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किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद
Agrisearch with a human touch

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कार्यकारी सारांश

संसाधन लक्षण

- कृषिमौसम सलाहों को वर्तमान में उपलब्ध `जिला स्तर' से `ब्लॉक स्तर' तक पहुंचाया जा रहा है। कृषि विज्ञान केंद्रों से एकत्र किए गए मौसम आंकड़ों से भारतीय मौसमविज्ञान विभाग द्वारा प्राप्त मौसम पूर्वानुमानों में सामंजस्य बिठाने एवं ग्रामणिक सूचना पर आधारित कृषिमौसम सलाह सेवाओं को बेहतर बनाने में सहायता मिल रही है। इस सूचना का उपयोग दैनंदिन कृषि कार्यों, जलवायु समुत्थान कृषि संबंधी कार्यों के लिए किसानों की योग्यता में वृद्धि एवं प्रभावी फसल प्रबंधन में किया जा सकेगा।
- चार मौसमों जैसेकि ग्रीष्म (मार्च से मई), मानसून (जून से सितंबर), मानसूनोत्तर (अक्तुबर से दिसंबर) एवं शीत (जनवरी से फरवरी) के लिए `एल नीनो' वर्षों के दौरान देश भर के मौसमी वर्षा के परिवर्तनों के विश्लेषण ने स्पष्ट किया कि `एल नीनो' घटनाओं के दौरान मौसमी वर्षा में परिवर्तन हुआ है। कुछ क्षेत्रों को छोड़, `एल नीनो' घटनाओं के दौरान ग्रीष्म एवं मानसूनोत्तर वर्षा में वृद्धि हुई एवं शीत तथा मानसून वर्षा में कमी आई।
- गेहूं की एच.डी.-2285, के-8804 एवं के-9107 तीन किस्मों में अनाज उत्पादन को प्रभावित करने वाले तापमान संवेदी घटनाविज्ञान(**Phenological**) के स्तरों की पहचान की गई। टिल्लरिंग से जोइंटिंग(पी$_4$) एवं डाउ से परिपक्वता(पी$_8$) तक सभी स्तरों के दौरान अधिकतम एवं न्यूनतम तापमान ने गेहूं की तीनों किस्मों को महत्वपूर्ण एवं प्रतिकूल रूप से प्रभावित किया। तापमान दबाव (अधिकतम एवं न्यूनतम दोनो) के लिए दुग्धवस्ता अत्याधिक संवेदनशील घटना स्तर के रूप में उभरी, उसके बाद डाउ एवं परागोद्भव स्तरों की बारी आती है। तापमान एवं उत्पादन संबंधों ने स्पष्ट किया कि दुग्धवस्ता के दौरान अधिकतम तापमान में वृद्धि की तुलना में न्यूनतम तापमान में 1^0 सेंटीग्रेड़ की वृद्धि से उत्पादन में काफी कमी आई।
- जिला स्तर के आंकड़ों पर आधारित विभिन्न जलवायु एवं कृषि परिवर्तनों को नए वर्षों से अद्यतन किया गया। जलवायु प्राचलों जैसेकि वर्षा, वर्षा के दिनों की संख्या, सूखा, अधिकतम तापमान, न्यूनतम तापमान आदि को भी डेटाबेस में शामिल किया गया। जनसांख्यिकीय, प्राकृतिक संसाधन प्रबंधन एवं सामाजिक-आर्थिक प्राचलों जैसेकि जनसंख्या वृद्धि, भूमिजल उपलब्धता, निम्नीकृत एवं अकृष्य भूमि, निर्धनता, शिक्षा, भूमि का आकार, अनुसूचित जाति एवं अनुसूचित जनजाति प्रतिशत, कृषि में व्यस्त श्रमशक्ति का प्रतिशत को भी डेटाबेस में शामिल किया गया। पिछले दस वर्षों के विभिन्न कृषि आंकड़ों को शामिल कर राज्य के डेटाबेस का विकास किया गया।
- पैनल रिग्रेशन अप्रोच का उपयोग कर आंध्रप्रदेश में दो मुख्य फसलों - अरहर एवं कपास की उत्पादकता पर तापमान एवं वर्षा के प्रभाव का मूल्यांकन किया गया। अरहर एवं कपास के लिए लगाए गए मॉड़लों ने क्रमशः 52 एवं 57 प्रतिशत की विविधता दर्शाई। अरहर के मामले में, 10 मिलिमीटर की वर्षा की वृद्धि से उत्पादन में करीब 1.9 किलोग्राम की वृद्धि पाई गई। वर्षा के दिनों की संख्या में वृद्धि से उत्पादन का महत्वपूर्ण रूप से नकारात्मक संबंध पाया गया, ऐसा पुष्पण के दौरान वर्षा होने की वजह से हो सकता है। कपास की फसल में, अधिकतम तापमान उत्पादन की(एक डिग्री की वृद्धि से 77 किलोग्राम की दर से) कमी का कारण महत्वपूर्ण बना। वर्षा में हर 10 मिलीमीटर की वृद्धि से उत्पादन में 4.1 किलोग्राम की वृद्धि पाई गई।
- राष्ट्रीय स्तर पर सांख्यिकीय तकनीकों की सहायता से सिंचित एवं वर्षा आधारित परिस्थितियों के अंतर्गत मुख्य वर्षा आधारित फसलों की उत्पादकता का आकलन किया गया। फसलवार बोया गया क्षेत्र, उत्पादन एवं सिंचित क्षेत्र पर जिलावार द्वितीयक डेटा को निवेश के रूप में लिया गया। सिंचित परिस्थितियों के अंतर्गत चावल, ज्वार एवं कपास का उत्पादन वर्षा आधारित उत्पादनों का लगभग तीन गुना था। वर्षा आधारित परिस्थितियों की तुलना में सिंचित परिस्थितियों के अंतर्गत बाजरा की फसल में लगभग चार गुना अधिक उत्पादन दर्ज किया गया।
- जलग्रहण सहित एवं रहित परिस्थितियों को देखते हुए आंध्रप्रदेश के अनंतपूर एवं प्रकाशम जिलों की जलीय इकाइयों में विभिन्न भूमि उपयोगों के लिए साधारण दो स्तरीय जल संतुलन मॉड़ल का उपयोग कर पृष्ट जल संतुलन का आकलन किया गया। भारतीय मौसम विभाग के ग्रिड़ डेटा से निवेश प्राचलों जैसेकि ई.टी. का आकलन किया गया।

आकलन के लिए दस वर्षों(2000-2010) के वर्षा डेटा का उपयोग किया गया।

- वेदरकॉक(***weathercock***) सॉफ्टवेअर एवं अन्य सांख्यिकीय उपकरणों का उपयोग कर कर्नाटक के उत्तरी शुष्क क्षेत्र(केवल बीजापूर, बगलकोट, बेलगाम, गड़ग, धावनगेरी एवं रायचूर जिलों में) के लिए वर्षा के मामले में जलवायु विविधता(25 से 35 वर्षों का पाइंट डेटा) का मूल्यांकन किया गया। परिणामों ने सूचित किया कि साधारण वार्षिक वर्षा 589.32 मि.मी.(बगलकोट) से 1276.7 मि.मी.(बेलगाम) तक थी, इन जिलों में 50 प्रतिशत से अधिक वर्षों में वर्षा की कमी 63.4 प्रतिशत तक थी। दक्षिण-पश्चिम एवं उत्तर-पूर्व मानसून के प्रारंभिक एवं अंतिम सप्ताह की विविधताओं ने अब दोनों खरीफ एवं रबी फसलों को प्रभावित करते हुए देखा गया। कभी-कभी खरीफ में पड़तियों की वृद्धि एवं वैकल्पिक फसलों को अपनाना पड़ रहा है।

जलवायु परिवर्तन

- 18 उड़द जीनरूपों पर उत्थित CO_2 के प्रभाव का अध्ययन किया गया। निखोलन(**shelling**) प्रतिशत को छोड़ सभी चयनित जांचों के लिए जीनरूपों में महत्वपूर्ण विविधता थी। प्राप्त डेटा के रेंकों एवं डब्ल्यु.ई.आई. मूल्यों के आधार पर वी5 एवं वी9 किस्में बेहतर पाई गई। शुष्क भार के लिए वी9 बेहतर था जबकि उत्थित CO_2 स्तरों के उत्पादन जांचों के लिए वी5 बेहतर थी।
- नाइट्रेट रिड़क्टेस एवं ग्लुटामिन सिंथटेस गतिविधियों पर उत्थित CO_2 का कोई महत्वपूर्ण प्रभाव नहीं था लेकिन परिवेश परिस्थितियों की तुलना में बाजरा के कुल बायोमॉस एवं बीज उत्पादन में थोड़ी में वृद्धि हुई।
- परिवेश एवं उत्थित CO_2 परिस्थितियों के अंतर्गत अरंड़ पर अछिआ जनता(***Achaea janata***) की वृद्धि के मूलभूत दर का आकलन किया गया। अरंड अर्धकुण्डलक पर उत्थित CO_2 के मुख्य प्रभाव थे : उत्पादन में देरी, वृद्धि की मूलभूत दर में कमी एवं उर्वरतापूर्ण वयस्कों की कमी ।
- परिवेश परिस्थितियों की तुलना में उत्थित CO_2 स्तरों के परिणामस्वरूप स्पिलोसोमा ओबलिक्वा(***Spilosoma oblique***) द्वारा अधिक अरंड़ पर्णसमूह का उपभोग एवं अधिक लार्वा भार देखा गया। जब इन जीवों को उत्थित CO_2 के अंतर्गत उगाए गए अरंड़ पर्णसमूह खिलाए गए तो लार्वा की सापेक्ष वृद्धि दर में महत्वपूर्ण रूप से कमी आई।
- आंध्रप्रदेश के सभी क्षेत्रों में जलवायु विविधता संबंधी मुख्य धारणाएं यह थी : तापमान में वृद्धि, वर्षा में कमी एवं फसलों पर नाशीजीवी और रोगों का आपतन। पूरे क्षेत्र को जलवायु विविधता से बचाने के लिए साधारण अनुकूलन उपाय हैं : बीमा, रोपण तिथियों में परिवर्तन एवं प्रवास मज़दूर के रूप में काम करना। सूखे की तुलना में बाढ़ के लिए औसत `अनुकूलन मूल्यांक' अधिक देखा गया।

वर्षाजल प्रबंधन

- एक अध्ययन में यह मान कर कि यदि रियायत दर 12 प्रतिशत हो और तालाब की अवधि 20 वर्ष तक का हो तो 14.5 हेक्टेयर जलग्रहण क्षेत्र सहित 1750 मी^{3} क्षमता वाले कृषि तालाब के अंतर्गत एल्फीसोल्स मृदाओं में मूंगफली + गाजर + मछली +पर्यावरण लाभ वाली उत्पादन प्रणाली सर्वश्रेष्ठ पाई गई।
- संरक्षण कूंड़ों को अधिक चौड़ा(60 सेंटीमीटर) एवं अधिक गहरा(25 सेंटीमीटर) बनाने के लिए वर्तमान मेंड़ एवं कूंड़ बनाने वाले उपकरणों को सुधारा गया। संरक्षण कूंड़ों से प्रारंभिक वर्षा प्रवाह में वृद्धि हुई, जिससे खेत के अपवाह में कमी आई। साधारण रोपण की तुलना में `रिड़जर' से बोए गए पंक्ति रोपण से अरंड़ एवं अरहर के उत्पादनों में यथेष्ट वृद्धि हुई।
- कुल स्थापना लागत एवं रख-रखाव में कमी लाने के लिए, सौर शक्ति चालित पंप को पुनःअभिकल्पित एवं डी.सी. चालित में परिवर्तित कर विकसित किया गया। इस प्रकार इसकी स्थापना लागत में 25 प्रतिशत की कमी आई। नए विकसित पंप में सक्शन एवं डेलिवरी हेड़ क्रमशः 1.0 मीटर एवं 2.5 मीटर सहित 700 लीटर प्रति हाउस की डिसचार्ज क्षमता है।
- वास्तविक-समय जल-संतुलन(**real time water balance**) के अध्ययनों के लिए डी.एस.एस. मॉड़ल का विकास किया गया एवं 2011 के 50वें मौसमवैज्ञानिक सप्ताह की जांच की गई। आई.एम.डी-ए.डब्ल्यु.एस. डेटा पोर्टल से 320 स्थानों के लिए संबंधित सप्ताह का दैनिक जलवायु डेटा संग्रहित किया गया। क्षमतायुक्त वाष्पन-वाष्पोत्सर्जन के साथ-साथ वर्षा के लिए दो अलग-अलग डेटाबेसों का निर्माण किया गया। दोनों डेटाबेसों को आगे 2 किलोमीटर X 2 किलोमीटर ग्रिड में अंतर्वेषित कर फैला दिया गया। जल संतुलन(अधिक या कम) के परिणामी डेटाबेस को इस प्रकार तैयार कर व्यवस्थित किया गया कि स्थान विशेष के अक्षांश एवं देशांतर रेखांश का उपयोग कर समाचार प्राप्त किया जा सके। डी.एस.एस. मॉडल को 20 स्थानों पर जांचा गया। अवलोकित एवं डी.एस.एस. अनुमानित मूल्यों के बीच अच्छा सामंजस्य देखा गया। सूचना को तुरंत प्राप्त करने के लिए ग्राफिक यूज़र इंटरफेस का भी विकास किया गया।
- ए.ई.एस.आर. 7.3 क्षेत्र में उपचारित सूक्ष्म जलग्रहणों के मूल्यांकन से स्पष्ट हुआ कि उपचारित जलग्रहणों में स्थित लगभग <20% भूमि संधारणीय(**sustainable**) पाई गई।

- 15 वर्षों के लिए हर वर्ष वर्तमान प्रतिफलों की अपेक्षा करते हुए 100 तालाबों के लिए कुल वर्तमान मूल्य(NPV) एवं लाभ लागत अनुपात(BC ratio) के माध्यम से कृषि तालाबों की आर्थिक स्थिरता की गणना की गई। यह देखा गया कि 100 तालाबों मे से 33 ने 30000 रुपए से भी कम कुल वर्तमान मूल्य(NPV) दिया। आश्चर्यजनक बात तो यह थी कि चार तालाबों ने दो लाख रुपए से ज्यादा का कुल वर्तमान मूल्य(NPV) दर्ज किया जबकि 15 तालाबों से कुल वर्तमान मूल्य(NPV) नकारात्मक पाया गया। अत्याधिक लाभदायक तालाबों के मामले में क्षेत्र एवं तालाब का आकार औसत से बहुत अधिक था।

फसल एवं फसल प्रणालियां

- केंद्रीय बारानी कृषि अनुसंधान संस्थान से आशाजनक कुलथी की तीन वंशावलियां(क्रीड़ा 19, क्रीड़ा 20 एवं क्रीड़ा 21) विमोचन हेतु सी.वी.आर.सी. को प्रस्तुत करने के लिए तैयार हैं। इसके अलावा, 2 कुलथी म्यूटेन्ट(सी.आर.एच.जी-6 एवं सी.आर.एच.जी-8) को एन.बी.पी.जी.आर., नई दिल्ली से पंजीकृत कराया गया।
- नियंत्रित परिस्थितियों के अंतर्गत दबाव सहीष्णुता के लिए ***mtld*** ट्रांसजेनिक ज्वार की छः वंशावलियों की जांच की गई। यह वंशावलियां मुख्य पादपक्रियात्मक प्राचलों के मामले में अरूपांतरित पौधों से बेहतर पाई गई।
- **DHNpCAMBIA 1303** युक्त जीन संरचना को एग्रोबेक्टेरियम टुमेफेसिन्स(***Agrobacterium tumefaciens***) विगलक में परिवर्तित कर दिया गया। एग्रोबेक्टेरियम मध्यस्त जननिक रूपांतरण द्वारा तंबाकू पौधों में डेहाइड्रिन जीन के मूल्यांकन के लिए रूपांतरित कल्चर का उपयोग किया गया। पी.सी.आर. एवं आर.टी-पी.सी.आर. विश्लेषणों ने तंबाकू पौधों में डेहाइड्रिन जीन के सफलतापूर्वक रूपांतरण की पुष्टी की।
- 24 एच दबावग्रस्त बाजरा पौधों से दो उच्च गुणवत्ता वाले सबस्ट्रेक्टिव **cDNA** लाब्रेरियों का निर्माण किया गया। विश्लेषित किए गए क्रमों में, 6 जीनों को पहचाना गया जो साधारणतया दोनों लाइब्रेरियों में शामिल किए जा सकते हैं, जबकि 104 एवं 102 जीनों को विशेष रूप से क्रमशः जल की कमी एवं उच्च तापमान दबावों में रखा गया।
- मूंग किस्मों (एम.एल. 267 एवं डब्ल्यु.जी.जी. 37) में जड़ वृद्धि पर किए गए अध्ययनों ने स्पष्ट किया कि डब्ल्यु.जी.जी. 37 के मामले में अधिकतम जड़ की लंबाई मृदा में 5-15 सेंटीमीटर गहराई तक थी जबकि एम.एल. 267 में 10-20 सेंटीमीटर मृदा गहराई तक जड़ों की लंबाई का अधिक वितरण देखा गया जिसके परिणामस्वरूप एम.एल. 267 में बेहतर सूखा सहीष्णु योग्ता पाई गई।
- जैविक फसल उत्पादन पर किए गए अध्ययनों ने स्पष्ट किया कि जैविक प्रबंधन के अंतर्गत दूसरे वर्ष के दौरान सूरजमुखी में 13.1 प्रतिशत, अरहर में 4.7 प्रतिशत एवं तिल में 15.4 प्रतिशत उत्पादन में कमी आई।
- नाशीजीव एवं रोग ग्रस्तता के कारण दबाव ग्रस्त कपास एवं उड़द वितानों के रेफलेक्टेन्स स्पेक्ट्रा लक्षणों को जानने के लिए *हाइपरस्पेक्ट्रल रेड़ियोमेट्री* का उपयोग किया गया। `मीली बग' दबाव सूचकों का विकास किया गया जिसमें कपास में मीली बग की तीर्वता का मूल्याकंन करने की शक्ति है। इसी प्रकार, उड़द में मोजेक तीर्वता के मूल्यांकन के लिए वाई.एम.डी. रोग पूर्वानुमान मॉडलों का निर्माण किया गया।
- सूखा एवं तापमान दबाव प्रबंधन के लिए प्रयोगशाला एवं क्षेत्रीय परिस्थितियों में दो जीवाणु संघों(पी-7+बी-30+जी-12 एवं पी-45+बी-17+जी-12) को जांचा गया। वर्षा आधारित परिस्थितियों के अंतर्गत संघ समावेश सहित सिफारिश किए गए नाइट्रोजन, फासफोरस एवं पोटाश के उपयोग से ज्वार एवं सूरजमुखी में बेहतर पादप वृद्धि एवं उत्पादन पाया गया।
- बारानी फसलों के *राइज़ोस्फीअर* में दबाव सहीष्णु पी.जी.पी.आर. विगलकों की उत्तरजीविता एवं स्थायीत्व पर किए गए अध्ययन से स्पष्ट हुआ कि सूरजमुखी एवं ज्वार में संरोपित विगलकों(दो *बेसिलस* एस.पी. विगलक जैसेकि बी.30 एवं बी.17 तथा दो *स्योड़ोमोनास* एस.पी. जैसेकि पी.7 और पी.45 के रिफामपिसिन प्रतिरोधी म्यूटेन्ट) द्वारा बेहतर उपनिवेशन हुआ।
- विभिन्न पादप वृद्धि को बढ़ावा देने वाले विगलकों में, *बेसिलस* बी.73(पहले गमला सस्ययन के अंतर्गत आशाजनक के रूप में पहचाना गया) से उपचारित पौधों ने 2570 किलोग्राम प्रति हेक्टेयर का ज्वार उत्पादन दिया, उसके बाद बी**87+**पी33(एक जस्ता घुलनशील) (2530 किलोग्राम प्रति हेक्टेयर) का मिश्रित संरोपण था, जबकि संरोपण रहित नियंत्रण में उत्पादन 2182 किलोग्राम प्रति हेक्टेयर था।
- समेकित कृषि प्रणाली मॉड्युलों पर किए गए अध्ययन से स्पष्ट हुआ कि कम वर्षा वाले वर्ष के दौरान सिंचित वर्षाजल से सिंचित सब्जियां, बाजरा+अरहर अंतरसस्ययन एवं फार्म में तैयार किए गए चारे से पोषित नेल्लूर नस्ल के भेड़ पालन ने आर्थिक स्थिरता प्रदान की।

मृदा स्वास्थ्य एवं पोषक प्रबंधन

- कर्षण एवं पोषक प्रबंधन पर 13 वर्षों के प्रयोगों के बाद, समानीत कर्षण की तुलना में पारंपरिक कर्षण ने ज्वार एवं मूंग बीन का बेहतर उत्पादन क्रमशः 5.7 प्रतिशत एवं 7.9

प्रतिशत बनाए रखा। पोषक प्रबंधन उपचारों में, पारंपरिक एवं समानीत कर्षण दोनों के अंतर्गत कंपोस्ट एवं यूरिआ के संयुक्त प्रयोग से ज्वार एवं मूंग बीन में बेहतर निष्पादन और महत्वपूर्ण रूप से बेहतर उत्पादन के साथ-साथ सस्य क्षमता दर्ज हुई।

- सात वर्षों के अध्ययन के बाद, 60 किलोग्राम नाइट्रोजन प्रति हेक्टेयर$^{-1}$ की दर के साथ में 6 टन प्रति हेक्टेयर$^{-1}$ की दर से अवशेष के प्रयोग की तुलना में नाइट्रोजन 60 किलोग्राम प्रति हेक्टेयर$^{-1}$ की दर के साथ में 4 टन प्रति हेक्टेयर$^{-1}$ की दर से ज्वार की कड़बी का प्रयोग करने से महत्वपूर्ण रूप से बेहतर ज्वार अनाज का उत्पादन प्राप्त हुआ। नियंत्रण(अवशेष प्रयोग रहित) की तुलना में 2,4एवं 6 टन प्रति हेक्टेयर$^{-1}$ की दर से अवशेष प्रयोग करने से अनाज उत्पादन में प्रतिशत वृद्धि क्रमशः 21.1,31.0 एवं 23.0 प्रतिशत रही।
- कर्षण पर 1995 में आरंभ किए गए लंबी अवधि के प्रयोग में, कृषि में नाइट्रोजन एवं अवशेष प्रयोग, न्यूनतम कर्षण की तुलना में पारंपरिक कर्षण ने ज्वार में थोड़ा बेहतर उत्पादन को बनाए रखा। अवशेषों में, *ग्लैरिसिड़िया* कर्तनों के प्रयोग के परिणामस्वरूप बेहतर ज्वार अनाज उत्पादन प्राप्त हुआ, जोकि ज्वार के कड़बी के प्रयोग के समान था। नाइट्रोजन 60 किलोग्राम प्रति हेक्टेयर$^{-1}$ की दर से प्रयोग करने से महत्वपूर्ण रूप से बेहतर उत्पादन उपलब्ध हुआ।
- ए.ए.आई.सी.आर.पी.डी.ए. के बेंगलूरू केंद्र के स्थायी खाद(अहाता खाद श्रंखला) प्रयोग में, एल्फीसोल्स मृदा में मूंगफली - रागी सस्ययन प्रणाली के अंतर्गत जैविकों एवं उर्वरकों के लंबी अवधि के उपयोग के लिए मुख्य गुणवत्ता सूचक कुछ इस प्रकार थे : ई.सी., उपलब्ध नाइट्रोजन, उपलब्ध पोटाश, उपलब्ध सल्फर, उपलब्ध जिंक, उपलब्ध लोहा, उपलब्ध बोरान, एम.बी.सी., एम.डब्ल्यु.डी., एवं स्थूल घनत्व थे। मक्का अवशेष श्रंखला में, मुख्य मृदा गुणवत्ता सूचक मृदा **pH,** ई.सी., जैविक कार्बन, उपलब्ध सल्फर, एम.डब्ल्यु.डी., एवं अस्थिर कार्बन थे। कर्षण प्रयोग में, मुख्य गुणवत्ता सूचक **pH,** उपलब्ध नाइट्रोजन, उपलब्ध सल्फर,उपलब्ध पोटाश, उपलब्ध कैलशियम, एवं अस्थिर कार्बन थे।
- अरजिया में आयोजित क्षेत्रीय प्रयोग के परिणामों ने स्पष्ट किया कि नियंत्रण(संरोपण रहित) की तुलना में मक्का के बीजों को *स्यूड़ोमोनास* के पी33 एवं पी29 से संरोपण करने से मक्का के उत्पादन में वृद्धि हुई। मक्का का अधिकतम अनाज उत्पादन 25 किलोग्राम प्रति हेक्टेयर$^{-1}$ जिंक सल्फेट प्राप्त करने वाले उपचार में दर्ज किया गया, उसके बाद पी29 एवं पी33 से मक्का के बीजों का संरोपण किए गए उपचारों ने दर्ज किया। हैदराबाद केंद्र में, अन्य उपचारों की तुलना में 25 किलोग्राम प्रति हेक्टेयर$^{-1}$ जिंक सल्फेट प्राप्त करने वाले उपचार में अधिकतम मक्का का उत्पादन प्राप्त किया गया।
- लंबी अवधि के कर्षण प्रयोग के अंतर्गत मृदा विश्लेषण से स्पष्ट हुआ कि कम कर्षण में जैविक पदार्थ उपयोग उपचारों एवं कुल कार्बन की मात्रा में वृद्धि हुई। ऑफ सीजन में बिना कर्षण के पारंपरिक कर्षण में अधिकतम अस्थिर कार्बन की मात्रा देखी गई, उसके बाद कम कर्षण + कंपोस्ट का स्थान था। कम कर्षण एवं कंपोस्ट प्रयोग उपचारों में जैविक कार्बन एवं अन्य अस्थिर कार्बन पूलों की वृद्धि हुई। कम कर्षण एवं कंपोस्ट प्रयोग से सोयाबीन प्रणाली में भी उत्पादन लाभ देखा गया।
- संपूरक सिफारिश की गई उर्वरक मात्रा सहित 3 टन प्रति हेक्टेयर की दर से कपास वृंत बायोचर का प्रयोग (एकांतर वर्ष के अंतर्गत) करने से अरहर की फसल में अधिकतम अनाज उत्पादन दर्ज हुआ। मक्का में सिफारिश की गई उर्वरक मात्रा + अहाता खाद(5 टन प्रति हेक्टेयर) सहित 4 टन प्रति हेक्टेयर की दर से अरंड़ वृंत के प्रयोग से अधिकतम अनाज उत्पादन प्राप्त हुआ।
- पारंपरिक कर्षण एवं समानीत कर्षण की तुलना में शून्य कर्षण में ईधन उपभोग एवं ऊर्जा खर्च न्यूनतम था। पारंपरिक कर्षण एवं समानीत कर्षण की तुलना में भूमि तैयारी एवं बोवाई के दौरान, शून्य कर्षण में CO_2 का उत्सर्जन क्रमशः 73 एवं 69 प्रतिशत कम दर्ज किया गया। पारंपरिक कर्षण की तुलना में शून्य कर्षण एवं समानीत कर्षण में महत्वपूर्ण रूप से कम अपवाह दर्ज किया गया। अपवाह को कम करने के अलावा, पारंपरिक कर्षण एवं समानीत कर्षण की तुलना में शून्य कर्षण से मृदा हानि महत्वपूर्ण रूप से कम थी। क्रमशः 0 सेंटीमीटर एवं 10 सेंटीमीटर की तुलना में कटाई की ऊंचाई में 30 सेंटीमीटर की वृद्धि के परिणामस्वरूप मृदा में 60 एवं 20 प्रतिशत अवशेष प्रतिफल में वृद्धि हुई।
- यद्यपि समानीत कर्षण एवं शून्य कर्षण की तुलना में पारंपरिक कर्षण से अरहर के उत्पादन में बेहतर वृद्धि हुई, प्रथम एवं द्वितीय वर्ष की तुलना में विभिन्न कर्षण प्रणालियों के बीच उत्पादन भिन्नता में कमी आई। क्रमशः 0 एवं 30 सेंटीमीटर की तुलना में कटाई की ऊंचाई 10 सेंटीमीटर रखने से महत्वपूर्ण रूप से बेहतर उत्पादन दर्ज हुआ।
- साधारण रोपण की तुलना में जोड़ी पंक्ति रोपण से महत्वपूर्ण रूप से बेहतर अरंड़ समतुल्य उत्पादन एवं अवशेष उत्पादन दर्ज हुआ। विभिन्न संसाधन संरक्षण प्रक्रियाओं में, मक्कीना(**muccina**) एवं अरंड़ के अंतरसस्ययन ने अधिकतम अरंड़ समतुल्य उत्पादन के साथ-साथ अधिक अवशेष उत्पादन दर्ज किया।

- कर्षण एवं पोषक तत्वों पर किए गए अनुसंधान से ज्ञात हुआ कि प्रयोग के प्रथम वर्ष में, मक्का की वृद्धि, उत्पादन बढ़ाने वाले लक्षण, बीज एवं कड़बी पर संरक्षण एवं पारंपरिक कर्षण उपचारों में महत्वपूर्ण भिन्नता नहीं थी। **NPKSZnB** के संतुलित उपयोग से क्रमशः 4.7 टन प्रति हेक्टेयर$^{-1}$ एवं 7.9 टन प्रति हेक्टेयर$^{-1}$ का महत्वपूर्ण रूप से बेहतर अनाज उत्पादन एवं कड़बी उत्पादन प्राप्त हुई इसके उपरांत जैविक बोरान एवं सल्फर का उपयोग न करने से उत्पादन में कुछ कमी आई।
- दक्षिण भारत में अल्फीसोल पर 20 वर्ष की लंबी अवधि के प्रयोग में, 1 मीटर की गहराई में मृदा जैविक कार्बन की सांद्रता में 50 प्रतिशत सिफारिश किए गए उर्वरक+4 **Mg** प्रति हेक्टेयर$^{-1}$ मूंगफली के छिलके के प्रयोग से उत्पादन में 2.5 से 3.5 ग्राम प्रति किलोग्राम$^{-1}$, 50 प्रतिशत सिफारिश किए गए उर्वरक+4 **Mg** प्रति हेक्टेयर$^{-1}$ अहाता खाद के प्रयोग से उत्पादन में 2.5 से 3.4 ग्राम प्रति किलोग्राम$^{-1}$ एवं 100 प्रतिशत सिफारिश किए गए उर्वरक के प्रयोग से उत्पादन में 2.5 से 2.6 ग्राम प्रति किलोग्राम$^{-1}$ तक वृद्धि हुई। इन उपचारों के लिए मृदा जैविक कार्बन पृथक्करण(**C ha^{-1} yr^{-1}**) का औसत दर क्रमशः 0.57,0.51,0.02 था। 50 प्रतिशत सिफारिश किया गया उर्वरक+4 **Mg** प्रति हेक्टेयर$^{-1}$ अहाता खाद से मूंगफली(4 **Mg** प्रति हेक्टेयर$^{-1}$) का बेहतर औसत फली उत्पादन प्राप्त हुआ। 1 मीटर की गहराई तक मृदा जैविक कार्बन भंड़ार में हर एक **Mg** की वृद्धि से मूंगफली उत्पादन में वृद्धि दर 13 किलोग्राम प्रति हेक्टेयर$^{-1}$ हो गई। मृदा जैविक कार्बन में शून्य परिवर्तन बनाए रखने के लिए 1.12 **Mg C ha^{-1} yr^{-1}** के न्यूनतम निवेश की आवश्यकता है।
- भारत में उप आर्द्र उष्णकटिबंधी परिस्थितियों के अंतर्गत आयोजित 21 वर्षों के क्षेत्रीय प्रयोग में, अहाता खाद रहित एवं सहित खनिज उर्वरकों के प्रयोग से कार्बन निवेश, मृदा जैविक कार्बन सांद्रता एवं भंड़ार में वृद्धि हुई। नियंत्रण की तुलना में, 100 प्रतिशत जैविक(अहाता खाद) उपचार ने महत्वपूर्ण रूप से बेहतर मृदा जैविक कार्बन दिया, 1986 के पूर्ववृत्त मूल्यों की तुलना में कार्बन निर्माण एवं कार्बन पृथक्करण 1 मीटर की गहराई में अधिक था। जड़ क्षेत्र में मृदा जैविक कार्बन के भंड़ार में हर **Mg** वृद्धि से चावल एवं मसूर के उत्पादन में क्रमशः 0.16 **Mg C ha^{-1} yr^{-1}** एवं 1.12 **Mg C ha^{-1} yr^{-1}** वृद्धि पाई गई। स्थिर मृदा जैविक कार्बन स्तर (सस्ययन के कारण शून्य परिवर्तन) बनाए रखने के लिए, इन मृदाओं में, जलवायु, सस्ययन प्रणाली एवं उर्वरक उपचारों के लिए 0.16 **Mg C ha^{-1} yr^{-1}** की न्यूनतम मात्रा की आवश्यकता है।

भूमि उपयोग विविधता

- अन्य उपचारों की तुलना में अमरूद में समेकित पोषण प्रबंधन युक्त 30 किलोग्राम अहाता खाद + सिफारिश की गई उर्वरक मात्रा के उपयोग ने अधिक संख्या में द्वितीयक एवं तृतीयक परिणामों के फलस्वरूप अधिक संख्या में फल एवं फलोत्पादन प्राप्त हुआ। अन्य जांच में, अहाता खाद की अधिक मात्रा सहित **VAM** या **PSB** या **ZSB** या **K** मोबिलाइज़रों के सूक्ष्म संरोपण मोसम्मी में शीघ्र प्रधावन वृद्धि, पुष्पण, एवं फल बनाने में प्रभावी पाई गई। *ट्राकोड़ेरमाया* पी.एस.बी. या *एज़ोसपिरिल्लम* सहित अहाता खाद की बेहतर मात्रा के उपयोग से अमरूद एवं सीताफल में शीघ्र पुष्पण एवं फल बनाने में सहायता मिली।
- जैविक प्रबंधन के अंतर्गत सीताफल एवं अमरूद में फलों का उत्पादन एवं गुणवत्ता(सीताफल में कम बीज भार एवं बेहतर गुदा; अमरूद में बेहतर कुल घुलनशील शक्कर एव कम अम्लता) दोनों ने बेहतर निष्पादन दिया।
- जट्रोफा के मुख्य नाशीजीवों एवं रोगों की पहचान की गई एवं नियंत्रण उपायों को मानक बनाया गया, तना बेधक को छोड़ । सिंचाई,(20 दिनों के अंतराल पर), 3**X2** मीटर दूरी एवं उर्वरक प्रयोग(**N90+P200** ग्राम प्रति पौधा) के संयोग से जेट्रोफा में अधिकतम बीज उत्पादन(0.2 टन प्रति हेक्टेयर) प्राप्त हुआ।
- पोंगामिया के मुख्य नाशीजीवियों एवं रोगों तथा उनके निवारण उपायों की पहचान की गई। रोपे गए पौधों में 0.069 से 1.73 किलोग्राम प्रति पौधा की तुलना में पोंगामिया का केरनल उत्पादन छठे वर्ष के दौरान 0.3 से 2.2 किलोग्राम प्रति पौधा हो गया।
- 10 वर्षों के दौरान आंध्र प्रदेश के चयनित जिलों में भूमि उपयोग में परिवर्तन पर किए गए अध्ययन ने दर्शाया कि अदिलाबाद एवं नलगोंड़ा में पड़ती क्षेत्र में वृद्धि हुई लेकिन वरंगल में कोई परिवर्तन नहीं देखा गया। सभी तीन जिलों में, कुछ गांवों में मुख्य भूमि उपयोग के रूप में बागवानी को छोड़ एन.डी.वी.आई. पर आधारित वनस्पति आच्छादन में कमी आई।

पशुधन प्रबंधन

- चराई परिस्थितियों के अंतर्गत छोटे रूमिनेंटों(जुगाली करने वाले पशु) में अतिरिक्त आवश्यकताओं को पूरा करने वाले सांद्रण मिश्रण की तुलना में भेड़ को समान उर्जा एवं नाइट्रोजन के आधार पर कुलथी या एज़ोल्ला का अतिरिक्त पोषण देने के परिणामस्वरूप भेड़ में महत्वपूर्ण रूप से बेहतर भार वृद्धि पाई गई।

- मोटे फसल अवशेषों सहित विभिन्न सांद्रणों(कुलथी का चूरा, मूंगफली का छिलका, सोया का चूरा, एज़ोल्ला का चूरा एवं स्टाइलों का चूरा) के अतिरिक्त पोषण से पशुधन के रूमेन में मनवोद्भवी उत्सर्जन(संचित गैस उत्पादन) की कमी दर्ज की गई।

उर्जा प्रबंधन

- लो टिल-हॉरिज़ोनटल प्लेट रोपक का निष्पादन जांच किया गया एवं सटीकता के लिए मीटरिंग प्लेटों को पुनःअभिकल्पित एवं कैलिब्रेट किया गया। क्षेत्र परिस्थितियों के अंतर्गत, पारंपरिक कर्षण एवं लो टिल प्लाट दोनों में रोपित बीज दर करीब समान था। थोड़ा अवशेष डालने से लो टिल प्लाटों में 0-15 सेंटीमीटर मृदा सतह में थोड़ी बेहतर नमी पूरी फसल(मक्का) वृद्धि के दौरान दर्ज की गई। पारंपरिक कर्षण उपचार में 109 किलोग्राम प्रति हेक्टेयर$^{-1}$ का न्यूनतम सूखा खरपतवार बायोमॉस दर्ज किया गया।
- नाइलॉन पंप को रूपांतरित कर जांचा गया। प्रोटाइप-2 में, घिसाई को कम करने के लिए स्टेनलेस स्टील के बुश लगाए गए। इसके अलावा, बहाव दर की तेजी को देखते हुए इमपेल्लर के आकार में परिवर्तन किया गया। इमपेल्लर का व्यस 110 मि.मी. से 120 मि.मी. एवं वेन की चौड़ाई 10मि.मी. से 15 मि.मी. तक बढ़ाई गई। संशोधित एवं वर्तमान पंप की तुलनात्मक जांच की गई। विभिन्न कालों के लिए 8 घंटों तक लगातार चलाया गया एवं पंप के संशोधित मॉडल के किसी भी पुर्जे में घिसाव नहीं देखा गया।

सामाजिक आर्थिक अध्ययन एवं प्रौद्योगिकी का हस्तांतरण

- चेवेल्ला मंड़ल के 12 गांवों के 60 सर्वेक्षण प्रत्यर्थी के परिणामों ने सूचित किया कि पिछले तीन वर्षों(2006 से 2008) के दौरान उनके द्वारा उगाए गई विभिन्न फसलों जैसेकि मक्का, कपास, खरीफ चावल, टमाटर, गाजर एवं चुकंदर के लिए कृषि उत्पादकता का स्तर अधिकतर किसानों के लिए `मध्यम' रहा।
- फारूखनगर मंड़ल की महिलाएं जिन्होंने अपने दैनिक पोषण में मिलेटों**(millets)** का उपभोग किया, उनके पौष्टिक स्तर ने स्पष्ट किया कि 87 प्रतिशत ग्रामीण महिलाओं का पौष्टिक स्तर साधारण था। केवल 9 एवं 4 प्रतिशत महिलाओं में कुपोषण श्रेणी क्रमशः I और III थी जबकि बालापूर मंड़ल में, ग्रामीण महिलाओं की 90 प्रतिशत संख्या में साधारण पोषण स्तर पाया गया एवं कुपोषण श्रेणी क्रमशः I और III में हरेक में 5 प्रतिशत जनसंख्या थी। ग्रामीण महिला जनसंख्या में इस कुपोषण को अपर्याप्त कैलोरी के रूप में देखा जा सकता है।
- सूचना एवं संचार प्रौद्योगिकी के उपकरणों एवं नॉलेड्ज शेर सेंटर**(Knowledge Share Center)** में प्रदान की गई सेवाओं के लिए उपयोग किए गए विश्लेषण ने स्पष्ट किया कि अधिकतर किसानों (73 प्रतिशत) ने कृषि सलाहों पर आधारित सस्यवाणी-मोबाइल प्रसार सेवाओं को अधिमत दिया उसके बाद इंटरनेट का स्थान था। सहसंबंध विश्लेषण ने स्पष्ट किया कि कुछ अस्थिरताओं जैसेकि अगम्यता, बार-बार मरम्मत एवं रख-रखाव ने महत्वपूर्ण रूप से नकारात्मक सह-संबंध दर्शाया जबकि सूचना एवं प्रौद्योगिकी उपकरणों को उपयोग करने वाले किसानों की क्षमता निर्माण ने के.एस.सी. स्थापित केंद्रों के समग्र निष्पादन सहित महत्वपूर्ण रूप से सकारात्मक संबंध दर्शाया।

राष्ट्रीय कृषि नवोन्मेषी परियोजना

- आंध्र प्रदेश के अदिलाबाद, महबूबनगर एवं रंगा रेड्डी जिलों के वर्षा आधारित कृषि की उत्पादकता वृद्धि के लिए प्रौद्योगिकी एवं संस्थागत विकल्पों के विश्लेषण ने स्पष्ट किया कि वर्तमान प्रौद्योगिकी के अंतर्गत छोटे किसानों के लिए जब अधिकतम संसाधन आबंटित किया गया तो वहां किसानों ने सोयाबीन+अरहर के स्थान पर कपास+अरहर को चुना। उचित प्रौद्योगिकी का उपयोग करने पर किसानों के शुद्ध प्रतिफल में 18 प्रतिशत की वृद्धि हुई। यही जब ऋण नहीं दिया गया तो शुद्ध प्रतिफल में 20.8 प्रतिशत की कमी आई।
- मार्गदर्शक के रूप में केंद्रीय बारानी कृषि अनुसंधान संस्थान सहित दस संगठनों के संघ द्वारा जीविकोपार्जन सहायक हस्तक्षेपों की योजना एवं कार्यान्वयन का पांच वर्षों में व्यापक अध्ययन किया गया। इससे ज्ञात हुआ कि स्थान विशेष प्राकृतिक संसाधन प्रबंधन गतिविधियों द्वारा वर्षाजल-सिंचाई, बेहतर फसल एवं फसल प्रणालियों की प्रोन्नति, सस्ययन, बागवानी एवं सस्योत्तर मूल्यवर्धन का पशुधन के साथ समेकन, छोटे कृषि यांत्रिकीकरण एवं क्षमता निर्माण इत्यादि ने आंध्र प्रदेश के आठ पिछड़े जिलों(अदिलाबाद, अनंतपूर, कड़पा, खमम्म, महबूबनगर, नलगोंड़ा, रंगा रेड्ड़ी एवं वरंगल) में गरीबों की जीविकोपार्जन सुरक्षा प्रदान की।
- आंध्रप्रदेश के मेदक जिले के इब्राहिमबाद के 30 एकड़ पर मीठी ज्वार की बोवाई के लिए तैयार किए गए 6 पंक्ति रोपक को जांचा गया। स्वचालित हारवेस्टर को संशोधित कर अधिक चौड़े तनों को काटने लायक बनाया गया। ऊर्जा कटौती एवं अधिक रस निकालने/निचोड़ने के दौरान अधिक तनों को लगाने के लिए तीन-पास 6 रोलर क्रशर को बेहतर बनाया गया।
- एक अन्य अध्ययन में, एक केंद्र में ग्रिड़ आधारित दृष्टिकोण, ऊर्जा क्षमता संबंधी हस्तक्षेपों एवं वर्तमान भूसुदर्शनीकरण में पेड़ों के समावेश का कार्यान्वयन किया गया। आरंभ के

कार्बन भंड़ार एवं परियोजना परिप्रेक्ष्य में कार्बन भंड़ारों में परिवर्तन को मापा गया। वरंगल जिले के ज़फरगुड़ेम के अलावा दो और गांवों को शामिल कर ग्रिड़ का विस्तार किया गया।

- कपास पर सोलेनोपसिस मीलीबग के जीवन चक्रों के लिए विकास अवधि, तापमान सीमा एवं ताप स्थिरता की पहचान की गई। नाशीजीव नियंत्रण के लिए निर्णय- सहायक-प्रणाली को तैयार करने के लिए विभिन्न मॉड्युलों जैसेकि कृषि-जलवायु विश्लेषण के लिए वेब द्वारा प्राप्त निर्णय सहायक उपकरण, चक्र विशेष मृत्युदर एवं आयु-विशेष जननक्षमता जीवन सारणी का निर्माण, डिग्री-डे केलकुलेटर एवं जनसंख्या झुकाव सूची केलकुलेटर का विकास किया गया।
- जैवनियंत्रण एजेंट, स्यूड़ोमोनास के पी43(लवणता सहीष्णु) एवं पी8(लवणता एवं तापमान सहीष्णु) विगलकों के संपूर्ण जिनोम क्रमों को पूरा किया गया एवं अजैविक दबाव सहीष्णुता प्रदान करने वाले क्रियाशील जीनों को पहचानने के लिए क्रमों को लिपिबद्ध किया गया।

राष्ट्रीय जलवायु समुत्थान कृषि पहल

- मक्का के लिए उर्वरकों की सिफारिश की गई आधारिक मात्रा के प्रयोग एवं बोवाई के 25 दिनों के बाद पोटाशियम, जिंक एवं सेलेनियम के प्रयोग से अनाज उत्पादन में महत्वपूर्ण वृद्धि हुई।
- जिला स्तरीय अतिसंवेदनशीलता मूल्यांकन में, जहाँ अतिसंवेदनशीलता को अनावरण, सूक्ष्मग्राहिता एवं अनुकूली क्षमता के कार्य के रूप में लिया गया, यह देखा गया कि अधिकांश हिंद-गंगा मैदानों के पश्चिमी भाग के जिलों एवं दक्षिणी राज्य अनुकूली क्षमता के मामले में सापेक्ष रूप से बेहतर थे। देश के पूर्वी एवं मध्य भागों के अधिकतर जिलों में अनुकूली क्षमता का स्तर कम था।
- विभिन्न पादप रोगजनक कवकों की तुलना में ट्राइकोड़ेरमा विरिड़े की जैव-नियंत्रण क्षमता को जब 100 पीढ़ियों के लिए उत्थित CO_2 के संपर्क में लाया गया तो जैवनियंत्रण क्षमता में कोई महत्वपूर्ण परिवर्तन नहीं देखा गया।
- एम.ओ.डी.आई.एस. द्वारा प्राप्त एन.डी.वी.आई. टाइम श्रंखला डेटा विश्लेषण ने स्पष्ट किया कि कर्नाटक एवं आंध्रप्रदेश के अलावा राजस्थान, गुजरात, मराठवाड़ा एवं महाराष्ट्र के विदर्भा क्षेत्रों के शुष्क, अर्ध-शुष्क, एवं शुष्क उप-आर्द्र के 81.3 मिलियन हेक्टेयर में जहां व्यापक रूप से वर्षा आधारित कृषि की जाती है वे जलवायु परिवर्तन एवं प्रतिकूल मौसम घटनाओं के शिकार हो सकते हैं।
- दो टन प्रति हेक्टेयर की दर से ग्लिरिसिड़िया कर्तनों का प्रयोग एवं 90 किलाग्राम प्रति हेक्टेयर की दर से नाइट्रोजन उर्वरकों के प्रयोग सहित न्यूनतम कर्षण अपनाने से मृदा में अरिलसल्फटेस(**arylsulphatase**), यूरेस(**urease**) एवं डेहाइड्रोजेनेस(**dehydrogenase**) इंजाइमों की गतिविधि सकारात्मक रूप से प्रभावित हुई। यह उपचार संयोग मृदा में सूक्ष्मजीवीय बायोमॉस कार्बन एवं अस्थिर कार्बन पूलों को महत्वपूर्ण रूप से बेहतर बनाने में भी बहुत प्रभावी था।
- शुष्क दौर के दौरान फसल प्रबंधन के लिए कृषि तालाबों से सिंचित वर्षाजल के प्रभावी उपयोग पर किए गए अध्ययन से स्पष्ट हुआ कि मूंगफली एवं मक्का फसल उत्पादन में करीब 67 प्रतिशत की वृद्धि हुई। क्रांतिक स्तर पर 59 मि.मी. अतिरिक्त सिंचाई से मक्का के मामले में जल उत्पादकता की वद्धि 5.82 से 9.4 किलोग्राम प्रति हेक्टेयर प्रति मि.मी. हो गई। अतिरिक्त सिंचाई से वर्षा आधारित मूंगफली में यह वृद्धि 3.13 से 5.09 किलोग्राम प्रति हेक्टेयर प्रति मि.मी. हो गई।
- मृदा कार्बन पृथक्करण(**sequestering**) में जड़ों की भूमिका पर किए जा रहे अध्ययनों ने स्पष्ट किया कि कुल पादप बायोमॉस का करीब एक चौथाई हिस्सा ज्वार एवं मूंग की जड़ों ने संग्रहित किया। दोनों फसलों में, तनों की तुलना में जड़ों की कोशिकों की झिल्ली की मात्रा एवं यथेष्ट रूप से बेहतर लिगनिन सांद्रता पाई गई।
- बाजरा से निकाले गए डी.आर.ई.बी.2ए, जी.आर.पी7 एवं ओ.सी.पी3 आंशिक **cDNAs** के पी.सी.आर. एमप्लीफिकेशन एवं क्रम विश्लेषण द्वारा डेटाबेस से उपलब्ध आंकड़ों से समजातता पाई गई। तत्पश्चात डी.आर.ई.बी.2ए के आंशिक क्रम को आगमन संख्या जे.एन.627404 सहित डेटा बैंक में जमा कर दिया गया।
- मक्का जिनोम के लिए डब्ल्यु.आर.के.वाई. प्रोटीनों का विस्तृत वर्गीकरण किया गया। समजातता इंटरफेस संबंधों के मैट्रिक्स से प्रोटीन डेटा बैंक एवं डी.एन.ए. डॉकिंग से टेमप्लेटों का उपयोग कर समजातजा मॉडलिंग तैयार की गई।
- जलवायु के दबावों से सहीष्णुता के लिए मक्का के समलक्षणों ने स्पष्ट किया कि खरीफ में, दबाव के कारण पुष्पण में 1 से 2 दिनों की देरी हुई, जबकि रबी में यह अंतराल बढ़कर 15 दिनों तक चला गया। पादप वृद्धि, बायोमॉस, बीज उत्पादन एवं बीज भार में क्रमशः 4.3,12.1, 14.8 एवं 11.4 प्रतिशत की कमी आई। इस वर्ष के दौरान पहचाने गए बारह जीनरूपों पर आगे विस्तृत अध्ययन किया जाएगा।
- ताप दबाव परिस्थितियों के अंतर्गत विभिन्न पादप क्रियात्मक एवं जैवरसायनिक के संबंध में मक्का जीनरूपों की जननिक विविधता का अध्ययन किया गया। इस अध्ययन में जीनरूपों ने टस्सेलिंग एनथेसिस एवं सिल्किंग में स्पष्ट भिन्नता दर्शाई। इसके अतिरिक्त अन्य घटकों जैसेकि एसकोरबेट,

मलोनड़ियलडेहाइड़, फेनोल्स एवं मुफ्त अमिनो अम्लों की कमी पाई गई। अनुसंधान में यह भी ज्ञात हुआ कि सहीष्णु दल की तुलना में उच्च तापमान ग्राहयता में `ग्लूकोस', `फ्रुक्टोस' एवं `स्टाच' में वृद्धि हुई।

- अतिथि-शाकाहारी संबंधों पर उत्थित CO_2 के मेटा विश्लेषण के प्रभाव ने स्पष्ट किया कि उत्थित CO_2 के अंतर्गत कीट प्रजातियों का खाद्यान्न उपभोग एवं अवधि महत्वपूर्ण रूप से बेहतर एवं सकारात्मक थी। उत्थित CO_2 के अंतर्गत अन्य प्राचलों जैसेकि जनसंख्या की अधिकता, प्रजातियों के भार एवं कीटों के निष्पादन सूचकों में महत्वपूर्ण रूप से भिन्नता थी।
- पर्ण नमी सूचक पर आधारित वायरलेस सेंसर नेटवर्क प्रसारित कवकनाशी छिड़काव सलाह ने स्थापित किया कि बोवाई के 90 दिनों के बाद मूंगफली में देर से आने वाले पर्ण चित्ती रोग का जब आरंभ हुआ तब पर्ण की नमी सीमा $\geq$2.3 थी। वर्षा अनुरूपक अध्ययनों ने जनसंख्या निर्माण पर उच्च-सघनता की वर्षा के प्रतिकूल प्रभावों को दर्शाते हुए, यह स्पष्ट किया कि 40, 60 एवं 80 मि.मी. वर्षा की घटनाओं की वृद्धि से पॉलिफगस कीट, स्पोड़ेप्टो लिटुरा (43 प्रतिशत तक) के मॉथ निकलने में महत्वपूर्ण रूप से कमी आई।
- अनंतपूर जिले में जुलाई के द्वितीय पक्ष एवं सितंबर के प्रथम पक्ष के दौरान हुए आंतरायिक सूखे मूंगफली पर्ण सुरंगी की तेजी से वृद्धि एवं प्रसार के अनुकूल थे। आई.आर.एस. पी6 एल.आई.एस.एस. के वर्गीकृत उपग्रह दृश्य ने नाशीजीव संदूषण के आकाशीय विस्तार एवं पांच मंड़लों में नाशीजीव के विस्तार को दर्शाया।
- आठ घंटों के सौर विकिरण से रूमेन के पेट में सूक्ष्मजीविता की संख्या पर महत्वपूर्ण रूप से नकारात्मक प्रभाव पड़ा जिसके परिणामस्वरूप दक्कनी भेड़ों में कम पाचनशक्ति एवं भार में कम वृद्धि देखी गई। विवो(*In vivo*) अध्ययन ने स्पष्ट किया कि पशुओं को अतिरिक्त एज़ोला खिलाने से एनटरिक मिथेन उत्सर्जन में महत्वपूर्ण कमी आई।
- राष्ट्रीय कृषि जलवायु समुत्थान कृषि पहल के प्रौद्योगिकी अवयव को आठ क्षेत्रीय परियोजना निदेशालयों में 100 कृषि विज्ञान केंद्रों में कार्यान्वित किया गया जो जलवायु विविधता में चार अवयवों जैसेकि प्राकृतिक संसाधन प्रबंधन, फसल उत्पादन, पशुपालन एवं मछली पालन तथा संस्थागत हस्तक्षेपों का समाधान कर रहा है। प्रारंभ में किसानों का पुनर्निवेशन उत्साहवर्धक रहा, जैसेकि प्राकृतिक संसाधन प्रबंधन हस्तक्षेपों के परिणामस्वरूप जल उपलब्धता में महत्वपूर्ण सुधार हुआ एवं जिससे उत्पादकता में वृद्धि हुई। इसी प्रकार, जलवायु विविधता चुनौतियों से किसानों को जूझने में सहायता करने के लिए उपलब्ध प्रौद्योगिकियों के प्रदर्शन के प्रयास किए जा रहे हैं।

कृषि विज्ञान केंद्र

- वर्ष के दौरान, ज्वार, मक्का, कपास, अरहर, चना, चावल, टमाटर एवं चारा फसलों की बेहतर प्रक्रियाओं पर आंध्र प्रदेश के रंगा रेड्डी जिले में कुल 212 अग्रगामी प्रदर्शनों का आयोजन किया गया। कृषि विज्ञान केंद्र द्वारा फसल एवं पशुधन उत्पादन के विभिन्न पहलुओं का समावेश करते हुए करीब 3221 किसानों के लिए 101 आवश्यकता आधारित एवं कौशलोन्मुख प्रशिक्षण कार्यक्रमों का भी आयोजन किया गया। प्रौद्योगिकी मूल्यांकन एवं परिष्करण के अंतर्गत, कृषि विज्ञान केंद्रों द्वारा अपनाए गए गांवों के किसानों के खेतों में किस्मों, फसल प्रबंधन, कृषि यांत्रिकीकरण, पशुधन प्रबंधन एवं पशुधन प्रजनन से संबंधित 10 प्रौद्योगिकियों को कृषि विज्ञान केंद्रों द्वारा मूल्यांकित किया गया। कृषि विज्ञान केंद्र द्वारा कई प्रसार गतिविधियों एवं प्रौद्योगिकी सप्ताह, क्षेत्रीय दिवसों(**field days**) एवं पशु चिकित्सा कैंपों का भी आयोजन किया गया।

मानव संसाधन विकास

- वर्ष के दौरान कई वैज्ञानिकों ने देश के भीतर एवं बाहर दोनों में प्रशिक्षण प्राप्त किए। संस्थान में कई स्नातक एवं स्नातकोत्तर विद्यार्थियों ने अपनी परियोजनाओं/अनुसंधान कार्यों को पूरा किया।

पुरस्कार एवं मान्यताएं

- क्रीड़ा-आईकिसान के प्रयासों से स्थापित सूचना एवं संचार प्रौद्योगिकी नॉलेड्ज शेर सेंटरों (संधारणीय ग्रामीण रोज़गारों पर राष्ट्रीय कृषि नवोन्मेषी परियोजना की उप परियोजना के रूप में) के लिए दिनांक 1-3 अगस्त, 2011 को नई दिल्ली में आयोजित ई-वर्लड़ सम्मेलन में आंध्र प्रदेश को श्रेष्ठ सिटिजेंस चॉइस पुरस्कार दिया गया। संस्थान के कई वैज्ञानिकों ने अपने कार्यों के लिए व्यक्तिगत पुरस्कार एवं मान्यताएं प्राप्त की। कई वैज्ञानिक भा.कृ.अनु.प. के बाहर प्रमुख संगठनों के कार्यकर्ता चुने गए।

संपर्क एवं सहयोग

- संस्थान पणधारियों एवं संगठनों से नए संपर्क एवं सहयोगों को बनाए हुए है जबकि अपने तकनीकी कार्यक्रमों को और अधिक प्रभावी रूप से कार्यान्वित करने के लिए पुराने संपर्कों को नवीकरण एवं मजबूती प्रदान कर रहा है।

प्रकाशन

- अभिजात समीक्षा पत्रिकाओं में संस्थान के वैज्ञानिकों के 75 लेख प्रकाशित हो चुके हैं। भारी संख्या में पुस्तकें, बुलेटिने एवं पुस्तकों के अध्याय भी प्रकाशित हुए हैं।

Executive Summary

Resource characterization

- Agromet advisories are being piloted at block level from the currently available district level. The real-time weather data collected at KVKs is helping in fine tuning the forecasts obtained from IMD and improving the agromet advisory services based on ground level information. This information can be used in crop management like day to day field operations, enhancing farmer's capability for climate resilient agriculture.
- Analysis of changes in seasonal rainfall over the country during El Nino years for four seasons viz, summer (March to May), monsoon (June to September) post monsoon (October to December) and winter (January to February) indicated seasonal rainfall shifts during El Nino events. Excepting a few regions, summer and post monsoon rainfall increased during El Nino events and winter and monsoon rainfall decreased.
- Temperature sensitive phenological stages influencing grain yield in three varieties - HD-2285, K-8804 and K-9107 of wheat were identified. The maximum and minimum temperature during all the stages from tillering to jointing (P_4) to dough to maturity (P8) significantly and adversely influenced the grain yield of all three varieties of wheat. The milking stage emerged as the most sensitive phenological stage for thermal stress (both maximum and minimum temperature) followed closely by dough and anthesis stages. The temperature and yield relations revealed that increase in minimum temperature by 1^0 C during milking stage caused higher reduction in yield than increase in maximum temperature.
- District database on various climate and agricultural variables was updated to latest years. Climatic parameters like rainfall, number of rainy days, drought, maximum temperature, minimum temperature, etc. were also included in the database. Demographic, natural resource management and socio-economic parameters like population density, ground water availability, degraded and wastelands, poverty, literacy, size of holding, % SC & ST population, % of workforce engaged in agriculture were also included in the database. State database covering various agricultural statistics was developed with latest 10 years.
- The effect of temperature and rainfall on the productivity of two important crops – pigeonpea and cotton in Andhra Pradesh was evaluated using panel regression approach. The models fitted for pigeonpea and cotton were found to explain 52 and 57 per cent of variation respectively. In case of pigeonpea, a ten millimetre increase in the rainfall was found to increase yield by about 1.9 kg. Increase in the number of rainy days was found to have a significant negative relationship with yield, which can probably be attributed to the occurrence of rainfall during flowering stage. In case of cotton, maximum temperature was found to cause a significant reduction (at a rate of 77 kg for one degree rise) in yield. The yield was found to increase by 4.1 kg for every 10 mm increase in the rainfall.
- Productivities of important rainfed crops under irrigated and rainfed conditions at national level were estimated with the help of statistical techniques. The district level secondary data on crop-wise area sown, production and irrigated area were used as input. Yields under irrigated conditions were about three times the rainfed yields in rice, sorghum and cotton. In case of maize, chick pea, pigeon pea and groundnut, productivities under rainfed conditions were half of the yields of irrigated

crops. Pearl millet responded very well to irrigation with nearly 4 times yield under irrigated conditions over rainfed conditions.

- Surface water balance estimations were done using a simple two layer water balance model for different land uses within hydrological units of Anantpaur and Prakasam districts of AP considering with and without watershed scenarios. Input parameters such as ET were estimated from IMD grid data. Ten years rainfall data (2000-2010) was used for estimation purpose.
- Climate variability assessment (point data of 25 to 35 years) in respect of rainfall was done for northern dry zone of Karnataka (comprising Bijapur, Bagalkote, Belgaum, Gadag, Dawangere and Raichur districts only) using *weathercock* software and other statistical tools. The results indicated that the normal annual rainfall ranges from 589.32 mm (Bagalkote) to 1276.7 mm (Belgaum) of which more than 50 per cent of the years there was deficit with deviation ranging up to - 63.4% in these districts. Deviations in start and end week of the onset of monsoon both for south-west and north east monsoon are now observed to be impacting the sowing windows of both *kharif* and *rabi* crops, sometimes leading to increase in fallows in *kharif* and shift to alternate crops.

Climate change

- The effect of elevated CO_2 on 18 black gram genotypes was studied. Genotypes differed significantly for all the selected traits except shelling %. Accessions V5 and V9 were identified as superior based on the ranks of observed data and WEI Values. V9 was superior for dry weight, while V5 was superior for yield traits at elevated CO_2 levels.
- Elevated CO_2 had no significant effect on nitrate reductase and glutamine synthetase activity but the total biomass and seed yield of pearl millet increased marginally compared to that under ambient conditions.
- The intrinsic rate of increase of *Achaea janata* on castor was estimated under ambient and elevated CO_2 conditions. Specific effects of elevated CO_2 on castor semilooper were longer generation time, decreased intrinsic rate of increase and less fecund adults.
- Elevated CO_2 levels resulted in higher castor foliage consumption by *Spilosoma obliqua* and higher larval weight compared to ambient conditions. However, the relative growth rate of larvae decreased significantly when fed on castor foliage grown under elevated CO_2.
- Common perceptions of climate variability across regions in A.P. are rise in temperatures, decrease in precipitation and incidence of pests and diseases of crops. Common adaptation measures towards climate variability across the regions are insurance, change in planting dates and work as migrant labour. The mean adaptation index value for floods was greater than that for droughts.

Rainwater Management

- Economic analysis of farm ponds considering 12% discount rate and 20 years of life period indicated the production system groundnut + carrot + fish + environmental benefits was the best for Alfisols under farm pond of capacity 1750 m^3 with 14.5 ha catchment area.
- An existing ridge and furrow making equipment was modified to create wider (60 cm) and deeper (25 cm) conservation furrows. The threshold rainfall for causing runoff increased with conservation furrows, thus reducing runoff from the field. The yields of castor and pigeonpea were considerably higher with paired row planting with ridger over normal planting.
- In order to reduce the total setup cost and minimize the maintenance, the solar powered pump was redesigned and developed by converting it into DC operated. In this way the setup cost was reduced by 25%. The newly developed pump has discharge capacity of 700 litre per house with suction and delivery head of 1.0 m and 2.5 meter respectively.
- A DSS model for real time water balance was developed and tested for the 50th meteorological week of 2011. Daily climatic data of the concerned week for 320 locations were collected from IMD-AWS data portal. Two separate databases were created for potential evapotranspiration as well as for rainfall. Both databases were further interpolated to 2 km X 2 km grid and overlaid. The resultant database of water balance (surplus or deficit) was thus deduced and arranged in such a way that it

could be retrieved using latitude and longitude of the location under interest. The DSS model was tested at 20 locations. Agreement between observed and DSS estimated values was fairly good. The graphic user interface (GUI) was also developed to facilitate quick retrieval of information.

- Evaluation of treated micro-watersheds in AESR 7.3 region indicated that <20% land within treated watersheds was found to be sustainable.
- The economic viability of farm ponds in terms of net present value (NPV) and benefit cost ratio (BC ratio) was calculated for 100 ponds assuming that the present returns would occur every year for a period of 15 years. It was observed that 33 out of 100 ponds gave an NPV of less than Rs. 30000. Interestingly, four ponds recorded an NPV in excess of Rs. two lakhs, and investment in 15 ponds was found to be unviable with a negative NPV. Average size of the plot and pond were much higher in case of the most profitable ponds.

Crops and cropping systems

- Three promising horsegram lines from CRIDA in the third year of multilocation trials are performing well in terms of grain yield and resistance to pests and diseases compared to check.
- Six lines of mtlD transgenic sorghum were tested for stress tolerance under controlled conditions. These lines were found superior to untransformed plants in terms of key physiological parameters.
- The gene construct containing DHNpCAMBIA1303 was transformed into *Agrobacterium tumefaciens* strain LBA4404. The transformed culture was used for the validation of dehydrin gene by expressing it in tobacco plants through *Agrobacterium* mediated genetic transformation. PCR and RT-PCR analysis confirmed the successful transformation of dehydrin gene in tobacco plants.
- Two high quality subtractive cDNA libraries (water-deficit and high temperature stress-induced) were constructed from 24 h stressed pearl millet seedlings. Among the sequences analyzed, 6 genes were identified to be commonly induced in both the libraries, while 104 and 102 genes were specifically induced in water-deficit and high temperature stresses, respectively.
- Studies on root growth in green gram cultivars (ML267 and WGG37) showed distribution of more root length to 10-20 cm soil depth with ML267 in comparison with the maximum root length at top 5-15 cm soil depth in case of WGG37, resulting in better drought tolerance ability of ML267.
- Studies on organic crop production showed that the yield reduction during the second year under organic management was 13.1% in sunflower, 4.7% in pigeon pea and 15.4% in sesame.
- Hyperspectral radiometry was used to characterize the reflectance spectra of cotton and black gram canopies under stress due to pest and disease infestation. Mealy bug stress indices were developed which have the potential to assess the mealy bug severity in cotton. Similarly, YMD disease prediction models were built to assess the mosaic severity in black gram.
- Two bacterial consortia (P7+B30+G12 and P45+B17+G12) were tested in lab and field conditions for drought and heat stress management. Use of recommended NPK with consortium inoculation improved plant growth and yield of sorghum and sunflower under rainfed conditions.
- Studies on survival and persistence of stress tolerant PGPR strains in the rhizosphere of dryland crops showed that there was efficient colonization by inoculated strains (Rifampicin resistant mutants of two *Bacillus* sp. strains, viz. B30 and B17, and two *Pseudomonas* sp. viz. P7, and P45) in sunflower and sorghum.
- Among different plant growth promoting strains, *Bacillus* B73 (previously identified as promising under pot culture) treated plants yielded 2570 kg/ha of sorghum grain yield, followed by mixed inoculation of B87+P33 (a zinc solubilizer) (2530 kg/ha) whereas in uninoculated control, the yield was 2182 kg/ha.
- Studies on integrated farming system modules showed that vegetable cultivation with harvested rainwater, bajra + pigeonpea intercropping, and feeding of Nellore breed sheep with farm generated feed and fodder provided economic stability to the system during the low rainfall year.

Soil health and nutrient management

- After 13 years of experimentation on tillage and nutrient management, conventional tillage maintained 5.7% and 7.9 % higher yield of sorghum and mung bean respectively over reduced tillage. Among nutrient management treatments, conjunctive application of compost and urea performed better and recorded significantly higher sorghum and mung bean yields as well as agronomic efficiency under both conventional and reduced tillage.
- After seven years of study, application of sorghum stover @ 4 t ha^{-1} in combination with N @ 60 kg N ha^{-1} recorded significantly higher sorghum grain yield compared to residue application @ 6 t ha^{-1} in combination with N @ 60 kg ha^{-1}. The percent increase in grain yields with residue application @ 2, 4 and 6 t ha^{-1} was to the tune of 21.1, 31.0 and 23.0 % respectively over the control (no residue application).
- In a long term experiment on tillage, nirtogen and residue application in operation since 1995, conventional tillage maintained slightly higher sorghum yields compared to minimum tillage. Among the residues, application of Gliricidia loppings resulted in higher sorghum grain yields, which was at par with application of sorghum stover. Application of nitrogen @ 60 kg ha^{-1} recorded significantly higher yields followed by N applied @ 90 kg ha^{-1}.
- In a permanent manurial experiment at Bangalore centre of AICRPDA, the key soil quality indicators for long term use of organics and fertilizers under Groundnut - Fingermillet cropping system in FYM series in Alfisols were EC, available N, available K, available S, available Zn, available Fe, available B, MBC, MWD and bulk density, and in maize residue series, the key indicators were soil pH, EC, organic carbon, available S, MWD and labile carbon. In a tillage experiment, the key soil quality indicators were pH, available N, available P, available K, available Ca and labile carbon.
- Results of field experiment conducted at Arija revealed that inoculation of maize seeds with P33 and P29 strains *of Pseudomonas* increased the yield of maize as compared to control (no inoculation). Highest grain yield of a maize was recorded in plots receiving 25 kg ha^{-1} of zinc sulphate followed by inoculation of maize seeds with P29 and P33. At Hyderabad, grain yield of maize was highest in treatment receiving 25 kg ha^{-1} of zinc sulphate as compared to other treatments.
- Ananlysis of soil under long term tillage experiment revealed that total carbon content increased in low tillage and organic matter application treatments. Highest very labile carbon was observed in conventional tillage without off season tillage, followed by low tillage with compost. Increase in organic carbon and other labile carbon pools in comparison to the initial was evident in low tillage and compost application treatments. Yield advantages were also seen in soybean system from low tillage and compost application.
- Highest grain yield of pigeonpea was recorded under alternate year application of cotton stalk biochar @ 3 t/ha supplemented with RDF. Application of castor stalk biochar at 4 t/ha in combination with RDF + FYM (5 t/ha) recorded maximum grain yield in maize.
- Fuel consumption and energy spent was lowest in zero tillage (ZT) as compared to conventional (CT) and reduced tillage (RT). Zero tillage recorded 73 and 69 percent lower CO_2 emission as compared to CT and RT respectively during land preparation and sowing. Zero tillage and RT recorded significantly lower runoff than CT. Besides reducing run off, zero tillage significantly lowered soil loss as compared to conventional and reduced tillage. Increase in harvesting height to 30 cm increased the residue return to soil by 60 and 20 percent as compared to 0 cm and 10 cm respectively.
- Although pigeon pea yields were higher with CT compared to RT and ZT, the difference in yields between different tillage systems narrowed down as compared to 1st and 2nd years. 10 cm harvesting height recorded significantly higher yield as compared to 0 and 30 cm respectively.
- Paired row planting recorded significantly higher castor equivalent yield and residue yield compared to normal planting. Among the different resource conservation practices, castor intercropped with

muccina recorded highest castor equivalent yield as well as residue yield.

- In the first year of experiment, there were no significant differences in conservation and conventional tillage treatments on maize growth, yield attributing characters, seed and stover yield. Significantly higher grain and stover yield of 4.7 t ha^{-1} and 7.9 t ha^{-1} respectively was obtained with the balanced use of NPKSZnB followed by B omission and S omission.
- In a 20-year long term experiment on an Alfisol in Southern India, the concentration of SOC to 1 m depth increased from 2.3 to 3.5 g kg^{-1} in 50% recommended dose of fertilizer (RDF) + 4 Mg ha^{-1} groundnut shells, to 3.4 g kg^{-1} in 50% RDF+4 Mg ha^{-1} farmyard manure (FYM) and to 2.6 g kg^{-1} in 100% RDF. The mean rate of SOC sequestration (Mg C ha^{-1} yr^{-1}) for these treatments was 0.57, 0.51, 0.02, respectively. Higher mean pod yield of groundnut (Mg ha^{-1}) was obtained with 50% RDF+4 Mg ha^{-1} FYM. The rate of increase in groundnut yield was 13 kg ha^{-1} for every one Mg increase in SOC stock to 1 m depth. A minimum of 1.12 Mg C ha^{-1} yr^{-1} input was needed to maintain the zero change in SOC.
- In a 21-year field experiment conducted under sub-humid tropical conditions in India, application of farmyard manure (FYM) without and with mineral fertilizers increased C input and SOC concentration and stock. In comparison with the control, the 100% organic (FYM) treatment had significantly higher profile SOC, more C build up and C sequestration to 1 m depth vis-à-vis the antecedent values of 1986. For every Mg increase in SOC stock in the root zone there was 0.16 Mg $ha^{-1}yr^{-1}$ and 0.18 Mg $ha^{-1}yr^{-1}$ yield increase of rice and lentil, respectively. For maintaining a stable SOC level (zero change due to cropping), a minimum quantity of 2.47 Mg C ha^{-1} yr^{-1} is required for this soil, climate, cropping system, and fertilization treatments.

Land use diversification

- Integrated nutrient management in guava involving application of 30 kg FYM + recommended fertilizers gave higher number of secondaries and tertiaries resulting in more number of fruits and fruit yield compared to other treatments. In another trial, microbial inoculation of VAM or PSB or ZSB or K mobilizers along with higher doses of FYM was found to be effective in early flush growth, flowering and fruit set in sweet orange. Higher doses of FYM along with *Trichoderma* or PSB or *Azospirillum* also helped in promotion of early flowering and fruit set in guava and custard apple.
- Custard apple and guava performed better under organic management in terms of both yield and quality of fruits (less seed weight and higher pulp in custard apple; higher total soluble sugars and less acidity in guava).
- The major pests and diseases of jatropha were identified and control measures standardized, except for stem borer. The highest seed yield (0.2 t/ha) of jatropha was obtained with combination of irrigation (20 days interval), 3x2 m spacing and fertilizer application (N90 + P200 g/plant).
- Major pests and diseases of pongamia and their control measures were identified. Kernel yield of pongamia during 6^{th} year ranged from 0.3 to 2.2 kg/plant in grafts compared to 0.069 to 1.73 kg/plant in seedling originated plants.
- Studies on changes in land use in selected districts of AP over a period of 10 years showed that there was an increase in area under fallow in Adilabad and Nalgonda but no change was observed in Warangal. In all the three districts, there was decline in vegetative cover based on NDVI with an exception of few villages with horticulture as predominant land use.

Livestock management

- Supplementation of either horsegram or *azolla* meal on equi-energy and nitrogen basis resulted in significantly higher weight gain in sheep compared to concentrate mixture, indicating the necessity of supplementation in small ruminants under grazing conditions.
- Supplementation of different concentrates (horse gram meal, groundnut cake, soya meal, azolla meal and stylo meal) with coarse crop residues helped in reduction of anthropogenic emission (cumulative gas production) in rumen of livestock.

Energy management

- The low till – horizontal plate planter was tested for its performance and metering plates were redesigned and calibrated for accuracy. Under field conditions, the planted seed rate was more or less equal both in conventional tillage and low till plots. Low till plots with partial residue incorporation recorded slightly higher moisture in the 0-15 cm soil layer throughout crop (maize) growth period. The lowest dry weed biomass of 109 kg ha^{-1} was recorded in the conventional tillage plots.
- Nylon pump was modified and tested. In prototype-2, impellor shaft was enforced with stainless steel bush to minimize wear loss. In addition, dimension of the impellor was changed in view of increasing flow rate. The diameter of the impellor was increased from 110 mm to 120 mm and vane width was increased from 10 mm to 15 mm. Comparative tests of refined and existing pump were conducted. The pump was operated for 8 hrs for different periods and no material wear was found in any components of refined model of pump.

Socio economic studies and transfer of technology

- The results of a survey of 60 respondents from 12 villages of Chevella mandal indicated that majority of the farmers are in 'medium' level of farm productivity for different crops viz., maize, cotton, kharif rice, tomato, carrot and beetroot cultivated by them during last three years (2006 to 2008).
- The nutritional status of women of Farooqnagar mandal who consumed millets in their daily diets, showed that 87% of rural women population studied were in normal nutritional status. Only 9 and 4 percent of women were found to be in I grade and III grade of malnutrition respectively whereas in Balapur mandal, 90 percent of rural women were found to be in normal nutritional status and 5 percent each in I grade and III grade of malnutrition. This malnutrition can be attributed to calorie insufficiency in the rural women population.
- Analysis done on the utility of ICT tools and services placed in the knowledge share centres (KSCs) revealed that majority of the farmers (73%) preferred the extension services of *Sasyavani* - mobile based agro advisories followed by Internet. Correlation analysis indicated that variables like inaccessibility, frequent repairs and maintenance showed significant negative correlation whereas capacity building of the farmers in using ICT tools showed significant positive relation with the overall performance of the clusters where the KSCs were installed.

NAIP

- Analysis of technological and institutional options for enhancing productivity of rainfed farming in Adilabad, Mahbubnagar and Rangareddy districts of A.P. revealed that for a small farmer under the existing technology when the resources were optimally allocated, soybean + redgram replaced cotton + redgram. There was 18 per cent increase in the net returns of the farmer when proper technology was used. The same when credit is a constraint, there is reduction in net returns by 20.8 per cent.
- In a five year comprehensive study of planning and implementation of livelihood supporting interventions by a consortium of ten organizations with CRIDA as the lead centre, rainwater harvesting through site specific NRM activities, promotion of better crops and cropping systems, integration of livestock into cropping, horticulture and post harvest value addition, small farm mechanization and capacity building proved to secure the livelihoods of the poor in eight backward districts (Adilabad, Anantapur, Kadapa, Khammam, Mahabubnagar, Nalgonda, Rangareddy and Warangal) of Andhra Pradesh.
- A 6 row planter developed for sowing sweet sorghum was tested on 30 acres at Ibrahimbad cluster, Medak district, A.P. Self propelled harvester was refined to cut stems of higher girth. Three pass 6 roller crusher was improved to accommodate more stems during the crushing for energy reduction and increased juice recovery.
- Following a grid based approach, interventions related to energy efficiency and integrating trees into the existing landscape were implemented in a cluster. The baseline carbon stocks and the carbon stocks in the project scenario were quantified. The grid has been expanded by including two more villages in addition to the Jaffergudem village in Warangal district.

- Developmental duration, temperature thresholds and thermal constants were determined for life stages of solenopsis mealybug on cotton. Different modules for decision support system of pest viz., web enabled decision support tools for agro-climatic analysis, construction of stage-specific mortality and age-specific fecundity life tables, degree-day calculator and population trend index calculator were developed.
- Whole genome sequences of P43 (salinity tolerant) and P8 (salinity and temperature tolerant) strains of biocontrol agent, *Pseudomonas* were completed and the sequences were annotated to identify functional genes imparting abiotic stress tolerance.

NICRA

- Basal application of recommended dose of fertilizers followed by foliar application of potassium, zinc and selenium at 25 DAS resulted in significant increase in grain yield of maize.
- In a district level vulnerability assessment, wherein vulnerability is taken as a function of exposure, sensitivity and adaptive capacity, it was observed that majority of districts in the western part of Indo-Gangetic plains and the southern states are relatively better placed in terms of adaptive capacity. Most of the districts with low levels of adaptive capacity are in the eastern and central parts of the country.
- Bio-control ability of *Trichoderma viride* against different plant pathogenic fungi when exposed to elevated CO_2 for 100 generations showed no significant change.
- MODIS derived NDVI time series data analysis showed that over 81.3 million ha in arid, semi-arid and dry sub-humid regions in Rajasthan, Gujarat, Marathwada and Vidharbha regions of Maharashtra in addition to Karnataka and Andhra Pradesh where rainfed agriculture is widely practiced could be vulnerable to climate change and extreme weather events. Over 12.1 million ha of kharif and 6.86 million ha of rabi cropland would be highly vulnerable to climate change.
- Practicing minimum tillage in combination with application of Gliricidia loppings @ 2t/ha and application of fertilizer N @ 90 kg/ha positively influenced the activity of arylsulphatase, urease and dehydrogenase enzymes in soil. This treatment combination was also very effective in significantly improving the microbial biomass carbon and labile carbon pools in the soil.
- In a study on potential use of rainwater harvested through farm ponds for crop management during dry spells it was observed that there was about 67% increase in crop yield of groundnut and maize. The water productivity increased from 5.82 to 9.4 kg/ha mm in case of maize with supplemental irrigation of 59 mm at critical stages. In groundnut it increased from 3.13 in rainfed to 5.09 kg/ha mm with supplemental irrigation.
- Studies on the role of roots in sequestering soil carbon indicated that in sorghum and green gram roots accounted for about $1/4^{th}$ of total plant biomass. In both the crops, roots had more cell wall fraction and considerably higher lignin concentration than shoots.
- PCR amplification and sequence analysis of DREB2A, GRP7 and OCP3 partial cDNA's obtained from pearl millet revealed homology with the sequences available in the database and the partial sequence of DREB2A was deposited in the gene bank with the accession number JN627404.
- A detailed classification of the WRKY proteins was done for the maize genome. Homology modelling was done using templates from protein data bank and DNA docking with a matrix of homologous interface contacts.
- Phenotyping of maize for tolerance to climatic stresses showed that in kharif, flowering got delayed by 1 to 2 days under stress, whereas in rabi the interval increased up to 15 days. Plant height, biomass, seed yield and seed weight decreased by 4.3, 12.1, 14.8 and 11.4%, respectively. Twelve genotypes identified during this year would be considered for further detailed study.
- Genetic diversity of maize genotypes in relation to various physiological and biochemical traits under heat stress conditions showed variations in tasselling, anthesis and silking intervals across the genotypes; Ascorbate, malondialdehyde, phenols and free amino acids declined, while glucose,

fructose and starch increased in the high temperature susceptible group as compared to the tolerant group.

- Meta analysis of impact of elevated CO2 on host – herbivore interactions indicated that food consumption and duration of insect species were significantly higher and positive under elevated CO_2. The other parameters viz., population abundance, weight of species and insect performance indices varied significantly under eCO_2.
- Wireless sensor network disseminated fungicide spray advisory based on leaf wetness index (LWI) established that late leaf spot disease initiation in groundnut was noticed 90 days after sowing when wetness threshold of leaf = 2.3. Rainfall simulator studies showed a significant decrease in moth emergence of the polyphagous pest, *Spodoptera litura* (up to 43%) with increase in rainfall events at 40, 60 and 80 mm indicating adverse effect of high intensity rainfall on population build-up.
- Intermittent droughts during second fortnight of July and first fortnight of September favoured rapid multiplication and spread of groundnut leaf miner in Anantapur district. The classified satellite image of IRS P6 LISS-III showed spatial spread of the pest infestation and provided the extent of pest damage in five mandals.
- Exposure to solar radiation for eight hours had significant negative effect on multiplication of microbiota in rumen and thus resulted in low digestibility and weight gain in Deccani rams. *In vivo* studies showed that supplementation of *Azolla* meal substantially reduced enteric methane emission from livestock.
- The technology demonstration component of NICRA implemented in 100 KVKs distributed among eight zonal project directorates (ZPDs) is addressing climate variability in four components viz. natural resource management, crop production, livestock and fisheries and institutional interventions. The initial feedback from the farmers has been encouraging, as natural resource management interventions have made significant improvements in water availability and have enhanced the productivity. Similarly, efforts are on to demonstrate available technologies to help farmers cope with climate variability challenges.

Krishi Vigyan Kendra

- During the year, a total of 212 front line demonstrations were conducted in Rangareddy district of A.P. on improved practices of sorghum, maize, cotton, pigeonpea, chickpea, rice, tomato and fodder crops. The KVK also organised 101 need based and skill oriented training programs to about 3221 farmers covering different aspects of crop and livestock production. Under technology assessment and refinement, the KVK assessed 10 technologies related to varieties, crop management, farm mechanization, livestock management and livestock breeding in farmers fields of KVK adopted villages. The KVK also carried out several extension activities and organised technology week, field days and animal health camps.

Human resource development

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

Awards and recognition

- CRIDA-IKISAN led initiative of setting up ICT enabled Knowledge Share Centers (as part of NAIP sub project on Sustainable Rural Livelihoods) A.P. won the **Best Citizen's Choice Award** at the e-World Conference held in New Delhi on 1-3 August, 2011**.** Several Scientists of CRIDA received individual awards and recognition for their work. Several Scientists were chosen as functionaries of important organizations outside ICAR.

Linkages and collaboration

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

Publications

- The Institute's Scientists published 75 research articles in peer reviewed journals. A large number of books, bulletins and book chapters were also published.

वार्षिक प्रतिवेदन
Annual Report
2011-12

केंद्रीय बारानी कृषि अनुसंधान संस्थान

संतोषनगर, हैदराबाद - ५०० ०५९

Central Research Institute for Dryland Agriculture

Santoshnagar, Hyderabad - 500 059

Preface

The year 2011-12 has been a very busy and eventful year for CRIDA. Impressive progress was made under the National Initiative on Climate Resilient Agriculture (NICRA) both at CRIDA and the cooperating centres, and initial results are very encouraging. District level vulnerability assessment revealed that most of the districts in the eastern and central parts of the country have low adaptive capacity. NDVI time series data analysis shows that over 81.3 million ha in arid, semi-arid and dry sub-humid regions in Rajasthan, Gujarat, Marathwada and Vidharbha regions of Maharashtra in addition to Karnataka and Andhra Pradesh, where rainfed agriculture is widely practiced, could be vulnerable to climate change and extreme weather events. Strategic research was undertaken on phenotyping of maize for tolerance to climatic stresses, classification of WRKY proteins for maize genome, meta analysis of published information on impact of elevated CO_2 on insect pests, wireless sensor network disseminated fungicide spray advisory, tillage effects on soil carbon pools and biological activity, role of roots in sequestering soil carbon, use of rainwater harvested through farm ponds for crop management during dry spells, and efficacy of biocontrol agents under elevated CO_2 conditions.

Noteworthy progress was made during 2011-12 in the programme areas of resource characterization, climate change, rainwater management, crops and cropping systems, soil health assessment and land use diversification. Pilot studies were carried out to extend agromet advisories to block level from the currently available district level. The economic viability of farm ponds in terms of net present value (NPV) and benefit cost ratio (BC ratio) was assessed. In eight backward districts of Andhra Pradesh, rainwater harvesting through site specific NRM activities, promotion of better crops and cropping systems, integration of livestock into cropping, horticulture and post harvest value addition, small farm mechanization and capacity building proved to secure the livelihoods of the poor. SMART-CDM frame work and tool box was validated in the Indian context to test the small holder carbon trading options in different carbon markets.

During the year, CRIDA organized several training programmes, workshops and seminars, and several of CRIDA's scientists were deputed for training in India and abroad. CRIDA continued its tradition of excellence as evidenced by the large number of publications in reputed journals, and awards and recognitions. CRIDA-IKISAN led initiative of setting up ICT enabled Knowledge Share Centers won the Best Citizen's Choice Award at the e-World Conference, 2011. Many individual Scientists received awards and recognition.

It is with great pleasure that I present the Annual Report of CRIDA for the year 2011-12. I am grateful to ICAR, all our collaborating institutions and stakeholders for supporting our efforts. I commend the editorial team members K. Srinivas, M. Prabhakar, K. A. Gopinath, K. Nagasree and A. K. Indoria for bringing out a good annual report.

B. Venkateswarlu

Hyderabad,
June, 2012

(B. Venkateswarlu)

Contents

1 Introduction

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

1.1 Rainfed Farming - Historical

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

1.2 CRIDA's Evolution

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

1.3 Mandate

The mandate of CRIDA is:

- To conduct basic and applied research for improving the productivity of natural resources in drylands

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

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

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

The following programmes have been identified to address the mandate:

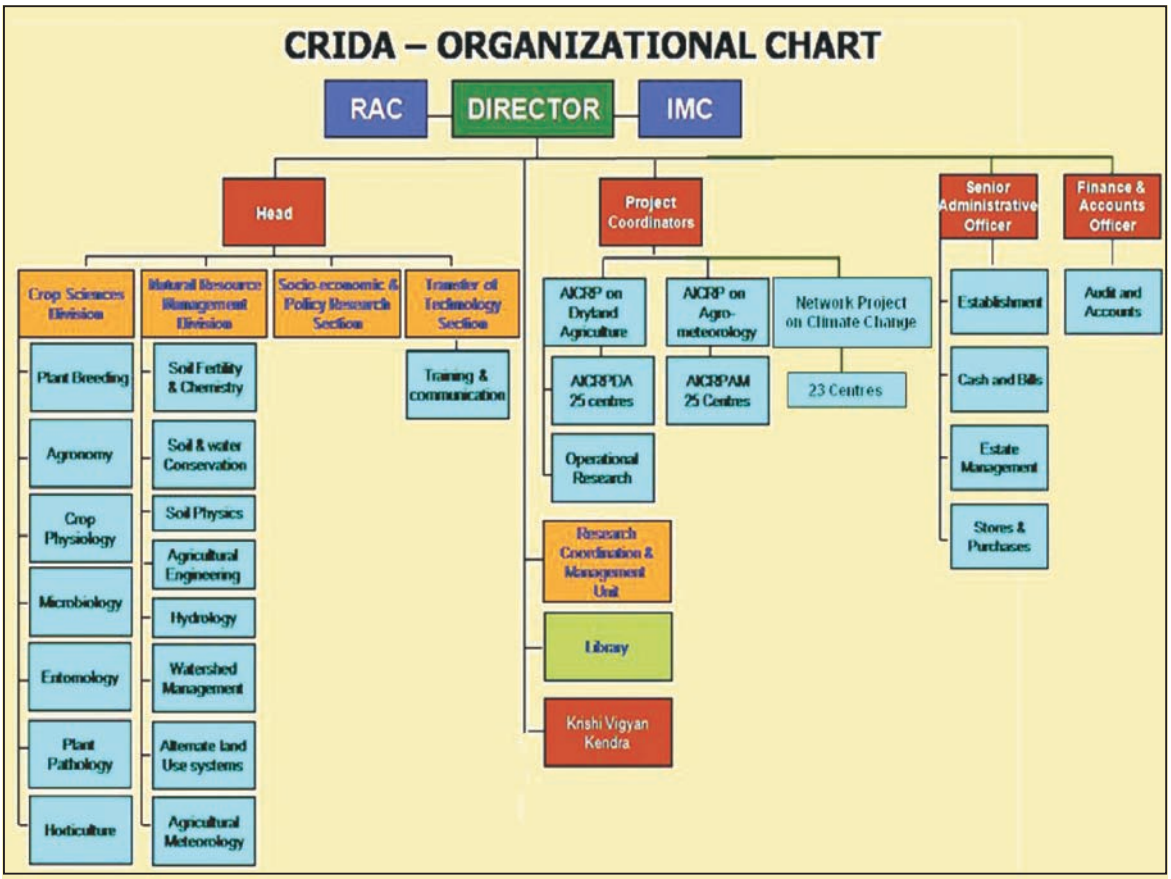
Programme No.	Programme title	Main components of sub-programmes
I	Resource characterization	Rainfall and soil characteristics, length of growing season, land capability-based potential and constraints, climatic analysis, crop weather modelling, and geographic information system
II	Rainwater management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

1.4 Current thrust areas

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

1.5 Organogram

The organizational setup of CRIDA is given below:



1.6. Past Achievements

Some of the accomplishments of the institute are as follows.

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

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

1.7 Infrastructure

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

Laboratories - CRIDA has 15 well-equipped laboratories to support research in different disciplines of natural resources management and crop sciences.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

serum, proteins, cholesterol, calcium, magnesium, albumin, etc.

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

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

Climate change study facilities: CRIDA has set up 6 Open Top Chambers (OTC) to study the impact of elevated carbon dioxide on crops.

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

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

Agriculture Knowledge Management Unit: Agriculture Knowledge Management Unit (AKMU) services are effectively used for e-mail, web hosting, internet and file transfer. The Government of India has selected CRIDA as one of the national research institutes under ICAR and given National Knowledge Network (NKN) connectivity @ one gigabit bandwidth under the national project. All servers and network activities of CRIDA have migrated from ERNET to NKN network to best utilize the NKN services. The computational power of CRIDA has been improved with latest desktops, GPU workstations, Dell servers and GPU server with 4 teraflops speed. Video conferencing facility has been established with AICRP centres. Centralized uninterrupted power supply systems (80 + 80 KVA) has been established in CRIDA premises. The websites of CRIDA and NICRA have been developed and are being maintained regularly.

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

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

Library: The Institute has a central library with a collection of over 8187 books and 4719 back volumes of periodicals. It subscribes to 132 Indian and 21 International Journals, and is equipped with AGRICOLA, AGRIS, CROP – CD and SOIL – CD Databases. Scientists access the CD-ROM

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

Research farms: The Institute has two well laid-out research farms at Hayathnagar (HRF, 280 ha) and Gunegal (Gunegal Research Farm, GRF, 80 ha) about 15 and 45 km from the main campus, respectively. These farms represent the predominant agro-ecological settings of the rainfed regions of the country. The mean annual rainfall received at Hayathnagar is 750 mm and that at Gunegal is 690 mm. The research farms have well equipped infrastructure and facilities for supporting field experiments and demonstrations including weather stations, mist chambers, maintenance workshop, tractors and farm equipments and a fabrication facility for farm tools and implements. Advanced facilities for processing of research material and data analysis are also available.

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

1.8 Financial Outlay for 2011-12 (as on 31.03.2012)

(Rupees in lakhs)

	CRIDA		AICRPDA		AICRPAM	
	Sanctioned	Utilized	Sanctioned	Utilized	Sanctioned	Utilized
Non-Plan	2855.00*	2823.80	49.50	38.85	59.50	50.40
Plan	265.00	257.84	3888.00	3888.00	805.00	805.00
Total	**3120.00**	**3081.64**	**3937.50**	**3926.85**	**864.50**	**855.40**

1.9 Staff position as on 31 March, 2012

Staff	Positions	
	Sanctioned	Filled
Scientific	66	62
Technical	80	71
Administrative	50	44
Supporting	59	54
TOTAL	**255**	**231**

2 Research Achievements

2.1 Resource characterization

2.1.1 Weather conditions at Hayathnagar Research Farm

The southwest monsoon set in the region by 10th June under the influence of a weak depression from Bay of Bengal leading to scanty rains. Afterwards monsoon was revived by an upper air cyclonic circulation from 4th July onwards and the rainfall activity continued till 27th July. Southwest monsoon finally withdrew during the first week of October.

The rainfall was 16 mm only during June at Hayathnagar Research Farm compared to the normal rainfall of 78 mm (Fig.1). Sowing operations in the farm were carried out after 14th July with proper revival of southwest monsoon. Monsoon was active during July and August with rainfall of 158 mm and 220 mm, respectively. Subdued monsoon activity was seen in September with a deficit rainfall (-45% of LPA). Rainfall during October was 22 mm (21% of LPA). There were only 34 days with rainfall >2.5 mm compared to an average of 48 rainy days showing low quantum and improper distribution of rainfall causing extreme stress to crops during the period (Fig. 2). The weekly weather conditions at the Hayathnagar Research Farm are given in Table 1. Above normal temperatures and winds were confined to May and June. In December extreme rainfall of 185.5 mm was recorded during 34th week and 1-day highest of 116.3 mm on 22nd August. The total southwest monsoon rainfall received at the Hayathnagar Research Farm was 453.9 mm (deficit of 11.9%) and the annual rainfall was 532.4 mm (deficit of 27.7%).

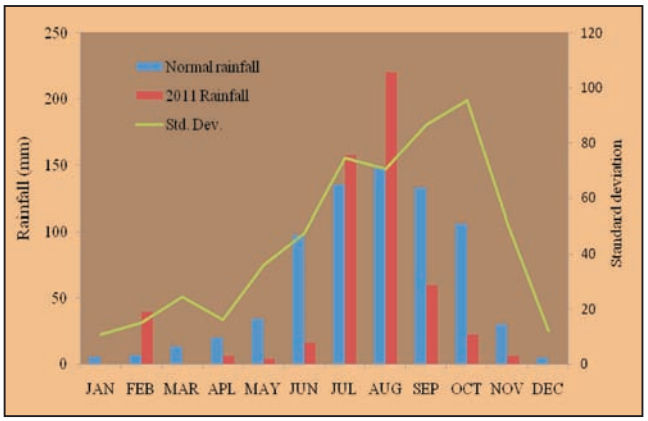


Fig.1 Rainfall distribution during 2011 at Hayathnagar Research Farm

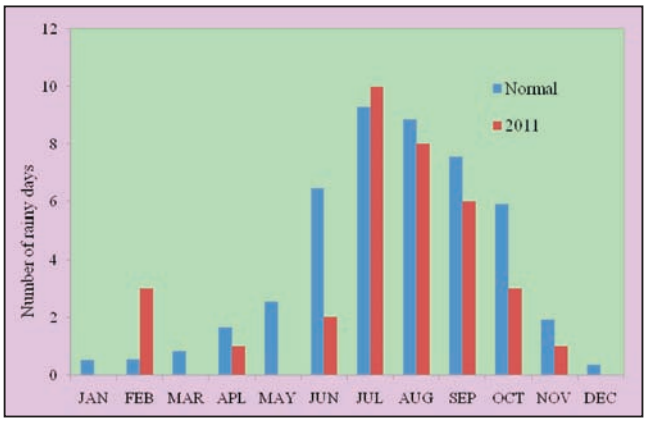


Fig. 2. Number of rainy days at Hayathnagar Research Farm during 2011

Table 1 : Weekly meteorological parameters recorded at Hayathnagar Research Farm during 2011

Standard meteorological week	Rainfall (mm)	Soil temperature (°C) at 10 cm depth		Air temperature (°C)		Relative humidity (%)		Sun shine (h)	Wind speed (km/hr)	Pan evaporation (mm)
		0716 h	1416 h	Max	Min	0716 h	1416 h			
1	0.0	19.3	27.4	26.2	11.9	90	57	6.8	2.5	2.6
2	0.0	17.0	27.4	23.7	08.3	89	25	9.8	3.9	4.0
3	0.0	19.3	29.1	30.8	11.7	90	19	9.5	2.6	4.0
4	0.0	20.0	29.7	29.7	12.3	92	32	9.6	5.7	4.6
5	0.0	21.1	30.6	30.3	12.6	94	35	9.5	5.2	5.6
6	0.0	21.1	31.2	31.2	12.8	88	38	9.6	4.8	5.8
7	0.0	22.9	32.1	31.3	13.7	82	35	8.2	4.7	5.1
8	31.2	21.4	27.5	31.1	18.0	94	44	6.4	5.2	4.7
9	8.5	22.7	28.5	29.8	17.4	89	44	9.5	3.2	4.7
10	0.0	25.3	26.9	35.7	16.9	74	28	9.2	4.6	7.6
11	0.0	25.9	36.2	33.7	16.3	89	30	9.6	6.2	7.6
12	0.0	27.0	38.7	36.5	17.6	87	27	8.5	3.8	7.7
13	0.0	26.9	36.5	36.9	18.1	69	35	8.5	4.6	7.2
14	0.0	28.7	39.2	36.9	20.0	81	36	1.4	5.6	6.2
15	6.0	29.3	38.6	35.2	21.0	85	37	7.0	5.0	7.2
16	0.3	28.8	40.1	35.9	21.6	75	35	7.0	5.2	7.6
17	0.0	30.1	40.7	35.7	21.7	85	39	9.2	5.5	5.8
18	1.4	31.1	41.6	38.3	24.2	65	30	8.5	6.5	8.8
19	0.0	32.4	42.0	38.8	25.5	50	26	7.6	6.5	9.7
20	1.2	32.8	42.2	39.4	25.9	65	29	9.4	6.0	8.1
21	0.0	33.5	43.4	38.5	27.9	66	33	7.7	8.2	10.4
22	1.2	32.4	40.2	37.7	24.9	74	42	4.2	7.4	8.1
23	8.4	30.2	38.5	33.9	23.6	82	48	4.5	6.5	0.7
24	4.2	28.2	37.7	34.2	51.4	83	45	4.9	11.2	7.7
25	0.0	29.9	32.9	34.5	23.8	79	42	6.2	13.3	9.8
26	3.4	29.5	37.1	34.2	23.6	75	43	2.1	11.2	7.9
27	19.0	23.6	32.9	31.1	21.8	86	63	2.1	9.1	5.0
28	33.8	26.8	33.0	30.7	21.8	86	68	5.0	12.0	7.5
29	13.7	26.6	29.5	32.1	22.7	84	57	3.7	10.6	5.1
30	91.0	25.7	33.5	30.3	22.6	91	64	5.8	6.5	5.5
31	11.3	26.6	33.1	29.8	23.3	86	65	3.9	10.2	5.0
32	1.2	27.4	35.0	31.6	23.8	88	61	5.0	9.3	7.1
33	5.2	28.6	35.0	32.4	24.0	83	59	4.2	6.9	5.1
34	185.5	26.4	32.0	29.7	22.9	94	70	2.0	4.1	3.3
35	40.4	24.7	30.0	26.7	22.6	90	78	1.9	9.8	3.3
36	13.1	25.1	32.6	29.9	23.1	78	69	4.9	9.0	4.0
37	1.4	26.8	30.3	30.4	23.5	89	62	4.2	4.4	3.7
38	8.4	26.6	35.3	29.6	23.9	80	58	5.9	6.5	4.4
39	13.8	26.6	30.1	30.3	22.4	83	52	6.0	3.0	4.3
40	2.8	25.9	34.5	30.3	21.3	88	50	6.2	3.4	3.6
41	10.8	26.8	34.8	33.2	21.0	93	57	6.4	3.9	3.8

Contd...

Standard meteorological week	Rainfall (mm)	Soil temperature (° C) at 10 cm depth		Air temperature (° C)		Relative humidity (%)		Sun shine (h)	Wind speed (km/hr)	Pan evapo ration (mm)
		0716 h	1416 h	Max	Min	0716 h	1416 h			
42	1.6	26.6	35.8	31.6	20.0	89	49	7.7	3.7	4.5
43	7.2	26.1	33.2	32.6	20.2	94	50	6.6	4.6	4.2
44	6.4	25.5	31.8	27.5	20.4	95	65	5.7	3.9	3.2
45	0.0	23.3	32.6	27.5	17.2	90	47	9.7	3.2	4.5
46	0.0	24.0	31.5	29.1	15.6	86	45	9.2	3.7	4.3
47	0.0	23.2	30.6	29.5	14.6	90	46	9.1	4.0	4.2
48	0.0	24.0	31.8	29.7	18.2	95	64	7.2	1.6	3.9
49	0.0	22.6	30.6	29.9	15.1	94	58	9.1	3.2	3.8
50	0.0	22.8	30.1	30.1	15.3	94	67	7.5	3.5	3.7
51	0.0	21.4	28.5	28.3	13.3	95	66	8.2	3.1	3.7
52	0.0	22.2	26.9	29.9	13.7	89	62	6.8	3.7	4.7

Rainfall is weekly total. Other parameters are weekly mean values.

2.1.2 El Nino and seasonal rainfall shifts over India

El Nino is an oscillation of the ocean – atmosphere system in the tropical pacific having important consequences for weather around the globe. It plays a significant role in the success or failure of Indian monsoon.

In order to study the change in seasonal rainfall amounts over the country during El Nino, sub divisional rainfall data was collected from IITM, Pune (1901-2009) and El Nino data was collected from NOAA, US website, and rainfall for the four seasons viz, Summer (March to May), Monsoon (June to September) Post monsoon (October to December) and Winter (January to February) during El Nino years was analyzed (Fig. 3).

- Summer (except in coastal Karnataka, West Bengal and Gujarat, where less than -10% deviation is observed) and post monsoon rainfall (except in Sourashtra & Kutch, Gujarat

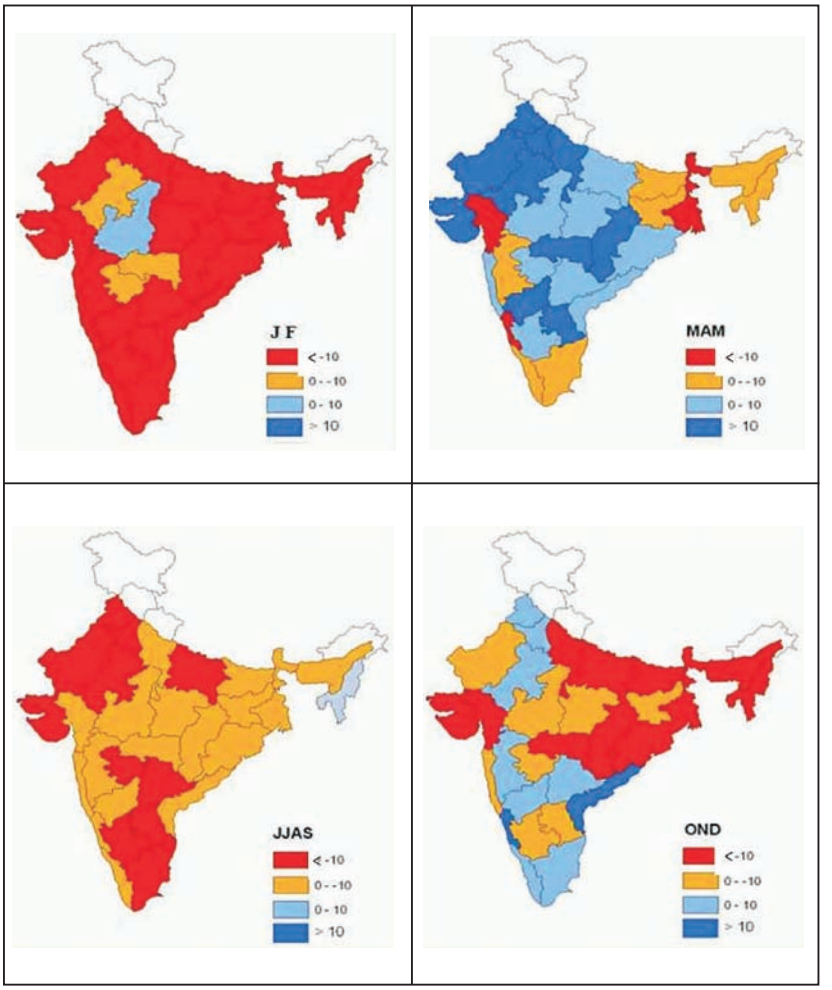


Fig. 3. Seasonal rainfall (% deviation) in different meteorological subdivisions during El Nino years

region, entire UP, Bihar, West Bengal, Orissa, Chhattisgarh and Vidharba where the < -10% is observed) increased during El Nino events.

- Except West Madhya Pradesh, winter rainfall showed negative deviation (<-10%).
- Negative deviation in rainfall was observed in monsoon season.
- Increased post monsoon season rainfall was observed over Punjab, Haryana, Eastern Rajasthan, North costal Karnataka, Madhya Maharashtra, coastal AP, Northern Telangana, Tamilnadu and Kerala.
- This clearly indicates the seasonal rainfall shift during El Nino events.

Proper planning is required to tap the natural resources and evolve management strategies in areas where monsoon and winter rains are decreasing during El Nino years in order to save *kharif* as well as *rabi* crops.

2.1.3 Micro level Agromet Advisory Services (AAS)

The main objective of the sub-project is to extend the Agromet advisories to block level from the currently available district level. The real-time weather data collected at KVKs will help in fine tuning the forecast obtained from IMD and also facilitate in improving the Agromet advisory services based on ground level information. This information can be used in crop management like day to day field operations and it will enhance farmer's capability towards climate resilient agriculture. The forecast and Agromet advisories prepared by Scientist (Agro meteorologist) or SRF of the KVK is disseminated through various modes viz. press & electronic media, mobile, and directly to farmers in person. The farmers receive the Agromet advisories for their own taluka/blocks. The flow diagram of the development and dissemination of Agromet advisories for Bagalkot district in Karnataka is given above (Fig. 4) as a case study.

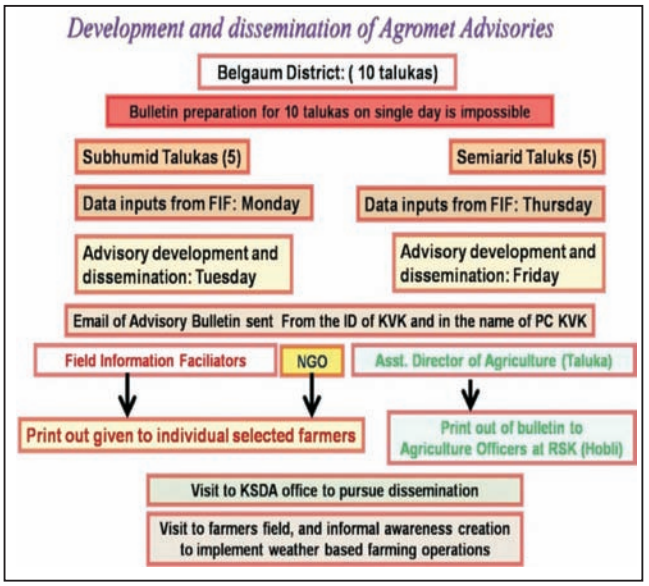


Fig. 4. Flow diagram of the development and dissemination of Agromet advisories

The State Department Agriculture Officers and NGOs also receive the advisories for their respective talukas/blocks through email. This helps them to disseminate the advisories to their contact farmers without losing any time.

2.1.4 Value addition to agromet database of AICRP on Agrometeorology – weather indices for crop insurance

Identification of critical phenological stages

To identify the temperature sensitive phenological stages influencing wheat yield, grain yield of three varieties viz.,HD-2285,K-8804 and K-9107 over 3 dates of sowing and 12 years of experimentation at Kanpur were related with phenophase-wise averages of maximum and minimum temperature. Correlation coefficients of yield with individual weather parameters: maximum and minimum temperature during phenological stages, sowing to emergence (P_1), emergence to crown root initiation (P_2), crown root initiation to tillering (P_3), tillering to jointing (P_4), jointing to anthesis (P_5), anthesis to milking (P_6), milking to dough (P_7) and dough to maturity (P_8) brought out that maximum and minimum temperature during all the stages from P4 to P8 significantly and adversely influenced the grain yield of all three varieties of wheat (Table 2). Though both maximum and minimum temperature during emergence and crown root initiation showed positive relationship with yield, the positive effect

of maximum temperature was more significant than the minimum temperature. The adverse effect of both maximum and minimum temperature on yield of all the three varieties was highest during milking stage followed by dough and anthesis stages in K-8804 and K-9107 and anthesis and dough stages in HD-2285.The yield and temperature relations pooled over all the varieties also showed similar results and milking stage emerged as the most sensitive phenological stage for thermal stress (both maximum and minimum temperature) followed closely by dough and anthesis stages.

Quantification of thermal stress on wheat yield

To quantify the impact of thermal stress, yield of varieties HD-2285, K-8804 and K-9107 were regressed with maximum and minimum temperature during the above identified critical period, milking stage of each variety. The temperature and yield relations revealed that increase in minimum temperature by 1^{0}C during milking stage caused higher reduction in yield of varieties K-8804 and K-9107 (179.9 and 182.5 kg/ha) than the increase in maximum temperature (176.5 and 158.6). However, in variety HD 2285, reduction in yield due to increase in maximum temperature was higher than the reduction with increased minimum temperature during milking stage. The reductions in yield of HD 2285 with unit increase in maximum and minimum temperature were 162.9 and 147.4 kg/ha, respectively (Fig. 5).

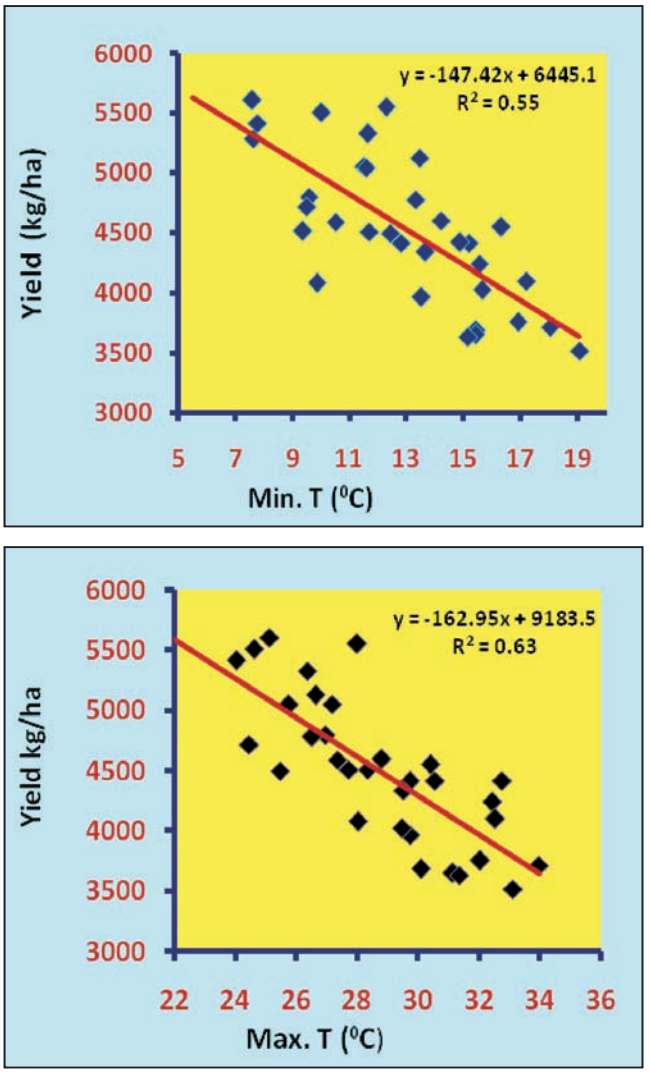


Fig. 5. Relation between yield and minimum temperature (top) and maximum temperature (bottom) during milking stage of wheat verity (HD 2285) at Kanpur

Table 2 : Correlation coefficient of wheat yield with phenological stage-wise maximum and minimum temperature in all three varieties at Kanpur

Phenological stage	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
Varieties				Maximum Temperature				
HD 2285	**0.55**	**0.38**	-0.12	**-0.31**	**-0.58**	**-0.61**	**-0.56**	**-0.43**
K9107	**0.57**	**0.46**	-0.24	**-0.41**	**-0.71**	**-0.76**	**-0.74**	**-0.43**
K8804	**0.63**	**0.53**	-0.24	**-0.41**	**-0.69**	**-0.74**	**-0.72**	**-0.59**
All varieties	**0.52**	**0.38**	-0.16	**-0.37**	**-0.64**	**-0.71**	**-0.69**	**-0.52**
				Minimum Temperature				
HD 2285	0.25	0.15	-0.25	**-0.51**	**-0.54**	**-0.55**	**-0.46**	**-0.39**
K9107	**0.52**	**0.45**	-0.21	**-0.47**	**-0.65**	**-0.71**	**-0.66**	**-0.57**
K8804	**0.34**	0.22	**-0.40**	**-0.59**	**-0.68**	**-0.71**	**-0.70**	**-0.60**
All varieties	**0.32**	0.24	**-0.25**	**-0.49**	**-0.59**	**-0.64**	**-0.61**	**-0.55**

Impact of thermal stress on crop development

The duration of vegetative, reproductive and total growing periods of the three varieties under three sowing dates over the 12 years of experimentation were related with maximum, minimum and average temperatures during respective stages. The correlation coefficients revealed that minimum temperature during reproductive period highly and adversely affects the duration of reproductive period than maximum or average temperature (Table 3). All the temperatures, however showed insignificant positive relation to the duration of vegetative period. The total durations of all the three crop varieties were more significantly and adversely affected by maximum and average temperature during the total growing period than minimum temperature.

Identification of average temperature conditions for optimum yield

Mean (M) and standard deviation (σ) in yield of all three varieties over all the three dates and 12 years were worked out. All the 36 values of yield were categorized into three types, *viz.*, above average (more than M +σ), average (M-σ to M +σ) and below average (less than M-σ). Average of weather parameters in different phenological stages over the years under each of the three categories of yield (Table 4) showed that highest average yield in all three varieties is recorded when average maximum and minimum temperature during jointing to maturity stages are lesser and vice versa.

Decline in yield in each category from above average to below average was observed to be in proportion to the increase in average maximum and minimum temperature during anthesis to dough stages. These stages in the years with below normal yield witnessed nearly 6 to 7^0 C increase in both maximum and minimum temperatures compared to the years with above normal yield (Table 4). The difference between the average yield of above and below normal years ranged between 1600 to 2000 kg/ha and the variety K8804 suffered higher yield loss in above normal temperature years compared to other varieties. The minimum temperature in the range 6.3 to 8.3^0 C during anthesis, 9.5 to 10.8^0 C during milking stage and 12.3 to 13.8 ^{0} C during dough stages were found to be optimum for achieving above normal yield.

2.1.5 Development of a database of rainfed districts

District database developed including various agricultural statistics was updated to latest years. Climatic parameters like rainfall, number of rainy days, drought, maximum temperature, minimum temperature etc. are also included in the database. Demographic, NRM and socio-economic parameters like population density, ground water availability, degraded and wastelands, poverty, literacy, size of holding, % SC & ST population, % of workforce engaged in agriculture were also covered in the database. State database covering various agricultural statistics was developed with latest 10 years.

Table 3 : Effect of temperature (maximum, minimum and average) on duration of different stages of wheat cultivars

Cultivars	Temperature	Vegetative	Reproductive	Total duration
K8804	MXT	0.29	-0.71	-0.67
	MNT	0.08	-0.76	-0.54
	AVT	0.24	-0.75	-0.67
K9107	MXT	0.18	-0.52	-0.64
	MNT	0.06	-0.57	-0.49
	AVT	0.15	-0.56	-0.63
HD2285	MXT	0.31	-0.62	-0.54
	MNT	0.15	-0.71	-0.57
	AVT	0.29	-0.69	-0.65

Table 4 : Average weather conditions during different phenological phases of wheat varieties in the years under three different yield categories at Kanpur station

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	Yield (kg/ha)
K8804 - Maximum temperature									
Above mean	26.2	24.5	21.8	20.7	22.8	25.8	29.6	32.4	5082
Mean	22.6	21.2	22.9	23.6	27.2	31.1	35.4	36.2	3820
Below mean	19.7	20.0	21.5	24.5	28.4	31.4	35.9	38.0	3061
K8804 - Minimum Temperature									
Above mean	8.8	7.9	7.3	5.9	6.3	10.0	12.9	15.7	5082
Mean	7.1	6.1	8	9.3	11.9	15.4	17.7	19.8	3820
Below mean	7.1	6.7	8.7	9.9	12.9	16.1	18.1	20.2	3061
HD 2285 - Maximum temperature									
Above mean	26.5	24.7	21.9	21.2	21.9	25	28.9	31.5	5453
Mean	24	21	22	22.3	25	29.3	33	34.9	4289
Below mean	19.7	20.2	22.6	25.2	28.8	32	34.7	36.5	3661
HD 2285 - Minimum Temperature									
Above mean	9.1	8.2	7.3	6.1	6.6	9.5	12.3	15	5453
Mean	8.5	6.6	7.3	7.9	9.8	13.1	15.9	17.7	4289
Below mean	6.4	6.5	8.9	10.8	13.6	16.7	18.3	19.7	3661
K9107 - Maximum temperature									
Above mean	25.6	23.8	21.6	21.4	23	26.5	29.7	33.9	4600.9
Mean	24.2	22	20.8	22.8	26	30.3	33.9	36.5	3733.3
Below Mean	20.7	21.7	23.3	26.7	29.5	33.3	36.7	37	3069.8
K9107 - Minimum Temperature									
Above mean	10.8	8.8	7.5	6.4	8.3	10.8	13.8	16.7	4600.9
Mean	7.8	6.5	6.8	7.9	10.7	14.2	17.1	19.2	3733.3
Below Mean	6.8	6.8	8.9	11.7	14.4	17.7	19.2	20.8	3069.8

Effect of rainfall and maximum temperature on yield of redgram and cotton in AP

The effect of temperature and rainfall on the productivity of two important crops – pigeonpea and cotton in Andhra Pradesh was evaluated using panel regression approach. Using the district level time series data, the yield of these two crops was regressed on maximum temperature during *kharif*, rainfall quantity and number of rainy days, in a one-way and two-way fixed effect model of panel regression. The coefficients were estimated following Least Squares Dummy Variable Method. This model gives the yield response coefficients after accounting for the district specific differences. The models fitted for pigeonpea and cotton were found to explain 52 and 57 per cent of variation respectively. In case of pigeonpea, the district specific effects were found to be significant in most of the districts. It was further observed that the response coefficients for rainfall and number of rainy days were found to be significant at 5 per cent level. On the other hand, a ten millimetre increase in the rainfall was found to increase yield by about 1.9 kg. Increase in the number of rainy days was found to have a significant negative relationship with yield, which can probably be attributed to the occurrence of rainfall during flowering stage. In case of cotton, about half of the major cotton growing districts differed significantly in mean yield levels. The maximum temperature was found to cause a significant reduction (at a rate of 77 kg for one degree rise) in yield. The yield was found to increase by 4.1 kg for every 10 mm increase in the rainfall.

Estimated productivities of important rainfed crops under irrigated and rainfed conditions at country level with the help of statistical techniques

Yields under irrigated conditions were about three times to the rainfed yields in rice, sorghum and cotton. In case of maize, chick pea, pigeon pea and groundnut, productivities under rainfed conditions were half of the productivities under irrigated conditions. Pearl millet was responding very well to irrigation with nearly 4 times yield under irrigated conditions in comparison to its rainfed counterparts (Fig. 6).

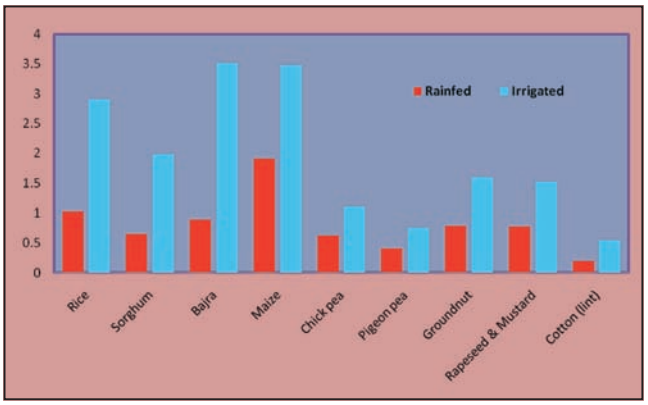


Fig. 6. Estimated productivities (t/ha) of important crops in rainfed and irrigated conditions

2.1.6 Impacts of meso-scale watershed development in Andhra Pradesh and their implications for designing

Hydrological units in Prakasam and Anantapur district of AP were selected for the study purpose (Fig 7). Hydrological changes at upstream, mid and downstream through watershed interventions were studied. Data on crops, soils, land use, crops and cropping systems etc were collected and digitised.

A simple two layer water balance model is being used for quantification of surface water balance components. The model provides the output of water balance model in distributed framework. The output of the model, particularly runoff and deep percolation would be used as input to the groundwater model. Data necessary (rainfall, soils

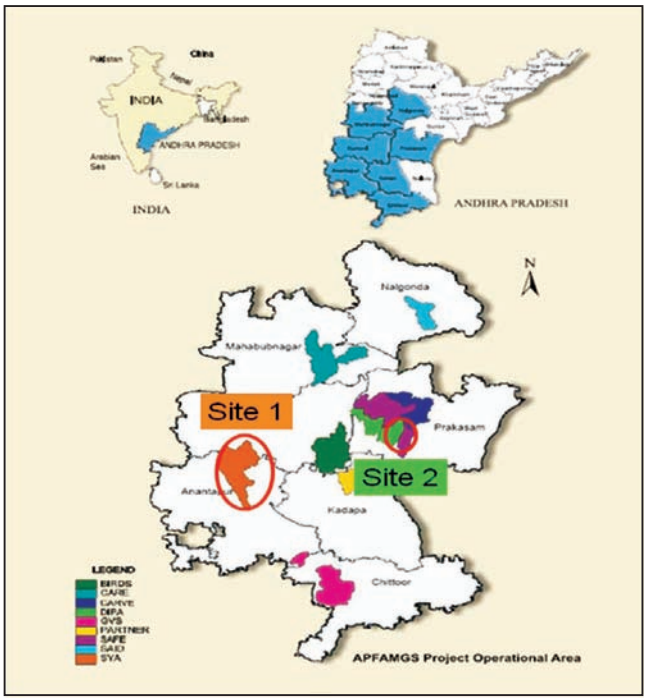


Fig. 7. Hydrological units in Prakasam and Anantapur district of AP

information, land use information etc) for surface hydrology modeling within the distributed modeling frame work is generated. Surface water balance estimations for different land uses within hydrological units of Anantapur and Prakasam were taken up considering with and without watershed scenarios. Input parameters such as ET were estimated from IMD grid data. Ten years rainfall data (2000-2010) was used for estimation purpose. Quantification of water balance components such as runoff was done considering scenarios of with and without watershed development.

2.1.7 Assessment of impact of regional climate variability/change on agriculture land use in rainfed regions

Climate variability, particularly rainfall variability, in core rainfed production systems in the country is impacting not only sowing windows of the predominant *kharif* and *rabi* crops but also the production and productivity due to early, mid and terminal droughts. To understand this, climate variability assessment (point data of 25 to 35 years) in respect of rainfall was done for northern dry

zone of Karnataka (comprising Bijapur, Bagalkote, Belgaum, Gadag, Dawangere and Raichur districts only) using *weathercock* software and other statistical tools. The impact of the anomalies on crops, their productivity, etc., was also studied.

Results indicates that the normal annual rainfall ranges from 589.32 mm (Bagalkote) to 1276.7 mm (Belgaum) of which more than 50 per cent of the years there was deficit with deviation ranging up to -63.4 per cent in these districts. The predominant rainfed crops in the zone in *kharif* are pearlmillet, pigeonpea, sunflower, soybean, groundnut, cotton, sorghum, greengram, chilli, maize, fingermillet and in the *rabi* are sorghum and chickpea. The normal onset of the south-west monsoon in the northern dry zone of Karnataka is first week to second week of June and north-east monsoon is first week to second week of October. The normal sowing window for *kharif* crops in the zone is from first week of June to fourth week of July and for *rabi* crops is from first week of September to fourth week of November. The deviation in start and end week of the onset of monsoon both for south west and north east monsoon are impacting the sowing windows of both *kharif* and *rabi* crops, increase in fallows in *kharif* and shift to alternate crops. For example in Bijapur district, due to late onset of south-west monsoon, the farmers are preferring onion/chillies and then relay cropping with either rabi sorghum or chickpea in medium deep black soils. Agricultural drought is recurrent during *kharif*. For example, in the recent decade, agricultural drought in Bijapur district is recurrent during 22 SMW to 40 SMW and in Raichur district, it is during 22 SMW to 42 SMW leading to a yield reduction up to 30 per cent in pigeonpea and sunflower. The extreme events like high intensity rainfall in short span are becoming common in the zone in the recent decade, particularly during south west monsoon. For example during 2004 - 2009, there were three high intense rainfall events (119 mm, 129 mm and 137.6 mm) in Raichur district. These events are creating land and soil related management problems and also overall performance of the crops and yield.

2.2 Climate Change

2.2.1 Effect of elevated CO_2 on rainfed crops

Black gram (*Vigna mungo* (L.) Hepper) is one of the major grain legumes in the rainfed agro-ecosystems of India. It is an important source of protein and cultivated as short duration rainfed crop in semiarid areas. The objective of the present study was to quantify the variability in 18 black gram genotypes (obtained from NBPGR) response to increased atmospheric CO_2 concentration in terms of biomass and seed yield and its components in order to identify the superior genotype and most responsive plant traits. The genotypes were evaluated at two elevated (550 ppm & 700 ppm) and ambient (380 ppm) levels of CO_2 in open top chambers. The 18 genotypes tested in the study were V1: Acc. No. IC587753, V2: IC436720, V3: IC436519, V4: IC343947, V5: IC519805, V6: IC282009, V7: IC436753, V8: IC436610, V9: IC436610, V10: IC343952, V11: IC587752, V12: IC587751, V13: IC281987, V14: IC398971, V15: IC436652, V16: PU-19 (check 1), V17: LBG-20 (check 2) and V18: T-9 (check 3). Observations were recorded at harvest on root length (RL), root volume (RV), shoot length (SL), number of branches (NOB), number of pods (PN), root dry weight (RDW), stem dry weight (SDW), leaf dry weight (LDW), pod dry weight (PW), fodder dry weight (FW), total dry weight (TDW), filled seed number (FSN), total seed number (TSN), filled seed weight (FSW), total seed weight (TSW), test weight (TW), husk weight (HW), percentage of shelling (SH) and harvest index (HI). Weighted efficiency index (WEI) was computed as an integrated function of the performance of black gram genotypes for different plant traits at different CO_2 levels. The WEI of each genotype was determined by converting the values of genotypes to linear scores in the range of '0 to 1' separately for each trait. The ranks would indicate numerical position which would not explain the relative

performance or superiority of genotypes or traits. WEI would take into account the relative superiority of all genotypes for each trait. The genotype with maximum WEI could be chosen as most efficient for attaining significantly higher values of different traits at different CO_2 levels.

There was a significant difference in the effects of CO_2 levels on the performance of genotypes for 16 traits *viz.* RL, RV, SL, NOB, PN, RDW, SDW, PW, TDW, FSN, TSN, FSW, TSW, TW, HW and HI at $p < 0.01$ level, while LDW and FW were significant at $p < 0.05$ level. Similarly, there was a significant difference among genotypes for all plant traits at $p < 0.01$ level. Significant interaction effect of CO_2 levels and genotypes was observed for 12 traits *viz.* RL, RV, PN, LDW, PW, FW, TDW, FSN, TSN, FSW, TSW and HW at $p < 0.01$ level, while it was significant for SDW and NOB at $p < 0.05$ level. The interaction effect was non-significant for SL, RDW, HI, SH and TW where as SH was non-significant for CO_2 levels, genotypes and their interaction. The genotype-wise WEI values were computed for each plant trait at each level of CO_2. Based on the WEI values of different traits, the genotypes were categorized as superior genotypes with WEI values exceeding $\mu + \sigma$, inferior genotypes with WEI values below $\mu - \sigma$, and moderate genotypes with WEI values ranging from $\mu + \sigma$ to $\mu - \sigma$ limit. For individual traits, the WEI value of more than 0.80 at each CO_2 level was considered as superior. At 380 ppm level of CO_2, the genotype V3 was found superior with maximum over-all WEI of 14.54, followed by V15 with 13.60. The genotypes V1 and V17 were inferior at 380 ppm level of CO_2. The remaining 14 genotypes had moderate WEI score at 380 ppm level of CO_2. At 550 ppm, V9 with over-all WEI of 12.89 and V8 with 12.38 were superior and V1, V10 and V12 were inferior with WEI of 7.08, 7.03 and 3.00, respectively. The remaining 13 genotypes had moderate WEI score at 550 ppm level of CO_2. At 700 ppm, V9 was superior, followed by V5 and V2 with over-all WEI of 14.35, 14.19 and 13.82, respectively. V10 and V13 were inferior with over-all WEI of 4.65 and 6.55, respectively. However, V13 was superior for SDW, RDW and RV and the remaining 13 genotypes had moderate WEI score at 700 ppm level of CO_2.

Among the 19 plant traits assessed, SDW for 14 genotypes showed improved response at 550 ppm as compared with 380 ppm CO_2, followed by SL for 13 genotypes, RDW for 12 genotypes, FSW for 11 genotypes, and PW, TSW and HI for 9 genotypes each. Similarly, decreasing response at 550 ppm was observed in RL for 17 genotypes, followed by SH, LDW and PN for 14 genotypes each, FSN and NOB for 13 genotypes each, FDW, HW, TSN, RV and TDW for 11 genotypes each and

Table 5 : Top two genotypes of black gram based on ranks of observed data and WEI of different plant traits

CO_2 level	Morphological traits	Dry weight traits	Yield traits	Over-all
Observed data				
380 ppm	V13, V15#, V12#	V13, V15, V3	V3, V15	V15, V3
550 ppm	V11, V8	V9, V16	V5, V2, V7	V8, V2
700 ppm	V17, V11	V5, V9, V17	V9, V2	V9, V14
Over-all	V13, V11	V9, V16	V5, V2	V5, V9
WEI values				
380 ppm	V18, V13, V4	V3, V13, V15	V3, V15	V3, V15
550 ppm	V17, V9	V9, V16	V3, V5, V7	V9
700 ppm	V17, V18	V5, V9, V17	V2, V9	V2, V5, V9
Over-all	V13, V11	V9, V13	V2, V5	V9, V5

Varieties with equal rank sum for morphological traits

TW for 10 genotypes (Table 5). In general, the response of elevated CO_2 in black gram was highest for traits such as SDW followed by SL and RDW. RL is an important trait which decreased with increase in CO_2. The assessment of 18 black gram genotypes for 19 traits indicated mixed effects of 380, 550 and 700 ppm levels of CO_2 on morphological, dry weight and yield traits. The genotypes differed significantly for all the selected traits except SH. V5 and V9 were identified as superior based on the ranks of observed data and WEI Values. V9 was superior for dry weights, while V5 was superior for yield traits at elevated CO_2 levels.

2.2.2 Impact of elevated CO_2 on plant nitrogen use efficiency

Plants nitrogen use efficiency (NUE) is most critical for efficient use of nitrogen. Pearl millet plants (ICTP 8203) were grown in OTC's at ambient (370 ppm) and elevated CO_2 (550 ppm) conditions with 15 mM nitrate supplied as KNO_3 to study the nitrogen use efficiency under elevated CO_2 conditions. Analysis of nitrate reductase (NR) and glutamine synthetase (GS) activity, the important enzymes of nitrogen assimilation, was carried out from the leaves collected at peak vegetative stage.

Table 6 : Nitrate reductase (NR) and glutamine synthetase (GS) activity at 45 DAS and biomass and grain yield at harvest in pearl millet grown under ambient and elevated CO_2 conditions

Parameter	CO_2 levels	
	380 ppm	550 ppm
Nitrate reductase activity (µ moles nitrate reduced/g FW/h)	4.1	4.0
Glutamine synthetase activity (µ moles GHA formed/g FW/15 min)	138.2	146.5
Total soluble sugars (mg/g FW)	36.7	49.8
Starch (mg/g fresh weight)	33.5	50.6
Total biomass (g/plant)	85.61	91.7
Root biomass (g/plant)	7.90	10.16
Grain yield (g/plant)	39.87	41.38
HI (%)	46.55	45.13

There was no significant difference in NR and GS activity at ambient and elevated CO_2 conditions (Table 6). But the total soluble sugars and starch increased under elevated CO_2 conditions. Under elevated CO_2 conditions, total biomass and seed yield increased marginally (non-significant) compared to that under ambient conditions. Analysis of nitrogen content of leaf, stem root and seed is in progress.

2.2.3 Impact of elevated CO_2 on host-insect herbivore interactions

Estimation of intrinsic rate of increase of castor semilooper

Castor (DCS 9) was grown in open top chambers at three different CO_2 concentrations (550±25, 700±25 and 380±25 ppm). Experiments were conducted on castor semilooper *(Achaea janata)* using elevated CO_2 foliage of castor to quantify the impact of elevated CO_2 on life table parameters. Various parameters viz., intrinsic rate of increase, the finite rate of increase, gross reproduction rate, net reproduction rate and mean generation time of castor semilooper were estimated. The intrinsic rate of increase (r_m), as a composite index of growth, development and fecundity of the whole population, was estimated by using the iterative bisection method from Euler-Lotka formula. Significant variation was observed with intrinsic rate of increase (r_m), mean generation time and net reproductive rate of castor semilooper under elevated CO_2 over ambient CO_2 (Fig. 8). Intrinsic rate of increase was found to be higher in ambient (0.1957± 0.0085) compared to eCO_2 i. e, 550 ppm (0.179±0.0074) and 700 ppm (0.1711± 0.0091). An extended mean generation time was observed under eCO_2 (30.63±0.29 and 30.59±0.18 days) than ambient conditions (28.06±0.51). The net reproductive rate was found to be higher in ambient (237.4±52.53) and 550 ppm (234.7±52.59) than 700 ppm (230.7±48.74). The study indicates that the specific effects of eCO_2 on castor semilooper are longer generation time, decreased r_m with less fecund adults.

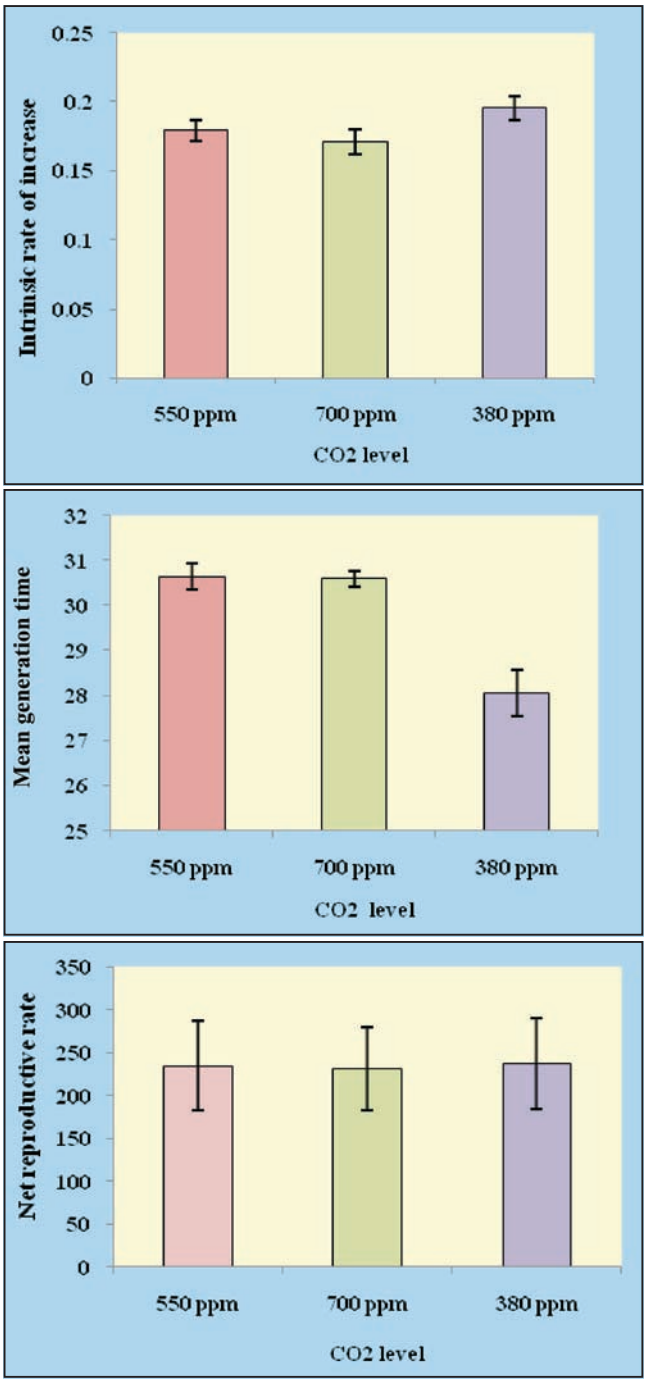


Fig. 8. Impact of eCO_2 on life history parameters of *A. janata* on castor

Impact of eCO_2 on Bihar hairy caterpillar

Feeding trials were conducted on Bihar hairy caterpillar *(Spilosoma obliqua)* using eCO_2 castor foliage. The impact of CO_2 concentrations and generations was significant on insect primary parameters. The weight of castor foliage consumed by *S. obliqua* was significantly varied by CO_2 levels ($F_{2, 8}$ = 938.56, P =<0.01) and generations ($F_{3, 36}$ =809.46, P =<0.01). The interaction between CO_2 conditions and generations was also found significant ($F_{6, 36}$ =9.81, P=<0.01). The weight of *S. obliqua* larvae was significantly different among four successive generations ($F_{3, 36}$= 64.07, P =<0.01) registering higher larval weights under elevated CO_2 condition ($F_{2, 8}$ = 63.91, P =<0.01). The interaction between CO_2 conditions and generations was found not significant ($F_{6, 36}$ =1.00, P= >0.05) (Fig. 9).

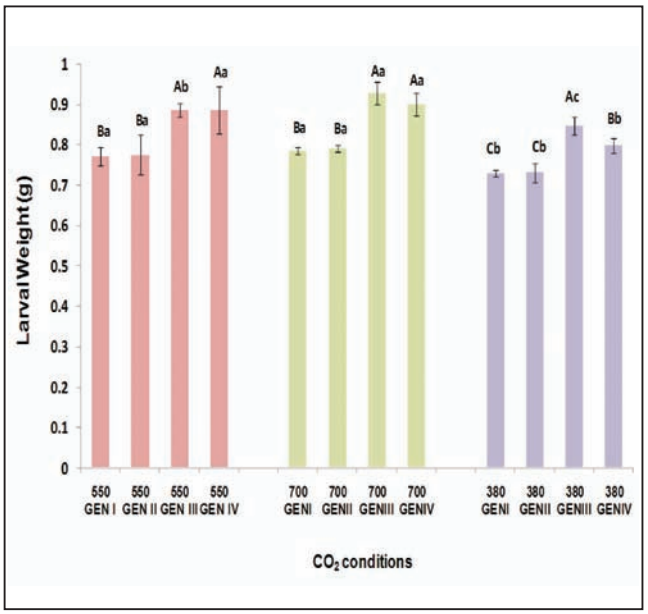


Fig . 9. Larval weight in four successive generations of *S. obliqua* on castor under three CO_2 conditions

The impact of elevated CO_2 ($F_{2, 8}$ = 17.44, P = <0.01) on approximate digestibility (AD) of castor foliage by *S. obliqua* was significant over four generations ($F_{3, 36}$ = 18.26, P = <0.01). The results indicated that CO_2 levels adversely affected the quality of castor foliage and increased the relative consumption rate (RCR) (mg/g/d) of *S. obliqua* larvae. The impact of elevated CO_2 on RCR ($F_{2, 8}$ = 4.83, P =<0.05) was significant over four generations ($F_{3, 36}$=3.88, P = <0.05). The interaction between CO_2 and generations was found not significant ($F_{6, 36}$ = 0.87, P=>0.05). The efficiency of conversion of ingested food (ECI) (%) for *S. obliqua* larvae fed on

castor foliage under elevated CO_2 concentrations was significantly reduced over generations ($F_{3, 36}$ =10.17, P = <0.01) and also due to elevated CO_2 concentrations ($F_{2, 8}$ = 98.82, P = <0.01). The impact of elevated CO_2 ($F_{2, 8}$ = 27.31, P=<0.01) on efficiency of conversion of digested food (ECD) of larvae was not significant over four generations ($F_{3, 36}$=1.54, P = >0.05). The interaction between CO_2 and generations was not significant ($F_{6, 36}$ = 1.29, P= >0.05). The relative growth rate (RGR) of larvae decreased significantly when fed on castor foliage under elevated CO_2 ($F_{2, 8}$ = 21.23, P =<0.01) and over generations ($F_{3, 36}$ =38.38, P = <0.01). The interaction between CO_2 and generations was found significant ($F_{6, 36}$ = 3.98, P=<0.01).

Differential feeding by *S. obliqua* of castor leaves grown under different CO_2 conditions

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

A study was conducted to identify farmers' perceptions and major farm-level adaptation measures followed towards climate variability in Coastal (East Godavari), Rayalaseema (Anantapur) and Telangana (Mahbumnagar) regions of A.P. From each district three mandals, and from each mandal two villages were selected based on rainfall averages. From each village, ten farmers were selected for data collection. In East Godavari, the perception of farmers about different parameters was: rise in temperature (90%), decrease in rainfall (88%), high incidence of insect-pests and diseases in *kharif* paddy (85%), occurrence of terminal and unseasonal rains (82%), excess use of chemicals in agriculture along with deforestation lead to climate change (78%), and 75% of farmers expressed that ITKs for rain forecasts are failing. The chief adaptation measures followed by farmers towards climate variability are: 93% of farmers have adopted early sowing in June to avoid November cyclones coinciding with harvest while 92% of farmers spray salt water on harvested paddy stalks to avoid discoloration and regermination. About 88% farmers felt that river banks should be strengthened and drainage should be improved. A majority of farmers expressed the need for survey number-wise insurance covering low lands (84%) and provision of sufficient loans to tenant farmers (80%). About 68% of farmers expressed that they migrate as construction labour if monsoon fails, particularly in rainfed areas. The adaptation indices for the three districts along with their SD and CV values are presented in Table 7.

Table 7 : Adaptation indices of farmers for drought and floods

Statistic/ Category	Ananthapur (Drought)	Mahbubnagar (Drought)	East Godavari (Floods)
Mean	74.4	72.8	75.8
S.D.	13.4	13.8	12.3
C.V.	18	19	16.2

2.3 Rainwater management

2.3.1 Economic analysis of farm pond with different production systems

Based on the experiments conducted, two options were considered as base crops of one oil seed and other vegetable. The crops selected were ground nut (ICGV91114) as oil seed and okra (Arka

Anamica) as vegetable crop of *kharif* season in alfisols. In *rabi*, carrot was considered as sufficient water was available for irrigation along with ground nut. The particulars of the crop and irrigation is given in Table 8 with different strategies based on the net water availability in a farm pond. Besides the crops in *kharif*, the fish was considered along with environmental benefits like soil and nutrient conservation. The various costs of the irrigating crops under different options of farm pond are given in Table 9. The economic analysis considering 12% discount rate and 20 years of life period for farm ponds, indicated that the farm pond considered for irrigating ground nut at critical stages and utilizing remaining water for carrot in *rabi* was more beneficial with B:C ratio varying from 11 to 28 under lined and unlined farm pond respectively as compared to okra with fish and environmental benefits (Table 10). Therefore, the production system groundnut+carrot+fish+environmental benefits was the best for alfisols under farm pond of capacity 1750 m^3 with 14.5 ha catchment area.

Table 8 : Crop and irrigation strategies with unlined and lined farm pond (capacity: 1750 m^3; catchment area: 14.5 ha)

Item description	Unlined			Lined ++		
	Kharif		*Rabi*	*Kharif*		*Rabi*
	Option 1	Option 2		Option 1	Option 2	
Crops	G Nut	Okra	Carrot	G nut	Okra	Carrot
Area, ha	0.4	0.4	0.4	1	0.8	0.4
Depth of irrigation, mm	50	50	20	50	50	30
Net water availability, m^3	1128	1128	630	1680	1680	680
No. of irrigations	2	4	5	2	4	5

Table 9 : Yield and cost details of different crops under unlined and lined farm pond

Item description	Unlined			Lined ++		
	Kharif		*Rabi*	*Kharif*		*Rabi*
	G Nut	Okra	Carrot	G nut	Okra	Carrot
Cost of farm pond(27.5x 27.5x3.5 m), Rs	40000			150000		
Yield , q/acre***	4	20	80	10	40	110
Total cultivation cost, Rs	5000	10000	20000	12500	20000	20000
Total irrigation cost, Rs*	4700	9400	5500	11750	18800	6900
Net Benefit from Fish culture, Rs/yr **	45000			45000		
Environmental benefits (Conservation of resources like soil and nutrients), Rs/yr +	15000			15000		

*Considering the custom hiring of 3hp diesel pumpset with raingun irrigation system (Application rate: 6.4 mm/h, Area coverage: 1384 m^2; Operating pressure: 200kPa) at a cost of Rs 50/hr), including diesel cost and operator cost.*** During *kharif*, only yield increase from rainfed was considered.++ Lining with Silpaulin of 300 gsm @Rs100/m^2. ** Yield of fish considered is 1.5t/yr @ Rs 40/kg with production cost of Rs 15000/yr.+ Soil loss at a rate of 0.64 t/ha @ Rs 1500/t and Rs 1500/- for nutrients.

Table 10 : Economic performance indicators of different production systems under unlined and lined farm pond (capacity: 1750 m^3; catchment area: 14.5 ha)

Item	Production system			
	G nut+ carrot+ fish+ EB		Okra + fish + EB	
	Unlined	Lined	Unlined	Lined
Life of farm pond (yr)	20	20	20	20
Discount rate (%)	12	12	12	12
Net present value (Rs in lakhs)	12.81	17.32	5.54	5.22
B: C ratio	28.05	11.02	12.69	4.32
Pay back period (yr)	1	1	1	2

2.3.2 Water productivity enhancement through *in-situ* rainwater harvesting

Development of suitable *in-situ* water harvesting mechanisms is important for improving the productivity from rainfed areas. The experiments were conducted at Hayathnagar Research Farm for castor-pigeonpea based system. Treatments included - Conventional planting, Conventional planting with vegetable cowpea as intercrop, Paired row planting (60 cm with in pair, 120 cm between pair) and Paired row planting+Intercrop (2 rows intercrop at 40 cm distance) with 3 replications. Pigeonpea and castor were sown during 2nd week of July. An existing ridger and furrow making equipment was used for after making feasible adjustments for making the paired rows with conservation furrows. Results shows that the total rainfall received for the cropping season is about 414 mm out of which about 134 mm was the runoff causing rainfall during the season. Runoff was monitored from the plots and is in the range of 4.5-6% and less than 1% of crop season rainfall for normal planting and paired row planting with ridger, respectively. The threshold rainfall for causing the runoff is increased with conservation furrows thus reducing the runoff from the field. An existing ridger and furrow making equipment was modified to create larger width furrow (60 cm) and 25 cm depth for creation conservation furrows. The yields recorded are in the range of 600-1800 kg/ha and 801-2235 kg/ha for normal planting and paired row planting with ridger, respectively.

2.3.3 Development of cost effective water management system for selected crops in alfisol

The present study is an attempt to develop an economical and efficient alternative to the water lifting and high pressure requiring irrigation system by enabling perfect match between the water available and area under command that could be extensively used for small scale vegetable production.

The developed irrigation system includes three broad components namely, solar power generation system, water lifting system and water distribution using water emitting devices operated through gravity. In order to reduce the total setup cost of the pump and minimize the maintenance problem, the pump was redesigned and developed by converting it into DC operated. In this way the setup cost was reduced by 25%. The new developed pump has discharge capacity of 700 litre per house with suction and delivery head of 1.0 m and 2.5 meter respectively.

Newly developed irrigation pump in operation

2.3.4 Development of DSS for real time water balance

The water balance modeling is of paramount importance as it forms the basis for several water related studies namely, hydrological systems modeling, water management at both farm and regional scale, soil-plant-water relationship, crop growth modeling etc. The DSS model has been developed and tested for the 50th meteorological week of year 2011. Daily climatic data of the concern week for 320 locations were collected from IMD-AWS data portal. Two separate databases were created for potential evapotranspiration as well as for rainfall. Both databases was further interpolated to 2 km X 2 km grid and overlaid.

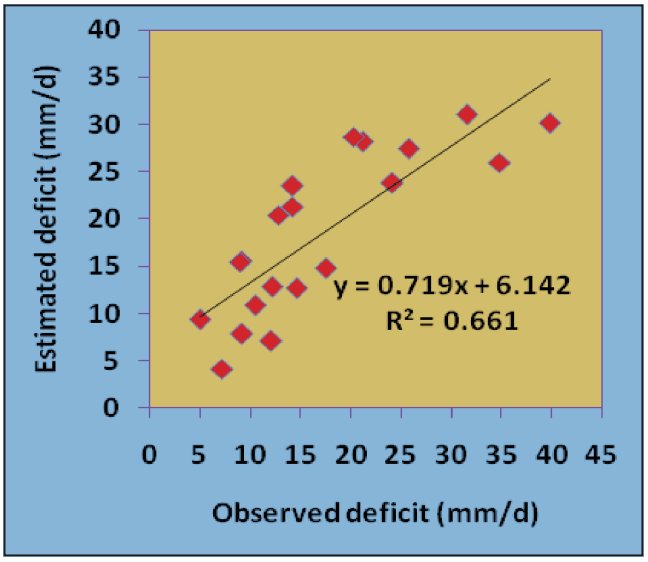
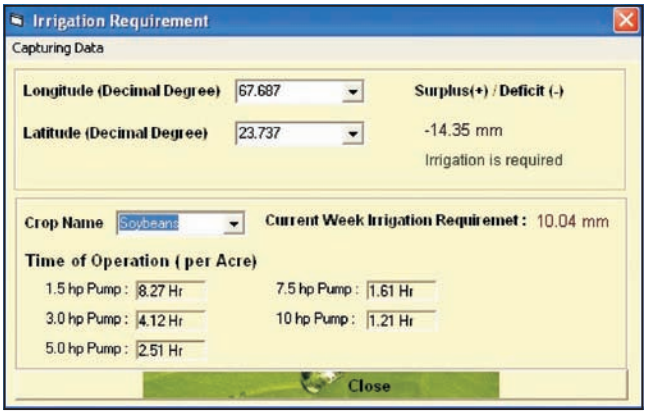


Fig. 10. Scatter plot of observed and DSS estimated values



Database management and retrieval system

The resultant database of water balance (surplus or deficit) was thus deduced and arranged in such a way that it could be retrieved using latitude and longitude of the location under interest. The DSS model was tested at 20 locations. Fairly good agreement between observed and DSS estimated values (Fig 10). The graphic user interface (GUI) was also developed to facilitate quick retrieval of information.

2.4 Crops and cropping systems

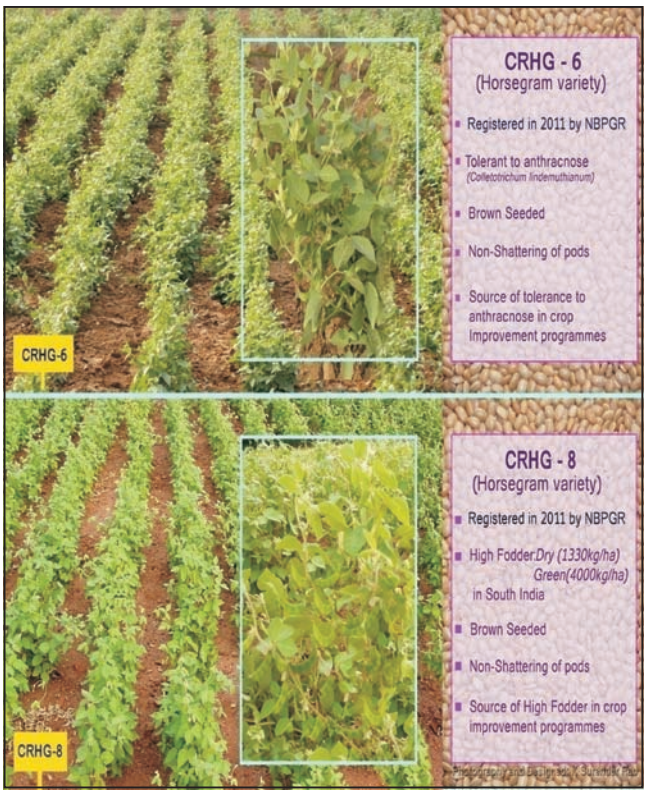
2.4.1 Evaluation of horsegram mutants in multi-locational AICRP trials

Horsegram is an important drought resistant dual purpose crop cultivated mainly in the tropics. The biomass of horsegram is highly nutritious and is used as fodder for livestock. Two horsegram mutants (Table 11) were registered with NBPGR, Delhi during 2011. They are i) CRHG-6: it is tolerant to anthracnose, a major disease of horsegram which can also infect other pulses like cowpea, blackgram, beans etc. This mutant can serve as a source of tolerance to anthracnose in crop improvement programs. ii) CRHG-8: it gives high fodder yield under rainfed conditions.

Table 11 : Salient features of CRHG-6 and CRHG-8

Parameter	CRHG-6	CRHG-8
Plant type	Semi-compact	Compact
Plant height (cm)	40	40
Branching pattern	Semi erect	Erect
No of branches/plant	4	5
Pods/plant (no)	32.6	24.0
Seeds/pod (no)	6	4.5
100 seed weight(g)	3	3.3
Seed colour	Brown	Brown
Days to 50% flowering	53	53
Days to to maturity	96	99

Advanced lines of horsegram were evaluated under two trials (AVT-II and IVT) during 2011. Three promising lines from CRIDA were identified viz. CRIDA 19, CRIDA 20 and CRIDA 21 and variety release proposals will be submitted to central variety release committee (CVRC) for possible release for their cultivation for either entire India or south India. Horsegram varieties released by CRIDA namely CRIDA 18R and CRHG 4 were taken to the farmers fields in several districts of Andhra Pradesh through various agricultural research stations and DAATTC of ANGRAU and state Dept of agriculture. Similarly, promising lines of horsegram (CRIDA 19, CRIDA 20 and CRIDA 21) were evaluated for grain and fodder yield through DAATTC, Nellore; ADA, Darsi, Prakasam district; college of agriculture, Mahanandi (ANGRAU) and KVK-CRIDA. These varieties gave 20-25% more yield across locations over local horsegram and promising lines yielded about 35-40% more grain yield (800-1000 kg/ha) than local varieties.



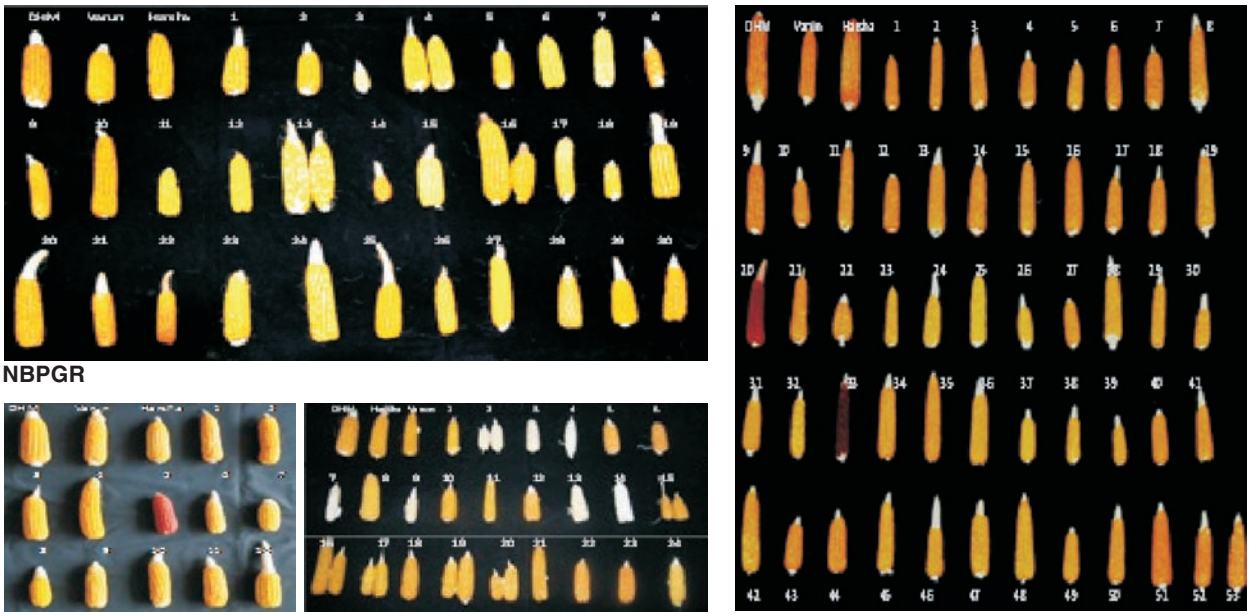
Salient features of CRHG-6 and CRHG-8

2.4.2 Field evaluation of maize for moisture stress tolerance

The experiment was conducted during *kharif*, 2011 with 33 genotypes (from Directorate of Maize Research, New Delhi) including three checks viz. DHM-117 (hybrid), Varun and Harsha (varieties) to evaluate their performance under rainfed conditions. The best check was DHM-117 (140.9 g/plant). The superiority over best check was found in three genotypes viz. DM-17, DM-25 and DM-14 (Table 12). The superiority of these genotypes over check was 34.7, 27.4 and 12.5%, respectively. About 17 rainy days were observed during crop season (107 days). A rainfall of 45.2, 38.4 and 56.0 mm was received on 26.7.2011, 25.8.2011 and 2.9.2011, respectively. There was no rainfall for about 13 days during vegetative stage (21-33 DAS) and about 22 days during flowering and post-flowering stage of the crop (55-77 DAS), which is a critical moisture stress stage.

Table 12 : Performance of maize genotypes under rainfed conditions

Sl. No.	Pedi-gree	Grain yield (g/plant)	Sl. No.	Pedi-gree	Grain yield (g/plant)
1	DM-2	82.4	18	DM-19	40.7
2	DM-3	39.6	19	DM-20	121.4
3	DM-4	6.7	20	DM-21	113.6
4	DM-5	109.1	21	DM-22	55.8
5	DM-6	65.3	22	DM-23	75.7
6	DM-7	101.5	23	DM-24	64.2
7	DM-8	71.9	24	DM-25	193.9
8	DM-9	59.5	25	DM-26	92.4
9	DM-10	51.8	26	DM-27	78.2
10	DM-11	67.0	27	DM-28	124.3
11	DM-12	73.7	28	DM-29	94.4
12	DM-13	87.2	29	DM-30	72.5
13	DM-14	161.1	30	DM-31	67.8
14	DM-15	25.8	31	DHM-117	140.9
15	DM-16	97.9	32	Varun	131.2
16	DM-17	215.7	33	Harsha	120.6
17	DM-18	79.1			



Germplasm of maize from various sources

Studies on tillering maize

Maize genotypes with 1 to 5 tillers are being developed. Studies on screening for effective tillers (tillers with cobs) are in progress (*rabi*, 2011-12) at HRF. Plants with tall tillers are also being selected for their future use as fodder varieties.

Tillering of mother plant with three tillers

Tillering of mother plant with five tillers

2.4.3 Drought tolerance in blackgram genotypes

An experiment was conducted during *kharif*, 2011 at HRF with 19 genotypes including 4 checks (PU-19, LBG-20, T-9 and Local-1). The best check was PU-19 (1.68 g/plant). The superiority over best check was found in 10 genotypes (Table 13). The percentage of superiority ranged from 2.8 to 32.7% in different genotypes. The 10 superior yielding genotypes over best check were V-5 (32.7%), V-15 (26.2%), V-7 (22.5%), V-1 (16.7%), V-13 (13.7%), V-14 (10.1%), V-8 (9.34%), V-4 (7.14%), V-6 (3.75%), and V-12 (2.8%). About 19 rainy days were observed during crop season (75 days). However, runoff events of 116.3 mm on 22.8.2011, 49 mm on 26.7.2011 and 48 mm on 21.8.2011 were observed. There was no rainfall for about 16 days during pre-flowering and early flowering stage (20-36 DAS), which is a very critical stage for moisture stress.

Table 13 : Yield components of blackgram genotypes

Genotypes	Pedegree	Grain yield (g/plant)	Fodder yield (g/plant)	Pods/ plant
V1	PSR-3798	1.952	1.62	8.9
V2	KARS-235	1.611	1.50	7.2
V3	KARS-012	1.418	1.49	6.5
V4	SKN-138	1.800	1.56	8.6
V5	KDRS-251	2.231	2.36	7.1
V6	SKN-158	1.742	1.84	8.7
V7	PSR-254/B	2.058	2.22	8.4
V8	PSR-001	1.836	1.89	8.4
V9	CN-9078	0.877	0.88	4.2
V10	KARS-268	0.876	1.47	4.1
V11	KARS-112	1.209	1.73	6.7
V12	KARS-170	1.724	3.80	7.7
V13	SK-023	1.907	6.07	6.6
V14	CN-9013	1.884	2.08	7.9
V15	KARS-157	2.121	2.46	9.3
V16©	PU-19 (c)	1.680	1.97	7.9
V17©	LBG-20 (c)	1.600	2.29	7.0
V18©	T-9 (c)	1.357	2.02	7.3
V19©	LOCAL-1	0.939	0.56	5.4

2.4.4 Enhancing tolerance of sorghum to abiotic stresses through genetic manipulation

Development of stress tolerant genotypes of sorghum to stabilize the productivity of drylands is of immediate priority. Sorghum cv 'SPV 462' was transformed with mtlD gene using biolistic gun method. Transgenic sorghum lines having stabilized mtlD gene were taken to maturity for advancing after thorough molecular and physiological characterization of events. Confined field trial for event selection with six individuals transgenic events and one untransformed control line of 'SPV 462' was carried out in *kharif*, 2011 as approved by genetic engineering approval committee (GEAC), Government of India. The experiment was conducted under protective net as per DBT guidelines for event selection trials. Each event was replicated thrice under irrigated and dryland treatments. PCR and RT-PCR analysis of the transgenics using *mtlD* gene specific primers revealed the presence of 800bp product confirming the carry forward of the integrated *mtlD* transgene

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

b. Transgenic sorghum under protective net

Confined field trial for event selection of transgenic sorghum with *mtlD* gene

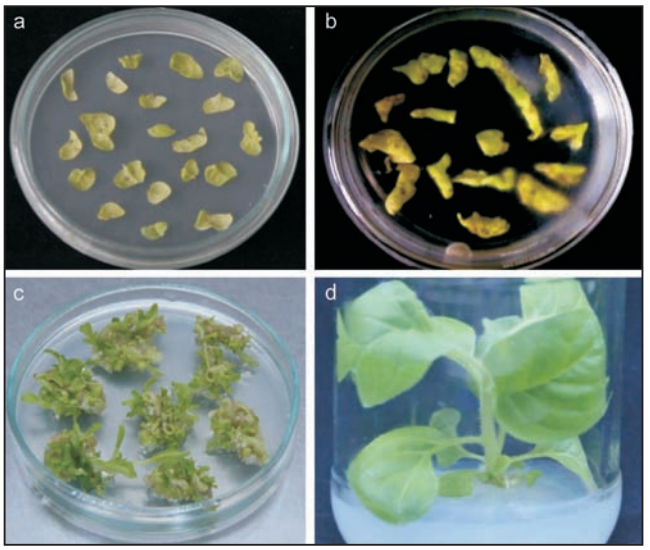
while untransformed control did not show such band. Observations on stomatal conductance, leaf temperature, canopy temperature, relative humidity, chlorophyll, leaf area, shoot length, and total biomass were recorded at vegetative, anthesis and reproductive stage. ELWRC was also carried out at 49 DAS. The capacity to retain water upon excision as determined by excised leaf water retention capacity was better in mtlD CRIDA 4-7-1-7-4, mtlD CRIDA 1-6-1-8-4 and mtlD CRIDA 3-3-18-7-2 than the untransformed control (SPV 462). In general, stomatal conductance was low under water stressed conditions and mtlD CRIDA 1-6-1-8-4, mtlD CRIDA 26-1-11-6-1 and CRIDA 75-2-21-2-1 were better in maintaining stomatal conductance under stress conditions. The transgenics maintained lower leaf temperature and cooler canopy under both well watered and water stressed conditions when compared to untransformed control. Chlorophyll content was highest in mtlD CRIDA 75-2-21-2-1 and 26-1-11-6-1. The highest shoot length was recorded with mtlD CRIDA 26-1-11-6-1. mtlD CRIDA 1-6-1-8-4 and mtlD CRIDA 3-3-18-7-2 reached anthesis earlier than untransformed control SPV462. mtlD CRIDA 3-3-18-7-2 and mtlD CRIDA 75-2-21-2-1 maintained higher yield when compared to untransformed control and other transgenics. Among the genotypes significant differences were observed in total biomass and harvest index.

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

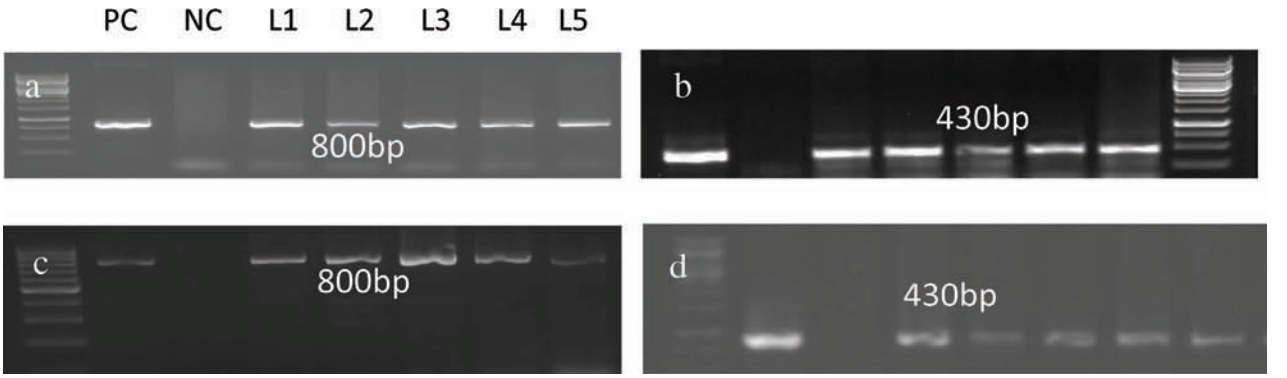
Identification of stress inducible genes and promoters from important dryland crops and their experimental analysis and functional validation in improving abiotic stress tolerance is an important objective in managing abiotic stress tolerance in dryland crops. PCR-based gene cloning and suppression subtractive hybridization approaches were used to clone important genes having role in abiotic stress tolerance. c-DNA clones induced under water deficit and high temperature stresses were characterized to elucidate their role. Sequences analyzed were matched for homology with available databases in NCBI.

Validation of dehydrin gene in tobacco Agrobacterium mediated genetic transformation

The gene construct containing DHNpCAMBIA1303 was transformed into *Agrobacterium tumefaciens* strain LBA4404. The transformed culture was used for the validation of dehydrin gene by expressing it in tobacco plants through *Agrobacterium* mediated genetic transformation. For tobacco transformation, seeds were sterilized thrice with 70% ethanol for 2 min and then twice with sterile water, blotted dry and inoculated on half MS media for 15 days. The leaves grown under sterile conditions were cut into pieces of explants which were incubated on tobacco shoot induction medium (MS media containing NAA (0.1 mg/l) and BAP (1 mg/l) at 25°C under a 12h photoperiod for 2 days for preconditioning. Then these explants were soaked in *Agrobacterium* LBA4404 cell culture containing DHN gene construct for 10 min followed by co-cultivation on TSM medium for 5 days. After washing with sterile water supplemented with (250 mg/ml) cefotoxamine, the explants were transferred



Agro-infected leaf discs growing on co-cultivation media (a) and selection media (b), shoot emergence (c) and elongating shoots (d)



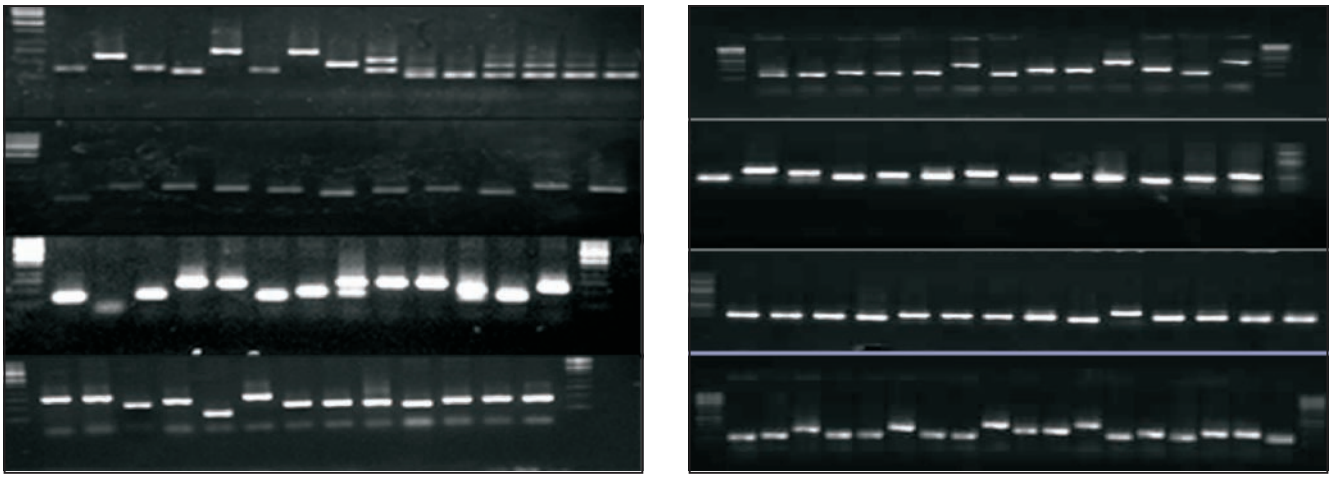
PCR and RT-PCR analysis using hpt primers (a, c) and dehydrin primers (b,d) PC: Positive control, NC: Negative control, L1-L5: Line1-Line5

PCR and RT-PCR confirmation of dehydrin transgenics with hpt and dehydrin primers

onto selection medium containing TSM supplemented with hygromycin (50 mg/ml) and cefotoxamine. After 3 weeks, the regenerated shoots were transformed onto rooting media containing plain MS medium. Rooted plantlets were planted in soil and grown in glasshouse at 23±1^{o}C under a 12h photoperiod. Untransformed control was also maintained along with the transformed plants. PCR and RT-PCR analysis was carried out using genomic DNA and total RNA isolated respectively from wild type (WT) and transgenic tobacco lines. Amplification of 800bp and 430bp products with hpt and dehydrin primers revealed the insertion of dehydrin gene into tobacco plants. Thus, PCR and RT-PCR analysis confirmed the successful transformation of dehydrin gene in tobacco plants.

Isolation of water-deficit stress induced genes from Pennisetum glaucum by Suppression Subtractive Hybridization

Two high quality subtractive cDNA libraries (water-deficit and high temperature stress-induced) have been constructed from the 24 h stressed pearl millet seedlings. Assesment of RWC, proline accumulation and membrane stability index (MSI) indicated that stress induced was sufficient for the maximum expression of stress-inducible genes. Appearance of colonies on LB agar containing ampicillin selection pressure indicated that the stress induced cDNA libraries have been successfully constructed. Colony PCR analysis of the cDNA clones randomly screened from the libraries resulted in the amplification of PCR products ranging from 250-1000bp. Of the 202 and 158 ESTS analyzed from water-deficit and high temperature stressed libraries, 77 and 83% of the clones were identified to be stress responsive in nature, respectively. In water-deficit library, mostly dehydrins, HVA22, Lea and early response to dehydration genes were found to be induced indicating their role in water-deficit stress tolerance. Induction of more Hsp70, Hsp90 and Chaperones in high temperature stressed library indicated their involvement in high temperature stress tolerance. About 13-15% of the transcriptomes contained uncharacterized genes that provide new candidate genes for investigation to elucidate their role in stress tolerance. Among the sequences analyzed, 6 genes were identified to be commonly induced in both the libraries, while 104 and 102 genes were specifically induced in water-deficit and high temperature stresses, respectively. In water-deficit stressed library, two of the sequences showed no homology to any of the sequences in NCBI databases hence were considered as unknown genes.



Screening of stress induced cDNA libraries – water deficit (left) and high temperature (right)

2.4.6 Genetic transformation of greengram for enhancing abiotic stress tolerance

Drought is one of the important abiotic stresses severely affecting crop growth and productivity under rainfed agriculture. Absence of sufficient and satisfactory level of genetic variability is the major hurdle in greengram improvement by conventional breeding. Present study was aimed at over-expression of *annexin Bj1* gene in greengram to enhance its abiotic stress tolerance. Double cotyledonary node (DCN) explants derived from three-day-old seedlings of variety ML 267 were transformed using *pCAMBIA 2301+annexin* gene construct through *Agrobacterium* mediated approach. Primary putative transformants (T_0) selected on kanamycin containing regeneration medium were taken to maturity for generation advancement after PCR verification using *npt II* and *annexin* gene specific primers. Only the PCR confirmed transgenic material was taken to maturity for advancing the generation. Currently the transgenic material generated is being characterized by PCR for confirming the integration of transgene using *annexin* gene specific primers. Simultaneously, attempts to generate more number of events were continued to develop a transgenic greengram with *annexin* gene.

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

Light energy absorbed by light-harvesting complex (LHC) is transferred to the reaction centres by various photochemical processes and about 3-9% of the light energy absorbed by chlorophyll pigments is re-emitted as fluorescence. By measuring the intensity and nature of this fluorescence, plant response to abiotic stress can be investigated. A study was undertaken to identify superior genotypes with drought acclimation characters by studying the relationship between chlorophyll fluorescence, carbon assimilation and drought tolerance in selected dryland crops. Further, correlations between growth, development and yield were analyzed in relation to photosynthetic and gas exchanges parameters of the plants. Levels of fluorescence in Photosystem II (PSII) photochemistry under reduced plastoquinone (QA) and maximum quantum efficiency of PSII photochemistry was significantly higher in control as compared to stressed maize ('Varun') plants during Anthesis Silking Interval (ASI). This indicates that there were more closed centres of PSII in the stressed plants. Quantum yield of PSII expressed as number of fluorescent events for each photon absorbed and proportion of open PSII under oxidized QA was also significantly higher in control as compared to stressed maize plants during ASI. Chlorophyll

fluorescence induction kinetics (Fig. 11) indicated that effective antenna size and the activity of the donor side of PSII was affected by stress. Non photochemical quenching (NPQ) representing the apparent rate constant for heat loss from PSII indicated that the apparent rate constant for heat loss from PSII was higher in stressed plants thus reducing PSII efficiency (Fig. 12)

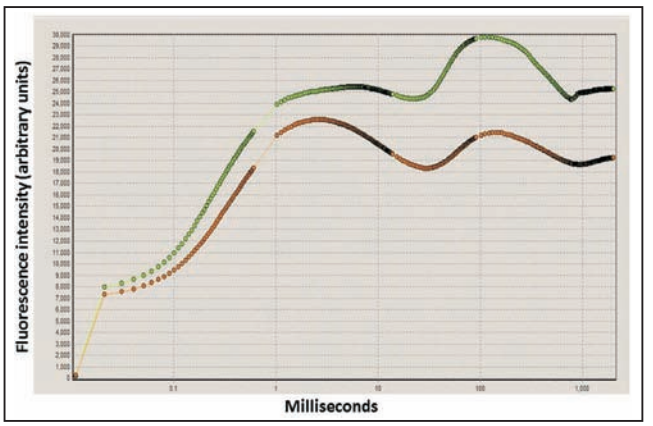


Fig. 11. Chlorophyll Fluorescence Induction Kinetics-OJIP transients, plotted on logarithmic scale at 0.05ms (O), 2ms (J), 30ms (I) and maximal (P) in control (green) and stressed (brown) maize var. Varun during Anthesis Silking Interval

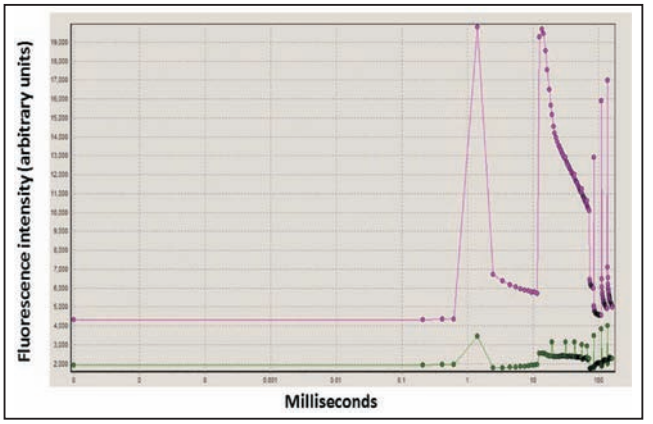


Fig. 12. Non Photochemical Quenching (NPQ) representing the apparent rate constant for heat loss from PSII plotted on logarithmic in control (green) and stressed (violet) maize (var. Varun) during Anthesis Silking Interval

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

During drought, root system of the plant is the interface between soil and drought. Hence, it is essential to understand the root dynamics and its concomitant effect on shoot parameters under varied drought situations which help us in monitoring drought impact and possible manipulation to some extent. Horsegram being a crop grown under receding soil moisture conditions, its performance to survive and yield was studied in the context of management strategy under varied resource availability in rainfed lands. Two varieties of CRIDA horsegram varieties (CRIDA18R and CRHG04) and a local cultivar from Mahabubnagar were grown under receding soil moisture conditions during 1st fortnight of October as a sequence crop to greengram in *kharif*, 2011. Trench method of plant root sampling was followed. CRHG04 with taller plants, more leaf area, high root to shoot ratio (0.449) and more rooting depth (5-10cm) than CRIDA 18R

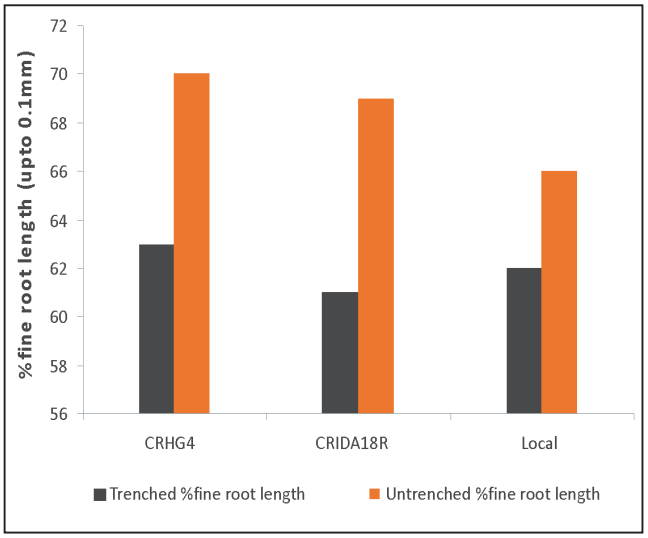


Fig. 13. Comparative performance of horsegram cultivars in relation to fine root length (cm) as influenced by *kharif* trenching

and local cultivar, yielded more stover yield than seed yield. There were no significant differences in yields as the crop received a total rainfall of just 26 mm in two rainy days. Excavated root system of horsegram grown in untrenched (no trenches dug) plots generated more fine root length than the crop grown in trenched plots (Fig. 13) relative to total root length. Therefore, compactness and the moisture stress forced the crop to produce more fine roots to encounter the stresses.

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

Rainfall amount and its distribution play a critical role in rainfed agriculture and invariably drought is a regular phenomenon. With the imposition of soil management measures for drought, crops express varied rooting patterns. Therefore, study on root proliferation while encountering moisture stress play critical role in understanding their contribution towards the abiotic stress management under field conditions. A field experiment consisting of two greengram cultivars (ML267 and WGG37) was sown with and without conservation furrow on 15th July, 2011. Plant root sampling was carried out by trench method both along the row as well as across the row. Root length was measured using WinRHIZO version 2009c. Formation of conservation furrow (CF) for every three rows of crop plants resulted in additional rooting depth of 5 cm, more total root length (TRL) and distribution of more root length to the deeper soil layers in the plant adjacent to CF than the plant in the middle row to CF. This impact was observed during 2011 up to 42 DAS irrespective of the variety. However, no explicit impact of CF was observed on the adjacent as well as on the middle row plants to CF at later stages of crop growth which might be due to receipt of only 46 mm rainfall during this period. Similar trend was observed with the CF treated plant when compared to No CF plot plant. Between the varieties, ML267 registered additional rooting depth of 10 cm in the plant adjacent to CF over the plant in the middle row to CF while WGG37 recorded similar rooting depths in both the plant positions. Both the varieties registered increased TRL in the adjacent plant to CF over the middle row plant at 42 DAS, but the increase was more with WGG37. Distribution of more root length to 10-20 cm soil depth of ML267 in comparison with the maximum root length at top 5-15 cm soil depth in case of WGG37 irrespective of the position of the plant in the initial stages of crop growth stresses the root proliferating ability of ML267 at deeper soil depths as a strategy of the plant to manage drought while the trend was not clear in case of second stage (Fig. 14).

Improved root growth in the adjacent row plant (left) over the middle row plant of CF (right) in WGG 37 at initial stages of crop growth

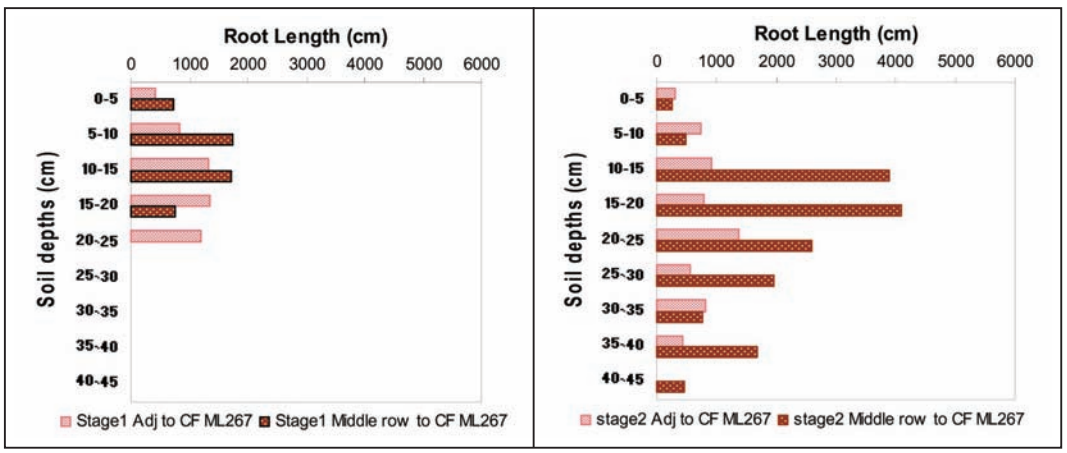


Fig. 14. Depth-wise distribution of root length (cm) in ML 267 at two growth stages

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

Performance of different crops under organic and conventional management

Organic agriculture is one of the fastest growing sectors of agricultural production. A field experiment was conducted during *kharif* 2011, the second year of experiment, at GRF of the Institute to evaluate the comparative performance of sesame, sunflower and pigeonpea under organic and conventional production systems. An unamended check was also included in the study. The experiment was laid out in a split-plot design with three production systems in main plots and crops in sub-plots. In the plots under organic management, farmyard manure was applied on the N equivalent basis to all the three crops and the P requirement was supplemented through rock phosphate. In general, the performance of sesame and pigeonpea was poor in all the treatments due to moisture stress at flowering and pod formation stages. Conventional management gave higher yield of all the three crops (sunflower, pigeonpea and sesame) compared to organic management. The yield reduction in plots under organic production was 13.1% in sunflower, 4.7% in pigeon pea and 15.4% in sesame (Fig. 15).

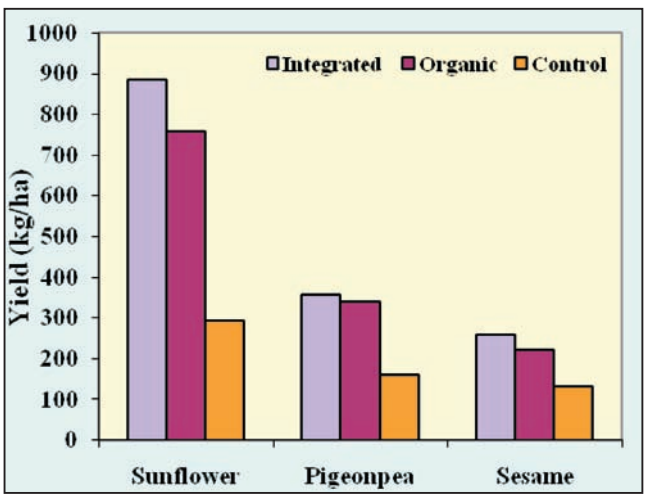


Fig. 15. Comparative performance of crops under different production systems

Performance of sunflower and pigeonpea under different spacing and nutrient management levels

The effects of crop density on the yield of crops are well established under conventional production systems. However, this information is not available for crops grown under organic management. Field experiments were conducted during *kharif* 2011, at GRF of the Institute to optimize the plant population of sunflower and pigeon pea under organic management. The experiment included three levels of plant population viz. recommended (P_1), 80% recommended (P_2) and 120% recommended (P_3), and four levels of nutrient management viz. 100 (F_1), 125 (F_2) and 150% (F_3) equivalent of recommended NP through FYM and rock phosphate. In addition, one fertilizer treatment (F_4) was also included as a check. In general, pigeonpea yields were poor in all the treatments due to moisture stress. Different plant population levels had no significant effect on pigeonpea yield. In sunflower, the seed yield was 11.7% higher at higher plant population and 5.8% less yield at lower plant population than that of recommended plant population (Fig. 16).

Among different fertility levels, fertilizer treatment gave marginally higher yields of both sunflower and pigeonpea compared to treatments involving

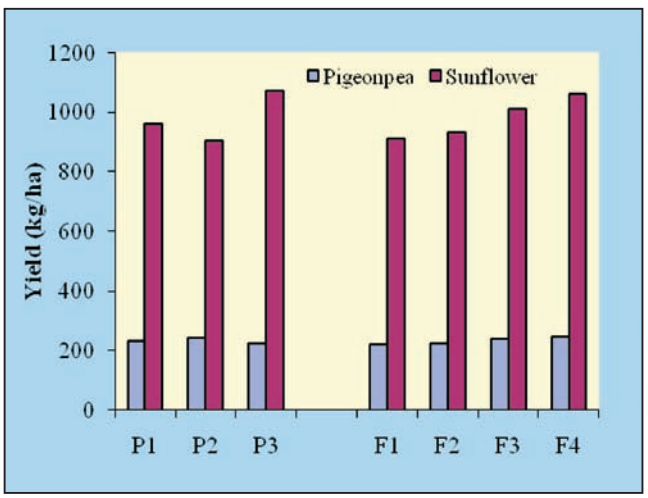


Fig. 16. Influence of plant population and fertility levels on yield of sunflower and pigeonpea

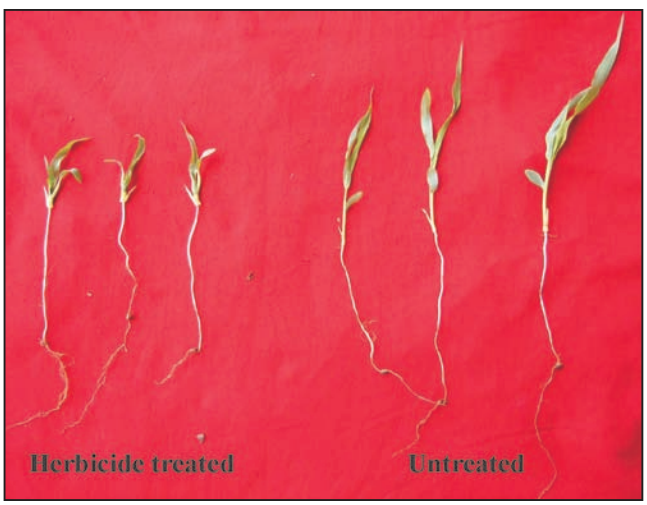
organic amendments. In pigeon pea, the seed yield was 10.6% less in the plots under 100% NP through organic amendments compared with fertilizer treatment. The seed yield increased with increase in application rate of organic amendments and application of 150% NP through organic amendments gave 3% lower yield than fertilizer treatment. In sunflower, application of 100% equivalent of rec. NP through organic amendments gave 14.2% lower seed yield compared to fertilizer treatment. The seed yields increased with increase in application rates of organic amendments. At higher application rate (150%) of organic amendments, the seed yield of sunflower was similar to that of fertilizer treatment.

2.4.11 Integrated weed management in reduced/ zero tillage crop production

Weed species shifts and losses in crop yields as a result of increased weed densities have been cited as major reasons why conservation tillage systems have not enjoyed widespread adoption. A field experiment was conducted to evaluate effect of different weed control methods in sorghum + pigeon pea intercropping system, for their weed control efficacy and on crop productivity under conventional (CT), reduced (RT) and zero tillage (ZT) systems. Sorghum + pigeon pea (intercropping in 2:1 ratio) were grown as test crops during *kharif* 2011 at GRF of the Institute with three tillage treatments viz. CT, RT and ZT in main plots and four weed control treatments viz. herbicide (T_1), hand weeding twice (T_2), herbicide + hand weeding (T_3), and weedy check (T_4) in sub-plots. There was a complete failure of pigeonpea due to drought. The performance of sorghum was better under conventional tillage than other tillage treatments (Fig. 17). The grain yield was reduced by 20.6 and 27.4% under reduced and zero tillage systems, respectively compared to conventional tillage (12.5 q/ha). This was mainly due to more weed infestation under reduced (7.3%) and zero tillage (10.8%) systems.

On average, the sorghum yield decreased by 74.6% due to season-long weed-crop competition in weedy check plots. Among the weed control treatments, the highest weed-control efficiency (91.8%) was achieved with hand weeding twice (20 & 40 days after sowing) closely followed by application of pendimethalin + hand weeding (88.8%). However, application of pendimethalin at 1.0 kg/ha severely affected the germination and initial growth of sorghum. Hence, hand weeding treatment gave higher grain yield of sorghum (16.2 q/ha) than other treatments.

Another field experiment was conducted to evaluate the effect of pendimathalin at different



Effect of pendimethalin application on sorghum

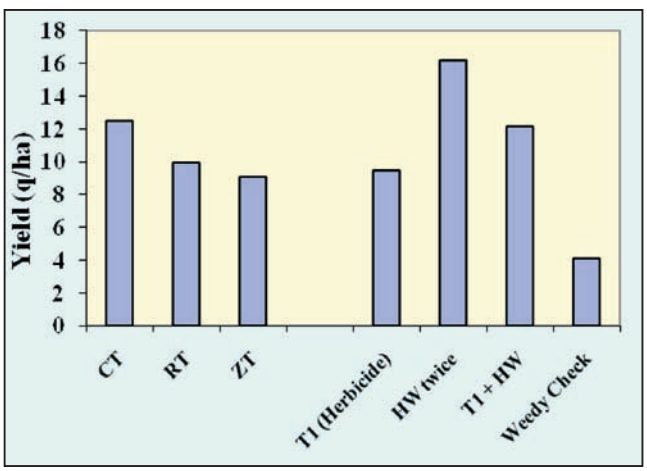


Fig. 17. Performance of sorghum under different tillage and weed control treatments

doses (0.5, 0.75 and 1.0 kg/ha) on weeds and productivity of sorghum + pigeonpea intercropping. In general, the germination of sorghum hybrid 'CSH-16' was higher than other cultivars. A gradual decrease in germination of all the three sorghum cultivars was observed with increase in pendimethalin dose from 0.5 to 1.0 kg/ha. Application of pendimethalin at 1.0 kg/ha gave higher weed control efficiency (68%) while its lower doses had less effect on weeds (41-57%). On average, hand weeded plots gave higher grain yield of sorghum than other treatments. Among herbicide treatments, application of pendimethalin at 0.75 kg/ha gave higher yield but further increase in application rate (1.0 kg/ha) resulted in lower grain yield (Fig. 18). There was a complete failure of pigeonpea due to drought.

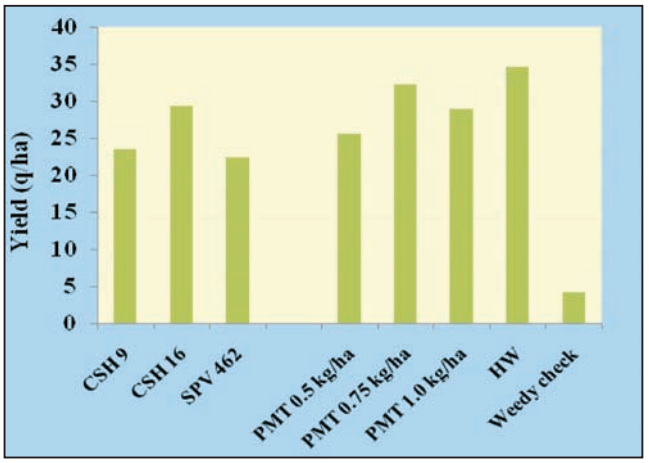


Fig. 18. Effect of pendimethalin on grain yield of sorghum cultivars

2.4.12 Characterization of biotic stress in rainfed crops using hyperspectral radiometry

Remote sensing for detection of biotic stress is based on the assumption that stresses induced by pests and diseases interferes with photosynthesis and physical structure of the plant, thereby affects the absorption of light energy and thus alter the reflectance spectrum of the plants. Studies were aimed to characterize the reflectance spectra of cotton and blackgram canopies under stress due to pest and disease infestation, identify sensitive spectral bands and develop models for damage assessment using identified hyperspectral indices. Fields were selected where a natural incidence of pest/disease outbreak was noticed, and sufficient number of plants with varying levels of infestation was available. Canopy reflectance data was recorded with FieldSpec 3 Hi-Res spectroradiometer (ASD Inc., Boulder, USA; spectral range: 350-2500 nm). After measuring the reflectance, the uppermost fully expanded leaf was collected from each plant for estimating chlorophyll and relative water content. The digital number (DN) values were converted to reflectance using the ASD ViewSpecPro software. Sensitive bands were identified by reflectance sensitivity analysis. The identified sensitive bands were used to build new indices specific to the stress. A significant reduction in leaf chlorophyll and relative water content was observed with increasing levels of mealybug infestation in cotton. Paired *t* test comparison of percent reflectance at broad-bands between healthy and severely infested plants showed that red (630-690 nm), near infra-red (760-900 nm) and mid infra-red (1550-1750 nm) were significantly different compared to other regions of the electromagnetic spectrum. Further, reflectance sensitivity analysis of the hyperspectral data revealed that the bands at 396, 492, 674, 1454 nm had positive peaks and bands at 550 and 768 nm had negative peaks, and hence all these six narrow bands are considered sensitive to mealybug infestation. Mealybug stress indices (MSIs) were developed using two or more of the identified sensitive bands, and were tested using multinomial logistic regression (MLR) analysis. Results showed that the MSIs were superior (R^2 = 0.82) to all other stress related spectral indices tested. Further, validation of the proposed MLR models using two independent field data sets, with one of the MSI as independent variable showed that the overall percent correct classification of cotton plants into different mealybug severity grades in the two fields was in the range of 38.3 and 54.9. Furthermore, high classification accuracy for Grade 1 (up to

Table 14 : Effect of mealybug infestation on chlorophyll and relative water content (RWC) in cotton

Mealybug Severity	Chl *a* (mg/g)	Chl *b* (mg/g)	Chl *a+b* (mg/g)	Chl *a:b*	RWC (%)
Grade 0	1.44	0.42	1.87	3.43	73.80
Grade 1	1.27	0.36	1.63	3.69	72.37
Grade 2	1.02	0.35	1.38b	2.95	64.51
Grade 3	1.01	0.29	1.31	3.57	63.88
Grade 4	0.88	0.31	1.20	2.95	56.46
Pr > F	<0.0001	0.0013	<0.0001	0.0763	<0.0001
LSD (95%)	0.26	0.08	0.30	0.92	6.82

81.8 %) showed that these models are capable of early detection of this pest. Thus, the proposed MSIs could find potential use in remote sensing of damage and spread of the solenopsis mealybug in cotton.

Reflectance at 669, 505 and 510 nm was sensitive to mosaic severity in blackgram (Fig. 19). There was a significant decrease in leaf chlorophyll (p <0.0001) with increase in disease severity, while no such relationship was observed for relative water content. By plotting coefficient of determination (R^2) between leaf chlorophyll and percent reflectance at one nm wavelength interval, two individual bands (R_{571}; R_{705}) and two band ratios (R_{571}/R_{721} ; R_{705}/R_{593}) with highest R^2 values were selected. These bands showed a significant linear relationship with

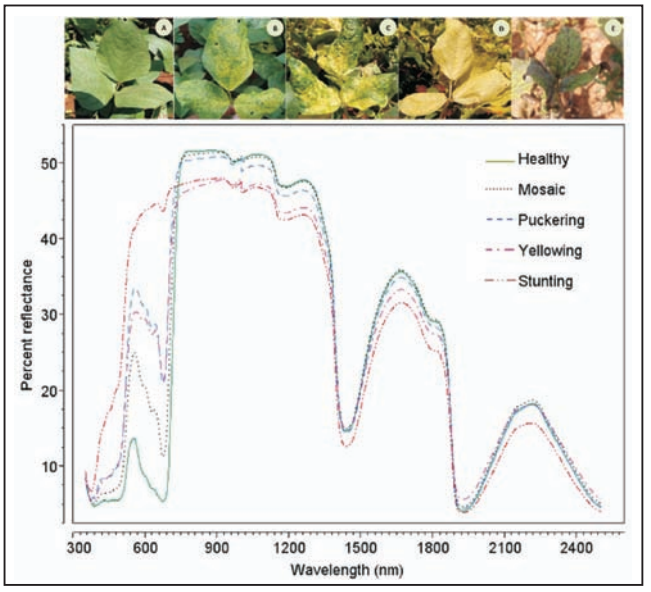
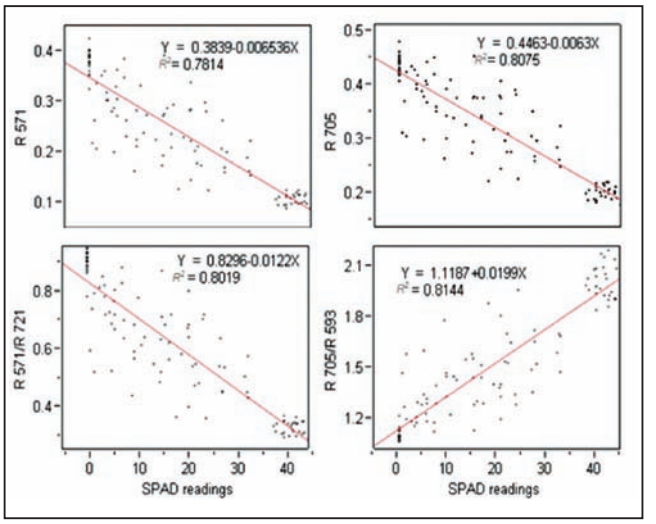


Fig. 19. Mean reflectance spectra of plants affected by blackgram yellow mosaic disease



Optimum spectral bands for estimating loss of leaf chlorophyll due to YMD in blackgram

SPAD readings (R^2 range 0.78 to 0.81). Further, the relationship was stronger for band ratios compared to single bands. With optimal band ratios as inputs, YMD disease prediction models were built using multinomial logistic regression (MLR) technique. Based on model fit statistics (AIC, SC, R^2 and Max-Rescaled R^2) reflectance ratios R_{571}/R_{721} and R_{705}/R_{593} were identified as they better explain the variation in the response variable 'disease severity grade' than the individual band reflectance (R_{571}; R_{705}).

Productivity and spectral response of safflower genotypes in response to varied soil moisture gradients

Remote sensing using ground based radiometry provide data for non-destructive and rapid estimation of biophysical parameters in several

Pearson correlation between narrow-band NDVI* and LAI with dry matter, seed yield and biomass of safflower

Parameter	50 DAS (24-11-2010)		73 DAS (17-12-2010)		92 DAS (06-01-2011)		122 DAS (05-02-2011)	
	NDVI	LAI	NDVI	LAI	NDVI	LAI	NDVI	LAI
Dry matter	0.447	0.544	0.656	0.652	0.474	0.501	0.195^{NS}	0.614
Seed yield	0.385	0.572	0.605	0.636	0.421	0.499	0.149^{NS}	0.607
Biomass	0.378	0.561	0.606	0.649	0.459	0.49	0.195^{NS}	0.614

*NDVI: $(R_{800}-R_{670})/(R_{800}+R_{670})$

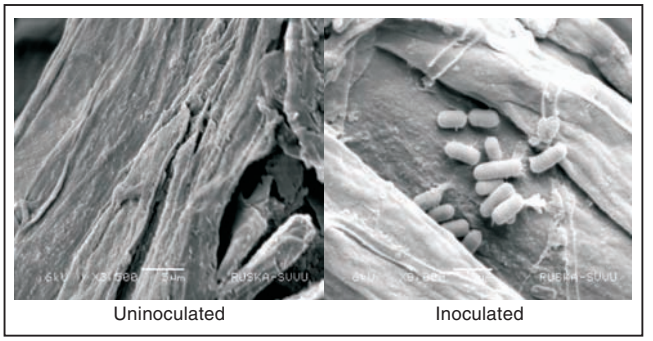
crops. Studies were conducted on retrieval of biophysical parameters and assessment of *Alternaria* disease severity in safflower (*Carthamus tinctorius* L.) using ground-based hyperspectral radiometry. The experiment was conducted during post rainy season with eight safflower cultivars grown under three depths. The plot size was 4.5 × 4 m. Crop was raised as rainfed following recommended agronomic practices. Data on canopy reflectance, leaf chlorophyll, leaf area index and dry matter were recorded at elongation, flower initiation, flowering and seed filling stages from all the plots, while yield and biomass were measured at harvest. Observations on *Alternaria* disease spectra were recorded only once during seed filling stage, when sufficient plant samples with different levels of disease were available. Results showed that normalised pigment to chlorophyll index (NPCI) had highest correlation (r= 0.78) with the measured chlorophyll. Regressing the NPCI upon measured chlorophyll resulted in a linear functional relationship (R^2 = 0.6086, $p < 0.001$), which when validated with independent data set showed promising results. NDVI and LAI measured during flower initiation stage (73 DAS) showed strong relation with dry matter, biomass and seed yield. Mean reflectance spectra between healthy and *Alternaria* diseased plants showed a distinct separation of bands in visible, NIR and SWIR regions. Among several hyperspectral indices tested, red edge normalised difference vegetation index $[(R_{750}- R_{705})/(R_{750} + R_{705})]$, normalised pigment chlorophyll index $[(R_{680}-R_{430})/(R_{680}+R_{430})]$ and normalised difference vegetation index $[(R_{800}-R_{670})/(R_{800}+R_{670})]$ were found superior for detection of alternaria disease at early stages of infestation.

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

A field experiment was conducted under rainfed conditions at GRF to evaluate two bacterial consortia [consortium I (P7+B30+G12) and consortium II (P45+B17+G12] in sunflower (DRSF 108) and sorghum (SPV 462). The experiment was conducted in a randomized block design with three replications. In general, the yields were low across all the treatments due to drought during flowering and maturity. Inoculation improved the biomass and seed yield of both crops compared to control treatments. Inoculation with consortium II and I increased sorghum yield by 21 and 10%, respectively. In another experiment, four selected drought tolerant isolates KB 142, KB 129, KB 133 and KB 122 from the new isolates were tested as seed inoculants in sorghum under drought stress conditions. The experiment was conducted in two sets with one set maintained at 50% water holding capacity (WHC) throughout the experiment period and second set maintained at 75% WHC initially followed by water withholding after 27 days of germination. Bacterial inoculation had positive effect on plant growth and biochemical parameters of sorghum (Table 15). Scanning electron micrograph confirmed bacterial colonization on root surface.

Table 15 : Effect of inoculation with *Bacillus* spp. strains on biochemical parameters in sorghum

Treatment	Biochemical parameters							
	Proline (µmol/g FW)	Sugars (mg/g FW)	Chlorophyll (mg/g FW)	RWC (%)	Proline (µmol/g FW)	Sugars (mg/g FW)	Chlorophyll (mg/g FW)	RWC (%)
UI control (no stress)	0.059±0.03	3.48±0.28	4.6±0.08	10.4±0.71	0.059±0.03	3.48±0.28	4.6±0.08	10.4±0.71
	Drought Stress							
	50 % stress				75 % stress			
UI control	0.311±0.18	5.38±0.09	3.7±0.03	5.83±0.16	1.008±0.11	5.66±0.01	3.8±0.02	3.32±0.19
KB 129	0.131±0.02	5.44±0.0	4.1±0.01	6.40±0.16	0.426±0.13	5.42±0.03	4.2±0.02	3.68±0.38
KB 142	0.963±0.09	5.56±0.02	4.4±0.06	6.04±0.38	0.973±0.09	5.58±0.04	4.2±0.04	3.75±0.12
KB 133	0.630±0.3	5.58±0.01	4.0±0.03	6.18±0.22	0.904±0.39	5.52±0.00	3.7±0.04	3.58±0.28
KB 122	0.935±0.12	5.68±0.03	3.7±0.02	5.84±0.23	0.813±0.26	5.48±0.06	3.9±0.06	3.68±0.07



Scanning electron micrograph showing uninoculated (no colonization) and inoculated sorghum root (bacterial colonization)

2.4.14 Diversity of consortia of poly-functional rhizosphere microorganisms for nutrient supply, including tolerance to abiotic stresses in major rainfed production systems and diversity of cowpea and pigeonpea rhizobia

Two potential isolates showing Zn solubilization on solid media were inoculated in liquid medium amended with 500 ppm Zn. After 15 days of incubation, isolates PSB-3 and PSB-1 showed 402.7 ppm (80%) and 374.2 ppm (75%) of solubilized Zn. The Zn solubilization was related with low pH of the medium. The strains were identified as *Burkholderia cepacia* sp. by 16SrDNA analysis.

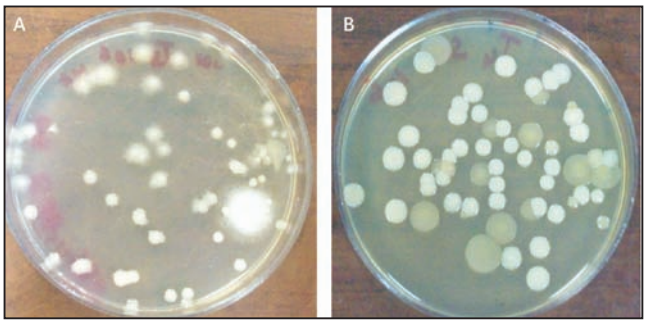
A pot experiment was conducted to study the effect of zinc solubilizing isolates on zinc uptake in sorghum plants. Inoculation with rhizobacterial isolates improved plant growth of sorghum in terms of plant height, biomass, leaf area and chlorophyll content compared to control treatment in both the experimental sets (with and without external $ZnCO_3$ application). Yellowing of leaves and reduced leaf area was observed in the plants with external $ZnCO_3$ application indicating toxic effect of external $ZnCO_3$ application. However, inoculated treatments showed better plant growth as compared to uninoculated plants indicating that microbial treatments can reduce toxicity effects of $ZnCO_3$ to some extent. Inoculation also improved P and Zn uptake significantly in both the experimental sets, but inoculated treatments with external $ZnCO_3$ application showed more than two fold increase in Zn uptake. Further, selected microbial treatments

Zinc solubilization by the rhizobacteria

were tested in sorghum and pigeonpea under field conditions. A mixed inoculums of two strains (AZT21+ P7 for sorghum and AZT21+ R251 for pigeonpea) increased plant growth and yield by 15% in sorghum and 17% in pigeonpea compared to respective uninoculated control treatments.

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

Rifampicin resistant mutants of two *Bacillus* sp. strains (B30, B17) and two *Pseudomonas* sp. (P7, and P45) were tested as seed inoculants in sorghum and sunflower under field conditions conditions to study rhizosphere colonization. The experiment was conducted in a RBD with three replications. Rhizospheric soil was serially diluted and appropriate dilutions were plated on king's B (for *Pseudomonas*) and Nutrient Agar (for *Bacillus*) media supplemented with 50 µg/ml of rifampicin. Inoculation with microbial cultures improved plant growth of sorghum as well as sunflower in terms of root length, shoot length and dry biomass.



***Pseudomonas* population on King's B Rif medium (A) and *Bacillus* population on NA Rif medium (B) from inoculated sorghum rhizosphere under field conditions**

Further, inoculated treatments showed higher counts of bacteria as compared to uninoculated control, indicating efficient colonization by inoculated strains in sorghum as well as sunflower (Table 16)

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

A total of 24 isolates tolerant to high temperature (50^0 C) were tested for plant growth promoting traits (PGP) such as IAA production, P and Zn solubilization and siderophore production under ambient (28^0 C) and high temperature (50^0 C). Antifungal activity was tested for heat tolerant isolates against two different fungi *Sclerotium* sp. and *Macrophomina phaseolina.* Isolates were also studied for mechanisms behind stress tolerance like Biofilm formation, Proline accumulation, sugars accumulation and exopolysaccharide production. All the 24 isolates showed IAA production under optimum as well as high temperature, whereas P-solubilization, siderophores production, Zn-solubilization and antagonism was exhibited by 16, 12, 1 and 8 isolates, respectively (Table 17). Further, it was observed that expression of PGP traits was reduced significantly under high temperature (50^{o}C). All the 24 isolates showed biofilm formation under both ambient and high temperature conditions, though adhering capacity was more under high temperature. Variation in efficiency of biofilm formation was observed among different isolates. All the isolates could acumulate proline under high temperature, however variation

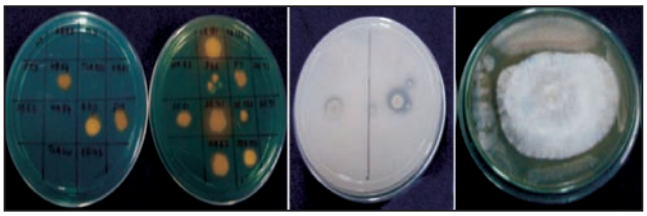
Table 16 : *Pseudomonas* population on King's B Rif medium and *Bacillus* population on NA Rif medium from inoculated sorghum rhizosphere under field conditions

Treatment	NA medium with Rif (Cfu/g soil)		King's B medium with Rif (Cfu/g soil)	
	Sorghum	Sunflower	Sorghum	Sunflower
Control	9 X 10^6	13 X 10^6	2 X 10^6	14 X 10^6
Bacillus B17	35 X 10^6	89 X 10^6	-	-
Bacillus B30	68 X 10^6	34 X 10^6	-	-
Pseudomonas P7	-	-	56 X 10^6	79 X 10^6
Pseudomonas P45	-	-	34 X 10^6	25 X 10^6

Table 17 : Expression of PGP traits by thermotolerant isolates

	IAA (µg/mg protein)		P-Sol (ppm)		Siderophore 28°C/50°C	Zn-Sol 28°C/50°C	Anti-Fungal 28°C
	28°C	50°C	28°C	50°C			
No.of ioslates +ve	All (24.4 to 124)	All (13.4 to 75)	16 (7.57 to 28.39)	16 (3.77 to 19.6)	12	1	8

was found among different isolates in terms of amount of proline accumulation. Isolate SE61 was found to be best in proline accumulation (37.26±0.82 µmol/ mg protein) followed by isolate NA84 (30.02±0.76 µmol/ mg protein). Similarly All the isolates except TSA441 showed significant increase in total suger concentration with isolates NA62, KB133, NA84 and SE62 showing about six-fold increase in sugar accumulation under high temperature as compared to that under normal temperature. EPS production also increased significantly (five-fold in isolate P7) under high temperature in all the isolates except isolate SE71.



Siderophore production, P-solubilization and antagonism by thermotolerant isolates

2.4.15 Microbes for plant growth promotion and nutrient management in sorghum

There is a renewed interest in agriculturally important microorganisms for enhancing crop productivity on two counts viz. increasing input costs and better understanding of the mechanisms of plant-microbe interactions. Any savings on input costs will definitely help rainfed farmers as they are resource-poor. Under the AMAAS network project, under the theme nutrient management and plant growth promotion, CRIDA has identified potential candidate strains of *Pseudomonas*, *Bacillus*, *Azospirillum* and *Azotobacter* for plant growth promotion in sorghum and pigeonpea. During *kharif* 2011, a field trial was conducted at GRF under rainfed conditions using sorghum cv. CSV15. Among ten treatments, *Bacillus* B73 (previously identified as promising under pot culture trials) treated plants yielded 2570 kg/ha, followed by mixed inoculation of B87+P33 (a zinc solubilizer) (2530 kg/ha) where as in uninoculated control yield was 2182 kg/ha (Table 18).

Table 18 : Grain yield of sorghum (cv. CSV15) as influenced by microbial treatment

Strain No.	Kg/ha	% increase over control	P (%)	K (%)	Mn (ppm)	Cu (ppm)	Fe (ppm)	Zn (ppm)
B73	2570	17.78	0.95	1.56	11.80	0.53	30.18	10.03
B87	2428	11.24	1.06	1.63	11.25	1.20	67.38	8.65
P1	2502	14.66	1.46	1.56	07.88	0.95	40.18	16.95
P17	2400	10.00	1.08	1.48	12.40	0.85	27.73	8.73
P22	2204	01.00	1.08	1.55	13.48	0.85	25.80	9.48
B73+ZSB	2430	11.36	0.93	1.59	12.03	0.95	28.50	9.80
B87+ZSB	2530	15.94	0.93	1.72	13.23	0.78	21.53	18.03
P1+ZSB	2360	08.16	0.89	1.50	12.95	0.73	24.28	15.48
P17+ZSB	2202	00.92	0.91	1.64	11.70	0.80	27.88	20.25
P22+ZSB	2404	10.17	0.97	1.68	12.73	0.43	40.83	16.15
Control	2182	—	0.93	1.60	13.13	0.68	27.63	8.38

The plant samples were analysed for nutrient uptake by plants. Plants treated with B87 had higher uptake of Cu (1.20 ppm) and Fe (67.38 ppm) whereas B87+ZSB treated plants had higher K uptake (1.72%). Uptake of Mn was highest (13.48 ppm) in the plants treated with P22. The plants treated with P1 had higher P uptake (1.46%) as compared to all other treatments including control.

2.4.16 Integrated Bio-resources Centre

CRIDA has established an Integrated Bioresources Centre at HRF for production of good quality bioinoculants required by different farmer clientele at a reasonable price. The unit has a production capacity of 4.5 metric tons per month of a given product. The uniqueness of the centre is to provide customized training to different stakeholders from farmers to young entrepreneurs. During 2011-12, the centre produced 2.3 tons of bioinoculants comprising *Trichoderma*, PSB, *Azotobacter*, *Azospirillum*, *Verticillium*, and ZSB and distributed to farmers earning revenue of Rs. 151600. Ten sponsored training programs were also conducted by the centre.

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

There is a need to evolve farming systems approach which minimizes risk while ensuring higher returns to meet the growing needs of the small and marginal farmers. After the analysis of existing farming systems, suitable interventions were identified for addressing the diagnosed constraints. These interventions were evaluated during *kharif* 2011, the second year of evaluation, to test their performance at selected farmers' fields. At Anantapur, the groundnut + pigeon pea intercropping suffered heavily due to prolonged dry spells during flowering and pod formation. The farmers harvested very low groundnut yields while pigeonpea failed completely. The groundnut yield, averaged across six farmers' fields, was only 248 kg/ha in the plots under farmers' practices (Fig. 20). Application of pendimethalin for weed control gave about 20% higher yield while use of recommended NPK gave 53% higher yield than farmers' practice. However, the yield increased by more than 2 times when both pendimethalin and recommended NPK were applied compared to farmers' practice.

Similarly in Seethagondhi cluster of Adilabad district, the interventions identified for addressing the diagnosed constraints were a) use of herbicide for weed control, b) use of recommended NPK, and c) use of both herbicide and recommended NPK in cotton + pigeonpea intercropping. These interventions were evaluated during *kharif* 2011 to test their performance at selected farmers' fields. On average, the yield of cotton + pigeonpea intercropping increased by 7% with the use of herbicide for weed control and 19% with application of recommended NPK compared to farmers' practice (Fig. 21). Use of both herbicide and recommended NPK enhanced the cotton + pigeonpea intercropping by 28% compared to farmers' practice.

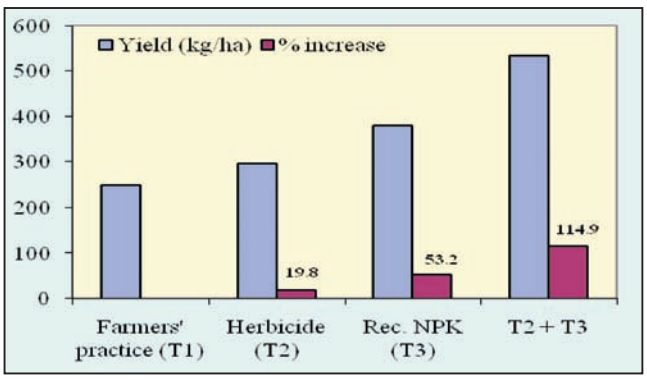


Fig. 20. Response of groundnut to different management practices

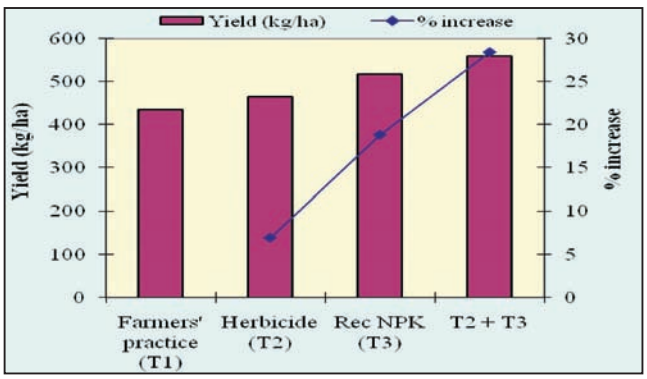


Fig. 21. Response of cotton to different management practices

2.4.18 Sustainable farming system modules for small and marginal farmers in Southern Telangana zone

Studies on farming system modules on micro-watershed basis were conducted in a 13,964 m^2 watershed at HRF. A total of 21 crops including cereals, pulses, oilseeds, vegetables, fruit crops, fodder, medicinal crops and timber yielding trees were grown during *kharif*, 2011 and *rabi*, 2011-12. The total rainfall during the year was 532.4 mm which was 29.5% less than normal. Actual number of rainy days were 34 compared to 49 normal rainy days. Sowing of crops was delayed due to late onset of rains during *kharif* and crops experienced prolonged dry periods during vegetative stage, resulting in low yields. Yield of castor (260 kg/ha) and pigeonpea (140-250 kg/ha) was low due to moisture stress during vegetative and reproductive phases. However, bajra performed better under moisture stress conditions and gave higher grain (1275 kg/ha) and fodder yield (23 q/ha). Similarly, horsegram also contributed to stability of the system by yielding 790-820 kg/ha grain and 11.75-12.4 q/ha of fodder. The excess runoff was collected in a cement lined farm pond (605 m^3). The pond was filled five times during *kharif*, 2011 yielding 748 m^3 of rainwater. This water was used for growing vegetables (okra, brinjal, bitter gourd, cluster bean, drumstick and leafy vegetables) and for providing supplemental irrigation to pigeonpea. A net return of Rs 69,761/ha was obtained from vegetable cultivation as against Rs 1,402/ha from bajra and a loss of Rs 900/ha from castor (Table 19).

Pigeonpea was grown with two different systems of planting (direct sowing and transplanting 30 days old seedlings raised in poly bags before start of the rainy season) and two soil moisture regimes (rainfed and 3 supplemental irrigations of 3 cm depth each with harvested rainwater). Supplemental irrigation under two systems of planting gave higher yield (180 and 267% higher yield with transplanted and direct sown crop, respectively) compared to rainfed crop (Table 20). Similarly, transplanted crop under both the moisture regimes gave higher yield over direct sown crop. However, yield levels in all treatments were poor due to prolonged moisture stress during vegetative and reproductive phases and low amount of rainfall.

Table 19 : Performance of different vegetables during *kharif*, 2011

Crop	Area (m^2)	Yield (kg/plot)	Net returns (Rs/plot)
Okra	600	310	4820
Brinjal	500	371	1928
Chillies	160	40	476
Bitter gourd	200	112	1351
Cluster bean	500	145	2900
Leafy vegetables	50 X 3	47	1597
Drumstick	——	920 fruits	950
	2010		14,022

Table 20 : Performance of pigeonpea under two systems of planting and supplemental irrigation

Systems of Planting	Grain yield (kg/ha)	
	Rainfed	Supplemental irrigation
Transplanted	250	450
Direct Sown	140	375

A feeding trial was conducted with 10 Nellore breed lambs using the fodder and feed material generated from IFS. Bajra stover was fed *ad libitum* as basal feed along with *Cenchrus* hay @ 250-300 g/day/animal. Mash prepared from pigeonpea *bhoosa*, horsegram haulms, clusterbean *bhoosa*, glyricidia foliage (sun-dried) and stylo dry fodder was also fed @ 300-350 g/day/animal as supplement. The available fodder from the farming system module was found sufficient for feeding 10 lambs for a period of 120 days. An additional income of Rs 13,350 was generated with the integration of small ruminants. Vegetable cultivation with harvested rainwater, bajra + pigeonpea intercropping and feeding of Nellore breed sheep with farm generated feed and fodder provided economic stability to the system during the low rainfall year (Table 21).

Table 21 : Profitability of IFS compared with popular cropping systems in the Southern Telangana Zone

System	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)
Castor	9,050	-900
Cotton	16,147	13,000
Sorghum + pigeonpea	11,342	14,027
Maize	10,658	6,957
IFS	20,660	29,706
IFS - animal component	18,860	18,176

2.4.19 Evaluation of forage sorghum varieties

A field experiment was conducted to study the comparative performance of seven sweet sorghum varieties ICSR 93034, ICSV 700, ICSV 93046, SPV 422, SPV 1411, SSV 84 and NTJ 2 (local) against two forage sorghum varieties (MP Chari and SSG Chari) in rainfed alfisols. All these varieties were grown as per recommended package of practices for forage sorghum. Observations were recorded on germination, morphogenesis, phenology, growth, forage yield, lodging resistance and crop re-growth. All the sweet sorghum varieties adapted well to increase in plant population, necessary for forage purposes, and competed well with forage sorghum varieties for growth, phenology, morphogenesis and yield. All the sorghum varieties were resistant to lodging in spite of higher plant population, but this has to be further tested across locations and years. The crop re-growth was more pronounced in forage varieties (MP Chari and SSG Chari) but was not satisfactory in sweet sorghum varieties. There were significant differences between varieties at all stages of observations. The yield sequence of varieties at 30 DAS was SSG Chari > ICSV 93046 and NTJ-2 > SPV 422, ICSV 700 and MP Chari > ICSR 93034>SSV 84>SPV 1411. At 60 DAS, the yield sequence was SSG Chari > ICSV 93046 > NTJ2 > MP Chari> ICSR 93034 and ICSV 700 > SPV 1411 > SPV 422>SSV 84. At final harvest, the yield sequence was SSV 84 > NTJ 2 and ICSV 93046 > ICSV 700 > ICSR 93034 > SPV 422 and SSG Chari > MP Chari>SPV 1411.

Table 22 : Fresh forage yield of different varieties at different growth stages (t/ha)

Varieties	30 DAS	60 DAS	Final harvest
MP Chari	3.0	18.0	28.0
SSG Chari	4.2	19.3	30.0
ICSR 93034	2.9	17.5	30.8
ICSV 700	3.0	17.5	32.0
ICSV 93046	3.2	19.0	33.2
NTJ 2	3.2	18.7	33.2
SPV 422	3.0	17.0	30.0
SPV 1411	2.7	17.2	25.0
SSV 84	2.8	17.0	34.5
CD5%	0.3	0.8	1.6

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

Fortification of finger millet with green gram dhal improves the nutrient profile of the finished product. Fortification of finger millet flour was attempted by developing nutrient rich, value added and ready to eat snack 'finger millet laddu'. The mean calcium and ash content of ragi based snack was found to be high compared to other mineral components estimated (Fig. 22).

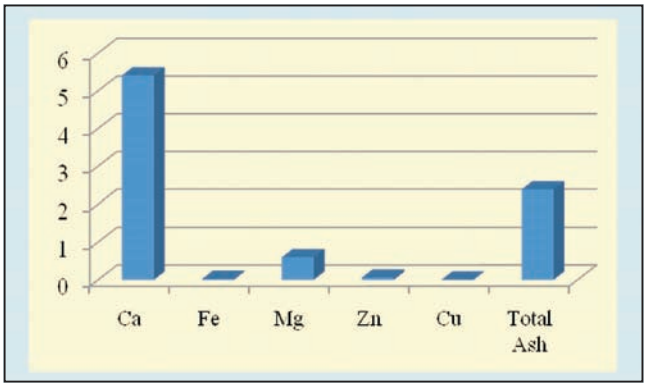


Fig. 22. Ash and mineral content (%) of value added finger millet snack product

2.4.21 Effect of processing on nutrient quality of processed drumstick leaves (*Moringa oleifera*)

Nutritional value of drumstick leaves is well known, but the nutrient quality of processed drum stick leaves is not yet explored. The drumstick leaves were subjected to different processing treatments like sun drying, oven drying, microwave

drying, pressure cooking, and boiling in water. The dried leaves were powdered and then analyzed for various vitamins and minerals like Ca, Mg, Zn, Cu, Fe and Mn. Pressure cooked drumstick leaves had significantly higher zinc content compared to leaves boiled in water, and sun dried and oven-dried leaves. However, Mg content was significantly higher in sun-dried drumstick leaves compared to microwave and oven drying. Oven-dried leaves had significantly higher Ca content compared to fresh leaves. The microwave dried leaves had significantly higher amount of Fe compared to sun-dried and pressure cooked leaves. Fresh and microwave treated leaves had significantly higher content of vitamin C compared to oven-dried, boiled, sun-dried and pressure-cooked leaves (Fig. 23). Vitamin C content was low in other treatments, as vitamin C is a heat labile and is destroyed when exposed to direct sunlight and heat due to oxidation.

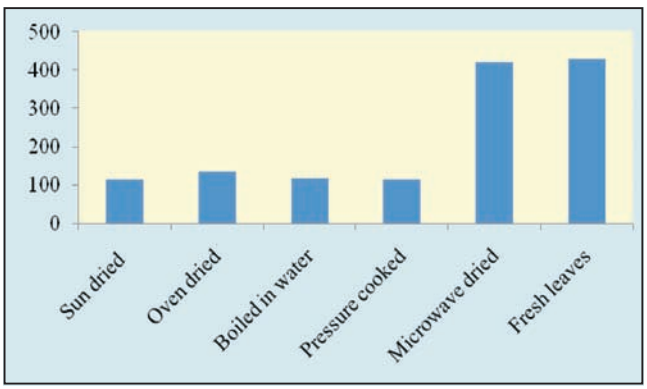


Fig. 23. Effect of different processing methods on vitamin C content (mg/100g) in drumstick leaves

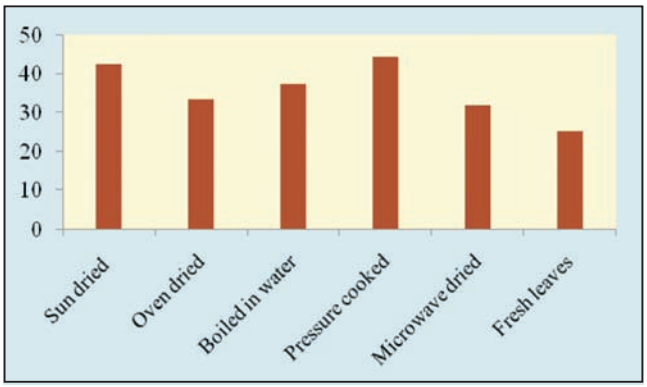


Fig. 24. Effect of different processing methods on β-carotene content (mg/100g) in drumstick leaves

Pressure-cooked drumstick leaves had significantly higher β-carotene content compared to oven-dried, microwave-dried and fresh leaves (Fig. 24). This could be attributed to exposure of leaves to higher temperature for longer time during oven drying and boiling.

2.5 Soil health and nutrient management

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

The objective of the present study was to identify effective integrated nutrient management (INM) treatments under conventional and reduced tillage in sorghum-mung bean system. The experiment was conducted at Hayathnagar Research Farm in a strip plot design with two tillage treatments: conventional (CT) and reduced (RT) and five INM treatments : control (T_1), 40 kg N through urea (T_2), 4 t compost + 20 kg N (T_3), 2 t *Gliricidia loppings* + 20 kg N (T_4) and 4 t compost + 2 t *Gliricidia loppings* (T_5) for sorghum (SPV 462); and control (no nitrogen) (T_1), 20 kg N through urea (T_2), 2 t compost + 10 kg N (T_3), 1 t *Gliricidia loppings* + 10 kg N (T_4) and 2 t compost + 1 t *Gliricidia loppings* (T_5) for green gram (ML 267). Recommended level of phosphorus was applied equally to both sorghum and green gram crops uniformly. The results in fourteenth year indicated that tillage as well as conjunctive nutrient use treatments and their interaction effects showed a significant influence on sorghum as well as mung bean yields. Among the nutrient management treatments, conjunctive application of compost and urea performed best and recorded significantly higher sorghum and mung bean yields as well as agronomic efficiency under both conventional and reduced tillage. On an average, conventional tillage maintained 5.7 and 7.9% higher yield of sorghum and mung bean over reduced tillage respectively. The sorghum grain yields varied from 813 to 1439 kg/ha while the mung bean grain yields varied from 619 to 1056 kg/ha across the tillage and nutrient management treatments. The highest

average sorghum grain yield was observed under application of 4 t compost + 20 kg N through urea (1439 kg/ha) followed by 2 t *Gliricidia loppings* + 20 kg N through urea (1276 kg/ha) under conventional tillage (Fig. 25).

Similar trend was observed in minimum tillage under application of 4 t compost + 20 kg N through urea (1284 kg/ha) followed by 2 t *Gliricidia loppings* + 20 kg N through urea (1168 kg/ha), and maintained significantly higher yields over the control. In case of mung bean, both application of 2 t compost + 10 kg N through urea (1056 kg/ha) and 2 t compost + 1 t *Gliricidia loppings* (912 kg/ha) recorded significantly higher yields over control. Agronomic efficiency for sorghum crop varied from 3.7 to 14.0 kg grain/kg N, while it varied from 5.6 to 20.5 kg grain/kg N for mung bean crop across the treatments (Fig. 26).

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

The present study was planned in three different experiment sets. The objective of the experiment I was to study the response of graded levels of surface residue application to cowpea under minimum tillage in alfisol. The treatments comprise surface application of 4 levels of sorghum residues @ 0, 2, 4, 6 t/ha in combination with uniform dose of 60 kg N/ha (through urea) and 30 kg P_2O_5/ha (through super phosphate) with minimum tillage. The system adopted for this study was sorghum-cowpea with yearly rotation. In 2011, sorghum (SPV 462) was grown as the test crop. The results showed that the sorghum grain yield varied from 462 to 870 kg/ha across the treatments and was significantly

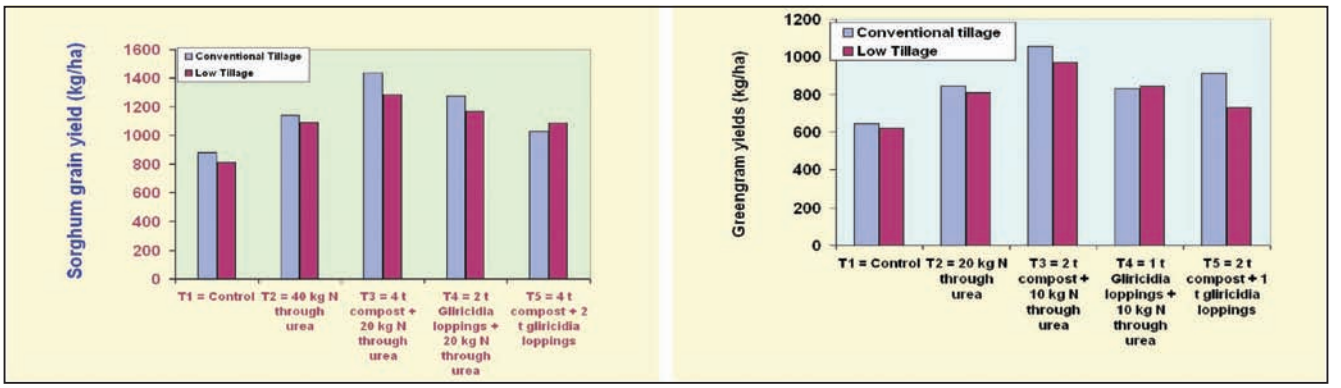


Fig. 25. Sorghum (SPV-462) and mung bean (ML - 267) grain yields as influenced by tillage and conjunctive nutrient management treatments during 2011

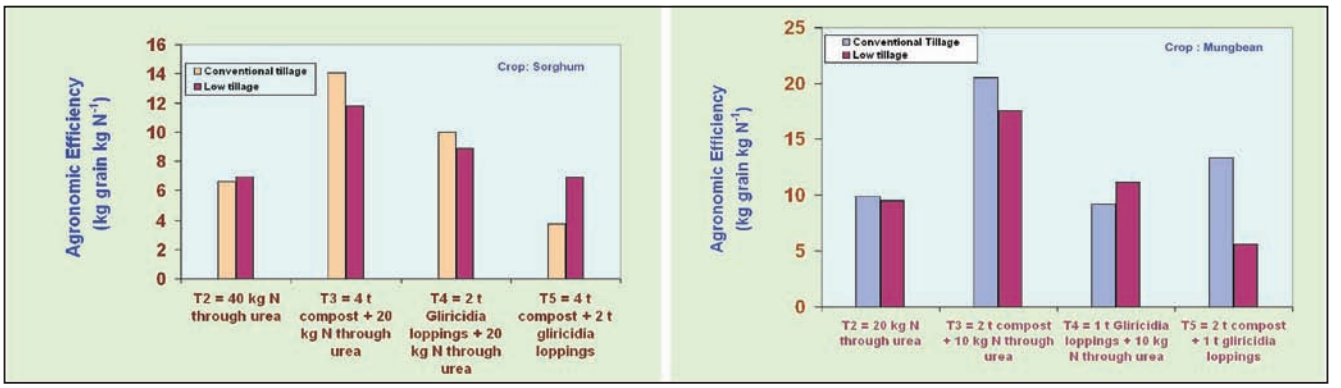


Fig. 26. Effect of tillage and conjunctive nutrient management treatments on agronomic efficiency of sorghum and mung bean crop in rainfed Alfisol

influenced by residue application (Fig. 27). Application of sorghum stover @ 4 t/ha in combination with N @ 60 kg N/ha recorded significantly higher sorghum grain yield (1616 kg/ha) when compared to residue application @ 6 t/ha in combination with N @ 60 kg/ha (1517 kg/ha). The percent increase in grain yields with residue application @ 2, 4 and 6 t/ha was to the tune of 21.1, 31.0 and 23.0 % respectively over the control (no residue application).

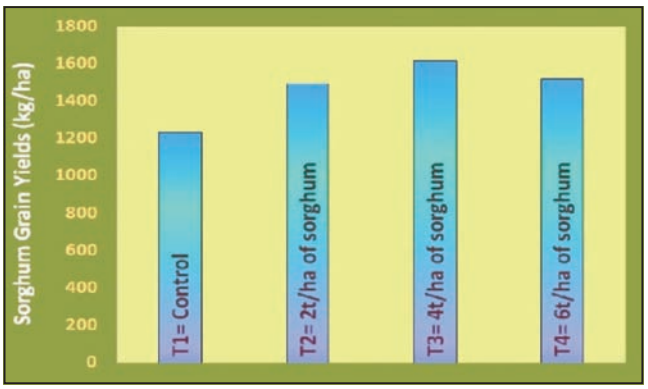


Fig. 27. Sorghum (SPV-462) yields as influenced by surface application of crop residue under minimum tillage during the year 2011

The objective of the experiment II was to study the influence of tillage practices, residue application and graded levels of N on castor bean yield under sorghum-castor system. A field experiment comprising of tillage, conventional (CT) and minimum (MT), residues (2 t/ha dry sorghum stover (SS), 2 t ha^{-1} fresh *Gliricidia loppings* (GL) and no residue (NR)) and nitrogen levels (0 (N_0), 30 (N_{30}), 60 (N_{60}) and 90 (N_{90}) kg N/ha) under sorghum - castor system was initiated in a strip split-split plot design at Hayathnagar Research Farm during 1995. During the current year, sorghum (SPV 462) was the test crop. The data showed that residues and N levels played a significant role in influencing the sorghum yields while tillage did not show any significant effect this year. However, irrespective of the statistical significance, conventional tillage (1014 kg/ha) could maintain slightly higher sorghum yields (2% higher) compared to minimum tillage (993 kg/ha) (Fig 28). Among the residues, application of *Gliricidia loppings* resulted in higher average sorghum grain yields (1114 kg/ha), which was at par with application of sorghum stover (1001 kg/ha). Nitrogen levels also played a significant role in influencing sorghum grain yields. Application of nitrogen @ 60 kg/ha recorded significantly higher average yield (1256 kg/ha) followed by N applied @ 90 kg/ha (1221 kg/ha). The interaction effects between tillage, residues and N levels showed significant influence on sorghum yields. Significantly higher yield was observed with CTGLN60 (1506 kg/ha) followed by CTGLN90 (1431 kg/ha) treatments.

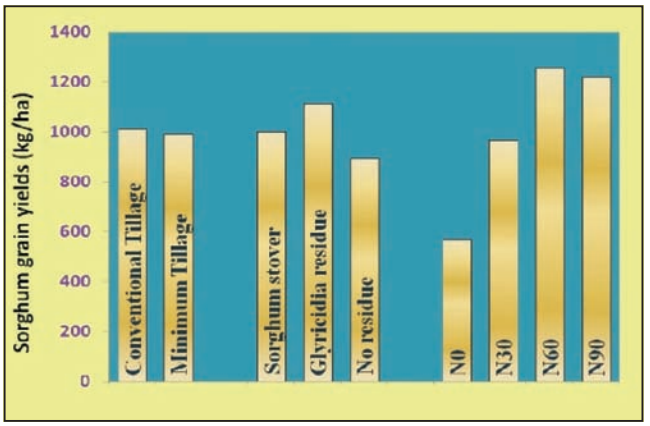


Fig. 28. Sorghum grain yields as influenced by tillage, residues and N levels under sorghum-castor system during 2011

The objective of the experiment III was to evaluate the long term influence of existing selected soil-nutrient management practices on soil quality using Integrated Soil Quality Index (ISQI) approach at Bangalore centre of All India Coordinated Research Project on Dryland Agriculture (AICRPDA). To achieve this objective, two long term experiments were adopted at Bangalore centre of All India Coordinated Research Project for Dryland Agriculture (AICRPDA). In a permanent manurial experiment (Expt.1), the key soil quality indicators for long term use of organics and fertilizers under groundnut - fingermillet cropping system in FYM series in alfisols of Bangalore were EC, available N, available K, available S, available Zn, available Fe, available B, MBC, MWD and bulk density,

while in maize residue series, the key indicators were soil pH, EC, organic carbon, available S, MWD and labile carbon.

Under fingermillet monocropping system with FYM series, the key soil quality indicators were: soil pH, organic carbon, available N, available P, available S, available Mn, DHA and labile carbon. However, in case of maize residue series, the key soil quality indicators identified were: organic carbon, available N, available P, available K, available Ca, available Mg, available S, available Fe, MBC and MWD.

In a tillage experiment (2), the key soil quality indicators emerged were: pH, available N, available P, available K, available Ca and labile carbon and their average percent contribution towards soil quality indices was pH (8%), available N (12%), available P (33%), available K (7%), available Ca (28%) and labile carbon (12%). From the view point of soil quality index (SQI), the best three practices identified were: Minimum tillage (MT) + 100% organic N (1.54), MT + 50% organic N + 50% inorganic N (1.51) and MT + 100% inorganic N (1.43). When both the experiments were considered together, the common soil quality key indicators emerged for Bangalore alfisol soils were: pH, Available N, Available P, Available K, Available S, OC, MWD and labile carbon (LC).

In case of groundnut-fingermillet rotation, highest carbon stock under FYM series was observed with FYM @ 10 t/ha + 100% N, P_2O_5, K_2O (9.86 Mg/ha) followed by FYM @ 10 t/ha + 50% N, P_2O_5, K_2O (9.71 Mg ha^{-1}). In case of maize residue series, highest carbon stock (9.28 Mg/ha) was observed with maize residue (MR) @ 5t/ha + 50% N, P_2O_5, K_2O which was on par with MR @ 5t/ha+ 100% N, P_2O_5, K_2O. In case of fingermillet monocropping, under FYM series, significantly higher carbon stock (9.85 Mg/ha) was recorded with FYM @ 10 t/ha + 100% N P_2O_5, K_2O which was on par with FYM @ 10 t/ha + 50% N P_2O_5, K_2O (9.68 Mg/ha). However, under Maize residue series, application of MR @ 5t/ha maintained significantly higher carbon stock (8.41 Mg/ha) followed by MR @ 5t/ha+ 100% N, P_2O_5, K_2O.

2.5.3 Soil and crop management options for managing zinc deficiency in maize-based cropping systems of rainfed regions

Field experiments were conducted in zinc deficient soils at two locations a) alfisols of Hyderabad (Andhra Pradesh) and b) inceptisols of Arija to validate the results obtained during the *kharif* 2010. The DTPA-extractable Zn at Hyderabad soil was 0.45 ppm whereas at Arija it was 0.40 ppm. The experiment in both the locations was laid out in randomized block design with three replications and seven treatments viz. T_1-control (No Zn), T_2-soil application of $ZnSO_4$ (25 kg/ha), T_3-seed priming with 1% $ZnSO_4$ solution, T_4-inoculation with P 29 strain of *Pseudomonas*), T_5-inoculation with P 33 strain of *Pseudomonas*, T_6-inoculation with B 116 strain of *Bacillus* and T_7-inoculation with B 41 strain of *Bacillus*. In Arija, apart from these treatments, additional treatment of foliar application of 0.5 % $FeSO_4$ (T_8) was also evaluated. The test crop used in both the locations was maize. Recommended package of practices were followed for raising the crop in both the locations.

Results of field experiment at conducted at Arija during the *kharif* 2011 season confirmed the results of 2010 trial. Inoculation of maize seeds with P 33

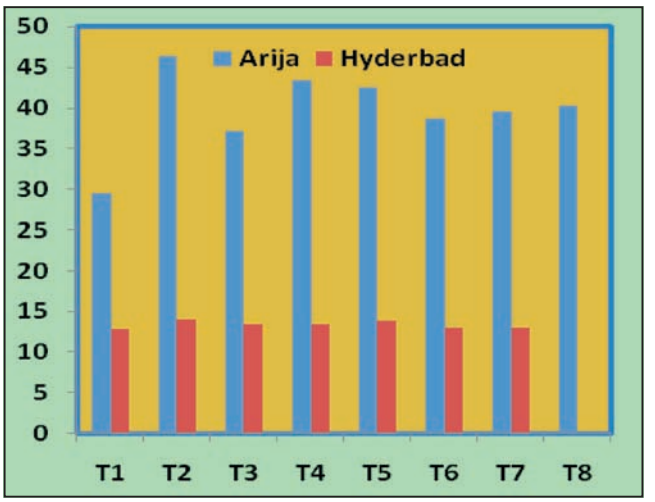


Fig. 29. Grain yield of maize (q ha^{-1}) as influenced by different treatments at Arija and Hyderabad

and P 29 strains of *Pseudomonas* resulted in increased yield of maize as compared to control (no inoculation). Highest grain yield of a maize (4630 kg/ha) was recorded in plots receiving 25 kg/ha of zinc sulphate followed by inoculation of maize seeds with P 29 (4282 kg/ha) and P 33 (4190 kg/ha) (Fig. 29).

However, results of field experiment conducted at Hyderabad have revealed that grain yield of maize was highest in treatment receiving 25 kg/ha of zinc sulphate as compared to other treatments. Although inoculation with P 29 and P 33 strains recorded higher yield than the control, the increase in grain yield was statistically non-significant. Non performance of these treatments in enhancing significant yield increase may be due to prolonged dry spell that prevailed during the reproductive and grain filling stages of the crop growth.

2.5.4 Carbon sequestration potential of reduced tillage systems under rainfed conditions

Long-term experiments initiated in All India Coordinated Research Project on Dryland Agriculture during 1998-1999 to study the effect of various tillage practices on the crop productivity and energy conservation are being used for the study. The template of the treatments is as follows: 1) Conventional tillage: 1 ploughing+ 2 harrowings+ 2 hoeings + 1 hand weeding, 2) Low tillage: 2 harrowings+ 1 hoeing + 1 hand weeding and 3) Minimum tillage: 1 harrowing+ 1 hoeing + 1 hand weeding, and sub plot treatments are 1) N_1- 100% Organic, 2) N_2- 100% Inorganic and 3) N_3- 50% Organic + 50% Inorganic. Both the treatment groups were imposed in split plot design. During this year soil samples were collected from Kovilpatti, Bijapur and Jammu center. Observations on crop related parameters were collected from sunflower, sorghum and maize systems.

Analysis of soil samples from soybean based system at Indore was completedare as follows. The long term tillage experiment at Indore was initiated during 2000 to evaluate the combined effect of different tillage intensities and application of chemical and organic sources of nutrients on carbon accumulation in soybean based system at Indore. Treatment details consists of T_1-conventional tillage+ recommended dose of fertilizers without off season tillage + hand weeding,T_2- conventional tillage + recommended dose of fertilisers with off season tillage + hand weeding,T_3 - low tillage + 4t/ha straw + hand weeding,T_4- low tillage + 4t/ha straw + use of herbicide,T_5 - low tillage + 4t/ha compost +hand weeding,T_6 - low tillage + 4t/ha compost + use of herbicide,T_7 - low tillage + 2t/ha gliricidia leaves + use of herbicide, T_8 - low tillage + 2t/ha gliricidia leaves + hand weeding. Low tillage with the application of straw @4t/ha and hand weeding (T_3) recorded maximum soybean yield (16.71q/ha) followed by conventional tillage (without offseason) tillage along with recommended dose of fertilizer (16.49 q/ha). Highest straw yield (28.01q/ha) was obtained in conventional tillage followed by low tillage with compost application (26.81q/ha).

The initial soil organic carbon content was 4.3 g/kg during 2000-2001 year in the surface layer. It increased in low tillage treatments and the increase was conspicuous in low tillage with compost application. The total carbon content also increased in the low tillage and organic matter application treatments (T_3-T_6). Microbial biomass carbon ranged from 0.31 mg/g (low tillage with gliricidia leaf application) to 0.67 mg/g (low tillage with straw application). Carbon pools such as very labile carbon, labile carbon and less labile carbon were estimated. Highest very labile carbon was observed in conventional tillage without off season tillage, followed by low tillage with compost. The fallow land use had higher levels of very labile and labile pools of carbon.

The amount of carbon added through crop residues including the root biomass was to the tune of 0.51 t/ha/year with low tillage and straw application followed by 0.46 t/ha/year with conventional tillage and recommended dose of fertilizers.

The increase in organic carbon and other labile carbon pools in comparison to the initial was evident in low tillage and compost application. Yield advantages are also seen in soybean system due to the low tillage and compost application.

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

Producing biochar from different agricultural residues and its utilization as a soil amendment is a promising method of achieving greater levels of certainty for carbon sequestration in soil and enhanced crop productivity in rainfed agricultural production systems. A study focused on the use of different crop residue derived biochars on pigeon pea performance was conducted. Three biochar sources (castor, cotton and pigeon pea stalks) were studied separately with biochar applied at 0.0 t/ha (control), biochar 3.0 t/ha and biochar 6.0 t/ha in alfisols. Each experiment had every year and alternate year application schedule for different biochars. Recommended dose of fertilizers (20:50:0 kg/ha of NPK) was applied every year in all the treatments. In addition, an unamended negative control (without biochar and fertilizer) was also included in the experiment. After the second year of imposition of the different biochar treatments, crop performance was evaluated for grain yield. Highest grain yield of 1685 kg/ha was recorded under alternate year application of cotton stalk biochar @ 3 t/ha supplemented with RDF. In case of castor stalk biochar experiment, application of 6.0 t/ha + RDF either every year or alternate year gave marginally higher yield than other treatments. However, in another experiment, application of pigeon pea stalk biochar+ RDF and RDF alone every year gave similar but significantly higher yield compared to all other treatments.

2.5.6 Biochar amendments for improving the performance of maize in drylands as climate change adaptation and mitigation strategy

The study focused on using four different crop residue derived biochars as soil amendments with and without organic and inorganic additions on dryland soils to enhance maize crop performance in rainfed agriculture with sustainable soil quality improvement, thereby helping to mitigate climate change through C sequestration and reduction in GHG emissions. Experiments were initiated with four biochar sources to study the effect of single application of BC @ 2 and 4 t/ha in combination with inorganic and organics in alfisols. Inorganic and organics were to be applied yearly. Biochar produced from maize, castor, cotton and pigeon pea stalks were to be applied separately one time for whole study period. Maize (DHM 117) was the test crop during the year 2011. The treatments imposed were, T_1- Control, T_2-RDF (120:60:60), T_3- Biochar (2.0 t/ha), T_4- Biochar (4.0 t/ha), T_5- RDF (120:60:60) + Biochar (2 t/ha), T_6- RDF (120:60:60) + Biochar (4 t/ha), T_7- RDF (120:60:60) + Biochar (2 t/ha) + FYM (5 t/ha), T_8- RDF (120:60:60) + Biochar (4 t/ha) + FYM (5 t/ha).

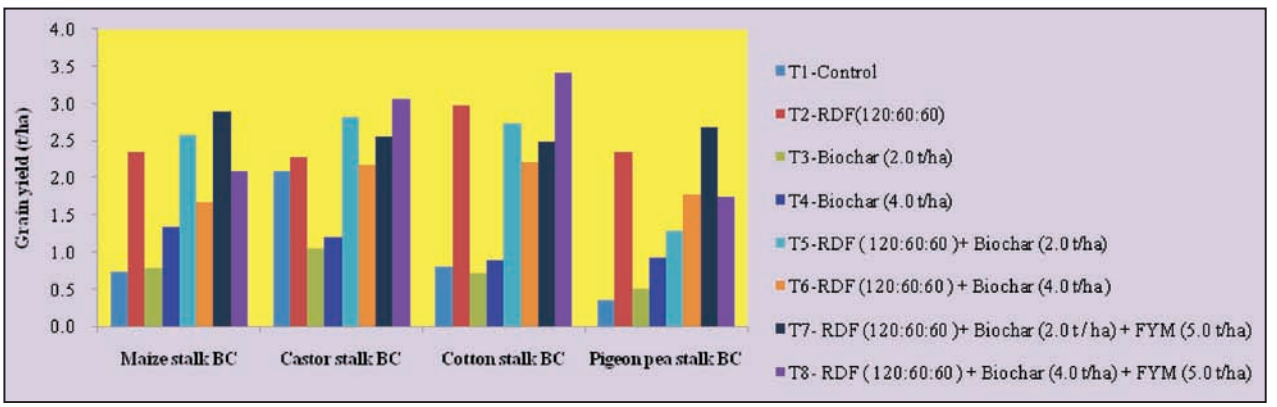


Fig. 30. Maize (DHM 117) grain yield as influenced by different biochars

During the first year, crop performed better with application of castor stalk biochar at 4 t/ha in combination with RDF (120:60:60) + FYM (5 t/ha) and recorded maximum grain yield increase of 34% over RDF (T_2) followed by 23 % yield increase over application of maize stalk biochar at 2 t/ha + RDF (120:60:60) + FYM (5 t/ha) whereas 14% increase was observed for pigeon pea and cotton stalk BC at T_7 and T_8 level of application compared to RDF (T_2), respectively (Fig. 30). In the first year of the study, combination of biochar with inorganic and organic amendments enhanced the crop performance.

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

This year experiment was conducted with pigeon pea which was sown after castor with different tillage practices like conventional tillage (disc ploughing twice, disc harrow and sowing of crop), reduced tillage (ploughing using cultivator, and disc harrow), zero tillage (direct sowing in residues), and different harvesting heights (0 cm, 10 cm and 30 cm) to increase the residue contribution to the field. The experiment was laid out in split plot design. Results showed that germination of pigeon pea in zero tillage when sown with the CRIDA precision planter was on par with conventional and reduced tillage. The fuel consumption and energy spent was lowest in zero tillage (ZT) as compared to conventional (CT) and reduced tillage (RT). Zero tillage recorded 73 and 69 percent lower CO_2 emission as compared to CT and RT respectively during land preparation and sowing (Fig. 31).

Zero tillage and reduced tillage recorded 28% lower runoff than CT. Increase in harvest height reduced the runoff, 30 cm height of harvest recorded 28 and 16 percent lower loss as compared to 0 cm and 10 cm height, respectively. Besides reducing run off, zero tillage has significantly lower soil loss as compared to conventional and reduced tillage. Increase in harvest height to 30 cm increased the residue return to soil by 60 and 20 percent as

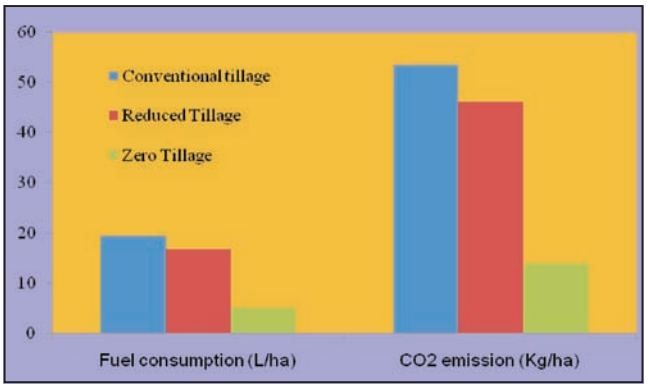


Fig. 31. Influence of tilage practices on fuel consumption and CO_2 emission

compared to 0 cm and 10 cm respectively. The difference in yields between different tillage systems narrowed down as compared to 1st and 2nd years. Zero tillage recorded lower yields (675 kg/ha) when compared to RT (1043 kg/ha) and CT (1177 kg/ha). 10 cm harvesting height recorded significantly higher yield as compared to 0 and 30 cm respectively, the ZT yields with residues has recorded higher yield as compared to 0 cm height harvest (Fig. 32).

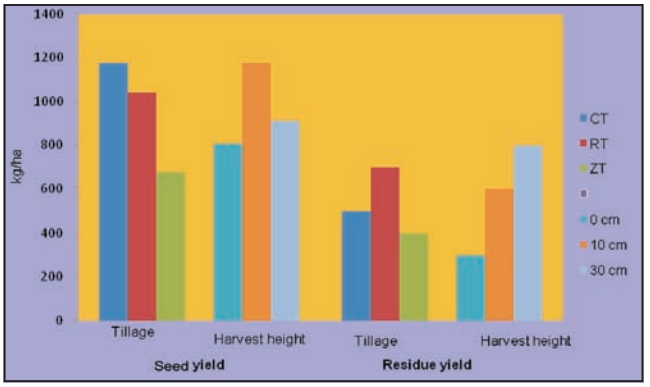


Fig. 32. Influence of conservation agricultural practices on seed yield and residue yield in pigeon pea

2.5.8 Management strategies for resource conservation and carbon sequestration in rainfed alfisols

A study was initiated to identify efficient resource conservation practices to enhance productivity and profitability of pigeon pea and castor system in rainfed Alfisols. Further in this project, carbon sequestration potential will be evaluated.

This year castor was sown after pigeon pea with different planting methods like normal (with 90 cm inter row spacing and 45 cm intra row spacing), paired row planting (60 cm castor pairs and 120 cm between pairs), different resource conservation practices like intercropping with cucumber, horse gram, muccina, mulch, furrow were evaluated. The experiment was laid out in split plot design. Results of this year show that paired row planting method recorded significantly higher castor equivalent yield (1136 kg/ha) compared to normal planting method. Among the different resource conservation practices, castor

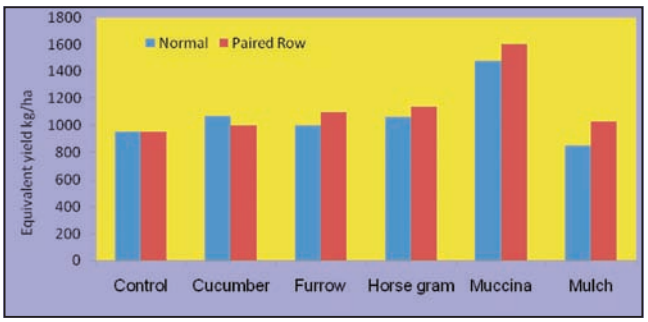


Fig. 33. Castor Equivalent yield as influenced by different planting methods and resource conservation treatment

intercropped with muccina recorded highest equivalent yield compared to other treatments. Paired row planting method recorded maximum residue yield (1544.2 kg/ha) compared to normal planting. Among different conservation practices, castor with muccina as inter crop recorded maximum residue yield (2283 kg/ha) and control recorded lowest residue yield (733 kg/ha) (Fig. 33).

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

2.5.9.1 Assessment of treatment effects on soybean yield at Indore

Field experiments were conducted during 1992 to 2009 on a permanent site in *kharif* season to study effects of fertilizer on soybean productivity in a semi-arid vertisol at Indore with treatments (T_1) control; (T_2) 20 kg N (urea) + 13 kg P/ha; (T_3) 30 kg N (urea) + 20 kg P/ha; (T_4) 40 kg N (urea) + 26 kg P/ha; (T_5) 60 kg N (urea) + 35 kg P/ha; (T_6) 20 kg N (urea) + 13 kg P + FYM @ 6 t/ha; (T_7) 20 kg N (urea) + 13 kg P + FYM @ 5 t/ha; (T_8) FYM @ 6 t/ha; and (T_9) Crop residue @ 5 t/ha. The rainfall during June to October ranged from 354 mm in 2002 (64.9% of annual rainfall) to 1308 mm in 1996 (98.3% of annual rainfall) with mean of 829 mm and variation of 28.8%. It ranged from 55 mm (in 1996) to 330 mm (in 2001) in June; 50 mm (in 2002) to 677 mm (in 1996) in July; 91 mm (in 1999) to 430 mm (in 2006) in August; 9 mm (in 2000) to 350 mm (in 2003) in September; and no rainfall (in 1994, 1998, 2000, 2003, 2005 and 2007) to 80 mm (in 1996) in October. Maximum mean rainfall of 295 mm with variation of 50.5% was received in July; followed by 231 mm with variation of 44.7% in August; 142 mm with variation of 64.3% in September; 131 mm with variation of 52.7% in June; and 29 mm with variation of 97.0% in October. The earliest date of sowing (DOS) of soybean was on 17th June in 2004; while farthest was on 20th July in 1996. The crop growing period (CGP) ranged from 91 days in 1992 to 117 days in 2004 with mean of 106 days and variation of 6.2%. The earliest date of harvest (DOH) was on 1st October in 2001; while farthest was on 29th October in 1996.

Effect of fertilizer treatments on soil nutrients

The soil N ranged from 161 to 426 kg/ha; soil P from 4.2 to 33.6 kg/ha; soil K from 320 to 1215 kg/ha; and soil S from 5.2 to 32.3 kg/ha. T_6 was superior with mean soil N of 269 kg/ha; soil P of 23.9 kg/ha; soil K of 757 kg/ha; soil S of 18.0 kg/ha over years. T_2 had lowest variation for soil N (6.8%) and soil K (16.5%); T_6 for soil P (30.4%), soil S (22.8%). In soil N, there was depletion in T_1, T_2, T_3, T_8 and T_9 over years. In soil P, there was a build-up in all treatments with maximum in T_6. In soil K, there was build-up in all treatments with maximum in T_6. In soil S, there was depletion in all treatments with minimum under T_6.

Effect of fertilizer treatments on soybean yield

The treatments gave significantly higher soybean yield compared to control in all years except 1995. T_6 gave maximum mean yield of 2182 kg/ha with variation of 27.6%; followed by T_5 with mean yield of 2075 kg/ha and variation of 28.2%; while control gave lowest yield of 1333 kg/ha with variation of 32.0% over years. T_6 gave maximum yield in 15 years in the range of 1449 to 3501 kg/ha; while T_5 attained maximum yield of 2343 kg/ha in 1992 and 2172 kg/ha in 1994; and T_3 attained maximum yield of 2415 kg/ha in 1995. T_6 attained best yields with lowest variation of 27.6%, while T_9 attained yield with maximum variation of 35.8%. T_6 gave highest mean yield increase of 63.7% over control, followed by T_5 with 55.7%, while T_2 gave lowest yield increase of 28.7% over control. Under normal rainfall condition with CRF of 927 mm and favourable monthly distribution, the treatments did not differ significantly in 1995. When pooled over years, T_6 gave significantly higher yield compared to remaining treatments; while T_5 was superior compared to control, T_2; T_3; T_7; T_8; and T_9. T_4; T_7 and T_8 attained at par yield over years. T_3 and T_7; T_2 and T_9 were at par.

Effect of soil nutrients on soybean yield

The R^2 ranged from 0.13 for T_3 to 0.40 for T_8; while standard error ranged from 420 kg/ha for control to 641 kg/ha for T_3. The effect of soil N on yield was negative for 5 treatments, while it was positive for 4 treatments. It ranged from -6.80 kg /kg in T_6 to 15.04 kg/kg in T_4. Soil P had a positive effect on yield attained by all treatments except control, while soil K had a negative effect on yield of all treatments. The effect of soil P ranged from -5.90 kg/kg in control to 22.78 kg/kg in T_3; while the effect of soil K ranged from -4.11 kg/kg in T_4 to 0.15 kg/kg in T_9. Soil S had a negative effect on yield attained by all treatments except T_6. The effect of soil S ranged from -48.50 kg/kg in T_4 to 33.07 kg/kg in T_6.

Effect of monthly rainfall on soybean yield

Based on models of yield through monthly rainfall, July, September and October rainfall had a positive effect. The August rainfall had a negative effect on yield attained by all treatments except control, while June rainfall had negative effect on yield attained by T_1, T_2 and T_7. Among different treatments, regression model of T_2 had lowest R^2 of 0.52, while T_8 had highest R^2 of 0.63. The standard error of yield was lowest of 430 kg/ha under control, while it was highest of 656 kg/ha under T_7.

Eigen values and percent of variance extracted by principal components

Based on the principal component (PC) model calibrated through monthly rainfall from June to October, soil N, P, K and S nutrients, four PCs extracted maximum variance in control, T_2; T_3, T_4, T_5 and T_9, while 5 PCs were leading and extracted maximum variance in case of T_6, T_7 and T_8. The leading PCs had eigen values in the range of 3.18 (control) to 3.57 (T_2; and T_9) for P_1; 2.33 (T_5) to 2.76 (T_4) for P_2; 1.87 (T_6) to 2.29 (T_3) for P_3; 1.36 (control) to 1.66 (T_4) for P_4; and 1.04 (T_8) to 1.27 (T_6) for P_5. The variance extracted by PCs ranged from 24.5% (T_6) to 27.5% (T_2 and T_9) for P_1; 17.9% (T_5) to 21.0% (T_2) for P_2; 14.4% (T_6) to 17.6% (T_3) for P_3; 10.4% (control) to 12.7% (T_4) for P_4 ; and 8.0% (T_8) to 9.8% (T_6) for P_5. The overall percent of variance explained by different PCs ranged from 72.9% (T_5) to 80.6% (T_6). The eigen values indicated that T_6 had above average value of 2.66 from P_2, 1.51 from P_4 and 1.27 from P_5; while T_8 had 2.57 from P_2 and 2.12 from P_3; and T_7 had 1.15 from P_5. However, T_6, T_7 and T_8 were superior since PCs of these treatments explained maximum variance of 80.6, 78.2 and 80.2% respectively compared to other treatments.

Loadings of rainfall, soil nutrient variables on leading PCs

The variables which have a loading of more than ± 0.70 are considered as significant. The

long term study indicated that July rainfall was important with loading on P_1 of 6 treatments and P_2 of 2 treatments. The soil N and soil S were important with significant loading on P_1 of 6 treatments, while soil P was significantly loaded on P_2 for 4 treatments and P_1 for 2 treatments. Nine variables were significantly loaded on PCs calibrated for T_2 out of which 5 were positive (Jun, Jul, Sep, soil N, soil S) and 2 were negative (soil P, soil K). The control had significant variables on PCs with positive effects of Jul, Sep, soil N and 3 and negative effects of Jun, soil P, soil K.

Effect of fertilizer treatments on sustainability yield index

The SYI based on PC model was higher compared to regression model for all treatments except T_5. Based on SYI using regression model of rainfall, T_6 had maximum SYI of 44.6%, while control had lowest SYI of 25.8%. T_5 was second best with SYI of 41.9% based on model calibrated through rainfall. Based on SYI values using regression model of soil nutrients, T_6 was superior with maximum 45.5%, while control had lowest of 26.1%. Thus based on rainfall and soil nutrients, T_6 was superior with maximum SYI for attaining maximum productivity of soybean.

Based on SYI derived under regression model of rainfall, soil nutrients, SYI ranged from 28.3% for control to 47.0% for T_6. Compared to this, SYI ranged from 28.1 to 50.2% based on PC model for respective treatments. T_6 was superior with maximum yield of 2182 kg/ha, gross returns of Rs. 34814/ha, net returns of Rs. 24346/ha and BC ratio of 3.33. This treatment was highly sustainable with SYI of 47.0% based on regression model compared to 50.2% based on PC model. Although, T_5 was superior with highest BC ratio of 3.57, it was the second best for attaining mean yield of 2075 kg/ha, gross returns of Rs. 33178/ha, net returns of Rs. 23877/ha, with SYI of 44.4% based on regression model and 43.2% based on PC model.

2.5.9.2 Effect of treatments on cotton yield at Akola

Permanent manurial trials of cotton *(Gossipium hirsutum)* were conducted in a fixed site in a semi-arid Vertisol at Akola during 1987 to 2007. The study was primarily initiated with the objective of identifying an efficient treatment for attaining a sustainable yield, apart from maintaining maximum soil organic carbon (SOC), N, P and K nutrients over years. The fertilizer treatments comprised of T1 : Control; T2 : 50 kg N (urea) + 25 kg P/ha; T3 : 25 kg N (urea) + 12.5 kg P/ha; T4 : 25 kg N/ha (*Leucaena*); T5 : 25 kg N/ha (FYM); T6 : 25 kg N (*Leucaena*) + 25 kg N (urea) + 25 kg P/ha; T7 : 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha; and T8 : 25 kg N (*Leucaena*) + 25 kg P/ha. The earliest date of sowing (DOS) of cotton was 11th June in 1993, while the latest was 23rd July in 2004. The earliest date of harvest (DOH) of crop was 28th November in 1990, while the latest was 26th March in 1997. The crop growing period ranged from 155 days in 1991 (crop seasonal rainfall of 429 mm) to 265 days in 1997 (781.5 mm).

ANOVA of effect of fertilizer treatments on yield

The lowest mean cotton yield of 492 kg/ha (variation of 51.2%) was observed under control compared to maximum of 805 kg/ha (variation of 54.8%) attained with 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha. The treatments differed significantly in all the years except in 1987, 1988 and 1994. The cotton yields decreased under all treatments over years. All treatments except 25 kg N/ha (*Leucaena*) gave significantly higher yield over control. 50 kg N + 25 kg P/ha; 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 were at par in performance over 21 years.

Effect of fertilizer treatments on soil fertility

25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha was superior with maximum SOC of 0.73%

under < 500 and 500-750 mm rainfall; while 25 kg N (*Leucaena*) + 25 kg N (urea) + 25 kg P/ha gave maximum of 0.71% under 750-1000 mm; and 25 kg N/ha (FYM) gave 0.66% under 1000-1250 mm rainfall. 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha maintained maximum mean soil N of 254 kg/ha under 500-750 mm and 262 kg/ha under 750-1000 mm; while 25 kg N (*Leucaena*) + 25 kg N (urea) + 25 kg P/ha maintained 274 kg/ha under < 500 mm and 50 kg N (urea) + 25 kg P/ha maintained 245 kg/ha under 1000-1250 mm rainfall. Similarly, 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha was superior with maximum mean soil P of 32.5 and 34.0 kg/ha under 500-750 and 750-1000 mm rainfall respectively; while 25 kg N/ha (FYM) gave 34.7 kg/ha under < 500 mm and 34.6 kg/ha under 1000-1250 mm. 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha provided mean soil K of 358, 364 and 490 kg/ha under < 500, 500-750 and 1000-1250 mm respectively; while 25 kg N/ha (FYM) gave maximum soil K of 354 kg/ha under 750-1000 mm rainfall.

The SOC and soil N significantly increased, while soil K significantly decreased over years. However, soil P did not change over years. The rate of increase ranged from 3.47 kg/ha/year with 25 kg N (*Leucaena*) + 25 kg P/ha to 6.58 kg/ha/year under control for soil N. The soil P decreased in all treatments except control and 25 kg N (urea) + 12.5 kg P/ha, although the change was not significant. Maximum decrease of 0.29 kg/ha/year was observed in 25 kg N (*Leucaena*) + 25 kg P/ha, while minimum was in 25 kg N (urea) + 12.5 kg P/ha (0.09 kg/ha/year). In soil K, rate of decrease ranged from 0.71 kg/ha/year in control to 7.92 kg/ha/year in 25 kg N (*Leucaena*) + 25 kg P/ha.

Eigen values and percent of variance explained by PCs

PC analysis was carried out to explain variability of monthly rainfall received from June to November, crop growing period, SOC, N, P and K nutrients in different years through PCs. Based on the PC model, 5 PCs were significant with an eigen value exceeding 'one'. The eigen values ranged from 1.05 for P_5 of 50 kg N (urea) + 25 kg P/ha to 2.59 for P_1 of 25 kg N (*Leucaena*) + 25 kg N (urea) + 25 kg P/ha and 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha treatments. The percent of variance explained by the PCs ranged from 9.6% by P_5 of 50 kg N (urea) + 25 kg P/ha to 23.6% by P_1 of 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha. The total variance explained by PCs ranged from of 75.8% under 25 kg N/ha (FYM) to 79.6% under 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha.

Loadings of monthly rainfall, crop growing period and soil nutrients on PCs

The PC model indicated that crop growing period had a significantly higher positive loading on P_2 of 5 treatments viz., 50 kg N (urea) + 25 kg P/ha; 25 kg N (urea) + 12.5 kg P/ha; 25 kg N (*Leucaena*) + 25 kg N (urea) + 25 kg P/ha; 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha; 25 kg N (*Leucaena*) + 25 kg P/ha;and P_4 of 25 kg N/ha (*Leucaena*). June rainfall had a significantly higher negative loading on P_1 of control, while it had a significant positive loading on P_1 of 25 kg N (*Leucaena*) + 25 kg P/ha and P_2 of 25 kg N/ha (FYM) treatment. July rainfall was found to have a significantly higher negative loading on P_4 of 25 kg N (*Leucaena*) + 25 kg P/ha; while September rainfall had a significant positive loading on P_2 of 5 treatments viz., control; 25 kg N + 12.5 kg P/ha; 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. October rainfall had a significantly higher positive loading on P_3 of 50 kg N (urea) + 25 kg P/ha and 25 kg N (urea) + 12.5 kg P/ha; while November rainfall had a significant negative loading on P_3 of 25 kg N (*Leucaena*) + 25 kg N (urea) + 25 kg P/ha and positive loading on P_4 of 25 kg N/ha (FYM). The SOC had a higher positive loading on P_1 in control and 25 kg N (urea) + 12.5 kg P/ha. The soil N had a significantly higher positive loading on P_1 of control compared to negative loading on P_1 of 25 kg N (*Leucaena*) + 25 kg N (urea) + 25 kg

P/ha. Similarly, significantly higher positive loadings of soil P on P_4 of control; and soil K on P_1 of 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha and 25 kg N (*Leucaena*) + 25 kg P/ha were observed based on the PC model.

Assessment of treatments based on PC scores

The PC scores of treatments were derived based on PC model with observed values of rainfall of June to November, crop growing period, SOC, N, P and K variables. A PC regression model was calibrated for each treatment by regressing cotton yield through PC scores of P_1 to P_5 over years. The contributions of P_1 on yield attained by all treatments except control; P_2 in control and 50 kg N (urea) + 25 kg P/ha; P_3 in 50 kg N (urea) + 25 kg P/ha and 25 kg N/ha (*Leucaena*) ; P_4 in control and 25 kg N (*Leucaena*) + 25 kg N (urea) + 25 kg P/ha were significant. The R^2 values ranged from 0.31 for 25 kg N/ha (FYM) to 0.73 for control; while standard error ranged from 132 kg/ha for Control; to 342 kg/ha for 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha.

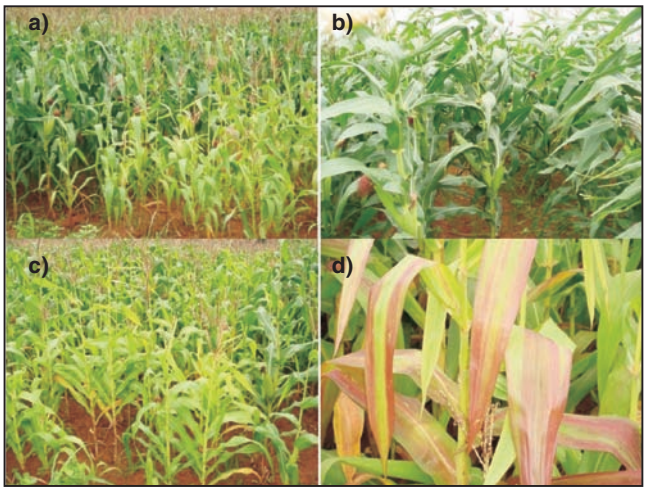
Sustainability and profitability of treatments

SYI was derived for treatments using the (i) treatment mean and standard error based on the PC model and (ii) maximum cotton yield (1910 kg/ha) attained by the treatment viz. 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha during the year 1993. 25 kg N (urea) + 12.5 kg P/ha under crop seasonal rainfall of < 500 mm and 750–1000 mm; Control under 500–750; and 25 kg N/ha (FYM) under 1000–1250 mm gave lowest SYI over years. 25 kg N (*Leucaena*) + 25 kg N (urea) + 25 kg P/ha under < 500 mm and 500–750 mm ; 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha under 750–1000 mm ; and 50 kg N (urea) + 25 kg P/ha under 1000–1250 mm gave maximum SYI over years. 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha provided maximum SYI of 30.5% under 750–1000 mm rainfall, while the crop had low sustainability under < 500 mm rainfall. The cost of cultivation ranged from Rs. 13370/ha under control to Rs. 22651/ha under 25 kg N (*Leucaena*) + 25 kg P/ha. The gross returns ranged from Rs. 19210/ha under control to Rs. 27463/ha under 25 kg N (*Leucaena*) + 25 kg N (urea) + 25 kg P/ha; while the net returns ranged from Rs. 19210/ha under control to Rs. 11598/ha under 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha. The benefit-cost ratio ranged from 1.20 under 25 kg N (*Leucaena*) + 25 kg P/ha to 1.70 under 50 kg N (urea) + 25 kg P/ha based on the study. 25 kg N (FYM) + 25 kg N (urea) + 25 kg P/ha gave maximum gross returns of Rs. 30272/ha and net returns of Rs. 11598/ha with benefit-cost ratio of 1.60. 50 kg N (urea) + 25 kg P/ha gave maximum benefit-cost ratio of 1.70 by providing gross returns of Rs.26409/ha and net returns of Rs. 11073/ha.

2.5.10 Conservation agriculture in maize-horsegram system on alfisols

A field experiment is being carried out at Gunegal Research Farm of Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad to study the individual nutrient effect of N, P, K, S, B and Zn in balanced fertilization on performance of maize-horsegram cropping sequence under conventional and conservation tillage, the impact of conservation tillage on nutrient use efficiency and to work out the economics of tillage, residue retention and balanced fertilization. The experiment was initiated in June, 2010. Hybrid maize (DHM 117) was grown using 60 cm row to row spacing and 25 cm plant to plant spacing. As in the first year of experiment (2010), there were no significant differences in conservation and conventional tillage treatments on maize growth, yield attributing characters, seed and stover yield. But significantly higher grain and stover yield of 4.7 t/ha and 7.9 t/ha respectively was obtained with the balanced use of NPKSZnB followed by B omission (4.4 and 6.9 t/ha), S omission (4.2 and 7.2 t/ha) and least was in control (1.3 and 3.5 t/ha). But certain yield attributing characters like cob length, no. of grains per cob were influenced by CT. Significantly higher cob length was found in CT (21.2 cm) compared to conventional tillage (20.0 cm). Significantly higher

cob length was found in balanced nutrition treatment comprising NPKSZnB (24.1 cm). But mean cob weight and cob diameter were not significantly differed due to tillage treatment. Significantly higher cob weight (246 gm) and no. of grains per cob (51) was obtained due to balanced application of NPKSZnB. In case of horsegram, significantly higher yields were obtained in CT. In conventional tillage, yields were in the range of 264-443 kg/ha, whereas in CT it was 464-643 kg/ha. Significantly higher seed yield of horsegram were obtained with the application of NPKSZnB with recommended dose. In conventional tillage N, P and K content in the seed was in the range of 1.54-2.49%, 0.2-0.6% and 0.74-0.97% respectively, whereas, in CT, N, P, K content of seed was 1.62-2.63%, 0.2-0.7% and 0.77-1.17% respectively. Nodulation was better in conventional tillage with NPKSZnB. With nutrient omissions both under conservation agriculture and conventional tillage, deficiency of N, P and K were noticed in maize.



Maize plants in a) control plots, b) NPKSZnB, c) N omission, and d) P omission plots

There was not much change in pH and EC after one year of cropping. pH was slightly acidic. pH varies from 5.31-5.82 in conventional tillage compared to 5.34-5.92 in CT. EC was normal. It varied from 0.06-0.08 dS/m in conventional tillage compared to 0.05-0.09 dS/m in CT. In conventional tillage treatment organic carbon varied from 0.29-0.42%. In CT, OC varied from 0.31-0.45%. There was depletion of the respective major nutrients (N, P, K) in omission plots and control irrespective of conventional and CT treatments after the harvest of horsegram. But this depletion was less in CT. Microbial biomass carbon (MBC) varied from 28-78 µg/g of soil in conventional tillage compared to 31-89 µg/g of soil in CT. Higher MBC was found in case of balanced fertilization of NPKSBZn. KMO_4 oxidizable C varied from 244-389 mg/kg in conventional tillage compared to 241-402 mg/kg in CT. Very labile, labile and less labile C was in the range of 0.33-0.67, 0.12-0.36 and 0.08-0.29 mg/kg respectively in CT compared to 0.28-0.56, 0.10-0.35 and 0.07-0.27 mg/kg respectively in conventional tillage system. Dehydrogenase activity ranged from 1.19-5.19 µg TPF/g/hr in conventional tillage compared to 1.09-4.4 µg TPF/g/hr. Residue cover in CT plots was higher in the month of February. It was 63.2 to 75.7%. But the subsequent months it was decreased. With balanced fertilization residue cover was more. In the year 2010 amount and distribution of rainfall was good.

2.5.11 Soil carbon sequestration and agronomic productivity of an alfisol for a groundnut-based system in an semiarid environment in southern India

Soil organic carbon (SOC), total magnitude and composition, is a strong determinant of soil quality and agronomic productivity especially under harsh arid and semiarid environments of the tropics. Thus, a 20-year experiment was conducted to assess the impact of rainfed groundnut (*Arachis hypogea*) monocropping, fertilization and manuring on soil quality, SOC sequestration and fractions, and crop yield sustainability on an alfisol in southern India. The concentration of SOC to 1 m depth increased from 2.3 to 3.5 g/kg (52.2%) in 50% recommended dose of fertilizer (RDF) + 4 Mg/ha groundnut shells (GNS), 2.3 to 3.4 g/kg (47.8%) in 50% RDF+4 Mg/ha farmyard manure (FYM) and 2.3 to 2.6 g/kg (13.0%) in 100% RDF over control. The mean rate of SOC sequestration (Mg C/ha/yr) was 0.57, 0.51,

0.02, respectively, for the above treatments. Microbial biomass carbon (MBC) and particulate organic carbon (POC) were significantly correlated (P<0.05) with SOC. Microbial quotient (MQ) and POC/SOC ratio were significantly correlated (P<0.05) with sustainable yield index (SYI). Higher mean pod yield of groundnut (Mg/ha) was obtained with 50% RDF+4 Mg/ha FYM (1.03). The rate of increase in groundnut yield was 13 kg/ha for every one Mg increase in SOC stock to 1 m depth. A minimum of 1.12 Mg C/ha/yr input was needed to maintain the zero change in SOC (Figs. 34 to 36). Hence, combined use of chemical fertilizers and organic manure is essential to enhancing SOC sequestration in monocrop regions in semi arid tropical conditions.

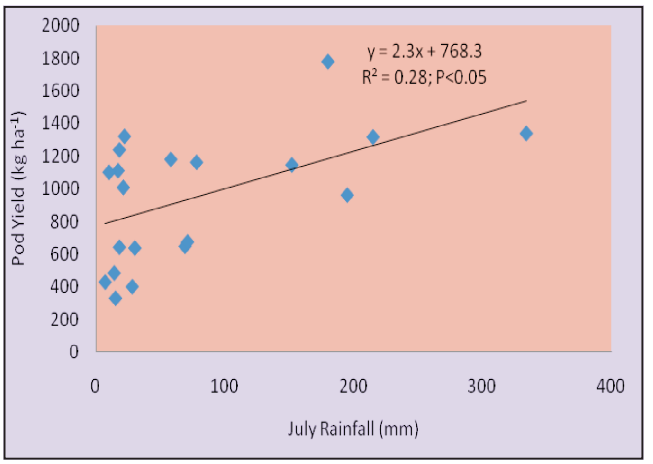


Fig. 34. Relationship between rainfall in July and mean pod yields of groundnut between 1985 and 2004

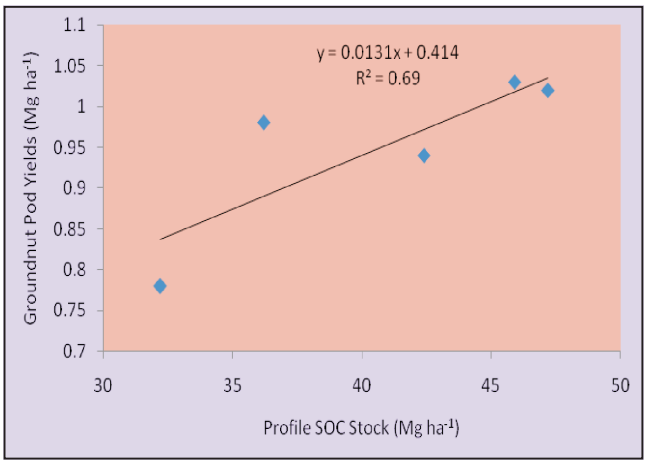


Fig. 35. Influence of profile SOC stocks on yield of groundnut pods in 20 years long term experiment under semiarid conditions.

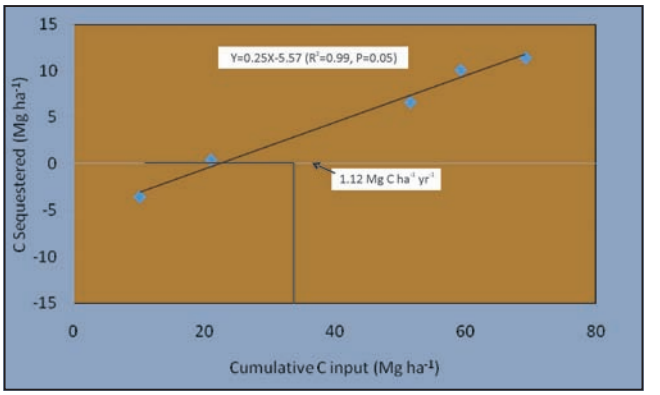


Fig. 36. Critical C input value and its influence on SOC sequestration in groundnut monocropping system under semiarid conditions

2.5.12 Long-term effects of soil fertility management on carbon sequestration in a rice-lentil cropping system of the Indo-Gangetic plains

Enrichment of soil organic carbon (SOC) stocks through sequestration of atmospheric CO_2 in agricultural soils is important because of its impacts on soil quality, agronomic production, and adaptation to and mitigation of climate change. In a 21-year field experiment conducted under sub-humid tropical conditions in India, the impacts of crop residue carbon (C) inputs were assessed for the rice (*Oryza sativa* L.)-lentil (*Lens esculenta* Moench) cropping sequence. These impacts were evaluated in an experiment involving mineral fertilizers and manuring treatments on crop yield sustainability with reference to critical biomass requirements for maintenance of SOC in an inceptisol. Application of farmyard manure (FYM) without and with mineral fertilizers increased C input and SOC concentration and stock. In comparison with the control, the 100% organic (FYM) treatment had significantly higher profile SOC (27.5 Mg/ha), and more C build up (55.0%) and C sequestration (6.6 Mg C/ha) to 1 m depth vis-à-vis the antecedent values in 1986. These parameters were also higher in 100% FYM treatment at a rate providing equivalent amount of the recommended dose of N followed by conjunctive use of FYM and mineral fertilizers. The SOC stock and rate of sequestration were positively correlated with cumulative C input, and with sustainable

yield index (SYI) of upland rice and lentil. Higher grain yield (1.95 and 1.04 Mg/ha of rice and lentil, respectively) was obtained with the application of 50% organic (FYM)+50% recommended dose of fertilizer (RDF). In comparison, higher SOC sequestration rate was measured with the application of 100% organic (FYM). For every Mg increase in SOC stock in the root zone there was 0.16 Mg/ha/yr and 0.18 Mg/ha/yr yield increase of rice and lentil, respectively. For maintaining a stable SOC level (zero change due to cropping), a minimum quantity of 2.47 Mg C/ha/yr is required for this soil, climate, cropping system, and fertilization treatments. In order to achieve this quantity of C, 7.1 Mg of biomass is required to be produced every year versus average rice and lentil yields of 1.6 and 0.7 Mg/ha, respectively (Figs. 37 to 39). The sole application of mineral fertilizers at 50% or 100% of the RDF did not maintain the SOC stock. Thus, application of FYM (or other organics) in conjunction with mineral fertilizers is essential to maintaining and enhancing the SOC stock in the rice-based cropping systems.

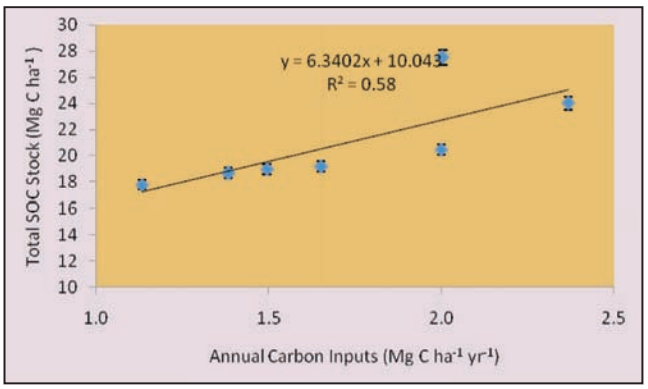


Fig. 37. Crop residue C inputs influence soil organic carbon (SOC; error bars represents the standard error of mean, P<0.05)

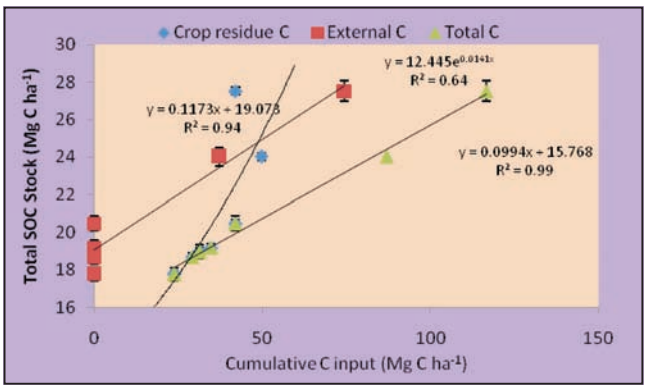


Fig. 38. Influence of cumulative carbon input through a) crop residue, b) external C (organics) and c) total carbon on total soil organic carbon stock (error bars represents the standard error of mean, P<0.05)

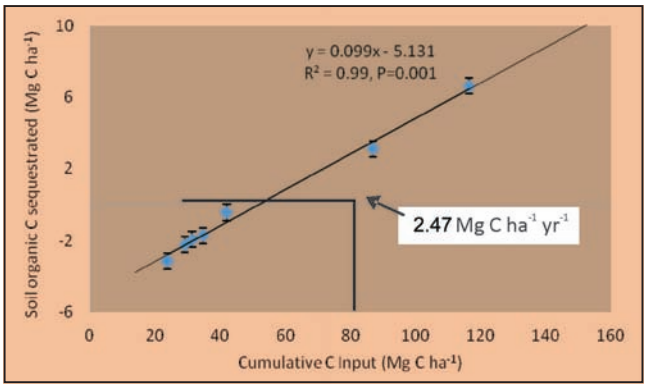


Fig. 39. The magnitude of critical C input and its influence on SOC sequestration in rice-lentil system on Inceptisols of Varanasi

2.6 Land use diversification

2.6.1 Dryland horticulture

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

Separate trials were initiated, both on farm and on station, to standardize efficient integrated nutrient management practices and bioinputs for optimum canopy architecture in custard apple, guava, citrus and mango. Twenty-seven years old guava and custard apple plantations were selected at GRF. The guava plantation was pruned leaving 50% portion of existing secondaries during early summer, 2009 to promote more fruiting units leaving one to three primaries per pit. The number of secondaries varied from two to six per plant after pruning. The data on tertiaries recorded after new flush indicated that the number of tertiaries varied from 4 to 87/ plant in the entire orchard.

In another study on the effect of different doses of chemicals and bioinputs on branching pattern (number of secondaries and tertiaries) and fruit

yield in guava cv Allahabad Safeda, application of 30 kg FYM + RDF gave higher number of secondaries and tertiaries resulting in more number of fruits and yield/plant, followed by application of 15 kg FYM + 50% RDF. Different combinations of all organic and bioinputs resulted in significantly more number of tertiaries thereby increasing the fruit yields. The yields were drastically reduced during 2011 due to continuous drought spell. The decline in guava yield, in terms of number of fruits and fruit weight/plant, ranged from 68.3 to 97.9% among different treatments. Fruit size was drastically reduced and many unmarketable small fruits dried up on the trees due to prolonged dry spell during the fruit development stage (Table 23). Similar trend was observed in Custard apple. The present study indicates that integrated nutrient management will not only result in optimum crop yields by reduced cost of production but also enhance the orchard fertility for a longer period. Early flush, flowering and fruit set, enhanced fruit number and yield per plant were observed with the soil inoculation of different microbes in the experimental orchard crops like guava, custard apple, mango and citrus.

In another experiment, different combinations of organic and inorganic sources of nutrients along with control were imposed during 2010 and 2011 in a RBD with four replications. The spacing adopted was 5x5 m for guava, custard apple and citrus and 10x10 m for mango. Similar type of pruning was adopted in custard apple. Microbial inoculation of VAM or PSB or ZSB or K mobilizers along with higher doses of FYM was found to be effective in early flush growth, flowering and fruit set in sweet orange in an on farm trial. Higher doses of FYM along with trichoderma or PSB or azospirillum also helped in promotion of early flowering and fruit set in guava and custard apple. Application of azospirillum along with 25 kg vermicompost enhanced soil Mn content in sweet orange orchard. Soil Application of paclobutrazol @ 10g a.i/plant improved leaf Mg content in mango orchards. Application of trichoderma in tree basins along with FYM for more than 27 years old guava trees improved N, P, Ca, Mg, Mo and Cu contents and application of PSB improved P, Ca, Mg, Mn, Cd, Si contents in the leaves when compared to RDF (Table 24).

2.6.1.2 Organic cultivation of fruits in drylands

Custard apple: A study was conducted to compare the effect of organic and inorganic nutrient management on growth, yield and quality of custard apple. Significantly higher fruit number and fruit yield were recorded by organic and inorganic treatments compared to control. However, both fruit number and fruit yield/plant were similar in organic and inorganic treatments. The fruit weight was significantly higher under organic nutrient management compared to other treatments. Both

Table 23 : Effect of chemicals and bioinputs on tertiaries and yield in guava cv Allahabad Safeda

Treatments	Tertiaries (No.)	Number of fruits		Yield (kg/plant)		% decline in yield	
		2010	2011	2010	2011	Number	Weight
30 kg FYM	22.65	90.67	17.5	11.65	0.25	80.69	97.85
100 kg FYM	33.25	108.00	26.43	12.13	3.85	75.53	68.26
200 kg FYM	51.75	165.25	39.00	14.93	3.46	76.40	76.82
15 kg FYM+ ½ RDF	44.50	186.75	57.00	22.88	4.67	69.48	79.58
30 kg FYM+RDF	52.00	251.63	53.66	26.26	4.80	78.68	81.72
200 kg FYM + PSB	38.00	155.56	20.00	18.44	1.90	87.14	89.70
200 kg FYM + Azo	43.25	167.25	47.00	17.38	4.46	71.90	74.34
200 kg FYM +Tricho	41.25	99.50	33.33	18.99	3.16	66.50	83.36
C.D. (P=0.05)	11.81	83.85	9. 69	6.47	0.97		

Table 24 : Effect of different sources of nutrients and bioinputs on leaf nutrient status in guava

Element	½ RDF	RDF	200 Kg FYM + trichoderma	200 Kg FYM + azotobactor	200 Kg FYM + PSB	200 Kg FYM	30 Kg FYM
N %	0.56	0.95	2.07	1.15	0.89	0.75	0.36
P%	0.17	0.21	0.27	0.24	0.26	0.40	0.13
K %	0.26	0.26	0.18	0.32	0.09	0.18	0.06
Ca %	2.65	2.92	3.87	3.68	4.66	5.02	1.23
Mg %	0.68	0.50	0.69	0.73	0.86	0.85	0.43
Fe x10ppm	3.8	3.2	2.7	3.2	3.2	3.2	1.6
Mn x10ppm	1.1	4.4	0.7	1.5	5.4	1.0	0.27
Zn x10ppm	1.0	0.2	0.21	1.08	1.51	0	1.08
Cu ppm	0.27	2.0	2.0	4.0	0.82	2.0	0.11
Mo ppm	0	0	0.6	0.6	0	0.6	0.3
Co x100ppm	0.30	1.67	2.28	2.03	3.14	2.56	0.14
Ni x10ppm	2.80	0.01	1.40	1.40	1.40	2.80	0.42
Si x10ppm	0.7	0	0.7	0.7	1.8	0	0.2
Hg x100ppm	0.63	0	0	1.88	0.63	0.63	0.33
Cd ppm	0	0.68	0	0.68	0.68	4	0.08

organic and inorganic treatments recorded similar but significantly higher polar diameter than control. Transverse diameter and TSS were significantly higher in organic treatment than other treatments. Similarly, the seed weight/fruit was significantly less in organic treatment than inorganic and control, which is a desirable character. Pulp weight was also significantly higher in both organic and inorganic treatments compared to control (Table 25).

Guava: Organic treatment gave significantly higher number of fruits/plant compared to other treatments. However, both organic and inorganic treatments recorded similar but significantly higher fruit yield than control (Table 26). Similarly, organic treatment recorded significantly higher TSS but lower acidity compared to inorganic and control treatments.

Table 25 : Yield and quality of custard apple as influenced by organic and inorganic fertilizers at HRF

Treatment	Fruits/ plant	Fruit yield (kg/plant)	Fruit wt (g)	Polar Dia (cm)	Trans Dia (cm)	TSS (^{0}Brix)	Seeds/ fruit	Seed wt (g)	Pulp wt (g)	Pulp (%)
Organic	140.2	35.8	216.2	25.6	24.5	28.4	29.3	6.5	170.9	57.2
Inorganic	130.3	29.0	178.4	24.0	18.5	26.0	26.8	11.0	158.7	47.8
Control	102.5	17.3	150.5	18.2	17.2	23.6	37.3	14.5	104.3	42.7
C.D (0.05)	26.3	10.3	22.72	2.36	2.24	2.38	8.26	4.31	20.7	NS

Table 26 : Yield and Fruit characters as influenced by organic and inorganic fertilizers in Guava at HRF

Treatment	Fruit per/plant	Fruit yield (kg/plant)	TSS (^{0}Brix)	Acidity (%)
Organic	175.4	20.3	12.6	0.28
Inorganic	121.4	17.6	10.7	0.42
Control	60.6	9.2	7.2	0.47
C.D (0.05)	50.7	7.3	0.74	0.07

2.6.2 National network on integrated development of jatropha and pongamia

Biofuels are prioritized by planning commission of India and pongamia and jatropha are two promising species for the production of biofuels in wastelands. The candidate plus trees (CPTs) of both jatropha and pongamia were selected during 2004-05 in germplasm survey and seeds from CPTs were collected. The collected germplasm was screened on the basis of nursery performance and oil content in seed and promising accessions are being evaluated in progeny, zonal and national trials at HRF. Agro-techniques for both the species have been standardized.

Jatropha : The progeny & multilocational trials were established in 2005 with 22 accessions in progeny trial, 16 in national-I, 22 in national–III and 8 in zonal trials. Year-wise performance of these accessions based on seed yield, oil content in seed, growth parameters and pest resistance indicates that the stabilisation of yield has not yet reached. The seed yield during 2011 in national network trial - III ranged from 0.23 to 1.27 t/ha. In progeny, national-I and zonal trials, severe infestation due to stem borer led to replanting of accessions on a continuous basis. As a result no seed yield was recorded across all the accessions during 2011. However, each accession has been saved by replanting stem cuttings from the same plants and also effort has been made to save the plantation by a variety of pest management interventions. As the root borer is soil born and resides in the soil at depths of up to 2 feet, all the interventions failed to arrest further infestation. This pest appears to be specific to the plots adjacent to the forest area of the research farm.

Borer damage

Larvae of Borer

In agri-silvicultural trials, major pests and diseases of jatropha were identified and control measures standardised except for stem borer. The highest seed yield (0.2 t/ha) was obtained with combination of irrigation (20 days interval), 3x2 m spacing and fertilizer application (N90 + P200 g/ plant).

Pongamia : The progeny & multilocational trials were established in 2005 with 23 accessions in progeny trial and 8 each in national and zonal trials. Year-wise performance of these accessions based on seed yield, oil content in kernel, growth parameters and pest resistance which indicates that the stabilisation of yield has not yet reached. Seed yield during May, 2011 ranged from 0.05 to 0.56 t/ha.

Pongamia progeny trial

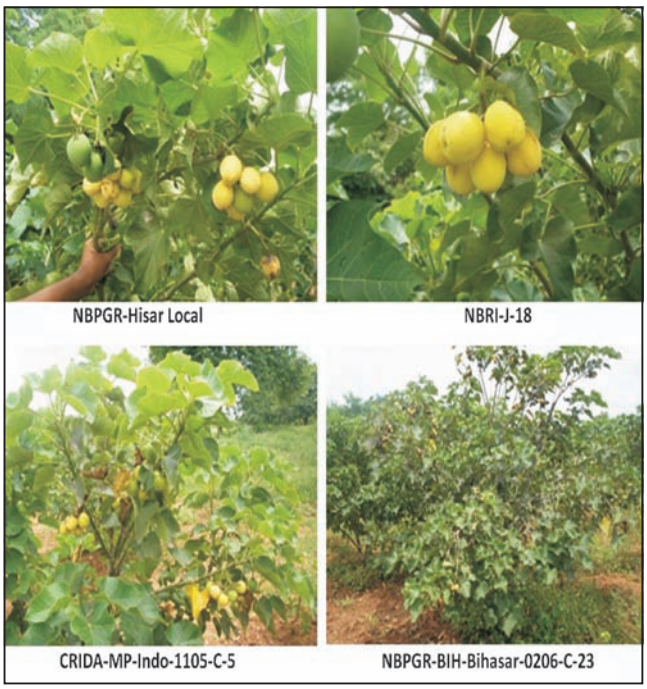
Pongamia zonal trial

In agri-silvicultural trials, major pests and diseases of pongamia and their control measures were identified. Intercropping was possible during first 5 years. Kernel yield of pongamia during 6th year ranged from 0.3 to 2.2 kg/plant in grafts compared to 0.069 to 1.73 kg/plant in seedling originated plants.

Genetic improvement of Jatropha curcas for adaptability and oil yield

Elite planting material (24) available with 8 network partners was exchanged and simultaneously survey and collection of wild germplasm was also carried out during 2005-06 from all the states of the country by respective partners. CRIDA collected the germplasm from Andhra Pradesh and Madhya Pradesh. The multilocational trials of elite (24 accessions) and wild (161 accessions) germplasm were established during 2005-06 at HRF. On the basis of DNA fingerprinting data the most divergent

parents were selected and crossed during 2008. About 44 hybrids (F1s) were planted for evaluation during 2009. Among wild accessions, the performance of best 3 accessions since 2007 on the basis of seed yield indicates that even after 6 years of establishment there is no stabilization of seed yield as the accessions performed differently in each year. At the end of sixth year, all the 3 accessions (AFRI-KER-Palak-0206-C-3, NBPGR-UA-Paur-0306-C-10, and AFRI-TN-Coimb-0206-C-7) performed better with seed yield ranging from 701.9 to 824.5 g/plant. Among the elite accessions, CRIDA-JR-06 performed better and recorded higher plant height, collar diameter, number of branches, canopy spread (E-W and N-S) during 2011. At the



end of sixth year, the performance of three accessions such as CSMCRI-GUJ-Banas-1205-C1, CRIDA-JL-06 and NBPGR-GUJ-SKN-0605-Hansraj was better with seed yield ranging from 635.5 to 787.5 g/plant. Female to male ratios ranged from 1:10 (NBRI - J-18 and PAPL -JPH108) to 1:23 (FRI-UA-Teh-1005-DD-EL-1) during sixth year.

In Parents' evaluation trial, the growth parameters and seed yield was highest in NBPGR-HAR-HAU-0306-Hisar Local. In Heterosis trial, at the end of third year F1 progeny of the cross between NBRI - J-18 x AFRI-KER-Palak-0206-C-1 showed superiority over other F1s in terms of growth and yield parameters. In LxT Analysis, the cross between CSMCRI-GUJ-Panch-0106-C3 x FRI-UP-Allah-1205-C-15 registered maximum values for growth and yield parameters. The studies on floral biology in the above three trials indicated that the female to male flower ratio ranged from 1:5 to 1:33. The hybrids were promising compared to their parents in terms of seed yield. There could have been much superior performance by F1s had there been supply of nutrients and water to hybrids.

2.6.3 Prospects of land use diversification opportunities in distressed districts of Telangana region in Andhra Pradesh

The study was carried out in different distressed districts of Telangana region in Andhra Pradesh State representing variation in soil type, climate and commodity-based production systems namely Adilabad, Nalgonda and Warangal. Each district was further sub-divided into three parts mainly peri-urban, semi-urban and rural to capture spatial and temporal variations in land use and their drivers. Trend analysis of area under cultivation of major crops was undertaken for all the mandals of Adilabad, Nalgonda and Warangal districts for the last two decades (1988-1998 and 1998 to 2008) using secondary data. Primary data were collected from nine villages one each from peri-urban, semi-urban and rural areas in each of the three districts. A total of 270 farmers were selected @ 90 for each of the three districts, 30 each from peri-urban, semi-urban and rural parts covering all the categories of farmers i.e., marginal, small and large based on random sampling with proportion to stratum size. These villages were identified using remote sensing imageries showing large variation in vegetative cover between two time periods namely 1998 and 2008. Remote sensing imageries were procured for two time periods (1998 & 2008) and two seasons (*kharif* & *rabi*) for peri-urban, semi-urban and rural parts of all the three districts.

Data were analyzed and detected change in area under various land uses and various thematic maps were prepared. The whole study culminated in preparation of an action plan along with credit requirement, needed support mechanism and policy measures.

The results of trend analysis showed wide variations in the area sown across the (major) crops and the mandals in the three districts. The area under cultivation of Bt-cotton registered a phenomenal increase at the cost of other crops mainly sorghum in Adilabad and castor in Nalgonda. Within cotton, a major shift in variety was noticed and all the ruling hybrids and varieties of cotton were displaced by Bt-cotton.

The results from primary data indicated that:

- Soybean + redgram intercropping in the peri-urban and semi-urban while sorghum + redgram intercropping in the rural part of Adilabad district emerged as the promising and profitable cropping systems with higher BCRs i.e., 3.98, 3.32 and 3.15, respectively.
- In Nalgonda, horticulture (sweet orange) and agriculture (cotton) sectors were found to be very promising and profitable registering higher BCRs i.e. 2.59 and 2.19 in peri-urban; 2.18 and 2.61 (paddy) in semi-urban and 2.32 and 2.65 (cotton) in rural parts of Nalgonda, respectively.
- In Warangal, 'crop-dairying' was a thumb rule rather than exception but registered decreasing trend for the last two decades in peri-urban and semi-urban areas.
- Livestock (dairying) fared better in peri-urban, semi-urban and rural parts of Adilabad district with higher BCRs i.e. 2.96, 3.38 and 2.77, while 2.95, 2.94 and 3.56 in Nalgonda and 3.56, 3.19 and 3.20 in Warangal districts, respectively.

The application of remote sensing and geographic information system detected changes in land use over a period of 10 years, namely:

- An increase in area under fallow was noticed in Adilabad and Nalgonda but no change in Warangal.
- In all the three districts, there was decline in vegetative cover based on NDVI with an exception of few villages with horticulture as predominant land use.

2.7 Livestock management

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

Grazed tropical pasture provides a low-cost source of nutrients for small ruminant production but it is characterized by seasonal variations in growth and nutrient composition, both of which can limit animal performance. Supplementation helps in nutrient supply during periods of inadequate pasture growth or to achieve higher levels of animal performance than those achievable from pasture alone. The study was conducted to evaluate the effect of supplementation of *azolla and* horsegram at different levels on the animal response in terms of average daily gain (ADG) and quality of meat under both intensive and extensive systems. Twenty four Nellore brown sheep with mean body weight (BW) of 19.8 ± 0.18 kg were randomly divided into four comparable groups (GI, GII, G III and G IV) (BW: 19.8 ± 0.17, 19.8 ± 0.19, 19.8 ± 0.15 and 19.8 ± 0.21 kg) and studied for 120 days under grazing conditions. Group I didn't receive any supplement and served as negative control, whereas Group II received concentrate mixture @ 1% of the live weight and served as positive control. Group III and IV received either horsegram or *azolla* meal on equi-energy and nitrogen basis. Body weight gain was measured at fortnightly intervals. In another experiment, 24 pregnant ewes with mean body weight of 23.7 2.04 kg were randomly divided into four comparable

groups (GI, GII, G III and G IV) (BW: mean ± S.E. = 23.7 ± 2.08, 23.7 ± 2.11, 23.7 ± 2.13 and 23.7 ± 1.98) and studied under grazing with or without supplementation. Group I served as negative control, whereas Group II, III and IV received concentrate mixture, horsegram and *azolla* meal @ 250 g/day for 120 days, respectively.

Supplementation of either horsegram or *azolla* meal on equi-energy and nitrogen basis resulted in significantly higher weight gain (Fig. 40) and ADG (Fig. 41) than concentrate mixture. The present study indicates the necessity of supplementation in small ruminants under grazing conditions. Higher birth weight and rapid gain in weight ($P<0.01$) of lambs were observed with supplementation, however a non significant difference was observed among the supplements (Fig. 42). Among the breeds, higher birth weight ($P<0.01$) was observed in Nellore than Deccani lambs with supplementation. Further, the difference in weight gain at different intervals (Fig. 43) indicates the significance of supplementation in pregnant ewes under grazing conditions.

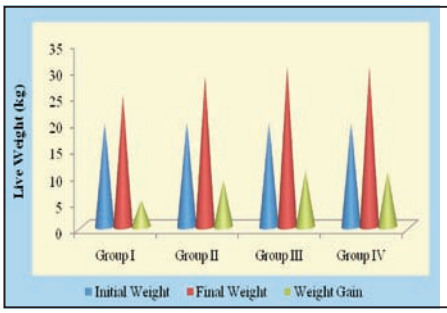


Fig. 40. Performance of Nellore sheep under grazing conditions fed with different protein supplements on equi-energy and nitrogen basis

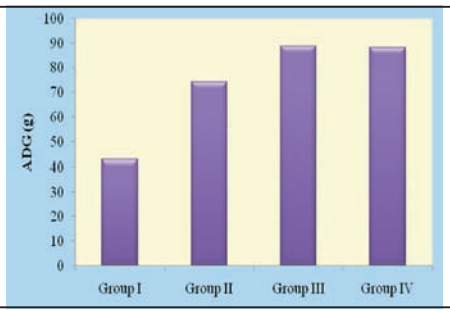


Fig. 41. Average daily gain (ADG) in Nellore sheep under grazing conditions fed with different protein supplements on equi-energy and nitrogen basis

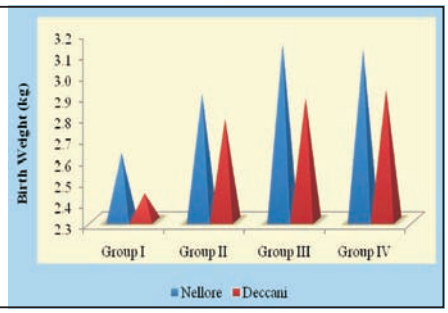


Fig. 42. Birth weight of lambs of dams under grazing conditions fed with different protein supplements

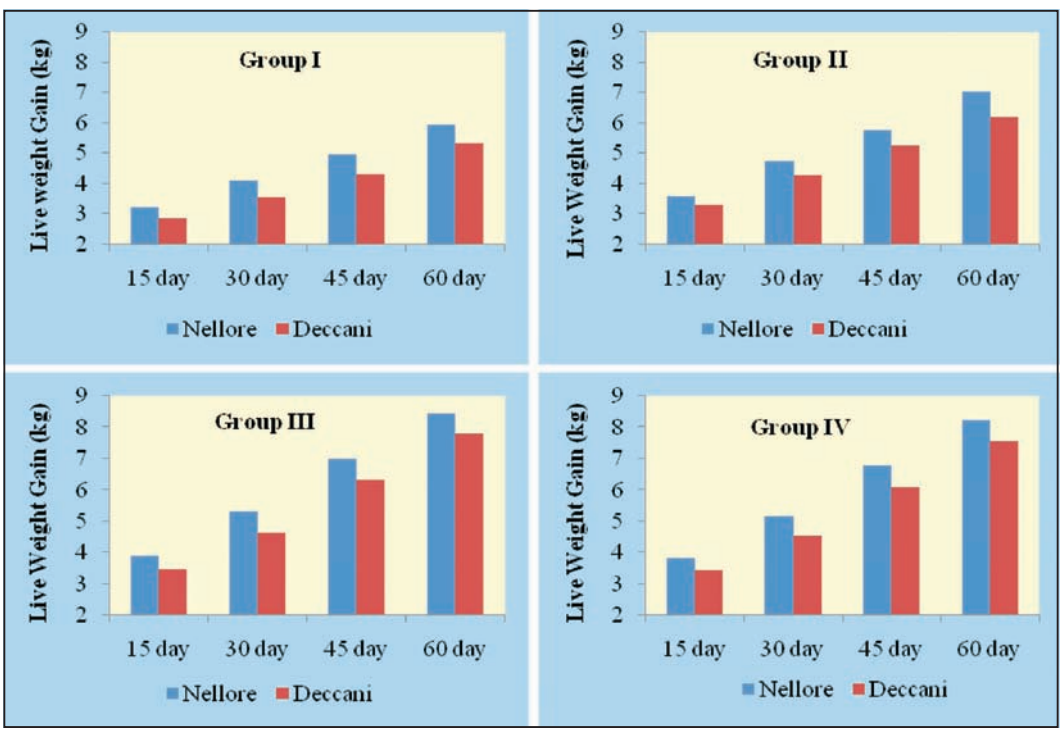


Fig. 43. Effect of supplementation to dams on the performance of lambs

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

Ruminants depend on microorganisms to digest plant cell wall polysaccharides present in coarse crop residues. However, microbial digestion in the rumen also results in waste products such as carbon dioxide (CO_2) and methane (CH_4) and approximately 7% of dietary gross intake energy is lost to the atmosphere as CH_4. Methane represents a loss of energy to the animal and also an important greenhouse gas that significantly contributes to global warming. Any attempt to reduce these emissions from livestock would enhance the productivity of the animal. *In vitro* gas production technique was carried out to assess the cumulative gas pool and concentration of methane in cumulative gas from the fermentation of coarse crop feed material (sorghum stover) with different supplements. Rumen liquor was collected from the slaughtered sheep and goat at Modern slaughter house, Chengicherla, Hyderabad. The gas pressure and volume were taken at 24 and 48 hrs and the gas samples were analyzed for methane concentration with gas chromatography. Cumulative gas production at 24 hrs of *in vitro* fermentation of sorghum stover varied with the supplementation. Gas volume was reduced significantly with supplementation and maximum reduction was observed with *S. cerevisiae*, followed by groundnut cake (Fig. 44). Tanniferous feed ingredients like stylo meal, sorghum grain, horsegram meal and tamarind seed cake also substantially reduced *in vitro* gas production during fermentation of sorghum stover. Similarly, methane concentration in the *in vitro* gas was less with supplementation compared to sole sorghum stover fermentation. Methane production from *in vitro* fermentation ranged from 17 to 37 g/kg IVDMD with maximum from sole sorghum stover and minimum with *azolla* supplementation (Fig. 45). Supplementation substantially reduced methane production form *In vitro* sorghum stover fermentation. Further, the *in vitro* degradability of dry matter and organic matter was also enhanced with supplementation. These results indicate the significance of supplementation along with the coarse crop residues while feeding to the livestock.

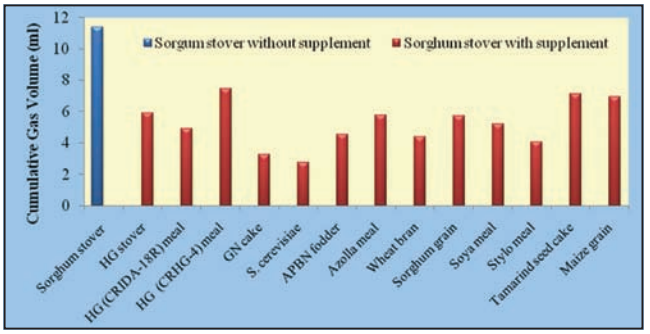


Fig. 44. Cumulative gas production at 24 hrs from the fermentation of sorghum stover with different supplements

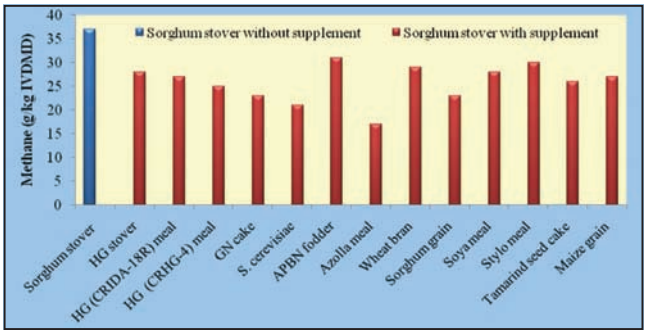


Fig. 45. Methane production profiles from the fermentation of sorghum stover with or without supplementation

2.8 Energy management

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

The effect of tillage and residue cover on soil moisture content and crop yields was evaluated with maize crop. Appropriate farm implements were also developed to implement the technical program. The maize crop was sown using tractor operated horizontal plate planter and stover management activity was taken up with tractor front mounted crop stalk slashing machine. The treatments for the experiment were: T_1- Removal of stover after cob harvest + tillage operations (CV -2, DH -2), T_2 – Stover slashing & spreading + disk harrow operation twice, T_3- Stover cutting to 50 cm height (stubbles) – No till and T_4- Stover slashing spreading on soil surface – No till.

Crop stands after 15 DAS in residue - no till plot (top) and residue - disc harrow twice plot (bottom)

The low till – horizontal plate planter was tested for its performance and metering plates were redesigned and calibrated for accuracy. Under field conditions, the planted seed rate was more or less equal both in conventional till (T_1) and low till plots. Results of soil moisture in top 15 cm profile indicates that low till plots with partial residue incorporation recorded slightly higher moisture throughout the crop growth period.

The lowest dry weed biomass of 109 kg/ha was recorded in the conventional practice (T_1). However, there was no significant difference in weed biomass among treatments. The dry biomass and grain yields were significantly influenced by treatments. Residue spread and twice disc harrowed plot (T_2) recorded highest grain (1389.8 kg/ha) and biomass (3893.9 kg/ha) yields and stubbles + No till practice recorded lowest 972.5 and 2265.5 kg/ha respectively.

2.8.2 Optimization and distribution of harvested rainwater through portable pumpset

A nylon pump suited for 1.5 hp petrol-start-diesel engine was developed (Prototype-1) and tested last year for improving portability of the pumpset. Considering defects in prototype-1, this year nylon pump was modified (Prototype-2) and tested. In protype-2, impellor shaft was reinforced with stainless steel bush to minimize wear loss. In addition to this, dimension of the impellor has been changed in view of increasing flow rate. The diameter of the impellor was increased from 110 mm to 120 mm and vane width was increased from 10 mm to 15 mm. Comparative tests of refined and existing pump were conducted.

The preliminary tests were performed for clean water lifting. The depth of water was 1m and pump was operated at 2000 rpm which was about 2/3 of rated speed for given engine. For these conditions, the flow rate of the refined model of nylon pump was 13 m^3 as against 12 m^3 with existing cast iron pump. Increase in flow rate was mainly due to increase in impellor diameter. The wear loss was examined. The pump was operated for 8 hrs for different periods and no material wear was found in any components of refined model of pump.

Demonstration of nylon pump: Demonstration of nylon pump with 1.5 hp petrol start diesel engine was conducted during National Consultation on "Application technologies for harvested rainwater in ponds" organized at CRIDA during 19-20 March, 2012. National level experts appreciated the performance of the nylon pump.

Demonstration of Nylon Pump

2.9 Socioeconomic studies

2.9.1 Sustainability of development watersheds in rainfed agro – eco – sub-regions of peninsular India using GIS and remote sensing

Watershed development program has been a major strategy to address the twin issue of soil erosion and water scarcity that restrict agricultural productivity in rainfed regions and hence has received huge public investments in the last four decades. However, the benefits have not been commensurate with the level of investment. This study aims to understand which aspects or factors are critical for sustainable development of rainfed agriculture and which indicators can serve as signpost for evaluation of sustainability of watershed project. As this task requires a multidisciplinary approach given the layered multi-pronged approach required for successful implementation of a watershed project, fifty-one sustainability indicators were constructed with score-card to evaluate the five aspects of agricultural sustainability, as mentioned earlier. This was followed by an exercise to identify critical indicators essential for monitoring and evaluation of impact of watershed development project based on two statistical techniques – Principal Component Analysis (PCA) and Bivariate Correlation techniques. A Raster Calculator tool was added to improve accuracy of spatial analysis within the watershed thus imparting objectivity to the evaluation procedure. Thematic maps pertaining to each indicator were generated which when combined in Raster Calculator, provided a Composite Sustainability Index to each individual field / land holding within the watershed. These indices were categorized into Deciles classes which were again grouped into three in the following manner indicating probability of achieving sustainable development. Deciles 1-4 denoted poor, 5-7 Deciles indicated moderate to fair and 8-10 Deciles indicated a good chance of attaining sustainable development.

During the year six Monitoring (Table 27) and six Non-Correlated Evaluation Indicators (Table 28) were identified from the set of fifty-one Sustainability Indicators constructed for evaluating five aspects of agricultural sustainability - agricultural productivity, livelihood security, economic viability, environmental protection and social acceptability at three spatial –levels viz., household (HH), field (FL) and watershed (WL) in watershed project villages. Six Non-Correlated A-Plastic Evaluation Indicators identified (Table 2) are critical and contribute to over 80% of sustainability.

Table 27 : Critical monitoring indicators for watershed programme

Watershed - level	Contribution of indictors to sustainable development (%)
Availability of fodder	3.5
Total crop production	7.8
Gross agricultural income	7.8
S & WC structures	17.9
Soil moisture conservation	17.9
Farm OM recycling	13.4

Table 28 : Evaluation indicators for sustainable watershed programme

Watershed-level	Contribution of indicators to sustainable development (%)
Soil organic carbon	13.4
Credit facility	15.9
Gainful employment	13.4
Availability of fodder	12.2
Soil fertility	12.4
Crop diversity index	13.6

Evaluation of treated micro-watersheds in AESR 7.3 region indicated that <20% land within treated watersheds was found to be sustainable (Fig.46). Trend in vegetation index indicated an increase in NDVI in post-monsoon period in treated watersheds compared to untreated watersheds. Sustainable Yield Index (SYI) analysis indicated higher yield in treated watersheds. However there was a decline in extent of rainfed agriculture in the region because

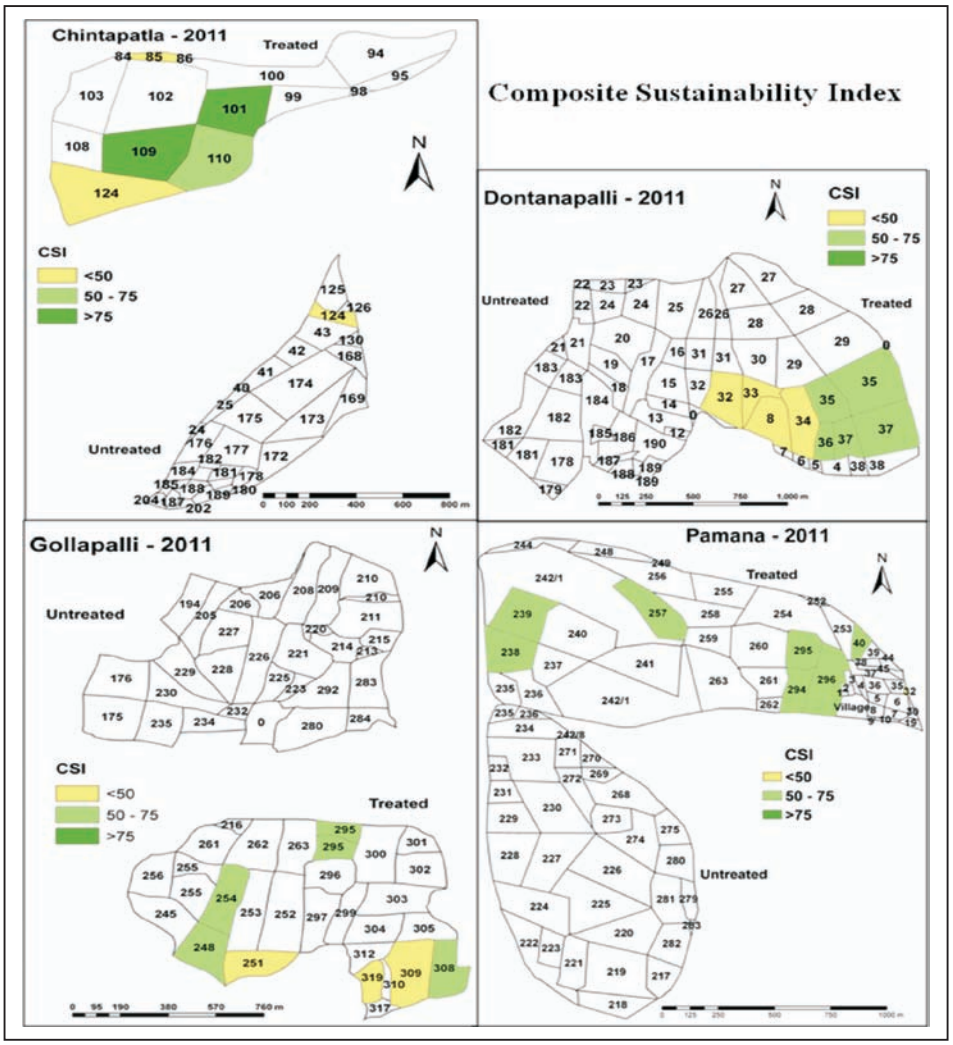


Fig. 46. Evaluation of watershed projects in Telengana region, Andhra Pradesh

of overlapping development programs like Accelerated Irrigation Benefits Program and Repair, Renovation & Restoration (RRR) of Water Bodies linked to Agriculture that have adversely impacted watershed development programme.

2.9.2 Assessment of factors of farm productivity based on modelling of socio-economic variables of rainfed farmers

The study is intended to identify socio-economic and other factors related to rainfed farmers influencing the production at individual farmers' level. It is to suggest extension strategies for increasing farm production on a sustained basis by utilizing the knowledge about different factors that exert influence on productivity of rainfed crops. The study has been conducted in Ranga Reddy district of Andhra Pradesh. Data were collected from sample number of respondents (60) from 12 villages of Chevella mandal and was analysed and results were interpreted based on analysed data. The results of the analysis indicated that majority of the farmers are in 'medium' level of farm productivity for different crops viz., maize, cotton, kharif rice, tomato, carrot and beetroot cultivated by them during last three years (2006 to 2008). Pooled analysis of correlation between dependent variable (crop yield) and selected independent variables indicated that variables viz., age, farming experience, mass media exposure and credit orientation were found to have significant correlation with the yield of cotton crop. This means farmers

who are elder in age with more experience in farming achieved higher yields. However negative correlation of variables like mass media exposure and credit orientation might be due to the ineffective roles played by mass media and farm credit sources respectively

Variables viz., farm power, planning orientation and management orientation were found to have significant correlation with the yield of kharif rice. This means higher possession of these attributes/ resources helped the farmer to achieve higher crop yields. Variables viz., price situation, market facility age and farming experience, were found to have significant correlation with the yield of tomato. This indicates that farmers with more age and experience in farming could achieve higher yields. However, negative correlation of price situation and market facility with the yield might be due to the prevalence of unremunerative prices and poor/ average facilities of market existing in the study area.

Out of the fifteen socio-economic variables only seven variables found to be jointly explain the variation in yield of maize to the extent of 17 per cent though non-significantly. Six variables in case of cotton were found to be contributing together to yield variation to an extent of 60 per cent significantly. The variables *viz.*, age, farming experience, credit orientation, extension agency, contact, and livestock possession were found to be contributing significantly and hence could be termed as good predictors of yield of cotton.

In case of *kharif* rice, the results indicated that six variables were found to be contributing together to an extent of 64 per cent significantly to yield variation. The variables *viz.*, farm power and planning orientation were found to be contributing significantly and hence could be termed as good predictors of yield.Seven variables in case of cotton were found to be contributing together to an extent of 64 per cent significantly to yield variation. The variables viz., land holding, price situation, market facility and credit orientation were found to be contributing significantly and hence could be termed as good predictors of yield.

In case of carrot eight variables, were found to be contributing together to yield variation to the extent of 80 per cent. The variables viz., farm power, credit orientation, marketing orientation, labour availability and land holding were found to be contributing significantly and hence could be termed as good predictors of yield. Five variables in case of beet root were found to be contributing together to an extent of 99 per cent significantly to yield variation. The variables *viz.*, education, farming experience, risk orientation and price situation were found to be contributing significantly and hence could be termed as good predictors of yield.

2.9.3 Economic analysis of rain water harvesting structures – Farm ponds

The project was initiated during 2009 with the objective of analyzing the economics and adoption of farm ponds. Farm ponds are considered as important rain water harvesting structures and have been found useful in enabling supplementary or critical irrigation to rainfed crops. During the year, extent and determinants of viability of farm ponds were examined using the data from one hundred farm ponds in Anantapur district of Andhra Pradesh. The results show that 14 out of 100 ponds generated an additional returns of less than Rs.3000 and 10 ponds generated more than Rs.15000 (Fig. 47). Majority of ponds generated an

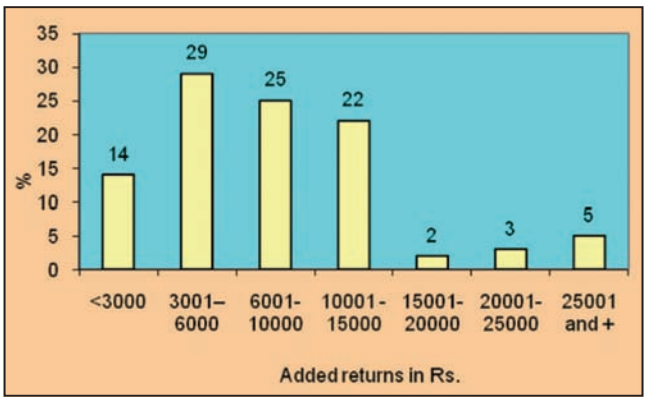


Fig 47. Distribution of farm ponds based on additional returns generated

additional returns varying between Rs. 3000 and 6000. Assuming these returns would occur every year for a period of 15 years, the economic viability in terms of NPV and BC ratio was calculated for all the 100 ponds. It was observed that 33 out of 100 ponds gave an NPV of less than Rs.30000. It is interesting to note that four ponds recorded an NPV in excess of Rs. Two lakhs and investment in 15 ponds was found to be unviable with a negative NPV. Similar findings were observed in case of BC ratio as well. The BC ratio was found to vary between 2-4 in a majority of ponds studied (Fig. 48).

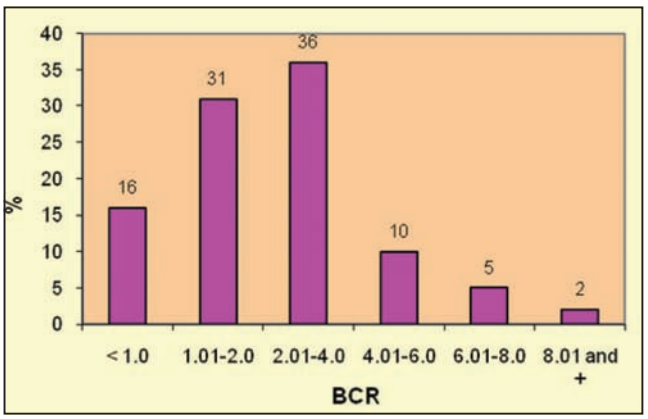


Fig 48. Distribution of farm ponds based on benefit-cost ratio

In order to examine the determinants of profitability of ponds, the additional returns generated was regressed on independent variables. The results indicated that four variables, size of plot, size of pond, change in cropping pattern and use of water for irrigation were found to have significant positive effect on the profitability (Table 29). Variables such as slope of the plot, presence of a bore well and number of fillings were not found to have significant effect.

In order to further understand the determinants of profitability, the characteristics of five most profitable and five least profitable ponds were examined. It was observed that the average size of the plot and pond were much higher in case of the most profitable ponds. Similarly, the yield effects were more prominent as well as the changes in cropping pattern. The profitability was found to be associated with changes in cropping pattern in favour of horticultural crops such as sweet orange and tomato.

Table 29 : Regression analysis of determinants of profitability of farm ponds in Anantapur district

Variable	coefficient	SE	*t*
Constant	-3572.7	4798.6	-0.78
Plot size	1661.48	322.98	5.144
Pond size	39.49	23.21	1.702
If lifted	3874.34	1544.06	2.508
D cropping pattern	10456.89	2147.91	4.868
Slope	-4.01	82.79	-0.048
D CI	-1432.24	2516.31	-0.569
Presence of bore well	-1783.83	1323.81	-1.347
No. of fillings	-1162.58	837.163	-1.389
R^2	0.55	n=100	
F	13.32	P=<0.001	

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

Body Mass Index (BMI) is an essential tool to assess basic nutritional status of a community which determines the grade of malnourishment status of population. Nutritional anthropometry of 40 rural women of Farooqnagar and Balapur mandals of Mahaboobnagar district was assessed using Anthropometric data collected by a structured

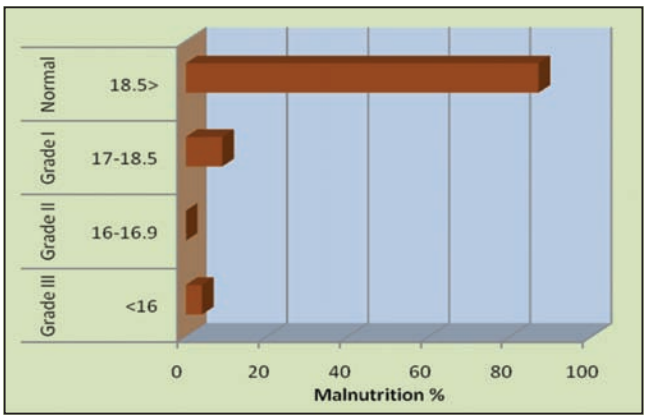


Fig. 49. Body Mass Index (BMI) of rural women of Farooqnagar mandal

pre tested questionnaire. Grading of nutritional status as Body Mass Index (BMI) was calculated using heights and weights of women. The present nutritional status of Farooqnagar mandal, showed that 87% of rural women population studied were found to be in normal nutritional status who consumed millets in their daily diets. Only 9 and 4 percent of women were found to be in I grade and III grade of malnutrition respectively (Fig. 49). In Balapur mandal, 90 percent of rural womem were found to be in normal nutritional status and 5 percent each in I grade and III grade of malnutrition. This can be attributed to calorie insufficiency in the rural women population.

2.10 Transfer of technology

2.10.1 ICAR sponsored scheme on "Scaling up of water proeductivity in agriculture for livelihoods through teaching cum demonstrations, training of trainer's and farmers

There is a need to promote better water management practices under limited water resources (small scale water harvesting structures) conditions to ensure better water use efficiencies and higher productivity.. In this backdrop it is planned to sensitize the experts, subject matter specialists, community workers, extension professionals and farmers about the need for increasing water productivity to drylands familiarizing them with the technological options available for achieving 'more' crop for 'raindrop'.Hence well structured training programmes for farmers and field level extension functionaries are conducted (Table 30).

Table 30 : Training of farmers and trainers

Particulars	No. of training programmes	No. of participants	Duration (days)
Farmers training	10	525	7
Trainers training	03	67	14

Demonstration units of micro irrigation system such as drip with online and in line emitters and also sprinkler and rain gun system for various crops established and demonstrated the utility of them to the clientele (farmers and trainers) by conducting field visits (Table 31, 32).

Table 31 : Details of technology demonstrated

Crop/season	Area/variety	Method of establishment	Spacing (cm)	Date of planting
Okra (Kharif)	450 sq.m, Arka Mallika	Direct sowing	50 x 45	13-7-2011
Tomato (Kharif)	450 sq.m	Trans-plantation	50 x 45	20-7-2011
Capsicum (Rabi)	237.3 sq.m, Santa (green) & Tara	Trans-plantation	50 x 45	17-12-2011
Okra (Rabi)	237.3 sq.m, Aruna	Direct sowing	50 x 45	29-12-2012

Table 32 : Details of yield obtained (kg/plot)

Crop/season	Surface	Sub-surface (5 cm)	Sub-surface (10 cm)
Kharif			
Okra*	152.9	156.2	163.7
Tomato	364.2	468.8	458.7
Rabi			
Capsicum**	64.3	66.7	79.6
Okra*	39.0	37.2	47.6

*No. of harvestings: 12 **No. of harvestings: 8

2.10.2 Technology transfer of good agricultural practices (GAP) management to improve profitability, sustainability and income from rainfed farming in Rangareddy District of Andhra Pradesh

In rainfed context GAP means production efficiency and environmental sustainability through adoption of sustainable agricultural methods such as IPM, INM and conservation agriculture. It reduces risks associated with use of pesticides, keeps food safety standards and sustainable natural resources management. The study objectives consists of integrating of GAP in farming systems and knowledge and skills improvement through farmers fields school approach.

Kandlapally village of Pudur Mandal in Rangareddy district has been selected with 30 SC women beneficiaries. A base Line Survey on socio-economic status, knowledge levels, and technological problems in crop, livestock, was carried out prior to implementation of project. Good soil management, soil test based fertilizer application to improve organic matter content, N, P, K and micro nutrient levels in soil was followed. A PRA survey indicated preferences of women beneficiaries with crop selection, preferably food crops with disease resistance and superior yield components.

Technology transfer in Good Agriculture Practices project was initiated in Kharif, 2011 in rainfed areas of Rangareddy district. Research in rainfed areas revealed poor socio economic status and depleted soils affecting crop productivity. With introduction of cotton and Maize crops in the region and farmers following indigenous technologies the need for improvement of soil and socio economic status found necessary. Soil testing and soil test based fertilizer application formed major intervention in Maize and Pigeon pea crops. GAP principle suggests that incorporation of organic manure improves soil fertility contributing to good soil management practice. Farmers in general apply organic manure to cash crops (cotton) more than food crops.

GAP intervention in crop production

Biofertilizer use : Two demonstration plots, each of size 7.7x17.5m was laid out for trials. Recommended doses of fertilizer based on soil test based values has been demonstrated in fields of women. PSB as substitute to P mixed with organic matter was also demonstrated with improved varieties of Maize and pigeon pea in 2:1 ratio.

Use of organic manure and bio-fertilizers : Utility and use of Bio-fertilizer was promoted as GAP intervention. PSB, a bio-fertilizer substituted inorganic 'P' in soil. PSB, bio-fertilizer mixed with FYM @ 8kg PSB per quintal of FYM. About 40kg of PSB applied to 30% of demonstration plots.

Use of $ZnSO_4$ in maize : Maize crop is a heavy feeder and micronutrient 'Zn' found crucial for crop development, which was applied through Zinc Sulphate fertilizer @ 20kg / per acre.

Use of IPM : Neem oil spray as a prophylactic measure in pigeon pea ensured protection against Helicoverpa spps. damage. Erection of pheromone traps for surveillance was followed to assess the helicoverpa adults likely to cause damage.

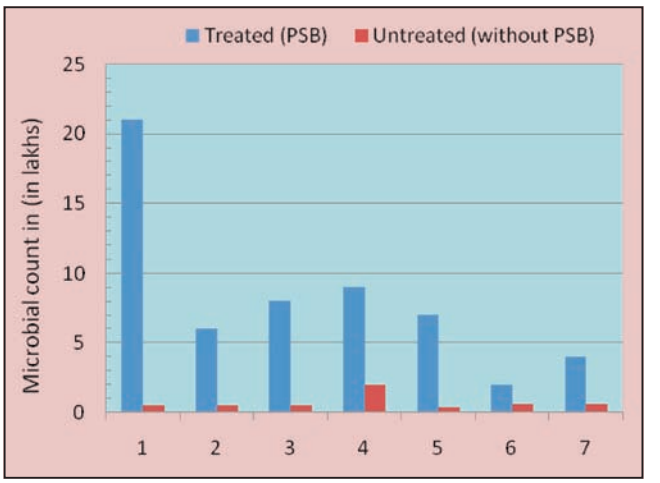


Fig. 50. Microbial count of PSB in treated and untreated plots:

Maize seedlings in zero tilled plots with hand dibbling

Zero tillage maize in rice fallows : Zero tillage maize intervention has reduced land preparation time by 2-3 weeks and Rs 6000 on cost of hiring of tractor, implements and labour.

GAP Interventions in livestock - Low cost animal housing

Cows and Buffaloes are affected with food and mouth disease during rainy season. Regular vaccination and immunization at the onset of monsoons to animals prevents from diseases like FMD and hemorrhages. Schedule of deworming and mineral mixture supplementation provided to animals of women group. Technological intervention relevant to animal housing, vermicomposting sheds demonstrated. Animal health camps were organized to provide vaccination to cows, buffaloes and goats as a prophylactic measure.

Animal feeding in clean designated areas reduces feed contamination with urine and dung. Urine drained out immediately keeps house dry and protects animal from infectious diseases. Milk drawn from such animals located in clean houses is less contaminated with bacteria and other harmful microbes. Animal housing should be kept clean with frequent cleaning of floor with water and antiseptics. Low cost housing costs about Rs 500.

Cattle shed before (top) and after (bottom) intervention

GAP Interventions in horticulture

Pro trays were utilized for nursery seedlings establishment in vegetables. Benefits derived from are time saving in nursery duration, production of healthy seedlings causing less damage to seedlings while removing from trays during transplanting in main field.

Nursery management in pro trays

Technology reduced land preparation time, seedlings mortality by 25 percent and its management on house roofs is much easier.

Tomato seedlings raised in pro trays

Staking of tomato crop

Staking improves quality of tomato fruits which otherwise fruits are subjected to damage on field by water and soil and as well fetching low price on produce.

2.10.3 Leveraging access to ICTs for improved rural Livelihoods: Development of strategic framework

The project used ICTs as key strategic tools for improving livelihoods through access to information on improved technologies and knowledge empowerment. During the period, the crop calendars were sunflower and sorghum were prepared and validated with the farmers of the clusters. The frame work for sending the messages under Sasyavani, mobile based agro advisories, was finalized. Preferential analysis towards withdrawal and sustainable strategies was conducted through structured interview schedule with 60 farmers of Anantapur, Mahabubnagar and Rangareddy districts. The maintenance /sustainability options as preferred by the farmers, were Knowledge Sharing Centre (KSC) to be with Gram panchayat (52%) followed by Govt depts. (18%) and field NGOs (13%) respectively.

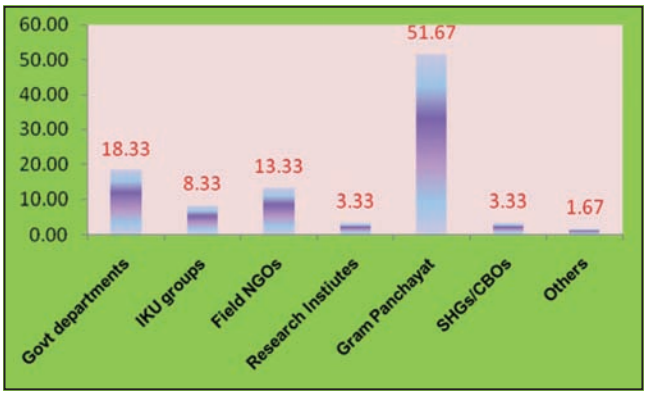


Fig. 51. Farmers' preference of maintenance / sustainability options for KSC's

The project showcased and documented the strategic processes involved in the dissemination of information on improved technologies through ICT tools.Based on the work gone in to the project suitable prototype depicting the processes of ICTs mainstreaming was developed in the study consisting main elements as situation analysis, content design & development, identification and deployment of suitable ICT tools, community mobilization and capacity building and sustainability efforts with pre requisites of feedback , monitoring, corrective measures , maintenance of ICT tools as continuous efforts at every level.

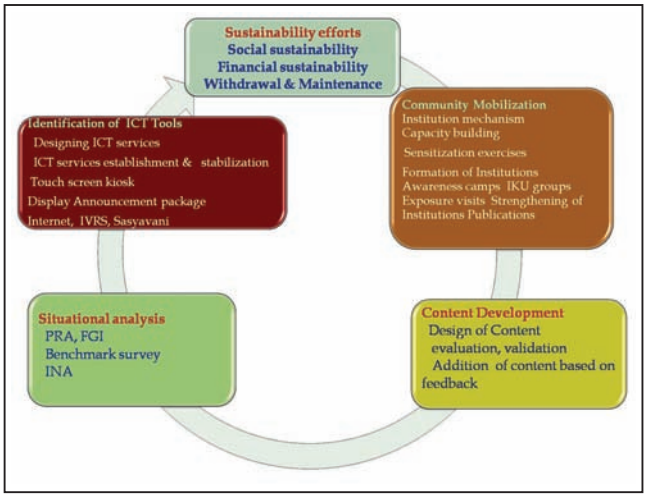


Fig. 52. Model depicting elements and strategic processes involved in use of ICTs as extension tools

2.10.4 Assessment of performance of knowledge share centres in technology dissemination

The study contributed to understand the performance of knowledge share centres across the clusters. The analysis was done on the utility of ICT tools and services placed in the kiosks. Majority of the farmers (73%) preferred the extension services of Sasyavani followed by internet.

The correlation analysis indicated that variables like in accessibility, frequent repairs and maintenance, have shown significant negative correlation where as capacity building of the farmers in using ICT tools has shown significant positive relation with the overall performance of the clusters. Based on the overall performance score the districts are classified under high medium and low performance categories. The current year viewers statistics of KSCs revealed that the average number of visitors for maximum in Rangareddy cluster.

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)

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

The project was initiated during 2009 with the objective to analyze the land and water productivity of rainfed agriculture. During this year technological and institutional options for enhancing productivity of the rainfed farming were analysed. The analysis of data obtained from three districts namely Adilabad, Mahbubnagar and Rangareddy was done to examine the impact of technology and credit on cropping pattern and resource use. Majority of the farmers in Adilabad district were cotton farmers with 70 per cent area under the crop. The most profitable crops grown were soybean + redgram (Rs. 36, 458/ha) and cotton + redgram (Rs. 30, 801/ha). The farmers were divided into small, medium and large based on their land holding. It was observed that for a small farmer under the existing technology when the resources were optimally allocated, soybean + redgram replaced cotton + redgram and about 81 per cent of the total area was allocated to soybean + redgram with rest of the land to Kharif Jowar (Fig. 51).

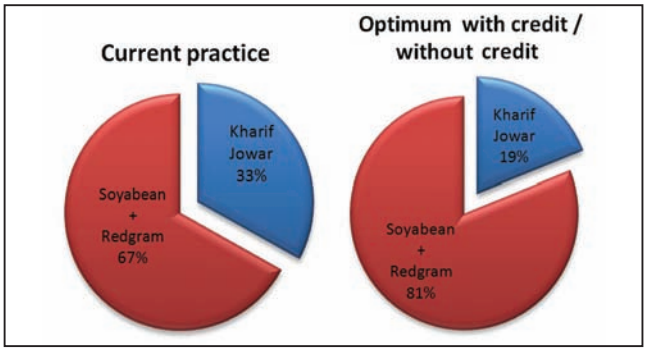


Fig. 51. Cropping pattern of a small farmer with existing technology in Adilabad

Credit restrictions did not show any significant changes in cropping pattern of the farmer. The farmer's income was only Rs.8016 but in the optimal plan the net returns of the farmer increases to Rs. 49,616 and with credit restriction the net returns decrease by 15 per cent.

The impact of recommended technology on cropping pattern and resource use was studied. Nearly 80 per cent of the area was allocated to soybean + redgram and rest of the area to jowar under credit restriction (Fig. 52). When proper

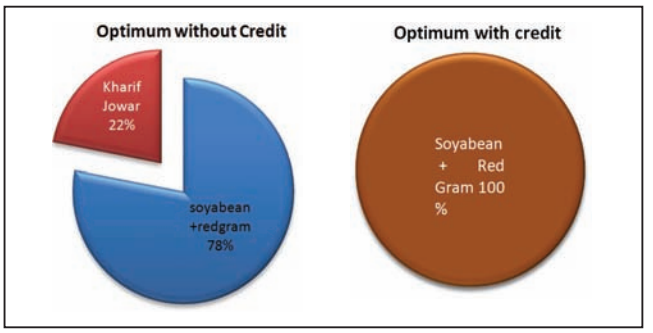


Fig. 52. Cropping pattern of a small farmer with improved technology in Adilabad

technology is used had there been no credit constraint cotton does not appear in the plan for a small farmer. Under this scenario all his land was allocated to soybean + red gram with net returns of Rs. 60,799. There is 18 per cent increase in the net returns of the farmer when proper technology is used. The same when credit is a constraint, there is reduction in net returns by 20.8 per cent (Table 33). Credit and technology play important role in efficiently utilizing the resources and in increasing farmer's income. The results for medium and large farmers also show similar results of increase in net returns with improved technology. Among the major crops grown in Mahbubnagar district rabi sunflower had the highest net returns of Rs. 55019/ ha while in Rangareddy district it was ridge guard (Rs. 45525 /ha). In Mahbubnagar and Rangareddy, the results showed that when credit is restricted it was optimum to lease out nearly 35 per cent or more of the farmer's land. Use of recommended technology increased the net returns of the farmers significantly.

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

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

Table 33 : Resource use under different plans (Adilabad)

Resources	Existing technology		Improved Technology		Actual
	Without credit	Optimal	Without credit	Optimal	
Capital, Rs.	6775	8147	5840	7222	12109
Family Labour, mandays	44	43	44	43	93
Hired Labour, mandays	23	24	23	24	56
Kharif Land, ha	1.2	1.2	1.2	1.2	1.2
Net Returns, Rs.	42468	49616	50334	60799	8016

- The grid area of the project has been expanded by including the adjacent two villages, Mekalagattu and Mangali banda along with the hamlets. These two villages are adjacent to Jaffergudem village and share border with the village. With this the grid size increases to 5000 ha covering approximately about 2000 households.
- Interventions related to energy efficiency were taken up in the entire grid. About 1123 households were covered with energy efficient lighting resulting in an emission reduction of 232 t of CO_2 per year.
- Interventions related to energy efficiency improvement in heating and cooking is being implemented in the cluster and about 164 households were covered with the intervention. The extent of usage of the fuel wood in the traditional and improved stoves has been calculated.
- Integrating trees in to the existing landscape is one of the important activities of the project as trees contribute improvement of the micro climate, provide additional income and stabilizes income even in low rainfall years. This year linkages have been established with National Horticultural Mission and the Mahama Gandhi National Rural Employment Guarantee Program (MGNREGP) for integrating trees in the existing land uses in the grid. About 11acres has been brought under mango cultivation in the grid. Boundary plantation with teak was taken up in about 232 acres in the cluster with the support from MGNREGP programme. Communities will get additional benefit in the form of labour charges towards the pitting, planting, staking and watering the trees.
- The baseline green house gas emissions in relation to the three activities were quantified in the cluster. The baseline carbon stocks and the carbon stocks in the project scenario were also quantified.

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

Mechanization of sweet sorghum crop helps in reducing the cost of cultivation and increases the yields with timeliness of operations. The research work also involves modification of crushers to increase juice recovery at decentralized crushing units established for production of syrup for ethanol use. During kharif season, 30 acres sweet sorghum crop was sown using the CRIDA 6 row planter at Ibrahimbad cluster, Medak district, A.P. Self propelled harvester was refined to cut the higher girth stems. The three pass 6 roller crusher which was developed during the last year is further modified to accommodate more stems during the crushing for energy reduction and also to increase the juice recovery. Salient findings are:

- Mechanized sowing resulted in 90 % of the germination which is 15 % more than the conventional sowing.
- The performance of single row self propelled sweet sorghum harvester was refined and tested satisfactorily and is ready for up-scaling at industry level.
- The three pass 6- roller crusher gave 8 % more recovery than the conventionally used 3- roller crusher.

Development and refinement of single row self propelled harvester

As the sweet sorghum is taller (around 12-14 feet) than the normal sorghum with girth ranging from 16 to 30 mm, it was found very difficult to use the commercial self propelled reapers available in the market. Apart from problems in cutting the stem, conveying it to the side was found very difficult because of its size and weight. Three different models of commercial harvesters were tested at field level and found not effective for sweet sorghum. Hence a new machine was conceptualized and developed at CRIDA. It is mainly

Side view of the harvester

Harvester in operation

powered by 6.5 hp petrol engine which reduced the normal vibrations. A three tier conveying system with chain mechanism was developed by anchoring with mild steel mesh panels at two sides. A horizontal 3- blade cutting disc was used to cut the stems as the machine moved forward. The rpm of the blade was adjusted to 850. The conveying speed was adjusted to synchronize with walking speed about 3 to 3.5 km/hour. The initial trials showed promising results and the design is under final refinement before commercializing it. It is also planned to develop a tractor drawn harvester to make it suitable for 2 to 3 rows.

3.4 Sustainable rural livelihoods through enhanced farming systems productivity and efficient support systems in rainfed areas (NAIP Componet-3)

This project was launched in September, 2007 and is being implemented in eight backward districts of Andhra Pradesh (Adilabad, Anantapur, Kadapa, Khammam, Mahabubnagar, Nalgonda, Rangareddy and Warangal) by a consortium of ten organizations with CRIDA as the Lead Center. It followed a participatory action research (PAR) framework to address the issues of Sustainable Rural Livelihoods in selected clusters of 3 to 4 villages in the target districts. In accordance with the PAR philosophy the project began with a series of consultations with the stakeholder communities by employing PRA, RRA, focused group discussions and brainstorming workshops and such other tools. The output of these exercises was fortified by a baseline survey conducted across the clusters that paved way for planning and implementing site specific need based interventions.

Though the project was formally launched in September, 2007, the beginning of *kharif* 2008 marked the flagging off of project in full stream. Thus, the project period encompassed five rabi seasons and four *kharif* seasons between 2007 and 2012. Since this was a large multi-institute, multi-disciplinary project addressing complex issues of livelihoods across eight districts having diverse biophysical and socio economic conditions, several consultations and meetings were held initially to develop a common vision for the project by all project partners. Natural resource management activities such as rainwater harvesting through site specific measures formed the flagship intervention of the project, as it was believed that better natural resource management practices would secure livelihoods of the poor. Around these, many livelihood supporting interventions were planned and implemented. These included promotion of better crops and cropping systems; integration of livestock into cropping; horticulture and post harvest value addition; small farm mechanization and capacity building.

Natural Resource Management

One of the major emphases of the project was on augmenting water availability through judicious use of rainwater by adopting site specific rainwater

harvesting strategies. Each cluster representing a unique agro-ecology presented different kinds of opportunities for rainwater harvesting and its efficient use. The rainfall ranged from around 400 mm (Pampanur cluster, Ananthapur) to over 1100 mm (Thummalacheruvu cluster, Khammam) across the project area. Similarly, soil types varied from deep Vertisols (Seethagondi, Adilabad) to medium and shallow Alfisols (Pampanur, Ananthapur). Hence, the runoff and infiltration capacity and therefore the water harvesting potential also varied. In high rainfall Vertisol areas (Adilabad) runoff was harvested in farm ponds for tiding over mid season droughts. In low rainfall shallow Alfisols (Anantapur and Mahbubnagar), the runoff was harvested in percolation ponds, trench cum bunds and CCTs for facilitating infiltration and re-charging of groundwater resources. Efforts were also made to put in place efficient water lifting and application systems to ensure better use efficiency. This included introduction of low lift pumps and micro irrigation systems on custom hiring basis. Besides, defunct and dilapidated rainwater harvesting infrastructure was revived to function to their full capacity. The impact of interventions aimed at enhancing rainwater harvesting and utilization capacity was very significant across the clusters. The efforts in this area resulted in the creation of an additional rainwater harvesting capacity of over 4.3 lakh cu m leading to increased cropping intensity by bringing over 400 ha of area under protective irrigation regime.

Improving crop productivity and profitability

The strategy for improving crop productivity and profitability included promotion of new crops and varieties; diversified cropping systems; better crop management through nutrient and pest management; facilitation of seeding and harvesting through promotion of improved implements made available on custom hiring basis; establishing support systems for accessing information on better cropping; capacity building of farmers for seed production; creating infrastructure for minimum processing (like drying yards), value addition and marketing. The major strategy for securing rainfed crops was to create systems for enabling farmers to take up timely sowing, correcting nutrient deficiencies, weed management, harvesting and post harvest handling and marketing. Besides, the most important aspect of drought management was addressed through improving the infrastructure and farmer capacity to use harvested rainwater for life saving irrigation during mid season droughts. Systems were also developed to address contingent situations such as delayed monsoon by promoting contingency crops through making available seeds of alternate crops. Analysis of soil samples collected for across the cluster showed multiple nutrient deficiencies, particularly of micro nutrients such as zinc and boron. Crops like cotton, groundnut, maize and vegetables responded favourably to application of micronutrients. As part of integrated nutrient management, raising of glyricidia on the bunds, vermicomposting, composting, incorporation of crop residue in soil were also promoted. These efforts put together contributed significantly to enhancing crop productivity ranging from 15-20% in groundnut to over 30% in cotton and vegetables.

Promotion of village level seed production and their spread within the cluster gave good results in groundnut growing areas (Anantapur, Kadapa and Mahbubnagar). A participatory framework of selection of suitable varieties and their production at the village level by select farmers resulted in replacement of old and non-descript varieties of groundnut across the clusters. Promotion of hybrid seed production through training and capacity building improved profitability of small farmers by several folds. Convergence with National Food Security Mission helped spread of pulses in rabi in Warangal and Khammam. Repair of minor irrigation tanks in Khammam resulted in increase of area under rabi pulses and vegetables under irrigation. Establishment of hortipasture in over 60 acres in BY Gudi cluster, Kadapa helped bring stability to the production system through introduction of livestock. Promotion of zero till maize

in Warangal; altering of spacing in Bt cotton in Khammam and Warangal; introduction of improved varieties of tomatoes and chilies in Nalgonda; use of plastic mulch for cultivation of melons in Anantapur; mulching of vegetable fields with shredded cotton and pigeonpea stalks in Adilabad; transplanting of pigeonpea in Mahbubnagar and Rangareddy; campaign for kitchen gardening in Khammam and Kadapa; community pest management in pigeonpea and convergence with AP micro irrigation project for promoting drip systems in mango in Warangal; turmeric cultivation in Khammam and promotion of horsegram as a contingency crop during the drought of 2009 were some other crop related interventions that were implemented. Though these interventions were sporadic in nature, they responded to the local needs and heightened the awareness of farmers about resource conservation and profitable crop production.

Livestock for livelihood improvement

Livestock provides much needed resilience to rainfed farming. Livestock also acts as the shock absorber for the families at times of distress. Animal component also complements crop productivity by providing draft and manure to the farmer. With this in mind, livestock interventions were promoted across the clusters. Wide spread awareness was created about preventable livestock diseases and the community was sensitized about the need for prophylaxis. Emphasis was also given to better management of feed and fodder resources. The communities were engaged on several trainings, workshops and exposure visits for understanding the need to augment feed and fodder resources. Cultivation of azolla as a feed supplement to cattle was intensified with renewed focus on cultivation practices. In order to supplement the veterinary health services, a group of youth selected from each cluster was trained in basic veterinary services like vaccination, deworming, castration, wound dressing etc. Promotion of small ruminants was taken up in a big way to augment income of the small and marginal farmers with emphasis on deworming, vaccination and insurance. Sheep units were the most favorite intervention among the landless across the clusters. Kuroiler birds were found to perform better both in terms of disease resistance and incremental body weight at Thummalacheruvu cluster, Khammam. Farmers across the clusters were encouraged to cultivate fodder for their cattle by allocating a portion of their land. Landless women and poor farmers were encouraged to take up ram lamb rearing and calf rearing as an enterprise.

The overall strategy for livestock productivity improvement was promotion of better health and feed management of the existing livestock along with prophylaxis and deworming. Besides, livestock insurance was promoted to avoid loss due to the death of animal. These things resulted in over 30% increase in returns by livestock as compared to the traditional management practices followed by the farmers. The project encouraged many land owning farmers to buy livestock and supplement their family income. They were also facilitated with veterinary health services by promoting convergence with the state department of animal husbandry. Livestock, both small and large ruminants, were promoted aggressively in the drought prone Pampanur cluster of Anantapur which earlier depended only on crop enterprise. Prior to the beginning of the project, this cluster was not producing any milk quantity worth a mention. By the end of the project, the daily milk production during peak season reached over 600 L while it was 400 L during lean season.

Innovations in institutions and support systems

The major aim of the project was to research on how to make technologies work for the poor. As part of this quest, the project laid enormous emphasis on building and promoting grassroots institutions and creating both physical and institutional support systems that helped in enabling the farmers to adopt technologies. Initially, a stock of the existing people's institution was taken and engaged with them for a considerable period to impart the objectives of the project. Later, Salaha

samithis were promoted as people's institution which articulated the community needs with the project and ensured that the project benefits flowed to all sections of the community. These Salaha samithis handled custom hiring service which was aimed at promoting small farm mechanization across the clusters. Custom hiring centers rented out machinery to the farmers and collected nominal user fee which would serve the purpose of the maintenance and repair of the equipment. Many of the inactive people institutions were rejuvenated to take up active part in the development of the cluster. The Rythu mithra group which was revived in Thummalacheruvu cluster, Khammam played a pivotal role in identifying defunct rainwater harvesting structures by working closely with the project staff. The Salaha samithis in Anantapur and Mahbubnagar, Navakalpana society in Warangal, the Banjara society in Nalgonda, the Youth association in Adilabad, the Water users association in Rangareddy, the Cluster Action Teams in Kadapa played major role in speeding up the process of implementation of need based interventions in the clusters. These apart, several small groups like the Women's group in Kadapa engaged in vermi compost production, the Land less labourers group in Anantapur running the calf rearing cum vermi compost unit, the Farmer's group managing the dal mill and the group of youth that has leased in Ibrahimpur tank for fish production in Rangareddy, the Manago and Watermelon farmers groups in Nalgonda were some of the production oriented grassroots institutions that were promoted by the project. These groups and institutions were supported by the Village Resource Centers (VRC) specially built at each cluster to house the ICT equipment in which latest content on different aspects of agriculture and livestock was made available. These centers accessed weather and market information through the Internet and made available to the farmers on daily basis. Farmers having cell phones were sent message alerts on market and weather on daily basis. An interactive voice response system was installed in the VRCs to provide information on crop, weather and markets to anyone who contacted via telephone.

An innovative project management framework was adopted to provide a strong a support to the entire project team. It consisted of a cluster coordination and monitoring team for each district which regularly visited project sites in their respective districts. These teams closely interacted and provided technical backstopping with the Cluster Anchoring partner who implemented the project at the ground level. Besides, a team of senior experts called technical support group held regular meetings with the entire project team to review the progress and offer advice from time to time. Periodical technical (one each at the end of kharif and rabi seasons) and financial reviews helped the project partners to register good progress on both the fronts.

3.5 Research into development of decision support systems for insect pests of major rice and cotton based cropping systems (NAIP Component- 4)

Effect of temperature on life cycle of the solenopsis mealybug, *Phenacoccus solenopsis* Tinsley, on cotton (*Gossypium hirsutum* L.) assessed under laboratory conditions at 10 constant temperatures indicated that the development duration of female and male nymphal instars linearly decreased with the increase in temperature from 18 to 32°C. Cumulative developmental time of females ranged from 43.9 d (18°C) to 15.0 d (32°C). Survival of crawlers to adulthood was lowest (<53%) at 20 and 36°C and highest (80%) at 32°C. The solenopsis mealybug exhibited obligate sexual ovoviviparous reproduction and the pre-oviposition period in mated females showed a significant decreasing trend between 20°C (23.0 d) and 30°C (9.5 d). The oviposition period of 10.2 to 11.5 d at = 25°C was nearly half the duration than at 20°C and the highest fecundity (245 eggs + crawlers) was observed at 30°C. Longevity of mated females

Table 34 : Developmental duration (days), temperature thresholds and thermal constants for life stages of solenopsis mealybug at constant temperatures

Temperature (± 1 °C)	I instar	II instar	III instar female	Male (III & IV instars)	Cumulative female development	Cumulative male development
20	13.1	13.5	13.9	14.3	40.5	41.7
25	7.4	9.9	7.9	8.1	25.2	25.4
30	6.3	6.5	5.6	6.2	18.3	18.9
36	4.8	5.4	5.5	6.1	15.7	16.3
Parameter estimates						
T_{min} (°C)	11.7	11.7	11.7	10.1	11.7	10.4
T_{max} (°C)	40.0	40.0	39.0	39.0	39.0	39.0
T_{opt} (°C)	33.3	33.4	32.0	32.3	32.3	32.8
Thermal constant (degree-days)	100.7	114.0	101.0	120.9	317.5	363.5

was significantly prolonged at 20°C (46.0 d) compared to 30°C (21.4 d). Proportion of females was highest (97.5%) at 25°C. Males required higher degree-days (363.6) for their cumulative development compared to females (317.5). Lower temperature thresholds estimated from the linear model for cumulative female and male development were 11.7 and 10.1°C, respectively. The estimated optimum temperature thresholds for nymphal instars were 32 to 33.4°C. The population trend index using survival, fecundity, and sex ratio of *P. solenopsis* with an initial population of 100 crawlers in the Morris-Watt life table model indicated a potential population increase of 170.3 and 97.6 times at 30 and 35°C, respectively in the next generation. These results on the temperature-dependent life cycle of *P. solenopsis* are vital for understanding and predicting its population dynamics on cotton with implications for its management under field conditions.

Towards development of Decision support system (DSS) with user friendly web enabled decision support tools

Developed a DSS incorporated with web enabled decision support tools for agro-climatic analysis, construction of stage-specific mortality and age-specific fecundity life tables, degree-day calculator, population trend index calculator and pest diagnostics and incorporated in the Decision Support System-version 1.0.

Crop-pest-weather database for rice and cotton

Crop-Pest-Weather Database

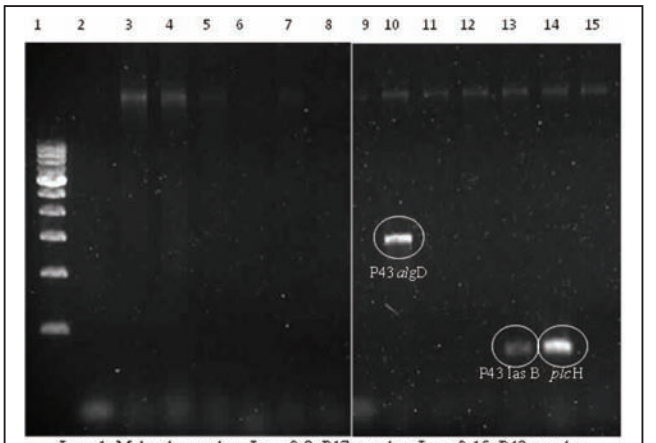
- Released a CD on crop-pest-weather database on 19th September 2011 in the National Stakeholders Consultation Workshop on Climate Change Platform held at CRIDA, Hyderabad.
- The crop-pest-weather database for rice and cotton documents weekly pest records (34,472) for 11 insect pests and diseases in rice and 13 insect pests and diseases in cotton along with corresponding weather across 12 important locations spread across India. The oldest continuous record up to date is from 1975 for rice yellow stem borer.

- The database is developed with MS Access as a back end and a user friendly front end in VB 6.0. Users can retrieve and view historical pest and weather records in the form of graphs and data tables which can be saved for further analysis. Time series pest data can be viewed as a graph for the selected period and can also be superimposed on corresponding weather parameters.
- The database is useful for pest forecast modelling groups as it provides a ready access to develop forewarning tools and also to extension functionaries such as KVK scientists and Agromet Field Units (AMFUs) involved in agro-advisory services.

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

Among several bioinoculants, *Pseudomonas* spp. is well known as biocontrol agents and plant growth promoting rhizomicroorganims. When introduced into the field, they are also exposed to abiotic stresses such as high/low temperature, salinity and drought. Strains possessing biocontrol ability coupled with abiotic stress tolerance could be a boon for farmers as they can successfully establish and give desired biocontrol effects. Under NAIP project, "Effect of abiotic stress on natural enemies of crop pests *viz.*, *Trichogramma, Chrysoperla, Trichoderma* and *Pseudomonas* and mechanism of tolerance to these stresses", efforts were made during last year to characterize the strains possessing tolerance to salinity, drought and high temperature to understand the mechanisms of tolerance.

Whole genome sequences of P43 (salinity tolerant) and P8 (salinity and temperature tolerant) strains was completed. From gene sequencing, the genome size of P8 strain was found to be 1193475 bp and for P43 it was 1147263 bp. These sequences were aligned with 17 known genomes of *Pseudomonas* to arrive at their identity. Gene predictions were made for the two whole length genome sequences



Gel showing screening for pathogenicity genes in *P. aeruginosa* P17 strain

using Prodigal software V 2.50, following the "ab initio model". In P43, 4766 genes were predicted whereas in P8, 13178 genes were predicted. In P8, out of 13178 genes, 4688 were functional genes of hydrolyzing enzymes and 7674 were unknown proteins. Similarly, in P43, 1222 were functional genes of hydrolyzing enzymes and 1136 genes were unknown proteins. Further analysis of the data is in progress for novel gene prediction. Strains of *Psuedomonas aeruginosa* (drought tolerant P17 and salinity tolerant P43) were tested for pathogenicity genes like algD, pilB, nan1, lasB, plcH, exoS and exoU by using suitable primers. P17 strain does not possess any of the aforesaid genes and therefore, it is a non-pathogenic strain and P43 has *alg*D, *las*B and *plc*H genes and hence could be promoted for further use.

3.7 Assessment of soil quality and resilience of soils in diverse agro-ecosystems (NAIP Component-4)

In order to work out the threshold and optimum level of different organic carbon pools of soil in AESR 7.2, geo-referenced soil samples (0-15 cm) were collected in 2008 (before the sowing of winter crops) from the farmers fields of Nalgonda (n=162) and Warangal (n=148) district and analyzed for total oxidizable organic C (SOC) by wet digestion method (Walkly and Black, 1934) and total C by

CN – analyzer. The Total organic carbon was apportioned into different pools by the modified Walkly and Black method using 5, 10 and 20 ml of concentrated H_2SO_4 that resulted in 3 acid-aqueous solution ratio of 0.5:1, 1:1 and 2:1. The amount of C thus determined, allowed the apportioning of TOC into very labile C (VL) (Organic C oxidizable by 12.0 N H_2SO_4), labile C (L) (the difference in C oxidizable by 18.0 N and that by 12.0 N H_2SO_4), less labile C (LL) (the difference in C oxidizable by 24.0 N and that by 18.0 N H_2SO_4) and non labile C (NL) (difference in C between TOC and SOC).

Table 35 : Distribution of different pools of SOC (%) in soils of Nalgonda

	VL	L	LL	NL
Alfisols				
Range	0.1-0.35	0.06-0.16	0.04-0.20	0.14-0.98
Mean	0.17	0.11	0.1	0.35
CV%	35.48	29.47	33.03	29.62
Vertisols				
Range	0.13-0.38	0.06-0.36	0.06-0.20	0.29-0.65
Mean	0.2	0.11	0.1	0.38
CV%	38.63	36.52	41.51	46.77
Inceptisols				
Range	0.10-0.33	0.05-0.12	0.06-0.19	1.07-2.76
Mean	0.19	0.08	0.12	2.09
CV%	39.46	35.35	40.11	36.17

Table 36 : Distribution of different pools of SOC (%) in soils of Warangal

	VL	L	LL	NL
Alfisols				
Range	0.05-0.38	0.03-0.18	0.05-0.21	0.10-0.48
Mean	0.19	0.097	0.104	0.21
CV%	34.90	40.70	40.59	40.99
Vertisols				
Ranges	0.08-30	0.05-0.14	0.04-0.16	0.15-0.36
Mean	0.19	0.084	0.100	0.26
CV%	28.90	31.16	35.19	31.40
Inceptisols				
Ranges	0.13-0.40	0.05-0.20	0.07-0.23	0.13-0.40
Mean	0.22	0.11	0.13	0.20
CV%	34.86	36.45	38.94	36.02

The thresholds (where yields are likely to be < 50% of the REY) and optimum values (where yields are likely to be > 80% of REY) for SOC ($SOC_{50,}$ SOC_{80}) and TC ($TC_{50,}$ TC_{80}) were calculated from the regression equation and were found to be:

For Nalgonda: SOC_{50} = 5.8 g/kg; TC_{50} = 9.5 g/kg; SOC_{80} = 6.5 g/kg; TC_{80} = 26.6 g/kg
For Warangal: SOC_{50} = 5.5 g/kg; TC_{50} = 14.2 g/kg; SOC_{80} = 6.7 g/kg; TC_{80} = 20.7 g/kg

4 National Initiative on Climate Resilient Agriculture (NICRA)

The project was initiated in 2010 to develop and promote climate resilient technologies in agriculture which will address vulnerable areas in India. The outputs of the scheme will help the districts and regions prone to extreme weather conditions like droughts, floods, frost, heat waves, etc. to cope with such extremes. Although the target area of the scheme are all climatically vulnerable regions of the country, more emphasis is placed on small and marginal farmers in rainfed, coastal and hill areas of the country. The specific objectives of the initiative are: to enhance the resilience of Indian agriculture covering crops, livestock and fisheries to climatic variability and climate change through development and application of improved production and risk management technologies; to demonstrate site specific technology packages on farmers' fields for adapting to current climate risks; and To enhance the capacity of scientists and other stakeholders in climate resilient agricultural research and its application. The project has four components: Strategic research on adaptation and mitigation, Technology demonstration to cope with current climate variability in 100 vulnerable districts, Capacity building and sponsored/competitive grant research to fill critical gaps. Considerable work was carried out during 2011-12 under the strategic research and technology demonstration components at CRIDA.

4.1 Strategic research

4.1.1 Phenotyping of rainfed crops for tolerance to climatic stresses

Aberrations in weather mainly due to climate change leading to water deficit and increase in temperature are well-known to affect crop growth and productivity. Large-scale screening of maize and pigeonpea crops germplasm including wild relatives for drought and heat tolerance will be carried out under both field conditions and phenomics platform facility for quick identification of promising lines which can be used as donors for development of drought/heat tolerant varieties.

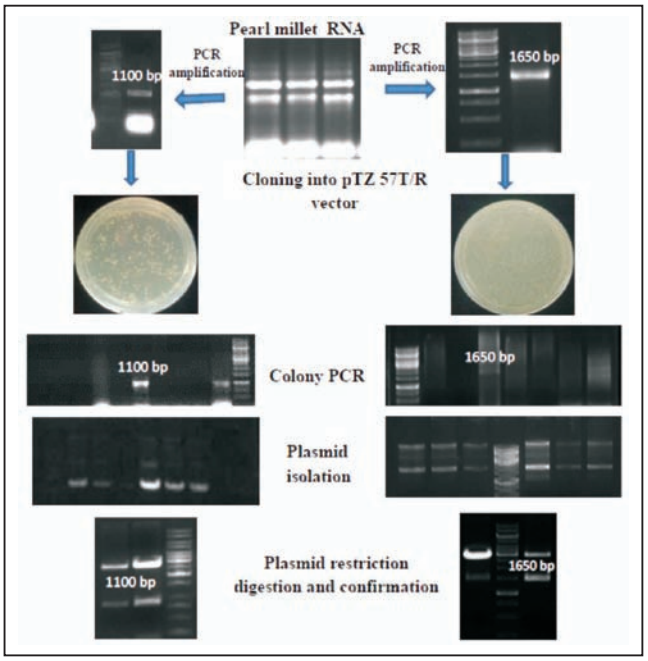
Prospecting of genes for multiple stress tolerance: PCR amplification and sequence analysis of DREB2A, GRP7 and OCP3 partial cDNA's obtained from pearl millet revealed homology with the sequences available in the database (Table 37). The partial sequence of DREB2A was deposited in the gene bank with the accession number JN627404.

Table 37 : Sequence analysis of the DREB2A, OCP3 and GRP7

Gene	Size (bp)	Homology
DREB2A	701	*P. glaucum* (99%) & *O. sativa* (84%)
OCP3	280	*AP2* domain of *Z. mays* (68%)
GRP7	438	*GRP7* of *Glycine max* (74%)

Cloning of full length cDNA sequence of DREB2A from Pennisetum glaucum into pTZ57R/T vector:

Cloning of cDNA of *DREB2A* (1650 bp with UTRs and Full length- 1100bp) into pTZ57R/T vector resulted in transformed colonies on selection medium containing ampicillin. Colony PCR analysis showed the presence of 1650 and 1100bp band in two of the transformed colonies. Plasmid isolated from this colonies upon restriction with KpnI/BamHI showed the respective1650 and 1100bp bands confirming the presence of the *DREB2A* gene. Efforts are underway for the amplification of 5' and 3' ends of *OCP3* gene using SMART RACE cDNA amplification kit.



Cloning of full length cDNA sequence of DREB2A from *Pennisetum glaucum* into pTZ57R/T vector

4.1.2 Phenotyping of maize for tolerance to climatic stresses:

Drought stress has a great impact on agricultural and forestry production and on yield reduction. The limited supply of water affects corn (*Zea mays* L.) due to its relative high water requirements. Determining crop yield response to irrigation is important for crop selection, economic analysis, and for practicing effective irrigation management strategies. Water stress can reduce biomass and grain yield due to reduction in the number of kernels and weight. Therefore, it is needed to develop plants that are adapted to changing and challenging environment. In this context, work was carried out on three major activities in three different cropping seasons (kharif-2011; rabi-2011 and zaid-2012) morphological, physiological and molecular studies, identification and selection of genotypes that fit into new cropping systems and seasons and multiplication of seeds.

In kharif, 94 maize genotypes received from DMR, NBPGR and CIMMYT were grown. Among these 50 high yielding genotypes were selected and studied in rabi 2011 and zaid 2012. Morphological and physiological studies carried out on 32 different traits. Genotypes were evaluated under stress and irrigated condition. They were grouped on the basis of their leaf rolling percentage. Cluster analysis was carried among 94 genotypes which revealed seven clusters. Thirty seven SSR markers revealed 108 alleles with highest PIC value of 0.96 by BNLG1136. Twenty four genotypes selected from different clusters grown in rabi and zaid. In both kharif-2011 and rabi-2011 photographs were taken for ground coverage on one month old seedlings. Using MATLAB Image Processing 2 programme ground cover for each genotype was carried out. During kharif and rabi-2011, ground

Difference in seed setting in irrigated and rainfed conditions

area was covered as 26.72 and 27.02% respectively. Comparative studies on plant growth revealed that plants grown in kharif-2011 were better than rabi-2011. SPAD reading shows plants were healthy. Comparison between kharif and rabi-2011 revealed no significant differences. Photosynthesis studies on recovery stage revealed that few plants could recover photosynthesis after withdrawing stress. After withdrawing stress, among 84 days old plants 50% recovery was noticed. In kharif flowering got delayed by 1-2 days under stress whereas in rabi season the interval increased up to 15 days. Plant height, biomass, plant yield and seed weight got reduced by 4.3, 12.1, 14.8 and 11.4%, respectively. Twelve genotypes identified would be considered for further study. Eight crosses were carried out which will be characterized in following season.

4.1.3 Physiological and metabolic indices for heat tolerance in maize

Seasonal aberrations leading to high temperature during crop growth is a major determinant of agricultural production throughout the world which affects plants right from seed germination to final yield harvested. High temperature stress affects various morphological, physiological and biochemical characteristics of crops plants, predominantly during reproductive stage. Better understanding of the mechanism involved in stress tolerance would facilitate speedy development of thermo-tolerant varieties to stabilize crop productivity under fragile environments. Thirty two maize genotypes received from DMR, NBPGR and CIMMYT were evaluated to understand the genetic diversity in relation to various physiological and biochemical traits under heat stress conditions. The material was sown in field on 30th January and 28th February, 2012 to coincide pollination and grain filling stages of the crop with heat stress. Observations were recorded for various traits *viz.*, leaf rolling, membrane stability, chlorophyll content, chlorophyll fluorescence, canopy temperature, stomatal conductance, photosynthetic rate, tasseling, anthesis, silking, lipid peroxidation, important metabolites, proline content and changes in activities of some enzymes related to sucrose anti-oxidative stress metabolism.

Tasseling (46-71 DAS), anthesis (48-80 DAS) and silking (50-88 DAS) intervals varied across the thirty two maize genotypes sown on 30th January. The minimum and maximum temperatures recorded during the crop growth period were 15 and 40 °C, respectively. The temperature tolerant genotypes possessed low ASI values while the susceptible ones had higher ASI values. Highest anthesis silking interval (ASI) observed was 10 days in genotypes *viz.*, HKI-3-4-8-6ER, Z93-194, RJR-163 and Z59-11. Observations on various physiological and biochemical parameters recorded in representative genotypes belonging to high temperature tolerant and susceptible groups revealed that the ascorbate and malondialdehyde (MDA), phenols, free amino acids declined while glucose, fructose and starch increased in the high temperature susceptible group as compared to the

Table 38 : Effect of high temperature stress on reproductive processes in maize

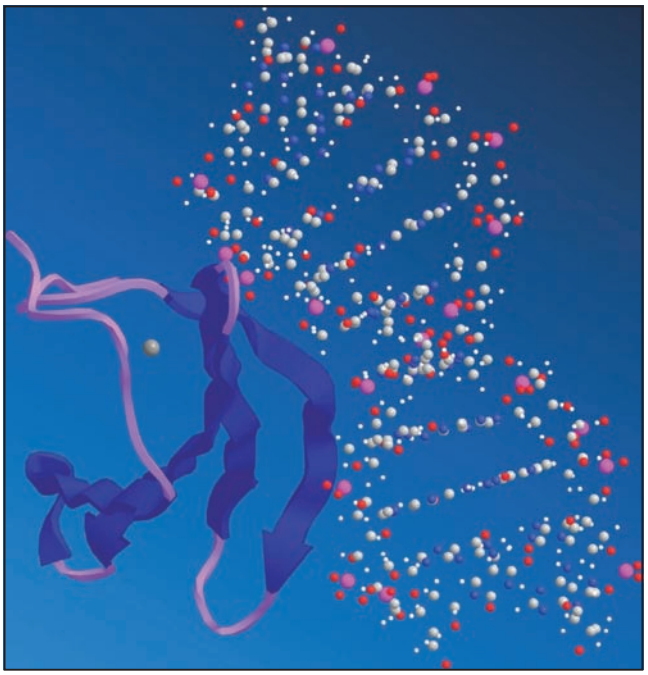
Phenological stage	I Date of sowing (30/01/2012)	II Date of sowing (28/02/2012)
Tasseling	46-71 DAS	38-61 DAS
Anthesis	48-80 DAS	42-68 DAS
Silking	50-88 DAS	42-67 DAS
Anthesis silking interval (ASI)	0-10 days	0-7 days

High temperature stress affecting kernel setting in different maize genotypes: HKI-3-4-8-6ER; Z40-183; PSRJ-13099; NSJ-155; Z93-194; NSJ-189; RJR-163; PSRJ-13038; PSRJ-13247

tolerant group. Activities of the enzymes related to anti-oxidative stress tolerance viz., superoxide dismutase, peroxidase and catalase were lower while important sucrose metabolizing enzyme sucrose synthase was higher in the susceptible group.

4.1.4 Bioinformatics

WRKY genes encoding transcription factors are differentially regulated by a range of environmental stresses specially drought. Studies were done to detect the presence of high similarity in nucleotide, mRNA or protein product of Arabidopsis WRKY gene in Maize. The AtWRKY53 was searched against



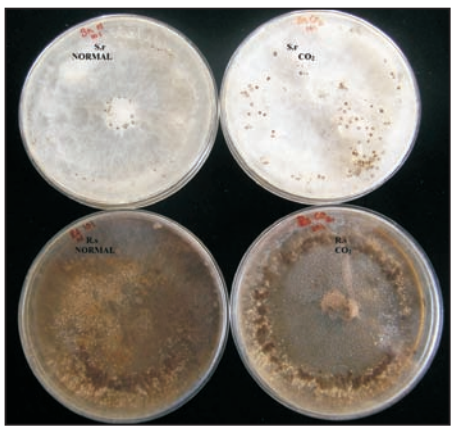
Model of DNA docking with the target protein with a matrix of homologous interface contacts

the annotated proteome of *Zea mays* using the BLAST tool available on Phytozome portal. A total of 154 genes coding for proteins were identified from this search with significant sequence similarity. Best match of AtWRKY53 in *Zea mays* is observed to be as GRMZM2G411766_T01. The single HSP with 57.3% identity or 70.2% similarity, alignment score of 353 and E-value of 1.5e-33. WRKY proteins identified from the sequence searches were multiple aligned using MAFFT with local-pair option to enable the alignment along the WRKY domains. The aligned set of sequences are analysed using the CLUSTALX tools to generate the closest phylogenetic tree. A detailed classification of the WRKY proteins was done for the maize genome. Homology modelling was done using templates from protein data bank and DNA docking with a matrix of homologous interface contacts.

4.1.5 Impact of elevated CO_2 on plant pathogens

Elevated CO_2 conditions are known to influence growth and metabolism of living organisms and microorganisms are no exception. Under NICRA, efforts are being made to understand the dynamics of host-pathogen-natural enemy interactions under elevated CO_2 conditions. Selected plant pathogens and bio-control agents have been exposed to 700 ppm CO_2 levels over generations to study its impact on morphology, physiology and pathogenicity of these organisms. Four pathogens and two bio-control agents were passed through elevated CO_2 conditions over generations. Even after 100 generations of exposure, the strains did not show significant difference in their growth pattern.

Bio-control ability of *Trichoderma viride* exposed to elevated CO_2 for 100 generations was evaluated against *Sclerotium Rolfsii*, *Macrophomina phaseolina*, *Rhizoctonia solani* and *Fusarium oxysporum* f.sp. *ricini*. No significant change in biocontrol ability was observed between treatment and control. The same culture of *Trichoderma* was used to study its



Increase in the number of sclerotial bodies under elevated CO_2

Table 39 : Hydrolytic enzyme production ability of *Pseudomonas* spp. at 100th generation of exposure to elevated CO_2

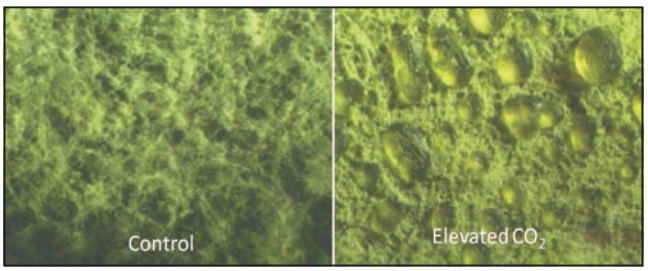
Pseudomonas Strain	Amylase		Protease		Pectinase		Cellulase		Ammonia	
	N	ECO_2	N	ECO_2	N	ECO_2	N	ECO_2	N	ECO_2
P17	-	-	+	+	-	-	+	+	+	+
P22	-	-	-	-	-	-	-	-	+	+
P23	-	-	-	-	-	-	-	-	+	+
P67	-	-	+	+	-	-	+	+	+	+

N: wild type; ECO_2: exposed to 700 ppm CO_2

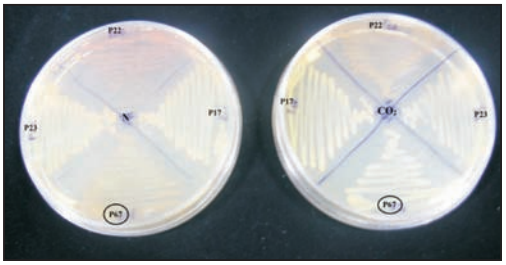
ability to parasitize sclerotia of *Sclerotium rolfsii* and *Rhizoctonia solani* by recording parasitisation at every 24h interval after 3rd day of inoculating sclerotia with *Trichoderma*. The parasitisation rate remained 100% by both elevated CO_2 and wild type strains. In case of *Rhizoctonia solani* and *Sclerotium rolfsii*, production of sclerotia increased in cultures grown in elevated CO_2 than under normal conditions.

Some strains of *Trichoderma* are known to produce secondary metabolites which are seen as oil globules in the medium. Such plates also give an odour which is unique to such isolates. *T. viride* exposed to elevated CO_2 showed such depositions in the medium as compared to control plates which were inoculated with wild type strain.

Spore count of *T. viride* was taken at 100th generation after exposure to elevated CO_2 and spore count of $6x10^8$ cfu/ml was observed whereas in wild type, the spore count was 3.5×10^8 cfu/ml. The P67 strain of *Pseudomonas* sp. grown under elevated CO_2 did not produce fluorescent pigmentation. In contrast, positive production of pigmentation was observed in wild type. On the other hand, P22 retained their pigment production even at 100th generation. In P17 and P23, there was no pigment production in treatment and control.



Production of extracellular metabolites by T. viride grown after 100th generation of continuous exposure to 700 ppm CO_2 concentration



Fluorescent pigment production in strains of *Pseudomonas* as influenced by exposure to elevated CO_2

Enzymatic Activity

Four strains of *Pseudomonas* spp. earlier identified for their PGPR, biocontrol abilities were exposed to elevated CO_2 conditions for 100 generations. The ability of these traits to produce hydrolytic enzymes was checked and it was observed that no significant change occurred in the strains.

4.1.6 Pest and disease dynamics under climate change scenario (CCS)

4.1.6.1 Meta analysis of impact of eCO2 on host-insect herbivore interactions

Meta analysis is the concept of combining results from several independent studies and is popularly known as secondary analysis or analysis of analyses. An index that would measure the degree of effects of interest "effect size" has been widely used in meta analysis.An alternative procedure to deal with the limitations of the qualitative synthesis of studies was put forward and came to be known as meta analysis. The quantification of impact of elevated

carbon dioxide (eCO_2) on the incidence of insect pests through statistical synthesis of published results or meta-analysis is attempted here.

Meta-analysis was conducted by including all the studies for various insect primary parameters viz., consumption of foliage by insects, duration and weight of insect as basic parameters. Further meta-analysis of data was done including various insect performance indices like approximate digestibility (AD), relative consumption rate(RCR),efficiency of conversion of ingested food (ECI), efficiency of conversion of digested food (ECD) and relative growth rate (RGR) also. Data on bio chemical constituents was also included for analysis.All the analysis was done using the software developed by Schwarzer (http://web.fu.berlin.de/gesund/gisu*engle/meta-e.htm.).

Integration of findings of independent studies by calculating the magnitude of treatment effects i.e., "effect size". Data for the meta analysis were gathered from the published studies (88 articles) in selected journals (28) for comparing the growth and development of insect herbivores under eCO_2 conditions and compared with ambient CO_2 condition. The basic requirements of the each study were identified as follows (1) published studies in which CO_2 concentrations were altered or manipulated above ambient (2) in which measurements of effects on herbivore insects were reported as means with a measurement of variance (standard error, standard deviation and confidence intervals) in either tables or graphs and (3) studies in which sample sizes for both ambient and elevated CO_2 conditions were reported. The mean effect sizes for various insect parameters varied significantly. Among the insect primary parameters consumption (2.94) and duration of insect species (0.751) were found to be significantly positive under eCO_2 and other parameters like weight (-0.46) and population abundance (-0.05) of species were negative. Insect performance indices showed positive effect size for approximate digestibility, AD (1.281) and relative consumption rate, RCR (3.61) and negative with respect to efficiency of conversion of ingested food, ECI (-3.20), efficiency of conversion of digested food, ECD (-1.891) and relative growth rate, RGR (-1.072). Meta analysis of biochemical constituents of host plants indicated that the effect sizes were found to be negative (Nitrogen) and positive (Carbon and C: N ratio) indicating a significant variation of constituents under ECO_2 condition than ambient CO_2 condition.

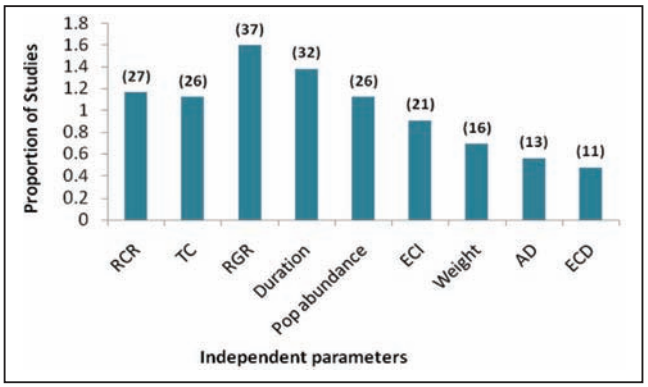


Fig. 53. Percentage of Independent parameters in the meta analysis

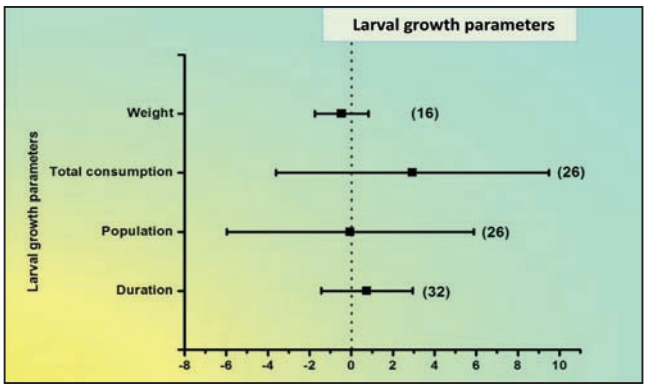


Fig. 54. Mean effect size of larval performance indices under ECO_2

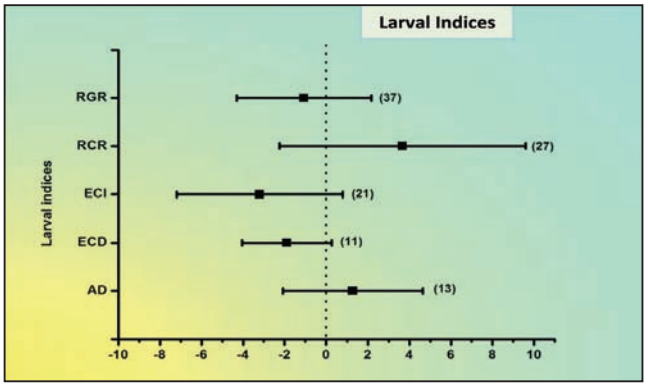


Fig. 55. Mean effect size of larval growth parameters under ECO_2

4.1.6.2 Real Time Pest Surveillance in target crops

- Training cum Workshop on Real Time Pest Surveillance (RTPS) in respect of all five crops rice, tomato, mango, pigeonpea and groundnut crops was held in collaboration with NCIPM, New Delhi.
- Geographical Positioning System (GPS) units procured for the RTPS centres were distributed to all 36 centres and their features were explained with demonstration.

Training cum workshop on RTPS in pigeonpea & groundnut

- Architecture of the software developed under the project for data entry by RTPS centres of five crops incorporating the respective data recording formats was explained with its off line and on line features through demonstration.
- All participants undertook hands-on training on the software in their respective target crops.

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

Wireless sensor network (10 motes) was established at Agricultural Research Station, Kadiri, A.P. to record leaf wetness at canopy height in groundnut crop during the *kharif* season. The daily leaf wetness hours data was received via internet at the CRIDA server and processed by decision support system (DSS) for fungicide spray advisory into leaf wetness index (LWI). Disease initiation was noticed 90 days after sowing when wetness threshold of leaf ≤ 2.3.

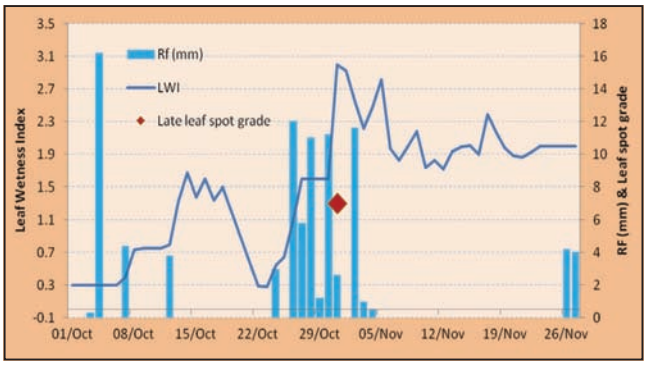


Fig. 56. Monitoring of leaf wetness using wireless sensor network for decision support for fungicide spray advisory against late leaf spot in groundnut

4.1.6.4 Effect of rainfall events of 40 mm or more on *Spodoptera litura* moth emergence

Rainfall events of 40 mm or more coinciding with 2 days prior to moth emergence was tested against the polyphagous insect pest, *Spodoptera litura* (Fabricius) using rainfall simulator. Moth emergence was highest (87%) in the absence of rainfall, while it gradually decreased to 40.3% with rainfall events of 40, 60 and 80 mm, respectively, indicating the adverse role of high intensity rainfall on moth emergence and subsequent population build-up. This could probably explain why populations of *Spdoptera* fluctuate from season to season.

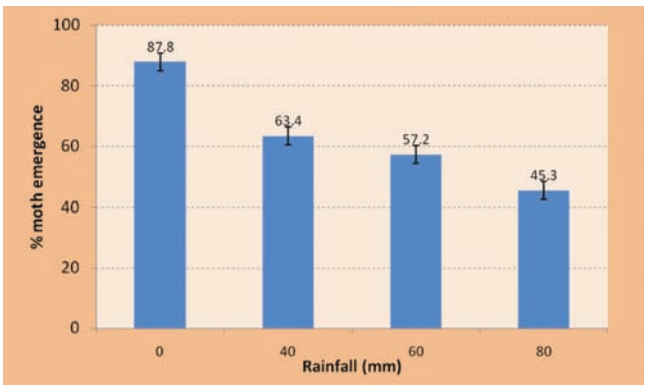


Fig. 57. Effect of rainfall events on *Spodoptera litura* moth emergence

4.1.6.5 Feasibility of using space-borne data for detection of groundnut leaf-miner incidence

Technological advancements in the field of remote sensing provide high spectral, spatial and temporal

resolution data from air-bore or satellite platforms necessary to field evaluate for detecting different kinds crop stresses. Extensive field surveys conducted in the Anantapur district of A.P. during kharif 2011 revealed a severe outbreak of leafminer, *Aproaerema modicella* Deventor (Lepidoptera: Gelechiidae) in four mandals. Nallamada is the worst affected of all the mandals surveyed. Collected about 45 ground control points (GCPs) with GPS at several locations covering the entire belt. Care was taken to collect data on the crop condition at all the GCP points.

It appears that drought during second fortnight of July and first fortnight of September was congenial for rapid multiplication and spread of this pest. Satellite image of IRS-P-6 -LISS-III acquired on 10 September 2011 was rectified using GCPs. The cloud cover areas in the image were

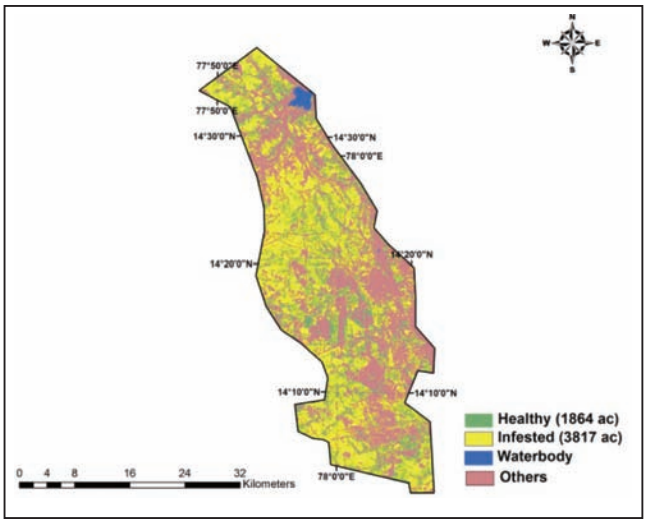


Fig. 58. Classified image showing the spatial extent of leafminer damage in four mandals of Anantapur district

masked and removed and rest of the data was subjected to supervised classification. Sub-set of the classified image with severely infested area was made for further analysis. The results showed severely infested area is about 3817 acres compared to healthy groundnut in 1864 acres. The classified image also showed spatial spread of the infestation in the entire village along with other land use features.

4.1.7 Effect of foliar spray of nutrients on yield of maize under rainfed conditions

In rainfed areas due to insufficient and irregular distribution of rainfall, the crop suffers from moisture stress during the various stages of crop growth resulting into decreased yield due to insufficient uptake of essential nutrients and impaired physiological processes. It is known that each essential nutrient has got a definite role to play in the plant metabolism. Apart from the essential nutrients, some of the beneficial elements are also known to influence the plant growth under some specific conditions. A study was initiated to study whether application of macro, micro (Zinc) and beneficial elements (Selenium) through foliar spray can influence some of the plant physiological processes and in-turn help to minimize the yield reduction due to drought/insufficient soil moisture. Maize (cv. DHM 117) was raised during kharif 2011 at Gunegal Research Farm with the following treatments: i) Control (No nutrients), ii) Recommended dose of fertilizers, iii) Treatment 2 + spraying of 1.5% KCl at 25 DAS, iv) Treatment 2 + spraying of 15 g/ha of sodium selenite at 25 DAS, v) Treatment 2 + spraying of 0.25% zinc sulphate at 25 DAS of sowing, vi) Treatment 2 + soil application of 15 g/ha of sodium selenite, and vii) Treatment 2 + spraying of 1.5% KCl + 0.25% zinc sulphate + 15 g/ha of sodium selenite at 25 DAS. These treatments were replicated thrice in randomized block design. The crop was raised by following recommended package of practices. Basal application of recommended dose of fertilizers followed by foliar application of potassium, zinc and selenium has at 25 DAS resulted in significant increase in the grain yield of maize as compared to control and basal application of recommended dose of fertilizers. It is also evident that foliar spraying of zinc sulphate at 25 DAS and foliar spraying of 1.5% potassium chloride have also resulted in increased grain yield of maize, but the increase was statistically non-significant. Foliar application of potassium, zinc (deficient) and selenium might have influenced several metabolic

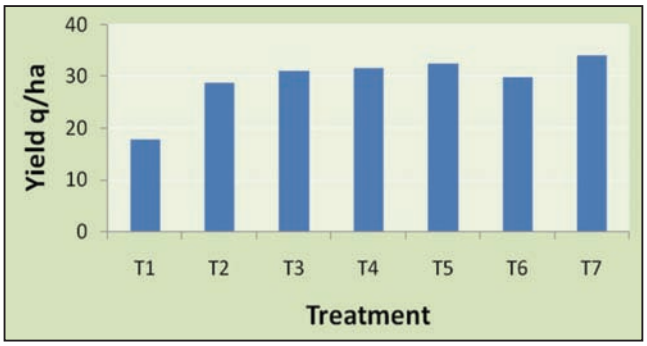


Fig. 59. Grain yield of maize (q/ha) as influenced by different treatments

process like photosynthesis, cellular respiration, water regulation etc. Similarly, the increase in the grain yield of maize due to foliar application of potassium, zinc and selenium is also accompanied by increased uptake of nitrogen, phosphorus, potassium and micro nutrients.

4.1.8 Role of plant roots in soil C sequestration

Studies were initiated to understand the role of plant roots in sequestering carbon in soil. Two varieties each of sorghum (CSH 14, SPV462) and green gram (ML 267, WGG 37) were grown in the field. Root systems of sorghum and green gram varieties at maximum biomass stage (late flowering) were extracted from the soil by washing exposed soil monoliths. Root and shoot biomass, and shoot: root ratios were determined. Root and shoot samples were fractionated using detergent fibre extraction method and cell contents (soluble C compounds) and cell wall contents (hemicellulose, cellulose and lignin) were determined. Carbon and nitrogen contents of root and shoot samples were determined. As a generalization, roots accounted for about 1/ 4th of total plant biomass. Shoot: root ratios of green gram varieties were lower than sorghum varieties. Differences in shoot: root ratios of sorghum varieties were small, but in green gram, varietal differences were larger. In both the crops, roots had more cell wall fraction than shoots, and considerably higher lignin concentration than shoots, especially so in case of green gram. However, in quantitative terms, sorghum roots had over 2 times more lignin per unit land area than green gram, and sorghum whole plants had up to 5 times more lignin than greengram. With the exception of green gram variety WGG 37, roots had a slightly lower N content than shoots. Values of lignin/N ratio (Fig. 60), the best predictor of decomposition rate, were considerably higher for roots, indicating that roots may decompose much more slowly compared to aboveground residues. Coupled with other mechanisms of organic matter preservation in soil such as physical protection and chemical stabilization, which are more prominent in root derived organic matter than shoot derived, it is likely that roots play an important role in sequestering atmospheric C into stable soil organic C with long turnover times. Thus roots potentially form a significant weapon in our arsenal in the fight against climate change.

Green gram monolith for root extraction

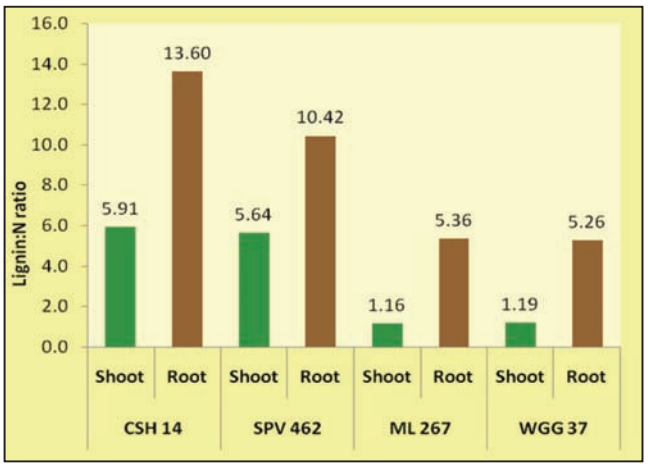


Fig. 60. Lignin:N ratios of plant parts of sorghum and green gram varieties

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

Among the various biological soil quality parameters, soil enzymes, microbial biomass carbon (MBC) and labile carbon (LC) play an important role in improving the functional capacity of soils. To improve these parameters, and functional capacity of soils, it is important to introduce reliable soil management practices such as minimum tillage, residue application and nutrient status. Effect of tillage, residue application and N levels were studied on important biological soil quality indicators including enzymes (acid phosphatase, alkaline phosphatase, arylsulphatase, urease, dehydrogenase), microbial biomass carbon (MBC) and labile carbon (LC). To achieve this objective, an ongoing field experiment comprising of tillage (conventional (CT) and minimum (MT), residue 2 t ha^{-1}dry sorghum stover (SS), 2 t ha^{-1} fresh gliricidia loppings and no residue (NR) and nitrogen levels (0(N_0), and 90 (N_{90}) kg N ha^{-1}) under sorghum and castor system was adopted. During the current year Sorghum (SPV-462) was the test crop.

Application of residues viz; Gliricidia loppings and sorghum stover showed significant influence on acid phosphatase and alkaline phosphatase activity in soils and it varied from 244.6 to 322.8 mg kg^{-1} and 129.3 to 186.7 mg kg^{-1}, respectively across the management treatments. However, tillage and varied N levels did not show any significant influence on acid and alkaline phosphatase activity. All the treatments *viz.,* tillage, residues and N level significantly influenced arylsulphatase activity in soils compared to control. Urease activity in soils varied from 7.72 to 17.4 mg kg^{-1} and was significantly influenced by the long term effects of tillage, residues and N levels. Dehydrogenase activity and microbial biomass carbon were also significantly influenced by different tillage, residues and N level treatments and were found highest under minimum tillage + application of Gliricidia (2t ha^{-1}) + N applied @ 90 kg ha^{-1}. Labile carbon in the soil varied between 167.0 to 277.8 mg kg^{-1} across various tillage, residues and nutrient management treatments. The long-term practice of residues as well as N levels played a significant role in influencing the labile carbon content in the soil while the tillage practices did not play any significant role.

This study conclusively indicated that the practicing minimum tillage in combination with application of Gliricidia loppings @ 2t $ha^{-1}$and application of fertilizer N @ 90 kg ha^{-1} positively influenced the activity of arylsulphatase, urease and dehydrogenase enzymes in soils. This set of treatment combination was also found very effective in significantly improving the Microbial biomass carbon and labile carbon pools in the soil.

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

Use of biofuels alternatively or in combination with petro fuels has been gaining momentum as they reduce GHG emissions and biofuel crops have the potential to sequester atmospheric CO_2. An attempt has been made to estimate the potential of biofuel crop, *Jatropha curcas* in sequestering CO_2 in drylands. Jatropha plantation established in 2003 at HRF was selected for the study. The plantation was divided into 4 diameters (collar diameter) classes (5-10cm; 10-15cm; 15-20 cm & 20-25 cm). Three plants were selected randomly from each diameter class for destructive sampling. The growth parameters like plant height, number of branches, canopy width and crown depth were recorded. The fresh and dry biomass (leaves; stem, fruit, litter fall and branches) was also recorded per each plant. The plants were cut with saw as per the established procedure. The above ground biomass was separated into different components (leaves, stem, fruit, and branches) and their fresh and dry weights were recorded. The roots were simultaneously excavated by carefully loosening and digging the soil. Root biomass at 4 depths (0-25cm; 25-50cm; 50-75cm & 75-100cm) was

recorded. Apart from this, root dia. (base & tip), number of lateral roots (<1, 1-2, 2-4, & >4 cm); largest root length & dia., root canopy (N-S & E-W), number of roots (primary & secondary) were also recorded. Salient findings are:

- As the diameter of the trees increases the above and below ground biomass increased
- The above ground dry biomass ranged from 1.2 to 18.3 t/ha. The contribution of leaves, stem and branches to above ground biomass was 9.24, 41.90 and 48.60 % respectively
- The below ground biomass varied from 1.04 to 5.50 t/ha
- In general 93.46 % of root biomass was recorded within 50 cm depth
- Majority of the lateral roots were less than 10 mm size
- Recovery of root biomass decreased with decreasing sieve sizes.

Excavation of whole tree system of jatropha and data recording

4.1.11 Scope of enhanced adaptation strategies for climate resilience in horticultural crops through improved management practices

The national productivity of mango in India is stagnant since long time. Major area of mango is under rainfed conditions. It was observed that, the performance of mango under rainfed situation was poor as compared to irrigated conditions. One of the important reasons for low productivity may be due to lack of proper moisture in the soil at appropriate phenological event of mango crop. The physiology of floral induction in mango is still controversial and thus further work is needed for a better understanding of reproductive physiology of this important fruit tree. A study was carried out to investigate the role of climatic factors on fruit bud differentiation. For this purpose secondary data sets on chronological weather events and mango yields need to be collected from different parts of India. In this direction, available weather data from Horticulture College and Research Institute, Anantharajupeta, Kodur, A.P. were collected from 1979 to 2010. Available yields of 10 different mango hybrids and cultivars were collected from 2001 to 2010. Attempts were made to correlate the no of fruits and fruits wt (kg/plant) with total rainfall during different months. A gibberellins biosynthesis inhibitor, paclobutrazol was applied to the experimental trees at HRF with a view to achieve floral induction of biennially bearing mango trees during off year and to examine the possible nutrient composition of such trees. For this purpose the samples were collected from on or off year trees, bearing or non bearing trees, control or organic or chemical source of fertilization, bearing or non bearing shoots, bearing or non bearing leaves. The experiment is in progress. Keeping in view the importance of climate and to understand it thoroughly in enhancing production and productivity of major fruit crops, both tropical and subtropical, their application along with locally available organic and inorganic constituents was attempted under limited moisture supply conditions in order to fill up research gaps with regards to integrated orchard management approaches for bringing in natural resource conservation practices and to improve soil health and economic yields in ever changing climate scenario.

4.1.12 Adaptation Strategies through Cropping Systems at Selected Soil benchmark sites

Risk coping production systems resilient to climate, land and water modifications require diversified structures in space and time such as cropping systems. Inter-annual and intra annual seasonal climate variability is one of the major factors influencing biophysical systems. Further, the spatial variability of soils affect the ability of the crops/cropping systems to cope up with dry spells/drought and finally yields. In this context, a study at three micro-watersheds *viz.*, Kaulagi, Bijapur district, Karnataka; Warkhed, Akola district, Maharshtra; and Sola ka Kheda, Bhilwara district, Rajasthan was undertaken with the objective of assessing climate risks at selected soil benchmark sites and identifying/developing adaptation strategy options at these sites**.** The methodlogy includes climate variability studies, assessing soil quality, land degradation and cropping systems strategies specific to soil sites.

- The predominant soil types in Kaulagi watershed are shallow to deep very fine, calcareous black soils (Calcic/Typic Haplusterts, Vertic Ustropepts, Typic/Lithic Ustorthents, Typic Ustifluvents) (Fig. 61). In Varkhed watershed soils are shallow to very deep, clayey loam to clayey black soils (Typic Ustorthents, Vertic Ustrochrepts,Typic Haplusterts) and in Sola ka Kheda are deep to very deep fine loamy black soils (Typic Ustorthents, Typic Haplustepts)
- Invariably, at these three locations, there is a deviation in annual and seasonal rainfall, shift in start and end of southwest monsoon, sowing windows and cropping patterns, particularly in kharif season. The traditional cropping systems practiced in dominant soil types are documented in Kaulagi watershed and shown in Table. 40.
- There is marked change in soil properties in 2011 compared to 2001, particularly in respect of pH, organic carbon and available N, P and K across Entisols, Inceptisols and Vertisols in Warkhed watershed. The soil microbial biomass (SMBC) (ug/g) and dehydrogenase activity (DHA) was analyzed for various crops across soil types in Warkhed and Kaulagi watersheds. At Warkhed watershed, across fallow lands, sorghum, soybean and cottons and across shallow entisols,

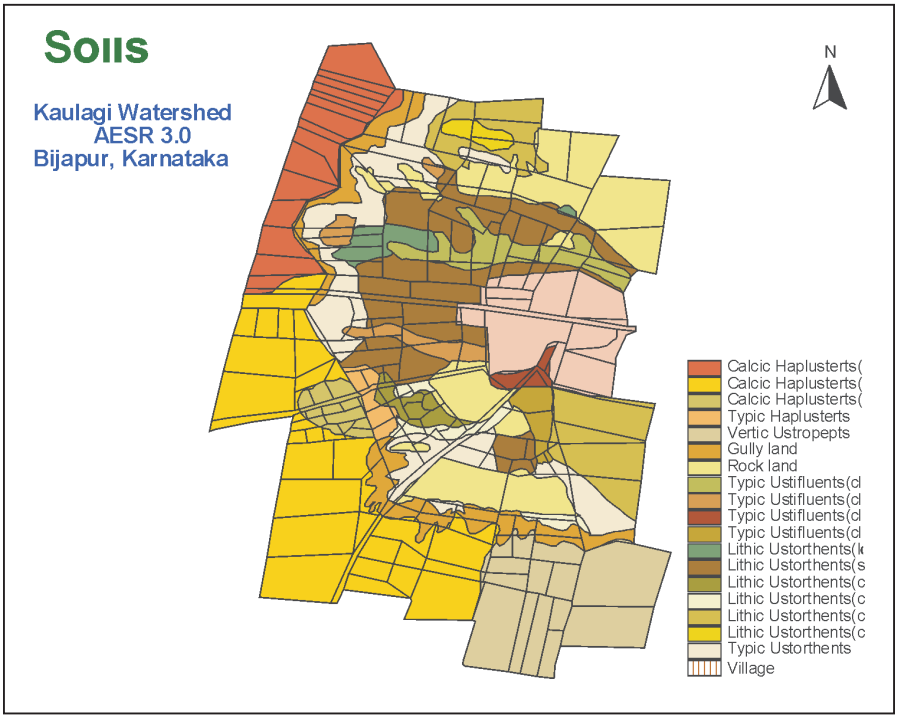


Fig. 61. Soils of Kaulagi watershed, Bijapur district

Table 40 : Traditional cropping systems in dominant soil types in Kaulagi watershed, Bijapur district, Karnataka

Soil Type	Traditional Cropping Systems	
	Kharif	Rabi
Very fine, very deep black soil (Calcic Haplusterts)	Pigeonpea, Groundnut, Onion, Pigeonpea+sorghum, Pigeonpea+groundnut Pigeonpea+pearlmillet, Onion+ chillies and Coton+onion	Sorghum and Onion
Very fine, very deep black soils (Typic Halusterts)	Pigeonopea, Onion, Pigeonpea+groundnut, Maize, Onion+ chillies	Sorgum, Chickpea Sorghum+chickpea
Very fine, very deep black soils (Vertic Ustropepts)	Pigeonpe and Onion	Sorghum, Chickpea Sorgum+chickpea Onion+sorgum relay cropping
Very fine, very deep, non gravelly black soils (Typic Ustifluvents)	Pigeonpea, Maize, Onion, Cotton, Groundnut and Pearlmillet	Onion
Fine, calcareous, very shallow black soils (Lithic Ustorthents)	Pigeonpea, Groundnut, Pigeonpea+groundnut and Onion+chillies	Sorghum and Chickpea
Very fine, very deep black soils (Vertic Haplustepts)	Pigeonpea, Maize, Groundnut, Pigeonpea+groundnut and Onion+chillies	Sorghum and Chickpea
Fine-loamy , very shallow brown soils (Lithic Ustorthents)	Pigeonpea, Pearlmillet, Maize, Onion, Cotton, Pigeonpea+groundnut and Pigeonpea+pearlmillet	Sorghum
Fine loamy very shallow black soils (Typic Ustorthents)	Pigeonpea, Maize, Pearlmillet, Onion, Cotton, Groundnut, Pigeonpea+pearlmillet and Pigeonpea+groundnut	Sorghum

deep inceptisols and very deep vertisols the SMBC ranged from 85.6 ug/g to 330.7 ug/g and DHA values ranged from 1.7 to 8.4 mic.g/g/hr while at Kaulagi watershed, across sorghum and chickpea and across shallow entisols to very deep, calcareous vertisols, the SMBC ranged from 96.8 u/g to 331.2 ug/g and DHA values ranged from 1.5 to 4.5 mic.g/g/hr.

- Over a period of one decade (2001 to 2011), there are no significant changes in chemical properties in the ground water quality in Kaulagi watershed.

4.1.13 Potential of rain water harvesting and recycling as an adaptation strategy to climate variability in rainfed crops

A network of 6 farm ponds of capacity ranging from 250 to 1750 m^3 with different catchments having the area from 2 to 14.5 ha was established at Gunegal Research Farm, CRIDA to assess the potential of rainwater harvesting for climate resilience in alfisols by managing dry spells. Four farm ponds were lined with Silpaulin of 300 gsm (250 microns) and the other two were lined with HDPE film of 500 micron. The average rainfall in the season was 350 mm with two runoff events producing 1500 m^3 runoff from 14 ha catchment in 2011. The evaporation loss from the farm pond was observed to be 4% of the total storage. The experiments were conducted with maize and groundnut by giving supplemental irrigation to the crops at critical stages. It was observed that there was an increase of 67% in crop yield in both groundnut and maize from the rainfed crops (Table 41). The water productivity increased from 5.82 to 9.4 kg/ha mm in case of maize with supplemental irrigation (SI) of 59 mm at critical stages. In groundnut it increased from 3.13 in rainfed to 5.09 kg/ha mm with SI (Fig. 62).

Table 41 : Productivity of maize and groundnut with rainfed (RF) and supplemental irrigation (SI)

Crops	Rainfall during season (mm)	Water applied as supplemental irrigation (mm)	Total water used (mm)	Crop productivity (kg/ha)	
				SI	RF
Maize (DHM-117)	319.8	59.0	378.8	3561	1862
Groundnut (ICGV-91114)	318.6	63.0	381.6	1942	1000

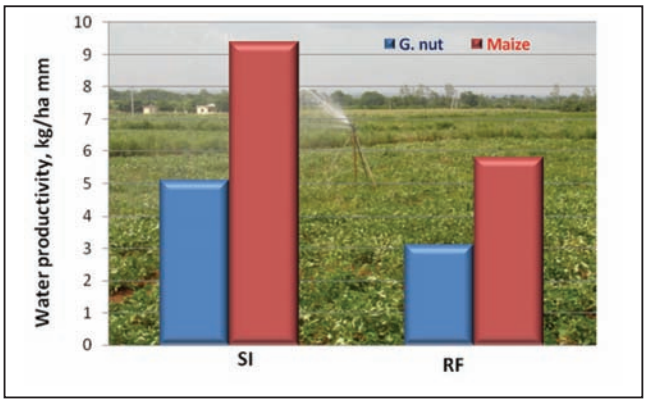


Fig. 62. Water productivity of maize (DHM 117) and groundnut (ICGV 91114) in rainfed (RF) and supplemental irrigation (SI) in Alfisols

4.1.14 Rainfall and temperature analysis for Southern Telengana by Using ECHAM5 and CSIRO MK 3.5 models

The rainfall and temperature analysis was done by downloading the climate data for different climate change scenarios (A1b, A2 and B1) from markshim DSSAT (www.ccafs.com) data source by using ECHAM5 and CSIRO mk3.5 models. These data were compared with 1980-2010 observed data taken from the observatory at Gunegal Research Farm, CRIDA. The analysis indicated that there was shift in the rainfall pattern indicating more rainfall from August to December (2010-2050) by both the models selected and number of rainy days had increased by 1.5 times (45 to 72) indicating the well distribution of rainfall in the rabi season (Table 42). However, the extreme rainfall was observed to be less as compared to the existing as predicted by the models. Also, the maximum and minimum temperatures would be affected by the climate change in the region with increasing trend by 1.5°C in Tmax and decreasing in Tmin. These would impact on the evapotranspiration of the crops in the region.

4.1.15 Assessing & mapping district-level vulnerability to climate change

Extreme climatic events like drought, heat-wave, flood, cold-wave, cyclones, etc., impact the bio-physical aspects of earth and can be discerned by Remote Sensing tools and techniques. Change in land use / land cover, vegetation growth and vigour can be used as proxy for vulnerability assessment. Normalized Difference Vegetation Index (NDVI) from Advanced Very High Resolution Radiometer (AVHRR) (8 km) and from Moderate Resolution Imaging Spectroradiometer (MODIS) 16-day (250m) time-series data were taken to analyse vulnerability of

Table 42 : Rainfall and temperature analysis in Southern Telengana

Parameter	Average (1980-2010)	CLIMGEN (2011-2050)	LARS-WG (2011-2050)	CSIROmk3.5 (2010-2050)			ECHAM5 (2010-2050)		
				A1b	A2	B1	A1b	A2	B1
Annual rainfall (mm)	739	803.7	872.1	603.9	597.8	628.80	642.6	615.4	611.1
Number of rainy days	45.6	46.6	41.7	63.1	63.9	72.4	72.5	66.2	67.7
Extreme events (mm)	204.0	179.8	189.6	91.2	99.2	46.6	44.9	47.5	44.9
Seasonal rainfall (mm)	495	563.3	444.3	382.3	343.3	406.4	422.9	411.1	382.7
Tmax (°C)	42.0	43.9	42.0	43.9	43.1	43.4	42.5	43.1	42.3
Tmin (°C)	9.0	7.6	8.4	6.1	7.2	8.2	9.3	7.1	7.7

Indian agriculture to climate change under NICRA project. The major objectives of the study were:

1) To understand variability in surface vegetation including agriculture, open scrub and forest stand or Surface Greenness as depicted by Normalized Difference Vegetation Index (NDVI) derived from NOAA-AVHRR (8km) datasets downloaded from website.
2) To examine correlation between NDVI variability and Standard Precipitation Index (SPI) to understand the impact of extreme weather events viz., droughts, floods, heat and cold waves, cyclones, untimely rains etc.
3) To document trends in NDVI at district-level as corollary to vulnerability to climate change and variability
4) To identify vulnerable districts and document the policies/ initiatives of the government at State and District- level.

NDVI datasets were freely downloaded from GIMMS and GLCF website in *Geo-tiff* format and re-projected in Geographic Projection. For corroborating NDVI variations, Standard Precipitation Index were estimated using 1^{o} x1^{o} girded rainfall data obtained from IMD. AVHRR (8km) NDVI images (1982-2006) were stacked for each year and multiplied with a scale factor of 0.0001 to convert to 16-bit signed integer value. For MODIS data (2001-2011) Savtizky - Golay filter was applied. Variations in MAX NDVI were analysed for assessing regional vulnerability. SPI was calculated and interpolated to 8km resolution for AVHRR data and 250m resolution for MODIS data. Based on CV of MAX NDVI vulnerability maps were drawn. MODIS (250m) data was used to draw district-level vulnerability maps. AVHRR (8km) data was used to draw State, AESR and ACZ level vulnerability maps.

It was estimated that over 241 million ha area in the country may not be vulnerable to climate change while over 81.3 million ha in arid, semi-arid and dry sub-humid regions in Rajasthan, Gujarat, Marathwada and Vidharbha regions in Maharashtra in addition to Karnataka and Andhra Pradesh where rainfed agriculture is widely practiced, may be vulnerable to climate change and extreme weather events (Fig. 63). Study indicated that over 12.1 and 1.81 million ha of *Kharif* cropland would be mildly and severally vulnerable while 6.86 and 0.5 million ha of *Rabi* cropland may be adversely affected in a similar manner (Fig. 64). Of the remaining agricultural

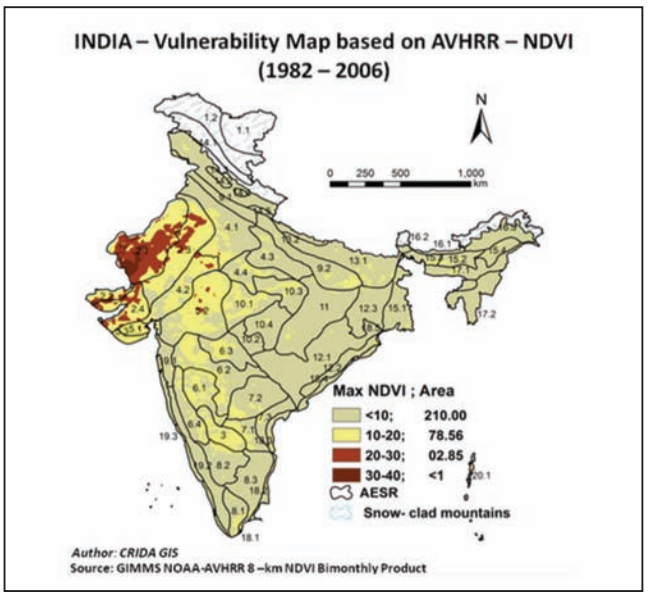


Fig. 63. India – vulnerability map based on AVHRR – NDVI (1982-2006)

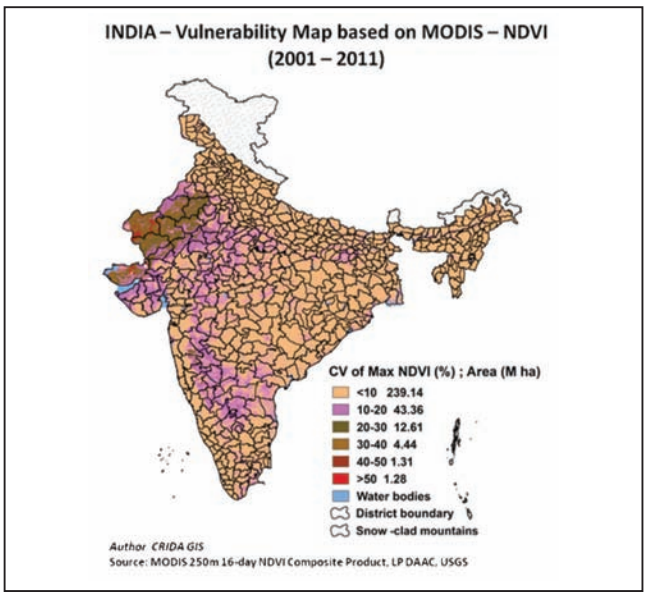


Fig. 64. India – vulnerability map based on MODIS – NDVI (2001-2011)

Table 43 : List of vulnerable districts in India based on variability in MODIS data

State	District
CV of Max NDVI (10-20%)	
Andhra Pradesh	Anantapur, Kurnool, Mahbubnagar, Prakasam
Bihar	Gaya, Jahanabad, Nawada
Gujarat	Ahmedabad, Jamnagar, Rajkot, Surendranagar
Karnataka	Belgaum, Bijapur, Chitradurga, Dharwad, Gadag, Gulbarga, Haveri, Koppal, Raichur
Madhya Pradesh	Barwani, Bhind, Dhar, Guna, Ratlam, Sheopur, West Nimar
Maharashtra	Ahmednagar, Aurangabad, Pune, Sangli, Satara, Solapur
Rajasthan	Ajmer, Alwar, Bhilwara, Ganganagar, Jaipur, Jhunjunu, Karauli, Sawai Madhopur, Tonk
Uttar Pradesh	Jhansi
CV of Max NDVI (20-30%)	
Gujarat	Kutch
Rajasthan	Barmer, Bikaner, Churu, Hanumangarh, Jodhpur, Nagaur
CV of Max NDVI (30 – 40 %)	
Rajasthan	Jaisalmer

lands, 29.93 and 5.24 million ha would also be vulnerable to climate change with impacts ranging in magnitude from moderate to severe (Table 43).

MODIS NDVI time-series data indicated a trend of moderate drying in West Bengal, eastern Bihar and Jharkhand, parts of Vidharbha and southern Madhya Pradesh, National Capital Region, southeastern Punjab, southern Himachal Pradesh and south-west Uttarakhand. This is a large region covering densely populated areas and cultivating important cash crop in the country.

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

Small ruminants play immense role in supporting the livelihood system of the poorest of the poor, especially in the marginalized rainfed areas. They also make a substantial contribution (Rs 24,000 million per annum) to the rural economy. The small ruminant keepers depend on pastoralist areas which are characterized by unpredictable and unstable climatic conditions as well as ecologically fragile ecosystems which is further stressed by rising populations and high ambient temperatures. Frequently climate related calamities particularly drought, have been increasing in the recent past in these areas and causing severe fodder shortage. All these are severely affecting the productivity in small ruminants.

A study was conducted to identify the physiological indicators of stress in grazing small ruminants and development of consolidated adaptation strategies under grazing conditions. Effects of age, breed and species on blood biochemistry of small ruminants reared during hot summer, a season characterized with relatively low available grazing resources were assessed. Accordingly, healthy animals (n=54) were chosen and divided into nine comparable groups having 6 animals each; male Deccani lambs (3 months old), male Nellore lambs (3 months old), male non-descriptive kids (3 months old), Deccani rams (15 months old), Nellore rams (15 months old), non-descriptive bucks (15 months old), aged Deccani rams (36 months old), aged Nellore rams (36 months old) and aged non-descriptive bucks (36 months old). All the animals were maintained on available grazing resources with supplementation (100-350 g/day depending on the body weight) of complete feed (CP 18% and TDN 70%) in the evening after returning back from grazing for a period of two months (April-May, 2011). Blood samples were collected in the month of May when the available pasture level for grazing was at its minimum. Further, documentation of forage availability (both quantity and quality) in grazing areas during different months of the year was systematically assessed. Forage availability increased till October

and there onwards, a substantial decrease was observed in grazing lands. A similar trend was also observed in crude protein (CP) content and in vitro dry matter digestibility (IVDMD) of the forage from grazing lands.

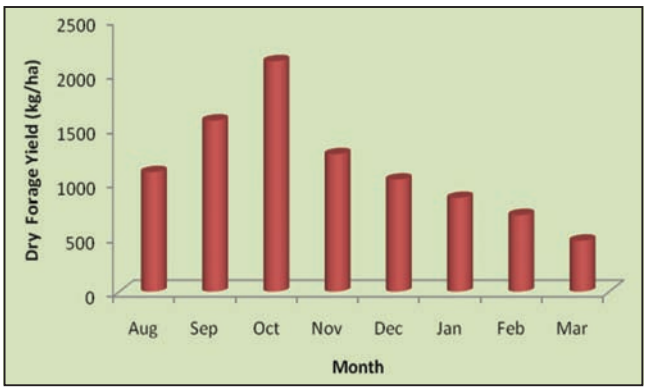


Fig . 65. Dry forage dynamics in grazing lands for small ruminants during different months of the year 2011-2012 at HRF, Hayatnagar

Electrolytes (Na, K and Cl) level was within the normal range in 3 months age group animals irrespective of breed and species, which might be due to non-exposure of these animals to hotter climate as they are not allowed for grazing along with the dams. However, increase in Na level and decrease in K and Cl was observed in 15 and 36 months age group grazing animals. Total protein levels were higher in all age groups of goat than in sheep. This might be due to efficient utilization of available tree fodder in goats by virtue of their browsing habit. Among the sheep breeds, Deccani is having higher total protein level than Nellore. Further, increase in level of total proteins was observed with increase in age in all the animals. Triglycerides level was comparable among the different age groups, however higher values were observed in sheep than goat and among the sheep breeds in Nellore than Deccani. The latter are comparatively lean animals and having low basal metabolic rate (BMR). Glucose level was comparable among the animals. Higher calcium level was observed in 15 months age group of animals indicating rapid growth phase. Increase in globulin levels was observed with increase in age of the animals. Further, higher ($p<0.05$) globulin levels were observed in Deccani animals than others indicating relatively high levels of disease resistance, an enviable character for any breed. It can be concluded that the vital biochemical parameters were within the physiological ranges in spite of low availability of grazing resources. Supplementation improved ($p<0.01$) body weight gain in grazing sheep (n=18) during the critical period characterized as period of relatively low available grazing resources. Significantly ($p<0.01$) higher weight gain was observed with supplementation (13.3 ± 0.16 kg) of concentrate mixture (300 g/day) than sole grazing (5.3 ± 0.10 kg). A similar trend was observed in average daily gain (24.9 ± 0.46 and 62.4 ± 0.58 g/day in sole grazing and grazing with supplementation, respectively) from the month of January to July, 2011. The result of the present study reveals the necessity of supplementation in the evening to meet the nutritional requirements of the small ruminants under traditional grazing practices.

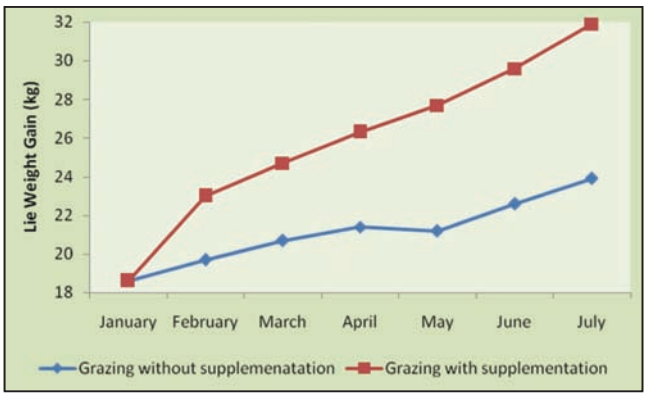


Fig. 66. Effect of supplementation on performance of grazing sheep during the critical period (low available grazing resources)

Effect of different levels of heat stress on microbiota in rumen fluid was assessed in Nellore and Deccani rams (12-18 months old) maintained on similar feeding conditions during the month of March, 2012. All the animals (n=24) were exposed to the experimental conditions for a period of 7 days before collecting rumen fluid in the morning for 3 consecutive days. Protozoan count ranged from 1.06×10^6 to 1.34×10^6 with slight decreasing of

Table 44 : Microbiota in ruminal fluid of experimental rams

Parameter	Group I (under complete shade)		Group II (exposed to 8 h solar radiation)		Group III (exposed to 4 h solar radiation)	
	Nellore	Deccani	Nellore	Deccani	Nellore	Deccani
Protozoan count	1.34 x10^6	1.26 x10^6	1.28 x10^6	1.25 x10^6	1.11 x106	1.06 x10^6
SE (±)	0.16	0.16	0.15	0.05	0.17	0.13
Bacterial count	3.56 x10^6	3.42 x10^6	2.88 x10^6	2.76 x10^6	3.11 x10^6	2.97 x10^6
SE (±)	0.10	0.26	0.20	0.13	0.05	0.08

counts with the increase of exposure to solar radiation (environmental temperature). A similar trend was observed in bacterial counts. This reveals the importance of proper shade for livestock for maintenance of ruminal microbiota, which in fact helps in proper digestion of feed material.

4.1.17 Assessment of vulnerability and adaptation to climate change

The major objective of the study was to assess the relative vulnerability of different regions to climate change and identify the districts that are relatively highly vulnerable to climate change and variability. The definition given by IPCC that vulnerability is a function of sensitivity, exposure and the adaptive capacity was adopted for this study. Relevant indicator variables that reflect each of these three components of vulnerability were identified and a database for about 550 districts was created. Considering the relationship of each of these variables with the vulnerability, the data on the variables was normalized so that they can be combined into an index. Variables such as proportion of rural poor, proportion of workers employed in agriculture, average size of land holding, literacy, available ground water, fertilizer consumption were considered to reflect adaptive capacity of the district. Similarly, variables such as incidence of drought and floods, average annual rainfall, incidence of extreme events, population density, coast length, extent of degraded lands were considered to reflect sensitivity. The changes in climate in terms of average rainfall, incidence of droughts, heat and cold waves as obtained from the A1B scenario of downscaled climate projections using PRECIS were used to determine the extent of exposure that the districts were subjected to. It was observed that a majority of districts in the western part of Indogangetic plains and the southern states are relatively better placed in terms of adaptive capacity. Most of the districts with low levels of adaptive capacity are in the eastern and central parts of the country. Similar indices for exposure and sensitivity were also constructed which in turn were used to construct the vulnerability index for each district.

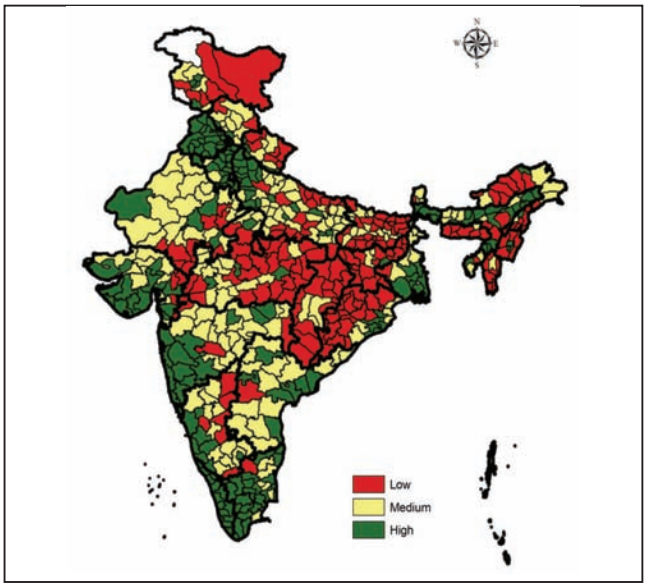


Fig. 67. Classification of districts according to adaptive capacity

4.2 Technology demonstration

The technology demonstration component of National Initiative on Climate Resilient Agriculture deals with demonstrating an integrated package of proven technologies for adaptation of the crop and livestock production systems to climate variability.

This component is implemented in selected vulnerable districts of the country by implementing location specific interventions through Krishi Vigyan Kendras in a participatory mode. The project is implemented in 130 districts involving over one lakh farm families across the country. Following is the breakup of the 130 project locations.

1. KVKs in eight zones -100
2. Co-operating centres of AICRP on Dryland Agriculture - 23
3. Technology Transfer Divisions of Core ICAR Institutes – 7

The selection of districts for implementing Technology Demonstration Component was done by following the criteria detailed below:

- Drought proneness based on 30 years rainfall data (Source : IMD)
- Cyclone proneness based on data on frequency as recorded by IMD and in consultation with State Disaster Management Departments.
- Flood proneness based on IMD data and National Disaster Management Authority (NDMA) maps.
- Vulnerability to heat wave and cold wave based on grid data (IMD) of temperatures.
- Actual incidence of floods and droughts as recorded by AICRPAM centers

Besides, areas affected with salinity and severe groundwater crisis were identified by superimposing salinity maps developed by CSSRI with water balance maps of NBSS&LUP. The criteria mentioned above were given a weightage of 70% while the remaining 30% was given to the ability/potential of the KVK in terms of its past performance, staff strength and the rating of the ZPD. Care was taken to see that each state and important agro-climatic region is covered so that all the ZPDs and the Directors of Extension of each SAU gets firsthand experience on how to deal with climate variability with the help of available technologies.

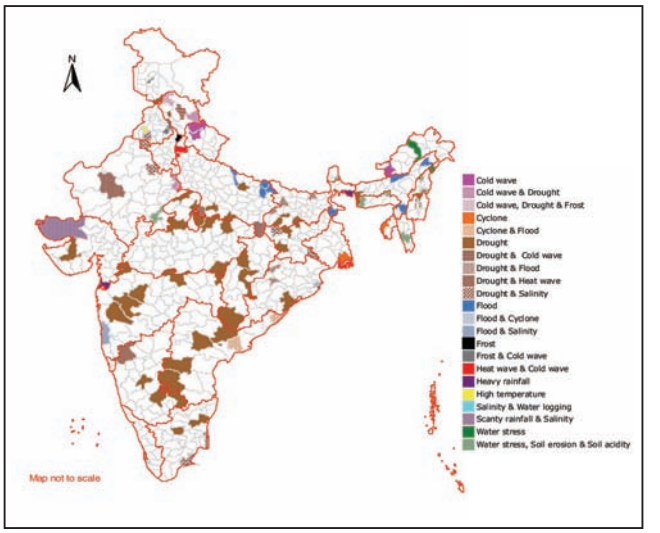


Fig. 68. Technology Demonstration locations

Agriculture in India is practiced for over 5000 years and during this long history, the agrarian communities have faced various climate related challenges. During the past five decades, challenges in agriculture are being dealt with application of science and technology. Over the years, a range of technologies suiting to different situations have been developed by the NARS. Though these technologies cannot be termed as climate resilient they were applied in situations challenged by climate variability in different agro climatic environments. Therefore, the TDC component takes a fresh look at these technologies and aims to demonstrate the technologies with climate resilience perspective. Besides, current efforts underway for developing climate resilient technologies may take a while before getting ready for implementation. To sum up, the following points capture the rationale for implementing technology demonstration component under NICRA.

- Availability of technologies
- Availability of indigenous practices
- Long experience of NARS in evolving drought/ flood resilient technologies
- Inherent resilience with the community for coping with disasters

The specific objectives of TDC are:

- To enhance the resilience of Indian agriculture (including crops, livestock and fisheries) to climatic variability and climate change through strategic research on adaptation and mitigation
- To demonstrate site specific technology packages on farmers' fields to cope with current climatic variability
- To enhance the capacity of scientists and other stakeholders in climate resilient agricultural research and awareness of impacts

The interventions covered under the component are broadly classified as four modules:

Module I: Natural Resources

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

Module II: Crop Production

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

Module III: Livestock and Fisheries

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

Module IV: Institutional Interventions

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

The Process

The KVK team for each district carried out a detailed exercise on the needs of the village, the climatic vulnerability (drought/floods/heat wave/ frost/cyclone) and the available technology options from the concerned Zonal Agricultural Research Stations of the SAUs. After a careful study of the gaps, specific interventions from each of the module were selected and an integrated package from all modules was formulated. Majority farmers are covered with one or more of the interventions in order to demonstrate a discernable effect. The project was launched in each village with wide publicity and by involving all the line departments under the leadership of the district administration. The launch event was used to generate wide spread awareness within the community and across line departments so as to prepare a platform for exploiting synergy through convergence of other government projects.

Project Launch at KVK, Namakkal, Tamil Nadu

Unique features of the project

- Baseline for all the project sites established through a systematic benchmark survey
- Emphasis on natural resource management interventions to build the communities' capacity to cope with climate variability through need based investment
- Establishment of a network of automatic weather stations across 100 KVKs as well as 100 small weather stations installed in project villages as part of enhancing weather literacy.

Small weather station in project village to raise weather literacy

- Establishment of custom hiring centers in each project village for promoting mechanization on small farms.
- Constitution of village climate risk management committees – grassroots peoples' institutions to take need based decisions at the village level.

Progress so far

The project has made some significant impact in each of the modules. Large number of farm ponds have been dug across the drought prone areas where due to shrinking of LGP the productivity of major crops was declining. This has led to increased moisture availability to cropping activity leading to higher cropping intensity. Increasing the rainwater harvesting capability along with crop production supporting activities such as introduction of improved cultivars, addressing micro nutrient deficiency through site specific nutrient management, supplemental irrigation, mulching, use of zero till drill etc. have brought in new energy into NICRA villages. For instance, in Hirehalli, Tumkur district, Karnataka introduction of fingermillet cv. ML-365, a short duration high yielding variety has increased the productivity by 25% whereas its local counterparts could not come to harvest due to moisture stress. Introduction of zero till drill has cut down cost of cultivation of wheat besides advancing date of sowing by 15 days in Baghpath, U.P. This has helped farmers in saving energy, water and most importantly time which is very crucial to get good wheat harvest. Mobilizing people to build a sand bag check dam across a rivulet in Gumla, Jharkhand has improved water table in the open wells and enabled farmers to secure their rabi crop. Introduction of sprinkler and drip systems through custom hiring center in Amadalavalasa, Srikakulam district, Andhra Pradesh has helped farmers to realize a bumper harvest of sunflower by using precious water judiciously. Improved housing for backyard poultry has reduced the mortality of chicks due to extreme cold in the hilly regions of Sikkim. Land shaping and harvesting rainwater has helped to reclaim the lands affected by sea water inundation due to Aila cyclone in South 24 Parganas, West Bengal. There is a tremendous support for custom hiring centers as institutions promoting timely agricultural operations in the remote villages across the country. Farmers

Rainwater harvested in pond for drought resilience

VCRMC meeting in progress

are paying user charges for hiring the equipment and many CHCs have collected sums as high as Rs. 50,000 during a single season. The custom hiring center at Namakal for instance has collected over Rs. 80,000 and has purchased an additional tractor through bank loan. Overall, the project has made significant progress in the past one year and generated positive response from farmers across the country.

Improved implements at village custom hiring center

To sum-up, the following may be highlighted as the most significant outcomes from across 100 KVKs.

- Simple in-situ moisture conservation measures like broad bed and furrow method can increase rabi sorghum yield by 80% during a drought year (KVK, Baramati).
- Zero till drill machines can advance sowing date of rabi crops like wheat and chickpea by 2-3 weeks besides avoiding burning of paddy straw and saving water and energy (KVKs, Baghpat & Yamunanagar).
- Improved housing for backyard poultry and goats will drastically reduce mortality in hill regions (KVK, East Sikkim).
- Introduction of short duration varieties suitable for late sowing will help promote family food security (Improved rabi for late sown conditions-KVK, Tumkur).
- Identification of existing rainwater harvesting structures and their renovation/repair will yield quick results in terms of improved water table (KVKs, Baramati, Tumkur, Srikakulam, Gumla & Bharatpur).
- Land shaping and rainwater harvesting will help rehabilitate small holders after seawater intrusion (KVK, South 24 Parganas).
- Custom hiring services can significantly contribute to alleviating labour shortage during peak demand period.
- Coarse crop residue can be used to blend with good quality fodder through silage making thus augmenting fodder availability during dry periods.

Lessons Learnt

- A combination of interventions aimed at community or common village resources and those aimed at individual farmers are necessary to ensure the participation of the entire village in the project.
- Custom hiring centers need to be equipped with multiple numbers of sowing equipment so that the sowing window can be effectively utilized.
- Programme coordinator is critically important as his ability to mobilize his own staff and the community will determine the success of the project.
- Expeditious fund flow from SAUs is crucial especially to implement NRM interventions by SAU-KVKs.
- The capacity of the KVKs to plan, organize and implement NRM interventions needs strengthening.

- The delegation powers to PCs for recruitment of contractual staff will avoid delay in recruitment.
- Convergence with on-going development programs requires special efforts by the Programme Coordinator.
- Livestock interventions bring the required resilience for the households to cope with climate variability, especially droughts.

Climate resilient technology demonstration at AICRIPDA centres

Out of 22 centers, 8 centers are operating Operational Research Project (ORP) for testing the research findings on farmers' fields, receiving feedback and refinement of such technologies to enable up-scaling in the target domains. These vary from arid to semi-arid, sub-humid and humid with varying soil types such as alfisols, vertisols, inceptisols, aridisols and entisols. Depending on the seasonal rainfall distribution, the centers are conducting experiments in *kharif*, *rabi* and *summer* seasons, by storing rainwater *in-situ* and *ex-situ.* Under NICRA, the rainfed technology demonstrations are being conducted under 4 sub-projects at 22 centers and one voluntary center at Jhansi during 2011-12. The 4 sub-projects were (i) Real time contingency plan implementation in a participatory mode; (ii) Rainwater harvesting *(in-situ and ex-situ)* and efficient use; (iii) Efficient energy use and management; and (iv) Alternate land use. There were 81 demonstrations (2444 farmers) under sub-project-1; 61 (562) under sub-project-2; 25 (262) under sub-project-3; and 38 (227) under sub-project-(4) under on-farm condition covering a total area of 1910.79 ha. Similarly, there were 42, 17, 4 and 32 demonstrations under the 4 sub-projects respectively in on-station condition covering an area of 70.09 ha.

Each center had to propose technological and institutional interventions for enhancing the resilience of farming systems to the climatic variability by involving the major stakeholders such as farmers, researchers, NGOs, officers of the line departments and extension specialists. Based on the detailed analysis of farming systems, resources, constraints, needs of the village, the climatic vulnerability (drought/floods/heat wave/frost/ cyclone) and the available technology options from the concerned Regional /Zonal Agricultural Research Stations of the SAU and ICAR institutes and time tested climate resilient farm practices adopted by innovative farmers, the stakeholders in the brainstorming sessions identified the gaps and selected specific interventions related to each of the four sub-projects. It was planned to saturate the whole village with the identified interventions in order to demonstrate a discernable effect and document the constraints and lessons. Further the preference was given to the interventions targeted/ focused on the following:

- Interventions benefiting larger and resource poor group
- Interventions which give long-term and sustainable benefits
- Interventions that address resource conservation
- Interventions that promote/strengthen village level institutions

In the beginning, the number of interventions of different types was decided as per the budget available, vulnerability status and cooperation of the farmers. The interventions which require high investment like farm pond were planned for few suitable locations in the village. The in-*situ* moisture conservation and improved agronomic practices, inter-cropping and new varieties were planned to be taken up for large number of farms in the village. In selection of beneficiaries, the farmers' most vulnerable to climatic variability and small holders were given priority. It was also ensured that the village has control farm/plot/animals for all the implemented interventions in order to assess the impact of interventions in a short period. Every centre was suggested to prepare the activity plan with details of activities along with roles and responsibilities of stakeholders, period and budget

for each intervention. The AICRPDA Network centers have been included in the NICRA Project of ICAR for taking up demonstration and research activities at various dryland centers in a network mode. Accordingly, the following centers have been identified in different states of India. The demonstration components of NICRA have been finalized in these centers in a participatory mode. The villages in districts and domain districts of the centers are given in Table 45.

Table 45 : Details of villages under NICRA program

State / (SAU)	Center	Villages	Districts	Domain districts
Andhra Pradesh (ANGRAU, Hyderabad)	Anantapur	Aminabad, Girigetla	Kurnool	Anantapur & Kurnool
Assam (AAU, Jorhat)	Biswanath Chariali	Chamua	Lakhlmpur	Sonitpur, Lakhimpur, Dhemaji & Darrang
Chittishgarh (IGKV, Raipur)	Jagdalpur	Tadpal, Gumiapal, Pahkapal	Bastar	Bastar, Dantewada, Bijapur & Nararyanpur
Gujarat (JAU, Junagadh)	Rajkot	Pata meghapar	Jamnagar	Rajkot, Jamnagar, Surendranagar, Amreli & Bhavnagar
Gujarat (SDAU, SK Nagar)	SK Nagar	Dholia, Kalimati, Chandanki	Banaskantha Mehasana	Banaskantha, Mehsana, Sabarkantha, Kutch, Patan & Gandhinagar
Haryana (CCSHAU, Hisar)	Hisar	Budhsheli, Charnod, Balawas	Bhiwani	Hisar, Bhiwani, Fatehbad & Mahendragarh
Jammu & Kashmir (SKUAS T, Jammu)	Rakh Dhiansar	Khaner	Rakh Dhiansar	Jammu, Samba, Kathua, Udhampur & Rushia
Jharkhand (BAU, Ranchi)	Chianki	Kumbhi-pankheta	Garhwa	Palamu, Garhwa, Latehar, Chatra, Lohardaga, Simdiga & Bhumla
Karnataka (UAS, Bengaluru)	Bengaluru	Chikkamaranahalli (Chikkamaranahalli colony, Chickaputtyanapalya, Hosapalya, Mudalapalya)	Bengaluru Rural	Tumkur, Bengaluru rural, Bengaluru urban, Ramanagar, Kolar & Chickballapur
Karnataka (UAS, Dharward)	Bijapur	Kaulagi	Bijapur	Bijapur, Bagalkot, Gadag, Koppal, Bellary, Dharwad, Belgaum, Raichur & Davangere
Madhya Pradesh (JNKVV, Jabalpur)	Rewa	Patauna	Rewa	Rewa, Jabalpur, Panna, Singraouli, Satna, Katni, Seoni & Sidhi
Madhya Pradesh (RVSKVV, Gwalior)	Indore	Ningnoti	Indore	Indore, Dhar, Ratlam, Dewas, Ujjain, Shajapur, Mandsour, Neemuch, Jhabua & Rajgarh
Maharashtra, (PDKV, Akola)	Akola	Warkhed, Belura	Akola	Akola, Buldana, Washim, Amaravati & Yavatmal
Maharashtra (MAU, Parbhani)	Parbhani	Pangri	Parbhani	Aurangabad, Jalna, Parbhani, Singole, Nanded, Osmanabad & Lathur
Maharashtra (MPKV, Rahuri)	Solapur	Raleras	Solapur	Solapur, Ahmednagar, Dhule, Pune, Nasik, Satara, Aurangabad, Jalgaon, Nandoorbar, Sangli, Beed & Kolhapur

State / (SAU)	Center	Villages	Districts	Domain districts
Orissa (OUAT, Bhubaneswar)	Phulbani	Budhadani	Kandhamal	Kandhamal (Phulbhani), Rayagadha, Gajapati, Ganjam & Boud
Punjab (PAU, Ludhiana)	Ballowal Saunkhri	Naiwan, Achalpur	18. Hosiarpur	S.B.S.Nagar (Nawanshahr), Hoshiarpur, Gurdaspur & Roopnagar (Ropar)
Rajasthan (MPUAT, Udaipur)	Arjia	Kocharia, Mandpiya, Lapsiya, Sola ka kheda, Tara ka kheda	Bhilwara Rajsamand	Bhilwara, Chittorgarh, Rajsamand, Udaipur& Sirohi
Tamil Nadu (TNAU, Coimbatore)	Kovilpatti	Nakkalamuthan-patti, Kalugachalipuram	Tuticorin Thoothukkudi	Toothukudi, Tirunelveli, Virudhanagar & Madurai
Uttar Pradesh (NDUA&T, Faizabad)	Faizabad	Hardoia	Faizabad	Faizabad, Ambedkarnagar, Barabanki, Jaunpur, Sultanpur, Basti & Gonda
Uttar Pradesh (RBS College, Agra)	Agra	Nagla Duleh khan	Agra	Agra, Aligarh, Etah, Firozabad, Hatraspur, Mathura & Mainpuri
Uttar Pradesh (BHU, Varanasi)	Varanasi	Terha Saraya	Mizapur	Varanasi, Mirzapur, Sonebhadra, Chordoli & Sant Rabidash Nagar
Uttar Pradesh (IGFRI, Jhansi)	Jhansi	Kadesara Kala	Lalitpur	Lalitpur

5 Coordinated / Network Projects

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

The All India Coordinated Research Project for Dryland Agriculture was started in 1971 with 16 centers. At present, it has a network of 22 centers located in 20 State Agricultural Universities, two other Universities (BHU, Varanasi and Agra University). AICRIPDA centers represent arid, semi-arid, sub-humid, humid and per-humid climates with diverse bio-physical and socio-economic settings of the rainfed agro-ecologies of the country. The project has a mandate to generate location specific technologies through on station research focusing on rain water management, integrated nutrient management, energy management, cropping systems, participatory varietal selection, alternate land use and farming systems in rainfed rice, maize, sorghum, pearl millet, finger millet, cotton, groundnut and soybean based production systems. The resultant technologies are subsequently assessed on farmers' fields through 8 Operational Research projects. The outreach programs like Frontline demonstrations (FLDs) on pulses and oilseeds, on-farm trials are also being undertaken. A total of 347 experiments were conducted with 18.7% of rain water management, 21.9% of INM, 11.8% energy management, 11.0% cropping systems, 22.8% participatory varietal selection, 1.7% integrated weed management, 4.6% alternate land use,4.3% integrated farming system, 1.4% On farm trials and 1.7% of other experiments across the production systems. These include 100 experiments on rice based production system (Jagdalpur, Jorhat, Faizabad, Phulbani, Ranchi and Varanasi); 44 on maize based production system (Arjia, Ballowal-Saunkri and Rakh Dhiansar); 17 on finger millet based production system (Bangalore); 42 on pearl millet based production system (Agra, Hisar and S.K.Nagar); 39 on sorghum based production system (Bijapur and Solapur); 35 on soybean based production system (Indore and Rewa); 34 on groundnut based production system (Anantapur and Rajkot); 36 on cotton based production system (Akola, Kovilpatti and Parbhani). Under ORP, there were 142 trials out of which 98 trials under Participatory Technology Development and 21 trials under Up-scaling of Technologies, 8 under NICRAT and 23 other trials (HRD, FLD and Livelihood activities etc.) The salient findings from the research are summarized below

5.1.1 Research findings

5.1.1.1 Rain water management

- At Faizabad, maximum paddy yield equivalent (6746 kg/ha) was recorded with paired row sowing of pigeonpea on ridge and paddy in furrow.
- At Arjia, summer deep ploughing with raised bed of 40 cm width recorded highest blackgram yield (1243 kg/ha) and highest net return, RWUE (2.19 kg ha^{-1} mm^{-1}) and lowest runoff (11.26%) and soil loss (0.58 t/ha).
- At Ballowal Suankhri, among different vegetative barriers, tested in *kharif* Kannah proved best yield, rainwater-use-efficiency and profitability. In *rabi*, lentil gave better economic returns under all vegetative barriers.
- At with one supplemental irrigation, higher seed yield was recorded with sorghum (1270 kg/ha) and horsegram (957 kg/ha). With two irrigations,

significantly higher seed yield was recorded by sorghum (1410 kg/ha) and horsegram (1225 kg/ha).

- At Anantapur, in a study on effects of dikes on productivity of rainfed groundnut, higher pod yield was recorded (2046 kg/ha) in one dike after every 4 rows by conserving *in situ* rain water effectively with BC ratio of 4.50 and rain water use efficiency of 3.61 kg/ha/mm.
- At Bijapur, pebble mulch was superior over sand mulch for reducing soil loss and runoff. Higher sunflower equivalent yield was recorded in pebble mulch plot.
- At Agra, among different moisture conservation and fertilizer practices tested for pearlmillet, ridge and furrow sowing together with recommended N fertilizer in 3 splits (1/3 each) gave significantly higher yield of 3218 kg/ha, net income of Rs. 14324/ha and BC ratio of 2.06.
- At Hisar, deep ploughing before the onset of monsoon was superior and gave a maximum and significantly higher mustard yield of 2556 kg/ha, net income of Rs. 29,594/ha and BC ratio of 2.34.
- At SK Nagar, opening of furrow at 3.6 m interval and sunhemp *in situ* as a mulch gave significantly higher cotton yield (467 kg/ha).
- At Akola, highest seed cotton (2352 kg/ha) yield was recorded in crop residue mulch treatment and was at par with furrow opening, mulching and thinning
- At Bengaluru, onion, Bellary red variety was superior with a significantly higher bulb yield (4318 kg/ha)

5.1.1.2 Integrated nutrient management

- At Biswanath Chariali, maximum grain yield (1041 kg/ha) and straw yield (2116 kg/ha) of toria were observed in treatment 50% N (inorganic) + 50% N (FYM).
- At Arjia, highest maize grain yield 4433 kg/ha was recorded under application of $ZnSo_4$, BC ratio and net income Rs. 36468/ha was found highest in soil application of $ZnSO_4$.
- At Ballowal Saunkhri, application of 30 kg P_2O_5 + 20 kg S/ha ($P_{30}S_{20}$) in chickpea gave maximum seed yield of 1631 kg/ha, gross returns of Rs. 52243/ha and BC ratio of 3.2.
- At Rakh Dhiansar, 100% recommended NPK + Zn SO_4 @ 20 kg/ha was superior and gave significantly higher maize grain yield of 2324 kg/ha with net returns of Rs. 14444/ha and BC ratio of 1.34.
- At Anantapur, highest haulm yield was recorded with sheep penning (3513 kg/ha), which was significantly superior to other treatments. Sheep penning increased the available K_2O in the soil. Sheep penning increased the pod yield by 15% and haulm yield by 32% over control. It also gave rain water use efficiency of 4.37 kg/ha/mm and BC Ratio of 6.42.
- At Rajkot, significantly higher seed cotton yield (2219 kg/ha) and maximum gross monetary return (Rs 99057/ha), net realization (Rs 81239/ha) were recorded under application of 80 kg N + 40 kg P_2O_5 + 250 kg gypsum/ha.
- At Bijapur, nutrient management practices produced significantly higher net returns as compared to application of FYM (10 t/ha).
- At Solapur, substitution of nitrogen 25 kg N/ha through CR + 25 kg N/ha through *Leucaena* loppings gave significantly highest sorghum grain and stover yield, total N uptake, moisture use efficiency for grain and stover at 24th year of experimentation.
- At Agra, 50% recommended N (urea) + 50% N (FYM) was efficient with a significantly higher pearlmillet grain yield of 3253 kg/ha, net income of Rs. 14821/ha and BC ratio of 2.11.
- At Hisar, application (60 kg N, 30 kg P_2O_5 and 20 kg K_2O/ ha) gave yield of 2063 kg/ha, net return Rs. 6546/ha and BC ratio of 1.39 in pearlmillet and 3070 kg/ha, net return Rs. 37529/ha and BC ratio of 2.50 in mustard.

- At SK Nagar, highest net income (Rs. 8620/ha) and BC ratio (2.21) were recorded due to application of 100% RDN through urea along with inoculation of Azotobacter for maize.
- At Akola, maximum cotton grain yield was recorded was 879 kg/ha in treatment of 50% N (urea) + 50% N/ ha FYM + 100% P_2O_5/ ha fertilizers.
- At Kovilpatti, maximum Bt cotton (Tulasi) yield recorded was 890 kg/ha in treatment of Urea (N 80) + DAP (P 40) + MOP (K 40) + $ZnSO_4$ 25 kg/ ha.
- At Bengaluru, application of N & K_2O (50:40 kg/ha) + Lime @ 300 kg/ha + Mg CO_3 @ 150 kg/ha + Borax @ 10 kg/ha recorded significantly higher fingermillet grain yield (3748 kg/ha).

5.1.1.3 Energy management

- At Biswanath Chariali, two harrowings + one pulverization by power tiller along with application of recommended dose of fertilizer (RDF) gave highest toria grain yield of 1075 kg/ha and rainwater use efficiency (17.5 kg/ ha/mm).
- At Faizabad, conventional tillage + 2 hand weeding at 20 and 40 DAS + 100 % N (organic) was superior for rice (yield of 1270 kg/ha) and recorded maximum equivalent output energy (37244 MJ/ha) and rainwater use efficiency (1.92 kg/ha/mm). This was also superior for performance of lentil in *rabi* season.
- At Jagdalpur, dibbling with 50% RDF placed gave rice yield of 1500 kg/ha, Dibbling with 100% RDF gave cowpea yield of 2800 kg/ha. For kodo millets, dibbled without fertilizer placement gave superior yield (2900 kg/ha). For maize, seed placement by dibbling + 100 % RDF gave superior yield of 3040 kg/ha.
- At Phulbani, low tillage + herbicide + one interculture + 50 % N (organic) + 50 % N (in organic) maximum yield of rice (1230 kg/ha), horse gram (153 kg/ha) and rice equivalent yield (1492 kg/ha) and proved significantly superior.
- At Varanasi bunding was superior compared to no bunding with rice yield of 2386 kg/ha. Among tillage practices conventional tillage was superior with rice yield of 2372 kg/ha.
- At Arjia, low tillage + herbicide + once weeding and hoeing gave significantly higher maize yield of 3636 kg/ha, net returns of Rs.37614.2/ha, BC ratio of 6.48 and rainwater use efficiency of 6.13 kg grain/ha/mm.
- At Ballowal, conventional tillage + interculture together with 100% recommended N through inorganic source gave highest maize yield (3441 kg/ha), net income (Rs. 22886/ha) and BC ratio (2.09).
- At Rakh Dhiansar, Conventional tillage + interculture + 100 % N (inorganic) was superior with highest maize grain yield of 1984 kg/ha in *kharif* and highest grain yield of wheat of 2377 kg/ha in *rabi*.
- At Bijapur, Conventional tillage along with sunhemp incorporation @ 5 t/ha gave highest *rabi* sorghum grain yield (604 kg/ha).
- At Solapur, conventional tillage + 50 % N (organics) + 50 % N (inorganic) gave highest sorghum grain and stover yield, moisture use efficiency for grain and stover and total N uptake.
- At Agra, higher pearlmillet yield of 3670/ha, net income of Rs. 18470/ha and BC ratio of 2.42 were attained by conventional tillage+ interculture + 50% N (organic) + 50% N (inorganic).
- At Hisar, significantly higher pearlmillet yield of 1646 kg/ha, net returns of Rs. 4559/ha and BC ratio of 1.26 were attained by low tillage + two intercultures + 100 % N (inorganic) application.
- At SK Nagar, highest yield of castor (1450 kg/ ha) was recorded under deep ploughing with disc plough which is 46.46 % higher than control (990 Kg/ha).
- At Akola, highest seed cotton yield (755 kg/ha) was recorded by recommended dose through

organic (FYM/Glyricidia) sources, which was superior over 50% recommended dose through inorganic and 50% through organic source.

- At Parbhani, among nutrient sources, 100% recommended inorganic fertilizer was superior with significantly higher seed cotton equivalent yield of 2910 kg/ha.
- At Bengaluru, conventional tillage gave significantly higher pigeonpea seed yield of 1025 kg/ha.

5.1.1.4 Cropping system

- At Biswanath Chariali, highest tuber yield of 12290 kg/ha of potato and rice equivalent yield of 13173 kg/ha were obtained with rice -potato sequence compared to others.
- At Arjia, HIM-129 variety of maize + 100 % recommended fertilizer (50 kg N + 30 kg P_2O_5 / ha) + ridging 30 DAS combination was superior with significantly higher yield of 4376 kg/ha, net income of Rs. 36984/ha, BC ratio of 5.87 and rainwater use efficiency of 7.39 kg grain/ ha mm.
- At Arjia, PM-3 variety of maize + RBU-38 variety of blackgram gave maximum maize equivalent yield of 5498 kg/ha, net income of Rs. 46562/ ha, BC ratio of 5.68 and rainwater use efficiency of 9.29 kg grain/ha/mm.
- At Anantapur, June first fortnight (5-6-2010) sowings recorded higher pod yield in groundnut (1900 kg/ha), castor (2147 kg/ha), sorghum (657 kg/ha), clusterbean (808 kg/ha), cowpea (1684 kg/ha), pigeonpea (2367 kg/ha), fieldbean (1533 kg/ha) and Pearl millet (2262 kg/ha). In greengram, higher seed yield (636 kg/ha) was recorded with second fortnight of June sowing (21-6-2010). In korra, July first fortnight (9-7-2010) sowing recorded higher seed yield (1259 kg/ha). In sunflower, higher seed yield (596 kg/ha) recorded when sown during second fortnight of July (21-7-2010).
- At Bijapur, pigeonpea with planting geometry of 135× 20 cm gave significantly higher yield of 1602 kg /ha.
- At Solapur, sorghum + chickpea system in different row ratios showed better performance compared to sole crops. Sorghum grain equivalent yield (3366 kg/ha) was significantly higher and highest LER (1.56) was attained in sorghum + chickpea (2:6) at 30 cm row spacing.
- At Agra, clusterbean + sesame (6:1) was superior with significantly higher clusterbean equivalent yield of 1010 kg/ha, net income of 7796/ha and BC ratio of 1.75.
- At Hisar, pearlmillet + mungbean (8:4 row ration) was superior with maximum pearlmillet equivalent yield of 2756 kg/ha, net income of Rs. 9641/ha and BC ratio of 1.67.
- At SK Nagar, cotton + blackgram gave highest cotton equivalent yield of 955 kg/ha with BC ratio of 1.15 and gross income (Rs.33425/ha) and net returns (Rs. 22315/ha). The LER was also higher under this system (1.39).
- At Parbhani, soybean + pigeonpea (4:2) was superior with maximum seed cotton equivalent yield of 1201 kg/ha.
- At Akola, cotton + soybean (1:1) recorded significantly highest seed cotton equivalent yield of 1479 kg/ha.
- At Parbhani, cotton + soybean (1:1) was superior with seed cotton equivalent yield of 1670 kg/ ha.
- At Bengaluru, castor + finger millet (1:2) registered significantly higher castor equivalent yield (1709 kg/ha).
- At Bengaluru, variety Samrudhi recorded highest green chilli yield (10.41 t/ha).

5.1.1.5 Participatory varietal selection

- At Chianki, rice variety RR-616-B-275-2 was significantly superior and yielded (2542 kg/ ha). Vandana which is drought tolerant gave 2417 kg/ha. The check variety BVD -109 gave 2113 kg/ha.
- At Jagdalpur, out of 12 varieties of midland rice, variety R -1262-1667-1-1 gave highest mean grain yield of 7300 kg/ha.

- At Phulbani, among 20 rice varieties tested under rainfed upland direct-sown condition, the genotype ODR-12 exhibited highest grain yield of 1661 kg/ha.
- At Arjia, among sesame cultivars, Pratap Til - 10 gave highest seed yield (932 kg/ha) which was 42 % higher over superior check RT-46 (654 kg/ha).
- At Ballowal Saunkhri, among three varieties evaluated in a cowpea trial, CL 367 performed best in terms of fodder yield (53667 kg/ha).
- At Anantapur, out of 12 horse gram entries evaluated, ATPHG-11 recorded highest yield of 864 kg/ha with net income of Rs. 7960/ha, BC ratio of 1.59 and rain water use efficiency of 1.95 kg/ha/mm.
- At Rajkot, significantly higher pod yield i.e. 1788 kg/ha was obtained by JSP-48 and maximum haulm yield i.e. 6615 kg/ha was recorded by genotype JSP-53.
- At Bijapur, M35-1 of sorghum gave higher seed yield in both control and ridge/furrow condition 680 and 630 kg/ha respectively, M35-1 recorded maximum fodder yield (3088 kg/ha) in control.
- At Hisar, pearlmillet hybrid HHB 223 gave highest seed yield (2963 kg/ha). Among cluster bean varieties, HG 884 gave highest seed yield of 474 kg/ha. In castor, DCH-32 gave highest seed yield of 1278 kg/ha. In sunhemp, DSH-5 gave1482 kg/ha seed yield; while T-9 gave highest yield of 741 kg/ha in blackgram.
- At Hisar, among different varieties tested in *rabi* RH-119 of mustard (2760 kg/ha); HC O212 of *B. carinata* (1670 kg/ha); T-27 of Taramira (475 kg/ha); BH-902 of barley (1430 kg/ha); HC-5 of chickpea (1900 kg/ha) gave higher yields.
- At SK Nagar, among different pearlmillet hybrids tested, hybrid GHB 744 performed better and gave significantly higher seed yield (1488 kg/ha).
- At Akola, AKA 8401 produced highest seed cotton yield (1456 kg/ha).

5.1.1.6 Integrated farming system

- At Ballowal Saunkhri, among different crops sown in crop based farming system, maize gave highest water use efficiency (6.08 kg/ha/mm) and net returns (Rs 19819/ha) with B: C Ratio (1.99).
- At Rakh Dhiansar, maize under maize-wheat system recorded a grain yield of 2240 kg /ha with maximum net returns of Rs. 15212/ha and BC ratio of 1.48. Wheat crop yielded 2460 & 2830 kg/ha under maize-wheat and mash-wheat cropping systems. However, in silvi-horti system, wheat grown in between the rows of Leucaena trees yielded 2040 kg/ha.
- At Anantapur, groundnut (var. Narayani) was sown during *kharif* and yield was 795 kg/ha. Sheep body weight increased from 9.84 kg to 19.72 kg (100%) during grazing period of 3 months.
- At Rajkot, significantly higher groundnut pod equivalent yield was recorded with cotton sole crop in integrated farming system. Maximum gross monetary return (Rs.48750/ha), net realization (Rs 29417/ha) were recorded under sole cotton, but maximum BC ratio (3.12) was recorded under fodder sorghum.
- At Bijapur, net income from different components *viz.* crops, horticulture, goat and poultry was Rs. 17404, 2643, 25307 and 6200, respectively with overall income from farming system was Rs. 51656/ha. About 60 % of income (Rs. 31309) was from livestock component and rest 40 % (Rs. 20347) was from crop component including horticulture. The IFS was carried out in an area of one ha with different components demonstrating work throughout the year for the family members.
- At SK Nagar, integrated farming system gave 95% higher gross return over traditional sole maize. Among different intercropping systems, castor + greengram recorded highest gross return (180.6 %) and also additional net income of Rs. 79705 from livestock component. Karingdo grown as intercrop in sorghum produced higher

fodder yield and 20.7 % higher gross return over traditional system.

5.1.2 Operational Research Project

5.1.2.1 Rain water management

- At Arjia, on-farm assessment of moisture conservation practices in maize + blackgram (2:2) maximum grain yield of 3163 kg/ha of maize and 160 kg/ha of black gram, net returns of Rs. 34600/ha and BC ratio of 4.04 were attained as compared to farmers practice).
- At Ballowal Saunkhri, two supplemental irrigation (CRI & flowering stage) in rainfed wheat cultivar PBW-175 recorded highest grain yield of 2333 kg/ha which was 36 % higher over rainfed plot (1714 kg/ha).
- At Bengaluru, opening of moisture conservation furrow between paired rows of pigeonpea in fingermillet + pigeonpea system produced higher fingermillet grain equivalent yield of 5481 kg/ha and net returns of Rs. 40312/ha with BC ratio 3.78 compared to farmers practice (BC ratio 1.97).
- At Hisar, higher grain yield of 1030 kg /ha of chickpea was attained when moisture conservation was done with disc harrow with BC ratio of 1.77.
- At Solapur, Higher mean grain yield of *rabi* sorghum (1176 kg/ha), fodder yield of 3193 kg/ha and BC ratio of 1.68 were attained with ridges and furrows.

5.1.2.2 Integrated nutrient management

- At Anantapur, pod and haulm yields and BC ratio were higher with soil test based fertilizer compared to farmer's practice. Net returns were higher (Rs.5032/ha) with soil test based fertilizer application compared to farmers practice (Rs.3382/ha).
- At Arjia, improved practice (50 kg N+ 30 kg P_2O_5 /ha) + spray of $ZnSO_4$ @ 0.5% gave the highest net returns of Rs.21335/ha, BC ratio of 3.30 from maize yield of 2477 kg/ha.
- At Ballowal Saunkhri, application of full dose of recommended fertilizer (62.5 kg N/ha, 40 kg P_20_5/ha) produced maximum lentil seed yield of 644 kg/ha (increase of 53 %) as compared to no fertilizer.
- At Bengaluru, application of micronutrients and bio-fertilizers along with RDF recorded higher pod equivalent yield of 1876 kg/ha with BC ratio of 2.86 compared to farmer practice (BC ratio 1.95) in groundnut + pigeonpea system.
- At Solapur, maximum mean grain yield of *rabi* sorghum (1404 kg/ha) and fodder yield (3477 kg/ha) was obtained as per soil test value (N: P 75:31 + 15kg zinc/ha).

5.1.2.3 Energy management

- At Anantapur, pod yield and net returns were higher (Rs.7651/ha) with mechanical seed drill compared to farmer's practice (Rs.5209/ha). The seed rate was 85 kg /ha with mechanical seed drill compared to 100 kg /ha in local seed drill. The time taken for sowing was 2 hours 15 minutes/ha, while it was 4 hours 18 minutest/ha with local seed drill.
- At Arjia, field capacity wheel hoe was found 7.18 man-day/ha compared to farmers practice (21.93 man-days /ha). The increase in efficiency due to wheel hoe was 205.43 % compared to *Kudali* (farmers practice).
- At Ballowal Saunkhri, sowing of wheat with modified seed cum fertilizer drill gave grain yield of 1964 kg /ha which was 13 % higher grain yield over sowing with wooden plough (1738 kg/ha) with BC ratio of 1.86.
- At Chianki, mean yield of wheat variety K-9107 (2785 kg/ha) was higher in zero tillage condition than conventional tillage (2637 kg/ha). Zero tillage facilitated 12 to 15 days early sowing. It saved two irrigations, higher net return and higher benefit cost ratio (2.46) compared to conventional tillage (2.05)
- At Solapur, two bowl ferti-drill seed droll was superior with maximum effective field capacity

(1.90 ha/day), lower power requirement i.e., 4.21 hr/ha of machine, 8.42 hr/ha of human labour and 8.42 hr/ha of bullock with a cost of operation of Rs.293/ha. The improved drill gave highest grain yield (988 kg/ha) and fodder yield (2320 kg/ha).

5.1.2.4 Cropping system

- At Arjia, sorghum crop under sorghum+ greengram (2:1) performed better under delayed sowing at all locations. Sorghum+ greengram (2:1) gave highest mean sorghum equivalent yield (3297 kg /ha), net return (Rs. 40601/ha) and BC ratio (5.25) under delayed sowing.
- At Ballowal Saunkhri, intercropping of toria and gobhi sarson recorded 1279 kg/ha of gobhi sarson equivalent yield, which was 82 % higher than sole toria (702 kg/ha) and 49 per cent higher than sole gobhi sarson (856 kg/ha). Intercropping recorded higher income of Rs 10590 and 7554 /ha over sole toria and gobhi sarson, respectively.
- At Bengaluru, among different fingermillet based cropping systems, growing of fingermillet and pigeonpea, (8:2 ratio) recorded fingermillet grain equivalent yield of 5198 kg/ha with BC ratio 3.59 compared to farmers practice (BC ratio 1.99).
- At Chianki, contingent crop (blackgram) yielded 974 kg/ha**,** net return of Rs.19107/ha and BC ratio (3.0).
- At Hisar, Chinese cabbage + in chickpea gave higher net return (Rs.11090/ha) and BC ratio (1.76) compared to chickpea alone with net return (Rs. 9230/ha) and BC ratio (1.63).
- At Solapur, sunflower + pigeonpea (2:1) gave highest net monitory returns (Rs. 32620/ha).

5.1.2.5 Participatory varietal selection

- At Anantapur, groundnut variety K6 (795 kg/ha) exhibited its superiority in out yielding the other two varieties viz., K-9 (752 kg/ha) and Narayani (730 kg/ha) compared to local (642 kg/ha).
- At Arjia, maize cultivar of PM-3 gave maximum grain yield of 2720 kg/ha, net returns of Rs. 24020/ha and BC ratio of 3.56 with highest rainwater use efficiency of 6.40 kg grain/ha/mm, while local variety gave yield of 1948 kg/ha, net returns of Rs. 15624/ha, BC ratio of 2.74 and rainwater use efficiency of 4.58 kg grain/ha/mm.
- At Ballowal Saunkhri, PMH 2 of maize hybrid gave maximum productivity of 4333 kg/ha, net returns of Rs. 29951/ha and BC ratio of 2.44 and maximum rainwater use efficiency of 83.4 kg/ha/cm.
- At Hisar, HHB 197 recorded higher grain yield (2138 kg/ha) and BC ratio (1.82) compared to HHB 67 improved (1930 kg /ha yield with BC ratio of 1.64). Variety HG 563 of clusterbean recorded slightly higher grain yield (1234 kg / ha) and BC ratio (2.92) compared to HG 365.

5.1.2.6 Alternate land use

- At Arjia, improved grasses like *Cenchrus setigerus* and *Stylosanthus hamata* performed better and gave the highest dry grass yield (3500 kg /ha) compared to local grass (1000 kg /ha).

5.1.3 Monitoring and Evaluation

The XIIIth Working Group Meeting of AICRPDA was conducted at CRIDA during 24-27, November, 2010 and various meetings were organized at Hisar centre.

5.1.4 Linkages and Collaborations

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

national agencies. The centers also established linkages with Medicinal Plant Board, local institutions for training programs and Ministry of Water Resources, GOI for implementing adhoc projects.

5.1.5 Publications

Overall 414 publications were contributed by AICRPDA scientists comprising of 91 research papers, 210 papers in conferences, 63 books/ bulletins/reports and 50 popular articles during the year. The scientists gave 77 radio talks, 46 television talks and delivered 97 lectures during 2011-12.

5.1.6 HRD, Impact and up-scaling of rainfed technologies

Scientists from AICRPDA centres participated in various training programs conducted by CRIDA and other state and National organizations.

5.1.7 Training Programs/Workshops/Meetings Conducted

SAARC international training Program on Techniques of Water Conservation & Rain Water Harvesting for Drought Management

This international training program was conducted for 22 delegates from 5 SAARC countries viz., India, Bangladesh, Bhutan, Srilanka and Afghanistan during 18-29 July, 2011 at CRIDA, Hyderabad. The course imparted knowledge, skills and information to the participants on techniques for water conservation and rain water harvesting for effective drought management.

Two Short Courses on Database Analysis and Management in Climate Variability and Rainfed Agriculture under National Initiative on Climate Resilient Agriculture (NICRA) were organized during 21- 25 February, 2012 and 27th February to 2nd March, 2012 by Project Coordination Unit, AICPRDA at CRIDA, Hyderabad. The program was conducted as a capacity building measure under NICRA. About 53 participants including scientists, technical officers/assistant and RA/SRFs from the network centres underwent this training.

The topics covered are i) concepts of database management ii) working experience of Weathercock software to analyze climate data iii) concepts of Remote sensing and GIS for spatial database design iv) updating and maintenance of the designed web pages of a centre using Joomla software v) statistical procedures for analysis of data of rainfed experiments vi) minimum data sets for cropping systems vii) analysis of Input and Output energy data in rainfed agriculture viii) rainwater management – data analysis ix) economic analysis of resource conservation technologies and X) updating of Agricultural Field Experimental Information systems (AFEIS).

23rd Biennial Workshop of AICRPDA was conducted at ZARS, Solapur during 19-23

Short Courses on Database Analysis and Management

XXIII Biennial Workshop of AICRPDA

December, 2011to review the progress and finalized the technical progem for the next year. Dr TA More, Hon'ble Vice Chancellor, MPKV, Rahuri presided over the inaugural meeting and Dr HP Singh, Chairman, 6th QRT and Dr B Venkateswarlu, Director, CRIDA were the other important dignitaries present.

Stakeholders Workshops

Twenty two stakeholder consultation workshops for research prioritization in rainfed area were held at across 22 AICRPDA centres during August-November 2011. Honorable Vice Chancellors, Directors of Research, Director/Assistant/Deputy of Extension, Zonal/Regional/Assistant Directors of Research, Heads of various departments,

Stake Holders Interactive Meeting at AICRPDA, Varanasi

Scientists from AICRPDA centres, SAUs, Zonal Project Directors/representatives from seven ZPDs, program coordinators/SMS from KVK, Joint/ Deputy/Assistant Directors of Agriculture/Animal husbandry, officials from the state line departments, NGOs etc and farmers participated.

Interactive Meetings

Twenty two interactive meetings of AICRPDA Centres with KVKs were held across 22 AICRPDA centres for technology up-scaling. Zonal Project Directors/representatives, Project Coordinators/ SMS from 106 KVKs participated in the meeting.

Interactive Meeting with KVKs at Dr.PDKV, Akola

QRT Meetings

Four AICRPDA review meetings of 6th QRT were held at UAS, Bangalore (13-15, June 2011), BAU, Ranchi (28-30, July 2011), RVSKVV, Indore (25-27, Aug 2011) & CCSHAU, Hisar (28-29, Aug 2011). The Progress of work of AICRPDA centres was reviewed by chairman of 6th QRT, Dr. H.P.Singh and other members. QRT members also visited Biswanath Chariali, Rajkot, Solapur, Bijapur, Faizabad, Rakh Dhiansar, Agra, Ballowal Saunkari.

5.2 All India Coordinated Research Project on Agrometeorology (AICRPAM)

The salient research achievements of various AICRPAM centers during *kharif* and *rabi* seasons of the year are summarized under the following four themes viz. Agroclimatic characterization, crop weather relationships, crop growth modeling and effects of weather on pests and diseases

5.2.1 Agroclimatic characterization

- The duration of assured weekly rainfall of 10 mm or more was longer (12 weeks) at Sindewahi of eastern Vidarbha compared to Akola (5 weeks) of western Vidarbha. It was further observed that none of the weeks during the normal sowing window at Akola (24-27 SMW) received more than 10 mm rainfall at 75 percent probability, thus indicating the risk in taking up normal sowing of *kharif* crops.

- Deficit and scanty rainfall occurred in 14 out of 43 years at Anantapur. In deficit years, start of growing season was delayed by two weeks, resulting in reduction of crop season by two weeks compared to excess or normal years.
- At Hisar, the average start, end of rainy season were found to be 27, 41 SMW and 15, respectively. and duration
- Analysis of 110 years rainfall at Jorhat revealed the declining trend in rainfall from the year 1980. During these three decades, more number of years with negative anomaly (20) was witnessed than the number of years with positive anomaly (6).
- At Kanpur, decadal average rainfall decreased by 101 mm from 920 mm during 1971-80 to 819 mm during 2001-2010.
- At Kovilpatti, the probability of getting rainfall of 20 mm or more is more than 50 percent during 39 to 47 SMW.
- Analysis of long-term (1961-2009) daily temperature at Parbhani revealed that the number of events of maximum temperature > 40°C are increasing slowly (at the rate of 1 event per decade), while events with minimum temperature < 10°C are increasing at a faster rate (5 events per decade).
- At Raipur centre, analysis of rainfall of pre and post-global warming periods (1901-70 and 1971-2009) of Chhattisgarh showed decreasing trend during post-global warming period compared to pre-global warming period in all the districts except Bijapur and Korba.
- Analysis of annual and seasonal rainfall of nine locations spread across north, central and southern parts of the scarcity zone of Maharashtra by Solapur centre brought out that both annual and southwest monsoon seasons' rainfall are highest at Solapur of southern part (731.8 and 550.5 mm) and lowest at Kopergaon (447.5 and 344.8 mm) of central part.
- Probability analysis of monthly rainfall in the districts of southeast Rajasthan showed that highest rainfall at 75 percent probability can be expected in the month of July at Banswara, Bhilwara, Bundi, Kota and Pratapgarh districts and in the month of August at Baran, Chittorgarh, Dungarpur, Jhalwar and Udaipur districts.

5.2.2 Crop-weather relationships

- At Akola, maximum and mean temperature during flowering and seed development sages and minimum temperature during pod formation stage showed significant adverse effect on seed yield of chickpea.
- At Jabalpur, higher decrease in seed yield with unit increase in minimum temperature (230.4 kg/ha) was observed than with unit increase in maximum (146.6 kg/ha) and average temperature (180.3 kg/ha). Growing degree days of 750°C day were found to be optimum for achieving higher seed yield.
- At Kanpur, both maximum and minimum temperature during reproductive period significantly and negatively influenced the yield of wheat. However, quantum yield reduction with unit increase in minimum temperature was higher (445.7 kg/ha) than with the increase in maximum temperature (238.1 kg/ha).
- Average maximum and minimum temperatures of 23.4 and 10.9 °C, respectively during reproductive period were found to be optimum for obtaining more than 3 t/ha yield of wheat at Palampur.
- At Ranchi centre, yield (Y) showed highly significant negative relationship with minimum temperature (X) during reproductive period.

  $Y = 6386.5 - 215X \qquad (R^2 = 0.74)$
- From the above regression equation, it is understood that yield decreased by 215 kg/ha with 1°C increase in minimum temperature during reproductive period.

- At Udaipur centre, average temperature of 18.2 to 18.8°C during reproductive period was observed to be optimum temperature range for obtaining highest yield of wheat (4618 to 4665 kg/ha) and increase in temperature by 3.6°C above this optimum limit caused reduction in yield by 42.2 percent
- At Hisar, seed yield and yield attributes of mustard crop showed significant positive correlation with maximum and minimum temperature, sunshine hours and evaporation during vegetative phase and negative relationship with same weather parameters during reproductive phase.
- Maximum temperature of 18.8°C and minimum temperature of 6°C were identified as optimum temperature limits for obtaining more than 2 t/ha yield of mustard at Palampur.
- Analysis of yield over the last five years in relation to weather parameters during vegetative and reproductive stages identified minimum temperature below 16°C and vapour pressure below 16 mm of Hg during flowering stage of sunflower crop as unfavourable weather conditions for higher yield at Bijapur.
- At Mohanpur, evapotranspiration during the season (SET) showed significant positive effect on tuber yield and each one mm increase in SET resulted in 0.383 t/ha increase in tuber yield of potato.
- At Kovilpatti, maximum temperature, minimum temperature and relative humidity in the range of 21.8-29.3°C, 17.7-23.3°C and 84-95 percent, respectively were found to be favorable for obtaining high maize yield.
- Rainfall and soil moisture content during pod formation stage had highly significant positive relationship with yield of soybean at Parbhani.
- Rainfall and rainy days during boll formation to first picking positively and significantly influenced the seed yield of cotton crop at Parbhani.
- About 27°C of temperature and rainfall of 116 mm during reproductive period were found to be optimum weather conditions for achieving highest grain yield in rice at Samastipur.
- At Udaipur, rainfall during tasseling to maturity period showed positive influence on both yield and yield attributes of maize.

5.2.3 Crop growth modeling

- The Campbell and Diaz model simulated dry matter production of all the four varieties of wheat, *viz.*, PBW-343, RSP-560, RSP-561 and RSP-529 accurately ($R^2 > 0.96$) at Rakh Dhiansar during *rabi* 2009-10.
- At Ranichauri, partitioning of drymatter in wheat crop to roots, leaves, stem and panicle were highest in tillering, jointing, anthesis and maturity stages, respectively.
- The errors in prediction of yield and phenological events like flowering and physiological maturity using WOFOST model at Bijapur were comparatively lower in case of early sown crop than in late sown *rabi* sorghum.
- Validation of statistical yield prediction models showed good yield prediction (0.3 to 5 % error) under early or normal sown mustard with two irrigations at Udaipur.
- Validation of regression models predicting phenology of groundnut at Anantapur showed that these models could predict flowering and pod initiation stages accurately (error of ± 1 day) in all three dates of sowing.
- At Rakh Dhiansar, Campbell and Diaz model perfectly simulated ($R^2 > 0.94$) the drymatter production of maize in all the three dates of sowing.
- At Faizabad, yield simulated with CERES Rice model were in close agreement (error of + 3.7%) with observed yield in case of early sowing (5th July) and prediction error increased with delay in sowing.

- Impact of climate changes on rice yield (cv B-370) studied with the help of CERES Rice model projected a decrease of 19 and 16.9 percent grain yield with increase of maximum and minimum temperatures, respectively by 2.5C above normal at Ambala and Karnal districts of Hisar.
- At Mohanpur, simulation of potential yield under different temperature levels using INFOCROP model showed that with 1°C rise in maximum and minimum temperatures, potential yield of rice decreased by 830 kg/ha while crop duration decreased marginally by 2 days.

5.2.4 Weather effects on pests and diseases

- At Akola, maximum temperature around 27°C, minimum temperature of 7 to 8°C and highest morning relative humidity of 73 percent were found to be congenial weather conditions for aphids population in safflower.
- At Anand, analysis of six years pest/disease data on stem rot, rust and sawfly in relation to weather parameters in different phenological stages of the mustard crop revealed that out of all the three pests, sawfly is more significantly influenced by weather parameters with minimum standard error of estimate (0.15 to 0.33). Low relative humidity during vegetative period favoured higher sawfly population in mustard.
- At Udaipur, though aphid population in mustard crop negatively related with maximum, minimum and mean temperature in all sowing dates, the mean temperature is more significantly related with aphid population.
- Maximum temperature in the range of 30 to 31°C, evening relative humidity of 76 to 78 percent was found to be congenial for semilooper population in soybean at Akola.
- Study on groundnut leaf miner in relation to weather conditions at Anantapur indicated that maximum temperature less than 34.5°C and afternoon relative humidity more than 36 percent favoured more than 10 percent leaf miner damage in groundnut.

5.2.5 Working group meeting of AICRPAM

To evaluate the research progress made during rabi 2009-10 and kharif 2010 and to finalize the technical program of all centers for the year 2011-12, Working Group Meeting of AICRPAM was conducted under the guidance of Dr. B.Venkateswarlu, Director, CRIDA, during 22-24 September 2011 at CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur.

Working Group Meeting of AICRPAM, Palampur

6 Krishi Vigyan Kendra

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

6.1 Frontline demonstrations

During khariff 2011-12 Front Line Demonstration of Sorghum (25), Cotton (25), Pigeonpea (47), Chickpea (10), Paddy (10), Tomato (15), Fodder crops (75) were conducted on different components of technology in farmers fields of Ranga Reddy District, Andhra Pradesh. These FLDs were supported by Zonal Project Directorate (ZPD) - Zone V, Hyderabad. During *rabi* 2011-12, KVK conducted FLDs of maize (5) and chickpea (10) in different villages of Ranga Reddy district. The details of FLDs are given below:

Table 33 : Results of frontline demonstrations conducted by the KVK during 2011-12

Crop	Component (Intervention)	No. of farmers	Area (ha)	Yield (Kg/ha)		% increase over control
				IP	FP	
Kharif						
Rice	Direct sowing of rice using drum seeder	5	2	4250	4100	3.7
Sorghum	Shootfly management	25	10	1280	750	70
Rice	BIPM in rice	5	2	3750	2500	50
Pigeon pea	Pigeon pea wilt tolerant variety PRG-158	27	10.8	750	620	21.0
Pigeon pea	IPM in pigeon pea	20	8	500	250	110
Cotton	Spacing and fertilizer management in cotton	5	2	800	638	25.4
Cotton	Management of sucking pests in cotton	20	8	1500	1000	50
Tomato	Raising hybrid tomato nursery in pro-trays under shade net	15	3	18000	14000	30
Hybrid Napier APBN-1	Perennial fodder Bajra – APBN-1	75	15	133000	25000	432
Rabi						
Maize	Zero tillage maize after rice	5	2	4900	4680	4.7
Chickpea	IPM in chickpea	10	4	Crop failure due to drought		

IP – Improved Practice ; FP – Farmers Practice

FLD on shade net nursery vegetable seedlings production using pro-trays

FLD on pigeon pea wilt tolerant high yielding variety PRG-158

Demonstration of NSKE preparation to rural youth

FLD on direct sowing in paddy using Drum seeder and Zero tillage maize after rice

6.2 NICRA technology demonstration component (TDC)

In order to address the climatic vulnerabilities of the adopted villages, different interventions were planned under the different modules. However the specific intervention under each module for a particular village was need based and decided based on climatic vulnerability and resource situation of that village.

Natural resources

This module consists of interventions related to In-situ moisture conservation, biomass mulching, residue incorporation, brown and green manuring, water harvesting and recycling for supplemental irrigation, improved drainage in flood prone areas, conservation tillage, artificial ground water recharge and water saving irrigation methods.

Rainwater harvesting and its recycling / recharging of ground water

Water scarcity for agriculture is considered to be one of major fallouts of climate change. Hence the intervention on rainwater harvesting and its recycling or utilization/recharging of ground water has been planned and taken up in most of the selected districts particularly in rainfed regions. Rainwater harvesting and recycling through farm pond and restoration of old water harvesting structure in the village may be useful in dryland/ rainfed areas. Percolation tanks / ponds may be tried for recharging of open as well as bore wells.

Table 34 : Soil and water conservation works compiled at KVK adopted villages under TDC of NICRA project

Name of the Structure	Location	Existing capacity (Cu. m)	Improved capicity (Cu. m)	Total capacity (Cu. m)
Farm Pond-1 17 x 17 x 3m Slope 1:1	Kandlapalli	New pond	—	650
Farm Pond-2 19 x 19 x4.5m Slope 1:1	Kandlapalli	New pond	—	1000
Farm Pond-3 9 x 9 x 2.5m Slope 1:1	Yenkepali	New pond	—	110
Community percolation Tank	Mirzapur	5,000	3,000	8,000
Community percolation Tank	Kandlapalli	5,575	3,540	9,115
Mini Percolation Tank	Mirzapur	200	800	1000

Table 35 : Number of soil and water conservation works constructed in NICRA villages

Name of the work	Mirzapur	Yenke Palli	Kandla Palli
New farm pond construction	——	1	2
Leveling and making compartments	7	5	12
Trench cum bunding	8	6	10
Percolation Tank Renovation work	2	——	1

Recharging of groundwater through injection well or other such customized structures may be useful in irrigated as well as the areas where ground water is saline. Micro irrigation along with high value crops would also enhance the systems resilience in dry land areas.

Mini percolation tank at Mirzapur village before (left) and after (right) renovation

Improving access to farm machinery

Large area in rainfed regions remains unsown due to poor access to farm machinery. Hence, improved access to farm machinery for sowing, harvesting etc. would be an important component of adaptation strategy to deal with climatic variability. Therefore community managed farm machinery custom hiring center was planned for in selected village. The type and quantity of machines have been decided based on actual needs and budget of the project. For this purpose amount of Rs. 6.25 lakhs was allocated for this NICRA village.

Farm machinery custom hiring center

Timely access to farm machinery for sowing, intercultural operations and harvesting etc. is an important component of adaptation strategy to deal with climatic variability. The sowing window in rainfed areas is most of the time very short and at the same time small farmers access to farm machinery is poor. As a result many farmers are not able to sow the crop timely and incur significant yield losses. Therefore an innovative institutional arrangement in the form of a Farm Machinery Custom Hiring Center has been created in KVK three adopted villages under NICRA Project. paired row planter ,Fertilizer cum seed drill, zero-till drill, Disc harrow, rotavators for residue incorporation, different type of weeders, sprayers, sprinklers, chaff cutting machine, weighing machine etc. are some of the important farm implements and machines which are part of the custom hiring center. For instance, we have encouraged the farmers to include a platform type weighing machine as a part of custom hiring center, so that it enables the farmers to weigh their goats and sheep at the time of sale, which may give them better bargaining power to sale the animals on per kg body weight basis.

Table 36 : Implements purchased under custom hiring programme under NICRA project

Name of the farm implement	Quantity
6-Row planter with ridger	1
3-Row animal planter	1
2-Bottom MB plough	1
9-Tyne cultivator	1
Disc harrow	1
Manual weeders	15
Iron plough	2
Animal drawn weeder (Guntaka)	3
Trevis	2
Mono pan balance	1
Power operated chaff cutter	2
Digital camera	1
Power operated knapsack sprayer	13
Hand operated compression sprayer	
Hand rotary duster	2
Water pumping diesel engine	1
Winnower fan with 2hp	1
GPS	1
Ground water level indicator (100m)	3
Power weeder (1feet)1.5hp	1
Electric weighing machine (50kg)	1
Cotton picking machine	4
Tractor drawn leveling blade	1
Sprinklers set with five raiser pipes	3
Rotavator	1
Brush cutter	1
Seed treatment instrument	3
Groundnut decorticator	2

Table 37 : Charges for hiring the farm implements at custom hiring center

Name of implement	Hiring units	Hiring cost (Rs.)
CRIDA 6-row planter	Acre	50
DISC harrow	Acre	25
9-Tyne cultivator	Acre	25
2MB plough	Acre	30
Power sprayer (767 Thayne sprayer)	Day	25
Power sprayer	Day	20
Hand compression sprayer	Day	10
Hand weeder	Day	5
Cotton picker	Acre	50
Sprinkler lateral pipe	Day	3
Sprinkler raiser pipe	Day	5

Custom hiring centre – farm implements and equipment

Automatic weather station at NICRA village

An automatic weather station is being installed KVK adopted village in Kandlapalli. This would strengthen our capacity and ability to issue weather based agro-advisories in future. Moreover, a mini manual weather observatory has been established in the NICRA village. The weather data collected from the village based observatory would be used along with IMD forecast to issue weather based agro-advisories.

NRM interventions and climatic vulnerabilities done in adopted villages

- Rainwater harvesting through farm ponds for protective irrigation during midterm drought
- Channelizing and utilizing water from perennial springs and streams for life saving irrigation during drought
- In-situ moisture conservation for drought resilient production
- Trench cum bunds in orchards for rainwater conservation
- Renovation of defunct rainwater harvesting/ recharging structures to improve water storage capacity for protective irrigation/ improve ground water table
- Rainwater harvesting in polythene lined farm ponds for providing life saving irrigation during midterm drought
- Reduced tillage for soil conservation
- Recharging of open wells for improving ground water table and protective irrigation during lean periods
- Soil test based nutrient application to promote balanced use of fertilizer and to improve water productivity
- Cultivation of vegetable on ridges and furrows for better water use efficiency
- Zero till sowing drought conditions and late sown in water logged areas for adjusting the crop season with climate and getting better yields by saving time on field preparation, use of residual soil moisture and early crop establishment
- Soil test based nutrient application to promote balanced use of fertilizer and to improve water productivity
- Tank silt application to improve soil
- Plastic mulching in vegetables for moisture conservation
- Compositing and vermi-composting to improve soil health
- structure and moisture holding capacity
- improving drainage in the low lying during floods

6.3 Training programmes

The Krishi Vigyan Kendra has organized 101 need based and skill oriented training programmes on various aspects of improved technologies to 3221 clientele (Farmers, Farm women, rural youth and field level extension workers). Of the total programmes 16 were sponsored by outside agencies/ schemes, the details are shown below.

Training programmes on ICT for Rural Youth

Vocational training for rural women on vermicomposting

Table 38 : Training programmes conducted by the KVK during the year 2011-12

Discipline	No. of Courses	No. of participants (SC/STs)			Total No. of participants		Total
		Male	Female	Total	Male	Female	
Crop production	11	26	116	142	252	145	397
Plant protection	11	200	14	214	200	14	214
Home science	19	-	156	156	-	403	403
Veterinary science	18	94	37	131	505	90	595
Agricultural engineering	10	31	11	42	116	26	142
Horticulture	13	13	125	138	416	204	620
Agricultural extension	9	300	25	325	300	25	325
Water management	10	110	26	136	456	69	525
Total	**101**	**774**	**510**	**1284**	**2245**	**976**	**3221**

6.4 Extension activities

Several extension activities were organized by the KVK both at the village and in institutional premises. The activities are listed in table 39.

The 'Agricultural Technology Week' was organized by CRIDA KVK between 21-26 September, 2011. Around 2300 farmers participated in it. The different themes were dryland horticulture, alternative land use systems, farm mechanization, soil and water conservation, women empowerment and livelihood, improved management of livestock and fodder production.

Animal health camp at Kadlapalli village

Table 39 : Extension activities carried out by KVK

Activity	Date
Raising of seedlings - Shade net nurseries	12.07.11
Animal health camp at Kandlapalli, Pudur Mandal, RR Dt.	20.07.11
Animal health camp at Mirzapur Mandal, RR Dt.	23.07.11
Animal health camp at Yenkepalli, Pudur Mandal, RR Dt.	26.07.11
Farmers' day at GRF, CRIDA	21.09.11
Technology Week at KVK, HRF, CRIDA	22.09.00 to 26.09.11
Zero tillage in maize	15.02.12
Soil health camp and Soil sample collection	12.04.11 to 30.05.11
FMD – Mass vaccination programme in Kandlapalli village	17.02.12
Exposure Visit : Visit to fruit research station , Sangareddy	31.10.11
Exposure Visit : Visit to Krishi Mela at GKVK and NDRI Bangalore	14.11.11 to 17.11.2011
Exposure Visit : Poly house flower cultivation at Nagisettipally village	24.2.12
Exposure Visit : Commercial vegetable cultivation through mulching, Nova Agritech, Zaheerabad	27.2.12
Exposure Visit : Mother Dairy plant - Hyathnagar	28.03.12
National Nutrition Week celebrations	1.09.11 to 7.09.11
World Food Day	16.10.2011

Value addition to Agricultural Products

Agricultural Technology Week organized by KVK

6.5 On farm evaluation trials

On farm testing (OFT)

The KVK under Technology Assessment and Refinement assessed technologies *viz.*, New varieties, farm mechanization, livestock management and livestock breeding in farmers' fields of KVK adopted villages (Table 40). Further the KVK also refined technologies *viz.*, IPM and ICM in farmers' fields of KVK adopted villages (Table 41).

Table 40 : Technologies assessed in OFTs

Crop/ Animal	Name of the technology	Thematic area	No. of farmers/ trials	Area (ha)	Yield (kg/ha)		Net return (Rs)	B:C ratio
					FP	Demo		
Sorghum	Assessment of Sorghum variety CSV – 23	Varietal	5	2	730	950	4660	2.00
Cotton	Intercropping of Bt cotton with redgram	ICM	5	2	610	550 (Cotton)+ 350 (Redgram)	1210	2.05
Chillies	Assessment of chilli variety	Varietal	10	4	3800	5400	87800	2.03
Coriander	Assessment of coriander variety APHU-Dahniya 1	Varietal	10	4	810	1100	27000	5.5
Cattle	Effect of supplementation of concentrate feed, mineral mixture, vitamin E and Tonophosphan in anoestrous condition in cattle	Livestock management	8	-	-	-	-	-

Crop/ Animal	Name of the technology	Thematic area	No. of farmers/ trials	Area (ha)	Yield (kg/ha)		Net return (Rs)	B:C ratio
					FP	Demo		
Sheep	Effect of supplementation of concentrate feed, mineral	Livestock management	5	-	-	-	-	-
Sheep & Goat	Replacement of Local Rams and bucks with better breeds of sheep and goat	Livestock Breeding	14	-	-	-	-	-
Cotton	Performance and evaluation cotton picker machine	Farm mechanization	5	2	35	130	-	-
Pigeon pea	Conservation furrows in pigeon pea with CRIDA paired row planter	Farm mechanization	2	1	550	775	18500	1.9
Chickpea	Planting chick pea with CRIDA 6 row planter	Farm mechanization	2	1	750	875	12200	2.1

FP – Farmers Practice

Table 41 : Technologies refined

Crop	Name of the technology	Thematic area	No. of farmers/ trials	Area (ha)	Yield (Kg/ha)		Net return (Rs)	B:C ratio
					FP	Demo		
Tomato	Sucking Pests Management	IPM	5	2	10000	15000	14350	2.25
Tomato	Use of bio-fertilizers	ICM	10	4	11200	18500	26500	2.12

FP – Farmers Practice

OFT on replacement of local rams and bucks – new generation from improved breeds of sheep and goat

OFT on CRIDA paired row planter for pigeon pea and Chickpea planting using CRIDA 6 row planter

7 Human Resource Development

7.1 Deputation within India

Name	Title	Duration	Venue
Ch. Srinivasa Rao	Carbon modeling	26 April – 5 May, 2011	NBSSLUP, Nagpur
G. Ravindra Chary	International training programme on techniques of water conservation and rainwater harvesting for drought management	18-29 July, 2011	CRIDA, Hyderabad
Josily Samuel	ICAR summer school on decision support system in agriculture using economic tools'	02-22 August, 2011	NCAP, New Delhi
Rajkumar Dhakar R.Nagarjuna Kumar	Capacity development for farm management strategies to improve crop water productivity using AQUACROP - a new crop model of FAO	18-22 October, 2011	CRIDA, Hyderabad
R.Nagarjuna Kumar	Recent trends of geoinformatics in land resource database management for sustainable agriculture	15-28 November, 2011	NBSS & LUP, Nagapur
Rajkumar Dhakar	Soil carbon sequestration for climate change mitigation and food security	24 November - to 03 December, 2011	
B.Bapuji Rao	Short course on cropping system models-applications in land resource management	05-09 December,2011	ICRISAT, Patancheru, India
B.Bapuji Rao	International training program on ecosystem approach to disaster risk reduction	12-15 December, 2011	NIDM, New Delhi
G.Pratibha	Climate change and carbon mitigation	5-10 February, 2012	ICFRE, Dehradun
N. Ravi Kumar	Training program on cyber security	6-10 February 2012	NIFM, Faridabad
S. Desai	Harnessing IP for strategic competitive and collaborative advantage	9-11 February, 2012	IIM, Ahmedabad
Ravi Dupdal Rajkumar Dhakar R.Nagarjuna Kuma	Training programme on decision support system for agro-technology transfer (DSSAT)	13-17 February, 2012	CRIDA, Hyderabad

7.2 Deputation outside India

Name	Title	Duration	Venue
G.Pratibha	Environmental impact assessment of conservation agriculture strategies	1 March - 30 June, 2011	Fort Collins, Colorado, USA
A.V.M. Subba Rao	DSSAT model for climate change coping strategies	18 April - 14 July, 2011	University of Florida, Gainesville, Florida, USA
B. Venkateswarlu	Concept note preparation on centre of excellence for dryland production systems	21-26 May, 2011	Alleppo, Syria
B. Venkateswarlu	Stakeholders meeting and policy dialogue on climate resilient agriculture in Asia	1-2 June, 2011	Bangkok, Thailand
V.U.M.Rao	Symposium on climate change and implications in plant science	07-09 June, 2011	Department of Environmental Sciences, University of Guelph, Ontario, Canada
M.Osman	CRP1.1 – Dryland systems: integrated agricultural production systems for the poor and vulnerable in dry areas	27 - 30 June, 2011	ICRAF, Nairobi, Kenya
B. Venkateswarlu V.U.M.Rao	Stakeholder meeting and international policy dialogue on building climate resilient agriculture in Asia	21-23 July, 2011	Hanoi, Vietnam
P. Vijaya Kumar	Exposure training workshop of SAARC-Australia project	8-10 August, 2011	SAC, Dhaka, Bangladesh
R. V. Adake	Sensor based application including bio-indicators	15 August - 15 November, 2011	Colorado State University, Fort Collins, USA
K.V. Rao	International workshop on using climate scenarios and analogues for designing adapataion strategies in agriculture by CCAFS of CGIAR	19-23 September, 2011	Kathmandu Nepal
V.U.M.Rao	Inter-agency consultation meeting on user interface platform for the agriculture and water sectors in GFCS	26-28 September, 2011	FAO, Rome, Italy
S. Desai	DAAD Re-invitation program to research chitin and chitosan modifying enzymes in microorganisms	21 October - 21 December, 2011	WWU, Muenster, Germany
P. Vijaya Kumar	Training workshop of SAARC-Australia Project	20-24 November, 2011	SAC, Dhaka, Bangladesh
Ch. Srinivasa Rao	Carbon balance models	6-8 February, 2012	Dhaka, Bangladesh

7.3 Under graduate and post graduate research and training

Scientist	Student	Degree	Discipline	Institute/University
K.A. Gopinath	Kasbe Sudhanshu Sudhakar	Ph.D	Agronomy	ANGRAU, Hyderabad
S. Desai	Praveen Kumar Mir Hassan Ahmed Shaik Naseeruddin	Ph D Ph D Ph D	Microbiology Microbiology Microbiology	OU, Hyderabad OU, Hyderabad OU, Hyderabad
M Maheswari	T. Vijayalakshmi T. Anoosha	Ph.D. Ph.D.	Genetics Genetics	OU, Hyderabad OU, Hyderabad
M. Vanaja	G. Vijay Kumar Y. Anitha Babu Abraham	Ph.D. Ph.D. Ph.D.	Genetics Genetics Botany	OU, Hyderabad OU, Hyderabad OU, Hyderabad
S. K. Yadav	M. Gopala Krishna	Ph.D.	Genetics	OU, Hyderabad
K.S. Reddy	R Nagarjuna Kumar	Ph D	Technology & Engineering	Birla Institute of Technology, Ranchi
Kaushalya Ramachandran	N. Thilagavathi	M.Tech	Remote Sensing & GIS	Bharathiar University, Coimbatore
K. Srinivas	G. Vijayakumari	M.Sc	Biotechnology	JNTU, Hyderabad
K.L. Sharma	C. Nandini G. Kiran Reddy Jayarsee	M.Sc MSc (Ag) M.Sc	Biotechnology Biotechnology	JNTU, Hyderabad ANGRAU, Hyderabad OU, Hyderabad
Minakshi Grover	Nimmy Mohan Aadinarayana Sindogi Priti	M Tech. M Sc M Sc	Biotechnology Biotechnology Biotechnology	Udaya School of Engineering, Tamil Nadu VIT University, Tamil Nadu VIT University, Tamil Nadu
K. Sreedevi Shankar	B. Harini V. Harish G. Pradeep Kumar	M Sc M Sc M Sc	Biotechnology Biotechnology Biotechnology	JNTU, Hyderabad JNTU, Hyderabad JNTU, Hyderabad
D.B.V. Ramana	B. Shobitha N. Rajesh	MSc MSc	Biotechnology Biotechnology	Rayalaseema University, Kurnool Osmania University, Hyderabad
VUM Rao	Sushma	M.Sc.	Satellite Meteorology & Weather Informatics	JNTU, Hyderabad
P. Vijaya Kumar	N. Sheetal	M.Sc.	Satellite Meteorology & Weather Informatics	JNTU, Hyderabad
S. Desai	Sonam Shaheen Rajashree Pradhan Pranitha Reddy Dev Santosh Mohanty B. Hima Bindu	M.Sc. M.Sc. M.Sc. M.Sc. M.Sc.	Applied Microbiology Applied Microbiology Applied Microbiology Applied Microbiology Biotechnology	VIT, Chennai VIT, Chennai VIT, Chennai VIT, Chennai Telangana University
K.S. Reddy	Vijayalaxmi	M Tech	Soil & Water Engineering	UAS, Raichur
Arun Kumar Shanker	Srivatsa Divya Sree	B.Tech	Bio Technology	JNTU, Hyderabad
Kaushalya Ramachandran	B. Virinchi	B.Tech	Information and Communication Technology	SHASTRA University, Tirchy

8 Women in Agriculture

CRIDA KVK is carrying out several activities to empower the farm women. The activities include demonstrations, value added chains capacity building, extension activities and experiments which enhances awareness towards the use of improved technologies.

As a part of these activities two value added chains were created during the year 2011-12 with a goal to generate maintenance value to farm products produced by farm women

8.1 Creation of value added chains

Table 42 : Value added chains created by CRIDA KVK

	Products	Outlets
Value chain 1	Amla products: 1. Amla supari 2. Amla candy 3. Amla muraba	1. Surrounding villages 2. KVK 3. Ayurveda shops
Value chain 2	Herbal oil made up of 1. Coconut oil 2. Guntakatagara fresh leaf 3. Eucalyptus	1. Surrounding villages 2. KVK 3. Ayurveda shops 4. Beauty parlours

Table 43 : Results of cotton harvesting bag demonstration

Parameters	Harvesting bag	Farmer's Practice	Additional quantity harvested in kgs & income/day	% increase
Qty harvested in kgs/day/person	30	22	8	37
Income (Rs/day)	150	110	40	36

8.2 Demonstrations

Demonstrations were laid out in the KVK villages on useful farm implements to reduce the drudgery and on nutrition aspects.

8.2.1 Demonstration on multi grain atta with jowar, wheat, maize, bajra, ragi, soya

- Village families : 20
- Observations : acceptance is good because they are soft palatable, locally available grains and can be used almost like their regular jowar rotis
- Benefits : Supplies good quality proteins, minerals and vitamins

8.2.2 Demonstrations on cotton harvesting bag

Ten demonstrations were carried out with cotton harvesting bag. Farm women expressed that by using harvesting bag, the speed of picking improved and hence time was saved. The cost of weeding was also reduced. Another advantage was postural problems and body pains were reduced

8.2.3 Demonstration on dryland weeder

Dryland weeder was demonstrated to 10 farm women. Farm women expressed that by using weeders, weeding efficiency is improved and time is saved. Cost of labour is reduced. Postural problems and body pains are reduced.

Table 44 : Results of dryland weeder demonstration

	Demo	Farmer's practice	% increase
Labour required / day	5	10	100
Cost of weeding (Rs/ac)	300	600	100

8.3 Training programmes

KVK under CRIDA carried out many training programmes for farm women for knowledge on income generation and skill development

8.3.1 Training programmes for farm women

Fourteen programmes were conducted in which 415 farm women were trained in different aspects with a varied duration of 1-30 days.

Training on tailoring and zardosi works

Table 45 : Off-campus training programmes for farm women

Title of the course	Duration (days)	Villages	No.of participants
Preparation of phenyl and detergents	2	Mirzapur	20
Tailoring and zardosi works	90	Mirzapur	30
Preparation of phenyl and detergents	2	Mirzapur	30
Tailoring and zardosi works	90	Tallapally	30
Preparation of detergents, pain balm and Vaseline	2	Mirzapur	20
Preservation of mangoes	4	Kandlapally, Mirzapur	41
National nutrition week	1	Mirzapur	20
National nutrition week	1	Tallapally	40
National nutrition week	1	Ethbarpally	40
Utilization of minor millets	1	Mirzapur, Kandlapally, Enkepally	50
Preparation of detergents	2	Kandlapally	30
Preparation of tomato products, packing and marketing	2	Jookal	23
Preparation of iron rich recipes	1	Kandlapally	25
Preparation of detergents	1	Shapur	15

8.3.2 Training programmes for rural youth: Sponsored by NABARD

Capacity building for rural adolescent girls was carried out through such training programmes in which 210 adolescent girls were trained.

Training on cloth bag making

Table 46 : Off campus training programmes organized for rural youth

Title of the course	Duration (days)	Village	No.of participants
Tailoring REDP	90	Kandlapally	30
Maggam works REDP	90	Kandlapally	30
Baking with LPG Oven -MEDP	14	Mirzapur	30
Cloth bag making -MEDP	14	Kandlapally	
Leaf plate making -MEDP	14	Enkepally	30
Paper bag making -MEDP	14	Chenchupally	30
Tie and dye -MEDP	14	MIrzapur	30

8.3.3 Collaboration with line departments

A total of 230 adolescent girls were trained through 4 training programmes in collaboration with line departments on income generating activities and health aspects

Table 47 : Details of training programmes for adolescent girls in collaboration with line departments

Title of course	Duration (days)	Collaborator	Venue	No. of participants
Anaemia- iron rich recipes	1	Food and Nutrition Board	Anganwadi, Kandlapally	60
Vitamin A deficiency	1	Food and Nutrition Board	Anganwadi, Mirzapur	60
Income generating activities –washing powder, pain balm, vaselin, phenyle	2	DAAT centre	Jukal Shapur	60
Income generating activities –washing powder, pain balm, vaselin, phenyle	2	SAMETI	Chevella mandal	40

8.3.4 Scaling up of water productivity

Table 48 : Details of on campus training programmes on scaling up of water productivity

Title of training programme	No. of participants	Duration (days)	No. of programmes
Watershed approach for sustainable development programme	200	7	4

8.4 Extension activities for farm women

8.4.1 Technology week

The fourth day of Technology week (24.09.2011) was celebrated with theme on "Women empowerment and livelihood" with the participation of 230 women farmers and rural youth from Ranga Reddy District with Dr. Sharda Devi, Dean (Home Science), ANGRAU and Dr. Padma Kamalakar, Psychologist as chief guests. Dr. Sharda Devi emphasized the need of drudgery reduction in farm women and technologies available with improved farm implements . Dr. Padma Kamalakar explained

Farm women observing crops during technology week

the women empowerment and personality development for farm women to stand on their own by citing different examples. Women progressive farmer Mrs. Rama Devi also spoke on the occasion about the farm women development. Different women groups displayed their products under livelihood activities.

8.4.2 National nutrition week

National Nutrition week was celebrated in 7 villages of Pudur and Chevella Mandals during September 1 to 7, 2011. The villages are Mirzapur, Tallapally, Enkepally, Kandipally, Ethebarpally, Sheriguda and Chenchupally and the themes covered are Aneama eradiction, millets usage, use of unpolished rice importance of uncultivated greens, and multi grain atta.

8.4.3 World Food Day

Farm women from villages Kandapally, Mirzapur, Yenkepally and Tattapally were taken for an exposure visit to DDS Zaheerabad. The following topics were covered.

- Diffferent types of old millets
- Uncultivated greens
- Preservation of seeds by ingenious methods
- Seed bank millet stores

8.4.4 Exposure visits

The following exposure visits were organized for women

- AICRP Poultry, Sri. Venkateswara Veterinary University
- Fodder Research Station Mamidipally
- Leaf plate making machine unit
- Annapurna Cottage Industries, Hyderabad
- Vermicompost unit of a progressive farmer
- Centre for Medicinal Plants

8.4.5 Entrepreneurship development

The following income generating units started in different adopted villages of KVK and NICRA

- Bakery Units – One in Mirzapur
- Maggam embroidery – four in Tallapally and Mirzapur
- Tailoring units – six in Kandapally, Mirzapur and Tallapally
- Pickle making unit – one in Tallapally

8.4.6 Farm field schools

Farm field schools organized to empower women with knowledge and skills in soil management, crop production and plant protection practices. 2 FFS programmes conducted using digital resources like CD's and other internet resources.

8.4.7 Field Day for women farmers

A field day was organized on zero tillage of maize under GAP project to disseminate to all farmers the package of practices, economics and benefits derived out of the new practice in the village. Many women farmers of Kandlapally, Yenkepalli and Mirjapur participated in the programme.

Field Day on zero till maize

9 Awards and Recognition

- CRIDA-IKISAN led initiative of setting up ICT enabled Knowledge Share Centers (as part of NAIP sub project on Sustainable Rural Livelihoods) A.P. won the **Best Citizen's Choice Award** at the e-World Conference held in New Delhi on 1-3 August, 2011**.** The award recognizes the novelty of the ICT initiative in timely delivery of location specific, need based advisories and diagnostic services to farmers through a combination of ICT tools viz. touch screen kiosk, IVRS, display announcement, online portal and mobile based weather and market alerts.

Dr. B. Venkateswarlu, Director, receiving Best Citizen's Choice Award

- Dr. Ch. Srinivasa Rao, Principal Scientist and Dr. B. Venkateswarlu, Director (CRIDA) were awarded **Golden Jubilee Award of FAI** for their significant contributions in "Integrated Nutrient Management Practices in Rainfed Agriculture" on 7 December, 2011 during Inaugural Session of FAI Annual Seminar-2011 at Hotel Ashoka, New Delhi.
- Dr K. L. Sharma, National Fellow was selected for 'Bharat Jyothi Award' during the year 2011 by International Friendship Society New Delhi.

Dr. Ch. Srinivasa Rao receiving the Golden Jubilee Award of FAI from Mr Srikant Kumar Jena, Minister for Chemicals and Fertilizers, Government of India

- Dr K. L. Sharma, National Fellow was selected for 'Best Citizens of India Award' during the year 2011 by Best Citizens Publishing House, New Delhi.
- Dr. K.S. Reddy was awarded Commendation Medal for research contribution in the field of soil and water engineering by ISAE, New Delhi on Feb 27, 2012 at GBPUAT, Pantnagar. The award was presented by Dr Gajendra Singh, Former Vice Chancellor, Doon University and President, ISAE, New Delhi.
- ISAE AP Chapter was given " Best Chapter award" by ISAE, New Delhi for the year 2011. Dr K S Reddy, Chairman, ISAE AP Chapter received the award from Dr V N Sharda, Member, ASRB, New Delhi on Feb 27, 2012 at GBPUAT, Pantnagar
- Sumanta Kundu, Ph.D Scholar working with Dr. Ch. Srinivasa Rao, Principal Scientist (Soil

Science), was awarded International Plant Nutrition Institute (IPNI), USA-Best Ph.D Scholar Award for his Ph.D research project "Enhancing Nutrient Use Efficiency through Conservation Agricultural Practices in Maize-Horsegram System on Alfisols under Semi Arid Tropics" for the year 2011.

Sumanta Kundu receiving the Best Ph.D Scholar Award from Dr. B. Venkateswarlu, Director, CRIDA

The following papers received best paper/ poster/ presentation awards

- Prabhakar, M., Prasad, Y.G., Thirupati, M., and Sreedevi, G. 2011. Assessment of mealybug, Phenacoccus solenopsis damage in cotton using hyperspectral radiometry. **Best Research Paper Award** at the National Seminar on Agrometeorological Research and Services to Combat Climate Change Challenges held at BCKV, Kalyani, W.B., during 9-10 December, 2011.
- Bapuji Rao, B. VP Pramod and VUM Rao. 2011. Reliability of Downscaling Rainfall Data in the Estimation of Rainfall Trends: A Case Study. **Best Research Paper Award** at the National Seminar on Agroclimatological Research and Services to Combat Climate Change Challenges held at Bidhan Chandra Krishi Viswavidyalaya, Kalyani during 09-10 December 2011.
- Rao, AVMS., VUM Rao, B. Bapuji Rao,T.Satyanarayana, N.Manikandan and B.Venkateswarlu. 2012. Trends in occurrence of extreme rainfall events over India. **Best Research Paper Award** at the National Seminar on Sustainable Agriculture and Food Security: Challenges in Climate Change held at CCS Haryana Agricultural University, Hisar during 27-28 March 2012.
- Pratibha Gudapaty, Srinivas Indavarapu, Girish R. Korwar, Arun Kumar Shankar, Ravi kant V.Adake, Venkateshwarlu Bandi, Srinivasa Rao Kanchu. 2010. Effect of open air drying, LPG based drier and pretreatments on the quality of Indian gooseberry (aonla). JFST, 47(5), 541-548. **Best Paper Award** from Association of Food Scientists & Technologists (India), CFTRI, Mysore.
- Bapuji Rao, B., N. Manikandan, VUM Rao and AVMS Rao. 2011. Trends in annual and seasonal evapotranspiration at different locations of India. **Best Poster Award** during National Seminar on Agroclimatological Research and Services to Combat Climate Change Challenges held at Bidhan Chandra Krishi Viswavidyalaya, Kalyani 09-10 December, 2011.
- Grover M, Singh S R, Venkateswarlu B. 2011. Nanoencapsulation of bacterial antifungal metabolite. **Dr. Menon Poster Award** at National Symposium on "Biology of Infection. Immunity and disease control in pathogen-plant interaction" held at School of Life Sciences, University of Hyderabad from 2-4 December, 2011.
- CH. Anjani Devi and K. Sreedevi Shankar 2011 Phytoremediation of Heavy metals with Amaranthus dubius in semi-Arid soils of Patancheru, Andhra Pradesh. **Best Paper Presentation Award** at the National Symposium on Innovative and Modern Technologies for Agricultural Productivity, Food Security and Environmemtal Management held at Mangalore during 22-23 July 2011.

Recognition

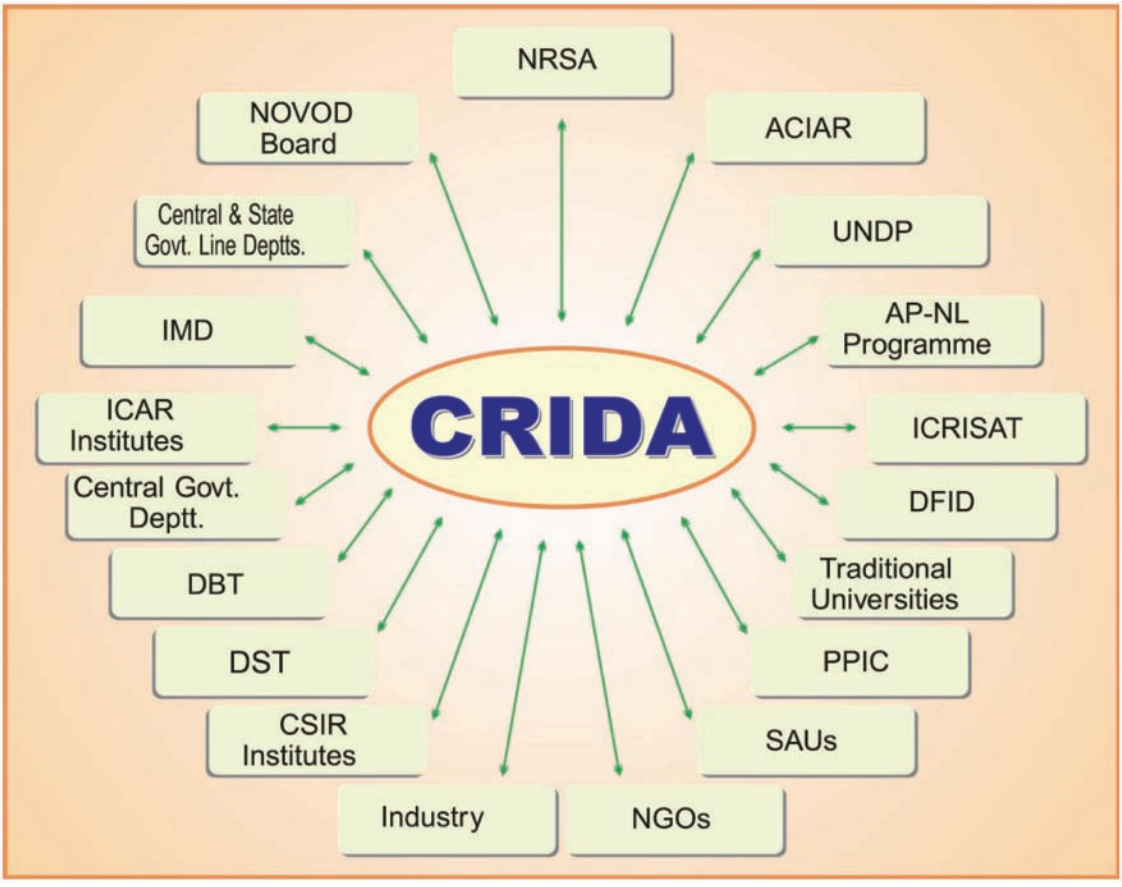
- Dr. Ch. Srinivasa Rao, Principal Scientist (Soil Science) was inducted as **Fellow of Indian Society of Soil Science** for his outstanding contributions in the field of nutrient dynamics and K recommendations in different agro-ecological regions of India and for evolving better soil organic carbon sequestration strategies in rainfed agriculture. The fellowship was presented on 16-11-2011 at 76th annual convention of ISSS, UAS, Dharwad by the Minister of Water Resource, Mr Basavaraja Bommai, Government of Karnataka.

Dr. Ch. Srinivasa Rao being inducted as Fellow of Indian Society of Soil Science

- VUM Rao, Project Coordinator (Agrometeorology) was inducted as **Expert to the Program Advisory Committee – Atmospheric Sciences** of the Department of Science & Technology, Ministry of Science & Technology, Government of India with the responsibility to strengthen the basic R & D in Atmospheric Science & Technology in the country.
- Dr S. Desai, Principal Scientist, was chosen as **Member, Scientific Panel on Biological Hazards, Food Safety and Standards Authority**, Government of India
- Dr K. S. Reddy, Principal Scientist was appointed as **Technical Advisor to C&AD, Govt. of AP** on Farm Pond Technology for its implementation in the state.

10 Linkages and Collaborations

CRIDA continually endeavours to forge new linkages and collaborations with stakeholders while renewing and strengthening old ones. CRIDA promotes action oriented research in public - private partnership mode through consortium approach. It has strong collaboration with ICRISAT, ILRI, IWMI, ANGRAU and other SAUs, JNTU, University of Delhi, Osmania University and other Universities and NGOs for developing and refining technologies for improving profitability in rainfed agriculture. CRIDA also plays a role in advising agencies such as central / state line departments to develop suitable policies for implementing programmes on rainfed agriculture. The Institute undertakes specific basic, applied, strategic and anticipatory research programmes fulfilling mandates of both itself and donors agencies. The partners in this mode include CSIR, DBT, DST, NOVOD Board, PPIC, Govt. of Andhra Pradesh and the like. CRIDA also undertakes consultancy programmes for specific tasks from Government of Andhra Pradesh, Madhya Pradesh, WWF, etc. CRIDA takes inputs from IMD and NCMRWF and generates value added outputs for the benefit of rainfed farmers.



11 Publications

Research papers

Bapuji Rao B, Linitha Nair, Rao VUM, Khushu MK, Hussai R, 2012. Assessing the impacts of increased temperature on mustard (*Brassica juncea* L.) yields using real time data from diverse environments. Cruciferae Newsletter 31: 31-33.

Chinmay Biswas, Ravindra Singh, Vijaya Kumar P, 2011. Dynamics of white rust disease in mustard (*Brassica juncea*) in relation to date of sowing and weather parameters. Indian Journal of Agricultural Sciences 81: 1187-90.

Daniel Amalraj L, Praveen Kumar G, Desai S, Mir Hassan Ahmed SK, 2010. In vitro characterization of *Trichoderma viride* for abiotic stress tolerance and field evaluation against root rot disease in *Vigna mungo* L. Journal of Biofertilizers and Biopesticides 2:1-5.

Gopinath KA, Venkateswarlu B, Venkateswarlu S, Srinavasa Rao Ch, Balloli SS, Yadav SK, Prasad YG, 2011. Effect of organic management on agronomic performance of sesame and on soil properties. Indian Journal of Dryland Agricultural Research and Development 26: 16-20.

Gopinath KA, Supradip Saha, Mina BL, 2011. Effects of organic amendments on productivity and profitability of bell pepper-french bean-garden pea system and on soil properties during transition to organic production. Communications in Soil Science and Plant Analysis 42: 2572-2585.

Grover M, Singh SR, Venkateswarlu B, 2012. Nanotechnology: Scope and limitations in agriculture. Intern Journal of Nanotech Applications 2:10-38.

Gupta S, Kumar M, Bandyopadhyay A, Raghuwanshi NS, Singh R, 2011. Modelling of evapotranspiration using artificial neural network. Hydrology Journal 34: 22-32

Jat ML, Sodani SN, Sammauria R, Sharma SK, Sharma KL, Mishra PK, Shankar GM, Kothari AK, Balyan JK, Jain LK, Sharma RK, 2011. Management of drought through crops and varietal description under dryland areas of western India. Indian Journal of Dryland Agriculture Research and Development 26: 32-40.

Kaushalya Ramachandran, Thilagavathi N, Venkateshwarlu B, Ramarao CA, Rao KV, Raju BMK, Saikia US, Gayatri M, Satish J, 2012. Assessment of vulnerability of Indian agriculture to climate change using NDVI variations as indicator – Use of NOAA-AVHRR (8km) & MODIS (250m) Time-Series NDVI Product, Journal of Climate Change and Environmental Sustainability (accepted)

Khushu MK, Tiku AK, Bapuji Rao B, Rao VUM, Mahender Singh, Charu Sharma, 2012. Transpiration responses to vapor pressure deficit in mustard (*Brassica juncea* L). Cruciferae Newsletter 31: 34-36.

Kumar M, Raghuwanshi NS, Singh R, 2011. Artificial neural networks approach in evapotranspiration modeling: A review. Irrigation Science 29: 11-25.

Kusuma Grace J, Sharma KL, Seshadri KV, Ranganayakulu C, Subramanyam KV, Bhupal Raj G, Sharma SHK, Ramesh G, Pravin N, Gajbhiye, Madhavi M, 2012 Evaluation of sweet orange (*Citrus sinensis* L. Osbeck) cv. Sathgudi budded on five rootstocks for differential behavior in relation to nutrient utilization in alfisol. Communications in Soil Science and Plant Analysis 43: 985-1014.

Mandal UK, Ramachandran K, Sharma KL, Satyam B, Venkanna K, Udaya Bhanu M, Moumita Mandal, Masane RN, Narsimlu B, Rao KV, Srinivasa Rao Ch, Korwar GR, Venkateswarlu B, 2011. Assessing soil quality under different land-use systems in a watershed of semi-arid tropics in India using GIS. Soil Science Society of America Journal 75: 1144-1160.

Mandal UK, Yadav SK, Sharma KL, Ramesh V, Venkanna K, 2011. Estimating permanganate-oxidizable active carbon as quick indicator for assessing soil quality under different land use system of rainfed Alfisols. Indian Journal Agricultural Science 81:927-931.

Mani Maheshwari, Krishnaiah N, Ramana DBV, 2011. Evaluation of polymerase chain reaction for the detection of *Vibrio cholerae* in contaminants. Annals of Biological Research 2: 212-217.

Maruthi Sankar GR, Mishra PK, Sharma KL, Singh SP, Nema AK, Kathmale DK, Upadhye SK, Sidhpuria MS, Osman M, Ravindra Chary G, Kusuma Grace J, Venkateswarlu B, Singh AK, 2012. Efficient tillage and nutrient practices for sustainable pearl millet productivity in different soil and agro-climatic conditions. Experimental Agriculture 48: 1–20.

Maruthi Sankar GR, Sharma KL, Dhanapal GN, Shankar MA, Mishra PK, Venkateswarlu B Kusuma Grace J, 2011. Influence of soil and fertilizer nutrients on sustainability of rainfed Finger Millet (Eleucine coracana) yield and soil fertility in semi-arid Alfisols. Communications in Soil Science and Plant Analysis 42: 1462 - 1483.

Maruthi Sankar GR, Subramanian V, Sharma KL, Mishra PK, Jyothimani S, Bhaskar K, Jawahar D, Rajeswari M, Raghavan T, Ravindra Chary G, Renuka Devi A, Gopinath KA, Venkateswarlu B, Kusuma Grace J, 2012. Modeling of interactive effects of rainfall, evaporation, soil temperature and soil fertility for sustainable productivity of sorghum + cowpea & cotton + black gram intercrops under rotation trials in a rainfed semi-arid vertisol. Communications in Soil Science and Plant Analysis 43: 756–787.

Mishra PK, Maruthi Sankar GR, Mandal UK, Nalatwadmath SK, Patil SL, Manmohan S, 2012. Amelioration of vertisols with sand for management of soil physical chemical and hydraulic properties in south India. Indian Journal of Soil Conservation 40: 13 – 21.

Momin UD ,Tamilmani , Reddy, KS, Laven KV, Kulkarni PS, Samuel MP, 2011. Development of soil moisture sensor and measurement system for automation. Indian Journal of Dryland Agricultural Research and Development 26:115-118.

Mukesh Kumar, Manoranjan Kumar, Chauhan RK, 2011. Designing framework for decision-making tools development water management and crop planning. International Journal of Science Technology and Management 2: 92-96.

Mukesh Kumar, Manoranjan Kumar, Chauhan RK, 2012. A Review on decision support system for water resource development and management. Indian Journal of Dryland Agriculture Research and development 26: 8-15.

Osman M, Shaik Haffis, Mishra PK, Vijaya Kumar P, 2010. A case study of drought in Andhra Pradesh: Socio-economic impacts and mitigating strategies. Indian Journal of Dryland Agriculture Research and Development 25: 44-57

Osman, M., Shaik Haffis, Ravindra Chary G, 2010. Crop diversification opportunities in distressed districts of Telangana region in Andhra Pradesh-A need of support mechanism. Agriculture Situation in India LXVII: 253-262.

Peeyush Sharma, Maruthi Sankar GR, Vikas Abrol, 2011. Statistical assessment of tillage and nitrogen management for sustainable soil moisture and productivity of maize and wheat in dry sub-humid inceptisoils. Indian Journal of Soil Conservation 39: 212-219.

Prabhakar M, Padmavathi P, Prasad RD, Lakshmi Prayaga, 2012. Retrieval of biophysical parameters and assessment of Alternuria disease severity in safflower using ground based hyper spectral radiometry. Journal of Oilseeds Research 29: 377-381.

Prabhakar M, Prasad YG, Thirupathi M, Sreedevi G, Dharajothi B, Venkateswarlu B, 2011.Use of ground based hyperspectral remote sensing for detection of stress in cotton caused by leafhopper (Hemiptera: Cicadellidae). Computers and Electronics in Agriculture 79: 189-198.

Prasad JVNS, Korwar GR, Rao KV, Srinivas K, Srinivasa Rao Ch, Pedababu B, Venkateswarlu B, Rao SN, Kulkarni HD 2011. On-farm evaluation of two fast growing trees for biomass production for industrial use in Andhra Pradesh, Southern India. New Forests 42: 51-61.

Prasad YG, Prabhakar M, Sreedevi G, Ramachandra Rao G, Venkateswarlu B, 2012. Effect of temperature on development, survival and reproduction of the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on cotton, Crop Protection 39: 81-88

Prasad YG, Prabhakar M, Sreedevi G, Tirupathi M, 2011. Spatio-temporal dynamics of the parasitoid *Aenasius bambawalei* Hayat (Hymenoptera: Encyrtidae) on mealybug, *Phenacoccus solenopsis* Tinsley in cotton based cropping systems and associated weed flora. Journal of Biological control 25: 198-202.

Pratibha G, Korwar GR, Srinivasa Rao Ch, Venkateshwarlu B, Yadav SK, Srinivasa Rao K, 2011. Nutrient management strategies in medicinal aromatic and dye yielding crops in rainfed regions. Indian Journal of Fertilizer News 7: 118-133.

Praveen Kumar G, Kishore N, Daniel Amalraj LE, Mir Hassan Ahmed SK, Abdul Rasool, Desai S, 2012. Evaluation of fluorescent Pseudomonas spp. with single and multiple PGPR triats for plant growth promotion of sorghum in combination with AM fungi. Plant Growth Regulation 67:133-140.

Rama Rao CA, Srinivasa Rao M, Srinivas K, Patibanda AK, Sudhakar C, 2011. Adoption, impact and discontinuance of integrated pest management technologies for pigeonpea in South India. Outlook on Agriculture 40: 245-250.

Ramana DBV, Nirmala G, Vijaya Kumar A, 2011. Mineral profile of feeds, fodders and blood plasma of dairy animals in KVK adopted villages of Rangareddy district in Andhra Pradesh. Indian Journal of Dryland Agriculture Research and Development 28: 26-31.

Ramana DBV, Reddy NN, Rao GR, 2011. Hortipastoral systems for ram lamb production in rain fed areas. Annals of Biological Research 2: 150-158.

Ramana DBV, Vijay Kumar A, Sreenath Dixit, Venkateswarlu B, 2011. Livestock production practices for sustainable rural livelihoods: A participatory action research in rainfed areas of AP. Journal of Rural Development 39: 71-79.

Rao GR, Arun K Shanker, Srinivas I, Korwa, GR, Venkateswarlu B, 2011. Diversity and variability in seed characters and growth of *Pongamia pinnata* (L.) Pierre accessions. Trees: Structure and Function 25: 725–734.

Rao KV, Bhaskara Rao I, Prasad JVNS, Rama Rao CA, Sahu RK, 2011. Farmers participation for effective utilization of water resources in Lift Irrigation schemes in rainfed areas. Indian Journal of Dryland Agricultural Research 26: 41-52.

Rao VUM, Bapuji Rao B, Linitha Nair, Diwan Singh, Chandersekhar, Venkateswarlu B, 2011. Thermal sensitivity of mustard (*Brassica juncea* L.) crop in Haryana. Journal of Agrometeorology 13: 131-134.

Rao VUM, Bapuji Rao B, Rao AVMS, Manikandan N, Venkateswarlu B, 2011. Assessment of rainfall trends at micro and macro level in Andhra Pradesh. Journal of Agrometeorology 13:80-85.

Ravi Shankar K, Nagasree K, Venkateswarlu B, Pochaiah Maraty, 2011. Constraints and suggestions in adopting seasonal climate forecasts by farmers in south India. The Journal of Agricultural Education and Extension 17:153-163.

Reddy KS, Kareemulla K, Rama Rao CA, Venkateswarlu B, 2012. Impact of SWC under MNAREGA on rural livelihoods in Rainfed Agriculture. Journal of Soil and Water Conservation (accepted).

Reddy KS, Rao BV, Umarfarooque Momin, 2012. Drinking water quality assessment of Bhaskar Rao kunta watershed, Dhamarcherla Mandal, Nalgonda District, Andhra Pradesh. Indian Journal of Natural Sciences 11: 847-851.

Saikia US, Venkatswarlu B, Rao GGSN, Korwar GR, Rao VUM, Srivastava NN, Mandal UK, Goswami B, Manoranjan Kumar, 2011. Estimating wheat productivity for Indian North Western Plain Zone in relation to spatial-Thermal Variation. Journal of Agrometeorology 13: 9-16.

Shalander Kumar, Raju BMK, Rama Rao CA, Kareemulla K, Venkateswarlu B, 2011. Sensitivity of yields of major rainfed crops to climate in India. Indian Journal of Agricultural Economics 66: 340-352.

Shalander Kumar, Sharma KL, Kareemulla K, Ravindra Chary G, Ramarao CA, Srinivasa Rao Ch, Venkateswarlu B, 2011. Techno-economic feasibility of conservation agriculture in rainfed regions of India. Current Science 101: 1171-1181.

Sharma KL, Kusuma Grace J, Mishra PK, Venkateswarlu B, Nagdeve MB, Gabhane VV, Maruthi Sankar GR, Korwar GR, Ravindra Chary G, Srinivasa Rao C, Pravin Gajbhiye N, Madhavi M, Mandal UK, Srinivas K, Ramachandran K, 2011. Effect of soil and nutrient- management treatments on soil quality indices under cotton-based production system in rainfed semi-arid tropical vertisol. Communications in Soil Science and Plant Analysis 42: 1298-1315.

Sharma KL, Padmaja KV, Srinivas K, Grace JC, Korwar GR, Venkateswarlu B, Mandal UK, 2012. Determination of optimum phosphorous level for grain sorghum using external and internal response indicators in rainfed semiarid tropical alfisol. Journal of Plant Nutrition 35: 854-873.

Sreenath Dixit, Venkateswarlu B, Srivastava AP, 2011. Promoting sustainable rural livelihoods: A framework for managing multi consortia. Journal of Agricultural Extension Management. XII: 55-65.

Srinivas I, Adake RV, Sanjeeva Reddy B, Korwar GR, Thyagaraj CR, Atul Dange, Veeraprasad G, Ravinder Reddy Ch, 2010. Comparative performance of different power weeders in rainfed sweet sorghum. Indian Journal of Dryland Agricultural Research Development 25: 63-67.

Srinivasa Rao C, Venkateswarlu B, Rattan Lal, Anil Kumar Singh, Sumanta Kundu, Vittal KPR, Gajanan GN, Ramachandra B, 2012. Long term effects of crop residues and fertility management on carbon sequestration and agronomic productivity of groundnut – fingermillet rotation on an Alfisol in southern India. International Journal of Agricultural Sustainability 10: 1-15.

Srinivasa Rao Ch, 2011. Nutrient management strategies in rainfed agriculture: Constraints and Opportunities. Indian Journal of Fertilizers 7:12-25.

Srinivasa Rao Ch, 2011. Nutrient ratios and crop response in relation to soil reserve K in India. Indian Journal of Fertilizers. 7(7): 36-51.

Srinivasa Rao Ch, Deshpande AN, Venkateswarlu B, Rattan Lal, Anil Kumar Singh, Sumanta Kundu, Vittal KPR, Mishra PK, Prasad JVNS, Mandal UK, Sharma, KL, 2012. Grain yield and carbon sequestration potential of post monsoon sorghum cultivation in Vertisols in the semi arid tropics of central India, Geoderma 175: 90-97.

Srinivasa Rao Ch, Satyanarayana T, 2012. Potassium mining in Indian agriculture. Indian Journal of Fertilizers 8(2): 22-31.

Srinivasa Rao Ch, Venkatesh M, Ali M, 2011. Sulphur management in pulse based production systems in India. Indian Journal of Fertilizers 7(5): 36-51.

Srinivasa Rao Ch, Venkateswarlu B, Lal R, Singh AK., Kundu S, Vittal KPR, Patel JJ, Patel MM, 2012. Long term manuring and fertilizer effects on depletion of soil organic carbon stocks ujnder pearl millet-clusterbean-castor rotation in western India. Land Degradation & Development (accepted)

Srinivasa Rao Ch, Venkateswarlu B, Rattan Lal, Anil Kumar Singh, Vittal KPR, Sumanta Kundu, Singh SR, Singh SP, 2012. Long term effects of soil fertility management on carbon sequestration in a rice-lentil cropping system of the Indo-Gangetic plains. Soil Science Society of America Journal 76: 168-178.

Srinivasa Rao Ch, Venkateswarlu B, Sharma KL, Mishra PK, Ramachandrappa BK, Patel JJ, Deshpande AN, 2011. Analyzing nitrogen use efficiency in long term experiments in rainfed conditions. Indian Journal of Fertilizer 7: 36-44.

Srinivasa Rao Ch, Venkateswarlu B, Singh AK, Vittal KPR, Sumanta Kundu, Gajanan GN, Ramachandrappa B, Chary GR, 2012. Critical carbon inputs to maintain soil organic carbon stocks under long term finger millet (*Eleusine coracana* (L.) Gaertn) cropping on Alfisols in semi arid tropical India. Journal of Plant Nutrition and Soil Science DOI: 10.1002/ppln.201000429.

Srinivasa Rao M, Rama Rao CA, Srinivas K, Pratibha G, Vidya Sekhar SM, Sree vani G, Venkateswrlu B, 2012. Intercropping for management of insect pests of castor *Ricinus communis* in the semi arid tropics of India. Journal of Insect Science 12: Article 14 1-10.

Srinivasa Rao P, Prasad JVNS, Umakanth AV and Belum VS Reddy, 2011. Sweet sorghum (*Sorghum bicolor* (L.) Moench) - A new generation water use efficient bioenergy crop. Indian Journal of Dryland Agriculture Research and Development 26: 65-71.

Srivastava NN, Rao VUM, Saikia US, Vijaya Kumar P, Subba Rao AVM, 2011. Modelling diurnal pattern of relative humidity from daily air temperature and relative humidity data of Hyderabad. Journal of Agrometeorology 13: 25-30.

Sunil N, Vanaja M, Vinod Kumar, Jainender, Babu Abraham, Varaprasad KS, 2012. Intra- specific variation response of Jatropha (*Jatropha curcas* L.) to elevated CO_2 conditions. Physiology and Molecular Biology of Plants. DOI 10.1007/s12298-012-0106-x.

Vanaja M, Raghu Ram Reddy P, Jyothi Lakshmi N, Yadav SK, Narshimha Reddy A, Maheswari M, Venkateswarlu B, 2011. Yield and harvest index of short and long duration grain legume crops under twice the ambient CO_2 levels. Indian Journal of Agricultural Science 81:666-668.

Vanaja M, Yadav SK, Archana G, Jyothi Lakshmi N, Raghu Ram Reddy P, Vagheera P, Abdul Razak SK, Maheswari M, Venkateswarlu B, 2011. Response of C_4 (Maize) and C_3 (Sunflower) crop plants to drought stress and enhanced carbon dioxide concentration. Plant Soil and Environment 57: 207-215.

Venkateswarlu B, Prasad JVNS, 2012. Carrying capacity of Indian agriculture, issues related to rainfed agriculture. Current Science 102: 882-888.

Vimala Rodhe A, Sateesh L, Sridevi J, Venkateswarlu B, Venkateswar Rao L, 2011. Enzymatic hydrolysis of sorghum straw using native cellulose produced by *T. reesei* NCIM 992 under solid state fermentation using rice straw. 3 Biotech 1: 207-215.

Yadav SK, Vanaja M, Reddy PR, Jyothilakshmi N, Maheswari M, Sharma KL, Venkateswarlu B, 2011. Effect of elevated CO_2 levels on some growth parameters and seed quality of groundnut (*Arachis hypogaea* L.). Indian Journal of Agricultural Biochemistry 24: 158-160.

Books/reports/bulletins

Bapuji Rao B, Ramana Rao BV, Subba Rao AVM, Manikandan N, Narasimha Rao SBS, Rao VUM, Venkateswarlu B, 2011. Assessment of the impact of increasing temperature and rainfall variability on crop productivity in drylands - An illustrative approach. Research Bulletin 1/2011, CRIDA, Hyderabad, 32p.

Gopinath KA, Venkateswarlu B, Venkateswarlu S, Yadav SK, Balloli SS, Srinvasa Rao Ch, Prasad YG, Maheswari M, 2011. Organic Sesame Production, Technical Bulletin, CRIDA, Hyderabad, 34p.

Kaushalya Ramachandran, Mandal UK, Sharma KL, 2011. Sustainable land management-Framework for epIA of Land Management Practices in Rainfed Agriculture LAP Lambert Academic Publishing, Dudweiler, Saarbruecken-D-66123, Saarland, Germany, ISBN: 978-3-8465-1230-2, 234p.

Mishra PK, Osman M, Satendra, Venkteswarl B, 2011. Techniques of water conservation and rainwater harvesting for drought management, SAARC Training Program, CRIDA, Hyderabad, India, 715p.

Naresh Kumar S, Anil Kumar Singh, Aggarwal PK, Rao VUM, Venkateswarlu B, 2012. Climate Change and Indian Agriculture: Impact, adaptation and vulnerability-salient achievements from ICAR Network Project, IARI Publication, 32p.

Rao VUM, Bapuji Rao B, Khandgond IR, Rao AVMS, Vijaya Kumar P, Dagar JC, Venkateswarlu B, 2011. Perception of Indian farmers on climate change - An assessment and awareness programme. Technical Bulletin, CRIDA, Hyderabad, India, 33p.

Rao VUM, Rao AVMS, Kumar PV, Desai S, Saikia US, Srivastava NN, Venkateswarlu B, 2011. Agricultural drought: Climate change and rainfed agriculture. Lecture notes of 5th SERC school, Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, India, 324 p.

Rao VUM, Subba Rao AVM, Bapuji Rao B, Ramana Rao BV, Sravani C, Venkateswarlu B, 2011. El Niño effect on climatic variability and crop production: A case study for Andhra Pradesh, Research Bulletin No. 2/2011, CRIDA, Hyderabad, India, 36p.

Ravi Shankar K, Sanjeeva Reddy B, Srinivas I, Adake RK, Prasad MS (Eds), 2011. Mechanization in Dryland Agriculture-Compendium of Lecture Notes, 103p.

Shanker AK, Venkateswarlu B (Eds), 2011. Abiotic Stress Response in Plants - Physiological, Biochemical and Genetic Perspectives. Intech Open. ISBN: 978-953-307-672-0.

Sharma KL, Nandini Ch, 2012. Soil management effects on biological indicators of soil quality, LAP Lambert Academic Publishing GmbH & Co. KG, Saarbrucken, Germany. 68p.

Sharma SK, Sharma RK, Kothari AK, Laddha KC, Sodani SN, Osman M, Ravindra Chary G, Balloli SS, Mishra PK, Mandal UK, Venkateswarlu B, 2010. Farmers participatory action research programme -Tank silt as an organic amendments for improving soil and water productivity. Dryland Framing Research Station, MPUAT, Udaipur, 8p.

Sharma SK, Sharma RK, Kothari AK, Laddha KC, Sodani SN, Osman M, Ravindra Chary G, Balloli SS, Mishra PK, Mandal UK, Venkateswarlu B, 2010. Outreach action research and learning for improved use of tank silt in maize-based production system, Dryland Framing Rear arch Station , MPUAT, Udaipur, 26p.

Srinivasa Rao Ch, Vankateswarlu B, Dinesh Babu M, Wani SP, Sreenath Dixit, Sahrawat KL, Sumanta Kundu, 2011. Soil health improvement with Gliricidia green leaf manuring in rainfed agriculture, CRIDA, Hyderabad, India, 23p.

Srinivasa Rao Ch, Venkateswarlu B, Dinesh Bab, M, Wani SP, Dixit S, Sharawat KL, Sumanta Kundu, 2011. Soil health improvement with Gliricidia green leaf manuring in rainfed agriculture, on farm experience, CRIDA, Hyderabad, 16p.

Srinivasa Rao Ch, Venkateswarlu B, Sreenath Dixit, Sumanta Kundu, Gayatri Devi K, 2011. Livelihood impacts of soil health improvement in backward and tribal districts of Andhra Pradesh. CRIODA, Hyderabad, India, 119p.

Srinivasa Rao Ch, Venkateswarlu B, Srinivas K, Kundu S, Singh AK, 2011. Soil carbon sequestration for climate change mitigation and food security, CRIDA, Hyderabad, 322p.

Srinivasa Rao Ch, Venkateswarlu B, Srinivas K, Sumanta Kundu, Singh AK, 2011. Soil carbon sequestration for climate change mitigation and food security. CRIDA, Hyderabad, India, 372p.

Srinivasa Rao Ch, Venkateswarlu B, Wani SP, Dixit S, Sahrawat KL, Sumanta Kundu, 2011. Benefits from micro and secondary nutrients: impacts on farm income and livelihoods in rainfed tribal and backward regions of Andhra Pradesh. CRIDA, Hyderabad, India, 20p.

Srinivasa Rao M, Rama Rao CA, Vennila S, Raju BMK, Srinivas K, Padmaja PCM, Rao AVMS, Maheswari M, Rao VUM, Venkateswarlu B, 2012. Meta analysis of Impact of elevated CO2 on host - insect herbivore interactions. Bulletin No. 2/2012, CRIDA, Hyderabad, India, 48 p.

Srinivasa Rao M, Srinivas K, Vanaja M, Manimanjari D, Rama Rao CA, Rao VUM, Venkateswarlu B, 2012. Response to elevated CO_2 of multiple generations of semilooper, Achaea janata L. (Noctuidae: Lepidoptera) feeding on castor. Research Bulletin 01/2012. CRIDA, Hyderabad, 28p.

Subba Rao, Srinivasa Rao Ch, Srivastava S, 2011. Potassium status and crop response to potassium on the soils of agro-ecological regions of India. International Potash Institute, Horgen, Switzerland, 185p.

Thyagaraj CR, Aum Sharma, Sanjeeva Reddy B, Srinivas I, Adake RK, Sudhakar Reddy P, Bhasker Reddy (Eds.), 2011. Souvenir - Andhra Pradesh agricultural machinery manufacturers meet and coordination committee meeting of AICRP on FIM. Organized by ICAR, New Delhi and ANGRAU, Hyderabad, 108p.

Usharani K, Sharm, KL, Kaushalya Ramachandran, 2011. Sewage water irrigation and heavy metals, LAP Lambert Academic Publishing GmbH & Co. KG, Saarbrucken, Germany, 179p.

Usharani K, Sharma KL, Nagasree K, 2012. Response of sunflower to sulphur, LAP Lambert Academic Publishing GmbH & Co. KG, Saarbrucken, Germany, 70p.

Venkateswarlu B, Singh AK, Prasad YG, Ravindra Chary G, Srinivasa Rao Ch, Rao KV, Ramana DBV, Rao VUM, 2011. District level contingency plans for weather aberrations in India. CRIDA, NRM Division, ICAR, Hyderabad, India, 136p.

Venkateswarlu B, Arun K Shanker, 2011. Abiotic stress response in plants: Physiological, biochemical and genetic perspectives. INTECH, 346p.

Venkateswarlu B, Arun K Shanker, Chitra Shanker, Maheswari M (Eds), 2012. Crop stress and its management: Perspective and Strategies, Springer, 611p.

Venkateswarlu B, Osman MD, Raju BMK, Mishra PK, Rao KV, Subbarao AVM, Ramarao CA, Kareemulla K, Bhatia VK, Anil Rai, Prachi Mishra Sahoo, Malhotra PK, 2011. A consultancy study report on prioritization of rainfed areas in India submitted to National Rainfed Area Authority (NRAA), New Delhi, 121p.

Venkateswarlu B, Singh AK, Prasad YG, Ravindra Chary G, Srinivasara Rao Ch, Rao KV, Ramana DBV, Rao VUM, 2011. District level contingency plans for weather aberrations in India. CRIDA, NRM Division, ICAR, New Delhi, 136p.

Vennila S, Prasad YG, Prabhakar M, Rishi Kumar, Nagrare VS, Amutha M, Dharajyothi, Meenu Agarwal, Sreedevi G, Venkateswarlu B, Kranthi KR, Bambawale OM, 2011. Spatio-temporal distribution of host plants of Cotton mealybug, Phenacoccus solenopsis Tinsley in India. NCIPM Technical Bulletin No 26, NCIPM, New Delhi, 49p.

Vijaya Kumar P, 2012. Agrometeorology of rainfed castor beans (*Ricinus communis*), Lambert Academic Publishing GmbH & Co. KG, Saarbrucken, Germany, 194p.

Book chapters

Balloli SS, 2011. Climate change impacts on soil fertility and carbon sequestration. In: Soil Carbon Sequestration for Climate Change Mitigation and Food Security (Eds. Ch Srinivasarao et al), CRIDA, Hyderabad, India. Pp 372.

Bijay Singh, John Ryan, Robert Zentner and Srinivasarao Ch, 2012. Rainfall/moisture and nutrient/fertilizer management options for enhancing productivity and water and nutrient use efficiency in arid/semiarid areas. IFA/IWMI/IPNI/IPI Scientific Publication on the Links between Fertilizer Use and Water management, pp 21.

Desai S, Grover M, Daniel Amalraj EL, Praveen Kumar G, Mir Hassan Ahmed SK, 2012. Exploiting plant growth promoting rhizo-microorganisms for enhanced crop productivity. In: Microorganisms in Sustainable Agriculture and Biotechnology (Eds. T Satyanarayana, BN Johri, A Prakash), Springer, Germany, pp 227-242.

Gopinath KA, Ravindra Chary G, Pratibha G, Mishra PK, Venkateswarlu B, 2011. Recent developments in rainfed organic farming. In: Recent Developments in Organic Farming (Eds. JML Gulati, T Barik), Orissa University of Agriculture and Technology, Bhubaneswar, pp 465-478.

Kareemulla K, Rama Rao CA, 2012. Socio economic and policy issues in abiotic stress management. In: Crop stress and its management-Perspectives and Strategies, (Eds. B Venkateswarlu, AK Shanker, C Shanker, M Maheswari) Springer, Netherlands, pp 565-584.

Maheswari M, Yadav SK, Arun K Shanker, Anil Kumar M, Venkateswarlu B, 2011, Overview of plant stresses: Mechanisms, adaptations and research pursuit. In: Crop Stress and Its Management: Perspectives and Strategies (Eds. B Venkateswarlu, AK Shanker, C Shanker, M Maheswari) Springer, Netherlands, pp 1-18.

Maruthi Sankar GR, Mishra PK, 2011. Sustainability of rainwater management practices for rainfed crops under different agro-ecological sub-regions of India. In: Techniques of water conservation & rain water harvesting for drought management- SAARC Training Program (Eds. PK Mishra, M Osman, Satendra, B Venkateswarlu), CRIDA, Hyderabad, pp 283-316.

Prabhakar M, Prasad YG, Rao MN, 2012. Remote sensing of biotic stress in crop plants and its applications for pest management. In: Crop Stress and its Management: Perspectives and Strategies (Eds. B Venkateswarlu, AK Shanker, C Shanker, M Mandapaka), Springer, Netherlands, pp 517-545.

Prasad JVNS, 2011. Mitigation of green house gas emissions through CDM technologies: In: Agricultural Drought, Climate change and Rainfed Agriculture (Eds. VUM, Rao AVMS Rao, PV Kumar, S Desai, Saikia, NN Srivastava, B Venkateswarlu), CRIDA, Hyderabad, pp 324.

Prasad JVNS, 2011. Carbon sequestration through agroforestry systems. In: Soil carbon sequestration for climate change mitigation and food security (Eds. Ch Srinivasa Rao, B Venkateswarlu, K Srinivas, S Kundu, AK Singh), CRIDA, Hyderabad, pp 322.

Pushpanjali, Karthikeyan K, 2011. Hyperspectral remote sensing for soil organic carbon prediction: An overview. In: Soil Carbon Sequestration for Climate Change Mitigation and Food Security (Eds. Ch Srinivasa Rao, B Venkateswarlu, K Srinivas, S Kundu, AK Singh), CRIDA, Hyderabad, pp 142-160.

Ramana DBV, 2011. Intensification of livestock production systems for off-farm livelihoods: Opportunities and Challanges. In: Sustainable Agriculture Production through Innovative Approaches for Enhanced Livelihoods, CRIDA, Hyderabad, pp 121-131.

Ramana DBV, 2011. Livestock integration for improving the livelihoods of rural poor. In: Production and farming system for livelihood improvement in rainfed areas, CRIDA, Hyderabad, pp 93-104.

Ramana DBV, 2011. Pasture development and intensification of livestock production in watershed areas. In: Use of High Science Tools and Methodologies in Planning, Implementation and Monitoring of Watershed Programmes under IWMP, CRIDA, Hyderabad, pp 138-148.

Rao, VUM, Rao AVMS, Rao GGSN, Satyanarayana T, Manikandan N, Venkateswarlu B, 2011. Impact of climate change on crop water requirements and adaptation strategies. In: Challenges and opportunities in Agrometeorology (Eds. SD Attri, LS Rathore, MVK Sivakumar, SK Dash) Springer-Verlag, Berlin Heidelberg, pp 311-320.

Ravindra Chary G., Vittal KPR, Venkateswarlu B, Mishra PK, Rao GGSN, Pratibha G, Rao KV, Sharma KL, Rajeshwar Rao G, 2010. Drought hazards and mitigation measures. In: Natural and Anthropogenic Disasters: Vulnerability, Preparedness and Mitigation (Ed. MK Jha), Capital Publishing Company, New Delhi and Springer, The Netherlands, pp 197 -237.

Reddy KS, Raji Reddy D, Kumar M, Nagarjuna Kumar R, Umarfarooque M, Umesh B, Srinivas Reddy K, Venkateswarlu B, 2011. Assessment of climate variability/change through climgen model: A case study of rainfall and temperature in Ranga Reddy district of A.P In: All Conserve water Preserve Climate, Institute of Engineers, Hyderabad, pp 31-38.

Sharma KL, 2011. Conservation agriculture for soil carbon buildup and mitigation of climate change. In: Soil Carbon Sequestration for Climate Change Mitigation and Food Security (Eds. Ch Srinivasarao, B Venkateshwarlu, K Srinivas, S Kundu, AK Singh), CRIDA, Hyderabad, pp 180-199.

Sharma KL, 2011. Role of conservation agriculture in protecting land and improving soil quality amidst changing climate. In: Techniques of Water Conservation and Rainwater Harvesting for Drought Management (Eds. PK Mishra, M Osman, Satendra, B Venkateshwarlu), CRIDA, Hyderabad, pp 622-645.

Srinivas K, Maruthi V, 2011. Plant roots and carbon sequestration. In: Soil Carbon Sequestration for Climate Change Mitigation and Food Security (Eds. Ch Srinivasa Rao, B Venkateswarlu, K Srinivas, S Kundu, AK Singh), CRIDA, Hyderabad, pp 200-223.

Srinivasa Rao Ch, 2011. Carbon sequestration and global warming potential of rainfed agriculture. In: Improving Water Productivity- Limits and Opportunities. Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, pp 23.

Srinivasa Rao Ch, 2011. Sustainable rural livelihoods through enhanced farming systems productivity and efficient support system in rainfed areas. Confederation of Indian Industries, Hyderabad, pp 35-44.

Srinivasa Rao Ch, Rao KV, Hegde DM, Venkateswarlu B, Sumanta Kundu, 2012. Use of organic fertilizers alone or in combination with inorganic ones: effects on water and nutrient use efficiency. In: Improving Water and Nutrient Use Efficiency in Food Production Systems (Ed. Z Rengel), ISUP, John Wiley & Sons, Iowa, USA.

Srinivasa Rao Ch, Sumanta Kundu, Vijay S Jakkula, Sharan Bhoopal Reddy, Prakash Naik, Rupendra Manideep, 2011. Soil carbon sequestration strategies in Rainfed agriculture. In: Soil Carbon Sequestration for Climate Change Mitigation and Food Security (Eds. Ch Srinivasarao, B Venkateswarlu, K Srinivas, S Kundu, AK Singh), CRIDA, Hyderabad, India, pp 372.

Srinivasa Rao Ch, Venkateswarlu B, Sumanta Kundu, 2010. Nutrient availability and management in diverse rainfed production systems in India. In: Future Strategies for Nutrient Management Research, Ranchi, Jharkhand, India, pp 19-23.

Srinivasarao Ch, Venkateswarlu B, Sreenath Dixit, Sumanta Kundu, 2011. Participatory soil health management and carbon build up in rainfed region of India: Field Experiences improvement and carbon sequestration through participatory nutrient management. In: Soil Carbon Sequestration for Climate Change Mitigation and Food Security (Eds. Ch Srinivasa Rao, B Venkateswarlu, K Srinivas, S Kundu, AK Singh), CRIDA, Hyderabad, India, pp 372.

Sujay Dutta, Choudhury I, Prasad YG, Prabhakar M, Katti G, Vasantbhanu K, Vennila S, 2011. Pest surveillance of rice crop using satellite data - A Case study for Brown Plant Hopper (*N. lugens*). In: Information and Communication Technology for Agriculture and Rural Development (Eds. R Saravanan, C Kathiresan, T Indra Devi), New India Publishing Agency, New Delhi, p 368.

Vanaja M, Raghu Ram Reddy P, Yadav SK, Jyothi Lakshmi N, Narasimha Reddy A, Reddy BMK, Maheswari M, Venkateswarlu B, 2012. Increasing CO_2 concentration and its probable influence on rainfed food and oilseed crop productivity in SAT. In: Impact of Climate Change in soils and rainfed agriculture of tropical ecosystem (Eds. T Bhattacharyya, DK Pal, Dipak Sarkar SP Wani), Studium Press, LLC, USA, pp 270-298.

Venkateswarlu B, 2011. Drought management and contingency planning in Eastern India. In: Technican Output and Recommendations – Strategies for Agricultural Transformation of Eastern Region (Eds. AK Singh, BP Bhatt, PS Minhas), ICAR Research Complex for Eastern Region, Patna, pp 61-98.

Venkateswarlu B, Arun K Shanker, 2012. Dryland agriculture: Bringing resilience to crop production under changing climate. In: Crop Stress and Its Management: Perspectives and Strategies (Eds. B Venkateswarlu, AK Shanker, C Shanker, M Maheswari), Springer, Netherlands, pp 19-44.

Venkateswarlu B, Prasad JVNS, 2011. Issues and strategies for managing degraded lands in rainfed ecosystem in India. In: Strategies for Arresting Land Degradation in South Asian Countries (Eds. Dipak Sarkar, Abdul Kalam Azad, SK Singh, Nasrin Akter), SAARC Agriculture Centre, pp 191-207.

Venkateswarlu B, Rao KV, Kaushalya Ramachandran, Mandal UK, 2011. Application of geomatics in watershed prioritization, monitoring and evaluation - CRIDA's experience. In: Use of High Science Tools in Integrated Watershed Management (Eds. SP Wani, KL Sahrawat, KG Kaushal), ICRISAT, CPE 169, pp 49-65.

Vijaya Kumar P, 2011.Characterization of droughts and development of forewarning system. In: Techniques of water conservation & Rainwater harvesting for drought management (Eds. PK Mishra, M Osman, Satendra, B Venkateswarlu), SAARC training program, CRIDA, Hyderabad, India, pp 428-440.

Vijaya Kumar P, 2012. Crop-weather relationships. In: Cropping system management (Eds. B Gangwar), Agrotech Publishing Academy, Udaipur, Rajasthan, pp 265-280.

Wani SP, Roy PS, Kesava Rao AVR, Barron J, Kaushalya Ramachandran, Balaji V, 2011. Application of new science tools in integrated watershed management for enhancing impacts. In: Integrated Watershed Management in Rainfed Agriculture (Eds. SP Wani, J Rockstrom, KL Sahrawat), CRC Press Publication, pp 159-204.

Wani SP, Venkateswarlu B, Sharda VN, 2011. Watershed development for rainfed areas: Concept, principles and approaches. In: Integrated Watershed Management in Rainfed Agriculture (Eds. SP Wani, J Rockstrom, KL Sahrawat), CRC Press Publication, pp 53-86.

Popular/ Technical articles

Desai S, Srinivasa Rao M, 2011. Impact of climate change on insect pests, pathogens and their natural enemies. Natural Rubber Research 24: 174-186.

Gopinath KA, Gupta HS, 2011. Production potential of new maize hybrids and composites at farmers' fields in Uttarakhand hills. Indian Farming 60: 8-9.

Kumar VVS, Raju BMK, 2011. Automation of distributed databases for National Initiative on Climate Resilient Agriculture. ICAR News 17: 5-6.

Ramana DBV, 2011. *Jevaalalo adhika mamsothpattiki sasthriya yajamanya paddatulu (in Telugu).* Agriculture Today 4(7): 29-32.

Ramana DBV, 2011. Metabolic profile tests: Application in dairy farm management. Raksha Technical Review 1:13-16.

Sanjeeva Reddy B, 2010. Bhusara Samrakshana - *Panta Vyardhala Viniyoga Aavashyakata (in Telugu).* Paadi Pantalu 68(9): 16-17.

Sanjeeva Reddy B, Udaykumar M, 2011. *Pantalanuchi Vachee Vyardhala Viniyogam – Aavashyakata (in Telugyu).* Annadata 43(4): 49 -50.

TV / Radio talks / shows

Nirmala G, All India Radio, Hyderabad, *Susthitara vyavasaym- melaina vyasaya paddautlu,* on 11 March, 2012.

Ramana DBV, All India Radio, Hyderabad, *Emu kolla pempakam,* on 8 January, 2012

Reddy BS, All India Radio, Hyderabad, *Vesavi Dukkulu Cheyadaniki Metta Sedyamku Adhunika Parikaralu* on 20 April, 2011.

Reddy BS, All India Radio, Hyderabad, Farm Machinery - Custom Hired Services, on 19 July, 2011.

Srinivasa Rao Ch, All India Radio, Anantapur Station, Andhra Pradesh, Drought management strategies in Anantapur

Srinivasa Rao Ch, All India Radio, Hyderabad, Soil health issues and crop productivity.

Vanaja M, All India Radio, Hyderabad, *Vathavarana ushnograthalu- Aruthadi pantalu,* on 8 January, 2012.

12 Ongoing Projects

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

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
7. EF009 (DST)	Carbon sequestration potential of reduced tillage system under rainfed conditions	**J.V.N.S. Prasad** K. Srinivas G. Ravindra Chary K.L. Sharma G.R. Korwar P.K. Mishra Ch. Srinivasa Rao **G. Pratibha**	**2009**	**2012**
8. EF034 (NAIP) (Comp-I)	Enabling small stakeholders to improve livelihoods and benefits from carbon finance	**J.V.N.S. Prasad** K. Srinivas G.R. Korwar Ch. Srinivasa Rao C.A. Rama Rao K.V. Rao	2009	2012
9. RM/NM/05	GHG emissions and global warming potential of crop production systems under rainfed conditions	**J.V.N.S. Prasad** G.R. Korwar Ch. Srinivasa Rao K. Srinivas	2010	2012
10. RM/RM/05	Hydrologic modeling of water yield in a micro watershed and its productivity in vegetable and oilseed production in Alfisols	**K. Srinivas Reddy** K.V. Rao B.Sanjeeva Reddy B.M.K. Reddy V. Maruthi K. Kareemulla	2008	2011
11. TOT/AE/28	Evaluation of water productivity under different types of micro irrigation systems	**K. Srinivas Reddy** K. Nagasree K. Ravi Shankar N.N. Reddy	2009	2014
12. RM/RM/06	Rainfall–Runoff and water use characterization of different crop/ cropping systems	**K.V. Rao** K. Srinivasa Reddy G. Pratibha M. Osman U.K. Mandal	2008	2012
13. RM/RM/10	Water Productivity enhancement through in-situ Rainwater Harvesting	**K.V. Rao** G. Pratibha I. Srinivas Y.G. Prasad	2008	2012
14. 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	2012
15. RM/FM/10	Development of an Electronic sensors based Instrumentation system to Evaluate Seed planter Performance	**B. Sanjeeva Reddy** Ravikant V. Adake G.R. Korwar N. Ravi Kumar	2010	2013

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
16. EF005 (NAIP) (Comp.V)	Assessment of Quality and Resilience of Soils in Diverse Agro-ecosystems	**U.K. Mandal** K.L. Sharma K. Srinivas Ch. Srinivasa Rao	2008	2012
17. RM/FM/08	Optimization of water lifting and distribution of harvested water	**Ravikant V. Adake** C.R. Thyagaraj I. Srinivas B.S. Reddy K.V. Rao M. Osman Sreenath Dixit Manoranjan Kumar B.M.K. Reddy	2009	2012
18. RM/FM/09	Use of Nano materials to minimize wear in critical parts of selected farm implements	**I. Srinivas** C.R. Thyagaraj R.V. Adake	2009	2012
19. EF030 (NAIP) (Comp.2)	Value chain Model for Bio-ethanol production from Sweet Sorghum in rainfed areas through collective action and partnership	**I. Srinivas** G.R. Korwar B. S. Reddy Ravikant V. Adake	2008	2012
20. RM/RM/08	Effect of Biochar amendment on soil properties and growth of crops	**G. Venkatesh** G.R. Korwar U.K. Mandal Ch. Srinivasa Rao K.A. Gopinath Minakshi Grover Dhanpal, AICRPDA Bangalore centre	2009	2012
21. RM/RM/12	Design and development of cost effective water management system for selected crops in alfisol (red soil)	**Manoranjan Kumar** K.S. Reddy K.A. Gopinath	2010	2013
22. RM/RM/13	Development of DSS for Real Time Water Balance Modeling	**Dr. Manoranjan Kumar** Dr. N. Ravi Kumar Dr. Pushpanjali	2012	2013
23. EF040 ACIAR	Impact of meso-scale watershed development in Andhra Pradesh (India) and comparative catchments in Australia	**K.V. Rao**	2010	2014
24. EF043	Improving nutrient use efficiency in rainfed production systems	**Ch. Srinivasa Rao** G. Pratibha K. Srinivas Pushpanjali	2010	2012
25. RM/RM/14	Assessment of relative performance of crop simulation models for dryland crops	**A.S. Rao** G.R. Maruthi Sankar A.V.M.S. Rao VUM Rao	2012	2015

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
26. RM/RM/15	Spectral signature development for rainfed crops cotton and castor crops using remote sensing to assess the trends in crop growth	**N.S. Raju**	2012	2015
DIVISION OF CROP SCIENCE				
27. EF017 (DBT)	Genetic transformation of greengram for enhancing abiotic stress tolerance	**S.K. Yadav** M. Maheswari B. Venkateswarlu N. Jyothi Lakshmi M. Vanaja P.R. Reddy	2004	2012
28. CS/CP/26	Metabolic indices for heat tolerance in short duration grain legumes	**S.K. Yadav** M. Maheswari M. Vanaja N. Jyothi Lakshmi Arun Kumar Shanker	2010	2013
29. CS/CP/21	Impact of elevated CO_2 on plant nitrogen use efficiency	**N. Jyothi Lakshmi** M. Maheswari M. Vanaja S.K. Yadav Ch. Srinivasa Rao	2009	2012
30. EF011 (ICAR Network Project)	Impact of elevated CO_2 on important rainfed crops	**M. Vanaja** M. Maheswari P.R. Reddy S.K. Yadav N. Jyothi Lakshmi B. Venkateswarlu	2004	2012
31. CS/CP/16	Evaluation of chlorophyll fluorescence as an indicator for drought tolerance in selected dryland crops	**Arun Kumar Shanker** M. Maheswari G. Rajeshwar Rao	2007	2012
32. CS/CP/18	Evaluation of horsegram mutants in multi-locational AICRP trials	**P.R. Reddy**	2007	2012
33. EF014 (NAIP) Comp.4	Development of Decision Support Systems for insect pests of major rice and cotton based cropping systems	**Y.G. Prasad** M. Prabhakar K.V. Rao G.R. Maruthi Sankar K. Nagasri A.V.M. Subba Rao B.M.K. Raju	2008	2012
34. CS/CP/20	Sustainable farming systems modules for small & marginal farmers in southern Telangana zone	**B.M.K. Reddy** V. Maruthi S.S. Balloli D.B.V. Ramana K.S. Reddy K. Kareemulla	2008	2012

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
35. EF016 (NPCC)	Impact of elevated CO2 and temperature on host herbivore interaction	**M. Srinivasa Rao** K. Srinivas M. Vanaja	2004	2012
36. CS/CP/25	Studies on Root characteristics in rainfed greengram and horsegram crop in relation to resource availability	**V. Maruthi** K. Srinivas K. Srinivas Reddy	2007	2012
37. EF023 (DST)	Root proliferation as influenced by soil management practices for drought and its physiological implications short duration pulses	**V. Maruthi** K. Srinivas Arun Kumar Shanker K.S. Reddy	2009	2012
38. CS/SS/03	Soil & Crop Management options for managing Zn deficiency in rainfed areas	**S.S. Balloli** P.K. Mishra G.R. Korwar K.L. Sharma and AICRPDA scientists	2008	2012
39. CS/SS/04	Improving Nutrient Use Efficiency through foliar nutrient supplementation	**S.S. Balloli**	2012	2015
40. CS/CP/19	Candidate gene approach for improvement of drought tolerance and yield in drylands	**M.M. Maheswari**	2008	2013
41. EF010 (APNL)	Enhancing tolerance of sorghum to abiotic stresses through genetic manipulation	**M.M. Maheswari** S.K. Yadav B. Venkateswarlu M. Vanaja N. Jyothi Lakshmi	2001	2012
42. CS/ALU/05	Evaluation of forage sorghum cultivars for different soil conditions	**G. Jayaram Reddy**	2009	2012
43. CS/Hort/08	Organic Cultivation of Fruits in Drylands	**V.S. Rao** N.N. Reddy M. Srinivasa Rao C.A. Rama Rao K. Sreedevi Shankar G.R. Maruthi Sankar	2008	2013
44. EF020 (AMASS)	Application of micro-organisms in agriculture and allied sectors (Nutrient Management, PGPR) (AMAAS)	S. Desai Minakshi Grover S.S. Balloli	2006	2012
45. EF021 (NAIP) Comp.4	Effect of abiotic stresses of the natural enemies of crop pests, Trichogramma, Chrysoperla and pseudomonas and mechanism of tolerance to these stresses	**S. Desai**	2009	2012
46. CS/CP/22	Survival and persistence of stress tolerant PGPR strains in the rhizosphere of dryland crops	**Minakshi Grover** S. Desai	2009	2012

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
47. EF015 (ICAR Network Project)	Application of micro organisms in Agriculture and allied sectors (AMAAS) – abiotic stress management (Management of Abiotic stresses)	**Minakshi Grover** S.K. Yadav	2006	2012
48. EF031 (ICAR Network Project)	Diversity of consortia of poly-functional rhizosphere microorganisms for nutrient supply, inducing tolerance to abiotic and biotic stresses in major rainfed production systems	**Minakshi Grover**	2009	2012
49. CS/CP/23	Improving the farming systems of small and marginal farmers in selected districts of Andhra Pradesh	**K.A. Gopinath** G. Ravindra Chary K. Kareemulla M. Osman Ch. Srinivasa Rao D.B.V. Ramana B.M.K. Raju	2009	2012
50. CS/CP/24	Integrated weed management in reduced/zero tillage crop production	**K.A. Gopinath** G.R. Korwar K.L. Sharma B. Sanjeeva Reddy G.R. Maruthi Sankar U.S. Saikia	2009	2012
51. EF036 (Lal Bahadur Shastri Young Scientist Award)	Crop yield and quality soil properties and economic returns under organic management in rainfed agro-ecosystem	**K.A. Gopinath**	2009	2012
52. CS/FN/02	Trends in food consumption and rural household food security in selected Dryland production systems of Andhra Pradesh	**K. Sreedevi Shankar** G. Nirmala N.N. Reddy	2008	2012
53. CS/FN/03	Development of ready-to-eat nutrient rich value added products with extrusion process technology from selected dryland crops	**K. Sreedevi Shankar** I. Srinivas C.R. Thyagaraj	2008	2012
54. CS/PP/13	Characterization of biotic stress in rainfed crops using hyperspectral radiometry	**M. Prabhakar** Y.G. Prasad S. Desai Arun Kumar Shanker P. Vijay Kumar	2010	2013
55. CS/Horti/09	Integrated nutrients & bio-inputs as components of horticultural crop production in dryland regions	**N.N. Reddy** B. Venkateswarlu V.S. Rao Minakshi Grover K.S. Reddy	2010	2014

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
56. CS/Horti/10	Developing supplemental irrigation schedules for sustainable vegetable production in dryland regions	**A. Gopala Krishna Reddy** **N.N. Reddy** **V.S. Rao** **K.S. Reddy**	2012	2014
SECTION OF TRANSFER OF TECHNOLOGY				
57. TOT/AE/24	Leveraging access to ICTs for improved rural livelihoods : development of strategic framework	**K. Nagasree** Sreenath Dixit K.V. Rao K. Ravi Shankar B. Venkateswarlu G. Ravi Kumar	2008	2012
58. TOT/AE/27	Assessment of Performance of Knowledge share Centers in technology dissemination	**K. Nagasree** K. Ravi Shankar Sreenath Dixit B.M.K. Raju	2009	2012
59. EF029 (ICAR/DARE)	Scaling up of water productivity in Agriculture for Livelihoods through Teaching-cum-Demonstrations, Training of Trainers and Farmers	**M.S. Prasad** C.R. Thyagaraj K. Nagasree K. Ravi Shankar D.B.V. Ramana G. Nirmala M. Osman	2007	2012
60. TOT/LM/04 (NRCM)	Invitro evaluation of enteric methane mitigation options for livestock fed with coarse crop residues as basal diet	**D.B.V. Ramana** S.K. Yadav P. Basava Reddy	2010	2013
61. TOT/LM/05 (NRCM)	Studies on Azolla and horsegram as lean season protein supplement in small ruminants	**D.B.V. Ramana** P.R. Reddy M. Muthukumar	2010	2013
62. D&A/AE/10	Farmers' Knowledge Perceptions and Adaptation Measures towards Climate Variability in different Agro-climatic Regions of Andhra Pradesh	**K. Ravi Shankar** A.V.M. Subba Rao G. R. Maruthi Sankar K. Nagasree	2010	2012
SECTION OF DESIGN & ANALYSIS				
63. D&A/AE/09	Economic Analysis of Rain Water Harvesting Structure – Farm Ponds	**C.A. Rama Rao** K. Kareemulla P.K. Mishra K.V. Rao B.M.K. Raju Ravi Dupdal	2009	2012
64. D&A/AS/01	Development of a database of rainfed districts	**B.M.K. Raju** K.V. Rao C.A. Rama Rao A.V.M. Subba Rao Josily Samuel	2009	2012

Institute Code No	Title of the Project	Investigators	Year of Start	Likely year of termination
65. D&A/AS/02	Unreaped yield potentials of major rainfed crops	**B.M.K. Raju** C.A. Rama Rao K.V. Rao A.V.M. Subba Rao G.R. Maruthi Sankar M. Osman Ravi Dupdal Josily Samuel	2011	2014
66. EF039 NAIP (Comp.1)	Policy and Institutional Options for Inclusive Agricultural Growth	**C.A. Rama Rao**	2009	2012
67. D&A/AE/11	An Economic Analysis of Agro-Met Advisory Services of AICRPAM centres	Ravi Dupdal	2012	2013
68. EF028 (NAIP) (Comp.3) **KVK**	Sustainable Rural Livelihoods through enhanced farming systems productivity and efficient support systems in rainfed areas	**Sreenath Dixit** CRIDA, ICRISAT, ANGRAU Scientists and NGOs	2007	2012
69. KVK/AE/03	Assessment of factors of farm productivity based on modeling of socio-economic variables of rainfed farmers	**M.S. Prasad** G.R. Maruthi Sankar K. Ravi Shankar C.R. Thyagaraj	2008	2012
70. EF042 **AICRPDA**	Technology transfer of good agricultural practices (GAP) management to improve profitability, sustainability and income from rainfed farming in Ranga Reddy district of Andhra Pradesh	**G. Nirmala**	2011	2012
71. PC(D)/1	Assessment of effects of soil and weather variables on sustainable rainfed agriculture using multivariate statistical and simulation models	**G. R. Maruthi Sankar** P.K. Mishra M. Osman K.L. Sharma G.G.S.N. Rao	2008	2014
72. PC(D)/2	Assessment of impact of regional climate variability/change on agricultural land use in rainfed regions	**G. Ravindra Chary** P.K. Mishra G.G.S.N. Rao V.U.M. Rao, K.V. Rao M. Osman, G. Pratibha Ch. Srinivasa Rao A.V.M.S. Rao, B.M.K. Raju Arun Kumar Shanker & Scientists from AICRPDA & AICRPAM	2009	2012

13 Consultancy, commercialization and intellectual property management

13.1 Consultancy

Impact Evaluation Study of Indo-German Watershed Development Program (IGWDP-AP) in Andhra Pradesh, funded by IGWDP-AP Unit, Hyderabad

Watersheds evaluated are Laxmipur, Shivar Venkatapur, Kakatiya and Shettihadapnur in Karimnagar, Medak, Warangal and Adilabad districts of Telangana region in Andhra Pradesh, respectively. Correspondingly the PFAs are namely KRUSHI, PEACE, MARI and COFA, respectively (**Rs. 4.06 lakhs**).

Prioritization of Rainfed Areas of the Country, funded by NRAA, New Delhi.

National Rainfed Area Authority (NRAA) awarded this consultancy to Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad as lead institute to work in collaboration with Indian Agricultural Statistics Research Institute (IASRI), New Delhi. CRIDA developed a "Natural Resource Index" (NRI) comprising of nine variables, viz., rainfall, frequency of drought, available water content, extent and per cent of degraded and wastelands, irrigation intensity, extent and per cent of rainfed areas and ground water status. Similarly, IASRI constructed an "Integrated Livelihoods Index" (ILI), which is a composite of three sub-indices, viz., socio-economic index, health and sanitation index and infrastructure index. Rainfed Areas Prioritization Index (RAPI) was derived by assigning two-thirds weight to NRI and one-third weight to ILI. Accordingly, the top one-third districts (167) based on RAPI score are considered as high priority districts for taking up crop and livestock-based interventions. The report has been published by the Planning Commission (**Rs. 18.75 lakhs**).

13.2 Commercialization

An MoU has been signed with Watershed Organization Trust (WORT), Pune for R&D, promotion and commercializing of technologies especially in watershed research.

13.3 Intellectual property management

- A patent 9319/CHE/2011 has been filed "Insect parasitoid and predator collection device" and the device has been designed for collecting the parasitoids and predators emerging from infested insect pests easily. The unit was designed by Dr. M. Prabhakar and his associates.
- Seventeen elite germplasm lines of horsegram (CRHG-01, CRHG-02, CRHG-03, CRHG-05, CRHG-06, CRHG-07, CRHG-08, CRHG-09, CRHG-10, CRHG-11, CRHG-12, CRHG-13, CRHG-14, CRHG-15, CRHG-16, CRHG-17, CRHG-18) developed by Dr P. R. Reddy and his associates were submitted for registration to NBPGR, New Delhi. Out of the above, CRHG-6 and CRHG-8 were registered with identity numbers INGR11017 and 11018.
- An application has been filed for copyright protection of the software "Weather Cock (Weather Analysis Tool)". The software was developed by VUM Rao and his associates.
- Copyright application submitted for Methodology for Post-facto assessment of watershed development projects developed under ICAR National Fellow Scheme. The application was made jointly by Kaushalya Ramachandran, K.L. Sharma, U.K. Mandal and B.Venkateshwarlu from CRIDA to The Registrar of Copyright, Copyright Office, New Delhi.

14 Meetings of RAC/IRC/IMC/SAC/QRT

XII Plan Sub Group Meeting

The Planning Commission has constituted an Expert Group on NRM and Rainfed Farming under the chairmanship of Dr.I.P.Abrol. Under this Group, a Sub Group was constituted on Production System with Director, CRIDA as the Convener. The Sub Group meeting was held at CRIDA on 30.05.2011 under the chairmanship of Dr.B.Venkateswarlu, Director, CRIDA. The Members of the Sub Group from CAZRI, CIFA, NRSC, WASSAN and CALPI have participated and made presentations on the respective components. It was decided that the report may contain constraints of production systems, livestock, marketing and opportunities for fishery in small water bodies.

IRC Meetings

The Institute Research Council meeting was held on on May 10, 11, 27, 28 & June 8, 2011 under the Chairmanship of Director, CRIDA. More than 75 projects funded by Institute and external agencies were reviewed critically. It was decided to reduce the number of projects to less than 60. During this year, most of the new projects are to be integrated with the new initiative on climate resilient agriculture.

VI QRT meeting

The VI QRT for CRIDA was constituted under the Chairmanship of Dr. H.P. Singh, former Director, CRIDA with Dr.C.J. Itnal, Dr.L.S. Rathore, Dr.Shiv Raj Singh, Dr.Ramesh Chand, Dr. Sidda Ramappa and Dr.G.S. Chaturvedi as members and Dr. S. Desai, Principal Scientist, CRIDA as Member-Secretary. The first QRT meeting was held in New Delhi on 16.05.2011 for interaction with DDG (NRM). In this meeting, the road map for the review was finalized.

The second meeting was held at CRIDA during 3-4 June 2011. In this the complete programs of the Institute were reviewed Division/Section wise. Presentations were made by the Director, Heads of Divisions and Project Coordinators. The members appreciated the achievements of the institute and the vision for XII Five Year Plan with focus on climate change and participatory action research.

Final stakeholder meeting of QRT on Dec 15-16, 2011

As a part of the series of field visits and on site reviews, the 3rd meeting was held at UAS, Bangalore during 13-15 June 2011. All the centers of AICRPDA, AICRPAM and NPCC falling in the states of A.P., Tamil Nadu, Kerala, Karnataka and Maharashtra made individual presentations. The team visited the field experiments and demonstration blocks at UAS, Bangalore. The Committee made several suggestions for the technical program for the XII Plan. The team appreciated the achievements of CRIDA and the network projects. The team held a Stakeholders' consultation at CRIDA on December

15-16, 2011 which was also attended by DDG (NRM) and took the feedback before finalizing the recommendations. The VI Quinquennial Review Team under the Chairmanship of Dr. H.P. Singh, Former Director, CRIDA reviewed the progress of CRIDA-AICRPDA-AICRPAM-NPCC for the period 2006-2010 and submitted its final report to ICAR during December, 2011.

RAC meeting

The 20th Research Advisory Committee Meeting was held on 30th November, 2011 under the chairmanship of Dr. R. Dwarakinath. The Committee reviewed the progress under the on-going projects and made several suggestions for horizontal diffusion of dryland technologies to farmers. A special session was held on how CRIDA can take leadership role not only in technology generation but also its upscaling. The members made several suggestions regarding design of farm ponds, adoption of silvi pasture models, measurement of carbon in field experiments. The committee commended the progress made under climate resilient agriculture initiative (NICRA) in a short time.

RAC meeting in progress

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

Scientist	Topic	Period	Venue
M. Maheswari	One-day brainstorming session on Onion and garlic in changing climate conditions	2 April, 2011	National Horticultural Research & Development Foundation, Nashik
B. Venkateswarlu	National conference on sustainable agriculture	8 April, 2011	Kolkata
K.S. Reddy	International water convention on water security and climate change: challenges and opportunities	13-15 April, 2011	New Delhi
A.G.K. Reddy	Brainstorming session on urban and periurban agriculture: policy framework	14 April, 2012	NAAS complex, New Delhi
G. R. Korwar	Strategic research for adaptation and mitigation strategies through soil, water and nutrient management	19-20 April 2011	CRIDA, Hyderabad
B. Venkateswarlu D.B.V. Ramana	Thematic workshop of NICRA on livestock	27 April, 2011	NDRI, Karnal
D.B.V. Ramana	Technical workshop under sponsored research component of NICRA	4-5 May, 2011	CRIDA, Hyderabad
B. Venkateswarlu	Thematic workshop on fisheries under NICRA	6 May, 2011	CMFRI, Cochin
B. Venkateswarlu	National workshop on dryland development to maximize crop productivity	12 May, 2011	TNAU, Coimbatore
C.A. Rama Rao	Financial instruments for climate change adaptation	16 May, 2011	GIZ, New Delhi
G. R. Rao	AICRPAF Annual Workshop	21-23 May, 2011	KAU Thrissur
I.Srinivas B.Sanjeeva Reddy	Andhra Pradesh agricultural machinery manufacturers meet (appammm-2011)	27-30 May, 2011	ANGRAU, Hyderabad
K.V. Rao	Sub Group-IV committee meeting on enhancing preparedness for climate change	7 June, 2011	NRM Division, ICAR, New Delhi
G. R. Korwar M. Maheswari	Meeting-cum-workshop of the heads of divisions and regional stations/ centres	13-15 June, 2011	CIAE, Bhopal

Scientist	Topic	Period	Venue
B. Venkateswarlu	National workshop on improving soil productivity in rainfed areas	29-30 June, 2011	IISS, Bhopal
C.A. Rama Rao	Workshop on agri-services for inclusive rural growth	30 June, 2011	CESS, Hyderabad
N. Ravi Kumar	GARUDA-NKN partners meet	15- 16 July, 2011	C-DAC, Bengaluru
P.Vijaya Kumar	Consultation workshop on climate resilience through risk reduction using micro insurance solutions	21 July, 2011	India International Center, New Delhi
M. Maheswari	NICRA thematic workshop on horticulture	28 July, 2011	IIHR, Bengaluru
B. Venkateswarlu	Meeting on rainfed agriculture chaired by President of India	5 August, 2011	Bengaluru
M. Vanaja	Brain storming session of researchers in plant physiology and biochemistry'	5-6 August 2011	IARI, New Delhi
G. R. Rao	Expert consultation meet on tree fodder and quality improvement	19 August, 2011	NASC, New Delhi
S.K. Yadav	DBT task force on agricultural biotechnology	23 August, 2011	TNAU, Coimbatore
K. L. Sharma	National conference 5th round table meet. Sustainable agriculture and climate change	23-24 August, 2011	CRIDA, Hyderabad
P.Vijaya Kumar	Workshop on environment and drought disaster management	25 August, 2011	APARD, Rajendranagar
B. Venkateswarlu	ICAR-ICARDA centre of excellence meeting	2 September, 2011	New Delhi
V.U.M.Rao B.Bapuji Rao A.V.M.S.Rao	Tropmet symposium	14-16 September, 2011	Marri Chennareddy Institute, Hyderabad
B. Venkateswarlu M Srinivasa Rao	AICRPAM Annual Workshop	22-24 September, 2011	HPKVV, Palampur
I.Srinivas	National mega meet on technology commercialization	29 September - 1 October, 2011	NAARM, Hyderabad
S.K. Yadav	GM platform meet	14 October, 2011	NRCPB, New Delhi
B. Venkateswarlu	USAID-FARMS meeting	18-19 October, 2011	New Delhi
D.B.V. Ramana	Interactive meeting of stakeholders to prioritize research programmes on meat sector	5 November, 2011	NRC Meat, Hyderabad
K. Ravi Shankar	International conference on innovative approaches for agricultural knowledge management: global extension experiences.	9-12 November, 2011	Vigyan Bhavan and NASC Complex, New Delhi
B.Sanjeeva Reddy	Brainstorming session on precision farming, farm mechanization and energy	16 November, 2011	IASRI, New Delhi
I.Srinivas	Innovations 4 industry meet in crop science	19 November, 2011	NAARM, Hyderabad

Scientist	Topic	Period	Venue
G. Nirmala	DST group monitoring workshop	23-24 November, 2011	NIN, Hyderabad
Minakshi Grover	National symposium on biology of infection immunity and disease control in pathogen-plant interaction	2-4 December, 2011	UoH, Hyderabad
B. Venkateswarlu	National workshop on simulation modeling	9 December, 2011	Bengaluru
K.V. Rao A.V.M.S.Rao	National workshop on climate observation and modelling for multi-disciplinary applications (CORMMA)	9-10 December, 2011	CMMACS, Bengaluru
C.A. Rama Rao M Srinivasa Rao M. Prabhakar	National seminar on agrometerological research and services to combat climate change challenges	9-10 December, 2011	BCKV, Kalyani
K.S. Reddy G. Nirmala	National extension education congress on emerging models of technology application for agri rural development	17-19 December, 2011	Goa
B. Venkateswarlu K. L. Sharma C.A. Rama Rao R.Nagarjuna Kumar	XXIII biennial workshop of AICRPDA	19-23 December, 2011	MPKV, Solapur
K.V. Rao	Workshop on finalizing methodologies for quantification of environmental services under MGNREGA	20 December, 2011	IISC, Bengaluru
V.U.M.Rao P.Vijaya Kumar G. Ravindra Chary	SAARC expert group meeting (EGM) on regional drought monitoring and early warning systems in South Asia	27-28 December, 2011	CRIDA, Hyderabad
K.S. Reddy	All India seminar on 'conserve water and preserve climate'	28-29 December, 2011	Hyderabad
B. Venkateswarlu Kaushalya Ramachandran	Consultation meet on policy framework on agriculture research & education	9 January, 2012	New Delhi
B. Venkateswarlu G. Ravindra Chary S. Desai	Meeting of expert team constituted by ICAR to assess agricultural situation in Anantapur district	18-20 January, 2012	Anantapur
M. Prabhakar	8th International safflower conference	19-23 January, 2012	DOR, Hyderabad
M Srinivasa Rao	Training cum workshop on real time pest surveillance (RTPS) for rice & tomato	20 -21 January, 2012	NCIPM, Pusa campus, New Delhi
B. Venkateswarlu A.G.K. Reddy	National dialogue on climate resilient horticulture	28-29 January, 2012	IIHR, Bengaluru
G. R. Korwar	Climate change awareness programme	2 February, 2012	ARS, Anantapur

Scientist	Topic	Period	Venue
C.A. Rama Rao B. M. K. Raju	National seminar on identification and prioritization of statistical indicators on climate change	3-4 February, 2012	CESS, Hyderabad
B. Venkateswarlu C.A. Rama Rao M. Vanaja M Srinivasa Rao	International conference on climate change, sustainable agriculture and public leadership	7-9 February 2012	NASC, New Delhi
A.V.M.S.Rao, V.U.M.Rao P. Vijaya Kumar	Ag MIP, South Asia workshop	20-24 February, 2012	ICRISAT, Hyderabad
I.Srinivas	State level agri tech exhibition on farm mechanization and scientific water management	23-24 February, 2012	Nalgonda, A.P
B. Venkateswarlu	Workshop on rainfed farming	27 February, 2012	IISC, Bengaluru
K.S. Reddy	46th ISAE annual convention and international seminar on grain storage	27-29 February, 2012	GBPUAT, Pantnagar
C.A. Rama Rao	National consultation on climate change and agriculture adaptation and mitigation by small and marginal farmers	28 February, 2012	India Habitat Centre, New Delhi
V.U.M.Rao	Expert committee meeting of ministry of agriculture, government of india for implementation of the hail control system in HP	1-3 March, 2012	Shimla
D.B.V. Ramana	Workshop cum poultry stakeholders group meet	2 March, 2012	TNVASU, Namakkal
Kaushalya Ramachandran	Application of geographic tools for rainfed agriculture, watershed management and climate change	5 March 2012	MKU, Madurai
B. M. K. Raju K. Ravi Shankar	National Workshop on opportunities for enhancing land and water productivity in rainfed agriculture	10 March, 2012	CRIDA, Hyderabad
M Srinivasa Rao	Training cum workshop on real time pest surveillance (RTPS) pigeonpea and groundnut crops	15-16 March ,2012	NCIPM, New Delhi
I.Srinivas B.Sanjeeva Reddy	Interaction meet of scientists of farm machinery & power and mechanical engineering	16 - 18 March, 2012	CIAE, Bhopal
R. V. Adake	National consultation on Application of harvested rainwater in ponds	19-20 March, 2012	CRIDA, Hyderabad
A.G.K. Reddy	Plant variety protection and commercialization	21 March, 2012	DSR, Hyderabad
K.S. Reddy	Seminar on water and food security	22 March, 2012	Hyderabad

Scientist	Topic	Period	Venue
B. Venkateswarlu M Srinivasa Rao V.U.M. Rao A.V.M.S. Rao	Final workshop of network project on climate change	22-23 March, 2012	NASC Complex, New Delhi
B. Venkateswarlu V.U.M. Rao M Srinivasa Rao A.V.M.S. Rao	National seminar on Indian agriculture: preparedness for climate change	24 -25 March, 2012	NASC Complex, New Delhi
Kaushalya Ramachandran	Global natural disasters – identifying hotspots, reporting disasters & improving country-level disaster preparedness	25-26 March 2011	Osmania University, Hyderabad
C.A. Rama Rao	Workshop on re-searching rainfed agriculture	26-27 March, 2012	IGIDR, Mumbai
V.U.M.Rao A.V.M.S.Rao	National seminar on sustainable agriculture and food security: challenges in changing climate	27-28 March, 2012	CCS-HAU, Hisar

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

16.1 Workshops, seminars and trainings

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

Programme	Period	Venue
Technical workshop under sponsored research component of NICRA	4-5 May, 2011	CRIDA, Hyderabad
Training program on crop growth simulation model (DSSAT) for wheat	23 – 28 May, 2011	PAU, Ludhiana
Brainstorming session on management of natural resources and rainfed farming during xii plan period, sub-group ii meeting	30 May, 2011	CRIDA, Hyderabad
One-day orientation program on use of automatic weather station and its maintenance	31 May-03 June, 2011	CRIDA, Hyderabad
Thematic group meeting on evaluation of major food and horticultural crops for tolerance to climatic stresses and genetic enhancement of tolerance	6-7 June, 2011	CRIDA, Hyderabad
Capacity building training programme on production and farming systems for livelihood improvement in rainfed areas (NRAA, GOI, New Delhi)	28-30 June, 2011	CRIDA, Hyderabad
Training program on "techniques of water conservation and rainwater harvesting for drought management from at CRIDA, Hyderabad, funded by SAARC disaster management centre, New Delhi, India	18- 29 July, 2011	CRIDA, Hyderabad
Training program on crop growth simulation model (DSSAT) for groundnut	8-12 August, 2011	AAU, Anand
ICAR sponsored training course on agricultural mechanization for enhancing water productivity of dryland crops	16 -29 August, 2011	CRIDA, Hyderabad
National conference on sustainable agriculture and climate change	23-24 August, 2011	CRIDA, Hyderabad
Capacity building training programme on sustainable agriculture production through innovative approaches for enhanced livelihoods	2-15, September, 2011	CRIDA, Hyderabad
Training programme on production and farming systems for livelihood improvement in rainfed areas (sponsored by RGMWM, GOI, MP)	5-9 September, 2011	CRIDA, Hyderabad

Programme	Period	Venue
National stakeholders consultation on climate change platform	19-20 September, 2011	CRIDA, Hyderabad
In-plant training programme on "agricultural mechanization" for final year M.Tech (Ag.Engg) students	3 October – 2 November, 2011	CRIDA, Hyderabad
Workshop on Capacity development for farm management strategies to improve crop water productivity using "AQUACROP"- a new crop model of FAO	18-22 October, 2011	CRIDA, Hyderabad
Training program on crop growth simulation model (DSSAT) for rice crop	24 – 29 October, 2011	CRIDA, Hyderabad
Model training course on impact of climate change in rainfed agriculture	22-29 November, 2011	CRIDA, Hyderabad
ICAR sponsored short course on soil carbon sequestration for climate change mitigation and food security	24 November – 3 December, 2011	CRIDA, Hyderabad
In-plant training programme on farm implements and machinery for final year B.Tech (Ag.Engg) students	01 December – 31 March, 2012	CRIDA, Hyderabad
Model training course on mechanization in dryland agriculture	13-20 December, 2011	CRIDA, Hyderabad
ICAR sponsored short course on crop –weather modeling	13 – 22 December, 2011	CRIDA, Hyderabad
SAARC expert group meeting (EGM) on regional drought monitoring and early warning in South Asia, funded by SAARC disaster management centre, New Delhi, India.	27-28 December, 2011	CRIDA, Hyderabad
Capacity building training programme on use of high science tools and methodologies in planning, implementation and monitoring of watershed programmes under IWMP	3-9 February 2012	CRIDA, Hyderabad
Training program on decision support system for agro-technology transfer (DSSAT) under national NICRA	13-17 February, 2012	CRIDA, Hyderabad
One day training program on farm implements for mechanizing small farms" jointly organized by CRIDA and ICRISAT	14 February, 2012	CRIDA, Hyderabad
Training-cum-review meeting of AICRPAM-NICRA	18-19 February, 2012	CRIDA, Hyderabad
Short course on database analysis and management in climate variability and rainfed agriculture	21-25 February 2012	CRIDA, Hyderabad
State level agri tech exhibition on farm mechanization and water management	23-24 February, 2012	ISAE –APC, Nalgonda
Short course on database analysis and management in climate variability and rainfed agriculture	27 February - 2 March, 2012	CRIDA, Hyderabad
ICAR sponsored training course on integrated nutrient, pest and disease management in dryland crops	28 February – 12 March, 2012	CRIDA, Hyderabad.
Quantification of environmental services under MGNREGA	5-7 March, 2012	CRIDA, Hyderabad
National workshop on opportunities for enhancing land and water productivity in rainfed agriculture of NAIP Component-I	10 March, 2012	CRIDA, Hyderabad

Programme	Period	Venue
Capacity building training programme on "use of high science tools and methodologies in planning, implementation and monitoring of watershed programmes under IWMP	13-19 March, 2012	CRIDA, Hyderabad
Farm implements for mechanizing small farms for male and female farmers of Parbhani and Nanded districts of Maharashtra	14 March, 2012	CRIDA, Hyderabad
National consultation meet on application technologies for harvested rainwater in ponds	20-21 March, 2012	CRIDA, Hyderabad

16.2 Other Activities

World Soil Day

The Southern Chapter of National Academy of Agricultural Sciences along with Hyderabad Chapter of the Indian Society of Soil Science jointly organized "World Soil Day" on 5th December, 2011 to focus on the importance of soil health for food security of the country. The programme was organized at Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad, and in memory of late Padmasree Dr. I.V. Subba Rao, former Vice-Chancellor, ANGRAU and former President of Indian Science Congress, a special lecture "Soil Science Research under Changing Climate Scenario" was delivered by Dr. B. Venkateswarlu, Director, CRIDA. The programme was chaired by Dr. M. V. Shantaram, Eminent Soil Scientist and former Dean, ANGRAU. About 120 agricultural scientists from various research institutes like CRIDA, ANGRAU, NRSC, DRR, DOR, ICRISAT, and Fellows of National Academy of Agricultural Sciences in the southern region attended the programme. Scientists discussed

various issues on soil health improvement, impacts of changing climate on food security of India, drought, floods, and weather aberrations, green house gas (GHG) emissions and soil carbon sequestration. Dr. Ch. Srinivasa Rao, Principal Scientist, CRIDA and Fellow of NAAS and Dr. G. Jayasree, Senior Scientist, ANGRAU facilitated the programme.

Foundation Day of CRIDA

The 25th CRIDA Foundation Day was organized on 12.04.2011. Mr. Mathew C. Kunnamkal, IAS, Director General, National Institute for Rural Development, Hyderabad was the chief guest. Dr.B.Venkateswarlu, Director, CRIDA introduced the

institute activities and its achievements. The Chief Guest delivered the Foundation lecture on "MGNREGS: The Road Ahead". Various issues regarding MNREGS were highlighted and role institutions like CRIDA can play in effective implementation of the scheme was emphasized. There was lively interaction on the topic thereafter. On this occasion, awards were given away to institute staff members with best performance in different categories. Mr.B.Buchaiah in Administrative category, Mr.P.Yadagiri in Technical Staff category and Mr.J.Mallesh in Supporting staff category were given the best employee award for the year 2010-11.

Expert group meeting (EGM) on regional drought monitoring and early warning systems

An Expert Group Meeting (EGM) on "Regional Drought Monitoring and Early Warning Systems" sponsored by SAARC was held during 27- 28th December, 2011 at CRIDA, Hyderabad. Experts from six countries participated to discuss drought monitoring issues. Shri Mohan Kanda IAS, former chief secretary, Govt. of A.P. and former member NDMA addressed the participants. Dr. O. P. Mishra,

Director SDMC, Dr. B. Venkateswarlu, Director CRIDA also shared their views on the subject. The recommendations of the meet can be seen on *www.saarc-sec.org*.

Farmers Day

CRIDA celebrated farmers' day on 21.09.2011 at Gunegal Research Farm with large participation of farmers, Extension workers, officials from line

departments and exhibition stalls. Dr. B. Venkateswarlu Director, CRIDA presided over the function and Dr.R. Ragava reddy, Ex. Vice Chancellor, ANGRAU was the Chief Guest. He emphasized the need of water harvesting in dryland agriculture and the utility of seed drills with herbicide application developed by CRIDA. Director, CRIDA scientists explained various dryland technologies developed by CRIDA and their usefulness and farming community by demonstrating the same in field demonstrations in CRIDA Farm. Farmers - Scientists interactions were also held with question answer session.

Hindi fortnight

The Hindi Fortnight was organized from 3-17 September, 2011. On this occasion Hindi Noting & Drafting, Hindi-English technical, terminology, Hindi Essay, competitions and 2 day workshop were organized. Winners were awarded cash prizes by the Director on the concluding day.

Official language technical seminar and liaison meeting

Two days National Technical Seminar was organized at CRIDA during 1-2 November, 2011 for CRIDA Technical and Administrative Staff and other Central Govt. Officials. A meeting of Liaison Officers of Official Language organized on 16.12.2011 under the Hindi Teaching Scheme of DOL for Central Govt. Offices, Undertaking, banks, etc., situated at Hyderabad-Secunderabad.

17 Distinguished Visitors

- A high level delegation from Ethiopian Institute of Agricultural Research visited CRIDA during February, 2011. Dr. Adefres Teklewold, Team Leader along with eight scientists were briefed about the research and developments in the area of rainfed agriculture in India. Senior faculty members of the institute interacted with the team followed by a field visit. The team leader expressed his happiness and found many of the technologies developed by CRIDA quite relevant to Ethiopian agriculture.

- Shri V.Venkatachalam, I.A.S. Additional Secretary, Ministry of Agriculture and Cooperation, Govt. of India visited the Institute and NAIP Project villages on February 3, 2011.

- Dr. B.M. Prasanna, Director, Global Maize Programme, CIMMYT, Nairobi, Kenya, visited CRIDA on 23rd April, 2011 and delivered a talk on CIMMYT's experience in combating abiotic stress in maize.

- Dr. B.A. Stewart, Director and Distinguished Professor, Dryland Agriculture Institute, West Texas, A&M University visited the Institute on 6th June, 2011. Dr. Stewart was a distinguished dryland scientist who helped in the initial years of the Institute and trained several Indian scientists in the US. He recalled fond memories of his earlier days spent at CRIDA during 70s.

- **Visit of African Agricultural Scientists**

  A seven member African agricultural scientists' team visited CRIDA on September 14, 2011 for exposure visit to Watershed programme in India. The team interacted with CRIDA scientists on key technologies of soil and water conservation and livelihood enhancement.

- **Visit of International trainees of NIRD**

  The trainees of International Training programme on "Disaster Management" visited CRIDA on 08.11.2011. The trainees got practical insights on dryland agriculture and technologies to reduce vulnerability to climate variability.

18 Personnel

(As on 31 March, 2012)

Dr. B. Venkateswarlu	**Director**

Division of Resource Management

Dr. G.R. Korwar	Principal Scientist (Agronomy) & Head
Dr. C.R.Thyagaraj	Principal Scientist (Farm Machinery and Power)
Dr. A.S. Rao	Principal Scientist (Agricultural Meteorology)
Dr. K. Srinivas Reddy	Principal Scientist (Soil and Water Conservation Engineering)
Dr. G. Rajeshwara Rao	Principal Scientist (Forestry)
Dr. Ch. Srinivasa Rao	Principal Scientist (Soil Science)
Dr. G. Pratibha	Senior Scientist (Agronomy)
Dr. K. Srinivas	Senior Scientist (Soil Science)
Dr. K.V. Rao	Senior Scientist (Soil and Water Conservation Engineering)
Dr. J.V.N.S. Prasad	Senior Scientist (Agronomy)
Dr. B. Sanjeeva Reddy	Senior Scientist (Farm Machinery and Power)
Dr. I. Srinivas	Senior Scientist (Farm Machinery and Power)
Dr. Ravikanth V. Adake	Scientist (Senior Scale)(Farm Machinery and Power)
Dr. Manoranjan Kumar	Senior Scientist (Soil and Water Conservation Engineering)
Sri. G. Venkatesh	Scientist (Forestry)
Sri . N. S. Raju	Scientist (Computer Applications)
Smt. Pushpanjali	Scientist (Soil Science - Pedology)
Dr. A. K. Indoria	Scientist (Soil physics / Soil and Water Conservation)
Kum. Reshma Shinde	Scientist (Soil Science)
Sri. J. B. Ramappa	Technical Officer (T-7/8)
Smt. K. Usha Rani	Technical Officer (T-7/8)
Sri. Ram Kumar	Technical Officer (T-6)
Sri. K. Venkanna	Technical Officer (T-6)
Sri. S. Veeradas	Technical Officer (T-5)
Sri. K. L. Prasad	Technical Officer (T-6)
Sri. P. Yadaiah	Technical Officer (T-5)
Sri. K. Sambasiva Rao	Technical Officer (T-5)

Division of Crop Sciences

Dr. M. Maheshwari	Principal Scientist (Plant Physiology) & Head
Dr. P. Raghuram Reddy	Principal Scientist (Plant Breeding)
Dr. V.S. Rao	Principal Scientist (Horticulture)
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. M. Vanaja	Principal Scientist (Plant Physiology)

Dr. S.S. Balloli	Principal Scientist (Soil Science)
Dr. B.M.K. Reddy	Senior Scientist (Agronomy)
Dr. M. Srinivasa Rao	Senior Scientist (Entomology)
Dr. V. Maruthi	Principal Scientist (Agronomy)
Dr. Arun Kumar Shanker	Senior Scientist (Plant Physiology)
Dr. M. Prabhakar	Senior Scientist (Entomology)
Dr. N. Jyothi Lakshmi	Senior Scientist (Senior Scale) (Plant Physiology)
Dr. K.A. Gopinath	Senior Scientist (Agronomy)
Dr. Minakshi T. Grover	Senior Scientist (Microbiology-Plant Science)
Dr. N. Ravi Kumar	Senior Scientist (Computer Applications)
Dr. K. Sreedevi Shankar	Senior Scientist (Food & Nutrition)
Dr. G. Jayaram Reddy	Scientist (Senior Scale) (Agronomy)
Dr. A. G. K. Reddy	Scientist (Horticulture)
Dr. K. Salini	Scientist (Plant Breeding)
Smt. P. Anantha V. Rao	Technical Officer (T-7/8)
Sri. Jainender	Technical Officer (T-6)
Smt. M. Pushpalata	Technical Officer (T-6)
Sri. S.S. Shishodia	Technical Officer (T-5)

Section of Design and Analysis

Dr. C.A. Rama Rao	Principal Scientist (Agricultural Economics) & Head
Dr. B.M.K. Raju	Senior Scientist (Agricultural Statistics)
Dr. Josily Samuel	Scientist (Agricultural Economics)
Sri Ravi Dupdal	Scientist (Agricultural Economics)

Section of Transfer of Technology

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

All India Coordinated Research Project for Dryland Agriculture

Dr. G.R. Maruthi Sankar	Principal Scientist (Agricultural Statistics) & Project Coordinator
Dr. G. Ravindra Chary	Principal Scientist (Agronomy)
Sri. R. Nagarjuna Kumar	Scientist (Computer Applications)
Dr. A. Girija	Technical Officer (T-7/8)
Sri. L. Sree Ramulu	Technical Officer (T-5)

All India Coordinated Research Project on Agrometeorology

Dr. V.U.M. Rao	Principal Scientist (Agricultural Meteorology) & Project Coordinator
Dr. B. Bapuji Rao	Principal Scientist (Agricultural Meteorology)
Dr. P Vijay Kumar	Senior Scientist (Agricultural Meteorology)
Dr. A.V.M. Subba Rao	Scientist (Senior Scale) (Agricultural Meteorology)
Sri. I. R. Khandgonda	Technical Officer (T-6)

National Fellow	
Dr. K.L.Sharma	Principal Scientist (Soil Science) & ICAR National Fellow
Dr. Kausalya Ramachandran	Principal Scientist (Geography) & ICAR National Fellow
NICRA Technology Demonstration	
Dr. Sreenath Dixit	Principal Scientist (Agricultural Extension)
Smt. P. Laksmi Narasamma	Technical Officer (T-7/8)
KVK	
Dr. B.M.K. Reddy	Senior Scientist (Agronomy) & OIC
Dr. G.Nirmala	Senior Scientist (Agricultural Extension)
Sri. R. Joseph	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-7/8)
Dr. D. Sudheer	Technical Officer (T.6)
Er. S. Vijaya Kumar	Technical Officer (T6)
Sri. G. Srikrishna	Technical Officer (T6)
Prioritization, Monitoring and Evaluation Cell	
Dr. M. Osman	Principal Scientist (Agronomy) & Head
Dr. S.S. Balloli	Principal Scientist (Soil Science)
Dr. Shaik Haffis	Technical Officer (T-7/8)
Agriculture Knowledge Management Unit	
Dr. N. Ravi Kumar	Senior Scientist (Computer Applications) & OIC
Sri. P. Chandrasekhar	Technical Officer (T-6)
Library	
Dr. Arun Kumar Shankar	Senior Scientist (Plant Physiology) & OIC
Sri. A. Malla Reddy	Technical Officer (T-6)
Farm Management	
Dr. G. R. Korwar	Principal Scientist (Agronomy)
Dr. S. Deasi	Principal Scientist (Plant Pathology)
Dr. G. Rajeshwara Rao	Principal Scientist (Forestry)
Dr. K. Srinivas Reddy	Principal Scientist (Soil and Water Conservation Engineering)
Dr. M. Srinivasa Rao	Senior Scientist (Entomology)
Dr. K. A. Gopinath	Senior Scientist (Agronomy)
Hayathnagar Research Farm	
Sri. B.Chandra Mohan Reddy	Technical Officer (T-9)
Sri. S. Srinivasa Reddy	Technical Officer (T-7/8)
Sri. Ganesh Ramji Hedau	Technical Officer (T-6)
Sri. T. Laxmaiah	Technical Officer (T-5)
Gunegal Research Farm	
Sri. V. Sree Ramulu	Technical Officer (T-9)

Administration	
Sri. Ashish Roy	Chief Administrative Officer
Sri. S. K. C. Bose	Senior Finance & Accounts Officer
Sri. P. Prakash Babu	Administrative Officer
Sri. P. Pushpakar	Asst. Administrative Officer
Sri. P. Vijay Kumar	Asst. Administrative Officer
Sri. K. R. Srinivasa Rao	Asst. Administrative Officer
Sri. G. Jaganmohan Rao	Asssistant Finance & Accounts Officer
Sri. Ch. Srinivas	Technical Officer (T-5)
Vehicles	
Sri. Ashish Roy	Chief Administrative Officer & OIC
Sri. G. Prem Kumar	Technical Officer (T-6)
Sri. P. Yadi Reddy	Technical Officer (T-5) (Driver)
Sri. P. Nagendra Rao	Technical Officer (T-5) (Driver)
Sri. T. Ravi Kumar	Technical Officer (T-5) (Driver)
Hindi Cell	
Sri. Ashish Roy	Chief Administrative Officer & OIC
Sri. S.R.Yadav	Asst. Director (OL) and Public Relations Officer
Sri. G. Prabhakar	Technical Officer (T-5)
Works	
Dr. C.R.Thyagaraj	Principal Scientist (Farm Machinery and Power) & OIC
Sri. D. Srinivas	Technical Officer (T-5)
Landscaping	
Sri. P. Yadagiri	Technical Officer (T-5)
Sri. M. Ramulu	Technical Officer (T-5)

19 Acronyms

AAS ..... Agro-Advisory Services
ACU ..... Adult Cattle Unit
AD ..... Approximate Digestibility
AICRPAM ..... All India Coordinated Research Project on Agrometeorology
AICRPDA ..... All India Coordinated Research Project for Dryland Agriculture
AU ..... Andhra University
BC ..... Benefit Cost
BD ..... Bulk Density
Bt ..... *Bacillus thuringiensis*
CAZRI ..... Central Arid Zone Research Institute
CICR ..... Central Institute for Cotton Research
DAS ..... Days After Sowing
DRR ..... Directorate of Rice Research
DST ..... Department of Science and Technology
FP ..... Farmers Practice
FYM ..... Farm Yard Manure
GIS ..... Geographical Information System
GRF ..... Gunegal Research Farm
HC ..... Hydraulic Conductivity
HQ ..... Headquarters
HRD ..... Human Resource Development
HRF ..... Hayathnagar Research Farm
IAA ..... Indole Acetic Acid
ICAR ..... Indian Council of Agricultural Research
ICRISAT ..... International Crops Research Institute for the Semi-arid Tropics
ICT ..... Information and Communication Technology
IIHR ..... Indian Institute of Horticultural Research
IISc ..... Indian Institute of Science
IISS ..... Indian Institute of Soil Science
IMD ..... India Meteorological Department
IPE ..... Institute of Public Enterprise
IPM ..... Integrated Pest Management
IRC ..... Institute Research Council
JNTU ..... Jawaharlal Nehru Technological University
KVK ..... Krishi Vigyan Kendra (Agricultural Sciences Centre)
LAI ..... Leaf Area Index
LER ..... Land Equivalent Ratio
LGP ..... Length of Growing Period
MANAGE ..... National Institute of Agricultural Extension Management
MBC ..... Microbial Biomass Carbon
MBN ..... Microbial Biomass Nitrogen
MSAVI ..... Modified Soil Adjusted Vegetation Index
MSSRF ..... M.S. Swaminathan Research Foundation
MtlD ..... Mannitol-1-Phosphate Dehydrogenase
MWD ..... Mean Weight Diameter
NAA ..... Naphthalene Acetic Acid
NAARM ..... National Academy of Agricultural Research Management
NASC ..... National Agricultural Science Complex
NBAIM ..... National Bureau of Agriculturally Important Microorganisms
NBSS&LUP .. National Bureau of Soil Survey and Land Use Planning
NCAP ..... National Center for Agricultural Economics and Policy Research
NCMRWF ..... National Center for Medium Range Weather Forecasting
NDVI ..... Normalized Difference Vegetation Index
NGO ..... Non-governmental Organization
NICRA ..... National Initiative on Climate Resilient Agriculture
NIR ..... Near Infra Red
NIRD ..... National Institute for Rural Development
NR ..... Nitrate Reductase
NRAA ..... National Rainfed Area Authority
NRCS ..... National Research Center for Sorghum
NRCWA ..... National Research Center for Women in Agriculture
NRM ..... Natural Resource Management
NRSA ..... National Remote Sensing Agency
NWDPRA ..... National Watershed Development Program for Rainfed Areas
ORP ..... Operational Research Project
OTC ..... Open Top Chambers
OU ..... Osmania University
PET ..... Potential Evapotranspiration
PRA ..... Participatory Rural Appraisal
PSB ..... Phosphorus Solubilizing Bacteria
QRT ..... Quinquennial Review Team
RAC ..... Research Advisory Committee
RCR ..... Relative Consumption Rate
RDF ..... Recommended Dose of Fertilizer
RH ..... Relative Humidity
RSQI ..... Relative Soil Quality Index
RUE ..... Radiation Use Efficiency
SAU ..... State Agricultural University
SAVI ..... Soil Adjusted Vegetation Index
SMW ..... Standard Meteorological Week
TAR ..... Technology Assessment and Refinement

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