Avg.	Min	Max	Avg.
1.	Anantapur	Groundnut	4.00	13.20	6.87	1.62	5.25	2.72
2.	Nalgonda	Castor	0.00	10.00	3.62	0.00	5.00	1.10
3.	Warangal	Cotton	5.00	30.00	21.80	2.500	25.00	18.40
4.	Kolar	Mulberry	1.75	4.50	2.69	1.65	4.47	2.58
5.	Solapur	*Rabi* Sorghum	14.10	20.10	16.66	6.90	10.00	8.56
6.	Bhilwara	Maize	32.20	44.60	37.91	27.10	33.40	30.62

Table 21. Gross returns from production of different crops in treated and untreated plots at different locations

Sl. No.	Centre	Crop	Gross returns (Rs/ha)					
			Treated			Untreated		
			Min	Max	Avg.	Min	Max	Avg.
1.	Anantapur	Groundnut	10750	39320	18388	4075	14050	6720
2.	Nalgonda	Castor	0.00	17600	5610	0.00	6000	1580
3.	Warangal	Cotton	14125	84750	60352	7062	77687	54574
4.	Kolar	Mulberry	28000	82650	43997	26500	82417	42314
5.	Solapur	*Rabi* Sorghum	21345	30345	25244	11350	15575	13517
6.	Bhilwara	Maize	28186	37815	33033	21116	29146	26889

2.5.5. Soil and crop management options for managing zinc deficiency in maize-based cropping system of rainfed areas

Zinc deficiency in soils is one of the most important causes of abiotic stress affecting the productivity of rainfed crops, particularly maize, groundnut and sunflower etc. In order to have first hand information of the extent of Zn deficiency in soils under maize-based cropping system, surface soil samples (0-20 cm) were collected from two maize growing districts viz. Karimnagar, Andhra Pradesh (Jubleenagar and Sircapalli villages) and Bhilwara, Rajastan (Darbia, Kocchariya, Madhopur, Mandipaya, Roopura and Sundarpura villages). The soil samples were analyzed for different physico-chemical properties by following recommended methods.

Results of the analysis of the soil samples collected from the Bhilwara district revealed that about 52% of the samples were deficient in available Zn (Table 22). Of the six villages, the all the samples collected from Kochariya and Roopura villages were deficient. In Sundarpura village about 75% of the samples were deficient. All the samples collected from Madhopur village were adequate with respect to available Zn. In Karimnagar district of Andhra Pradesh, the available Zn status in Jubleenagar ranged from 0.44-1.69 ppm whereas in Sircapalli village it ranged from 0.69-3.84 ppm (Table 23). About 33% of the samples collected from Jubleenagar village were deficient in available Zn, whereas none of the sample form Sircapalli village was tested low for available Zn as the farmers in this village apply huge quantities of organic manures and recommended dose of zinc sulphate.

Table 22 Zinc status (ppm) in Bhilwara district, Rajastan

Village	Percentage of samples	
	Deficient	Adequate
Dariba	25	75
Kochariya	100	0
Madhopur	0	100
Mandipaya	20	80
Rooppura	100	0
Sundarpura	75	25
Overall	52	48

Table 23. Zinc status (ppm) Karimnagar district, Andhra Pradesh

Available Zn	Jubleenagar village	Sircapalli village
Minimum	0.44 ppm	0.69 ppm
Maximum	1.69 ppm	3.84 ppm
Mean	**0.738 ppm**	**1.907 ppm**
Deficient (%)	33	None

2.5.6. Carbon sequestration in major rainfed production systems

The long term experiments underway in different AICRPDA centres are being examined for their carbon sequenstration potential.

Groundnut production system (Anantapur, Arid, Alfisol): Long term (1985-2004) cropping, fertilization, manuring (groundnut shells, FYM) and integrated nutrient

management (INM) practices improved the soil organic carbon in a groundnut mono- cropping system under arid conditions. Carbon buildup and organic carbon sequestration rate was higher with addition of FYM and crushed groundnut shells along with 50% recommended dose of fertilizer. Application of groundnet shells, a renewable resource, was found as good as the FYM treatment and in some cases better than FYM in terms of pod yields and carbon buildup in the soil.

Fingermillet Production System (Bangalore, Semi-arid, Alfisol): Under fingermillet production system, with both groundnut-fingermillet and fingermillet-fingermillet sequences, after 27 years (1978-2005), FYM 10t ha^{-1} +100% NPK and FYM 10 t ha^{-1} + 50% NPK showed higher build of soil organic carbon. Under both the sequences, organic carbon sequestration rate was positively influenced by application of FYM.

***Rabi* Sorghum Production System (Solapur, Semi-arid, Vertisol):** After 21 years of cropping (1985-2006), soil organic carbon levels improved from 0.38% (1985) to 0.58 (2006) with regular additions of crop residue, FYM and luecaena along with 25 kg urea. Profile carbon stocks also improved substantially with different organic manure additions. Net soil organic carbon sequestration rate was positive under different nutrient management options.

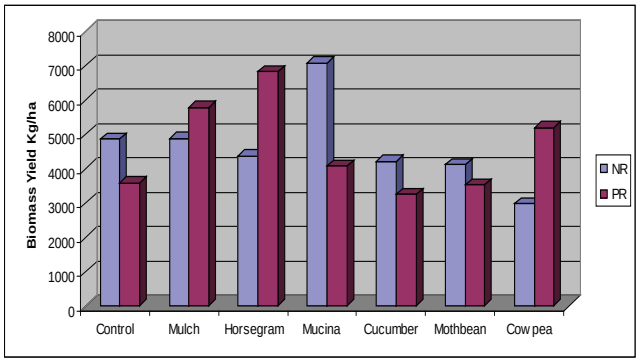
Pearlmillet Production System (S.K. Nagar, Arid, Aridisol): After 18 years of cropping (1988-2006), there was a reduction of organic carbon from initial level (0.31%). Even regular addition of FYM for 18 years could not influence organic carbon status positively under arid conditions in Gujarat. Addition of FYM to the extent of 50% N equivalent was not sufficient to maintain organic carbon similar to initial levels due to rapid oxidation of added organic manures. Net organic carbon sequestration rate also was negative in all the treatments.

Soybean Production System (Indore, Semi-arid, Vertisol): Continuous cropping for 15 years (1992-2007) with nutrient management options including soybean residue and FYM along with N and P application improved soil organic carbon from 0.50% (initial) to 0.67% (FYM 6t ha^{-1}+$N_{20}P_{13}$). Addition of soybean residue (5t ha^{-1}+$N_{20}P_{13}$) also improved soil organic carbon to 0.64%. However, continuous soybean cropping with inorganic fertilizers caused depletion of organic carbon while integrated use of organic manures (soybean residue/FYM) along with inorganic fertilizers improved carbon stocks in the profile and net soil organic carbon sequestration rate.

Rice Production System (Varanasi, Semi-arid, Inceptisol) : Long term rice-lentil cropping sequence for 21 years (1986-2007) with organic manure (FYM) showed improvements in organic carbon from initial level (0.25%). Continuous cropping with out any manure/ fertilizer (control) resulted in depletion of organic carbon while application of only inorganic fertilizers maintained organic carbon at the initial level. However, combined addition of FYM and RDF improved the carbon levels. Similarly regular addition of FYM improved the profile organic carbon stocks and carbon sequestration rate in surface layer of the profile.

2.5.7 Management strategies for resource conservation, and carbon sequestration in rainfed Alfisols

There is a need to develop strategies for efficient conservation of resources, weed management and carbon sequestration that are more economical to the farmers in dryland situation. Experiments were conducted in pigeon pea - castor rotation system at GRF. Both crops are grown each year and the following year the crops are interchanged. Treatments consisted of normal (90 cm between rows) and paired row (60 cm between rows within a pair, 120 cm between pairs) planting with and without intercrops. In 2008, castor crop failed, so only pigeonpea results are presented. Paired row planting recorded highest pigeonpea equivalent yields as compared to normal planting (Fig 33). All the intercropping systems recorded higher equivalent yields than control and mulch treatment. Among different intercrops, cucumber and horse gram recorded higher pigeonpea equivalent yields. Soil moisture, leaf water potential and light interception were influenced by treatments.



[NR = Normal Row; PR = Paired Row]

Fig 33. Biomass yield of pigeonpea with different planting methods and intercrops

2.5.8. Residual effect of FYM applied to castor on pearlmillet

A field trial was conducted at HRF during *kharif* 2008 with pearlmillet in plots where castor was previously grown (2006-07 and 2007-08) with (10 t/ha) and without application of FYM. Results of the experiment have revealed that there was a significant increase in grain and fodder yields in FYM supplied residual plots as compared to no FYM plots. Pearlmillet crop under residual FYM plots produced more number of fertile cobs with better grain filling over no FYM residual plots. Consequently, there was an increase of 2.58 q/ha (about 35%) in grain yield and 3.30 q/ha (about 30%) in fodder yield in FYM applied residual plots over no FYM applied plots.

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

Based on the long term experiments conducted on finger millet during 1984 to 2006 in a semi-arid Alfisol at Bangalore, an assessment of sustainability of 5 fertilizer treatments applied in FYM and maize residue (MR) blocks was made for attaining maximum crop productivity and maintenance of soil fertility (N, P and K). The treatments tested were control, FYM @ 10 t/ha, FYM @ 10 t/ha + 50% recommended NPK, FYM @ 10 t/ha + 100% recommended NPK (50 kg N + 50 kg P + 25 kg K/ha) and 100% recommended NPK in FYM block; and control, MR @ 5 t/ha, MR @ 5 t/ha + 50% recommended NPK, MR @ 5 t/ha + 100% recommended NPK, and 100% recommended NPK in MR block. FYM @ 10 t/ha + 100% NPK was superior with maximum sustainable yield index (SYI) of 56.9% in FYM block, while MR @ 5 t/ha + 100% NPK was superior with maximum SYI of 37.2% in MR block. These treatments differed significantly for yield and soil fertility in both blocks. They gave significantly higher mean yield and maintained soil N, P and K over years. The statistical models for yield with best treatments in each block are given in Table 24.

Similarly based on long term experiments 1987 to 2007 on cotton + green gram (1:1) in a semi-arid vertisol at Akola, the sustainability assessment of 8 fertilizer treatments was made for attaining maximum productivity of crops and soil fertility (N, P and K). The treatments tested were control; 50 kg N + 25 kg P/ha; 25 kg N + 12.5 kg P/ha; 25 kg N/ha (*Leucaena*); 25 kg N/ha (FYM); 25 kg N (*Leucaena*) + 25 kg N (urea) + 25 kg P/ha; 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha; and 25 kg N (*Leucaena*) + 25 kg P/ha. The treatments differed significantly in influencing soil nutrients and grain yield in different years. The regression models of yield through monthly rainfall, crop growing period and soil N, P and K nutrients gave predictability in the range of 0.35 to 0.46 for cotton and 0.40 to 0.71 for green gram yield. The study indicated the superiority of 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha with a maximum Sustainable Yield Index of 16.5% for cotton and 38.7% for green gram over years (Table 24).

Table 24. Multivariate regression models for yield prediction yield through rainfall and soil nutrients

Treatment	Multivariate regression model	R^2	Error	SYI
Bangalore : Semi–arid Alfisols : Finger millet				
FYM @ 10 t/ha + 100% NPK	GY = −3747 + 14.95 (CGP) + 3.61 (Jul RF) + 1.32 (Aug RF) + 0.98 (Sep RF) – 0.87 (Oct RF) + 4.08* (Nov RF) + 8.44 (SN) + 3.75 (SP) + 15.51* (SK) (FYM block)	0.56*	614	56.9
MR @ 5 t/ha + 100% NPK	GY = −3566 + 32.85 (CGP) – 0.23 (Jul RF) + 1.49 (Aug RF) + 0.17 (Sep RF) – 2.32 (Oct RF) + 9.16 (Nov RF) + 14.96 (SN) – 11.59 (SP) + 2.64 (SK) (Maize Residue block)	0.51*	893	37.2
Akola : Semi–arid Vertisols : Cotton + Green gram (1:1)				
25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha	GY = 2353 + 1.34 (CGP) – 0.59 (Jun RF) + 2.14 (Jul RF) + 0.50 (Aug RF) – 1.29 (Sep RF) + 0.49 (Oct RF) – 1.14 (Nov RF) – 3.20 (SN) – 15.52 (SP) – 2.02 (SK) (Cotton)	0.38*	490	16.5
25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha	GY = - 103 + 1.72 (CGP) + 1.36 (Jun RF) + 0.01 (Jul RF) + 0.20 (Aug RF) + 0.93 (Sep RF) + 0.04 (SN) + 1.71 (SP) + 0.25 (SK) (Green gram)	0.40*	195	38.7

* Significant at p = 0.05

2.6. Land Use Diversification

2.6.1. Agroforestry

2.6.1.1. Influence of different nutrient management practices and agroforestry systems on soil quality in rainfed regions

In rainfed regions, arable crop production is uncertain. In recent years, due to recurring droughts, arable crop failure has become a regular phenomenon. Agroforestry (AF) systems for rainfed regions have very good ameliorative effects. The effect of different AF trees species on soil fertility is not well understood. Experiments were taken up at HRF, CRIDA, to study the influence of different tree species of AF system on soil quality, performance of intercrops under tree species and influence of organic and inorganic sources of nutrients on growth and yield of trees in rainfed regions. Two arable crops viz., Setaria (PS-4) and Ragi (IE2052) were sown as sole crops and as intercrops with three tree species, viz., amla (Anand-2), tamarind (PKM-1) and *Acacia senegal* (planted at 10m X 5m spacing in 1998). Sole trees of the above species were also maintained. Seven nutrient management practices, viz., vermicompost (VC), FYM, inorganic fertilizers (IF), VC + IF, FYM + IF, sunhemp in basin and castor cake were imposed on amla and tamarind.

In 2008, both the arable crops were adversely affected due to poor distribution of rainfall. So the sole crops and intercrops performed very poorly, and yielded little. However the agroforestry systems performed well with the trees yielding well despite poor rainfall distribution. Arable crop growth parameters were significantly influenced by the tree species. In Setaria, plant stand (2 months after sowing) was significantly higher in sole, amla and *A senegal* over that in tamarind (Table 25). In ragi, number of plants (2 months after sowing) as intercrop with amla, tamarind and *A Senegal*, were significantly lower than sole crop. Numbers of tillers in ragi at harvest stage as intercrop with amla, tamarind and *A senegal* were significantly lower than sole crop. Further, number of tillers in *A senegal* was significantly superior to that in amla and tamarind.

Amla yields (Table 26) were significantly higher 8277 kg per ha) in sole trees than intercropped trees (3875 kg per ha). Among the nutrient management practices significantly higher yields (8017 kg per ha) were obtained with a combination of FYM and inorganic fertilizers. The lowest yield (4174 kg per ha) was with vermicompost (VC) and inorganic fertilizers (IF)

Fingermillet intercropped with amla

Table 25. Crop performance with different tree species-2008-09

Treatment	Plants per m²	% of Sole	Tillers Per m²	% of Sole
Setaria				
Amla	7.24	86	4.57	33
Tamarind	5.47	65	4.00	29
A senegal	8.31	98	4.92	36
Sole crop	8.45	100	13.79	100
Mean	**7.37**		**6.82**	
SEm ±	**0.452**		**0.538**	
CD (5%)	**1.252**		**1.492**	
Ragi				
Amla	4.86	65	2.63	11
Tamarind	4.86	65	2.34	9
A senegal	5.02	67	7.46	30
Sole crop	7.44	100	24.7	100
Mean	**5.55**		**9.28**	
CD (5%)	**0.704**		**0.618**	

combination. However, FYM and IF were significantly superior to VC and combination of VC and IF. The fruit quality in terms of vitamin C was highest with FYM + IF followed by VC + IF, and the lowest was with FYM. Reducing sugars were highest with VC and lowest with FYM.

Table 26. Amla fruit yield and quality with different treatments 2008-09

Treatment	Fruit Yield kg per ha			Fruit Quality	
Nutrient Management	Sole trees	Intercropped trees	Mean	Vitamin C mg /100 g	Reducing Sugars (%)
Vermicompost (VC)	7274	2134	4704	193	8.83
FYM	9380	4386	6883	164	6.70
Inorganic Fertilizers (IF)	9066	4140	6603	182	6.80
V C + IF	4914	3434	4174	236	7.72
FYM + IF	10754	5280	8017	264	7.72
Mean	**8277**	**3875**			
			CD (5%)		
Cropping System			1073.8		
Nutrient Management			1697.8		

2.6.1.2. Improving the productivity of *Leucaena leucocephala* for industrial biomass production

There is a need to develop technology for enhancing the productivity of leucaena in view of the shortage of the wood for the manufacture of various kinds of paper and packaging material at the country level. A study was begun in 2007 to develop agronomic practices that can improve the productivity of leucaena based systems. The project focuses on three aspects, evaluation of different shade tolerant grass species for growth and biomass production, identification of optimum dose of fertilizers and suitable tillage practices for enhancing the wood production and effect of different microbial inoculants on the biomass productivity of leucaena. To address these aspects, three experiments were initiated. In the first experiment, five shade tolerant grasses, viz., guinea grass (*Panicum maximum*) varieties makueni, riversdale and green panic, congo signal grass (*Brachiaria ruziziensis*) and *Cenchrus ciliaris*, were sown between trees of *Leucaena leucocephala* var. K636. Sole trees without grasses and sole grasses with out trees were also maintained. In the second experiment, effect of fertilizers and tillage practices on wood production of leucaena was studied. The fertilizer treatments are, control (with out any fertilizer), 50% of estimated requirement, 100% of estimated requirement and 150% of estimated requirement. Tillage treatments consisted of no tillage, tillage with cultivator twice in a year and tillage with disc plough twice in a year. In the third experiment, treatments consisted of rhizobium alone, VAM alone, phosphorus solubilizing bacteria (PSB) alone, fertilizer application alone, fertilizers + rhizobium, fertilizers + PSB, fertilizers + PSB + rhizobium and no fertilizer (control). Trees in all the three experiments were planted at 3x1m spacing.

In 2008, guinea grass variety riversdale produced highest dry fodder biomass (14.2 t/ ha/ year) which was significantly higher than other grasses (Table 27). Of the three guinea grass varieties tested, riversdale produced highest biomass followed by makueni and green panic. The biomass production of Congo signal grass was 9.3 t/ ha/yr which was higher than cenchrus grass which produced the lowest green and dry fodder biomass. Tree growth was influenced by intercropping perennial grasses with Leucaena. Tree height and diameter at breast height were highest with sole trees with out intercrop. Application of fertilizers had positive influence on tree growth, though differences were not significant. Application of 100% of the estimated fertilizer requirement (60-40 kg P_2O_5 and K_2O) recorded highest tree height of 5.90 m and recorded a DBH of 3.13 cm. Application of fertilizers along with microbial inoculants improved the tree growth. Maximum tree height and DBH was recorded with the application of fertilizers (60 kg P_2O_5 and 40 kg K_2O) in combination with phosphate solubilizing bacteria and minimum tree height and DBH in control plot with out chemical and biofertilizers.

Table 27. Leucaena tree growth and grass biomass productivity in leucaena based silvi pastoral system.

Intercrop	Leucaena tree height (m)	Leucaena DBH (cm)	Grass Productivity (t/ha)
Guinea grass (*Panicum maximum)* variety makuni	4.47	3.26	12.05
Guinea grass variety riversdale	3.91	2.85	14.20
Guinea grass variety green panic	4.37	3.40	6.61
Congo signal grass (*Brachiaria ruziziensis)*	5.00	3.63	9.32
Cenchrus ciliaris	4.38	3.15	7.72
CD (0.05)	**NS**	**NS**	**2.14**

2.6.2. Dryland horticulture

Tree-tree interactions, tree-annual crop interactions, efficient use of rainwater for raising an orchard, sustainability during the initial years of orcharding or during the juvenile period through vegetable cultivation in the inter spaces of tree crops, primary value addition practices, vegetable cultivation as a source of livelihood option in dryland watersheds and productivity enhancement practices in neglected dryland orchards were the areas of work under dryland horticultural research.

2.6.2.1. Rainwater management in fruit trees

To generate technologies for regular income to the farmer during the gestation period of the main crop and to workout irrigation schedule for such tree-tree interaction among fruit crops, attempts were made to collect, conserve and utilize rainwater in dryland situations for realizing better yield potential of fruit crops. A trial was undertaken on efficient rainwater management and intercropping with four fruit species viz., mango, *aonla*, tamarind and fig. The plantation was done during September 2005, gap filling was done during 2006 and the treatments were imposed in an RBD with four replications. The spacing adopted was 5x5 m for mango, 6x6 m for *aonla*, 7x7 m for tamarind and 2x2 m for fig. Fig was grown as filler crop in mango, tamarind and *aonla* and also as a sole crop. The plants were given protective irrigation (from harvested rainwater) @ 16, 12 & 8 liters/irrigation along with control for observing the survival. Good growth and survival was observed with 16 and 12 litre treatments till establishment, which were on par and superior to 8 litre treatment per irrigation. In the established plants, four water management treatments were imposed (I_1 - irrigation at 0.75 Ep, I_2 - irrigation at 0.5 Ep, I_3 - irrigation at 0.25 Ep, I_0 - no irrigation). Maximum height and canopy diameter of mango, *aonla* and fig were achieved under I_1 while in tamarind the differences were not clear. On established plants, irrigation at 0.75 Ep and 0.50 Ep was found to support better growth than 0.25 Ep treatments. Fig was a successful and compatible intercrop with mango, aonla and tamarind.

Highest survival of all the fruit species was observed with protective watering while no irrigation led to high mortality. Mango and aonla recorded high mortality under complete rainfed conditions while tamarind was able to show better performance. On established plants, irrigation at 0.75 Ep and 0.50 Ep was found to support better growth than 0.25 Ep treatments. Maximum height and canopy diameter of mango, aonla and fig were achieved under I_1 while in tamarind the differences were not clear. Fruit setting in fig was noticed even after severe pruning. The fruit plants can be grown under rainfed conditions with minimal water. Mango, aonla and fig can be raised even with minimal water. Evaporation replenishment of 75% was more beneficial in imparting good growth and fruiting units than 50% and 25% replenishment rates.

Fig was pruned to impart good shape and more fruiting units in the subsequent season. Good growth and yields of intercrops of cowpea, horsegram, cenchrus, stylo, roselle, sweet corn and baby corn were recorded in the interspaces without any irrigation. Reasonably good crops of sweet corn and baby corn were obtained during *kharif* 2007 and 2008 without any irrigation.

Income generating baby corn, sweet corn, capsicum, cluster bean, tomato (local), beans and okra were raised as intercrops in between tree rows during *Kharif* 2008 under

rainfed conditions without any supplemental irrigation. Okra (Okra-016), hybrid tomato (TO-848), chilies (Pusa jwala), peas (Exotica), french beans, (Seville), dolichos beans (Flora), long Brinjal (BE-706), round Brinjal (Ravaiya) and tomato (Meghali) were raised as intercrops for good income generation in between tree rows during *Rabi* 2008-09 with supplemental irrigation.

Brinjal between tamarind rows in rainy season

Dolichos in mango + fig system

For value addition, roselle calyces were harvested and dried under shade to retain good colour. Powdered calyces were tested for culinary utility in place of amchoor and tamarind. Scope also exists for usage of roselle calyces extract for blending with other natural fruit juices like acid lime, *aonla*, guava, ginger, pineapple, etc., for good natural colour and taste as a replacement to artificial colours. It also imparts body and pectin to jellies. Roselle provides ample scope in the dryland regions especially in the orchards during the initial years of orcharding.

Fruit plants can be established with minimal quantity of irrigation. Tamarind can withstand drought spells and may be recommended for planting even under rainfed conditions. However good growth can be ensured even under minimal water supply/irrigation conditions. Growing vegetable crops in the initial years of orcharding may be beneficial for generating incomes. When vegetable crops like brinjal, cauliflower, chilli and tomato were raised as intercrops on conserved moisture in a limited area (0.5 to 0.6 acres) with family labour from a family of two adults and two children, it appeared economic to cultivate them and support their livelihoods. Sweet corn and baby corn during *kharif* were found more promising without any irrigation. Brinjal was found more promising than other vegetable crops (tomato, cauliflower and chilli) during *rabi* when they were sown/the seedlings were raised during the rainy season and three protective irrigations were given with conserved moisture during crop growth stage.

2.6.2.2. Rainfed vegetable production in peri-urban areas

Farmers of peri-urban regions are switching over to vegetable cultivation for higher incomes and also as a livelihood option. With the advent of supermarkets in Hyderabad, farmers in Ranga Reddy district are growing vegetables for supply to local markets. *Kharif* vegetables are grown without irrigation and *rabi* vegetables on conserved moisture in several villages The yields of vegetable crops are low due to the paucity of information on the selection of vegetables or suitable varieties for different markets, balanced nutritional needs of the selected crops, supplemental irrigation practices at critical stages of crop growth, marketing facilities etc. Farmers were selected and training on profitable vegetable cultivation was imparted which included supplemental irrigation. Soils in majority of the farmers' fields were poor in nutrients and showed deficiencies of macro as well as micronutrients. Need based recommended doses of nutrients were applied in the selected crop varieties along with micronutrients and supplement irrigation.

Tomato, brinjal, okra, chilli, cucumber, watermelon, guar, ridge gourd, bottle gourd, bitter gourd, capsicum, onion, french bean, dolichus, spinach, amaranthus and fenugreek were grown in the farmers field by applying micro nutrients like borax (0.25%), $FeSO_4$ (0.5%), $ZnSo_4$ (0.25%), $CasO_4$ (1%) and with supplemental irrigation. There was 40 to 250% increase in the yields because of the interventions (Table.28). Bitter gourd, tomato, cooking melon, brinjal and ridge gourd were also grown during summer by applying micronutrients

and supplemental irrigations. In 2007-08, bitter gourd excelled all other vegetables in giving higher net income to the farmer. French bean, ridge gourd and bitter ground gave better net returns during 2008-09. Growing vegetable crops during summer months with 100% followed by 67% replenishment rates was found beneficial in terms of net monetary returns. During *rabi* summer satisfactory yields of vegetable crops were obtained with six supplemental irrigations. Cooking melon with 2 mm, brinjal and dolichos with 3 mm, ridge gourd and french bean with 4 mm, hybrid tomato with 5 mm and bitter gourd with 6 mm at 67% replenishment rates gave satisfactory yields with supplemental irrigations when there was shortage of water.

Table 28. Yield of vegetable crops grown in Ranga Reddy district (t/ha area)

Vegetable	Improved practice	Farmers practice	% change
Tomato	22	7.6	189
Brinjal	25	12.1	107
Okra	13	6.6	97
Chilli	13.2	4.4	200
Cucumber	27.5	13.1	110
Watermelon	71	23.2	206
Guar	12	3.8	216
Ridge gourd	19.1	5.2	267
Bottle gourd	22	6.5	238
Bitter gourd	20.5	4.4	366
Capsicum	12.2	4.1	198
Onion	11.6	4.2	176
Dolichos	13.0	3.4	282
Spinach	5.8	1.8	222
Amaranthus	7.1	3.3	115
Fenugreek	7.6	2.4	217
French bean	10.3	3.2	222
Peas	3.4	2.1	62

Tomatoes with and without application of micronutrients and supplementary irrigation

2.6.2.3. Productivity enhancement in neglected orchards in drought prone areas

An on farm adaptive programme involving selected farmers in Mahabubnagar district was undertaken for productivity enhancement in the existing neglected orchards. Poor yields of mango were observed in the orchards. Farmers were not applying recommended dose of fertilizers. Due to poor soil fertility conditions, the new plantings were showing slow growth. Farmers were advised to apply recommended dose of fertilizers and FYM according to the age of the plant and to take up in-situ water conservation during rainy season. One farmer was advised to spray NAA at 200 ppm to combat vegetative malformation. Selected farmers were advised to take up measures for improving the productivity and this was done through farmers' participatory approach. A sweet orange orchard belonging to Sri P.Yadaiah in Gundala village in Veldanda Mandal, which was planted in gravelly soil and plants were showing symptoms of citrus decline, was revived with our interventions. Productivity of a declining 20 years old guava orchard belonging to Sri Vishnu of Chintagudem village was taken up for improving the yields by pruning, cleaning of basins and also by applying recommended doses of fertilizers as revival measures.

Improved growth of mango with round basin and recommended fertilizers

2.6.2.4. Evaluation of tamarind cultivars

Flowering and fruiting behaviour of tamarind was studied in 40 cultivars planted in 1998 and cultivars having regular bearing were identified. The ranking was modified taking quality, growth parameters and fruiting behaviour into consideration. Among the top five identified last year, the Red variety which stood first (2006-07), didn't flower in the second (2007-08) and the third year (2008-09), thus the ranking was revised, similarly SLM-132 also failed to flower in the second year. Thus NZB was ranked as first (Table 29).

Table 29. Ranking of Tamarind Cultivars

Variety	Rank 2006-07	Rank 2007-08	Rank 2008-09	Average yield (kg/plant)			Revised ranking based on bearing
RED	1	-	-	22.6	-	-	-
NZB	2	1	1	28.1	6.0	8.1	1
SLM-132	3	2	-	16.7	2.0	-	-

NZB-S

SLM-132

RED

Tamarind varieties under evaluation

2.6.3. Value addition

2.6.3.1. Studies on enrichment of quality and utilization of palmyra fruit

Palmyra pulp was fortified with mango, guava, papaya and pineapple in different proportions, and palmyra fruit squash, palmyra jam, palmyra fruit bar and palmyra fruit cheese were prepared using the fortified palmyra syrup. The products prepared with blends of 20% - 40% of papaya, pineapple, mango and guava pulp were found suitable for acceptable product development. Palmyra squash was fortified with roselle extract to impart excellent colour to the product.

Extract of ripe Palmyra fruit

2.6.3.2. Development of ready-to-eat nutrient rich value added products

Horse gram is the unexploited legume of the tropics and subtropics grown mostly under dryland agriculture. The chemical composition is comparable with commonly cultivated legumes. Like other legumes, these are deficient in methionine and tryptophan. Horse gram is an excellent source of iron and molybdenum. Comparatively, horse gram seeds have higher trypsin inhibitor and hemaglutinin activities and polyphenols than moth bean seeds. Dehusking, germination, cooking, and roasting have been shown to produce beneficial effects on nutritional quality of horse gram. Work was initiated to develop

Jam and squash from Palmyra fruit

nutrient rich millet based food products from horse gram. In 2008, two formulations were prepared with 30% roasted horse gram flour with potato and carrot, using chickpea flour to improve the amino acid balance and to raise the energy level of the extruded products. The nutritive values of extruded product fortified with potato are presented in Table 30.

Ready to eat nutrient rich horse gram products-*snacks*

Table 30. Nutritive value of extruded product fortified with potato

Product	Protein (g)	Mineral (g)	Crude fibre (g)	Energy (kcal)	Calcium (mg)	Iron (mg)
Horse gram alone	44.0	6.4	10.6	321	287	6.77
Extruded product	96.2	9.8	18.0	1962	750	35.42

2.6.4. Biofuels

On-station experiments and on-farm demonstrations are being conducted on biofuels (Jatropha, Pongamia & Simarouba) since 2004. This research is being funded by three agencies, *viz.* NOVOD, CSIR & RSAD (Govt. of AP).

2.6.4.1. Jatropha

2.6.4.1.1. Breeding trials

Out of 59 intra-specific (*J. curcas*) crosses attempted, 26 crosses resulted in >50% fruit set. The F1 progeny would be planted during June-July, 2009 for evaluation in field conditions.

F1 Generation of Jatropha

Four accessions were identified as promising out of 23 accessions evaluated in a progeny trial of Jatropha (based on the growth and seed yield at the end of third year of plantation). The seed yield of these promising accessions ranged from 0.98 to 1.30t/ha at the end of 3rd year.

2.6.4.1.2. Agronomic trials

Pruning

- The following recommendations emerged from the pruning trials
- Cut back the plants to 45cm from ground level in the first year.
- Remove 1/2 of each branch in the second year.
- Third year onwards light thinning as and when needed.
- Heavy thinning from third year onwards reduces the seed yield drastically.

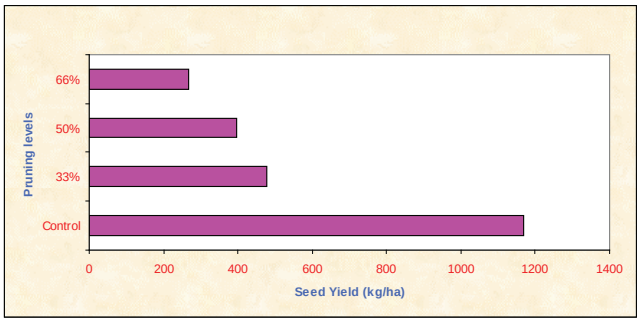


Fig 34. Effect of pruning on yield of jatropha

Irrigation, spacing and fertilization

Out of four treatments (2x2m, 3x2m, 4x2m & 4x3m) evaluated, spacing at 2x2 m showed higher seed yield (280 kg/ha) with combination of fertilizers N135+ P300 g/plant at the end of second year under rainfed conditions.

Pests

Common pests observed on jatropha during this year were stem borer and red hairy caterpillar

Damage caused by red hairy caterpillar

2.6.4.1.3. On–farm trials in Nalgonda, Anantapur and Mahaboobnagar districts

On farm trials continued for the 4th year in two districts of Andhra Pradesh viz, Nalgonda and Anantapur. The main treatments comprised of different levels of fertilizers, irrigation, spacing and pruning. So far the initial trends indicated that seed yield was highest (260 kg/ha) with combination of pruning at 30 cm and 2 x 2 m spacing under irrigated conditions in Nalgonda district (Fig 35), where as in irrigation and pruning trial at Anantapur district, seed yield was highest (398 kg/ha) with combination of pruning at 45 cm and irrigation at 0.75 ET (Fig 36).

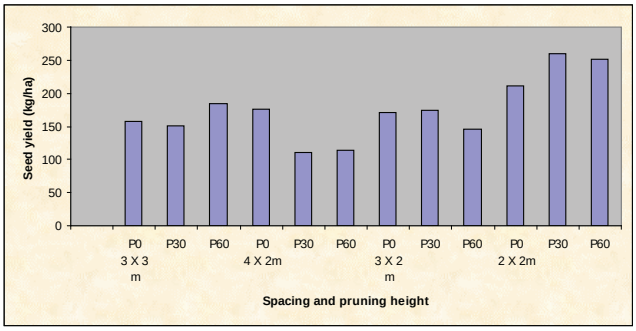


Fig 35. Effect of spacing and pruning height on seed yield of jatropha (Dilawarpur, Nalgonda district)

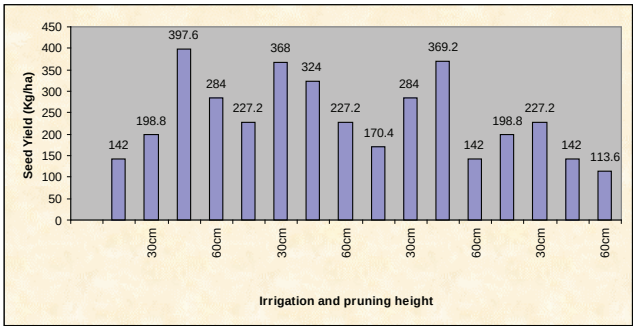


Fig 36. Effect of irrigation and pruning height on seed yield of jatropha, (Hampapuram, Anantapur district)

Effects of pruning, irrigation, nutrition and soil and water conservation measures were studied in farmers'fields at Chintagudem and Veldanda in Mahabubnagar district. Pruning at 0, 30, 60 cm height from ground level was done. Pruning at 30-60 cm height was better in influencing number of secondary branches, stem girth, canopy spread. The position of plants at the center and on the eastern side imparted more height than in the western direction.

Application of irrigation at 10 days interval was significantly superior to irrigation at 20 days interval in promoting the height and girth of plant. However, this did not differ from 15 days interval which means saving of irrigation water. Application of even 22.5 g N and 50 g P per plant was markedly superior to no nutrition and at par with higher level but more girth was observed with higher doses of nutrients.

Plant growth parameters such as height, number of primary and secondary branches, stem girth, length of longest branch and canopy spread was influenced by irrigation interval and soil and water conservation measures. Both crescent shaped basin as well as trench (45 x 22.5 x 22.5 cm) were superior to the farmer's practice of small basin. Preparation of trench on the upper side of the plant slope was highly beneficial. There was good response to all levels of irrigation and soil and water conservation interventions. Trench was superior to crescent shaped basin, which in turn was superior to small basins of farmers practice. Jatropha responded well to frequent irrigations at 10 to 15 days intervals along with SWC measures.

2.6.4.2. Pongamia

2.6.4.2.1. Breeding and agronomic trials

Grafts

Seedlings

Progeny trial

On the basis of growth parameters, 4 out of 23 accessions of pongamia evaluated in progeny trial showed superior performance compared to other genotypes. All four accessions started flowering during this year.

Agri-silvicultural trial

During fifth year of plantation of pongamia, kernel yield in grafted plants ranged from 0.7 to 2.9 kg/plant. Seedling originated plants started flowering during fifth year and the kernel yield ranged from 0.4 to 0.9 kg/plant.

Intercrop trial

The yield of intercrops viz., pigeonpea, castor and horse gram taken in the inter row spaces of pongamia was significantly reduced this year as compared to control (open) plots. However, no significant negative effect of crops on growth and yield of pongamia was observed across different spacings.

Horse gram intercrop in pongamia

2.6.4.2.2. Experiments on farmers' fields in Mahabubnagar district

Seedlings were planted in wasteland (saline soil) in a farmer's field at Telkapally in Mahabubnagar district on 18.10.2006. A trial was undertaken to determine the optimum plant density and irrigation interval for higher productivity of pongamia. A spacing of 6 m x 6 m resulted in greater plant height, number of branches, length of longest branch and canopy spread. These characters were significantly higher with 6 m x 6 m, compared to 5 m x 4 m spacing but on par with 6 m x 4 m. Irrigation at 10 days interval was superior to 15 days, 20 days and no irrigation treatments in improving plant height, number of branches, length of longest branch and canopy spread.

2.6.4.2.3. Nutrient and hormonal management

To increase economic yield and improve quality of seed oil in pongamia and to the study photosynthesis, water relations and growth in pongamia as influenced by various hormonal and chemical manipulations, a study was initiated in 2007 at HRF, CRIDA. The effect of treatments on cumulative increase in DBH in pongamia at four stages viz., 30, 60, 90 and 120 days after imposition of treatments showed that in general there was an increase in DBH in the $ZnSO_4$, borax, urea, brassinolide (BR1), combination spray and paclobutrazol (4-chlorophenyl dimethyl triazol pentan), where as there was a slightly negative trend with ethaphon and morphactin. Among the growth stages studied, the maximum increase was at 90 days after imposition of treatments after which the rate of increase decreased indicating that the physiological effect of the nutrients and hormonal spray peaked till 3 months. A similar trend was seen in the growth retardants too with a significant negative trend in ethaphon as compared to morphactin.

The fraction of the sky visible under the canopy was significantly less with BR1, combination spray and urea. On the other hand, paclobutrazol reduced the fraction of the sky visible under the canopy but was not significant. In the case of mean tip angle, which is a measure of the orientation of the leaf (vertical to horizontal), all the treatments excepting urea influenced the orientation of the leaf positively. Although urea spray increased leaf area and subsequently the LAI, the orientation of leaves was not influenced. This clearly shows that hormonal spray induced nastic movements in leaves favorably orienting them for increased interception of light and in turn increased growth rather than direct increase of leaf area.

Growth of trees in terms of DBH and collar diameter was increased by BR1, urea and combination spray. Urea spray and combination spray was effective in increasing the LAI significantly. Although urea spray increased the LAI, the orientation of leaves were not influenced by urea. BR1, Paclobutrazol and urea increased the number of racemes per branch. Paclobutrazol and urea increased flower retention by reducing bud and flower drop. BR1 and Paclobutrazol increased the number of developing pods per raceme at 3rd week after initiation. BR1, paclobutrazol and urea increased both the total number of pods and number of pods per branch. Combination spray, $ZnSO_4$, Borax and Paclobutrazol positively influenced the 100 seed weight. The highest increase of carbon fixation over control was seen in paclobutrazol, BR1 and combination spray all of which were significant.

Net Photosynthetic rate of the leaves of pongamia is depicted in Fig 37. The highest increase of carbon fixation over control was seen in Paclobutrazol, BR1 and combination spray. The rest of the nutrient and hormonal treatments did not show any significant difference in photosynthetic rate over control although ethaphon marginally reduced the rate of photosynthesis. The effect of BR1 and combination spray was in turn evident in growth increase where the same was not the case in paclobutrazol suggesting that the there was diversion of photsynthates to processes other than dry matter production.

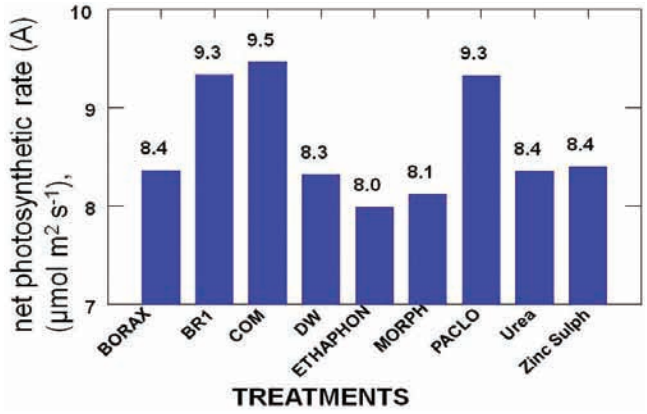


Fig 37. Effect of treatments on net photosynthetic rate in pongamia

Paclobutrazol 10 g ai/tree spray

1.0% Urea spray

Leaf Area Index measured by LAI 2000 using fish eye lens revealed that urea spray and combination spray was effective in increasing the LAI significantly, this was followed by BR1 although the increase effected was not significant. A clear and consistent trend was noticed in all the stages of observation viz., 30, 60, 90 and 120 days after imposition of treatments excepting for paclobutrazol which exerted a positive and significant influence on LAI only at 30 days. This could be due to the fact that paclobutrazol initially increases the photosynthetic rate and over time the effect of the chemical wears off.

2.6.4.3. Simarouba

At the end of fifth year of plantation, the dry yield of fruits was in the range of 6.59 to 13.2 kg per plant. The inter spaces of simarouba (6 X 6 m) could be used for raising castor and cowpea without any negative effect on tree growth (Table 31).

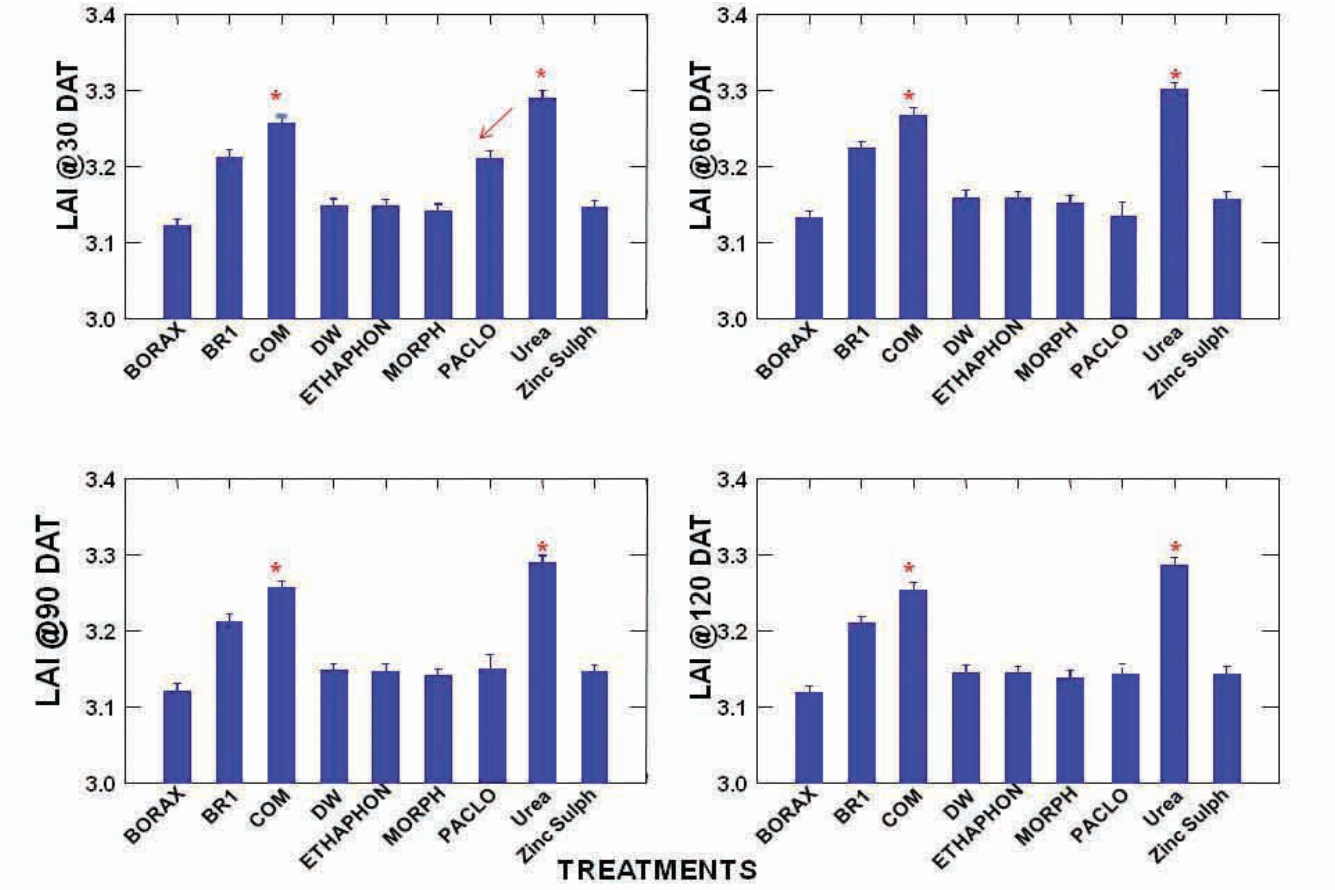


Fig 38. Effect of treatments on leaf area index (LAI) in *Pongamia*

Table 31: Effect of intercrops on the growth of simarouba

Intercrops	Plant height (cm)	Collar Diameter (cm)	No. of branches	Canopy (cm)		Intercrop yield (q/ha)
				East-West	North-South	
No intercrop	430.60	14.26	143.64	469.96	482.07	
Castor	411.03	14.57	153.56	474.28	475.37	0.381
Cowpea	397.94	14.06	145.64	438.45	447.73	0.382

Fruiting in simarouba

Castor intercrop in simarouba

2.6.4.4. Perennial castor

One year after planting, in 2006-07, the survival of perennial castor (PC-1), identified among 35 genotypes, was 90 per cent as against 98 percent for jatropha. Perennial castor yielded in the first year itself (250 kg/ha) while jatropha didn't flower. The yield (538 kg/ha) of perennial castor was high during second year (2007-08) as against 175 kg/ha of jatropha, but survival was found to be poor (Table 32). In the third year (2008-09), jatropha out yielded castor as perennial castor had to be replanted. Growth parameters like plant height and branching were higher in perennial castor compared to jatropha. It is concluded from the study that perennial castor can survive for two years and it is possible to grow in areas having facility of supplemental irrigation and better soils. It is best suited for planting on field bunds and contour bunds.

2.6.5. Medicinal, aromatic and dye plants

2.6.5.1. Impact of drought management practices and organics on secondary metabolites and yield potential of medicinal crops

The demand for the quality material of the medicinal plants is increasing. The quality of medicinal plants is influenced by water stress and the management practices. Hence experiments were initiated in 2007 to study the impact of water stress and drought management strategies on growth and yield of medicinal plants. Two experiments were laid out in GRF of CRIDA. The first experiment was to study the influence of drought management practices. There was differential response of crops to drought management treatments. In general the drought management practices recorded higher yield and better quality over control.

Table 32: Yield of jatropha and perennial castor in different years

Parameters	Castor			Jatropha		
	2006-07	2007-08	2008-09*	2006-07	2007-08	2008-09
Plant height (m)	1.14	2.19	95.0	0.87	1.86	1.95
Collar diameter (cm)	3.2	5.78	3.0	5.4	9.30	14.0
No. of branches	4.1	5.8	6.0	2.1	4.8	10.0
No. of spikes/ capsules per plant	2.6	7.1	3.8	-	36	85
Spike length (cm)	37.3	38.5	37.5	-	-	-
Survival percent	90	50	98	100	98	96
Yield (kg/ha)	250	538	367	-	175	460

Date of planting: July 2006 * Replanted: July 2008

In senna, (fig 39 a) paired row+ cover crop gave higher leaf yields, closely followed by compost, grass mulching, bio nectar, antitranspirant, life saving irrigations and cover crop. Higher sennasoide content (1.63%) was recorded with compost application followed by life saving irrigation (1.56%), bio nectar, and grass mulching. In andrographis, (fig 39 b) paired row+cover crop recorded 116% higher yield over control. Biomass yields of andrographis were in order of paired row+cover crop > anti transpirant > grass mulching > compost > bio nectar > life saving irrigation > cover crop > control. Andrographolide content was significantly influenced by the drought management practices and was highest with grass mulch (0.58%) followed by cover crop (0.45%). Root yields (Fig 39 c) of ashwagandha were highest with cover crop, closely followed by life saving irrigation and paired row+cover crop. Life saving irrigation recorded higher withanoid content (3.03%), followed by antitranspirant (2.94%).

The second experiment was to study the effect of tank silt and organic fertilizers. The tank silt @- 250 M^3 was applied during summer of first year and was ploughed thoroughly to mix the contents in the soil. Organic fertilizers, applied 15 days before sowing, were equated to the recommended dose of N. Test crops were Senna, Andrographis and Ashwagandha. Tank silt application and the organic fertilizers influenced the yield and quality of senna, ashwagandha and andrographis. Tank silt application gave 15, 53, and 33% higher yields than no tank silt in senna, andrographis and ashwagandha respectively and 4, 29, and 4% higher sennasoide, andrographalide & withanoid content respectively.

There was a differential response of crops to different organic fertilizers. Biomix (a mixture of *Trichoderma reseii, Phenerochyte chrysosporium, Bacillus subtilis* and *B. coagualans*) recorded 80% higher yields in senna followed by vermicompost (74%) and castor cake (70%) over control. In andrographis, vermicompost application gave higher biomass yields where as in ashwagandha, castor cake application recorded highest root yields followed by vermicompost and FYM. Sennosoide, andrographalide, and withanoid contents were influenced by organic fertilizers (Table 32). Different crops responded differently to different organic fertilizers. Castor cake recorded 66 and 86% higher sennosoide andrographalide content over control followed by FYM. In ashwagandha, vermicompost application recorded higher withanoid content followed by FYM application.

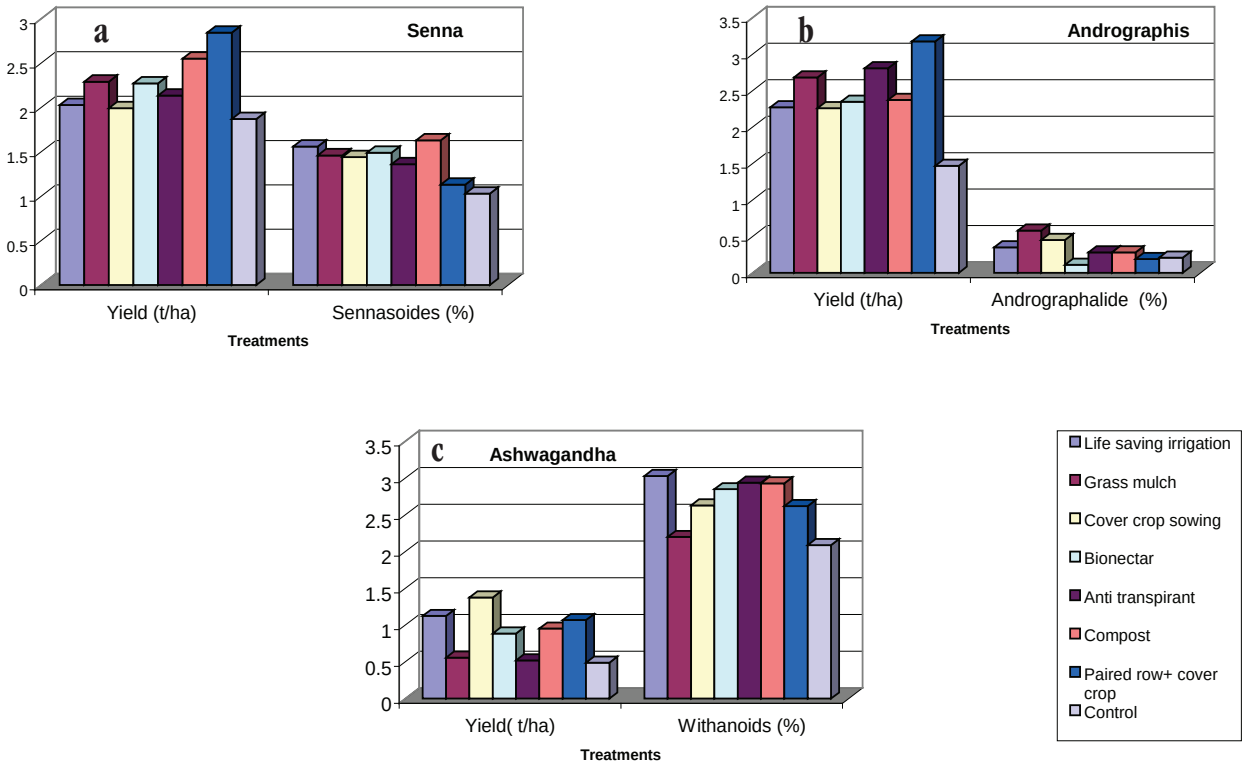


Fig. 39. Influence of different drought management practices on yield and quality of a. Senna, b. Andrographis and c. Ashwagandha

Table 33. Influence of different treatments on yield and quality of senna, andrographis and aswagandha

Treatments	Senna				Andrographis				Aswagandha			
	Yield (kg/ha)		Sennasoids (%)		Yield (kg/ha)		Andrographolide (%)		Yield (kg/ha)		Withanoids (%)	
	TS	NTS	TS	NTS	TS	NTS	TS	NTS	TS	NTS	TS	NTS
FYM	1650	1532	1.62	1.44	2673	1610	0.41	0.24	1643	1335	3.21	3.57
Vermicompost	2210	1723	1.28	1.17	5979	2325	0.30	0.27	2103	2111	3.59	3.60
Castor cake	2042	1807	1.96	1.35	2410	2385	0.50	0.30	2477	2121	3.04	2.57
Biomix	2247	1832	1.21	1.38	3590	2420	0.30	0.33	1698	1117	3.01	2.35
NPK	2019	1774	1.00	1.29	2289	2533	0.27	0.28	1645	1543	3.12	3.14
Control	1136	1163	0.95	1.03	1538	1303	0.25	0.17	961	399	2.05	2.08

2.6.5.2. Organic nutrient management of medicinal and aromatic crops

Organically grown medicinal plants fetch higher price in the international market and demand for these plants is increasing day by day with increase in awareness of the side affects of the synthetic drugs. Rainfed regions can be exploited to grow these crops organically. To examine this possibility, experimental work was initiated in 2004 at HRF, CRIDA to identify sustainable organic/ inorganic practices for higher productivity and quality of medicinal and aromatic plants. The organic fertilizers, viz., farm yard manure, castor cake and neem cake, equated to the recommended dose of Nitrogen (50 kg/ha), were applied 15 days before sowing. Vermicompost and NPK were applied at the time of sowing.

Highest senna leaf yields were recorded with vermicompost application followed by neem cake. The biomass yield of andrographis was highest with neem cake application. However it was on par with castor cake and vermicompost. Highest andrographolide content was observed with neem cake application followed by NPK. Castor cake gave significantly higher ashwagandha root yields followed by FYM and vermicompost. Better root length and girth were observed with vermicompost and castor cake application. Biomass yields of three cuts of lemon grass and palmarosa, and oil yield were recorded. Lemongrass and palmarosa biomass yields and oil yields were highest in inorganic fertilizer treatment followed by vermicompost and castor cake. Highest citral content and geranial in lemongrass and palmarosa respectively were recorded with vermicompost and castor cake application and the lowest content was recorded in inorganic fertilizer.

2.7. Livestock management

2.7.1. Strategies for enhancing breeding efficiency of dairy animals under rainfed conditions

Long calving intervals in dairy animals are causing huge economic losses to the farmer and there is an increased concern to check the problem in order to enhance milk production from the dairy animals. Investigations were made to examine the metabolic profile of dairy animals and to correlate the results with nutritional status and take corrective measures in feeding management and to studying its impact on calving interval, reproductive problems and milk production. Preliminary data on feeding and management practices adopted by farmers and reproductive problems in their dairy animals were collected from Tallapalli village during 2007. Offered feed samples and blood were also collected and analyzed. This year, nutritional management, animal management, housing management and hormonal management interventions were implemented with the help of local veterinary assistant surgeon to improve breeding efficiency of the dairy animals.

Dairy animals with low energy and protein intake were offered with at least 2-3 kg green fodder and 1 kg concentrate mixture for a period of 5-6 months depending on the breed. Health camps were conducted to create awareness about identification of silent heat in buffaloes especially in summer and importance of timely insemination. Heat stress was managed by providing proper housing to the animals and early morning and late evening grazing during summer and feeding roughages during night. Synchronization of oestrus technique (with hormonal injections) was implemented in anoestrus and repeat

breeders. With these interventions, the number of animals that exhibited oestrus and the percentage of conception increased, and the number of animals free from postpartum reproductive disorders decreased (Fig 40).

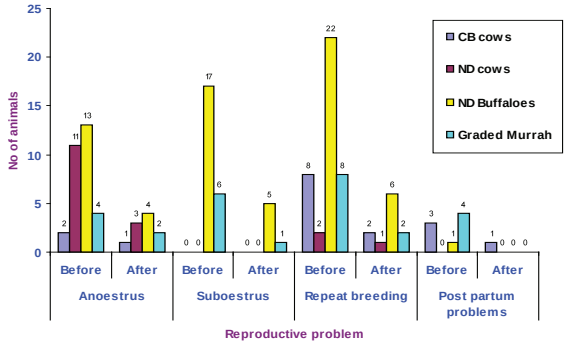


Fig 40. Effect of various interventions on occurrence of reproductive problems in dairy animals

2.7.2. Performance of sheep reared under different management systems

Quantitative and qualitative shortage of feed and fodder resources are becoming major constraints for sustaining a positive growth in the livestock sector, especially in small ruminants. Further, the selection of plant-derived protein sources for use as animal feeds should take human food security interests into account. It would be helpful if the foliage from plants like leucaena, gliricidia etc., which are unfit for human consumption could be used as protein supplement to small ruminants along with routine basal roughage diet. Experiments were initiated in 2005 to study the effect of different management systems on average daily gain (ADG), carcass weight and dressing per cent in growing lambs fed with roughage (chopped sorghum stover) as basal diet. Eighteen growing Deccani lambs were divided into three comparable groups (Group I, II and III) on body weight basis. Group I was maintained on intensive system of feeding management with chopped sorghum stover as basal diet and stylo/gliricidia leaf meal as protein supplement and compared with semi-intensive (Group II) and extensive (Group III) system of management. The slaughter characteristics of lambs reared under different management systems were recorded. In 2008, a feeding trial was conducted on growing Deccani lambs for 120 days under intensive system of management with sorghum stover as basal diet. The leguminous fodder (stylo + gliricidia) was used as protein supplement to the basal diet of chopped sorghum stover to feed the lambs and compared with semi-intensive (lambs were fed with concentrate mixture on equal nitrogen basis in the evening after grazing) and extensive (lambs were allowed to graze for 8 hours without any external supplementation) system of management.

The weight gain in lambs was comparable among the different types of protein supplemented groups under intensive system of management. The weight gain was significantly ($P<0.05$) higher under intensive when compared to semi-intensive and semi intensive when compared to extensive system of management (Table 34). A similar trend was observed in the average daily gain of the lambs. The slaughter characteristics of lambs reared under different management systems indicated significantly ($P<0.05$) higher carcass weight and dressing per cent with intensive followed by semi-intensive and extensive systems (Table 35). These results indicate that Stylo + Gliricidia leaf meal could be used as alternative to concentrate mixture to feed growing Deccani lambs along with the roughage basal diet (chopped sorghum stover) under intensive system of management for higher live weight gain, carcass weight and dressing per cent.

Table 34. Weight gain, average daily gain (ADG) and feed intake in growing Deccani lambs under different management systems

Parameter	Intensive+	Semi-intensive	Extensive
Initial body weight (kg)	12.7 ± 0.18	13.0 ± 0.32	12.7 ± 0.24
Final body weight (kg)	22.7 ± 0.31	21.9 ± 0.28	19.8 ± 0.24
Weight gain (kg)	10.0 ± 0.25	8.9 ± 0.25	7.1 ± 0.21
ADG (g/day)*	83.3^{c} ± 2.13	74.2^{b} ± 31.7	59.2^{a} ± 3.34
DMI (kg/100kg bw)*	3.96^{b}	4.12^{c}	4.01^{b}
DMI w $^{0.75}$	2.81	2.89	2.83

*Means with different superscripts in same row differ significantly ($P<0.05$)

Table 35. The slaughter characteristics of lambs reared under different management systems

Parameter	Intensive	Semi-intensive	Extensive
Slaughter Weight, kg	28.96	24.90	19.78
Full GIT, kg	5.12	5.07	4.91
Full GIT, %SW	17.68	20.36	24.80
Gut Fill, kg	2.98	3.10	3.18
Gut Fill, %SW	10.29	12.45	16.06
Empty GIT, kg	2.14	1.97	1.73
Empty Body Weight, kg	23.84	19.83	14.89
Carcass Weight, kg	16.50	13.85	10.10
Dressing, %	56.99	55.62	51.01

GIT= Gastro Intestinal Tract; **SW**= Slaughter Weight

2.7.3. Development of strategies for sustainable livestock production in the rainfed regions of India

The most widespread technical constraint to livestock production in rainfed farming systems is inadequacy and improper use of available feed and forage resources to feed the animals adequately throughout the year. Further, lack of awareness about technological changes and timely availability of essential inputs/services like vaccines/deworming drugs/ veterinarian services are the other reasons that affect the productivity of the livestock. To demonstrate and promote promising livestock production strategies and study their impact on livestock productivity and sustainability of rainfed agriculture, hands on training on implementation of promising livestock production strategies was imparted with the support of local animal husbandry department resources. The following promising technologies in ORP villages of Anantapur and Solapur led to fewer disease out breaks (Fig 41) and higher production from livestock and substantially improved the economic returns to the stakeholder (Table 36).

- Green fodder cultivation in farmer's fields
- Conservation and preservation of crop residues
- Efficient utilization of available feed and fodder resources by using chaff cutter
- Mineral mixture supplementation to the milch animals
- Vaccination against contagious diseases like FMD
- Deworming of calves and small ruminants
- Top feed supplementation to the small ruminants during summer

Focused interventions like capacity development of stakeholders through imparting training in goat rearing, backyard poultry and dairying created a lot of awareness in different aspects of health and nutrition management of livestock.

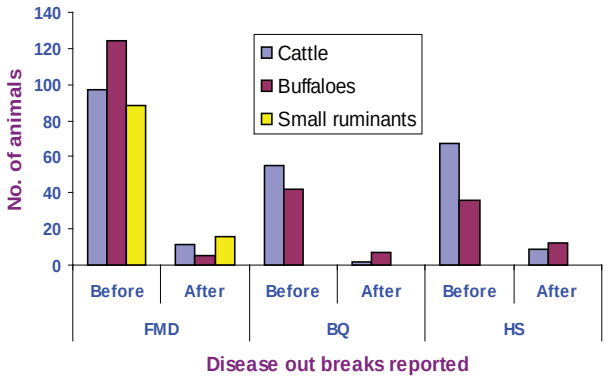


Fig 41 Impact of health camps on disease outbreaks

Table 36. Effect of green fodder feeding on milk production in milch animals

Parameter	Sole dry roughage feeding	Dry roughage with green fodder feeding
Average milk yield (l/day)	4.5	6.1
Total milk yield (l/305 days)	1372.5	1860.5
Gross returns (Rs.)	16470.0	22326.0
Cost of green fodder cultivation (Rs.)	-	1500.0
Net returns	16470.0	20826.0

2.8. Energy Management

2.8.1. On farm evaluation of CRIDA rotary tiller for biomass incorporation

Machinery for effective incorporation of biomass with minimum cost of operation and energy is very essential for improving soil fertility and supplying nutrients to crops. A modified rotary tiller was developed to improve the efficiency of incorporation. Performance evaluation of MB plough and modified rotary tiller was carried out in farmer's field in Timmareddyguda village of Rangareddy district. Sunhemp crop was grown on Vertisol and 40 day old crop was incorporated in soil by using the two implements. Biomass density per square meter before incorporation was observed. Green biomass at the time of incorporation was 28 t/ha. After incorporation, the amount of biomass distributed in 0-15 cm soil layer was observed by discarding surface biomass. 'size wise broken pieces' distribution was also observed in 0-15 cm depth. Sixty four percent of the broken biomass was in the range of 8 cm length in case of rotary tiller. Incorporation efficiency of rotary tiller was 74% as against 67% with MB plough.

In order to validate the variation of biomass incorporation within farm implements, if any, organic carbon content and nitrogen availability in soil after 30 and 60 days were analyzed. Rotary tiller performed better than MB plough both in terms of soil N content and soil organic carbon content after 30 days as well as 60 days of incorporation. Soil N content in rotary tilled plots was higher as compared to MB ploughed plots indicating that biomass decomposition was better in rotary tilled plots. Similarly, soil organic carbon content also was higher in rotary tilled plots than in MB ploughed plots.

Field capacity of rotary tiller was higher at 0.26 ha/hr as against 0.18 ha/hr with MB plough. Cost of operation with rotary tiller was less (962 Rs/ha) as compared to MB plough (1321 Rs/ha). Thus, rotary tiller is a superior implement than MB plough in terms of higher incorporation efficiency and low cost of operation.

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

Soils in rainfed regions are low in organic carbon and moisture holding capacity and need to be improved through appropriate cultivation practices in general and crop residue management in particular to sustain the productivity over the long run. Maize is grown over 7.52 M ha in the country, of which 72 percent is rainfed. Farmers are not interested to cut and lift the stover, which is low value fodder, from the field. Thus stover is either incorporated using MB plough or left in the field, creating problems during planting operations. Considering these factors, a field study was taken up to manage the stover *in–situ*. In the first year of this study the maize stover management activity was taken up. Different cutting options were exercised to cut the standing stover. Grain and stover yields of maize were 2448 and 2930 kg/ha respectively. Cutting stover to 50 cm height using manually carried motorized cutter followed by operating tractor rear mounted slasher gave uniformly cut material and uniform spread through out the field.

CRIDA Rotary Tiller for biomass incorporation

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

To assess sustainability of treated watersheds in rainfed agro-eco-sub-region AESR 7.2, eight micro-watersheds in four villages are being studied in-depth since 2005 using multidisciplinary sustainability indicators. To assess overall

impact of watershed development program (WDP) in these villages, a set of fifty sustainability indicators was constructed for evaluating impact at three spatial levels - household, field and watershed. Critical indicators were identified using three statistical techniques- bivariate correlation, PCA and factor analysis. A major objective of the study was to evaluate impact of WDP by comparing pre-watershed phase situation prevalent in 1998 with post-WDP condition 2005 onwards. In order to evaluate impact of WDP in the selected treated micro-watersheds, conditions were compared with those prevalent in an untreated micro-watershed in the same village. It was presumed that evaluation would help in identifying factors that limit gains accrued to farmers in rainfed regions as a result of watershed program. It is proposed to communicate the results of this study to watershed implementing agencies that could use this information to initiate corrective measures wherever required. Evaluation of WDP was undertaken for five aspects of sustainability - agricultural productivity, economic viability, livelihood security, environmental protection and social acceptability.

In 2008, field survey was undertaken in the eight micro-watersheds. Evaluation of impact of WDP was done through socio-economic study of farmers' condition, crop production, productivity and economic returns from farming activity, soil fertility status, NDVI changes, land productivity per unit area, and social acceptability of WDP. Study helped in identifying critical indicators useful for evaluation studies and also for initiating corrective measures for proper implementation of WDP. Three hundred and fifty eight (358) farmers were interviewed and their farm holdings surveyed in eight micro-watersheds in four villages. In Pamana village, Chevella mandal, Rangareddy district, a total of 123 farm households were evaluated of which 74 belonged to a treated micro-watershed (TMW) while the rest belonged to an untreated micro-watershed (UTMW) in the village, selected for the study. In Chintapatla village, Yacharam mandal, Rangareddy district, 113 farm households were assessed; 72 belonged to TMW and rest to UTMW in the village. In case of Dontanpalli village, Shankarpalli mandal, Rangareddy district, 49 farmers were assessed of which 19 belonged to TMW and the rest to UTMW. In Gollapalli village, Chintapalli mandal, Nalgonda district, 73 farm households were evaluated and 40 of them belonged to a TMW while the rest belonged to an UTMW in the village. Data pertaining to each household was stored in a database created in MS-Access for which a front-end application was created using DOT.NET framework.

Evaluation of sustainability at household – level

Evaluation of sustainability as a result of implementation of WDP at household-level was undertaken for three aspects - livelihood security, economic viability and social acceptability. Analysis indicated that in TMW in the study area in 2008, only one household was able to achieve sustainable development as a result of WDP in Pamana, Chintapatla and Gollapalli. For instance, in Pamana, one out of 74 farm households could turn sustainable in all three aspects relevant at this spatial level. In case of Chintapatla, one household out of 72 in TMW turned sustainable while in Dontanpalli none of the households was found to be sustainable. In Gollapalli, one household was sustainable while fourteen others achieved sustainable development in two of the three aspects that falls short of sustainability. Hence, it may be stated that WDP had a marginal impact on ensuring household sustainability in TMW in the study area.

Evaluation of sustainability at farm and watershed level

Evaluation at farm and watershed levels was undertaken based on assessment of all five aspects of sustainability. Evaluation of sustainability at both spatial levels in Pamana indicated that two Survey nos. accounting for 3.42 ha out of 133.52 ha in the TMW or 2.56 % of its' area was sustainable in four of the five aspects except in case of economic viability (Figure 42). This is highly improbable, as sustainability cannot be attained without economic viability. Other land parcels were unsustainable in the watershed due to issues related to Environmental Protection. In case of Chintapatla, one landholding of 3.5 ha (6.6% of the 52.92 ha area in TMW) was found to be partially sustainable, as Social Acceptability was not achieved. In Dontanpalli, four farm holdings were assessed sustainable in all five aspects; they accounted for 19.34 ha or 18% of the area in TMW. In Gollapalli, three farm holdings measuring 10.75 ha or 11.7% of the area under TMW was found sustainable in all aspects. Thus, only seven land holdings accounting for 30 ha or 15.24 % of total area under TMW in Dontanpalli and Gollapalli was found to be sustainable.

Reasons for failure to achieve sustainability at household-level

The study highlighted the limitations of WDP in the study area. At household- level, sustainability of livelihood security is critical; however, not much progress was noticed in the areas of contingency crop planning in the event of drought, securing

nutritional security among women & children to stave off hunger or ill-health, ensuring irrigation water availability for increasing agricultural production and consequently income from agriculture and ensuring fodder availability that could help in increasing income from livestock as well as check open-grazing that would fuel un-sustainability. Economic viability was low due to lack of gainful employment options in the village resulting in out-migration.

Reasons for failure to achieve sustainability at farm level

Sustainability of agricultural productivity was adversely affected due to failure to adopt contingency crop planning in the event of onset of drought, poor maintenance of soil and water conservation structures and lack of irrigation facility for critical crop phenophases. In case of livelihood security, development and proper maintenance of soil and water conservation structures, security of tenure, improving crop cafeteria index or area under cultivation, availability of credit and increasing gainful employment were absolutely essential; however, presently development was less than satisfactory. For environmental protection, there is a need to follow contingency crop planning, securing land tenure, increasing fodder availability through cultivation and encouraging extension agents to work closely with farmers; however, at present these were sorely inadequate across TMWs. For sustainable economic viability of agriculture, there was necessity to maintain S&WC measures properly, improve accessibility to credit facility, increase agricultural income, role of extension agents, and irrigation facility besides securing land tenure so that farmers can take care of their leased holdings. To ensure sustainable Social Acceptability, it was seen that opportunities for gainful employment must be increased, Contingency Crop Planning implemented effectively, credit facility ensured and fodder cultivation encouraged in a big way. The analysis reiterates that the five aspects of sustainability are interrelated as selection of indicators recurs under various aspects in the study and sustainable development is only possible if achieved under all five aspects as mentioned earlier.

Reasons for failure to achieve sustainability at watershed level

WDP at present has failed to ensure sustainable development at watershed – level for several reasons. These reasons are as follows: presently, agricultural productivity has not been sustainable due to lack of farm OM recycling, yield gap, failure to adopt Contingency Crop Planning and lack of irrigation facility. For ensuring livelihood security, agriculture needs to be backstopped with increased farm OM recycling, improving and maintaining S&WC structures, increasing Crop Cafeteria Index or judiciously using available cultivable land, development of opportunities of gainful employment, easy accessibility to credit facility and adoption of Contingency Crop Planning in the event of drought; all of these aspects have however, not been adequately addressed at present. During the study, three indicators pertaining to agricultural production systems were identified that adversely affected Environmental Protection; these were lack of security of tenure, non-availability of fodder for livestock or failure to cultivate fodder that resulted in unchecked open grazing causing biomass shortage for incorporation in soil in order to enhance soil OC content, besides failure of extension agents to do their duty. Economic Viability was adversely affected due to lack of security of tenure for tenant farmers, poor soil and water conservation measures, lack of proper guidance to farmers by the extension agents, lack of contingency crop planning and non-availability of gainful employment opportunities that lead to forced migration by the vulnerable category of farmers from the village, irrespective of implementation of WDP at great cost. The program also failed to get social acceptability due to yield gap, poor role of extension agents, exclusion from Government funded poverty reduction program, lack of gainful employment and easy accessibility to credit, failure to adopt contingency crop planning and non-availability of fodder, all of which forced farmers and their family to abandon agriculture in their own holdings and seek employment as labour elsewhere.

Undoubtedly, WDP implemented in rainfed regions at a great cost is absolutely essential for agriculture. However, studies indicate that at present the program has failed to address the various aspects of sustainable development. The present study has helped to identify the weak links in the program that must be addressed at the earliest.

2.9.2. Impact of NREGA on Rainfed Agriculture

Rural employment guarantee scheme of government of India in the name of NREGA has brought in lot of hopes for the land less and the farmers. Investment starved rainfed agriculture has a lot to gain from the scheme. An investigation was undertaken to study the changes in livelihoods of the job seekers, nature and extent of natural resource management (NRM) structures created in agricultural lands and their

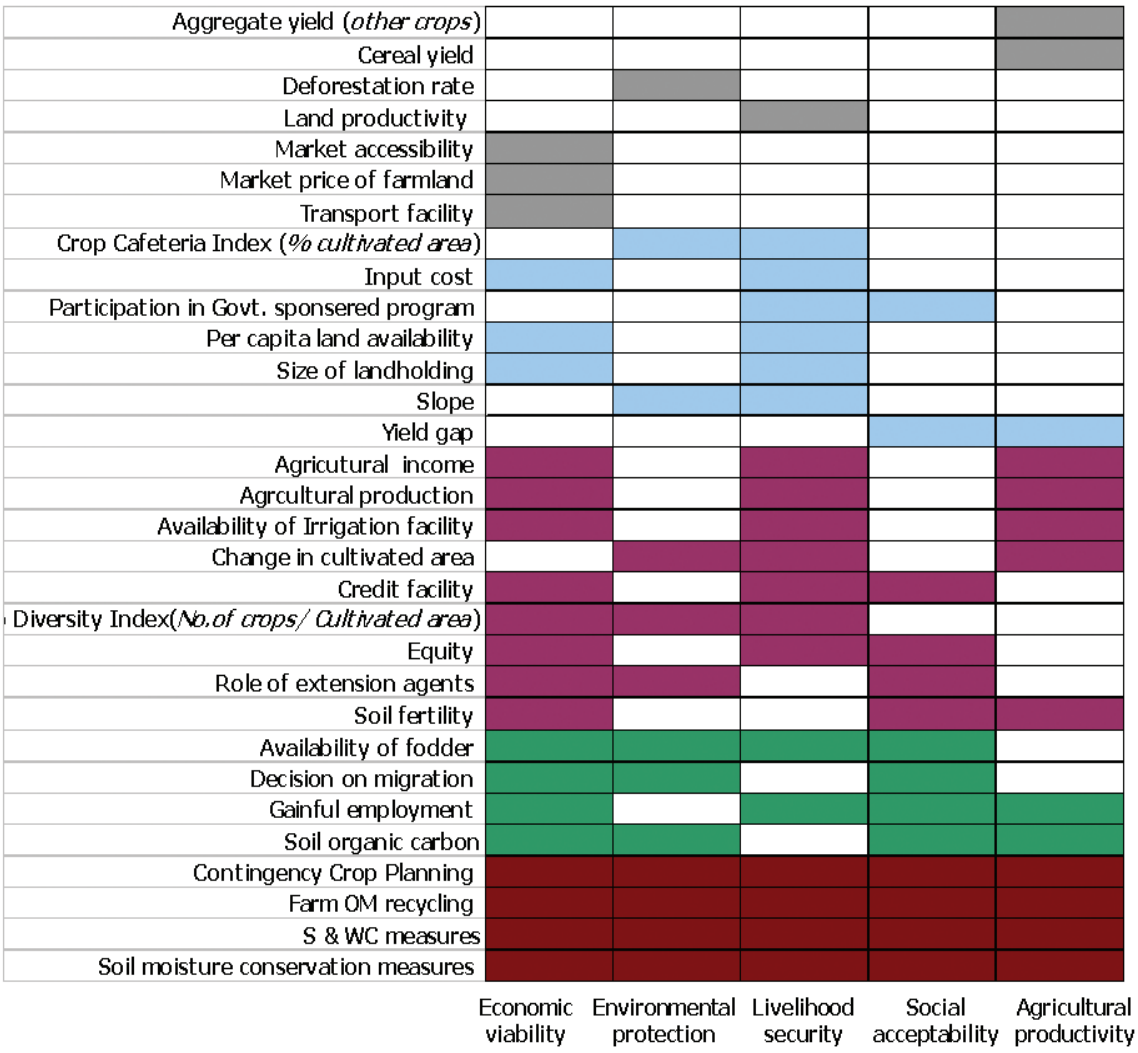


Fig 42. Identification of critical indicators for evaluation of Pamana TMW through various statistical techniques

utility. Based on the highest number of works taken up under NREGA, one district each in Andhra Pradesh and in Karnataka were selected for the study. Similarly three mandals/ blocks per district and two villages per each selected mandal/block formed the sample. From each sample village 10 job seekers, 12 farmers and 9 work sites were selected for getting primary data.

The proportion of households covered with employment opportunities under the scheme was as high as 76% in some villages. NRM works like farm ponds, earthen and stone bunds were made on farmlands. Works on common property resources included restoration of tanks and clearing of obstructive jungles in the villages. This to a great extent compensates for the lower public direct investment in agricultural infrastructure. Study results indicate that the employment benefit was obtained from NREGS both by labour and by farmers. The scheme significantly reduced the migration levels (Table 37). In some mandals, the NREGA earnings formed almost one third of the family income. The earnings were used mainly for ensuring food security (60%), family health (35%), debt repayment (30%) and purchase of household assets. NRM interventions like farm ponds resulted in increased yields. The implementation of NREGA has resulted in an increase in the wage rates for agricultural labour (Table 38).

Table 37. Impact of NREGS on seasonal labour migration in Anatntapur district

Particulars	Before NREGS	After NREGS
Average no. of family members involved in migration	1.3	0.3
% of family members on migration	27	7
Average Annual Income from migration (Rs.)	8135	1414

Table 38. Trend in Wage Rates for agricultural labour (at current prices) **(Rs./day)**

Period	Year	Peak Season		Slack Season	
		Male	Female	Male	Female
Before NREGS	2005-06	48	36	36	27
After NREGS	2006-07	67	53	50	38
	2007-08	84	64	61	45

Stone bund under formation

Farm Pond with harvested water

2.9.3. Trends and determinants of agricultural diversification in Andhra Pradesh

It is now recognized that diversification is one of the potential avenues for enhancing the income of the farmers in the fast changing environmental and economic scenario. Concerns that the recent diversification towards horticultural crops was accompanied by reduction in cereal consumption are also being expressed. To examine the nature of and trends in diversification that is taking place in Andhra Pradesh agriculture, a study was started in 2007. Both primary and secondary data were used to measure the diversification in terms of Simpson's index and area under dominant crop.

In 2008, Simpson's measure of diversification was computed for the 64 mandals in Mahabubnagar district of Andhra Pradesh. The Simpsons's index was found to vary between 0.62 and 0.86 in different mandals, indicating relatively high degree of diversification. The index of diversification for the district as a whole was found to be 0.84. Based on the Simpson's index, five mandals viz., Nagarkurnool, Weepangandla, Midjil, Gopalpet, and Damargidda were identified as most diversified and five mandals, viz., Itikyal, Waddepally, Atmakur, Maldakal, Devarakadra, as least diversified mandals. Further, mandals where the cropping pattern was dominated by a single crop were also identified so that technology transfer programmes can be better targeted. An analysis at household level indicated that the incomes are more diversified for small farmers compared to large farmers although the latter earned more. The contribution of crop production to total household income was higher (98%) for large farmers compared to small farmers (59%).

The trends in per capita food grain production were examined at district as well as state level. In particular, these trends were examined in districts with a growing horticulture. It was observed that the per capita food grain production was either stagnant or fluctuating in the districts with growing horticulture. The per capita food grain production was lowest in Anantapur district (Fig 43). It ranged between 41 and 83 kg/year during 1991-2005. For the state as a whole, the per capita food grain production ranged from 145 kg during 1998 to 208 kg/year during 2005. There was however no significant growth in per capita food grain production even at the state level (Fig 44).

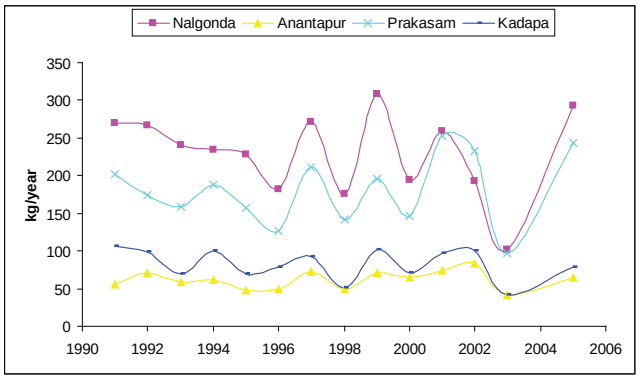


Fig 43. Trends in per capita food grain production in selected districts of Andhra Pradesh

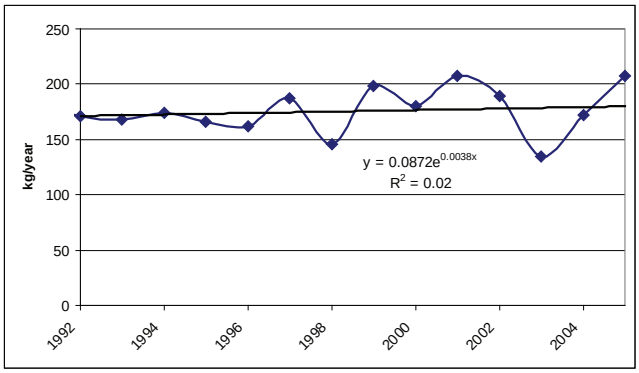


Fig 44. Trends in per capita food grain production in Andhra Pradesh

2.9.4. Trends in food consumption and rural household food security in rainfed areas

A study was initiated in 2008 to assess nutritional status of preschool children and women in rainfed areas of Rangareddy district of AP in terms of anthropometry and household food and nutrient intake by 24 hr recall method. Prevalence of chronic energy deficiency (CED) i.e., Grade I malnutrition was higher (17.86-18.76 percent) in Ibrahimpatnam mandal, prevalence of Grade II malnutrition was found to be higher (7.14-28.57 percent) in Shabad mandal and prevalence of Grade III malnutrition was higher (15.62-21.42 percent) in both Shabad and Yacharam mandals.

Household food consumption and extent of deficit in mean intake of foodstuffs (as % recommended dietary allowance, RDA) is depicted in Fig 45 and 46 respectively. Food intake in rural women was assessed by 24 hour recall method. The average daily intake of various foodstuffs especially protective foods such green leafy vegetables, other vegetables and milk and milk products, were lower than the RDA. The extent of deficit in mean intake of different food groups was higher for milk and milk products (77-83 percent), green leafy vegetables (25-67 percent) and other vegetables (33-41 percent).

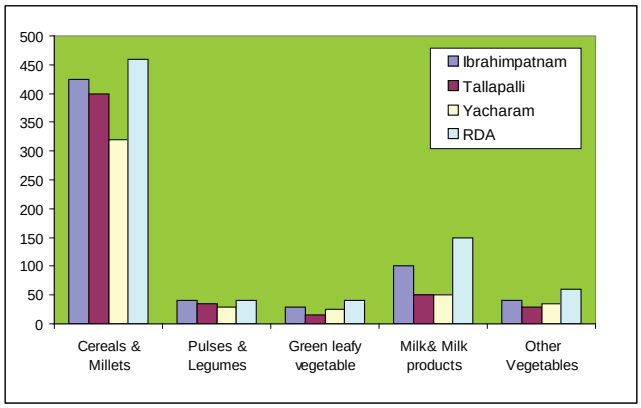


Fig 45. Food consumption (per/Cu/Day) in rural women Rangareddy district

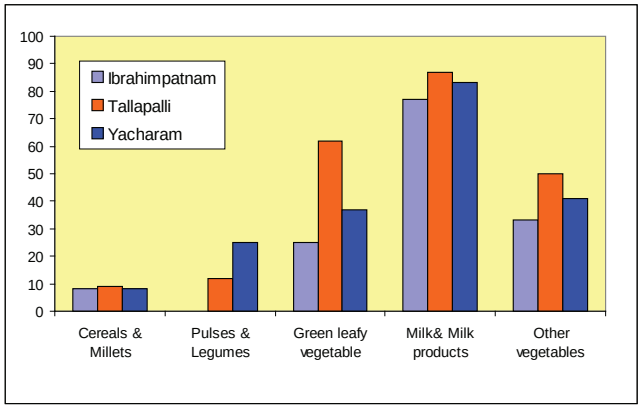


Fig 46. Extent of deficit in mean intake of foodstuffs (as % RDA) in different mandals of Rangareddy district

2.9.5. Economic analysis of technology interventions of KVK

In order to promote technology adoption, KVK is making efforts to promote various technological interventions appropriate to the farmers' situation in the villages. Economic viability is a necessary condition for a technology to be adopted by farmers. With this in view, this project was started in 2007 with the main objective of assessing the economic viability of important technologies promoted by KVK. The findings of partial budgeting analysis of interventions in the form of FLDs in pigeonpea in the KVK adopted villages are summarized in Table 39. There were three technologies-varieties, intercropping and integrated pest management-demonstrated in the

farmers' conditions. All the three technologies were found to yield significantly higher compared to farmers' practice. The marginal rate of return (MRR), the ratio of additional returns to additional costs associated with the technology, was found to be high (ranging between 3.18 and 6.09) in all cases. Highest returns were observed when integrated pest management was adopted in combination with intercropping.

Table 39. Marginal rate of return associated with technological interventions in pigeonpea

Year	Additional cost	Additional returns	Technology	MRR
2004-05	1725	5485	Variety	3.18
2005-06	1827	6888	Variety	3.77
2006-07	1375	7823	Variety	5.69
2008-09	1880	11449	Intercropping, IPM	6.09

2.9.6. Gender analysis in watershed development programmes of Andhra Pradesh and Karnataka

The United Nations' (UN) systemwide evaluation of progress made in gender mainstreaming revealed inadequate information from gender perspective in planning and implementation of natural resource projects like the watershed development. Gender mainstreaming is a cross cutting issue in all development programmes and integrating women's knowledge will help the sustainability of the programme. To identify the gender issues for mainstreaming in relation to participation, decision-making activites, access and control of resources in watershed programmes a study was initiated in 2007. The study was undertaken at two levels.1. Project level, 2. Watershed level. At project level, the project directors of Andhra Pradesh and Karnataka states were contacted with a questionnaire to ascertain their preparedness of integrating gender concerns into watershed programmes. Using the data collected, gender mainstreaming scores were computed (Table 40). Later, one watershed in each state was evaluated for gender differences at different stages of watershed implementation.

Forty per cent of project directors in AP reported that medium gender mainstreaming (GM) was seen in planning to implementation and post project stages whereas in Karnataka the project directors reported medium to high gender mainstreaming activities in planning and implementation stages. The differences in decision making as influenced by gender are presented in fig 47.

Table 40. District wise gender mainstreaming in watersheds of AP and Karnataka

Andhra Pradesh			Karnataka		
District	GM score	Rank	District	GM score	Rank
Chittoor	83	1	Chitradurga	87	1
Medak	72	2	Shimoga	77	2
Mahabubnagar	68	3	Bellary	71	3
Khammam	62	4	Bengaluru	67	4
West Godavari	61	5	Bhagalkot	62	5
Rangareddy	59	6	Chikamagalur	61	6
Cuddapah	56	7	Davangere	55	7
Krishna	55	8	Haveri	58	8
			Tumkur	54	9
Mean	**62**		**Mean**	**63**	

At watershed level, the gender issues identified revealed that women participation was more in manual and SHG related works whereas men participated in manual and management type of works (Table 41). Their participation was restricted to digging channels and making bunds.

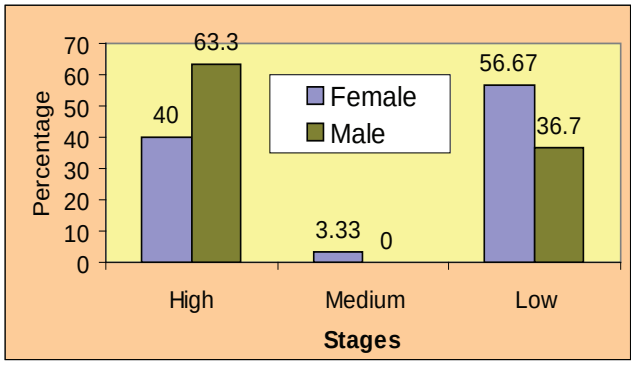


Fig 47. Gender differences in decision making in AP watersheds

Table 41. Gender participation at watershed level in AP

Type of work	Female				Male			
	Nil	Low	To some extent	Completely	Nil	Low	To some extent	Completely
SHG	-	-	96.7	3.33	-	-	-	-
Manual	-	-	23.33	76.67	16.67	13.33	26.67	43.3
Management	-	76.67	23.33	-	40	-	26.67	33.3

2.10. Transfer of Technology

2.10.1. Identification and digital documentation of dryland technologies

A study was begun in 2006 to identify and document adopted dryland technologies in a digital form that would pave way for informed decision-making and sustainable management of dryland regions. The study aimed to provide a knowledge/ information base about the adopted dryland technologies of CRIDA in a digital form that helps in informed decision making to the local people. Data was collected using pre-tested interview schedules from farmers cultivating both red and black soils. Maximum adoption was observed for dryland technologies like row ratios, fertilizer recommendations, conservation furrows and cultivation of *Bt* cotton. Digital documentation of adopted CRIDA technologies was completed.

2.10.2. ICTs as a tool of agricultural extension for technology dissemination

Rapid developments in information and communication technology (ICT) have opened avenues for agricultural technology dissemination and extension. To document the ICT's potential for technology dissemination, analyze the impact and identify the constraints of ICTs operated by different organizations a study was initiated in 2006. The impact created by ICTs eSagu (IIIT), weather based agro advisory services (WAAS, crop weather outlook, CRIDA), Ikisan (Nagarjuna group), kisan call centers (KCCs), Govt of India, MANAGE as state level center) was assessed. The results revealed that different ICTs had a moderate (WAAS, Ikisan, KSCs,) to high (eSagu) levels of overall impact in terms of technology dissemination.

Results showed that 40-60% of stakeholders had awareness of ICTs. Content for the clientele is mainly concentrated on advisory services (eSagu 54%, WAAS 45%, KCCs 50%,), clientele communication (eSagu 26%, KCC 50 %,WAAS 5%) and information dissemination (Ikisan 66%, WAAS 40%). Almost all the ICT initiatives were accessible to clientele through their respective websites round the clock on all days except KCCs which were accessible to farmers through telephone numbers 1500, 1100 for 10 hours/day. The duration for timely updation of the content/ technology varied from 24–36 hrs (eSagu, WAAS) to 1-2 years (I kisan). Language usage was mostly local languages for personal access and English for websites. All the ICT initiatives had well established partnerships with Government sector, NGOs and private sector agencies. eSagu had additional partnership with financial institutions like NABARD for disbursing crop loans to farmers. KCC and WAAS are providing free service to clientele which is affordable whereas eSagu (Rs.100/acre in case of field crops, Rs.300/acre in case of horticulture crops, Rs.1000/pond for aquaculture) and Ikisan (paying Rs. 100 per year or Rs. 20 per month) are levying service charges.

The study identified some bottlenecks in implementation of these technologies at field level such as inadequate capacity building, high cost of maintenance, frequent repairs of infrastructure (computers software and hardware), frequent change of trained personnel, lack of coordination between agricultural extension services from ICTs and traditional extension services by departments, non cooperation from some related departments, farmers' resistance to change (convenience in using alternative sources of information available at their doorsteps) etc.

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).

In CRIDA, six subprojects of different components of NAIP are being implemented.

3.1. Sustainable rural livelihoods through enhanced farming systems productivity and efficient support systems in rainfed areas

National Agricultural Innovation Project (NAIP) Component-3, sub project on "Sustainable rural livelihoods through enhanced farming systems productivity and efficient support systems in rainfed areas" was launched in September, 2007 at CRIDA, Hyderabad. This project is being implemented in 8 backward districts (Adilabad, Anantapur, Kadapa, Khammam, Mahabubnagar, Nalgonda, Rangareddy and Warangal) of Andhra Pradesh by a consortium of 9 partners with CRIDA as the lead center. It follows a participatory action research (PAR) framework to evolve replicable and up scalable models of livelihood enhancement in selected clusters of 3-4 villages in the target districts. In accordance with the PAR philosophy, the project began with a series of consultations with the stakeholders by employing PRA, rapid rural appraisal (RRA), focused group discussions and brainstorming sessions. The output of these exercises helped in understanding the livelihood issues across the clusters and designing appropriate interventions.

The project implementation began in September, 2007, close to the end of the *kharif* season. Between September 2007 to May 2008, initial project activities like detailed PRA, bench mark survey, clusterwise needs assessment, resource mapping, household livelihood analysis and entry point activities were carried out. A few interventions on seed production were taken up during *rabi* 2007. Formation of village level committees/ user groups and strengthening of existing groups was also done. Based on the needs analysis a clusterwise livelihoods intervention matrix was prepared. A detailed exercise was made to ensure that the interventions covered all the households during the project period, particularly, SC and ST and women headed households. In each cluster one or two major interventions which are likely to have maximum impact on livelihoods were taken as flagship interventions and the rest as supporting.

During *kharif* 2008, project activities picked up momentum in all the 8 clusters. The interventions covered all the major areas having bearing on livelihoods like NRM, crops & livestock production, farm mechanization, post harvest processing & value addition, market linkages, and capacity building. Based on the analysis of the benchmark data, the target households in each cluster were identified intervention-wise and a detailed participatory process was followed for implementing them and early lessons from the process were documented. In order to bring a common understanding among the members, visioning and thematic workshops were organized. The major challenge was to remain focused on livelihood enhancement as the final goal and considering the project interventions as the means to achieve that goal. The interventions in agriculture were related to variety replacement, village level seed production, introduction of improved cropping systems, and balanced nutrition. While no major constraints were faced in three of these interventions, several issues remain to be addressed in village level seed production. Breeder seed production and training of farmers to achieve satisfactory seed yields were achieved during *kharif*

2008 in Anantapur (groundnut), Kadapa (groundnut) and Mahabubnagar (sorghum, castor, groundnut) clusters. But storage and reuse during next season and related institutional arrangements are yet to be evolved and these will be focus areas in the future.

Breeder seed production in Anantapur cluster

Extensive work has been done in the project villages on NRM under several projects in the past. The project sought to build on this and focus on the most relevant interventions, which have potential to generate additional income in the short term. Water harvesting through farm ponds and its recycling for increasing cropping intensity was taken as a flagship intervention across the clusters. The project adopted a scientific approach in locating and designing farm ponds based on a careful analysis of rainfall and runoff potential, simultaneously undertaking capacity building of the project staff and village watershed committees. The other innovation was involving other stakeholders like District Water Management Agency (DWMA) that is in charge of NREGA programme in the state from the beginning, and ensuring that the proposed NRM activities in the clusters got included in the shelf of works of that panchayat. This model will help in institutionalizing the upscaling process of NRM interventions through NREGA. This approach succeeded during the first year itself. Farm ponds were dug in Mahabubnagar, Adilabad and Anantapur clusters and the harvested water was recycled for growing fodder/vegetable crops or providing supplementary irrigation to groundnut crop to generate additional income. This had an immediate impact on income and livelihoods of participating households.

Farm pond in Adilabad cluster

Small farm mechanization through custom hiring centers (CHC) was another intervention tried in a big way in all the clusters during the first year. This scored highest in the need assessment chart in most clusters. The need based equipments were made available, the farmers groups formed, and training provided on institutional mechanism of CHCs. The optimum size of CHC with a sustainable economic model and a proper mix of implements has to be worked out.

Custom hiring center in Kadapa cluster

Experiences from market linkage interventions like village milk centers and group marketing of graded mangoes were mixed. Initial enthusiasm was good, but an economic model to sustain groups is still to evolve. These are on a small scale and new constraints will surface as scaling up is attempted. In the areas of livestock production, a series of well organized animal health camps as entry point activity generated awareness among

the farmers on health and nutrition. Innovative approaches in fodder production like homestead azolla cultivation, fodder growing on CPRs, were introduced and showed promise. The most successful intervention was raising of ram lambs by landless women as an income generation activity. This intervention has tremendous scope of upscaling and can have a significant livelihood impact. The project also began evaluating different improved breeds of poultry for comparative performance, and innovative efforts to produce chicks in the village itself through decentralized hatching system involving women groups. New constraints such as parasitic worm infestation are surfacing due to unprotected and unhygienic rearing of the chicks.

Raising of ram lambs in Khammam cluster

Backyard poultry in Mahabubnagar cluster

Knowledge management through ICTs was introduced in all the clusters. The VRCs installed in the clusters became functional by the end of 2008. Each VRC consists of a computer, touch screen kiosk and IVRS. These centers are to be used for knowledge sharing, market and weather information. However, content generation and providing dynamic market information remain as challenges. Capacity building of farmers and rural youth was also taken up in the first year, extensive field visits and trainings were organized for the farmers. The training of youth in on-farm and off-farm skills proved to be fairly successful. But lot of ground is to be covered to identify right skill in demand and handholding of the trainees until they find a livelihood.

Village resource centre in Warangal cluster

A total of 4967 households were covered across all the clusters with one or other intervention (Table 42). Some of the significant accomplishments are: replacement of local and nondescript varieties with 16 high yielding varieties covering eight crops spread over 300 ha, which generated an additional income of Rs.16 lakhs at an average of Rs.5,400/ ha. About 500 kg/ha additional yield in cotton was obtained by altering the spacing from the conventional 90 x 90 cm to 90 x 60 cm to accommodate more plants. Households were assisted to generate an average additional income of Rs.5,500/ ha by growing vegetables like onions, tomatoes and brinjal. The success of zero tilled maize was up scaled from one farmer in *rabi* 2007 to 18 farmers in *rabi* 2008. Multiple use of harvested rainwater was demonstrated by digging a large size community farm pond in the Vertisols of Adilabad. Through various interventions of NRM, an additional rainwater storage capacity of over 10000 cu m was created across the clusters. This also generated an additional 17500 mandays of work besides enabling 473 farmers to tide over midterm droughts. Under the livestock interventions, over 18000 animals were attended to for diagnosis and treatment through animal health camps and prophylaxis campaigns. Many interventions were implemented in training and capacity building of youth and women. All the interventions were taken up by following certain process and the resulting learnings were recorded during the year. These are presented in detail in this report.

Table 42. Households covered by project interventions

Name of the cluster	Households covered						
	NRM	Crops	Horti-culture	Live-stock**	Agril. Implements/ Machinery	Capacity building	Value addi-tion
Adilabad	4	254	0	32	0	11	0
Ananatapur	28	141	94	118	400	12	0
Kadapa	16	59	0	7	23	5	0
Khammam	12	288	0	50	80	7	0
Mahabubnagar	54	65	80	68	629	7	4
Nalgonda	0	162	621	100	222	0	0
Rangareddy	258	156	10	328	54	7	12
Warangal	*	158	53	110	160	8	0
Total	372	1283	858	813	1568	57	16

* NRM activities were carried out by other projects operating in the cluster
** Through animal health camps all the livestock owning households were covered.

3.2. Development of Decision Support Systems for insect pests of major rice and cotton based cropping systems

Pest forecasts and forewarning systems are an important component of the broad IPM philosophy. Delivery of such information is facilitated by decision support systems that have emerged as essential tools to bridge the gap between science-based technology and end-users. An NAIP component 4 sub project 'development of decision support systems for insect pests of major rice and cotton based cropping systems' was launched in 2008 with CRIDA as the consortium leader and Central Institute for Cotton Research (CICR), Nagpur; Directorate of Rice Research (DRR), Hyderabad; Space Applications Centre (SAC), Ahmedabad; and National Centre for Integrated Pest Management (NCIPM), New Delhi as consortium partners.

The sub project involves field studies in two major cropping systems: rice-based and cotton-based cropping systems for development of pest forewarning models based both on biological and ecological processes. The rice-based cropping systems include rice-rice-pulse, rice-wheat and rice-rice-rice systems targeting stem borer, brown plant hopper, white-backed planthopper and leaf folder. The cotton based cropping systems include cotton + pigeonpea-fallow, cotton-wheat and cotton-groundnut/cotton-maize sequences targeting mealybug, mirid bugs, pink bollworm and *Helicoverpa*. The field studies are designed to generate information on off-season survival, pest-carry over on alternate hosts and pest-natural enemy interactions. Complementing field studies, laboratory experiments under controlled temperature and humidity conditions will generate data on developmental growth rates for mealy bug and mirid bugs in cotton; white-backed planthopper and leaf folder in rice. These studies will lead to phenology models for estimating the timing of pest attack. Extrapolation of model results over larger areas s envisaged through remote sensing techniques. Generation of spectral library using hand held spectro-radiometer for crop damage by insect pests will aid in developing pest specific vegetation indices which in turn leads to area-wide crop condition assessment using space borne remote sensing data. Derivation of spatial distribution of meteorological variables will lead to extrapolation of model outputs at the macro level. Integration of all the four components i.e., past database; generated data on field, laboratory and remote sensing studies through the development of a decision support system will strengthen the on-going integrated pest management programmes in rice and cotton with objectivity. The research achievements of the project are as follows:

1. A web-enabled historical database on six insect pests and two diseases of cotton and seven insect pests and two diseases on rice along with corresponding weather for 43 locations in the country was developed (Fig. 48)

2. Using field cage technique a nine fold growth rate for Brown Plant Hopper (BPH) population between 50 to 80 days after transplanting was quantified at Maruteru, West Godavari district.

3. Of the four mealy bug species recorded, *Phenacoccus solenopsis* Tinsley was the most widely distributed in all the cropping systems. *Maconellicoccus hirsutus* and *Nipaecoccus viridis* were specific to cotton+pigeonpea cropping system in the Central zone while *Paracoccus mariginatus* was specific to cotton+pulse cropping system in the Southern zone.

4. New sampling plans were devised for field population assessment based on source/foci of infestation for mealybug in cotton-wheat cropping system and for mirid bugs in cotton+pulse cropping system.

5. Seed cotton yield loss was estimated based on mealybug severity (Grade 1 to Grade 4) for two mealybug species: *P. solenopsis* (2 to 44% loss in Central zone and 14 to 54% loss in North zone) and *M. hirsutus* (36-76% in the Central zone). A one gram reduction in seed cotton weight per affected boll was estimated for mirid damage. A yield loss estimate of 85 kg/ha was worked out based on 5% damage on open bolls due to mirids.

6. Taxonomic identity of three mirid species in different cotton production systems was established. *Campylomma livida* was the dominant species in the Central zone while *Crenotiades biseratense* was specific to the Southern zone. *Hyalopelpus lineifer* occurs in both the zones.

7. Developmental biology of *P. solenopsis* and *Paracoccus marginatus* was quantified. In the Central zone, reproduction was mainly viviparous (97%) while in the Southern zone, it was oviparous. Maximum fecundity of 812 crawlers per female was recorded during a short developmental period of 13-18 days. Longevity of females was higher (47 days) and duration of effective reproduction was longer (17 days) in the Central zone.

8. Off-season incidence of pink stem borer on wheat in rice-wheat cropping system during Jan-Feb in the North zone was quantified (2% dead hearts and peak adult activity of 3 moths/trap/day).

9. In Boro rice in West Bengal, infestation of BPH on early maturing cropped areas served as a source of infestation that spread to late planted crop in other areas.

10. Peak infestation window due to mealybugs in cotton–wheat system (North zone) was during last week of August to mid September while in cotton + pigenonpea system it was during September to November in the Central and Southern zones.

11. Among weed species, *Xanthium* was found to be the major starter host for the onset of infestation on cotton at the start of the season while *Parthenium* sp harboured severe infestation towards the end of the season. In the Central zone, a total record of 91 host plants spread across 24 families was recorded. Plant species from three families viz., Compositae, Leguminaceae and Malvaceae constituted 50% of the host plants of *P. solenopsis*. *Hibiscus rosa-sinensis* was the triggering host in the Southern zone. *Abutilon indicum* was the most common weed host across the three production zones.

12. Diversity of natural parasitoids of mealybug species reported was greater in rainfed production system compared to irrigated system. Three species of Hymenopteran parasitoids from rainfed cotton based cropping system were identified to parasitize *P. solenopsis*. The dominant parasitoid was *A. bambawalei* across the cropping systems and production zones (up to 58% parasitisation recorded in cotton-wheat cropping system).

13. Cotton + cowpea intercropping system had significantly low incidence of mirid (nymphs) and damage to squares and bolls compared to sole cotton and cotton adjacent to tomato fields.

14. An unusually low pink bollworm incidence was observed on cotton in cotton+pigeonpea-maize cropping system in Warangal district of AP both in Bt and non-Bt genotypes during the season and off-season of 2008-09.

15. Web-enabled software was developed for data input and reporting system for the project activities taken up by consortium partners and associate centers. The partners can access the system over internet and submit the near real time data in prescribed formats every week (Fig. 49 and 50)

16. A prototype spatial level meteorological input generation through remote sensing at 5 km grid interval using combination of raster and vector database in Geographic Information System (GIS) was developed and tested as input for a pest forecast model for rice BPH in the Godavari zone.

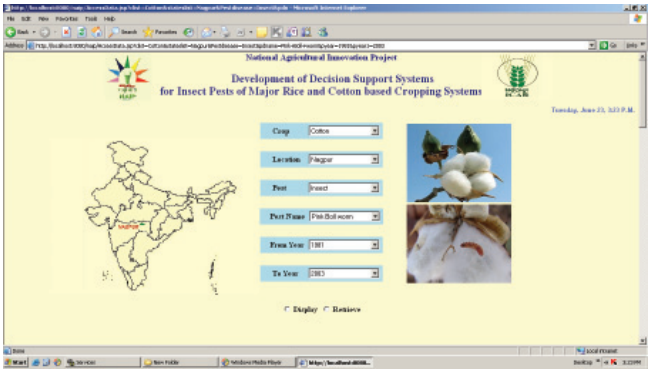


Fig. 48. Web-enabled historical database management system on crop pest-disease-weather

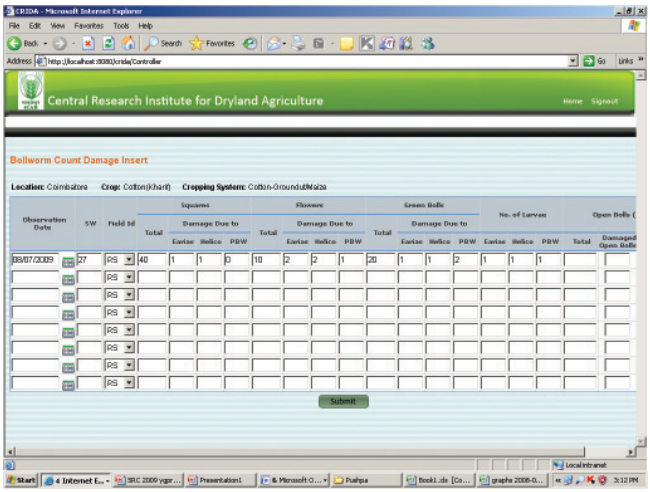


Fig. 49. Data input screen for the web-enabled software for on-line input of field collected pest data in prescribed data formats over internet

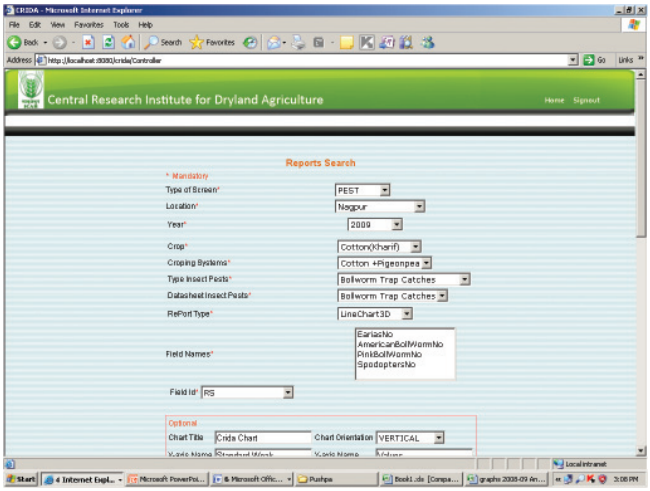


Fig. 50. On-line report generation screen for web-enabled software

3.3. Assessment of quality and resilience of soils in diverse agro-ecosystems

Out of the 20 agro-ecological regions in the country, this NAIP project is being implemented in 4 agro-ecological regions covering major soil types and climatic conditions. From each identified agro-ecological region, two districts representing high and low fertilizer use were selected. CRIDA is responsible for 7.2 AESR (Agro-eco-subregion). Nalgonda and Warangal districts were selected for the study. Nalgonda district had the second highest fertilizer consumption in this agroecoregion after Rangareddy district. Warangal district has the highest gross irrigated area.

A large number of soil samples, 160 from Nalgonda district and 149 from Warangal district from 0-15cm soil depth were collected. Most of the samples were collected after the harvest of *kharif* crop from the dominant cropping system of the district. Paddy, cotton and castor are dominant crops in Nalgonda district In Warangal district, paddy, cotton and maize are the dominant crops. The latitude, longitude and elevation of all the samples point were marked with GPS (Global positioning system). The farmer's name, crop grown, input use, yield level and dominant soil type were also recorded while collecting the samples. In each village, at least two samples were collected from undisturbed fallow land considering them as pristine samples.

The mean, maximum, minimum and coefficient of variation (CV) values of different soil parameters are given in table 43. Available nitrogen was low (<280kg/ha) in all the samples of Warangal district where is in Nalgonda district, out of 160 samples 16 samples were in medium range of available N (281-560kg/ha) while remaining samples were in low. Out of 160 samples analyzed for available phosphorus 12% samples were low (<10kg/ha), 56% samples were medium (11-25 kg/ha) and 32% samples were high level of available P in Nalgonda district, whereas in Warangal out of 149 samples 19% were low, 53% medium and 28% were high in available P. Six samples in Nalgonda and 7 samples in Warangal had available P more than 50 kg/ha. In one paddy field in Warangal, available P was as high as 106 kg/ha, which is toxic to crops. About 8% of samples in Nalgonda and 10% samples in Warangal were low (<120kg/ha) in available K. While 48 % samples in Nalgonda and 30% samples in Warangal were high in available K, the remaining samples were in medium range of available K (121-280kg/ha).

Table 43. Mean, minimum, maximum and coefficient of variation (CV) of some soil parameters in samples from Nalgonda and Warangal districts

Parameter	Nalgonda				Warangal			
	Mean	Min.	Max.	CV (%)	Mean	Min.	Max.	CV (%)
Bulk Density (g/cc)	1.55	1.17	1.87	9.41	1.5	1.15	1.79	8.77
Moisture @ 0.3 Bar W/W%	14.4	2.30	37.03	52.04	15.18	3.51	38.36	49.17
Moisture @ 15 Bar W/W%	7.2	0.81	22.6	68.1	7.94	1.77	19.93	54.2
AWC (mm/m)	110.4	20.8	282.6	49.8	107.2	24.0	378.2	56.2
pH	7.93	5.39	9.32	9.17	7.52	5.48	8.92	10.12
EC (dS/m)	0.21	0.03	0.87	80.7	0.19	0.03	0.84	62.3
Available N (kg/ha)	177.8	86.5	469.1	37.3	149.2	82.7	270.9	21.9
Available P (kg/ha)	19.3	3.3	77.7	67.6	21.8	0.45	105.9	78.5
Available K (kg/ha)	267.1	75.9	630.0	43.6	237.1	62.0	655.7	47.0
% clay	32.67	6.62	75.56	38.11	36.1	20.78	66.62	30.99
% silt	6.12	0.85	17.14	57.65	6.75	1	17	45.03
% sand	61.21	13.95	82.24	22.76	57.16	22.17	76.01	22.86

3.4. Value chain model for bio-ethanol production from sweet sorghum in rainfed areas through collective action and partnership

Mechanization of sweet sorghum sowing operation

As part of the mechanization of sweet sorghum crop, CRIDA introduced planters for sowing operation in Imbrahimbad cluster of Medak district, Andhra Pradesh. These include 4-row bullock drawn planter, 6-row and 9-row tractor drawn planters which were the designs of CRIDA extensively popularised in dryland regions of India. Sowing period in sweet sorghum is limited, ranging from 2 to 5 days depending on the moisture availability after arrival of monsoon. Success of sweet sorghum cultivation depends on completion of sowing operation within this limited period. Keeping this in view, specific planters (specifications are given below) were given to the cluster farmers' group to facilitate timeliness in sowing operation.

Specifications of CRIDA 4-row Planter

Weight: 120 kg

Source of power: Bullock

Row to row spacing: 45 cm

Plant to plant spacing: 20 cm

Row coverage: 4

Field coverage: 3-3.5 ha/day

Cost of operation: 400 Rs/ha

Specifications of CRIDA 6-row planter

Weight: 240 kg

Power: Tractor (at least 35 hp)

Row to row spacing: 45 cm

Plant to plant spacing: 20 cm

Row coverage: 6

Field coverage: 7-8 ha/day

Cost of operation: 350 Rs/ha

To propagate the concept of mechanization in the backward and tribal area of Medak district, a field demonstration cum training was arranged in farmer's field at Ibrahimbad thanda village. During field testing, the performance of 4-row bullock drawn and 6-row tractor drawn planter was found satisfactory. Farmers could not use the 9-row tractor-drawn planter since their holdings were small. Some modifications were done to the CRIDA planter in seed metering mechanism to achieve 20 cm plant to plant spacing as against 12cm spacing in traditional sorghum. Though a row to row distance of 60 cm is recommended for sweet sorghum, the farmers refused to adopt it as they perceived a yield reduction with less plant population. Hence the demonstration was conducted with 45 cm row to row spacing only. As part of the training programme, farmers were trained in repair and maintenance of sowing equipment which helped them to understand the basic principles. The demonstration motivated the farmers for mechanizing sorghum sowing. About 40 acres was was sown during the *kharif* season with CRIDA 6-row planter.

Demonstration cum training to farmers with CRIDA Planters

Mechanized sowing

Farmer's practice

Mechanization of intercultural operations

In sweet sorghum growing in dry land regions, weeds compete with crops for moisture, nutrition, light and space and constrain plant growth. Effective and timely weed control in sorghum crop plays a very important role in improving crop productivity. Conventionally farmers use hand tools like khurpi, wooden hoes, bullock drawn guntaka etc, which are slow, labour intensive and less effective. Improved tool designs like manual weeder, blade hoe, duck foot sweeps, rotary devices etc are available for interculture operations. These tools remove weeds, create soil mulch and enable different soil configurations between rows to conserve rainwater and support the plant rows by creating the soil ridge. Interculture and weeding operations predominantly use human and animal power tools involving drudgery. Deficit of human and animal power during peak operation period, higher wages and drudgery affect timely weed control in drylands. Therefore, new power operated tools like power weeder and improved manual weeder suitable for sweet sorghum crop were identified and introduced in the project area for demonstration purpose during this *kharif* season.

CRIDA Manual Weeder

CRIDA manual weeder was demonstrated in cluster village for creating awareness among farmers. Farmers were satisfied with its working. Two manual weeders were given to farmers in the project village.

Woman farmer using CRIDA manual weeder

Power weeder

It is self-propelled moving type interculture implement. It works with 1.5 h.p. petrol engine. It has rotary tines as working element and mounted below the front end of the frame. Engine is mounted on the working element at the front end of the

frame. The handle body with clutch and gear lever arrangement is attached to rear side of the frame. Engine provides power for forward movement and rotary blade attached to frame removes the weeds and pulverize the soil. Clutch can be used to engage and disengage the rotor during operation. This machine has better manoeuvrability in the field during operation and turning. Weed control is effective and soil mulch desirable under dryland conditions is created.

The power weeder was demonstrated in cluster village for creating awareness among farmers. Farmers were satisfied with weed removal in short time and better manoeuvrability in sweet sorghum field. A training cum demonstration was conducted at the Ibrahimbad village to test its feasibility, create awareness and evaluate its performance.

Field performance of the weeder

Weeding Efficiency: 90 %

Field coverage: 0.15 ha/hr

Cost of operation: 150 Rs/ha

Saving of time compared with khurpi: 65%

Saving of cost of weeding compared with khurpi: 50%

Demonstration and training of power weeder

Identification of harvesting equipment for sweet sorghum

The following equipment was identified for harvesting the sweet sorghum crop during the *rabi* season:

1. Modified tractor drawn front mounted vertical conveyer reaper
2. Self propelled sweet sorghum harvester with 6.5 hp petrol engine with multi tool frame attachment
3. Tractor drawn hydraulically operated automatic harvester (PDKV, Akola model)

Modification of tractor front mounted reaper as sweet sorghum harvester

A tractor front mounted reaper which can be attached to Massey Ferguson tractor was modified to suit the harvesting operation of sweet sorghum. The reaper is a multi crop harvester and is suitable to harvest soybean, paddy, wheat and other crops. It consists of cutting bar to cut the crop and guiding wheels to convey the crop in to the cutting zone. The cut crops stalks are conveyed with the belt of the reaper to a side to form a windrow. Since the sweet sorghum crop is more than 8 ft tall, the reaper was not found suitable. In addition to this, the stalk thickness is more, hence the cutting blades are also to be changed.

Modifications were carried out by increasing the height of the reaper to support the sweet sorghum stalk after cutting. An additional conveying belt was arranged at the top of the harvester for conveying the cut stems and additional set of guiding wheels were fixed to the conveyer to pick up the stems.

Modified tractor drawn front mounted reaper

Field testing of Modified harvester

Initial field testing on fodder sorghum showed that the equipment requires some refinement to cut and carry the stems properly. The refinement work is in progress.

Crushing operation

Two models of cane crushers in the capacity range of 250 kg/hr – 1000 kg/hr were identified to test and modify as needed. These are under procurement process. Crushing operation at the decentralized crushing unit at Ibrahimpur was observed during the *kharif* season. Manual feeding was laborious and juice recovery was low. Juice recovery can be improved by modifying the crusher and also with pretreatment of stalks. These will be attempted in the next season.

Crushing operation at decentralized cluster unit

Briquetting of sweet sorghum bagasse

The bagasse samples were collected from decentralized crushing centre and briquettes were made at a commercial briquetting facility. Bagasse had to be chopped into small pieces for making the briquettes in screw type briquetting machine. Hence the sampled material was chopped in a chaff cutter to reduce its size to less than ¼" length. Two different types of briquettes were made using begasse alone and with mixture of saw dust (25-30%) + bagasse (70-75%). The briquttes made of the mixed material were superior in terms of visual observations. However, further studies are needed for finalizing the quality standards of the sweet sorghum bagasse briquettes.

Sweet sorghum bagasse

Briquettes with sweet sorghum bagasse

3.5. AGROWEB – Digital Dissemination System for Indian Agricultural Research (Addsiar)

This NAIP Project aims to increase the web presence of CRIDA's research activities through updated content. Accomplishments during the year 2008-09 include.

- Development of digital databases on crop production, area statistics, etc., has been completed.
- Development of templates for AICRPDA centres
- Creation of meta tables for available databases on research information
- Conducting the needs assessment workshop for AICRPDA and AICRPAM during the annual workshop held at BCKVV, Kalyani.
- Sensitization workshops for chief scientists and scientists of AICRPDA centers at production system wise group meetings held at different places i.e Jagdalpur, Rajkot, Arjia, Bijapur, Madurai, Indore and Hissar.
- Organisation of a training programme for staff of CRIDA on web design and content management system at CRIDA for 2 weeks. Participants included staff of ARIS from Directorate of Oilseeds Resaerch, Directorate of Rice Research, National Research Centre on Sorghum and Project Directorate on Poultry, located at Hyderabad.

3.6. Effect of abiotic stress on natural enemies of crop pests: *Trichogramma, Chrysoperla, Trichoderma* and *Pseudomonas* and mechanism of tolerance to these stresses

One of the reasons for the failure of the biocntrol agents is their failure to establish in the introduced harsh environment such as high temperature, salinity or drought. Hence, a project

was formulated to screen biocontrol agents of insect-pests and plant pathogens for their ability to withstand high temperature, salinity or drought. Further, the project aims at understanding genetic mechanisms regulating these tolerance to these stresses.

The objectives of the project are

- To identify abiotic stresses in *Trichogramma* (collected from sugarcane and vegetable based ecosystem), *Chrysoperla* (cotton based ecosystem), *Trichoderma* (sorghum and groundnut based ecosystem) and *Pseudomonas* strains (sorghum, redgram and groundnut based ecosystem) and to assess their with biocontrol potential.
- Morphological / biological, biochemical and molecular characterization of mechanisms of tolerance to high temperature, salinity, drought stresses and pesticides in target organisms.
- To study the stress factors on the sex ratio in *Trichogramma* and *Chrysoperla*.
- To understand the inheritance pattern of high temperature and insecticide tolerance in *Trichogramma* and *Chrysoperla* and their genetic improvement.

The significant findings under this project so far are

One hundred and twenty strains of Pseudomonas were isolated from diverse soils of India covering stress affected different cropping systems. These isolates were analysed for biocontrol potential against five major phytopathogenic fungi viz. Rhizoctonia solani, Sclerotium rolfsii, Fusarium ricini, Macrophomina phaseolina and Botrytis ricini. 30 strains were characterized with bio-control potential. Tolerance towards abiotic stresses i.e salinity, high temperature and drought in-vitro were evaluated. 41 stains were tolerant to abiotic stresses. Protocol for routine genomic DNA isolation was standardized. Preliminary indications were recorded for differential expression of proteins under stress.

Results:

- One hundred and twenty strains of Pseudomonas species have been isolated from diverse soil samples.
- Thirty isolates were found to inhibit the growth of phytopathogens. 4 strains (PI 20, 21, 59 and43) could inhibit the growth of all the five test phytopathogens. Apart from these 13 strains were effective against Botrytis ricini, 5strains against Fusarium ricini, 6 strains against Rhizoctonia solani, and 11 strains against Microphomina phaseolina while 3 strains were effective against Sclerotium rolfsii.
- One strain could tolerate as high as 2.05 M salt concentration in vitro, while 5 strains could tolerate 1.88M. 3 strains could tolerate 1.71M salt concentration, 5strains could tolerate 1.54M, 5 strains could tolerate 1.36M and 4 strains could tolerate 1.2 M salt concentration.
- One strain could able to tolerate the temperature as high as 52^{0}C.10 strains could able to tolerate temperature of 50^{0}C, while 3strains could able to tolerate temperature of 48^{0}C and 1 strains could tolerate temperature of 47^{0}C .
- Two strains could able to tolerate -1.5MPa drought concentration while 7strains could able to tolerate-1.4 MPa drought concentration and 13 strains could able to tolerate -1.2 MPa drought concentration.
- For molecular characterization genomic DNA from 40 isolates with biocontrol potential and/or abiotic stress tolerance was isolated.
- SDS-PAGE analysis of whole cell extracts was carried out and induced/repressed proteins were observed. KDa proteins were overexpressed / repressed. These are further being characterized for its regulatory role in stress tolerance, if any.

Route map for collection of isolates of *Pseudomonas* from western India

4. Coordinated / Network Projects

4.1. All India Co-ordinated Research Project for Dryland Agriculture

The All India Coordinated Research Project for Dryland Agriculture (AICRPDA) has a network of 25 centers representing arid, semi-arid, sub-humid and per-humid climates with diverse biophysical 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 in 8 Operational Research Projects. The outreach programs like Frontline demonstrations (FLDs) on pulses and oilseeds, on-farm trials through other externally funded projects like AP Cess schemes are also being undertaken. A total of 487 experiments were conducted at the 24 centers with a percentage of 20.3, 12.7, 10.1, 14.6, 16.6, 1.2, 7.2, 3.7 and 2.7 under INM, rain water management, energy management, cropping systems, participatory varietal selection, integrated weed management, alternate land use, integrated farming system and other experiments respectively across the production systems.

4.1.1 Research Highlights

AICRPDA Centre / Theme	Salient Findings / Promising Technologies
Rain Water Management	
Agra	Ridge and furrow sowing together with recommended fertilizer in 3 splits (1/3 each) gave significantly higher pearl millet yield of 2262 kg/ha, net income of Rs.12847/ha and BC ratio of 2.53.
Akola	Furrow opening was the best treatment with a grain yield of 1305 kg/ha and stalk yield of 7159 kg/ha, highest net income of Rs.24484/ha and BC ratio of 3.45.
Anantapur	Mulching with crop residues/removed weeds was superior with maximum pod yield of 1175 kg/ha, net income of Rs.22185/ha and BC ratio of 3.22
Arjia	strip cropping of maize and blackgram with deep tillage together with ridging after sowing was efficient with highest maize equivalent yield of 1679 kg/ha, net income of Rs. 8031/ha and BC ratio of 2.10.
Ballowal Saunkhri	Paddy straw mulch was highly effective for wheat with maximum yield of 1209 kg/ha, net income of Rs. 5625/ha and BC ratio of 1.54 in *rabi*.
Hisar	Polythene mulch was superior for pearl millet with a significantly higher yield of 2085 kg/ha.
Indore	Vegetative barrier (bund) + sowing across the slope was superior with maximum soybean yield of 3369 kg/ha, net income of Rs.56408/ha, BC ratio of 5.12 and sustainability yield index of 0.38.
Jorhat	In case of rajmah, mustard and wheat tested during *rabi*, one irrigation at critical stage gave a net income of Rs.40207/ha in rajmah and Rs.817/ha in wheat.
Parbhani	Conservation furrow at 2.7 m was superior for sorghum + pigeonpea, soybean + pigeonpea and cotton + soybean systems. Soybean + pigeonpea was superior with a maximum net income of Rs.27248/ha and BC ratio of 2.37.
Phulbani	Higher cauliflower yield of 4400 kg/ha in *kharif* and radish yield of 225 kg/ha in *rabi*, with a net income of Rs.124723/ha and BC ratio of 2.27 were attained with a critical irrigation from a lined pond with soil; cement (6:1) plaster of 8 cm thickness
Rajkot	At 30 cm distance between rows having 3 rows on broad bed of 90 cm and furrow of 45 cm for maximum groundnut pod yield of 1474 kg/ha, net income of Rs.34649/ha and BC ratio of 3.47.
Ranchi	Hoeing between rows + leaf mulching was superior with upland rice yield of 1976 kg/ha.
SK Nagar	Two life saving irrigations + FYM @ 5t/ha was superior with a significantly higher castor seed yield of 937 kg/ha, net income of Rs. 14925/ha and BC ratio of 2.76.

AICRPDA Centre / Theme	Salient Findings / Promising Technologies
Solapur	Pearl millet + cowpea (6:3) was superior for minimum runoff of 2.1 mm, 500 kg/ha of pearl millet and 27 kg/ha of cowpea.
Varanasi	In late season drought, life saving irrigation gave maximum yield of 1963 kg/ha with net returns of RS.3700/ha and BC ratio of 1.30.
Cropping Systems	
Agra	Cluster bean + sesame (6:1) was superior with a significantly higher cluster bean equivalent yield of 1130 kg/ha, net income of 12849/ha and BC ratio of 2.72.
Akola	Castor + green gram (1:2) gave maximum and significantly higher castor equivalent yield of 1175 kg/ha;
Anantapur	Groundnut gave maximum net returns in the range of Rs.5986/ha (5th date of sowing: 3rd August)
Arjia	Maize + blackgram (2:2) was superior with a significantly higher maize equivalent yield of 2607 kg/ha, net income of Rs. 15793/ha and BC ratio of 2.73.
Ballowal Saunkhri	Maximum maize equivalent yield of 3921 kg/ha in *kharif* and barley yield of 1956 kg/ha in *rabi* were attained by maize-barley sequence.
Bangalore	DCH-177 in combination with a spacing of 120 x 45 cm and nipping was superior with a significantly higher seed yield of 1197 kg/ha.
Bijapur	Castor (60 x 15 cm) + sunflower (60 x 20 cm) in 2:4 ratio was superior for maximum net income of Rs.32094/ha and BC ratio of 4.2; seed hardening with calcium chloride for 8 hrs was superior for chickpea with a significantly higher seed yield of 1536 kg/ha.
Faizabad	Higher maize equivalent yield of 8217 kg/ha was attained by pigeonpea + blackgram..
Hisar	Castor paired rows (60-120-60 cm) + two rows of green gram was superior with maximum castor equivalent yield of 1643 kg/ha, net income of Rs.4788/ha and BC ratio of 1.32;
Indore	Higher soybean equivalent yield of 4789 kg/ha with a net income of Rs.75192/ha and BC ratio of 783 were attained by pigeonpea + soybean.
Jagdalpur	Line seeding by Indira seed drill + recommended fertilizer (50-30-20) kg/ha of NPK) + seed rate @ 100 kg/ha + post emergence weedicide + weed control by dora at 25 DAS was superior with significantly higher yield of 1347 kg/ha, net returns of Rs.4132/ha and BC ratio of 1.75 in upland condition.
Jorhat	Rice-pea was superior with a rice yield of 4367 kg/ha and pea yield of 332 kg/ha, net returns of Rs. 30839/ha and BC ratio of 2.31.
Parbhani	Maize + black gram (2:2) with 45/75 cm spacing was efficient with significantly higher maize yield of 5859 kg/ha and black gram yield of 152 kg/ha, fodder yield of 8230 kg/ha, net returns of Rs.44248/ha and BC ratio of 3.52.
Phulbani	Under broad bed and furrow planting, pigeonpea + cauliflower was superior with significantly higher pigeonpea equivalent yield of 4735 kg/ha, net returns of Rs.47030/ha and BC ratio of 1.99.
Ranchi	Safflower was superior with maximum wheat equivalent yield of 1720 kg/ha, net returns of Rs.10906/ha and BC ratio of 4.81 under zero tilled condition.
Rewa	Maximum soybean equivalent yield of 4415 kg/ha, net income of Rs.38090/ha and BC ratio of 2.71 were attained by soybean + pigeonpea (3:2) with a yield of 985 kg/ha of soybean and 2242 kg/ha of pigeonpea; 6:2 row ratio.
SK Nagar	Sole castor (90 x 60 cm) at onset of monsoon was superior with a significantly higher yield of 943 kg/ha, net income of Rs.14446/ha and BC ratio of 3.29 compared to relay in green gram.
Solapur	Sorghum + chickpea (2:1) at 45 cm row spacing was superior for attaining significantly higher grain yield 934 kg/ha of sorghum and 383 kg/ha of chickpea, with sorghum equivalent yield of 2217 kg/ha, net returns of Rs.23020/ha and BC ratio of 3.87.
Varanasi	75 cm (2 rice rows) and paired 50 + 100 cm (3 rice rows) was superior among plant geometry with pigeonpea equivalent yield of 1510 kg/ha, net returns of Rs. 27845/ha and BC ratio of 3.60.
Integrated Nutrient Management	
Agra	75 kg N + 50 kg P_2O_5 + 50% K_2O/ha (soil test based) + zinc + boron + magnesium gave significantly higher grain yield of 2026 kg/ha, net income of Rs.7129/ha with BC ratio of 1.60.

AICRPDA Centre / Theme	Salient Findings / Promising Technologies
Anantapur	FYM @ 5 t/ha was superior with a significantly higher pod yield of 1198 kg/ha, net returns of Rs.24534/ha and BC ratio of 3.41.
Arjia	100% recommended NP + zinc was superior for significantly higher yield of 1736 kg/ha, net returns of Rs. 7356/ha and BC ratio of 1.71.
Ballowal Saunkhri	80 kg N/ha (urea) was superior for wheat in *rabi* season in the plot where FYM @ 6 t/ha + 40 kg N/ha (urea) was applied for maize in *kharif* season with highest net returns of Rs. 10676/ha and BC ratio of 1.89 from a yield of 1766 kg/ha.
Bangalore	100 % recommended NK + lime @ 300 kg/ha + Mg CO3 @ 500 kg/ha + boron @ 10 kg/ha was superior with a significantly higher finger millet yield of 4245 kg/ha, net income of Rs. 40097/ha and BC ratio of 3.15.
Bellary	15 kg N (green leaf) + 20 kg N/ha (urea) was superior for *rabi* sorghum with a grain yield of 1779 kg/ha.
Bijapur	100% recommended fertilizer + Zn @ 10 kg/ha + Fe @ 50 kg/ha was superior for maximum sorghum grain yield of 2191 kg/ha.
Faizabad	45 kg/ha of sulphur + 10 kg of zinc was superior for mustard with yield of 642 kg/ha.
Hisar	40 kg N + 20 kg P_2O_5/ha + biomix was superior with a significantly higher pearl millet yield of 2202 kg/ha, net income of Rs.3149/ha and BC ratio of 1.20;
Indore	FYM @ 6 t/ha + 20 kg N + 13 kg P_2O_5/ha was superior with maximum soybean yield 3501 kg/ha, net income of Rs. 47110/ha and BC ratio of 3.96 in *kharif* and 1532 kg/ha of yield, Rs. 19019/ha of net returns with BC ratio of 3.45 from safflower in the *rabi*;
Jorhat	50% N (FYM) + 50% recommended NPK was superior with significantly higher rice yield of 4075 kg/ha and niger yield of 282 kg/ha under rice – niger sequence;
Kovilpatti	100% recommended NPK (soil application) + foliar spray of 1% $MgSO_4$ + foliar spray of 0.5% $ZnSO_4$ + foliar spray of 0.5% Boran (Borax) was superior for cotton with a significantly higher seed yield of 600 kg/ha, net income of Rs.6916/ha and BC ratio of 1.67.
Rajkot	100% recommended fertilizer applied to groundnut in the previous season had maximum residual effect on blackgram in the current season with a yield of 874 kg/ha, net income of Rs.5926/ha and BC ratio of 1.78.
Rakh Dhiansar	FYM @ 10 t/ha + 40 kg N/ha + recommended PK was superior with a significantly higher maize yield of 2403 kg/ha, net income of Rs. 8383/ha and BC ratio of 1.61 in *kharif*, wheat yield of 2338 kg/ha, net income of Rs. 17411/ha with BC ratio of 2.39 in *rabi*.
Ranchi	15 kg N (compost) + 10 kg N (green leaf) + 10 kg N/ha (farm residue) was superior with significantly higher rice equivalent yield of 2415 kg/ha in rice + blackgram, 2205 kg/ha in rice
Rewa	20 kg N + 40 kg P + 10 kg $ZnSO_4$/ha was superior for soybean – chickpea sequence with a yield of 2099/ha, net income of Rs. 9815/ha and BC ratio of 3.76 in *kharif*,
SK Nagar	50% recommended N (urea) + 50% N (vermicompost) + azatobactor + $ZnSO_4$ @ 8 kg/ha +$FeSO_4$ @ 115 kg/ha gave significantly higher sorghum dry fodder yield of 9250 kg/ha with net income of Rs.3797/ha and BC ratio of 1.38
Solapur	Soil test based fertilizer dose of 75 kg N + 31 kg P_2O_5 together with 15 kg/ha of zinc was superior for *rabi* sorghum to attain a grain yield of 992 kg/ha.
Varanasi	100% recommended fertilizer + $ZnSo_4$ + Manganese @ 25 kg/ha + Boran + Molybdenum @ 10 kg/ha (soil application) was superior for maize with a grain yield of 1365 kg/ha
Participatory Varietal Selection	
Akola	BBH-58 of pearl millet (3505 kg/ha); AKA-5 of cotton (1990 kg/ha) were superior.
Anantapur	DRVT-3 (1233 kg/ha); MLTG-2 (1508 kg/ha); TR-51 (1167 kg/ha); ICGV-02266 (2096 kg/ha); Narayani, (1495 kg/ha) of groundnut were superior.
Arjia	AVT-07-17 of sesame (643 kg/ha); ARV-015 of Jatropha (410.2 gm/plot); HG-4 of horsegram (813 kg/ha) were superior.
Bangalore	2KM-142 of green gram for early *kharif* (539 kg/ha); VL-6372 of greengram for late *kharif* (729 kg/ha); TAU-1-4 of black gram for early *kharif* (753 kg/ha); BDU-2 of blackgram for late *kharif* (768 kg/ha); IT-38956-1 of cowpea for early *kharif* (1410 kg/ha); KM-6 of cowpea for late *kharif* (1503 kg/ha); US-389 of vegetable cowpea for early *kharif* (fresh pod yield of 8500 kg/ha); PV-3 of vegetable cowpea for late *kharif* (8000 kg/ha); DCA-97 of chilli (dry chilli yield of 2550 kg/ha); Samrudhi of chickpea (1651 kg/ha) were superior.

AICRPDA Centre / Theme	Salient Findings / Promising Technologies
Bellary	JG-11 of chickpea (1650 kg/ha) was superior.
Bijapur	DSS-9 of sesame (746 kg/ha); JNS-27 of niger (519 kg/ha); SMLHT-6 of sunflower (1776 kg/ha); NAUSUF-7 of sunflower (2178 kg/ha); GPM-31of mustard (1307 kg/ha); CRHG-14 of horse gram (2200 kg/ha); CRIDA-06 JR of jatropha (305.5 g/ plant); HMT-100-1 of foxtail millet (3663 kg/ha) were superior.
Faizabad	Varuna of mustard (1450 kg/ha) was superior
Hisar	HHB-197 of pearl millet (yield of 2643 kg/ha), HFC-98-46 of cowpea (798 kg/ha), HT-1 of sesame (267 kg/ha), HGS-870 of cluster bean (1541 kg/ha), MH-96-1 of green gram (644 kg/ha), T-9 of black gram (1110 kg/ha), RMO-240 of moth bean (366 kg/ha), DCH-32 of castor (1029 kg/ha), DSH-5 of sunhemp (555 kg/ha), RH-819 of mustard (yield of 1554 kg/ha), RB-50 of raya (2146 kg/ha), HNS-9605 of Brassica napus (1054 kg/ha),T-27 of Taramira (555 kg/ha), BH-87 of barley (668 kg/ ha) and HC-5 of chickpea (777 kg/ha) were superior.
Indore	ICP-8863 of pigeonpea (1869 kg/ha); JS-95-60 of soybean (3973 kg/ha); JG-218 of chickpea (1979 kg/ha); JNS-208 of niger (405 kg/ha); JNM-1 of niger (389 kg/ha) were superior.
Jagdalpur	RT-54 of sesame (503 kg/ha; ICGS-37 of groundnut (1600 kg/ha); E-7 of sorghum (2937 kg/ha); ICP-8863 of pigeonpea (1880 kg/ha); RT-54 of sesame (737 kg/ha); ICGS-37 of groundnut (1600 kg/ha); ICP-8863 of pigeonpea (1882 kg/ha); E-7 of sorghum (2938 kg/ha) were superior.
Phulbani	ZHU-11-26 of rice (3482 kg/ha); Prachi of sesame (434 kg/ha); pusa-9531 of greengram (752 kg/ha); Jwalamukhi of sunflower (1315 kg/ha); Lakdong of turmeric (2557 kg/ha); Suprabha of ginger (11433 kg/ha); Jwalamukhi of sunflower (1315 kg/ha) were superior.
Rajkot	JSP-45 (1484 kg/ha) and JVB-2024 (1484 kg/ha) of groundnut; GT-10 of sesame (919 kg/ha); GM-996 of greengram (1125 kg/ha); SR-1904 of sorghum (1987 kg/ha) were superior.
Ranchi	RR-166-645 of rice (2675 kg/ha); BAU-20 of groundnut (2869 kg/ha); RT-125 of sesame (493 kg/ha); HG–26 of horsegram (492 kg/ha); GPU-28 of fingermillet (2562 kg/ha); CSH-18 of sorghum (2500 kg/ha); RLC-94 of linseed (793 kg/ha); Birsa chana-3 of chickpea (1742 kg/ha); JBV-3 of pearlmillet (1220 kg/ha) were superior.
Rewa	Vandana of rice for early sown (3240 kg/ha), medium sown (3008 kg/ha) and late sown (2176 kg/ha) conditions; PDU-1 of blackgram (1486 kg/ha); Surabhi of soybean (1735 kg/ha); JG-722 of chickpea (1556 kg/ha) were superior
SK Nagar	Gujrat maize-4 of maize (1451 kg/ha); GCH-7 of castor (1556 kg/ha); G.Cot-21 of cotton (1054 kg/ha); Gujarat garm-2 of chickpea (1961 kg/ha); GH-3 of mustard (1287 kg/ha).
Solapur	CK-07-IHT-59 of castor (1215 kg/ha); HG-33 of horse gram (903 kg/ha); G-11 of clusterbean (912 kg/ha) were superior.
Varanasi	Indury Sambha of rice (2249 kg/ha); T-12 of sesame (1037 kg/ha); KLS-218 of lentil (2015 kg/ha) were superior
Energy Management	
Agra	Conventional tillage + interculture + 50% N (organic) + 50% N (inorganic) gave significantly higher pearl millet yield of 1441/ha, net income of Rs.5062/ha and BC ratio of 1.55.
Akola	Low tillage + herbicide + 50% N (inorganic) + 50% N (organic through FYM/gliricidia) was superior with maximum sorghum grain yield of 2330 kg/ha and cob weight of 43.15 g.
Anantapur	Ananta Planter was superior for attaining maximum groundnut pod yield of 1500 kg/ha, depth of seed sowing of 4-5 cm, field capacity of 6-7 ha/day and lowest seed rate of 100-kg/ha and plant population of 35 per $m^{2.}$
Arjia	Conventional tillage + twice weeding and hoeing + 50% N (urea) + 50% N (compost) was superior with a maize yield of 1989 kg/ha, net returns of Rs. 10740/ha and BC ratio of 2.50. HIM-1 variety + 100 % recommended fertilizer + ridging after sowing combination was superior with significantly higher yield of 3048 kg/ha, net income of Rs. 18563/ha and BC ratio of 3.20
Ballowal Saunkhri	Low tillage + interculture + herbicide application together with 100% N through inorganic source was superior with significantly higher maize yield of 3016 kg/ha, net income of Rs. 17191/ha and BC ratio of 2.80 in *kharif*, wheat yield of 1611 kg/ha, net income of Rs. 11864/ha and BC ratio of 2.24 in *rabi* season.
Bangalore	Conventional tillage + 50 % N (organic) + 50 % N (inorganic) was superior with a significantly higher fingermillet grain yield of 1286 kg/ha.
Bellary	Conventional tillage of 1 ploughing + 2 harrowings + 1 hoeing + 1 hand weeding + 150% recommended N comprising of 50% N (FYM) + 50% N (urea) gave a significantly higher *rabi* sorghum grain yield of 1661 kg/ha.

AICRPDA Centre / Theme	Salient Findings / Promising Technologies
Bijapur	Ridger ferti-seed drill was superior for maximum sorghum yield of 1523 kg/ha, soil moisture of 17.56%; low tillage together with farmers practice and sunhemp green manuring was superior for sunflower with a maximum grain yield of 1013 kg/ha.
Faizabad	Conventional tillage + 2 hand weedings at 20 and 40 DAS together with 100% N through organic source was superior with a rice yield of 1663 kg/ha and lentil yield of 984 kg/ha under rice – lentil sequence
Hisar	ridger seeder (2 rows) was superior with a significantly higher mustard seed yield of 2057 kg/ha, net returns of Rs.29540/ha and BC ratio of 2.34 under normal moisture condition and 1649 kg/ha, net returns of Rs.17725/ha and BC ratio of 1.40 under receding moisture condition.
Indore	conventional tillage + recommended fertilizer + hand weeding gave significantly higher soybean yield of 3499 kg/ha, net income of Rs. 5998/ha, BC ratio of 5.73 and sustainability yield index of 0.23.
Jagdalpur	Dry line seeding by bullock drawn Nari seed drill was superior for chickpea with grain yield of 1001 kg/ha; wet line sowing with drum seeder was superior for rice in midland situation with a grain yield of 2958 kg/ha, fodder yield of 3800 kg/ha, net income of Rs.20412/ha and BC ratio of 2.28
Kovilpatti	Low tillage + interculture + 100 % N (inorganic) gave maximum net income of Rs.4685/ha and BC ratio of 1.66 from a yield of 2337 kg/ha. 60 X 25 cm was superior for cotton with a yield of 455 kg/ha, net returns of Rs.4100/ha and BC ratio of 1.48.
Parbhani	Conventional tillage + 100% recommended fertilizer was superior for cotton + soybean with a significantly higher seed equivalent yield of 1951 kg/ha, net income of Rs. 23629/ha and BC ratio of 1.75;
Rajkot	Conventional tillage + 100% N through organic source was superior with a significantly higher yield of 493 kg/ha, net income of Rs.15595/ha and BC ratio of 2.73.
Ranchi	Off-season tillage + low tillage + 2 hand weedings together with 50% organic + 50% inorganic fertilizer was superior for rice with a yield of 1883 kg/ha;
Rakh Dhinasar	low tillage + interculture + weedicide together with 100% N through urea was superior with significantly higher maize grain yield of 2291 kg/ha, fodder yield of 3437 kg/ha, net income of Rs. 13407/ha and BC ratio of 2.72 in *kharif* and wheat yield of 3336 kg/ha, straw yield of 3635 kg/ha, net income of Rs. 30087/ha and BC ratio of 3.37 in *rabi* season.
Rewa	In case of wheat, low till + weedicide + interculture + 100% (organic) ie. FYM @ 8 t/ha was superior with maximum yield of 953 kg/ha, net income of Rs. 9666/ha and BC ratio of 2.13 under soybean – wheat sequence.
SK Nagar	Low tillage + interculture + weedicide + 100% N (inorganic) gave maximum pearl millet yield of 1079 kg/ha, net returns of Rs.3789/ha and BC ratio of 1.89.
Solapur	Conventional tillage of plough once in 3 years + 1 harrowing + ridges and furrows + SSDH + 3 hoeings + 50% N (organic) + 50% N (urea) was superior for *rabi* sorghum with significantly higher grain yield of 1457 kg/ha.
Varanasi	Rotavator in combination with pretlachlor @ 1 kg a.i/ha (pre-emergence) + one interculture was superior for rice with a yield of 2585 kg/ha, net profit of Rs.5483/ha and BC ratio of 1.45;
Alternate Land Use	
Agra	Maximum net income of Rs.13740/ha and BC ratio of 2.33 were attained with aonla + cluster bean.
Bangalore	Maximum net income of Rs.25500/ha was attained by growing mango + finger millet + castor + avare + horse gram.
Kovilpatti	Sapota + maize was superior with maximum sorghum equivalent yield of 2327 kg/ha, net income of Rs.7125/ha and BC ratio of 1.89
Rakh Dhiansar	Aonla + green fodder was superior in *kharif* with maximum net income of Rs. 58496/ha and BC ratio of 15.62 from fodder yield of 16680/ha and fruit yield of 5208 kg/ha
Indore	Drumstick+soybean–chickpea was superior with maximum net income of Rs. 40910/ha and BC ratio of 4.19 from soybean equivalent yield of 2986 kg/ha.
SK Nagar	Aonla + stylosanthes hamata was superior with a significantly higher aonla yield of 8310 kg/ha and grass yield of 3050 kg/ha, net returns of Rs.20735/ha and BC ratio of 3.36.
Solapur	Maximum aonla equivalent yield of 1026 kg/ha, net returns of Rs.12564/ha and BC ratio of 2.58 were attained under aonla + pearl millet + pigeonpea

4.1.2 Operational Research Project (ORP)

The major activities in adopted villages / watersheds include participatory technology refinement/development in the theme areas of rain water management, INM cropping systems, varietal selection, alternate land use/ farming systems. Besides these, other activities include front line demonstrations, organizing field days / diagnostic field visits, farmer's field schools, preseason training programmes to farmers, agro advisories technology in coordination with KVK's, ATMA, state line departments etc.

Anantapur (Narsapuram National Watershed, Nagulagudem and Tanda villages of Channavaram villages, Anantapur district)

- Mechanical seed drill was superior for groundnut in farmers' fields with mean pod yield of 937 kg/ha, net returns of Rs.15365/ha and BC ratio of 2.1.

Arjia (Kochariya and Pathliyas villages, Bhilwara district)

- Thiourea spray gave maximum mean grain yield of 3363 kg/ha, straw yield of 4785 kg/ha and harvest index of 40.93% of wheat.
- PROM @ 30 kg P_2O_5 /ha gave maximum net returns of Rs.21641/ha, BC ratio of 3.09 from maize equivalent yield of 3537 kg/ha under maize + blackgram (2:2).
- Maize + Pigeonpea (1:1), supplemental irrigation gave maximum net returns of Rs.19387 /ha BC ratio of 2.73 from maize equivalent yield of 3325 kg/ha; Groundnut + sesame (6:2) gave maximum net returns of Rs.35272/ha and BC ratio of 4.29.
- AK-51 of horse gram gave maximum yield of 500 kg/ha, net returns of Rs.2648, and BC ratio of 1.61.
- Two-row seed drill performed better than country plough for attaining higher maize grain yield with lower time of operation and field capacity; rota-till drill was superior to traditional practice in 3 farmers' fields for time of operation, field capacity and crop yield.

Ballowal Saunkhri (Harman-Teehra-Janganian villages, (Kukarsua watershed) Nawanshahr district)

- PBW-175 of wheat gave a yield of 2076 kg/ha, net returns of Rs.12550/ha and BC ratio of 1.97; RLM-619 of raya gave a yield of 625 kg/ha, net returns of Rs.8165/ha and BC ratio of 2.09.
- Bangalore(Chikkamaranahalli village, Bangalore Rural District).
- Staggered moisture conservation furrow gave higher finger millet grain yield of 2193 kg/ha fodder yield of 4275 kg/ha and pigeonpea grain yield of 344 kg/ha with BC ratio of 2.12 under finger millet + pigeonpea (10:2).
- Finger millet (MR-1) + pigeonpea (TTB-2) in 10:2 ratio gave finger millet yield of 2530 kg/ha and pigeonpea yield of 365 kg/ha, net returns of Rs.16595/ha and BC ratio of 2.38; pigeonpea (TTB-7) + cowpea (IT-38956-1) gave pigeonpea yield of 854 kg/ha, cowpea yield of 280 kg/ha, net returns of Rs.7058/ha and BC ratio of 1.60;
- In an integrated farming system model, pigeonpea + cowpea was superior and gave maximum net returns of Rs.4705/ha with BC ratio of 3.04 in an area of 0.2 ha. The dairy component gave maximum net returns of Rs. 15000 with BC ratio of 1.82. There was a total net returns of Rs. 32609/ha with BC ratio of 2.01 from 1 ha of land in the study.

Hisar (Dariyapur village, Bhiwani district)

- Disc harrow was superior for conserving moisture and gave maximum mean net returns of Rs. 3285/ha with BC ratio of 1.28 from chickpea seed yield of 630 kg/ha in 3 farmer's fields.
- 40 kg N/ha gave maximum mean pearl millet yield of 1630 kg/ha, net returns of Rs.6374/ha and BC ratio of 1.58
- Chickpea in paired rows (30/60 cm) + Chinese cabbage fodder (70 DAS) gave chickpea yield of 420 kg/ha, Chinese cabbage fodder yield of 4630 kg/ha, net returns of Rs.2590/ha and BC ratio of 1.21
- HHB-67-2 of pearl millet for maximum grain yield of 1780 kg/ha, stover yield of 5260 kg/ha, net returns of Rs.6650/ha and BC ratio of 1.60; RH-9304 of mustard gave maximum mean seed yield of 860 kg/ha, net returns of Rs.4570/ha and BC ratio of 1.42; BH-393 of barley gave maximum mean yield of 2560 kg/ha, net returns of Rs.8875/ha and BC ratio of 1.63.

Indore (Hingonia, Indore district)

- 100% recommended NPK + sulphur @ 30 kg/ha through gypsum was superior with a significantly higher grain yield of 2300 kg/ha, net income of Rs.26475/ha and BC ratio of 3.75.
- JG-412 of chickpea for maximum grain yield of 1929 kg/ha with net returns of Rs.38673/ha and BC ratio of 4.50.

Ranchi (Jahar Nala watershed, Ranchi district)

- Pigeonpea + upland rice (1:3) in farmers' fields gave maximum pigeonpea equivalent yield of 1085 kg/ha.
- K-9107 of wheat with minimal irrigation was efficient with a grain yield of 2970 kg/ha, net income of Rs.16863/ha and BC ratio of 2.30 under late sown condition.
- Liming gave a maximum finger millet yield of 1901 kg/ha, black gram yield of 1576 kg/ha and upland rice yield 1473 kg/ha in upland acidic soils

Solapur (Hanjgi village, Solpaur district)

- Sunflower (Bhanu) + pigeonpea (Vipula) in 2:1 ratio was efficient with 615 kg/ha of sunflower yield and 820 kg/ha of pigeonpea yield, maximum net returns of Rs.23471/ha and BC ratio of 2.83; blackgram–sorghum sequence was superior with a maximum net returns of Rs.20695/ha and BC ratio of 2.28 from a yield of 630 kg/ha of black gram, 1180 kg/ha of grain and 2660 kg/ha of fodder of *rabi* sorghum in 7 farmers' fields.
- Ridges and furrows for *rabi* sorghum in 3 farmers' fields gave a higher mean grain yield of 1190 kg/ha, fodder yield of 3125 kg/ha and BC ratio of 1.65.
- 100% recommended dose of fertilizer gave significantly higher *rabi* sorghum grain yield of 1055 kg/ha, fodder yield of 2903 kg/ha and BC ratio of 1.60 in
- M–35-1 of sorghum gave higher mean yield of 787 kg/ha and net returns of Rs.11400 in shallow soils while Phule Yashoda gave a yield of 1306 kg/ha and net returns of Rs.17095/ha in deep soils.

XII Working group meeting of AICRPDA

XII Working Group Meeting of AICRPDA was held at OUAT, Bhubaneswar during 2-4 June, 2008. Dr.A.K.Singh, DDG (NRM), Dr. A.K. Gogoi, ADG (Agronomy), Dr. GGSN Rao, PC (AICRPAM) and Dr G. Subba Reddy , PC (AICRPDA), scientists from CRIDA and AICRPDA Centres participated during three day deliberations where in centre wise technical programme was reviewed, focus areas were identified to strengthen linkage between AICRPDA and AICRPAM and centre wise action points were identified for follow up.

Working group meeting of AICRPDA at OUAT Bhubaneswar

One day awareness programme on climate change

One day awareness programme on climate change and its impact on agriculture was organized across 10 AICRPDA centres to sensitize the farming community about the climatic variability/change and its likely impact on agriculture, animal husbandry etc. Feed back also was taken from the farming community about their knowledge on climatic variability and adaptation measures, if any.

Climate change awareness programme

National Group Meetings at AICRPDA Centers

In order to prioritize XI Plan research programme of AICRPDA network centers, production system-wise seven group meetings were organized viz. for Rice based production system was organized at Jagdalpur during 16-19 December, 2009;

for Groundnut and Fingermillet based production system at Rajkot during 6-9 January 2009; for Maize based production system at Arjia during 19-22 January, 2009; for Sorghum based production system at Bijapur during 28-31 January, 2009; for Cotton based production at Madurai during 24 – 27 February, 2009; for Soybean based production system at Indore during 16-19 March, 2009 and for Pearlmillet based production system at Hisar during 21-24 March,2009. Dr. B. Venkateswarlu, Director, CRIDA,Dr. P.K. Mishra, PC(AICRPDA), scientists form CRIDA and AICRPDA centers and ORPs, AICRPS/KVK/ATMA etc and officials form state govt. participated in the deliberations. During these meetings, centrewise technical programme of 2008-09 was thoroughly reviewed, developed technical programme for 2009-10 and action plans to be followed up by the individual scientists and centers.

National group meeting of AICPDA centres (Maize based production system, Arjia)

Front Line Demonstrations / On-farm trials

During the period, FLDs were conducted on *rabi* pulses viz. chickpea, lentil and peas to demonstrate the performance of improved varieties/nutrient management etc. across AICRPDA centers. At Bijapur, recommended dose of fertilizer in chickpea gave a minimum mean yield of 645 kg/ha with net returns of Rs.16392/ha and BC ratio of 2.4 and the recommended dose of fertilizer + sulphur + zinc gave yield of 780 kg/ha with 20.8% variation, net returns of Rs. 21708/ha with BC ratio of 2.7. Maximum mean yield of 1010 kg/ha was attained with A-1 variety with net returns of Rs. 29525/ha and BC ratio of 4.3.At Solapur with Digvijay variety, a mean yield of 1175 kg/ha with a BC ratio of 1.91 was attained with improved practice compared to farmers' practice and application of sulphur in chickpea gave a mean yield of 1033 kg/ha with improved practice. Rhizobium and PSB inoculation attained a yield of 1078 kg/ha and 988 kg/ha with the improved and farmers' practice. At Indore, cv. Vishal of chickpea gave a yield of 1513 kg/ha compared to 1413 kg/ha by farmers' practice and sulphur application in chickpea gave maximum mean yield of 1695 kg/ha yield with improved practice whereas the farmers' practice gave 1570 kg/ha.At Agra, chickpea gave a mean yield of 1297 kg/ha with a gross income of Rs. 26400/ha and BC ratio of 2.78 with improved practice while it was 1003 kg seed yield/ha,Rs. 20548/ha of gross income and a BC ratio of 2.38 under farmer's practice. Nutrient management in chickpea i.e. recommended NPK + S application gave a yield of 1310 kg/ha, gross income of Rs. 28820/ha and BC ratio of 2.94 under improved practice, compared to a yield of 1028 kg/ha, gross income of Rs. 25212/ha and BC ratio of 2.52 under local practice. Lentil cv. DPL-15, gave a mean yield of 1353 kg/ha with a gross income of Rs. 24345/ha and BC ratio of 2.93 under improved practice. At Rewa, improved practice of nutrient management for chickpea cv. KK-1, recommended NP + zinc gave maximum yield of 1450 kg/ha with net returns of Rs. 27125/h and BC ratio of 4.23 while recommended NP + sulphur gave 1412 kg/ha, net returns of Rs. 24875/ha and BC ratio of 4.03.

Publications

From AICRPDA centers, there were 286 publications/ Seminar/ Symposium papers 38 research papers published in journals, 125 presented in conferences, 25 books/bulletins/ reports and 98 popular articles, during the reporting period.

Outreach programmes

Across the centers, capacity building of farmers was done by organizing trainings in theme areas, Kisan Melas/Kisan Diwas/Field Days, exposure visits etc., On farm demonstrations/ trials/ Farmers Field Schools in ORP areas helped in upscaling the rainfed technologies. Agro-Advisories were given through electronic media/Radio talks/ newspapers in the centres' respective domain areas.

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, Private agencies, 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 national institutions for training programs and Ministry of Rural Development, Ministry of Water Resources, GOI for adhoc projects. AICRPDA centers established strong linkages with NGOs like Rural Development Trust (Anantapur) etc. in their respective domains.

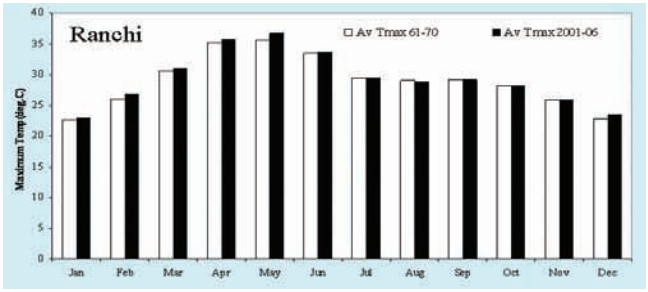
4.2. All India Coordinated Research Project on Agrometeorology

The All India Coordinated Research Project on Agro-meteorology was initiated by ICAR in May 1983 with the establishment of Coordinating Cell at the Central Research Institute for Dryland Agriculture, Hyderabad and 12 Cooperating Centres at various State Agricultural Universities. After evaluating the progress made by the project and realizing the importance of Agrometeorological Research support for enhancing food production, ICAR had extended the Cooperating Centres to the remaining 13 Agricultural Universities of the country with effect from April, 1995. The network of 25 Agrometeorological Cooperating Centres are at Akola, Anantapur, Anand, Bangalore, Bhubaneswar, Bijapur, Dapoli, Faizabad, Hisar, Jabalpur, Jammu, Jorhat, Kanpur, Kovilpatti, Ludhiana, Mohanpur, Palampur, Parbhani, Raipur, Rakh Dhiansar, Ranchi, Ranichauri, Samastipur, Solapur, Thrissur and Udaipur.

The research program was carried out at all the 25 centers of the project agroclimatic characterization, crop weather relationships, crop growth modeling, weather influence on pests and diseases.

Agroclimatic characterization

- Based on the tehsil wise rainfall for the years 1981-2004 in respect of Marathwada region, various thematic maps of rainfall, water balance components, length of growing period etc. were prepared using GIS facilities.
- Raipur centre has delineated agro ecological regions of Chhattisgarh region were declined into comprising Northern hills, Chhattisgarh plains and Bastar plateau using micro level data including weather, soil, land use/land cover information.
- The impact of pre-monsoon showers on the subsequent occurrence of rainfall was carried at out by Bangalore centre and it was observed that above normal rains in May and June bring less rains in the subsequent months of July and August.
- The monthly average maximum temperatures at Ranchi for the periods 1961-70, 2001-06 was analyzed and it was found that the average maximum temperatures for all the months for the period 2001-06 have shown higher values during summer and winter months. However, there was no significant difference of average maximum temperatures during monsoon period.



Monthly average maximum temperature for the period 1961-70 and 2001-06 at Ranchi

- The shifts in climate type viz., from perhumid to humid over Kerala for the period 1951-2005 was analyzed and found that the moisture index (Im) values decreased from 94-68 over the period.
- Occurrence of frequency of higher maximum temperatures viz., >40°C during March and >45°C during May and June for the period 1970-2005 was analyzed at Bhubaneswar and was found that frequency of occurrence of high temperatures above 40°C is more during the present decade (2000-2008) compared to the earlier decades.

Occurrence of years with extreme Tmax at Bhubaneswar

Period	Years with > 40⁰C in March	Years with >45 ⁰C In May	Years with > 45 ⁰C in June
1970-79	0	1	1
1980-89	1	0	0
1990-99	2	2	2
2000-05	2 (of 6 y)	6 (of 6 y)	3 (of 6 y)

Crop weather relationships

- Relationship between the departures of average temperature on the flowering behaviour of olive plants for the period 2004-05 to 2006-07, was worked out at Jammu. When the temperature deviations are higher by 2-3°C during the first

week of February, the flowering of the olive plants were advanced by more than 30 days over the normal period of flowering (2nd fortnight of March).

- The following multiple regression models were developed to predict wheat yield for Udaipur region using growing degree days (X_1), maximum (X_2) and minimum (X_3) temperature at both vegetative and reproductive phases.

  Vegetative phase

  $Y = -335.1 + 0.18 + 4.4X_2 + 18X_3$ $R^2 = 0.87$

  Reproductive phase

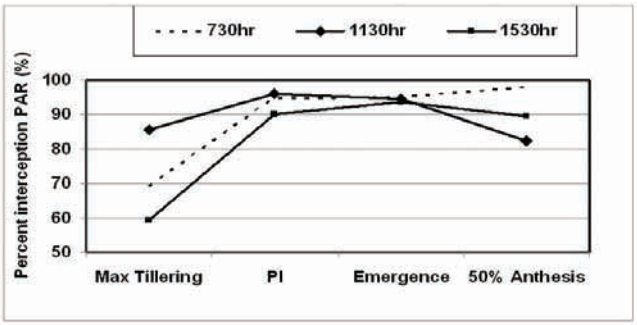
  $Y = 174.3 + 0.01X_1 - 8.3X_2 + 8.4X_3$ $R^2 = 0.86$

- As a collaborative programme between AICRPAM and AICRPDA temperature profile measurements in pearl millet grown under different fertilizer treatments were recorded and analyzed at Hisar. The canopy temperatures in treatment that was grown with N40+P20 had shown higher temperatures from jointing to hard dough stage where as at physiological maturity the treatment N40+P20 biomix recorded higher temperature

- Diurnal radiation interception at different crop growth stages of rice viz., maximum tillering, panicle initiation, ear head emergence and 50% anthesis was studied at Mohanpur centre. It was observed that maximum absorption of radiation is found at PI stage. However, with the advancement of the growth stages the absorption percentage decrease due to leaf senescence.

- Relationships between heat units (X) and grain yield of wheat was studied out by Samastipur centre and the following regression model was fitted.

  $Y = 4.295X-4027.7$ ($R^2 = 0.6659$).



Per cent intercepted PAR values for different growth stages at Mohanpur

Crop weather modeling

- SOYGRO model was tested at Hisar for four cultivars viz., HS40, DS9814, PK416 and PS1042 for three dates of sowing viz., 1st week and 3rd week of June and 1st week of July. The deviations between observed and predicted values for different phenological stages were analyzed. It was observed that the deviations of all parameters are more in respect of cultivar PS1042 compared to other cultivars. The deviations in respect of pod and seed yield is little higher in third week of July sown crop in cv.SH40 and JS 1042.

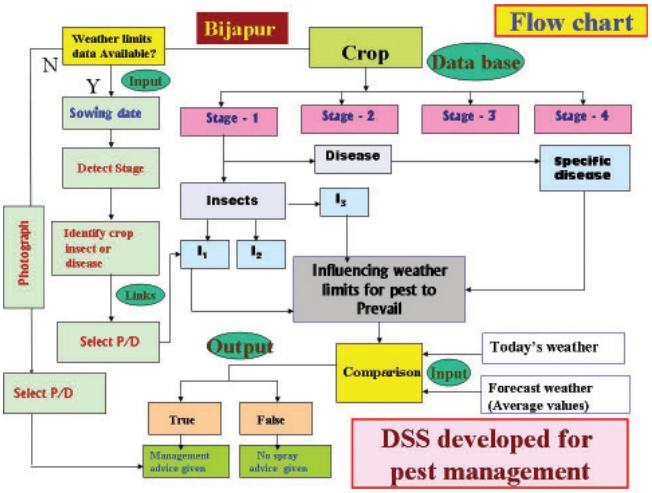
- Integration of remote sensing data with HERMES model was attempted at Raipur for predicting wheat yields. Data from 14 samples were analyzed. The deviations between observed and the original datasets are large. With integration of remote sensing data the deviations between observed and predicted have decreased considerably. There is a need to still improve the output of the model.

- At Anand, observed and simulated phenology, growth and yield parameters in respect of summer pearl millet using DSSAT model indicated that the model predictions of various parameters are in tolerable limits except straw yield.

- The influence of climate change on the yield of *kharif* rice variety (Lalat) in Orissa for the years 2020 was studied at Bhubaneswar using INFOCROP model. The results indicates that the crop duration may be reduced by a week and the yield will reduce to about 10% over the production recorded in 2006.

Weather pests & Diseases

- A Decision Support System (DSS) was developed by Bijapur centre for pest management in different crops. Based on the level of information on the limits of weather parameters for the pests to survive and to multiply available in DSS and the current weather, crop and pest/diseases status it will advise farmers the action to be taken. The input to the DSS is the current crop, weather and pest/diseases data on daily basis.



Decision support system for pest management at Bijapur

- The following ideal meteorological limits for infestation of rice Hispa and rice Gundhi bug for Kalyani region was identified by the Mohanpur centre.

Pest	Tmax (°C)	Tmin (°C)	Tmean (°C)	RH-1 (%)	RH-II (%)
Rice Hispa	33.5 - 34.3	23.8 - 26.6	28.7 - 30.5	98 - 99	68 - 94
Rice Gundhi bug	32.4 - 33.7	23.5 - 25.6	28.6 - 29.7	98 - 100	71 - 98

- The influence of relative humidity and minimum temperature on pod borer in chickpea was studied by Faizabad. Indicated that highest population of pod borer recorded when minimum temperature was around 9-12°C with afternoon relative humidity values around 35-50%.

Other activities at coordinating Unit, AICRPAM

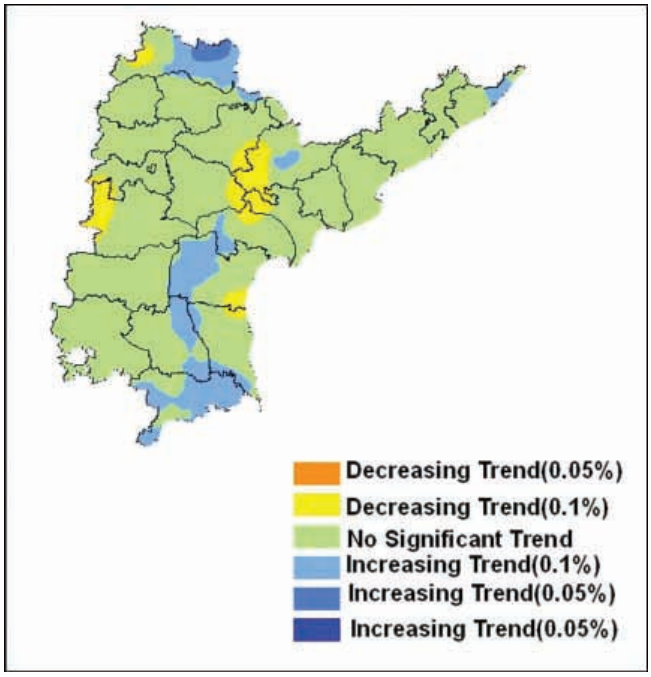
- Under the Network Program on Climate Change (NPCC), the agroclimatic analysis in respect of Andhra Pradesh was carried out. Annual average maximum and minimum temperature trends in respective of nine stations have been worked out and presented in Table.

- The spatial distribution of rainfall trends have also been worked.

- The crop water requirements during the year 2020 and 2050 under different dates of sowing of oilseed crops viz., groundnut, mustard, sunflower and castor at Rajkot and Anantapur, Hisar and Bharatpur, Kurnool and Osmanabad,

Temperature trends in the stations of Andhra Pradesh

Station	Annual average max. temp (°C)	Annual average min. temp (°C)	Annual average temp (°C)
Anantapur	↑1	↑0.8	↑0.8
Arogyavaram	↔	↑0.4	↑0.3
Hyderabad	↑1.1	↑1.3	↑1.1
Khammam	↓1.3	↑0.4	↓0.4
Kalingapatnam	↔	↔	↔
Kurnool	↑0.3	↑0.8	↑0.6
Mahabubnagar	↑1.4	↑1.2	↑1.2
Vishakapatnam	↑1.5	↓0.3	↑1.5



Rainfall trends over AP

Mahabubnagar and Tumkur respectively was computed and compared with the values of the base year 1990. No major changes were observed in the crop water requirements for these above crops.

- The impact of climate change on the availability of water surplus amounts at 21 stations in Andhra Pradesh for the years 2020 and 2050 was computed using Thornthwaite and Mather (1955) procedure. These values have been compared with the base years values (1990).

- About 50% of the stations that are considered for the study have not shown any change on the availability water surplus on annual basis for the year 2020 and 2050. However, at some locations in parts of North Telangana and parts of central and Northern coastal region have shown decreased availability of water surplus which can be mainly attributed to increased PET values and slight decrease in rainfall situations.
- Under the DST project on Utilization of Agroclimatic information for Agro advisories, weekly maps on Soil Moisture Index (SMI) for Andhra Pradesh state was computed throughout the growing season and provided to the Agromet centre ANGRAU for value addition to the agro advisories.
- Under the collaborative program with ICRISAT on "Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience, the general climatic characteristics of the SAT regions of India" were filtered the required weather data for detailed agro climatic analysis of Mahabubnagar & Anantpur in Andhra Pradesh, Akola & Solapur in Maharashtra has been collected.

4.3. Network Programme on Climate Change

To meet the challenges as posed by climate change on the agricultural system, ICAR has accorded high priority in understanding the impacts of climate change and developing adaptation and mitigation strategies through its network research program (NPCC) in the X plan. The budget during X Plan was Rs. 9.11 crore with 15 network centers and in XI Plan it is Rs.15.15 crore by increasing the total network centers to 23. 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. A summary of the output from all the participating centres is given below:

Analysis on mean annual temperature trends of 47 locations spread across the country indicated increasing trend in the central and southern parts and north eastern region. While decreasing trend is observed in some parts of Gujarat, Konkan region, NW parts of Madhya Pradesh and Eastern Rajasthan.

Experiments conducted under controlled environment conditions (FACE, TGT, OTC and portable chamber) to assess the effect of elevated temperature and CO_2 showed that a rise in atmospheric temperature reduced the biomass and yield of rice, greengram, pigeon pea, wheat and chickpea. Among the crops rice, pigeonpea and chickpea showed greater thermal stability as compared to greengram and wheat. Rice and chickpea showed greater thermal sensitivity during reproductive growth phase, while pigeonpea and greengram showed greater thermal sensitivity during ripening growth phase. Inreased CO_2 lead to higher biomass in plantation crops such as coconut, arecanut and cocoa; while reduced stomatal conductance, stomatal density and leaf surface wax leading to increased water use efficiency. However, slight reduction in polyphenols may predispose coconut and cocoa plants for pest and disease incidence in elevated CO_2 conditions. Tomato yields increased by 26.5% in elevated CO_2 (550ppm).

In order to quantify the impact of climate change on quality, analysis was carried out on the economic produce of various crops. Results indicated that protein content of wheat, greengram and chickpea grain increased marginally with rise in temperature, whereas it decreased marginally with rise in CO_2 level. Starch content however, showed reverse trend under elevated temperature and CO_2 in wheat grain. Oil content of sunflower seed increased markedly under elevated CO_2 condition. In tomato, even though lycopene and carotenoid content did not differ, antioxidants were higher at elevated CO_2 (550 ppm) concentrations. Influence of storage temperature from 22 to 45 oC on keeping quality of coconut copra and oil reduced oil percentage while it increased starch, carbohydrates and reducing sugars in copra. It also reduced the shelf life of coconut oil as indicated by increase in free fatty acids, acid value and peroxide value.

While crops may take some time to adapt to climate change, our preliminary results showed that high thermal stress imposed on soil microorganism led to the generation of some distinct forms indicating their rapid adaptation to further extended/widened range of temperature.

The impacts of climate change on hydrology of Belura watersheds Akola, using SWAT model indicated that under same cropping pattern and management activities, surface runoff and total sediment load, total aquifer recharge, water yield and PET are likely to increase significantly with increase in rainfall. The cost of bunding and trenching is likely to increase considerably due to additional earth work required.

A Livestock Strain Index (LSI) for assessing thermal stress on animals is being suggested which is based on displacement of physiological reactions from the normal resting level. The displacement of rectal temperature (T_{re}) and respiratory frequency (Rf) measured simultaneously helps quantifying the extent of stress in cattle and buffaloes on a universal scale of 0-10.

Increase in oil sardine abundance along the northwest coast is attributed to increase in seawater temperature and changes in other oceanographic parameters. ECOPATH model with Ecosim simulation developed for northwest coast ecosystem showed that the biomass of oil sardine closely followed the change in fishing effort. The highest increase in biomass (more than 3-times) occurred in the group small pelagic herbivores consisting of oil sardine. This shows that the biomass of small pelagic herbivores in the ecosystem is likely to increase in future (even under very high fishing pressure), which will be reflected in the catch. Simulations further indicate that most other fisheries groups in the ecosystem may not be impacted immediately due to increase in the biomass of small pelagic herbivores.

Laboratory experiments on the effect of seawater temperature on seven marine phytoplankton species showed that the microalgae grew faster at higher temperature (29ºC), but the decay set-in earlier than at lower temperature (24ºC). The dominance ranking of the microalgae differed between the two temperatures. This shows the temperature-related changes in the abundance and species dominance of phytoplankton, indicating the potential impacts on the base of food web in the marine ecosystems.

Preliminary results showed that Carp reared at 34ºC grew significantly faster (18.38 cg in a day) than those at 29-33ºC and 35ºC. It would take average 54-55 days for a carp to double in weight at 30ºC to 33ºC and 35ºC, but at 34ºC it would take only 35-36 days.

Rise in atmospheric temperature enhanced the emission of greenhouse gases such as CO_2 and CH_4 from the soil in standing crops of pigeonpea and greengram. However, elevated CO_2 enhanced the emission of GHG viz., CO_2 and CH_4 but reduced the emission of N_2O from the soil of standing crops.

The carbon sequestration potential of coconut plantations was assessed using real time estimates and InfoCrop-Coconut simulation models. The outputs were up-scaled to state level for four major coconut growing states viz., Kerala, Tamil Nadu, Karnataka and Andhra Pradesh, which have about 90% of all India coconut area and production. Simulation results indicated that the carbon sequestered and stored in stem in coconut plantations in four states is to the tune of 0.732 million tonnes of carbon every year. These suggest that coconut has a vast carbon sequestration potential, which can further go up if all aspects of carbon sequestration are taken into consideration.

In diary sector, methane is emitted in expired air normally at much lower rates than that appear in an eructation. The content of methane occasionally rises to more than 0.2 % in expired air during an eructation from an average concentration of 0.05+0.02%. The numbers of eructations were observed to increase during post feeding period. Methane emissions of crossbred cows were measured and related with milk yield/ day. High milk producing cows were observed to emit more methane than low producing cows. The methane emission from fresh dung of indigenous breeds (Tharparker and Sahiwal) was lower than in crossbred cattle and Murrah buffaloes.

It is estimated that annual CO_2 emission of marine fishing boats in India was 3.6 million tonnes during 2005-2007. It was found that the mechanized boats emitted 1.67 tonnes of CO_2 per tonne of fish catch, and motorized boats with outboard engine emitted 0.48 t CO_2 per t of fish catch. Among the mechanised craft, the trawlers emitted more CO_2 than the gillnetters and dolnetters. Based on the data available on the number and size of fishing boats in India in the past years, it is estimated that CO_2 emission per tonne of fish caught has increased by 64% in a period of 25 years.

5. Krishi Vigyan Kendra

Krishi Vigyan Kendra (KVK) was established in 1976 to cater the needs of the farming community of Ranga Reddy district. The major objectives of KVK is to organise 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 the Ranga Reddy District are being benefited by the KVK activities and trainings since its inception. The KVK has the following mandate:

- Conducting "On - farm testing" for identifying technologies in terms of location specific sustainable land use system.
- Organise training to update the extension personnel with emerging advances in agricultural research on regular basis.
- Organise short and long - term vocational training courses in agriculture and allied vocations for the farmers and rural youths with emphasis on "learning by doing" for higher production on farms and generating self employment.
- Organise frontline demonstrations on various crops to generate production data and feedback information.

5.1. Frontline Demonstrations

During *kharif* 2008 frontline demonstrations of maize (200), cotton (100), sunflower (27), castor (10), pigeonpea (23) and lady's finger (21) crops were conducted on farmers fields of Rangareddy district, Andhra Pradesh. Besides, block demonstrations of IPM (50 ha) and mechanization (25 ha) on cotton crop were conducted in KVK adopted villages in Ranga Reddy district. Theses FLDs were supported by Direct of Maize Research (DMR) New Delhi, Central Institute for Cotton Research (CICR) Coimbattore and Zonal Coordinator (ZC) Hyderabad. During *rabi* 2008-09, KVK conducted FLDs of chickpea (20) and maize (100) in different villages of Rangareddy district. The details of FLDs are given below:

Results of Frontline Demonstration conducted by the KVK during 2008-09

Crop	Component	No.of farmers	Area (ha)	Yield (kg/ha)		% increase over control
				IP	FP	
Sunflower	STBF	08	3.2	1210	825	46.76
	Hybrid (VSFH-1008)	19	7.6	1106	820	41.46
Castor	STBF	02	0.8	925	660	40.15
	Varietal (DCS-9)	08	3.2	870	660	31.8
Pigeonpea	Intercropping with Maize (2:1)	09	3.6	1163	940	23.72
	IPM (PRG-100)	14	5.6	1477	964	53.2
Maize	Super 900 M CP818 Pioneer(30v92)	60 87 53	24.0 34.8 21.2	4081 4309 4208	3460	17.95 24.53 21.62
Cotton	PT (Bt)	100	40	1995	1395	43.0
	IPM (Bt)	44	50	2115	1395	51.61
Chickpea (*Rabi*)	Varietal (JG-11) IPM	08 12	3.2 4.8	2212 2327	1328 1308	66.56 77.90
Maize (*Rabi*)	Super 900 M (WP/PT)	61	40	7932	5680	39.65

STBF – Soil test based fertilization; IP- Improved Practice ; FP- Farmers Practice

FLD in sunflower

FLD in cotton

5.2. Training Programmes

The Krishi Vigyan Kendra has organized 70 need based and skill oriented training programmes on various aspects of improved technologies to 1784 clientele (farmers, farmwomen, rural youth and field level extension functionaries) (details are enclosed in Table).

Details of training programmes conducted by the KVK during the period from 01-04-2008 to 31-03-2009 (including various sponsored programmes)

Discipline	No. of programmes			No. of participants		Total
	On	Off	Total	Male	Female	
Agronomy	01	09	10	248	1	249
Horticulture	03	04	07	141	8	149
Plant Protection	00	08	08	144	4	148
Agrl.Extn	00	07	07	92	3	95
Home Science	02	15	17	00	483	483
Agrl. Engg	03	07	10	171	11	182
Watershed programmes*	10	1	11	383	95	478
Total	**19**	**51**	**70**	**1179**	**605**	**1784**

Including those sponsored by the Ministry of Agriculture, Govt. of India (Scaling up of water productivity)

Details of sponsored training programmes

Title of Training	Date / duration	No .of participants			Sponsoring agency
		Male	Female	Total	
Watershed Development for Sustainable Agriculture / improving water productivity	5-11/05/08 12-18/05/08 25-31/08/08 15-21/09/08 20-26/09/08 10-16/11/08 07-13/02/09 16-22/02/09 24-2/02/09 04-10/03/09	383	95	478	Water Technology Centre, Bhubaneswar
Horticulture production technology for the members of Rytu clubs of Tamil Nadu (2 programmes)	24-26/09/08 04-06/02/09	46	8	54	NABARD, Chennai
S&WC and watershed development (1 programme)	27-28/01/09	30	0	30	Govt. of Andhra Pradesh.
Agronomical and Micro irrigation systems in Horticulture crops for Para Extension workers (1 programme)	26-30/11/08	21	0	21	APMIP, Govt. of A.P.

5.3. Extension Activities

S.No.	Activity	Date
1	Rythu Sadassu at Rythu Bazar, Alwal, R.R.dist	24-05-2008
2	Rythu Sadassu at Bandlaguda village, Rajendranagar, R.R.dist	21-06-2008
3	Parthenium Awareness Week	06-12/09-2008
4	Field day on cotton at Thimmareddyguda village of Shabad mandal, R.R.dist	22-09-2008
5	Farmers' Day (CRIDA) at GRF	30-09-2008
6	Rythu Sadassu at Poddutur village in Shankarpally Mandal of R.R.dist (Attended by Director, CRIDA)	14-10-2008
7	Field day on Maize at Jalaguda village of Shabad mandal, R.R.dist	30-10-2008
8	Exhibition – Participated in Rythu Protsahaka Utsavalu at Chevella and put up CRIDA Stall	19-11-2008
9	Rythu Sadassu at Dharur village of R.R.dist	02-12-2008
10	Women in Agriculture Day	04-12-2008
11	Field day on Pigeonpea at Jalaguda village in Chevella Mandal	07-12-2008
12	Exhibition – Participated in Regional Agricultural Fair – 2008 and put up CRIDA Stall	20-23/12-2008
13	Field day on Sunflower at Thimmareddyguda village in Shabad Mandal	03-01-2009
14	Exhibition – Participated in Kissan Mela at ARS Tandur, put up CRIDA Stall	17-18/02-2009

5.4. On-Farm Testing

The KVK conducted four on farm testing on farmers' fields of adopted villages and results are given below :

1) Soil test based – fertilizer application in rice: Based on the refined practice (STBF) conducted in five farmers field, highest yield (4910 kg/ha) was recorded in STBF plots as against recommended practice (4935 kg/ha) and control–farmers practice (4030 kg/ha). An additional input of Rs.427.50/ha gave additional returns of Rs.7568/ha with additional benefit cost ratio of 17.70:1.

2) Integrated management of rice yellow stem borer: Refined practice (mass trapping with pheromone traps + spraying insecticide) gave highest yield (4520 kg/ha) as against recommended practice (toping and insecticidal application –4430 kg/ha) and control–farmers practice (spraying insecticides–4220 kg/ha). An additional input of Rs.800/ha gave additional returns of Rs.2280/ha with benefit cost ratio of 4.47:1.

3) Weed management through mechanization in maize: Refined practice (interculture with blade harrow + weeding with power weeder) gave highest yield (4530 kg/ha) as compared to 4260 kg/ha in recommended practice (interculture blade harrow + weeding with manual weeder) and 4080 kg/ha in control (farmers practice, blade harrow + manual weeder). The refined practice has resulted 11% increase over control with 80% reduction in weeding cost.

4) Drum seeder: Use of paddy drum seeder gave crop yield of 5240 kg/ha as compared to 5020 kg/ha in traditional practice of transplantation. The savings in cost of cultivation (sowings and weedings) was Rs.5600/ha with the use of drum seeder (as compared to traditional transplanting).

5.5. Sale / supply of improved implements

KVK supplied following implements to farmers on sale/ subsidy basis:

Name of the Implement	No. of units
Manual weeder	37
Bhendi ring cutters	02
Bhendi plucker (Rahuri model)	50
Cono Weeder for SRI Cultivation	01
TOTAL :	**90**

5.6. Visitors to KVK:

Visitor(s)	From	No. of Visitors	Date
Farmers	Krishna Dist (A.P)	35	01-04-08
Farmers	A.P. (Mahabubnagar Dist)	35	10-04-08
Farmers	Tamil Nadu	28	24-04-08
Farmers	PROGRESS (Chevella Mandal of R.R.dist)	20	16-06-08
Farmers	Warangal Dist (A.P.)	05	16-06-08
Farmers	PROGRESS (Chevella Mandal of R.R.dist)	40	18-06-08
Trainees	NPPTI, Hyderabad	08	21-06-08
Farmers	Shamshabad	15	24-06-08
	Sri. N.Raghuveera Reddy, Hon'ble Minister for Agriculture, Govt. of A.P		24-06-08
Farmers	Medak dist. (A.P)	15	09-09-08
Farmers	Medak dist. (A.P)	28	23-09-08
Adarsha Rythulu	Rajendranagar mandal (A.P)	07	23-09-08
Agriculture officers	Haryana State	21	22-10-08
Students of B.Sc (Agrl)	ANGRAU	61	11-12-08
Students	Cornell University, U.S.A	25	13-01-09
Participants of Winter School	ToT trainees / CRIDA	25	18-02-09
Extension funcationes (AO, ADA, SMS)	Karnataka, State Dept of Agriculture	30	18-02-09
Progressive farmers	Medak dist.	200	19-02-09
Assistant Director of Agriculture	"Sameti" Hyderabad	10	20-02-09
Progressive farmers	Bijapur, Karnataka	14	16-03-09
Progressive farmers	Hayathnagar Mandal, Ranga Reddy Dist	12	16-03-09

Lessons learnt

- Large number of front line demonstrations on different crops viz., Maize, cotton, chickpea etc. have convinced the farmers about the improved technologies viz., use of Hybrids, IPM, use of recommended doses of fertilizers, intercropping systems etc. and bridge the gap in adoption and hastened the process of transfer of technology. For example adoption of technologies of cotton crop has resulted an yield increase of 52 percent over the farmers practices.
- 'Rythu Sadassu' meetings conducted with a village back drop with the active involvement of officials of various development departments along with the scientists (KVK and Agricultural University) in interacting mode with the farmers has gone a long way in solving the problems of farmers of remote villages. It has helped in popularizing the technologies. As an example many clarifications raised by farmers with regard to supply of power, availability of seeds and fertilizers etc., were resolved instantly by the officials participating in the meetings.
- Theoretical orientation supported by field practicing by the trainees and visits to demonstration sites and discussions has helped in improving the quality of training programmes. This was clearly established from the evaluation of training programmes on water productivity where there was a significant increase of knowledge levels of trainees up to 60-70 per cent.

6. Human Resource Development

The institute is aware of the need to improve the human resources to keep pace with the latest developments in the areas of relevance. The following scientists participated in different training programmes within and outside the country.

Deputation within India

Name	Title	Duration	Venue
G. Venkatesh	Winter school on 'Technological Advances in Conservation of Natural Resources in Rainfed Agriculture'.	November 26 - December 16, 2008	CRIDA, Hyderabad
	Winter school on 'Alternate land use options for resource conservation, emerging market needs and mitigation of climate change in rainfed regions'.	January 16 - February 5, 2009	CRIDA, Hyderabad
B.M.K. Raju	Attended a training programme on 'Data Mining and GIS for Decision Support in Agriculture'.	February 16-27, 2009	IIM, Lucknow
G. Nirmala	International training cum Workshop on Gender analysis and its application in sustainable livelihood security.	September 4-8 2008	NAIP at NRCWA, Bhubaneswar

Deputation outside India

Name	Programme	Duration	Country
V. Maruthi	Post-doctoral Rothamsted International fellowship on 'Monitoring traits of root growth and architecture of sorghum for improved resource capture in dryland agriculture'.	June 9, 2008 – May 29, 2009	Harpenden, U.K.
M. Prabhakar	A three months deputation training on Hyperspectral Radiometry at the Centre for Application of Remote Sensing (CARS)	February 15 - May 14, 2009	Oklahoma State University, Stillwater, US.

Apart from research and transfer of technology, the expertise and infrastructure facilities available at CRIDA are also utilized to provide research facilities and impart education and training to undergraduate and post graduate students of various universities and institutions.

Under graduate and postgraduate research and training provided

Supervisor	Student	Discipline	Institute/University
B. Venkateswarlu	Abdul Rasul, SK. Z. Ali, V. Sandhya Rao, Vimla Rodhae	Microbiology	Osmania University
B. Venkateswarlu	E. Leo Daniel Amalraj	Microbiology	JNTU
K. L. Sharma	J. Kusuma Grace, K. Usha Rani	Environmental Sciences	JNTU
Kausalya Ramachandran	B.M. Somasekhara, H.R. Sashikala, R. Madhumitha, S. Sundari	Geographic information system	Bharathidasan University
Kausalya Ramachandran	B. Aditya Reddy, S. Dharma Reddy, G. Anjaneyula, B. Venkateshu	Geospatial technologies	JNTU
S. Desai	G. Praveen Kumar, Mir Ahmed Hussain, P. Naveen Kumar, Lanka Sateesh	Microbiology	Osmania University
S. Desai	Padma Latha, Sindhuja,	Biotechnology	Osmania University
S. Desai	Venkatachalapathi, Sandeep	Biotechnology	Satyabama University
S. Desai	Ch. Jyoti Priya, K. Chandana	Biotechnology	Periyar University
S. Desai	Saravanan, Pagalavan, Singaravadivelu, Sathiyaselan	Microbiology	Bharatidasan University
S.K. Yadav	P. Sreenu, M. Gopala Krishna	Genetics	Osmania University
Y.G. Prasad	B. Pushpa Rajas, V. Nagaraju	Biotechnology	Andhra University
M. Vanaja	N. Sunil, D. Ashok Vardhan	Genetics	Osmania University
	Babu Abraham	Botany	Osmania University
M. Srinivasa Rao	K. Krishna Reddy, Sunitha Devi	Entomology	Acharya NG Ranga Agricultural University
K.S. Reddy	K. Nagaraju	Computer science	Birla Institute of Technology and Sciences

7. Women in Agriculture

CRIDA has a fair representation of women in all spheres. There are ten women in the scientific, eight in the technical, fourteen in administrative and fifteen in supporting staff categories. They are actively involved in carrying out the research and extension as per the mandate besides other institute building activities. Women scientists undertake both institute and externally funded projects contribute liberally to scientific literature. They have also been instrumental in attracting funds from several funding agencies. Besides carrying out the research activities, they are active in institute committees like RAC, IMC, IJSC, Grievance and Vigilance.

Farm women

KVK under CRIDA, carried out many activities for empowerment of farmwomen. These included training programmes for skill development and exposure visits.

Capacity building activities

Conducted 16 training programmes in which 487 farm women were provided with needbased, skill oriented training in various aspects of agricultural development.

Date	Name of the Training	Participants	Duration Days
1.3.08 to 30.6.08	Tailoring & Embroidary	35	90
11.8.2008	Candle making	15	1
06.9.2008	Balanced Diet & Nutritious Recipes	14	1
10.9.2008	Balanced Diet & Nutritious Recipes	15	1
17.10.2008	Value added products of Amla	17	1
21.10.2008	Value added products of Amla	25	1
17 & 18.11.2008	Women training programme on Value added products of Amla	32	2
04.12.2008	Value added products of Maize	15	1
17.12.2008	Value added products of Maize	15	1
29.12.2008	Preparation of pain balm	18	1
09.01.2009	Income generation activities	50	1
12.01.2009	Pickle making	52	1
20 & 21.02.2009	Preparation of washing powder & phenyl	50	2
17.03.2009	Value added products on maize (FTC)	34	1
VOCATIONAL TRAINING PROGRAMMES FOR RURAL YOUTH (WOMEN)			
6-7.2.09	Post harvest value addition to groundnut (NAIP)	15	2
5-10.3.09	Income generation activities	50	5
1.3.09 to 25.6.09	Tailoring & Embroidrary	35	3 months

The topics of the training programmes are preservation of fruit and vegetable, livelihood activites, organic compost making, neem seed extracts, human nutrition, preparation of Amla candy and supari etc. The details are given in Table.

Sale / supply of improved Implements to Farm-women in KVK adopted villages for drudgery reduction during 2008 to 2009.

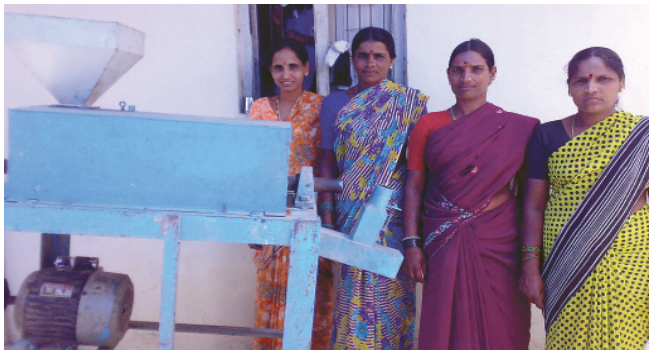
107 farm women were supplied with manual weeders 37, bhendi ring cutters 20, Bhendi plucker 50 for drudgery reduction during farm activities.

Name of the Implement	Units
Manual weeder	37
Bhendi ring cutters	20
Bhendi plucker (Rahuri model)	50
Total	**107**

Drudgery removal through use of rotary weeders

Dal mill

One women self help group was encouraged to establish dhal mill in Pamana to reduce arduous work during arhar dal processing.



Special events

Celebration of 'Women in Agriculture' Day

"Women in Agriculture Day" programme was conducted on December 4th in Jalaguda village. About 200 farmwomen participated in the event and trained under following themes.

1) The main theme was awareness on removal of drudgery of farmwomen. Gadgets like bhendi plucker for plucking bhendi with less fatigue and speedy work, dry land weeders were demonstrated.

Celebration of 'Women in Agriculture' Day by farm women

2) Introduction of Maize into their daily diet was emphasized and a small competition was conducted among farmwomen in preparing recipes with maize as the main ingredient and prizes were distributed for good recipes.

Exposure visit

Women in CRIDA

Women scientists at CRIDA has received distinctions through national and international recognition of their work. Dr. Kaushalya Rama Chandran work on sustainability indicators for watershed input evaluation earned her recognition by global land project - VGBP & IHDP in Germany. Dr. V. Maruthi was invited for a Commonwealth Fellowship in U.K for her research on root architecture.

Projects handled by women scientists

A number of institute and externally funded projects are handled by women scientists. Results emanating from these are presented in this report, elsewhere.,

Human resource development

One woman scientist attained international training. Five women technical officers and one woman Administrative Officer underwent need-based trainings in their specialized foelds within the country. Mrs. K. Usha Rani, Technical Officer (T-7/8), was awarded Ph.D (Environmental Science) from JNTU, Hyderabad.

Participation in scientific gatherings

All the women scientists actively participated in seminars, symposia, conferences and workshops conducted by prestigious scientific organizations spread across India (see chapter 14 for details).

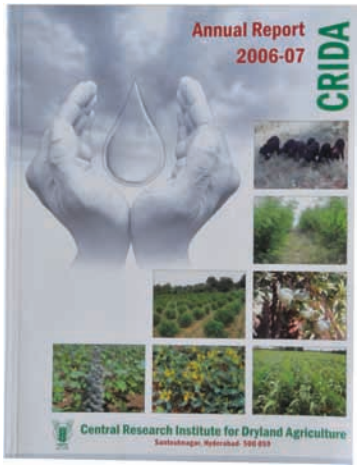
Women's Cell

There is an active women's cell in the Institute, which looks after the welfare of the women staff. It has the following members. Dr. G. Pratibha (Scientific); Ms. V. Savithri (Technical); Ms. K.V. Manikyam (Administration); Ms. K. Rajamani (Supporting)

Sl. No.	Project title	Handled as P.I.
Externally funded		
1	Enhancing tolerance of sorghum to abiotic stress through genetic manipulation	M. Maheswari
2	Nitrate uptake and assimilation in crop plants under elevated CO_2	N. Jyothi Lakshmi
3	Impact of elevated CO_2 on important rainfed crops	M. Vanaja
4	Assessment of Sustainability of Treated/ Developed Watersheds in Rainfed Agro-Eco-Sub Regions of Peninsular India using GIS and Remote Sensing	Kausalya Ramachandran
5	Impact of drought Management practices and organics on yield and secondary metabolites of medicinal plants	G. Pratibha
6	Root proliferation as influenced by soil management practices for drought and its physiological implications short duration pulses	V. Maruthi
7	Application of micro organisms in Agriculture and allied sectors (AMAAS) – abiotic stress management (Management of Abiotic stresses)	Minakshi Grover
8	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
Institute funded		
1	Candidate gene approach for improvement of drought tolerance and yield in drylands	M. Maheswari
2	Physiological responses of crop plants to water deficit under elevated CO_2	M. Vanaja
3	Organic management for sustainable production of medicinal and aromatic plants	G. Pratibha
4	Soil and crop management strategies for resource conservation, weed control and carbon sequestration in pigeonpea-castor system	G. Pratibha
5	Crop diversification for sustainability of drylands through dye yielding crops	G. Pratibha
6	Mechanism of drought tolerance in rainfed short duration pluses	N. Jyothi Lakshmi
7	Impact of elevated CO_2 on plant nitrogen use efficiency	N. Jyothi Lakshmi
8	Studies on root characteristics of greengram and horsegram crops in relation to resource use	V. Maruthi
9	ICTs as a tool of agricultural extension for technology dissemination – a critical analysis	K. Nagasree
10	Leveraging access to ICTs for improved rural Livelihoods : Development of strategic framework	K. Nagasree
11	A study on documentation of ITKs on pest forewarning in rainfed crops	K. Nagasree
12	Development of farming situation-based extension for Ranga Reddy district	G.Nirmala
13	Gender analysis in watershed development programmes of Andhra Pradesh	G. Nirmala
14	Studies on enrichment of quality and utilization of palmyra fruit	K. Sreedevi Shankar
15	Survival and persistence of stress tolerant PGPR strains in the rhizosphere of dryland crops	Minakshi Grover

8. Awards and Recognition

- CRIDA received the ICAR Best Annual Report Award for its Annual Report 2006-07.

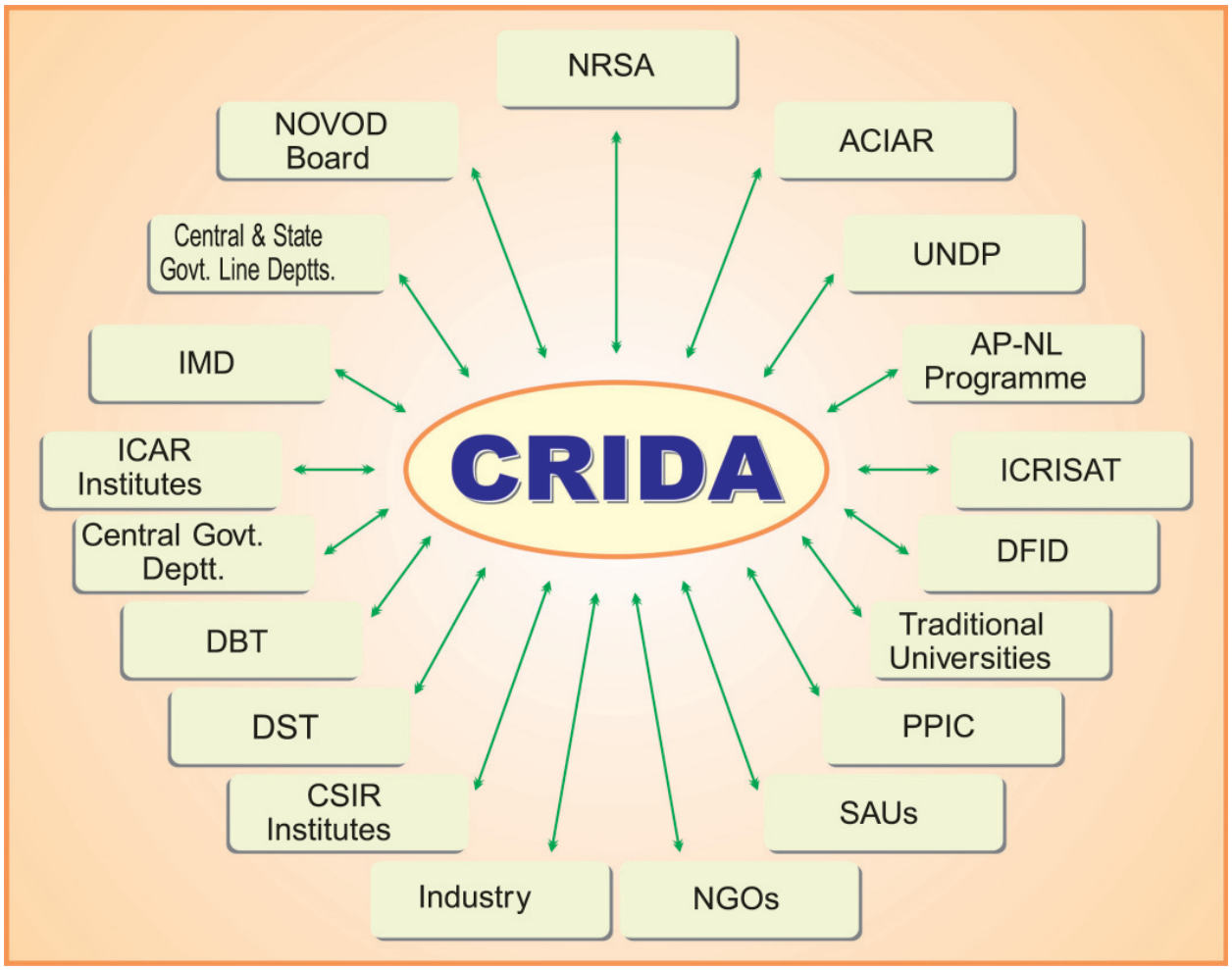


- CRIDA received the Best Institutional Award for the Best Rosary and Lawns awarded by Hyderabad Rose Society held during Dec. 13-14, 2008. Further, it received a total of 32 prizes in different categories of rose show and rose competition, and also the Anil Kumar Memorial Silver Challenge Bowl for getting highest number of aggregate points. The gardens were maintained under the supervision of Dr N.N. Reddy, Principal Scientist (Horticulture).
- Dr K. Kareemulla Principal Scientist (Agril. Economics) received the 'Best Team Award on Watershed Project' – 2008, from NRCAF, Jhansi.
- Dr Ch. Srinivasa Rao, Principal Scientist (Soil Science) was elected as "Fellow of National Academy of Agricultural Sciences (NAAS)" for the year 2008 for best work done in the field of Natural Resource Management. He also received the ICRISAT Millennium Science Award for the year 2008 for article "Carbon sequestration and improving livelihoods in semiarid tropical India" published in International Journal of Environmental Studies, and a prize from International Plant Nutrition Institute (IPNI), Canada for documenting P deficiency symptoms in chickpea on P deficient Inceptisols.

- Dr. G. Ravindra Chary Senior Scientist (Agronomy), was awarded Fellowship of Indian Society of Pulses Research and Development by Indian Society of Pulses Research and Development, IIPR, Kanpur during International Conference on Grain Legumes and Food Security at IIPR, Kanpur during February 14 - 16 2009.

9. Linkages and Collaborations

Keeping in pace with the changing scenario of agricultural research and development, CRIDA has beenrenewing existing linkages and establishing new partnerswith all the stake holders. CRIDA promotes actionoriented research in public - private partnership modethrough consortium approach. It has strong collaborationwith ICRISAT, ILRI, IWMI, ANGRAU and other SAUs, JNTU, University of Delhi, Osmania and other Universities and NGOs for developing and refining the technologies forimproving the profitability in rainfed agriculture. CRIDAalso plays a role in advising agencies such as central / state line departments to develop suitable policies forimplementing the programmes on rainfed agriculture. The Institute undertakes specific researchprogrammes fulfilling mandates of both CRIDA and thedonar to delve into basic, applied, strategic andanticipatory research. The partners in this mode include CSIR, DBT, DST, NOVOD Board,PPIC, Govt. of Andhra Pradesh and the like. CRIDA alsoundertakes consultancy programmes for specific tasksfrom Govt. of Andhra Pradesh, Madhra Pradesh, WWFetc. CRIDA takes inputs from IMD, NCMRWF andgenerates value added outputs for the benefit of therainfed farmers.



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Ravi Shankar, Radio talk on Metta Vyavasayamulo Antara Pantala Avasyakatha on July 4, 2008.

11. 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	2009
2. RM/ALU/01	Organic management for sustainable production of medicinal and aromatic plants	G.Pratibha G.R.Korwar K.Srinivas S.K.Yadav I.Srinivas B.Venkateswarlu	2004	2009
3. RM/NM/2	Viability of organic production of pigeonpea and sorghum in drylands	K. Srinivas M. Srinivasa Rao K.L. Sharma	2005	2009
4. RM/ALU/02	Effect of different nutrient management practices and agroforestry systems on productivity and soil quality in rainfed regions	G.R. Korwar G. Pratibha K. Srinivas	2005	2010
5. RM/RM/03	Standardization of agri-techniques of perennial castor	M. Osman M. Vanaja P.R. Reddy	2006	2010
6. Externally funded - (MoWR)	Tank silt as an organic amendment for improving soil and water productivity	M. Osman G. Ravindra Chary G.R. Korwar S.S. Balloli U.K. Mandal K.V. Rao K.S. Reddy K. Srinivas Shaik Haffis	2008	2010
7. ICAR Adhoc Scheme (under Lal Bahadur Shastri Young Scientist Award)	Assessment and improvement of soil quality and resilience in a watershed under rainfed agroecosystem using GIS and remote sensing	U.K. Mandal	2006	2009
8. Externally Funded (NOVOD)	National Network project on integrated development of Jatropha and Pongamia	G. Rajeshwar Rao G.R. Korwar M. Prabhakar	2004	2009
9. Externally Funded (CSIR)	Genetic improvement of Jatropha for oil yield and adaptability	G. Rajeswar Rao G. Ravindra Chary Y.G. Prasad D.P. Dubey M.P. Jain P.R. Reddy	2005	2010

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
10. Externally funded (Govt. of A.P.)	Collection and evaluation of germplasm, standardization of agro-techniques and pilot demonstration of Jatropha curcas in rain shadow districts of A.P.	G. Rajeswar Rao K.V. Rao I. Srinivas	2005	2010
11. RM/NM/04	Improving the productivity of Leucaena leucocephala for industrial biomass production	J.V.N.S. Prasad G.R. Korwar B. Venkateswarlu	2007	2009
12. RM/FM/06	On-farm Evaluation of CRIDA Rotary tiller for Biomass Incorporation	Ravikant V. Adake C.R. Thyagaraj U.K. Mandal K.L. Sharma	2008	2010
13. RM/RM/04	Soil and crop management strategies for resource conservation, weed control and carbon sequestration in castor-pigeon pea system	G. Pratibha G.R. Korwar K.V. Rao K. Srinivas, I. Srinivas M. Srinivasa Rao K.L. Sharma K. Arun Kumar Shankar	2008	2013
14. RM/RM/05	Hydrologic Modelling of water yield in a micro watershed and its productivity in vegetable and oilseed production in Alfisols	K. S. Reddy K.V. Rao B.S. Reddy B.M.K. Reddy V. Maruthi K. Kareemulla	2008	2011
15. 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
16. 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
DIVISION OF CROP SCIENCE				
17. AP-NL project	Enhancing tolerance of sorghum to abiotic stress through genetic manipulation	M. Maheswari S.K.Yadav B. Venkateswarlu M. Vanaja N. Jyothi Lakshmi	2001	2007 (extended upto June 2008 and likely to be extended further for two more years)
18. CS/CP/09	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	2009 (merged with DBT project)
19. CS/CP/07	Mechanism of drought tolerance in rainfed short duration pulses	N.Jyothi Lakshmi M.Maheswari M.Vanaja S.K.Yadav B.Venkateswarlu	2004	2008

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
20.ICAR network project (NPCC)	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
21. CS/CP/16	Evaluation of chlorophyll fluorescence as an indicator for drought tolerance in selected ryland crops	Arun Kumar Shanker M. Maheswari G.R. Rao	2007	2010
22. CS/CP/17	Nutrient and hormonal management for manipulation of flowering, fruiting and seed set in Pongamia pinnata (L.) Pierre	Arun Kumar Shanker G.R. Rao M. Maheswari S.K.Yadav	2007	2010
23. CS/CP/18	Evaluation of horsegram mutants in multi-locational AICRP trials	P.R.Reddy	2007	2012
24.CS/CP/12	Drought management practices in castor	S.Venkateswarlu	2004	2009
25.CS/PP/12	Utilization of candidate microbial isolates for management of ryland insect pests	Y.G.Prasad M.Prabhakar B.Venkateswarlu G.R.Rao I.Srinivasa Rao S.Dixit	2007	2010
26. Externally funded (APNL)	Generation of data for registration of Achaea janata Baculovirus (AP-NL)	Y.G. Prasad M. Prabhakar B. Venkateswarlu	2005	2008
27. Externally funded (WWF)	Sustainable Cotton Initiative in Warangal district of Andhra Pradesh	Y.G. Prasad K.V. Rao M. Prabhakar	2006	2009
28. CS/CP/13	Organic farming in rainfed production systems	B. Venkateswarlu G.R. Maruthi Sankar Y.G. Prasad S. Venkateswarlu S. Desai S.S. Balloli	2005	2009
29. ICAR Net work project	Application of micro organisms in Agriculture and allied sectors (AMAAS)	B. Venkateswarlu S. Desai S.K.Yadav	2006	2010
30. CS/PP/10	Integrated disease management in groundnut based production systems	S. Desai	2005	2010
31. CS/PP/11	Impact of elevated CO_2 on Bt cotton and boll worms	M. Srinivasa Rao K. Srinivas M. Vanaja	2007	2009
32.CS/PP/13	Development and evaluation of Low External Input IPM modules in pigeonpea and castor	M.Srinivasa Rao C.A.Rama Rao G.Pratibha	2007	2009
33. NPCC project	Impact of elevated CO2 and temperature on host herbivore interaction	M.Srinivasa Rao K.Srinivas M.Vanaja	2004	2012

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
34.CS/CP/16	Studies on root characteristics of greengram and horsegram crops in relation to resource use	V. Maruthi K. Srinivas Arun Kumar Shankar K. Srinivas Reddy	2007	2009
35.CS/Horti/07	Vegetable cultivation as a source of livelihood option in watershed areas of Ranga Reddy District	N.N. Reddy G. Nirmala M. Srinivasa Rao C.A. Rama Rao V.S. Rao K. Sreedevi Shankar	2006	2011
36. CS/Horti/06	Studies on tree-tree interactions in conjunction with water management in fruit crops	N.N. Reddy J.V. Rao V.S. Rao MV. Padmanabhan	2005	2010
37. RSAD (J) MBNR	Collection, evaluation of standardization of agro-techniques and pilot demonstrations of Jatropha & Pongamia	N.N. Reddy V.S. Rao G.R.Rao	2005	2010
38. CS/SS/03	Soil & Crop Management options for managing Zn deficiency in rainfed areas	S.S. Balloli	2008	2012
39. CS/CP/19	Candidate gene approach for improvement of drought tolerance and yield in drylands	M.M. Maheswari	2008	2013
40. CS/ALU/05	Evaluation of forage sorghum cultivars for different soil conditions	G. Jayaram Reddy	2009	2012
41. CS/Hort/08	Organic Cultivation of Fruits in Drylands	V.S. Rao N.N. Reddy M. Srlnivasa Rao C.A. Rama Rao K. Sreedevi Shankar G.R. Maruthi Shankar	2008	2013
42. CS/Horti/04	Productivity enhancement in existing fruit orchards in drought prone areas	V.S. Rao N.N. Reddy	2006	2010
SECTION OF TRANSFER OF TECHNOLOGY				
43.TOT/RM/1	A critical evaluation of conservation furrows in semi arid Alfisols	M.V.Padmanabhan U.K.Mandal G.Pratibha K.V.Rao	2004	2009
44.TOT/LM/1	Performance of sheep reared under different management systems	D.B.V. Ramana G.R. Rao A.R. Sen, NRCM	2005	2009
45.TOT/LM/2	Development of strategies for sustainable livestock production in the rainfed regions of India	D.B.V. Ramana G. Ravindra Chary K. Ravi Shankar C.A.Rama Rao Scientist from ACIRPDA Centres of Jagadalpur, Anantapur, Sholapur	2006	2009
46. TOT/LM/3	Strategies for enhancing breeding efficiency of dairy animals under rainfed conditions	D.B.V. Ramana G. Nirmala	2007	2010

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
47. TOT/AE/22	Identification and Digital Documentation of Dryland Technologies	K. Ravi Sankar G.R. Maruthi Sankar	2006	2009
48. TOT/AE/23	ICTs as a tool of agricultural extension for technology dissemination – a critical analysis	K. Nagasree G.G.S.N. Rao Y.G. Prasad	2006	2009
49. TOT/AE/24	Leveraging access to ICTs for improved rural Livelihoods : Development of strategic framework	K. Nagasree Sreenath Dixit K.V. Rao K. Ravishankar B. Venkateswarlu G. Ravi Kumar	2008	2011
50. TOT/AE/25	A study on documentation of ITKs on pest forewarning in rainfed crops	K. Nagasree Y.G. Prasad M. Prabhakar	2008	2010
51. 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 Shankar K. Nagasree	2008	2011
SECTION OF DESIGN AND ANALYSIS				
52. SEPR/AE/04	Trends and determinants of agricultural diversification in Andhra Pradesh	C.A Rama Rao V. Maruthi K. Ravi Shankar K. Kareemulla	2007	2009
53. SEPR/AE/05	Economic Analysis of Technology Interventions of KVK	C.A. Rama Rao M.S. Prasad G. Nirmala	2007	2009
54. SEPR/AE/06	Strategies to enhance profitability in backyard poultry through use of non conventional feed sources – An on-farm participatory action research	S. Dixit D.B.V. Ramana M. Prabhakar Y.G. Prasad	2007	2009
55. SEPR/AE/07	Development of Rainfed Agri-Knowledge Network (RAKNet)	S. Dixit G. Ravindra Chary A.V.M. Subba Rao K.V. Rao	2007	2010
56. AEPR/AE/08	Impact of NREGP (EGS) on Rainfed Agriculture	K. Kareemulla K. Srinivasa Reddy C.A. Rama Rao B.M.K. Reddy G. Nirmala	2008	2010
KVK				
57. KVK/FN/01	Studies on Enrichment of Quality & utilization of Palmyra fruit	K. Sreedevi Shankar N.N. Reddy V.S. Rao	2007	2009
58. KVK/AE/01	Gender analysis in watershed development programmes of Andhra Pradesh	G. Nirmala S. Dixit	2007	2009
59. KVK/AE/02	A study of adoption of Income generating technologies by rural women	M.S. Prasad A. Vidyadhari R. Joseph C.R. Thyagaraj	2008	2011

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
60. 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 Y. Padma Latha K. Bhargavi	2008	2011
61. KVK/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
62. KVK/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
AICRPDA				
63. PC(D)/1	Assessment of effects of soil and weather variables on sustainable rainfed agriculture using multivariate statistical and simulation models	G. Maruthi Shankar P.K. Mishra Mohd. Osman K.L. Sharma G.G.S.N. Rao	2008	2014
AICRPAM				
64. Externally Funded (ICAR)	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	2010
65. 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 D. Raji Reddy	2007	2010
66. 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.R. Chary K. Ravi Shankar	2008	2012
NATIONAL FELLOW				
67. Externally Funded (ICAR 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	2010
68. Externally Funded (ICAR 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	2010

12 Consultancy, Patents and Commercialization

- Consultancy for World Wide Fund – India (WWF-India) project on Monitoring and evaluation: Sustainable cotton initiative in Warangal district of Andhra Pradesh at a cost of Rs. 2.54 lakhs (Y.G. Prasad, K.V. Rao and M. Prabhakar).
- License is given to M/s Kale Industry, Latur (MS) for manufacturing of CRIDA Three-row planter under Revolving Funds Scheme on farm implements. MoU is signed between CRIDA and Industry on 18th November, 2008. (I. Srinivas and R.V. Adake).
- An MOU was signed between CRIDA and M/S. Invitro International, Bangalore, on 30/03/2009 for transfer of micropropagation technology of teak on a non-exclusive basis (B. Venkateswarlu)
- Evaluation of four water sheds funded by NABARD (K. Kareemulla, M. Osman)
- Ayurvet Lmited sponsored project: "Efficacy evaluation of some herbal products on digestibility in sheep" (D.B.V. Ramana).
- A process patent application was filed for pretreatment of Jatropha/Pongamia seed before oil expulsion to reduce free fatty acids in oil and to increase oil yield for higher Biodiesel recovery (I. Srinivas).

13. Meetings of RAC / IRC / IMC / SAC

13.1 Research Advisory Committee Meeting

Research Advisory Committee of the Institute was constituted with Dr R Dwarakinath, former Vice Chancellor, University of Agricultural Sciences, Bangalore and former Chairman, Karnataka Agricultural Commission, as Chairman. The following are the other members on the committee:

- Dr R K Aggarwal, former Head Regional Station, CSWCR&TI, and Principal Scientist, CAZRI, Jodhpur.
- Dr S M Virmani, Agrometeorologist (Retd), ICRISAT, Hyderabad.
- Dr K Palanisamy, Director, IWMI South Asia Regional Office, Hyderabad.
- Dr A T Rao, NAAS Fellow.
- Dr D C Uprety, Emeritus Scientist, IARI, New Delhi.
- Shri Vijay Barode, Marathwada Sheti Sahaya Mandal, Aurangabad, Maharashtra.
- Dr B Venkateswarlu, Director, CRIDA, Hyderabad.
- Dr Y G Prasad (Member-Secretary) Principal Scientist, CRDA, Hyderabad.

13.2. Institute Research Council (IRC)

The mid term IRC meeting was held on November 5th, 2008 under the Chairmanship of Dr. B. Venkateswarlu, Director, CRIDA. The meeting reviewed the progress of research in various projects (Institute/ externally funded), particularly collection of minimum data sets, focussing the research programme in addressing emerging issues and measures to over come constraints in conducting field experiments and on-farm trials.

13.3. Institute Management Committee (IMC)

The 38th IMC was held on 4th October, 2008 at CRIDA under the Chairmanship of Dr. B Venkateswarlu, Director, CRIDA. The meeting was attended by Drs. B K Ramachandrappa, Chief Scientist, AICRPDA centre Bangalore, Dr. Harvir Singh, Principal Scoentist, DOR, Mrs. Sobha Rani, Principal Scientist, DRR, Dr GGSN Rao, Project Coordinator (AICRPAM), Dr G.R Korwar, Head, DRM, CRIDA and Mr. Charles Ekka, SAO. Dr. Mohammad Osman, Principal Scientist, Dr P K Mishra, Project Coordinator (AICRPDA), Dr M V Padmanabhan, Head, TOT, Dr V S Rao, Head, DCS and Mr B D Sati, FAO were also present as special invitees from CRIDA. The Committee reviewed the progress of works, expenditure, research activities of the Institute and approved the prioritization of works, equipments, etc.

13.4 Scientific Advisory Committee (SAC) Meeting:

The SAC meeting of KVK, Ranga Reddy district was held on 2nd August, 2008 at KVK Campus, Hayathnagar Research Farm, CRIDA under the chairmanship of Dr.B Venkateswarlu, Director, CRIDA. The meeting was attended by scientists from CRIDA and ZC Unit V Hyderabad, KVK Staff besides officials of the line departments, representatives from ANGRAU, National Banks, mass and electronic media and farmer's representatives. The meeting reviewed the progress made in *rabi* 2007-08 and reviewed the action plan for *kharif* 2008 to be taken up by KVK.

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

Scientist	Particulars	Period	Venue
I. Srinivas	Annual workshop of the NAIP Bioethanol value chain project	April 9, 2008	ICRISAT, Hyderabad
B. Sanjeeva Reddy	Stake holders group meeting to discuss progress of work NAIP sub project on " Value Chain Model for Bioethanol production from Sweet Sorghum in Rainfed areas through Collective action and Partnership"	April 9, 2008	ICRISAT Hyderabad
K.V. Rao	3rd Executive Committee meeting of NRAA	April 11,2008	NASC Complex, New Delhi
G.R. Korwar	ICAR-ICRAF Collaborative Research Plan Workshop	April 19-20, 2008	ICAR, NASC, New Delhi
M. Vanaja	Joint FAO/ICRISAT Technical Expert Meeting on 'Climate Change and its Effects on Conservation and Use of Plant Genetic Resources and Associated Biodiversity for Food Security.	April 28-30, 2008	ICRISAT, Patancheru
I. Srinivas	NAIP Sustainable Rural Livelihood project Annual Workshop	May, 2008	
D.B.V. Ramana	ICAR-ILRI Interaction Workshop	May 1 -2, 2008	NASC complex, New Delhi
N.N. Reddy, G.R. Korwar	National Seminar on Clean Development Mechanism and Carbon Trading Opportunities in Agriculture	May 8 -9, 2008.	CRIDA, Hyderabad
K. Ravi Shankar	National Workshop on Clean Development Mechanism and Carbon Trading Opportunities in Agriculture and Allied Sectors.	May 8 -9, 2008	CRIDA, Hyderabad
Kuashalya Rama Chandran	National Seminar on Natural Resources Management, Department of Geography, University College of Science	June, 2008	Osmania University, Hyderabad,
K.L. Sharma, G. Ravindra Chary, G.R. Korwar, K.V. Rao, D.B.V.Ramana, G.R. Maruthi Sankar, M. Osman, Y.G. Prasad, C.A. Rama Rao, G. Pratibha, B. Venakteswarlu, G. Subba Reddy, G.G.N.S. Rao, V.U.M. Rao	12th Working Group Meeting of AICRPDA	June 2-4, 2008	OUAT, Bhubaneshwar
K. Srinivasa Reddy	International Symposium on Rain Water Harvesting	June 23-24, 2008	TNAU, Coimbattore
G.G.S.N. Rao, V.U.M. Rao, A.V.M.S. Rao M. Vanaja, M. Srinivasa Rao	Annual workshop of ICAR Network project on "Impact, Adaptation and Vulnerability of Rainfed Ecosystem to Climate Change"	June 23 – 24, 2008	CRIDA, Hyderabad.
D.B.V. Ramana	Training programme on "Impact of climate change on Indian Agriculture"	June 25-26, 2008	CRIDA, Hyderabad.
G.R. Korwar, P.K. Mishra, G.R. Maruthi Sankar, B. Venkateswarlu, G. Ravindra Chary	National Seminar on Soil, Water Conservation and Crop Management Technologies under Rainfed Agriculture	June 28-29, 2008	ZARS, MPKV Solapur.
A.V.M.S. Rao, N. Manikandan, T. Satyanarayana, V.U.M. Rao, G.G.S.N. Rao	International Workshop on Weather Modification Technologies & Symposium on Natural Disaster Management	June 27-29, 2008	Jawaharlal Nehru Technological University, Hyderabad

Scientist	Particulars	Period	Venue
S.K. Yadav	GM Food Safety Assessment in India: Taking Stock and Planning for Future on Bio-safety	July 7, 2008	NIN, Hyderabad
G. Ravindra Chary K. V. Rao	NAIP – Component –1- AGROWEB Project- Launching Workshop	July 18 -19, 2008	NBPGR, New Delhi
B. Venkateswarlu G. Ravindra Chary	National Brain Storming Meeting on Land Use Planning	July 25 -26, 2008	NBSSLUP, Nagpur
K. Kareemulla, C.A. Rama Rao, Sreenath Dixit,	ISAM Seminar on Agribusiness potential in Andhra Pradesh: A Temporal and Spatial Analysis	July 29 -30, 2008	ANGRAU, Hyderabad
V.U.M. Rao, G.G.S.N. Rao, A.V.M.S. Rao, T. Satyanarayana, N. Manikandan	National Seminar on Climate Changes – Its impact on different sectors in India	July 30 –31, 2008	VSR & NVR College, Tenali
G.G.S.N. Rao, A.V.M. Rao, V. U. M. Rao	National Seminar on Climate Change	July 30-31, 2008	VSR & NVR College, Tenali
C.R.Thyagaraj	KVK Progress Report & Action Plan	August 2, 2008	KVK , Hayatnagar, RR Dist,A.P.
D.B.V. Ramana	Value Chain for Clean Meat Production from Sheep	September 2, 2008	NRC Meat, Hyderabad
Kuasalya Rama Chandran	International Symposium on Education & Research in Sustainability, Golden Jubilee of Indo-German Cooperation in Higher Education	September 8-9, 2008	IIT Chennai & DAAD
V.Maruthi	International conference on " Resource Capture by crops: integrated approaches' conducted by Annals of Applied Biologists	September 10-12, 2008	University of Nottingham at Sutton Bonington, U.K.
D.B.V. Ramana	Epidemiology and Economic Tools in the Development of Animal Disease Control Polices and strategies in India	September 16-17, 2008	NASC Complex, New Delhi
G. Ravindra Chary	National Symposium on Land Resource Management for Livelihood Security	September 10-12, 2009	NBSSLUP, Nagpur
S.K. Yadav	National Workshop on Normative Concerns, Challenges and Opportunities in the new era of watershed development projects	September 18-19, 2008	NASC Complex, New Delhi
Kuasalya Rama Chandran	International Conference on Environment, Forced Migration & Social Vulnerability (EFMSV 2008)	October 9 - 11 2008	UN Univ. Campus, Bonn, Germany
G. R. Korwar, G. Ravindra Chary	National Seminar on "Second Green Revolution Necessity or Compulsion	October 18-19, 2008	ARS, ANGRAU Adilabad
D.B.V. Ramana	Livestock and Development in a Changing Context	October 13-15, 2008	ICRISAT, Hyderabad
M. Vanaja	Golden Jubilee Conference on 'Challenges and Emerging Strategies for Improving Plant Productivity'	November 12-14, 2008	IARI, New Delhi.
V. S. Rao	National Guava Symposium on improvement, production and utilization held at SHIRD	November 24 - 26, 2008	Guava Grower's Association of India in collaboration with CISTH, Lucknow.
N.N. Reddy	Jellies with Guava Roselle blend	November 24 – 26, 2008	Maharashtra
Kuashalya Rama Chandran	Winter School on Technological Advances in Conservation of Natural Resources in Rainfed Agriculture	November 26 –December 16, 2008	CRIDA, Hyderabad
K.V. Rao, B. Venkateswarlu Y.G. Prasad, G.G.S.N. Rao, V.U.M. Rao, G.Ravindhra Chary, A.V.M.Subba Rao, P.K.Mishra	Biennial workshop of AICRPAM	December 3-5,2008	BCKVV, Kalyani

Scientist	Particulars	Period	Venue
Kuashalya Rama Chandran	National Seminar on Urban Infrastructure Development: Issues and Challenges.	December 18 – 19, 2008	MVSR College of Engineering Hyderabad
M. Vanaja	6th meeting of Programme Advisory Committee on Plant Science of DST	21st December 2008	University of Hyderabad, Hyderabad
G. Nirmala	National conference on KVK	December 27-29, 2008	G.B.PAUT, Pantnagar
V. Maruthi	Mid-term Evaluation meeting with the Rothamsted International and the Panel from Rothamsted Research	December 16, 2008	Rothamsted Research, Harpenden, U.K.
K. Sreedevi Shankar	6th International Food Convention (IFCON-2008) on "Newer challenges in Food Science and Technology: Industrial Perspective".	December 14-19, 2008	CFTRI, Mysore
S.K. Yadav	One day State Level Workshop on, Management and Monitoring of field trials of genetically engineered crops	December 17, 2008	ANGRAU, Hyderabad
K.L. Sharma	Workshop on Potassium nutrition in Andhra Pradesh Agriculture	January 19, 2009	Hyderabad
S. S. Balloli, B. Venkateshwarlu, P.K. Mishra, G.R. Maruthi Sanker, G. Ravindhra Chary	National Group Meeting of Maize-based Cropping Systems	January 19-22, 2009	AICRIPDA centre, Arija..
K.A. Gopinath	National seminar on Changing global vegetable oils scenario: Issues and challenges before India.	January 20-30, 2009.	DOR, Hyderabad.
Y.G. Prasad B. Venkateswarlu	IPM strategies to combat emerging pests in the current scenario of climate change	January 28-30, 2009	Pasighat, Arunachal Pradesh
S. Venkateswarlu K.A. Gopinath M. Srinivasa Rao I. Srinivas G. Rajeshwar Rao	National Symposium on "Vegetable Oil Scenario: Approaches to meet the growing demands"	January 29-31, 2009	ANGRAU, Hyderabad
V. S. Rao	Technologies for increasing horticulture production" to the farmers from Tamil Nadu state. NABARD	February 4-6, 2009	KVK, HRF
K.L. Sharma, B. Sanjeev Reddy, C.A. Rama Rao M. Srinivasa Rao, K. Srinivas	World Congress on Conservation Agriculture for improving efficiency, equity and environment – Indian perspective.	February 4 -7, 2009	New Delhi, India
K.L. Sharma	Global Knowledge Millennium Summit 2008 on Bio-Nano-The War on Hunger, New Delhi, organized by ASSOCHAM	February 13-14, 2009	Hotel Shangri- La, New Delhi
S.K. Yadav	International Conference on, Grain Legumes: Quality Improvement, Value Addition and Trade	February 14 -16, 2009	Indian Institute of Pulses Research, Kanpur
V. Maruthi	British Soil Science Society meet (the 43rd British Soil Physics Group Meeting on Soil-Plant Interactions)	February 18, 2009	Rothamsted Research, Harpenden, U.K
N.N. Reddy	3rd meeting of Agricultural Systems and Management Sectional Committee, FAD- 22	February 25, 2009	BIS, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi
M. Prabhakar	Annual Conference of American Society for Photogrametry and Remote Sensing (ASPRS)	March 9-13, 2009	Baltimore, Maryland, USA
Kuashalya Rama Chandran	Regional Workshop on Water Use Efficiency and Water Quality Issues –	March 13 – 14 , 2009	CGWB, South Region, Hyderabad
B. Venkateswarlu	Brain storming session on drought management	March 24, 2009	Directorate of Maize Research, New Delhi
M. Prabhakar	Annual Conference of Association of American Geographers (AAG)	March 25-27, 2009	Las Vegas, Nevada, USA

15. Workshops, Seminars, Summer Institutes, Winter Schools, Farmer's Day etc., organized by the Institute

Programme	Period	Venue
Review workshop on "Tank silt as an organic amendment for improving soil and water productivity"	February 21, 2008	CRIDA. Hyderabad
Optimum input use for higher production and productivity livelihood based integrated farming system development in different water management regime.	April 21-27, 2008	Krishi Vigyan Kendra, Hayatnagar Research Farm
Watershed approach for sustainable development	May 5-11, 2008	Krishi Vigyan Kendra,Hayatnagar Research Farm
National Workshop on Clean Development Mechanism and Carbon Trading Opportunities in Agriculture and Allied Sectors	May 8-9, 2008	CRIDA, Hyderabad
Optimum input use for higher production and productivity livelihood based integrated farming system development in different water management regime	May 12-18, 2008	Krishi Vigyan Kendra, Hayatnagar Research Farm
Participatory Natural Resource Management For Enhancing Water Productivity in Drylands	June 10-23, 2008	CRIDA, Hyderabad.
Training programme on "Farm Implements and Machinery "for under graduate students of B.Tech (Agricultural Engineering). 4 students from CAE, Bapatla (ANGRAU),6 students from CAE& T, Bhubaneshwar (OUAT) and 5 students from K.K.W.CAE&T, Nasik (MPKV) participated.	June 1 – 30, 2008	CRIDA, Hyderabad
Brainstorming Workshop on "Livestock Development for Improving Rural Livelihoods	August 19, 2008	CRIDA, Hyderabad
Integration of livestock with fodder production and agroforestry systems	July 24 - August 6, 2008	CRIDA, Hyderabad
Watershed approach for Sustainable Development	August 25-31,2008	Krishi Vigyan Kendra Hayatnagar Research Farm
Rainwater harvesting Techniques for Improved Water Productivity	September 15-21, 2008	Krishi Vigyan Kendra Hayatnagar Research Farm
Impact of Climate Change on Rainfed agriculture system an adaptation strategies	September 18-25, 2008	CRIDA, Hyderabad
Integrated Nutrient, Pest and Disease Management in Dryland Crops	October 17-24, 2008	CRIDA, Hyderabad.
Community water management through people's institutions	October 20-26, 2008	Krishi Vigyan Kendra Hayatnagar Research Farm
"Effect of Climate Change on Water Productivity: Coping Strategies and Management"	November 4 -17, 2008	CRIDA, Hyderabad
Watershed Approach for Sustainable Agriculture	November 10-16, 2008	Krishi Vigyan Kendra Hayatnagar Research Farm
Winter school on " Technological advances in conservation of natural resources in rainfed agriculture"	November 26 –December 16, 2008.	CRIDA, Hyderabad
Launch workshop of NAIP-Component 3 project on Development of Decision Support System for Insect pests of rice and cotton based cropping systems	November 28-29, 2008	CRIDA, Hyderabad
Improved Livestock Management Practices for Higher Productivity	February 6-12, 2009.	CRIDA, Hyderabad

Programme	Period	Venue
Winter School on "Alternate land use options for resource conservation, emerging market needs and mitigation of climate change in rainfed regions"	January 16 to February 5, 2009	CRIDA, Hyderabad
Emerging Concepts of Soil and Water Management in Drylands	February 10- March 2, 2009	CRIDA, Hyderabad.
Winter school on "Emerging concepts in soil and water management in drylands"	February 10- March 2, 2009	CRIDA, Hyderabad
Watershed Approach for Sustainable Development	February 16-22, 2009	Krishi Vigyan Kendra Hayatnagar Research Farm
Watershed Approach for Sustainable Agriculture	February 24- March 2, 2009	Krishi Vigyan Kendra Hayatnagar Research Farm
Training cum workshop on "Statistical tools for data analysis"	March 2-7, 2009	CRIDA, Hyderabad
Technological Advances in Livestock Production for Higher Productivity and Efficient Utilization of Resources	March 3-16, 2009	CRIDA, Hyderabad.
Water management, Optimum input use and watershed approach for sustainable Development	March 4-10, 2009	Krishi Vigyan Kendra Hayatnagar Research Farm

One Day Review Workshop on 21st February 2009

Scientific activities

The Biennial Workshop of All India Coordinated Research Project on Agrometeorology (AICRPAM)

The Xth Biennial workshop of AICRPAM was held during 03-05 December 2008 at BCKVV, Mohanpur to review the progress of research and to finalize the technical program for 2009-10. The workshop was inaugurated by Dr. LS Rathore, ADG, IMD. Dr. AK Gogoi, ADG (Agronomy), Dr. B. Venkateswarlu, Director, CRIDA. Dr. JP Gupta, Acting Vice-chancellor of BCKV, Kalyanai and S.K.Sanyal, Director of Research were the guests of honour. Dr. GGSN Rao, Project Coordinator briefly narrated achievements of the project over the 25 years period. Chief Scientists from AICRP for Dryland Agriculture, where both projects (i.e., AICRPDA and AICRPAM) have common centers, scientists from IMD, SAC, PRL, NBPGR and IARI participated in the deliberations of the workshop. The main focus of the deliberations was on convergence among various institutions involved in research for early development of decision support systems for control of key pests/diseases based on long term data generated on crop- pest-weather relation by AICRPAM centers. The project has completed 25 years of its establishment. The project envisages strong collaboration with AICRPDA in solving the key issues related to rainfed agriculture. Human Resource Development through intensive trainings is one of the major thrust areas identified for strengthening the project.

Climate change research, particularly on identification of vulnerable regions in the country and documentation of the impacts of extreme weather events on crops were other points emphasized at the workshop.

Biennial Workshop of AICRPAM in progress at Mohanpur

South zone workshop on mealy bug in cotton

South Zone Workshop on mealy bug in cotton was organized in CRIDA on 13th March, 2009 on occurrence and spread of mealy bug in Karnataka, Tamil Nadu, Andhra Pradesh and extent of damage in cotton and Mealy bug species composition and management strategies, Govt. initiatives – past and future, on-line pest monitoring for mealy bug and other cotton pests, role of decision support systems.

Farmers' day at GRF

Farmers day was organized at Gunegal Research Farm on September 29, 2008 with a theme of "contingency crop planning in low rainfall years. One thousand farmers from the districts of Ranga Reddy, Nalgonda, Warangal, Adilabad Mahaboob Nagar and Kadapa witnessed the demonstrations of different technologies like water harvesting and its utilization in vegetables and oil seed crops, inter cropping systems (sorghum + pigeon pea), contour cultivation, improved farm implements, productivity enhancement with silt application in red oils, organic cultivation of sesamum and pigeon pea, etc. Exhibition stalls on technologies and inputs were organized by ICRISAT, DOR, and NGOs. Dr P Raghava Reddy, Hon'ble Vice Chancellor, ANGRAU was chief guest and while Director, CRIDA presided over the function. Dr.L.G.Giri Rao, Director of Extension, ANGRAU was the guest of honour.

Farmers' day at Gunegal Research Form

Field day on cotton

Krishi Vigyan Kendra (Ranga Reddy Dt.), CRIDA organized field day on cotton in one of the KVK adopted villages i.e. Thimmareddyguda, Shabad Mandal, Ranga Reddy district on September 22, 2008. Under the Chairmanship of Dr. M.S. Prasad, Principal Scientist & PC, KVK, organized this day. All KVK members attended and demonstrated technologies on Integrated Pest Management Practices in Cotton crop over an area of 50 hectares,. About 50 farmers took advantage of the demonstrations.

B. Venkateswarlu, Director, CRIDA addressing farmers field day

Awareness meet on conservation agriculture

A press conference was organized on November, 25th at CRIDA to generate awareness on conservation agriculture on the eve of the 4th World Congress on Conservation Agriculture scheduled to be held in February 2009 at New Delhi. A special presentation on prospects of conservation agriculture in Andhra Pradesh was made by scientists from ANGRAU. Dr. P.K. Joshi, Director, NCAP, Dr.T.P. Trivedi, Director, DIPA have organized the conference in the presence of Dr. S.M. Virmani, retired ADG,Principal Scientist (ICRISAT) and subject experts. It was attended by major media representatives and covered well in both print and electronic media.

B. Venkateswarlu and P.K. Joshi addressing the press meet

National Science Day

The National Science Day was celebrated on 28th February, 2009. On this occasion, an elocution competition was arranged on the theme "How to use water efficiently in agriculture" and "Climate change and its consequences in day to day life" for the school children and certificates and prizes were awarded to the participants. 110 students attended CRIDA Science day celebrations from surrounding 11 schools and were shown around the different laboratories and explained the scientific activities carried out on Dryland agriculture

Director, CRIDA presenting the certificates to winner

School childrens visiting the laboratories on National Scince day

Hindi fortnight

CRIDA Celebrated Hindi fortnight from 14-29 September, 2008. On this occasion, several competitions were organized such as Hindi – English speaking, Hindi elocution, Hindi noting & drafting. A two-day Hindi workshop was organized for scientific, technical & administrative staff. On the concluding day i.e., 29 September, 2008, Dr. GGSN Rao, OIC (Official Language) welcomed the staff and Shri S.R. Yadav, Asst. Director (OL) presented the yearly progress report. The winners of different competitions were awarded with cash prizes and certificates by the Director, CRIDA.

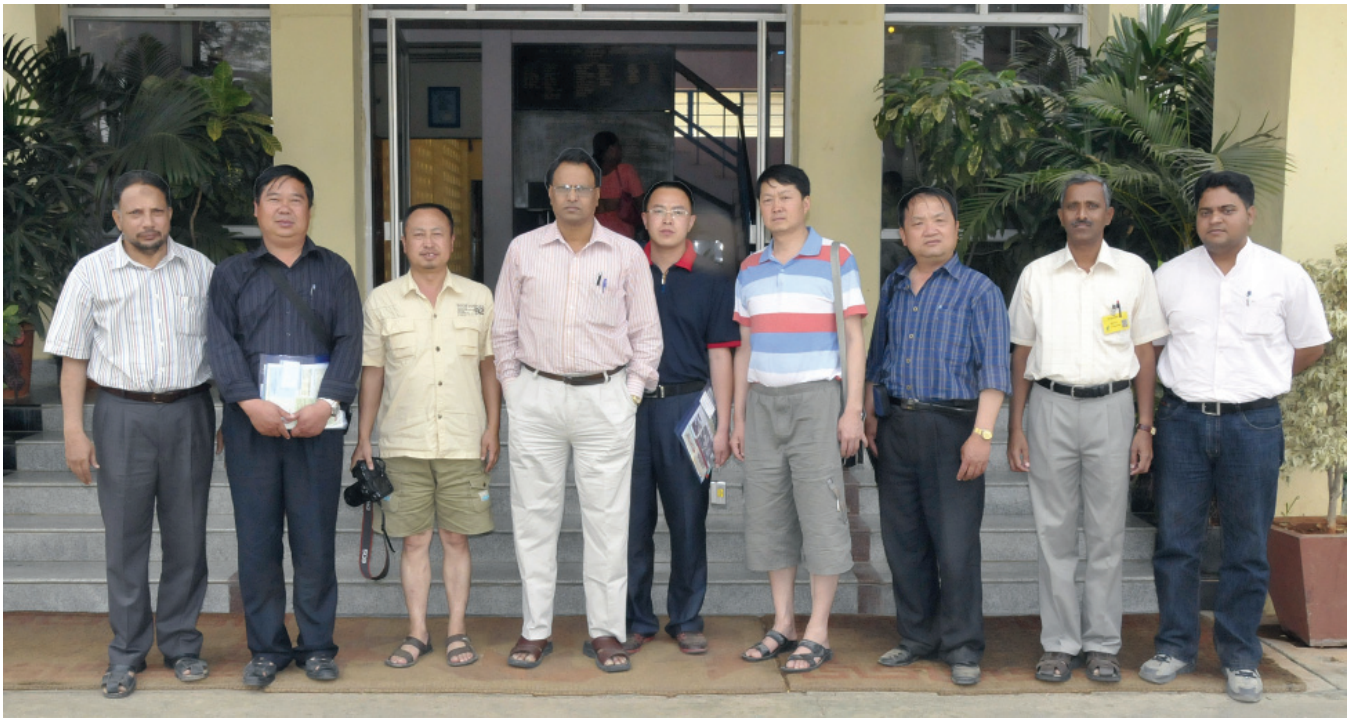
Director awarding certificate to winner (Dr.Kareemulla, Principal Scientist) of elocution competition

16. Distinguished visitors

- Ruchir Garg, Managing Director, EBE Agrotech India, Hyderabad and three others on 17.03.2009
- Six Chinese scientists from Chinese Academy of Agricultural Sciences on 20.03.2009
- Nityanand Singh, Head, Climatology and Hydrometeorology Division, IITM, Pune on 25.03.2009
- His Excellency Mr. Rosario, High Commissioner of Mozambique on 11.04.2008
- A team consisting of 50 students and faculty of Cornell University on 13.01.2009
- A. K. Gogoi, ADG (NRM) on CRIDA on 19.01.2009
- Chris Funk and Robert Web, US experts on drought monitoring, on 21.01.2009
- Exposure-cum-study visit of 23 participants from 17 countries attending the International Programme on Management of Natural Resources and Sustainable Rural Livelihood on 11.02.2009.

US experts interacting with CRIDA scientists

- Executive committee members of Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli, on 12.02.2009



Chinese scientists visit to CRIDA

17. Personnel

(As on March 31, 2009)

Dr. Y.S. Ramakrishna	Director (Retired on superannuation on 30.06.2008)
Dr. B. Venkateswarlu	Director from 07.07.2008

Division of Resource Management

Dr. G.R. Korwar	Principal Scientist (Agronomy) & Head, DRM
Sri. N.N.Srivastava	Principal Scientist (Ag. Meteorology)
Dr. C.R.Thyagaraj	Principal Scientist (FM&P)
Dr. K.L.Sharma	Principal Scientist (Soil Science) & ICAR National Fellow
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 (S&WCE)
Dr. J.V.N.S. Prasad	Senior Scientist (Agronomy)
Dr. K. Srinivasa Reddy	Senior Scientist (S&WCE)
Dr. B. Sanjeeva Reddy	Senior Scientist (FM&P)
Dr. U.K. Mandal	Senior Scientist (Soil Physics)
Dr. I. Srinivas	Senior Scientist (Selection Grade) (FM&P)
Dr. U.S. Saikia	Senior Scientist (Agril. Meteorology)from 18.10.2008
Er. Ravikanth V. Adake	Scientist (Senior Scale) (FM&P)
Shri G. Venkatesh	Scientist (Forestry) from 10.09.2008
Sri I. Ramamohan	Technical Officer (T-7/8)
Sri V. Sree Ramulu	Technical Officer (T-7/8)
Sri B. Narsimlu	Technical Officer (T-7/8)
Dr. K. Usha Rani	Technical Officer (T-7/8)
Sri J. B. Ramappa	Technical Officer (T-6)
Sri Ram Kumar	Technical Officer (T-6)
Sri K. Venkanna	Technical Officer (T-6)
Sri S.S. Sishodia	Technical Officer (T-5)

Division of Crop Sciences

Dr. V.S. Rao	Principal Scientist (Horticulture) & Incharge Head, DCS
Dr. P. Raghuram Reddy	Principal Scientist (Plant Breeding)
Dr. M. Maheshwari	Principal Scientist (Plant Physiology)
Dr. S. Desai	Principal Scientist (Plant Pathology)
Dr. N.N. Reddy	Principal Scientist (Horticulture)
Dr. Y.G. Prasad	Principal Scientist (Entomology)

Dr. S.K. Yadav	Principal Scientist (Biochemistry)
Dr. Minakshi T. Grover	Senior Scientist (Microbiology-Plant Science) from 01.09.2008
Dr. S. Venkateswarlu	Senior Scientist (Agronomy)
Dr. M. Vanaja	Senior Scientist (Plant Physiology)
Dr. B.M.K. Reddy	Senior Scientist (Agronomy)
Dr. M. Srinivasa Rao	Senior Scientist (Entomology)
Dr. V. Maruthi	Senior Scientist (Agronomy)
Dr. Arun Kumar Shankar	Senior Scientist (Plant Physiology)
Dr. M. Prabhakar	Senior Scientist (Entomology)
Dr. N. Jyothi Lakshmi	Senior Scientist (Senior Scale) (Plant Physiology)
Dr. Sreedevi Shankar	Senior Scientist (Food & Nutrition)
Dr. K.A. Gopinath	Senior Scientist (Agronomy)
Dr. G. Jayaram Reddy	Scientist (Senior Scale) (Agronomy)
Smt. P. Anantha V. Rao	Technical Officer (T-7/8)
Sri T. Madhusudhan Swamy	Technical Officer (T-7/8)
Smt. D. Renuka	Technical Officer (T-6) (Retired on 30.04.2009)
Smt. P. Lakshminarasama	Technical Officer (T-6)
Sri G. Prem Kumar	Technical Officer (T-6)
Sri Jainender	Technical Officer (T-6)
Smt. M. Pushpalata	Technical Officer (T-6)
Sri P. Yadagiri	Technical Officer (T-5)

Section of Design and Analysis

Dr. K. Kareemulla	Principal Scientist and Head
Dr. C.A. Rama Rao	Senior Scientist (Agril. Economics)
Dr. B.M.K. Raju	Senior Scientist (Agril. Statistics) from 21.08.2008

KVK

Dr. C.R. Thyagaraj	Principal Scientist (FM&P) & OIC
Dr. M.S. Prasad	Principal Scientist (Agril. Extension)
Dr. G.Nirmala	Senior Scientist (Agril. Extension)
Smt. A Sambrajyamma	Technical Officer (T-9) (Retired on superannuation on 30.06.2008)
Sri R. Joseph	Technical Officer (T-9)
Sri P. K. Mathad	Technical Officer (T-9)
Sri Pukh Raj Singh	Technical Officer (T-9)
Sri R. Dasaratha Rami Reddy	Technical Officer (T-9)
Dr. S.M. Vidyasekhar	Technical Officer (T-7/8)
Smt. A. Vidyadhari	Technical Officer (T-6)

NAIP

Dr. Sreenath Dixit	Principal Scientist (Ag. Extension)

Section of Transfer of Technology

Dr. M.V. Padmanabhan	Principal Scientist (S&WCE) & Head, TOT
Dr. D.B.V. Ramana	Senior Scientist (LP& M)
Dr. K. Ravi Shankar	Scientist (Senior Scale) (Agril. Extn.)
Dr. K. Nagasree	Scientist (Senior Scale) (Agril. Extn.)
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. G. Subba Reddy	Project Coordinator (Retired on superannuation on 30.06.2008)
Dr. P.K. Mishra	Project Coordinator from 26.08.2008
Dr. G.R. Maruthi Sankar	Principal Scientist (Ag. Statistics)
Dr. G. Ravindra Chary	Senior Scientist (Agronomy)
Sri S.R. Meena	Asst. Administrative Officer
Smt. A. Girija	Technical Officer (T-7/8)
Sri R.V.V.S.G. Krishnam Raju	Technical Officer (T-7/8)
Sri L. Sree Ramulu	Technical Officer (T-5)

All India Coordinated Research Project on Agrometeorology

Dr. G.G.S.N. Rao	Principal Scientist (Ag. Meteorology) & Project Coordinator
Dr. V.U.M. Rao	Principal Scientist (Ag. Meteorology)
Dr. Kausalya Ramachandran	Principal Scientist (Geography) & ICAR National Fellow
Dr. A.V.M. Subba Rao	Scientist (Senior Scale) (Ag. Meteorology)
Sri I. R. Khandgonda	Technical Officer (T-5)

Research Coordination and Management Unit

Dr. M. Osman	Principal Scientist (Agronomy) & Head
Dr. S.S. Balloli	Senior Scientist (Soil Science)
Dr. Shaik Haffis	Technical Officer (T-7/8)

ARIS Unit

Dr. K.V. Rao	Senior Scientist (S&WCE) & OIC
Shri P. Chandrasekhar	Technical Officer (T-6)

Library

Dr M. Maheswari	Principal Scientist (Plant Physiology) & OIC
Sri A. Malla Reddy	Technical Officer (T-6)
Sri I. Syam Prasad	Technical Officer (T-6)
Sri K. Bazar Raju	Technical Officer (T-5)

Hayathnagar Research Farm

Dr S. Desai	Principal Scientist (Plant Pathology) & OIC
Sri B.Chandra Mohan Reddy	Technical Officer (T-7/8)
Sri Ganesh Ramji Hedau	Technical Officer (T-6)
Sri S. Srinivasa Reddy	Technical Officer (T-7/8)
Sri Y. Venkatesha Reddy	Technical Officer (T-6)
Sri M. Arokia Swamy	Technical officer (T-5) (Retired on 30.09.2008)
Sri J.B. Swamy	Technical Officer (T-5)
Sri M. Ramulu	Technical Officer (T-5)
Sri M. Yadaiah	Technical Officer (T-5) (Retired on 31.08.2008)
Sri P. Yadaiah	Technical Officer (T-5)
Sri B. Balakrishna	Technical Officer (T-5)
Sri S. Narsimha	Technical Officer (T-5)
Sri M. Srinivasulu	Technical Officer (T-5)

Gunegal Research Farm

Dr. K. Srinivasa Reddy	Senior Scientist (S&WCE) & OIC

Administration

Sri Charles Ekka	Senior Administrative Officer
Shri B.D. Sati	Finance & Accounts Officer
Sri V. Govardhan	Asst. Administrative Officer (Retired on 31.03.2009)
Sri G. Lakshminarayana	Asst. Administrative Officer
Smt. A. Prema Kumari	Asst. Administrative Officer
Shri P. Pushpakar	Asst. Administrative Officer
Shri Narsingh Singh	Asst. Administrative Officer
Sri K. Ramakrishnaiah	Technical Officer T-5
Sri Ch. Srinivas	Technical Officer T-5

Vehicles

Sri P. Nagendra Rao	Technical Officer (T-5) (Driver)
Sri P. Yadi Reddy	Technical Officer (T-5) (Driver)
Sri T. Ravi Kumar	Technical Officer (T-5) (Driver)

Hindi Cell

Dr. G.G.S.N. Rao	Project Coordinator (Ag. Met.) & OIC (Official Language)
Dr. S.R. Yadav	Asst. Director (OL) and Public Relations Officer
Sri G. Prabhakar	Technical Officer (T-5)

Works

Dr. M.V. Padmanabhan	Head, TOT & OIC (Works)
Sri D. Srinivas	Technical Officer (T-5)

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
GSM	Groundnut Shell Manure
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
IVLP	Institute Village Linkage Programme
JNTU	Jawaharlal Nehru Technological University
KVK	Krishi Vigyan Kendra (Agricultural Sciences Centre)
LAE	Land Area Equivalent
LAI	Leaf Area Index
LC	Labile Carbon
LER	Land Equivalent Ratio
LGP	Length of Growing Period
LIS	Lift Irrigation Scheme
MANAGE	National Institute of Agricultural Extension Management
MBC	Microbial Biomass Carbon
MBN	Microbial Biomass Nitrogen
MtlD	Mannitol-l-Phosphate Dehydrogenase
MSAVI	Modified Soil Adjusted Vegetation Index
MSSRF	M.S. Swaminathan Research Foundation
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
NE	North East
NGO	Non-governmental Organization
NIR	Near Infra Red
NIRD	National Institute for Rural Development
NR	Nitrate Reductase
NRCS	National Research Center for Sorghum
NRCWA	National Research Center for Women in Agriculture
NRM	Natural Resource Management
NRSA	National Remote Sensing Agency
NW	North West
NWDPRA	National Watershed Development Program for Rainfed Areas
OU	Osmania University
PET	Potential Evapo Transpiration
ppm	Parts per million
PRA	Participatory Rural Appraisal
PSB	Phosphorus Solubilizing Bacteria
QRT	Quinquennial Review Term
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
SRC	Scientific Research Council
TAR	Technology Assessment and Refinement

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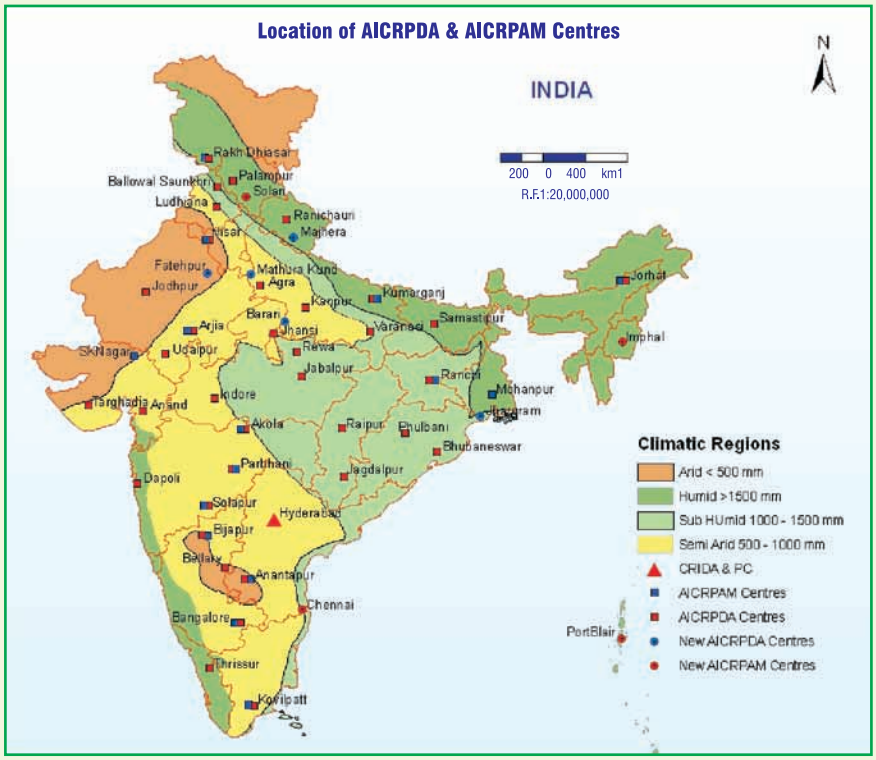

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