CRRI

वार्षिक प्रतिवेदन
ANNUAL REPORT 2011-12

भाकृअनुप ICAR

केंद्रीय चावल अनुसंधान संस्थान
भारतीय कृषि अनुसंधान परिषद

Central Rice Research Institute
(Indian Council of Agricultural Research)

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Preface

It is a matter of pride that India has achieved a record rice production of 104.3 million tonnes during 2011-12. It becomes possible due to favourable policy of the Government, technology back up provided by the research institutes, appropriate delivery mechanisms and painstaking efforts of farmers. However, it remains still challenging to sustain and further enhance the productivity in order to feed the ever-growing population which is expected to reach 1.6 billion by 2050. Rice being the principal staple crop of our country, any deterioration of rice production system because of declining resource base, adverse weather conditions under rapidly changing climate, etc. would negatively impact our food security. Research efforts at CRRI using traditional and modern tools have been successful in developing improved and hybrid varieties and other rice production technologies suitable for diverse rice ecologies in the country, which have greater environmental, economic and social benefits. The Institute continues striving for developing varieties and technologies to make rice farming profitable and attractive. Reducing the cost of cultivation, enhancing the resource use efficiency, farm mechanization and drudgery reduction, designing effective crop protection strategies, technology dissemination and capacity building are being pursued with vigour. As nodal monitoring agency, CRRI is actively involved in "Bringing Green Revolution in Eastern India" programme of the Department of Agriculture & Cooperation, Government of India, New Delhi which is addressing the constraints limiting the productivity of rice-based cropping systems in Eastern India. The Annual Report of 2011-12 is a compilation of the progress made in the last one year on all the above aspects. As the premier rice research institute in the country, CRRI has strong commitment to achieving excellence and spearheading rice innovations for sustaining national food security and prosperity.

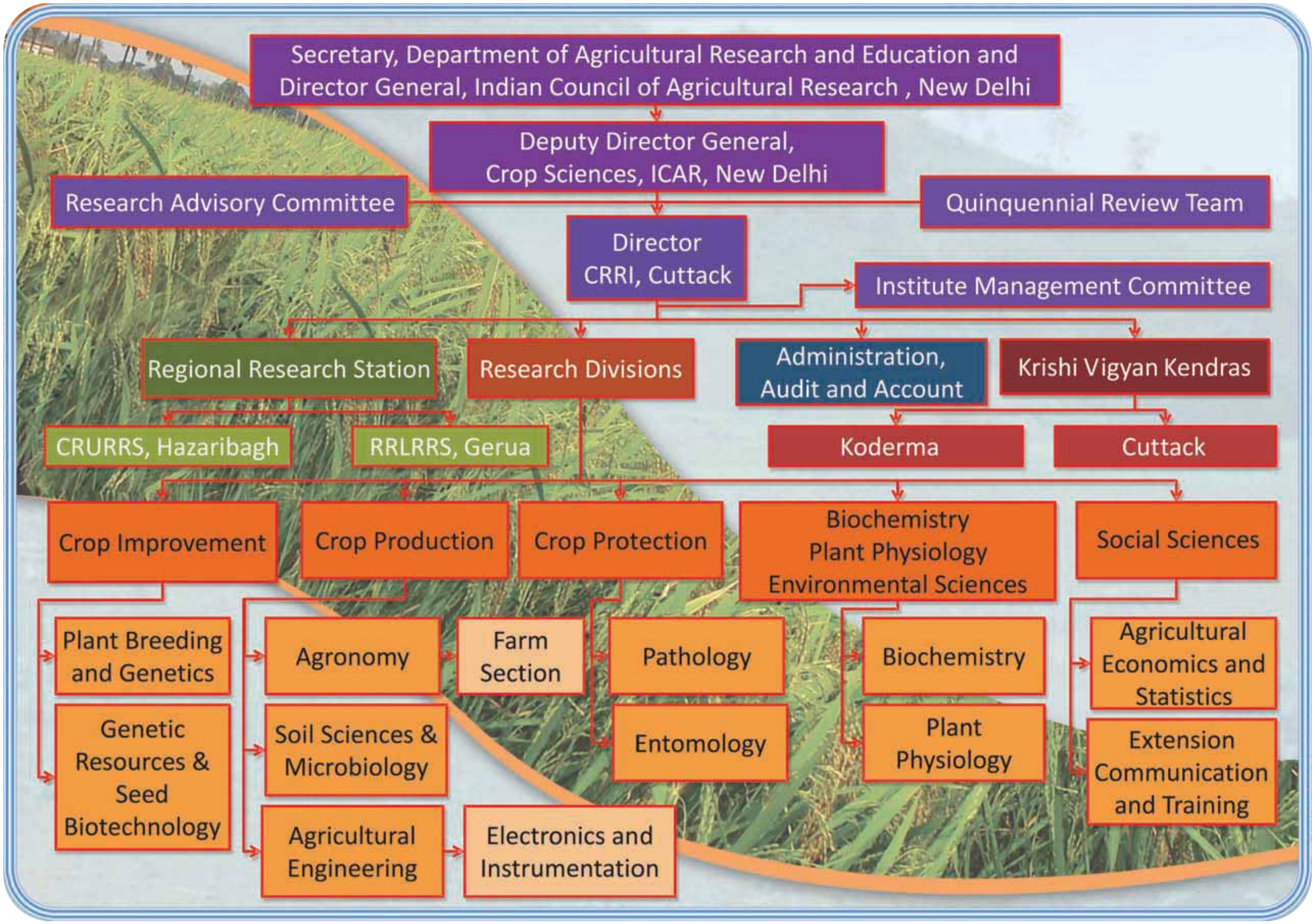
The guidance and inspiration received from Dr. S. Ayyappan, Hon'ble Secretary, DARE and Director General, ICAR, New Delhi, Dr. S. K. Datta, Deputy Director General (Crop Science), ICAR, New Delhi, Dr. E.A. Siddiq, Chairman, QRT and its members, and Dr. R.B. Singh, Chairman, RAC and its members are deeply acknowledged.

I acknowledge the support extended by Dr. R.P. Dua, Assistant Director General (FFC), ICAR, New Delhi for successfully implementing the institute activities. I appreciate the efforts of Heads of Division, OIC of Regional Research Stations, Publication Committee, Administration, Finance and Publication Unit of the Institute for compiling and editing the Annual Report. My sincere thanks are due to all the staff of the institute for their whole-hearted support in carrying out institute's activities.

I hope that this report will be useful for policy makers, researchers, development functionaries, farmers and students.

(T. Mohapatra)
Director

Organogram



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Extension Communication and Training

कार्यकारी सारांश

इस वर्ष केंद्रीय चावल अनुसंधान संस्थान द्वारा भारत के विभिन्न राज्यों की जलवायु व भूमि पारिस्थितिकी के अनुकूल विशिष्ट गुणयुक्त तेरह चावल की किस्में विकसित की गई जिनमें ऊपरीभूमि के लिए एक, उथली निचलीभूमि के लिए एक, गहराजल परिस्थितिकी के लिए दो, सिंचित पारितंत्र के लिए दो, समुद्र तटीय लवणीय भूमि के लिए दो, एरोबिक (कम सिंचाई वाली)परिस्थिति के लिए एक तथा दो सुगंधित किस्में शामिल हैं। इसीप्रकार, ओडिशा के जीवाणुज अंगमारी (ब्लाइट) क्षेत्रों के लिए चिन्हक सहायतित चयन (एमएएस) का प्रयोग करते हुए दो जीवाणुज अंगमारी प्रतिरोधी किस्में विकसित की गईं। अखिल भारतीय चावल उन्नयन परियोजना (एआईसीआरआईपी) के तहत विभिन्न परीक्षणों के अंतर्गत नामित धान के १३२ विकसित प्रजनन वंशों में से, ४१ को अगले परीक्षण के लिए चयनित किया गया।

सुमित (सीआर ६६-२२-१-१-१-१; आईईटी १९९१३) किस्म को ओडिशा के वर्षाश्रित निचलीभूमियों में खेती के लिए संस्तुति की गई। यह किस्म आईआर-३२/आईआर १३२४६ के संकर से विकसित की गई है। यह किस्म १५० दिनों में पक कर तैयार होती है, पौधों की ऊंचाई १०८-११५ सेंटीमीटर होती है, इसका दाना लंबा मोटा है तथा इसकी औसत उपज ५.२० टन/हैक्टर है।

सत्यभामा (सीआर २३४०-२२-११; आईईटी २०१४८) किस्म को आईआर ३१२३८-३५०-३-२/आईआर ४१०५४-१०२-२-३-२ के संकर से विकसित किया गया तथा ओडिशा की अनुकूल ऊपरीभूमियों में खेती के लिए उपयुक्त है। यह किस्म ११० दिनों में पक कर तैयार होती है, अर्द्ध-बौनी है, पौधों की ऊंचाई १००-१०५ सेंटीमीटर होती है, इसका दाना मध्यम पतला है तथा सामान्य परिस्थिति में इसकी औसत उपज ४.७० टन/हैक्टर है एवं सूखा पड़ने पर इसकी औसत उपज २.३० टन/हैक्टर होती है।

जलमणि (सीआर २२८२-१-२-५-१; आईईटी २०२१४) किस्म पानीकेकवा/अंबिका के संकर से विकसित की गई है तथा ओडिशा के गहराजल क्षेत्रों में खेती के लिए उपयुक्त है। यह किस्म १६०-१६५ दिनों में पक कर तैयार होती है, इसका पौधा लंबा (१५० सेंटीमीटर) होता है, इसका दाना मध्यम पतला है तथा इसकी औसत उपज ४.६० टन/हैक्टर है।

जयंती धान (सीआर २०८०-१६९-३-२-५-२; आईईटी २०७०६) किस्म सामसन पोलो/जलनिधि के संकर से विकसित की गई है। इस किस्म को ओडिशा के गहराजल चावल की खेती की जाने वाले क्षेत्रों में खेती के लिए उपयुक्त है। यह किस्म १६५-१७० दिनों में पक कर तैयार होती है, इसका पौधा लंबा (१७० सेंटीमीटर) होता है, इसका दाना मध्यम पतला है तथा इसकी औसत उपज ४.६० टन/हैक्टर है।

प्यारी (सीआर २६२४-आईआर ५५४२३-०१; आईईटी २१२१४) किस्म को यूपीएल आरआइ ५/आईआर १२९७९-२४-१ के संकर से विकसित किया गया है। यह किस्म ओडिशा के ऐरोबिक तथा सीमित जल वाले क्षेत्रों में खेती के लिए उपयुक्त है। यह किस्म ११५-१२० दिनों में पक कर तैयार होती है, अर्द्ध-बौनी है, इसके पौधे खेत में गिरते नहीं है, इसका दाना छोटा मोटा है तथा इसकी औसत उपज ४.५० टन/हैक्टर है।

ह्यू (सीआरके २६-१-२-१; आईईटी १९३५१) किस्म को ओडिशा राज्य के सिंचित क्षेत्रों में मध्यम अवधि खेती के लिए आईआर ४२/राहसपंजर के संकर से विकसित व विमोचित किया गया है। यह किस्म १३०-१३५ दिनों में पक कर तैयार होती है, इसका दाना लंबा पतला है तथा इसकी औसत उपज क्षमता ४.५० से ५.५० टन/हैक्टर है।

लुणा सांखी (सीआर २५७७-१; आईईटी २१२३७) किस्म को आईआर ३११४२-१४-१-१-३-२/आईआर ७१३५० के संकर से विकसित किया गया है। यह किस्म ओडिशा राज्य के तटीय लवण क्षेत्र में शुष्क मौसम में खेती के लिए उपयुक्त है। यह किस्म १०५-११० दिनों में पक कर तैयार होती है, पौधों की ऊंचाई १०५ सेंटीमीटर होती है, इसका दाना मध्यम पतला है तथा इसकी औसत उपज क्षमता ४.६० टन/हैक्टर है।

लुणा बरियल (सीआर २०९२-१५८-३; आईईटी १९४७२) किस्म जया/लुणीश्री के संकर से विकसित की गई है। यह ओडिशा राज्य के तटीय लवण क्षेत्र में खरीफ मौसम में खेती के लिए उपयुक्त है। यह किस्म १५०-१५५ दिनों में पक कर तैयार होती है, पौधों की ऊंचाई १२० सेंटीमीटर होती है, इसका दाना मध्यम पतला है तथा इसकी औसत उपज क्षमता ४.१० टन/हैक्टर है।

सुधरित ललाट (सीआरएमएएस २६२१-७-१; आईईटी २१०६६) किस्म को ललाट/आईआरबीबी ६० के संकर से विकसित किया गया है। यह किस्म ओडिशा राज्य के जीवाणुज अंगमारी आक्रांत क्षेत्र में खेती के लिए उपयुक्त है। इसका दाना लंबा पतला है, मिलिंग में चावल कम टूटता है, इसके चावल में एमिलोस मध्यम मात्रा में होता है। यह १३० दिनों में पक कर तैयार होती है तथा इसकी औसत उपज क्षमता ४.५०-५.०० टन/हैक्टर है। यह गालमिज प्रतिरोधी है तथा इसमें थोड़ा तना छेदक प्रतिरोधी गुण भी है।

सुधरित तपस्विनी (सीआरएमएएस २६२२-७-६; आईईटी २१०७०) किस्म को तपस्विनी/आईआरबीबी ६० के संकर से विकसित किया गया है। यह किस्म ओडिशा राज्य के जीवाणुज अंगमारी आक्रांत क्षेत्र में खेती के लिए उपयुक्त है। इसका दाना छोटा व मोटा है, चावल कम टूटता है, इसके चावल में एमिलोस की मात्रा मध्यम है। यह १३० दिनों में पक कर तैयार होती है तथा सामान्य परिस्थिति में इसकी औसत उपज क्षमता ४.५०-५.०० टन/हैक्टर है। यह किस्म प्रमुख नाशककीट जैसे भूरा पौध

माहू, पीला तना छेदक, सफेदपीठवाला पौध माहू प्रतिरोधी है तथा मध्यम रूप से तना छेदक प्रतिरोधी है।

पूर्णभोग (सीआरएम २२०३-४; आईईटी १८००८) किस्म को उत्परिवर्ती प्रजनन के माध्यम से पूसा बासमती-१ से विकसित किया गया है। यह ओडिशा राज्य के सींचित क्षेत्रों में खेती के लिए उपयुक्त है। इसका दाना लंबा पतला है। इस सुगंधित किस्म के पौधों की ऊंचाई १०० सेंटीमीटर होती है, १४०-१४५ दिनों में पक कर तैयार होती है तथा इसकी औसत उपज क्षमता ४.५०-५.०० टन/हैक्टर है। इसके दाने पारभासी हैं एवं चूने की तरह सफेद नहीं हैं, इसके पकाने तथा खाने के गुण अच्छे हैं।

सीआर धान ९०७ (आईईटी-२१०४४) किस्म को पूसा ४४/दुबराज से विकसित किया गया है। यह सुगंधित किस्म है। इसका दाना छोटा है, अर्द्ध-बौना है तथा इसकी औसत उपज ४.०० टन/हैक्टर है। इसे ओडिशा, छत्तीसगढ़, गुजरात तथा आंध्र प्रदेश राज्यों में खेती के लिए केंद्रीय किस्म विमोचन समिति द्वारा अनुमोदित किया गया है।

सीआर धान ३०३ (सीआर-२६४९-७; आईईटी २१५८९) किस्म को उदय तथा आईईटी १६६११ के संकर से विकसित किया गया है। इसे मध्य प्रदेश, उत्तर प्रदेश तथा ओडिशा के सिंचित क्षेत्रों में खेती के लिए उपयुक्त पाया गया है। यह पत्ता प्रध्वंस, गला प्रध्वंस, आच्छद विगलन तथा राइस टुंग्रो रोग के प्रति मध्यम रूप से प्रतिरोधी है तथा इसकी औसत उपज ५.०० टन/हैक्टर है।

चावल के पंद्रह जीनप्ररूपों को कई जैविक दबाव अर्थात रोग व कीटों के लिए प्रतिरोधी पाया गया तथा एनएसएन १ तथा एनएसएन २ परीक्षण में तीन संबर्द्धनों यथा, सीआर २६५२-१४, सीआर २६५६-११-३-४-२ तथा सीआर २६४४-२-६-४-३-२ को राइस टुंग्रो रोग के प्रति कम ग्राह्यशीलता के साथ प्रतिरोधी पाया जिनका सूचक ४.० से कम था। दो जीनप्ररूप सीआर एसी ४३०१९ तथा सीआर ४३०२० धान जड़ गांठ सूत्रकृमि प्रतिरोधी पाई गईं और विगलन सूचक क्रमशः ०.७ तथा ०.३ था। भूरा पौध माहू प्रतिरोधिता के लिए परीक्षण किए गए जीनप्ररूपों में से छह जीनप्ररूप जैसे सीआर ४२६६८, सीआर ३००५-७७-२, सीआर ३००५-२३०७-५, सीआर ३००५-११-३, सीआर ३००५-२२६-७ तथा सीआर ३००६-८-२ अत्यधिक प्रतिरोधी पाई गई और एसईएस में इनका स्कोर १ था।

बाढ़ के पानी में लवणता के होते हुए भी दो कृषिजोपजातियां आईआर-८४६४९-२६०-२८-१-बी तथा आईआर-८४६४९-२१-१५-१-बी में जलनिमग्न सहिष्णुता का स्तर अधिक पाया गया। वर्षाश्रित ऊपरीभूमि परिस्थितियों के तहत, आरआर ३८३-२, आरआर २-६, सीआर १४३-२-२, झू ११-१६, आरआर ४४३-२, आईईटी २१६२०, आईईटी २२०३०, कालाकेरी तथा सहभागी धान की फसल वृद्धि तथा फूल या दाना भरने की अवस्थाओं में सूखा पड़ने पर भी उपज क्षमता १.५ टन/हैक्टर से अधिक थी एवं ५० प्रतिशत से अधिक दाना भरण हुआ था। संकर धान अजय को ऐरोबिक परिस्थितियों में तथा बारी बारी से गीली एवं शुष्क तकनीकी में उगाने पर भी दोनों परिस्थितियों में ५.३० टन/हैक्टर की स्थिर उपज प्राप्त हुई जिससे इसकी पहचान कम पानी वाली स्थिति के लिए उपयुक्त किस्म के रूप में हुई। नए पौध प्रकार लक्षण वाले आठ सुधरित प्रजनन वंशों का विकास भी किया गया।

डीएनए फिंगरप्रिंटिंग के लिए एसएसआर तथा आईएसएसआर चिन्हकों का प्रयोग करते हुए छप्पन कृषिजोपजातियों (९ सुगंधित किस्में तथा ४७ भूमिजातियां) का लक्षण वर्णन किया गया। सीआरआरआई द्वारा विमोचित छब्बीस किस्मों को फिंगरप्रिंटिंग के लिए एसएसआर चिन्हकों का प्रयोग करते हुए निचलीभूमि के लिए उपयुक्तता एवं उन किस्मों में आनुवंशिक संबंद्धता के लिए लक्षण वर्णन किया गया। चार संबर्द्धन-सीआर २७१३-११, सीआर २७१३-१७९, सीआर २९४७-१८ तथा सीआर २७१३-१८० आशाजनक पाए गए तथा इन्हें एआईसीआरआईपी के तहत सुंगधित छोटा दाने वाले किस्मों के परीक्षण के द्वितीय/तृतीय वर्ष में आगे बढ़ाया गया। दो उच्च प्रोटीनयुक्त चावल कृषिजोपजातियों जैसे एआरसी १००६३ (१६.४१ प्रतिशत) तथा एआरसी १००७५ (१५.२७ प्रतिशत) में सर्वाधिक दौजी निकलने की अवस्था में ग्लूटामिन सिन्थेटेस तथा ग्लूटामेट ओक्सो-ग्लूटारेट एमिनोट्रांसफेरेस की सक्रियता अधिक पाई गई।

मृदा गुणवत्ता को बनाए रखने के लिए पोषक तत्वों का संतुलित प्रयोग महत्वपूर्ण है। भिन्न भिन्न पोषक प्रबंधनों के अंतर्गत की ४१ वर्ष की अवधि से चल रहे निरंतर चावल की खेती वाले क्षेत्र में किए गए अध्ययन में जब नत्रजन-पोटाश-फास्फोरस उपचार की तुलना में कंट्रोल नत्रजन, नत्रजन-फास्फोरस तथा नत्रजन-पोटाश उपचारित खेतों में मृदा गुणवत्ता क्रमशः ४७.३, ३५.८, ५.७ तथा १४.० प्रतिशत कम हुई।

ऐरोबिक चावल में, नत्रजन तथ जस्ता प्रबंधन एक मुख्य भूमिका निभाते हैं। एक प्रयोग में यह पाया गया कि सिफारिश की गई मात्रा की तुलना में, पत्ते के रंग वाले चार्ट (एलसीससी) पर आधारित सिफारिश से अधिक नत्रजन प्रयोग क्षमता (१७-१८ प्रतिशत) एवं नत्रजन प्राप्ति क्षमता (२६-३० प्रतिशत) प्राप्त हुई। ऐरोबिक आर्द्रता व्यवस्था में जल घुलनशील तथा विनिमेय जस्ता, जैविक संबंद्ध जस्ता तथा क्रिस्टलीय सेसक्विऑक्साइड संबंद्ध जस्ता अधिक पाया गया जबकि जलनिमग्नता से मैंगनिज ऑक्साइड संबंद्ध जस्ता, एमरफस सेसक्विऑक्साइड संबंद्ध जस्ता एवं अपशिष्ट जस्ता की वृद्धि होने में मदद मिली।

फास्फोरस की कमी वाली भूमि में चावल की किस्म की जड़ो से निकलने वाले कार्बनिक अम्लों के प्रकार एवं उनकी मात्रा चावल किस्म पर निर्भर करती है। इससे पता चला कि भूमि में मौजूद पोषक तत्व यह निर्धारित करते हैं कि पौधों में जड़ो से स्रवित होते कौन से पर्दाथ बनेंगे व किस मात्रा में स्रवित होंगे।

२६ वर्षों में ओडिशा में हुई वर्षा के आंकड़ों पर आधारित एक मानचित्र तैयार किया गया जिससे हर तीन महीनों में कितनी वर्षा हुई या सुखा पड़ा, संबंधित जानकारी प्राप्त की जा सकती है जो भविष्य में पड़ने वाले सूखे से निपटने के कार्यक्रम बनाने में सहायक होगा।

चावल की खेती के लिए विकसित एसआरआई या 'सिरी' प्रणाली (१२ दिन वाली पौद, २५ x २५ सें.मी. दूरी, ५.० टन/हैक्टर दर पर फार्म यार्ड खाद का जैविक प्रयोग तथा कोनोवीडर की मदद से निराई) की अलग से अपनाई गई खेती पद्धतियों से तुलना की गई जिसमें कई पोषक तत्व प्रबंधन तथा खरपतवार निराई पद्धतियां शामिल थीं। सिरी प्रणाली में पौद आयु तथा दूरी को बनाए रखा गया। इससे पता चला कि जैविक खाद की अपेक्षा सिफारिश की गई रासायनिक उर्वरक १२० प्रतिशत दर पर प्रयोग से उपज में भारी वृद्धि हुई। उसी प्रकार, शाकनाशी एजिमसल्फ्यूरान (कम मात्रा, अधिक प्रभावी एवं सुरक्षित) ३५ ग्राम/हैक्टर का प्रयोग प्रमुख खरपतवारों के नियंत्रण के लिए प्रभावी पाया गया तथा कोनोवीडर के प्रयोग के बराबर उपज मिली।

आर्द्र सीधी बुआई खेती प्रणाली में, बेनसल्फ्यूरान मिथाइल तथा प्रिटिलाक्लोर (बुआई के १८ दिन बाद ५० अ ४५० ग्राम/हेक्टर दर पर) प्रयोग को प्रमुख खरपतवारों के नियंत्रण के लिए बहुत अच्छा पाया गया तथा दो बार हाथों की निराई से ५.७७ टन/हैक्टर उपज की तुलना में, इससे ५.६७ टन/हैक्टर की उपज प्राप्त हुई।

तीन चावल आधारित फसल प्रणालियों जैसे चावल-आलू-तिल, चावल-मक्का-लोबिया तथा चावल-मूंगफली-मूंग का मूल्यांकन किया गया, जिससे यह पता लगा कि चावल-आलू-तिल में सर्वाधिक उत्पादन क्षमता (चावल तुल्य उपज १४.९ टन/हैक्टर) है, साथ ही निचलीभूमि के प्रयोग की उच्च्य क्षमता है जबकि चावल-मक्का-लोबिया फसल प्रणाली को आर्थिक रूप से सबसे अच्छा पाया गया।

संस्थान में गहराजल पारिस्थितिकी के लिए विकसित चावल-मछली-बागवानी फसल-कृषि वानिकी समन्वित खेती प्रणाली से एक लाख रुपये प्रति हैक्टर की शुद्ध आय मिली, उसीप्रकार गेरुआ में बाढ़ प्रवण क्षेत्रों के लिए विकसित चावल-मछली समन्वित खेती प्रणाली से १.६३१ रुपया लाख प्रति हैक्टर की शुद्ध आय मिली।

एक सौ सैंतीस कृषि उपयोगी सूक्ष्मजीवों की पहचान की गई जिसमें ९ क्लोरपइरिफास का विघटन करने वाले जीवाणु, १७ बी.थूरिनजेनसिस के जीवाणु तथा ५९ सूडोमोनास उपभेद थे। यह साइडरोफोर, हाइड्रासायनिक तथा सैलिसायलि अम्लों का स्राव करते हैं जो अनेक कीटों एवं रोगाणुओं के विरुद्ध प्रभावी हैं।

चावल की बाली में लगने वाले कीटों के विरुद्ध मिलबीमेक्टीन का प्रयोग बहुत प्रभावी पाया गया। पहली बार अनाज सरंक्षक के रूप में साइट्रोनेला तथा शोरिया रोबस्टा के तेलों को चावल कीट के विरुद्ध उपयोगी पाया गया। साइटोट्रोगा सेरेलेला की रोकथाम के लिए फिरोमोन बहुत प्रभावी पाया गया तथा तीन सप्ताह के भीतर कीट पकड़ ९६.४८ प्रतिशत कम हो गई।

समन्वित नाशककीट प्रबंधन परीक्षण में कटक जिले में खरीफ के दौरान किसानों के खेतों में पूजा किस्म की खेती गई जिससे पता चला कि बिन-समन्वित नाशककीट प्रबंधन खेतों की अपेक्षा समन्वित नाशककीट प्रबंधन नियंत्रित खेतों में १.३ टन/हैक्टर की अधिक उपज प्राप्त हुई है। हजारीबाग तथा चतरा जिलों में समन्वित नाशककीट प्रबंधन परीक्षण के तहत ऊपरीभूमि पारितंत्र में ०.९-१.६ टन/हैक्टर की अधिक उपज प्राप्त हुई है।

गहन जैविक समन्वित नाशककीट प्रबंधन के साथ नाशकजीवों की उचित निगरानी तथा उचित समय पर वानस्पतिक के प्रयोग से सिंचित पारितंत्र में २३.६ प्रतिशत तथा उथली अनुकूल निचलीभूमि पारितंत्र में २५ प्रतिशत उपज वृद्धि हुई।

जलवायु परिवर्तन के कारण विभिन्न रोगाणु उत्पन्न होते हैं, जिसकी निगरानी बहुत महत्वपूर्ण है। यह देखा गया है कि चावल उत्पादन के क्षेत्र में बाइपोलारिस सोरोकिनिआना तथा बाइपोलारिस ओराइजा प्रमुख नाशकजीव के रूप में उभर रहे हैं। भारत के इस भाग में पहली बार एक चावल रोगजनक के रूप में बाइपोलारिस सोरोकिनिआना की पहचान की गई है।

'प्रकाश-जाल पकड़' यंत्र से प्राप्त आंकड़ों के विश्लेषण से पता चला कि पिछले कई वर्षों में खरीफ के मौसम में पत्ता मोड़क का प्रकोप बढ़ा है। पारंपरिक रोपित चावल की तुलना में चावल की 'सिरी' प्रणाली से खेती में पीला तना छेदक का प्रकोप कम हुआ है।

चावल एंडोफाइटिक के कई फायदे हैं। एंडोफाइटिक डेंड्रीफिला से पौध को ओज प्राप्त हुआ तथा इनमें पौधों को चावल रोगजनकों से सुरक्षित रखने की क्षमता है। एंडोफाइटिक पेनिसिलियम में भी पौधों को चावल रोगजनकों से सुरक्षित रखने की क्षमता पाई गई।

सीआरआरआई, कटक में पास्पालम स्क्रोबीक्यूलाटम नामक खरपतवार पाया गया जो कि रोगजनक करव्यूलेरिया प्रजाति का समानांतर परजीवी है जिससे पत्तों में धब्बा होता है तथा चावल की पौध नष्ट हो जाती है।

नौवीं, दसवीं पंचवार्षिकी योजनाओं तथा २००५-०९ की अवधि के दौरान चावल की खेती के क्षेत्र, उत्पादन तथा उपज आंकड़ों के विश्लेषण से पता चला कि नौवीं योजना की तुलना में दसवीं योजना में अखिल भारतीय स्तर पर उत्पादन वृद्धि दर घटी है यद्यपि २००५-०९ की अवधि में यह वृद्धि दर दुबारा प्राप्त हुई।

डब्ल्यूटीओ के पूर्व अवधि (१९९०-९४) के दौरान भारत से कुल चावल निर्यात २६५३ करोड़ रुपये का था जबकि डब्ल्यूटीओ पश्चात अवधि (२००५-०९) के दौरान कुल चावल निर्यात चार गुना बढ़ गया अर्थात ११५०० करोड़ रुपये का चावल निर्यात हुआ। डब्ल्यूटीओ के पूर्व अवधि (१९९०-९४) की अपेक्षा डब्ल्यूटीओ पश्चात अवधि (२००५-०९) के दौरान भारत की बासमती चावल निर्यात की मात्रा २८९ प्रतिशत बढ़ी जबकि मूल्य के रूप में २६४ प्रतिशत बढ़ी।

ओडिशा के किसानों की पंसद के आधार पर, सर्वाधिक लोकप्रिय निचलीभूमि चावल किस्मों में से, पूजा किस्म को सर्वाधिक उपयुक्त पाया गया। सीआरआरआई द्वारा विकसित किस्मों जैसे नवीन, वंदना, अभिषेक, सहभागी धान, हजारीधान, तपस्विनी तथा अंजलि को झारखंड एवं छत्तीसगढ़ के लिए बीज उत्पादन श्रृखंला में स्थान प्राप्त हुआ।

व्यावसायिक, मध्यम तथा लघु स्तर पर उद्यम विकास के लिए चावल-मछली समन्वित फसल प्रणाली प्रौद्योगिकी पर पांच सप्ताह अवधि वाला एक शिक्षक प्रशिक्षण माड्यूल तैयार किया गया। पूजा किस्म के अभिग्रहण के लिए एक सिम्यूलेशन मॉडल विकसित किया गया तथा इस वास्तविक रूप से की जाने वाली खेती के लिए अनुरूप बनाया गया।

टांगी-चौद्वार, कटक के आदर्श गांव-गुरुजंग में सीआरआरआई द्वारा विमोचित नई किस्मों के प्रदर्शनों से पता चला कि चावल किस्म सहभागी धान की औसत उपज ३.२९ टन/हैक्टर है। २०१२ के शुष्क मौसम के दौरान केंद्र में सीआरआरआई द्वारा विकसित २६ किस्मों में से संकर चावल अजय से सर्वाधिक ७.८ टन/हैक्टर उपज मिली।

चावल आधारित फसल कार्यकलापों में शामिल अनुसूचित जनजाति महिलाओं के सशक्तिकरण पर किए गए एक कार्य अध्ययन से पता चला कि सशक्तिकरण में कुल ज्ञान लाभ २५.६ प्रतिशत है जो मुख्यतः आय उत्पन्न करने वाले क्रियाकलापों के विस्तार के कारण संभव हुआ।

सीआरआरआई द्वारा विकसित प्रौद्योगिकियों को लोकप्रिय बनाने के लिए ४३७० आगंतुकों को प्रक्षेत्र सलाहकार सेवाएं प्रदान की गई। इस अवधि के दौरान सीआरआरआई न्यूजलेटर मार्च २०१२ तक २०१०-११ का वार्षिक प्रतिवेदन तथा आठ तकनीकी बुलेटिनों का प्रकाशन हुआ है।

संस्थान ने पूर्वांचल क्षेत्रीय कृषि मेला का आयोजन किया जिसमें बिहार, झाखंड, पश्चिम बंगाल तथा ओडिशा से १२५० किसनों ने भाग लिया। इसके अतिरिक्त, 'चावल उत्पादन प्रौद्योगिकी' पर छह प्रशिक्षण कार्यक्रम तथा अन्य संबंधित विषयों पर भी प्रशिक्षण कार्यक्रमों का आयोजन किया गया।

इस अवधि के दौरान सीआरआरआई द्वारा विकसित प्रौद्योगिकियों का प्रदर्शन करने के लिए कटक एवं ओडिशा के बाहर आयोजित पांच महत्वपूर्ण प्रदर्शनियों में संस्थान ने भाग लिया।

Executive Summary

During 2011-12, Central Rice Research Institute released thirteen ecosystem and trait specific varieties include which upland (1) shallow lowland (1), deepwater (2), irrigated (2), coastal saline (2), aerobic (1), aromatic (2) and two varieties resistant to bacterial blight were identified for bacterial blight endemic areas of Odisha by using marker assisted selection (MAS). Out of the 132 advanced breeding lines nominated under different trials under AICRIP, 41 were promoted to next level of testing.

Sumit (CR662-22-1-1-1-1; IET19913) developed from the cross IR32/IR13246 was released for rainfed lowland areas of Odisha. It has maturity duration of 150 days, plant height of 108-115 cm and long bold grain with an average yield of 5.20 t ha^{-1}.

Satyabhama (CR2340-11; IET20148) developed from the cross IR 31238-350-3-2-1/IR41054-102-2-3-2 was released for favourabe upland areas of Odisha. It has maturity duration of 110 days with semi-dwarf plant type (100-105 cm), medium slender grain with an average yield of 4.70 t ha^{-1} under normal conditions and 2.30 t ha^{-1} under drought situation.

Jalamani (CR 2282-1-2-5-1; IET20214) developed from the cross Panikekoa/Ambika was released for deepwater rice areas of Odisha. It has maturity duration of 160-165 days, tall plant type (150 cm) with medium slender grain and an average yield of 4.60 t ha^{-1}.

Jayantidhan (CR2080-169-3-2-5-2; IET20706) developed from the cross Samson Polo/Jalanidhi was released for deepwater rice areas of Odisha. It has maturity duration of 165-170 days, tall plant type (170 cm) with medium slender grain and an average yield of 4.60 t ha^{-1}. It is tolerant to stem borer.

Pyari (CR2624-IR 55423-01; IET21214) developed from the cross UPL RI5/IR12979-24-1 (Brown) was released for aerobic/ water limiting rice areas of Odisha. It has maturity duration of 115-120 days, semi dwarf, non-lodging plant type and short bold grain with an average yield of 4.50 t ha^{-1}.

Hue (CRK26-1-2-1; IET19351) developed from the cross IR 42/Rahaspanjar was released for mid duration irrigated ecology of Odisha state. It has maturity duration of 130-135 days, long slender grain and average yield of 4.50 to 5.50 t ha^{-1}.

Luna Sankhi (CR2577-1; IET21237) developed from the cross IR31142-14-1-1-3-2/IR71350 was released for dry season cultivation in coastal saline areas of Odisha. It has maturity duration of 105-110 days, plant height of 105 cm, medium slender grain and has average yield of 4.60 t ha^{-1}.

Luna Barial (CR2092-158-3; IET19472) developed from the cross Jaya/Lunishree was released for wet season cultivation in coastal saline areas of Odisha. It has maturity duration of 150-155 days, plant height of 120 cm, medium slender grain and has average yield of 4.10 t ha^{-1}.

Improved Lalat (CRMAS2621-7-1; IET21066) developed from the cross Lalat/IRBB60 was released for growing in the bacterial bight endemic areas of Odisha. It has long slender grain, high HRR with intermediate amylose content, maturity duration of 130 days with an average yield of 4.50 to 5.00 t ha^{-1}. It is resistant to gall midge and moderately resistant to stem borer.

Improved Tapaswini (CRMAS2622-7-6; IET21070) developed from the cross Tapaswini/IRBB 60 was released for growing in the bacterial blight endemic areas of Odisha. It has short bold grain, high HRR with intermediate amylose content, maturity duration of 130 days with an average yield of 4.00 to 5.00 t ha^{-1} under normal condition. It is resistant to major pest like BPH, YSB and WBPH and moderately resistant to stem borer.

Poorna Bhog (CRM2203-4; IET18008) developed from Pusa Basmati-1 through mutation breeding was released for irrigated areas of Odisha. This aromatic variety has 100 cm plant height, 140 -145 days to maturity with long slender grain and yield capacity of 4.50 to 5.00 t ha^{-1}. Its grains are translucent without chalkiness with desirable cooking and eating qualities.

CR Dhan 907 (IET21044), an aromatic short grain culture developed from Pusa44/Dubraj with semi-dwarf stature giving a yield of 4.00 t ha^{-1} was identified for CVRC release in four states (Odisha, Chhattisgarh, Gujarat and Andhra Pradesh).

CR Dhan 303 (CR2649-7; IET21589) derived from the cross between Udaya/IET16611 was identified for irrigated areas of Madhya Pradesh, Uttar Pradesh and Odisha. This culture is moderately resistant to leaf blast, neck blast, sheath rot and rice tungro disease with an average yield of 5.00 t ha^{-1}.

Fifteen genotypes were identified having resistance to various biotic stress including three cultures (CR2652-14, CR2656-11-3-4-2 and CR2644-2-6-4-3-2) resistant to rice tungro disease with low susceptibility index less than 4.0 in NSN 1 and NSN 2 trial, six genotypes

(CR42668, CR3005-77-2, CR3005-230-5, CR3005-11-3, CR3005-226-7 and CR3006-8-2) resistant to BPH with (SES) score 1, two genotypes (CRAC43019 and CR43020) resistant to rice rootknot nematode with 0.7 and 0.3 gall index and four genotypes (CR3005-230-5, CR2711-76, CR3005-77-2 and CR3006-8-2) highly resistant to planthoppers.

Two cultivars (IR84649-260-28-1-B and IR84649-21-15-1-B) were identified to have higher level of submergence tolerance irrespective of salinity of the flood water. Under rainfed upland situation, even with exposure to drought stress at both vegetative and reproductive stages conditions, RR383-2, RR2-6, CR143-2-2, Zhu 11-16, RR443-2, IET21620, IET22026, IET22032, Kalakeri and Sahabhagidhan had yield potential of more than 1.50 t ha^{-1} with more than 50% grain filling. The hybrid Ajay grown under aerobic and AWD conditions, gave a stable yield of 5.30 t ha^{-1} indicating its adaptation to water limited conditions. Eight improved breeding lines with new plant type characters have been developed.

Fifty six cultivars (nine aromatic varieties and 47 landraces) were characterized through DNA finger printing using SSR and ISSR markers. Twenty six CRRI released varieties for lowland situations were also characterized using SSR for assessing the genetic relatedness among them. Four promising aromatic short grain cultures *viz.,* CR2713-11, CR2713-179, CR2947-18 and CR2713-180 were promoted to next year of testing under AICRIP. Two high protein rice cultivars *viz.,* ARC10063 (16.41%) and ARC10075 (15.27%) were found to have higher activities of glutamine synthetase (GS) and glutamate oxo-glutarate aminotransferase (GOGAT) at the maximum tillering stage.

Balanced application of nutrients plays a major role in maintaining the soil quality. In a long term (41 years) rice-rice system under different nutrient management, when compared with NPK treatment, soil quality declined by 47.3, 35.8, 5.7 and 14.0% in control, N, NP and NK applied plots, respectively.

Nitrogen and zinc management plays important role in aerobic rice, it is found that leaf colour chart (LCC) based recommendation resulted higher agronomic N use efficiency (17-18%) and N recovery efficiency (26-30 %) over the recommended dose of fertilizer (RDF). The water soluble plus exchangeable zinc, organically bound zinc and crystalline sesquioxide bound zinc were higher under aerobic moisture regimes while the submergence helped to increase the manganese oxide bound zinc, amorphous sesquioxide bound zinc and residual zinc.

The differential response on individual rice genotypes to P deficiency is based on the type and quantity of organic acids exuded, thus suggested a genotype and nutrient-specific regulation of biosynthesis and release of root exudates.

The standardized precipitation index (SPI) based drought map of Odisha, prepared based on 26 years of rainfall data using Spatial Analyst tool of Arc GIS, showed the seasonal pattern of meteorological drought at three months time scale; this will be useful in developing mitigation strategies of the drought events in the region.

The SRI method of rice cultivation (12 days old seedling, 25 cm x 25 cm spacing, organic source of nutrients through application of FYM @ 5.0 t ha^{-1} and weeding by using conoweeder) was compared with the practices in which various nutrient and weed management practices were taken separately, keeping the seedling age and spacing of SRI method unchanged. It was found that application of chemical fertilizer @ 120% RFD significantly enhanced the yield over that applied with organic manure. Similarly the herbicide Azimsulfuron @ 35 g a.i. ha^{-1} (low dose high efficacy and safe) were found to be effective and produced at par yield with that of conoweeder.

In wet direct seeded, tank-mix application of bensulfuron methyl + pretilachlor (applied as post-emergent 18 DAS at 50 + 450 g a.i. ha^{-1}) was found to be most effective for controlling the predominant weeds [weed control efficiency (WCE) 91%] and produced comparable yield (5.67 t ha^{-1}) with hand weeding twice (5.77 t ha^{-1}).

Three rice based cropping systems such as rice–potato–sesame, rice–maize–cowpea and rice – groundnut–green gram were evaluated, it was found that highest production efficiency (REY 14.9 t ha^{-1}) and lowland utilization efficiency was observed in rice-potato-sesame cropping system although rice-maize-cowpea was found to be the most economical system.

The rice-fish-horticultural crops-agro forestry based integrated farming system model developed at Cuttack for deepwater ecology generated a net income of Rs.1 lakh ha^{-1}, similarly integrated rice-fish farming system developed for flood prone areas at Gerua generated gross income of Rs.1.63 lakhs ha^{-1}.

One hundred and thirty seven agriculturally important microbes were identified including nine chlorpyrifos degrading bacteria, 17 *B. thuringiensis* and 59 *Pseudomonas* strains isolates produced siderophore, HCN and salicylic acid, effective against insect pests and plant pathogens. Four potent native entomopathogenic Bt against leaf folder were formulated for mass field application.

Milbemectin was found to be effective miticide against rice panicle mite, oils of Citronella and *Shorea robusta* were identified for the first time as grain protectants against rice moth. New bio-control agents (*Bacillus vallismortis* and *Bacillus amyloliquefaciens subsp. planta*) for management of rice pathogens and aflatoxigenic fungi were identified. Pheromone for *Sitotroga cerealella* [(Z6-E11)16Ac] was highly effective and the moth catch was reduced by 96.48% within three weeks.

In an IPM trial conducted in the farmers' paddy fields during wet season 2011, grain yield of variety Pooja increased by 1.30 t ha^{-1} in the IPM fields over non-IPM fields. IPM trial conducted at Chatra and Hazaribag districts in upland ecosystem showed yield increase of 0.9-1.6 t ha^{-1} in comparison to farmers' practice. Bio-intensive IPM with proper monitoring of pests and botanical application at proper time resulted in 23.6% and 25% yield advantage in irrigated and shallow favorable lowland ecosystems, respectively.

The rice pathogens are continuously evolving, monitoring of which is very important in the context of climate change. It was observed that *Bipolaris sorokiniana* and *B. oryzae* were coming up as major threats to rice production. *B. sorokiniana* was recorded as a rice pathogen from Odisha for the first time.

Incidences of leaf folders have increased over the years during wet season as reflected by analysis of historical light-trap catches. Incidences of yellow stem borer were found to be less under SRI compared to conventional transplanted rice.

Rice endophytes have several beneficial effects, endophytic *Dendryphiella* promoted seedling vigour and protected the seedlings from rice pathogens. Endophytic *Penicillium* also protected rice seedlings from rice pathogens.

Paspalum scrobiculatum a weed species of rice field was found to be a collateral host of pathogenic *Curvularia* spp. which caused leaf spots and seedlings mortality of rice seedlings.

Analysis of area, production and yield data for ninth, tenth five year plans and for the period 2005-09 revealed that the production growth at all India level declined in tenth plan in comparison to ninth plan, however, the growth has regained during the period 2005-09.

The total rice export from India has increased more than four times i.e. from Rs. 2653 crores during pre-WTO period (1990-94) to Rs. 11500 crores during post-WTO period (2005-09) at costant prices of 2010-11. India has increased basmati rice exports by 289% in quantity and 264% in value terms in the post-WTO period (2005-09) over the pre-WTO period (1990-94).

Based on the perception of rice growers of Odisha, Pooja was found to be the most appropriate variety in shallow lowlands. A number of CRRI varieties *viz.*, Naveen, Vandana, Abhisek, Sahabhagidhan, Hazaridhan, Tapaswini and Anjali were found in the seed chain of Jharkhand and Chhattisgarh, states.

A five-week trainer's training module on entrepreneurship development for commercial, medium and small scale rice-fish integrated farming systems was developed. A simulation model of adoption of Pooja variety was developed and validated to suit the real life data.

The demonstration of newly released CRRI rice varieties conducted in model village-Gurujang, Tangi-Choudwar, Cuttack, revealed that the rice variety, Sahabhagidhan had an average yield of 3.29 t ha^{-1}. The rice hybrid Ajay gave the highest yield of 7.80 t ha^{-1} in an on-station demonstration of 26 CRRI rice varieties conducted during dry season 2011-12.

An action research on empowerment of tribal women engaged in rice-based farming activities indicated that the overall gain in empowerment was found to be 25.6 per cent which was mainly due to expansion of income generation activities.

Farm Advisory Services was provided to 4370 visitors so as to popularize the CRRI technologies. Four Newsletters, an Annual Report and eight Technological Bulletins were published during 2010-11.

The Institute organized Eastern Zone Regional Agriculture Fair, in which 1250 farmers from Bihar, Jharkand, West Bengal and Odisha participated besides, six training programmes on 'Rice Production Technology' and other related areas were also organized.

The Institute participated in five important exhibitions for disseminating the CRRI technologies outside Cuttack and Odisha.

Introduction

CRRI was established by the Government of India in 1946 at Cuttack, as an aftermath of the great Bengal famine in 1943, for a consolidated approach to rice research in India. The administrative control of the Institute was subsequently transferred to the Indian Council of Agricultural Research (ICAR) in 1966. The Institute has two research stations, one at Hazaribag, in Jharkhand, and the other at Gerua, in Assam. The CRRI regional substation, Hazaribag was established to tackle the problems of rainfed uplands, and the CRRI regional substation, Gerua for problems in rainfed lowlands and flood-prone ecologies. Two Krishi Vigyan Kendras (KVK) also function under the CRRI, one at Santhapur in Cuttack district of Odisha and the other at Jainagar in Koderma district of Jharkhand. The research policies are guided by the recommendations of the Research Advisory Committee (RAC), Quinquennial Review Team (QRT) and the Institute Research Council (IRC). The CRRI also has an Institute Management Committee (IMC), for formulating administrative policies.

Mandate

The goal is to improve the income and quality of life of rice farmers in India.

The Mandate of the institute are:

- Conduct basic, applied and adaptive research on crop improvement and resource management for increasing and stabilizing rice productivity in different rice ecosystems with special emphasis on rainfed ecosystems and the related abiotic stresses.
- Generation of appropriate technology through applied research for increasing and sustaining productivity and income from rice and rice-based cropping/ farming systems in all the ecosystems in view of decline in per capita availability of land.
- Collection, evaluation, conservation and exchange of rice germplasm and distribution of improved plant materials to different national and regional research centres.
- Development of technology for integrated pest, disease and nutrient management for various farming situations.
- Characterization of rice environment in the country and evaluation of physical, biological, socio-economic and institutional constraints to rice production under different agro-ecological conditions and in farmers' situations and develop remedial measures for their amelioration.
- Maintain database on rice ecology, ecosystems, farming situations and comprehensive rice statistics for the country as a whole in relation to their potential productivity and profitability.
- Impart training to rice research workers, trainers and subject matter/extension specialists on improved rice production and rice-based cropping and farming systems.
- Collect and maintain information on all aspects of rice and rice-based cropping and farming systems in the country.

Thrust Areas

- Germplasm collection, characterization of genetic diversity and gene function assignment. Designing, developing and testing of new plant types, super rice and hybrid rice for enhanced yield potential.
- Identification and deployment of genes for nutrient deficiency, tolerance to submergence, drought, salinity and biotic stresses and productivity traits.
- Intensification of research on molecular host parasite/pathogen interaction to design suitable control strategy.
- Understanding the pest genomics for biotype evolution, off-season survival and ontogency for integration into a control strategy.
- Developing nutritionally enhanced rice varieties with increased content of pro-vitamin A, vitamin E, iron, zinc and protein.
- Improvement of short-grain aromatic rice and organic management of aerobic rice.

Research Achievements

Released a total of 100 rice varieties including three hybrids for cultivation in upland, irrigated, rainfed lowland, medium-deep waterlogged, deepwater and coastal saline ecologies.

Developed interspecific hybrid derivatives including *O. sativa* and *O. longistaminata* with tolerance to bacterial leaf blight (BLB).

Maintains more than 30,000 accessions of rice germplasm including nearly 6,000 accessions of Assam Rice Collection (ARC) and 5,000 accessions from Odisha. Compiled Passport information on more than 30,000 germplasm.

Used RFLP/RAPD and other DNA markers for genetic analysis of bacterial blight, blast and gall midge resistance.

Used marker-assisted selection for pyramiding BLB resistance genes and for developing BLB-resistant rice cultivars.

Developed a rice-based farming system including rice-fish farming system integrating multiple enterprise initiatives with a rationale for ensuring food and nutritional security, stable income and employment generation for rural farm family.

Knowledge-based N management strategy for increasing N-use efficiency for rainfed lowlands including use of integrated N management involving use of both organic and inorganic sources of N-fertilizer. Developed several agricultural implements such as manual seed drill, pre-germinated drum seeder, multicrop bullock and tractor drawn seed drill, flat disc harrow, finger weeder, conostar weeder, rice husk stove, mini parboiler and power thresher with the sole aim of reducing both drudgery and cost of rice cultivation.

Evaluated, developed and tested several plant products with pesticide potential against field and storage insects and pathogens.

Identified biochemical and biophysical parameters for submergence and other abiotic stress tolerance in rice.

Developed crop modelling of G x E interaction studies that showed that simulation of crop growth under various environments could be realistic under both irrigated and favourable lowland situations.

Developed suitable rice production technologies for rainfed uplands, lowlands and irrigated ecology including production technologies for hybrid rice and scented rice that were field tested and transferred to farmers.

Evaluated and popularized its varieties through frontline demonstrations (FLDs) in farmers' fields.

Provided farmers' advisory service through regular radio talks and TV telecasts on rice production technologies.

Developed 15 training modules for farmers and extension workers.

Imparted short-term and long-term training for personnel from the State Departments of Agriculture, State Agricultural Universities (SAUs) and other educational institutions.

Imparted advance training and research leading to Masters (M.Sc.) and Doctoral degrees (Ph.D.).

Linkages

The CRRI has linkages with several national and international organizations such as the Council for Scientific and Industrial Research (CSIR), Indian Space Research Organization (ISRO), SAUs, State Departments of Agriculture, and the institutes of the Consultative Group for International Agricultural Research (CGIAR), such as the International Rice Research Institute (IRRI), Philippines and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad.

Location

The Institute is located at Cuttack about 35 km from Bhubaneswar airport and 7 km from the Cuttack railway station on the Cuttack-Paradeep State Highway. The institute lies approximately between 85°55′48" E to 85°56′48" E longitudes and 20°26′35" N to 20° 27′ 20" N latitudes with the general elevation of the farm being 24 m above the MSL. The annual rainfall at Cuttack is 1,200 mm to 1,500 mm, received mostly during June to October (*kharif* or wet season) from the southwest monsoon. Minimal rainfall is received from November to May (*rabi* or dry season).

Genetic Resources and Seed Technology

Genetic Resources

Collection, characterization and conservation of trait specific germplasm

An exploration and collection programme of wild rice germplasm for the 'submergence cum saline tolerance' trait was conducted in the Bhitarkanika mangrove sanctuary of Kendrapara district in Odisha. During the survey, 10 accessions of *Oryza coarctata* Tateoka were collected from different estuaries of the mangrove forest like Khola, Dangmal, Kalibhanja, Talchua, Sapua Tenko, Jayanagardiha, Mahisamada creek, Suajore creek, Bagapatia and Gupti jetty point. *Oryza coarctata* was found along the riverside creeks and creeklets of the estuaries where high tides are experienced twice a day. Thus, they are tolerant to submergence and salinity. The plant flowers twice a year in August and February and seed setting is low. They bear the recalcitrant seeds which upon drying desiccate. The local name of the wild rice is 'Dhanidhan'. The collections made have been given temporary Collector No. prefixed with BMW.

Another exploration and collection was made in drought prone areas of Kalahandi, Nuapada, Bolangir, Phulbani, Subarnpur districts of Odisha and 59 germplasm accessions were collected with passport information. The common landraces are Saria, Setka, Kusuma, Punei, Dasaramatia, Chingerdhan, Kundadhan, Menakasala, Chhetka and Karni etc.

Collection of salt tolerant rice germplasm was also made in saline areas of Sunderban and adjoining regions. Sixty two germplasm accessions were collected from different places of South 24-Praganas district with passport information. The common landraces collected were Rupsal, Ordosal, Boyrabota, Haldibatala, Dudhkamal, Getu, Nonabokra, Gheus, Dudheswar and Govindbhog etc.

Collection of wild rice and landraces of Tripura State

An exploration for wild rice species and landraces in the west and south districts of Tripura State was carried out in collaboration with NBPGR. In West Tripura district, various villages in different Blocks *viz.*, Mohanpur, Chebri, Padmabail, Dukli, Barajala, Shipahijala, Teliamura, Kalyanpur, Bisalgarh, Jirania, and Dugli were covered. Seeds of 39 land races and five accessions of *O. rufipogon* were collected. From South Tripura district covering different blocks *viz.*, Udayapur, Melaghar, Belonia, Sabrum, Dhumbur, Manubazar, 29 landraces and one accessions of *O. rufipogon* were collected. All the six accessions of *O. rufipogon* and 68 accessions of landraces were deposited in the CRRI gene bank.

Characterization and rejuvenation of rice germplasm

Five hundred fifty germplasm accessions were characterized for their morpho-agronomic characters according to IRRI-IBPGR descriptors. The panicle length was highest in AC38488 (30.6cm), AC38431 (30.3cm), AC38497 (30.0cm) and AC36758 (29.6cm). Culm number was highest in AC38519 (20), AC38617 (18), AC38590 (15), AC38573 (14.2). The grain number per panicle was highest in AC36759 (265), AC36141 (256), AC36627 (255) and AC37407 (224). High panicle weight was observed in AC38614 (8.5g), AC38617 (7.5g) and AC38834(7.0g). The leaf length varied from 35.0cm (AC39315) to 75.0cm (AC36637). Days to fifty percent flowering ranged from 62.3 (AC38615) to 144 (AC38599).

Conservation of germplasm and development of database for genetic resources management and seed supply

A total of 3000 accessions of rice germplasm were conserved in National Active Germplasm Site at CRRI, Cuttack for medium term storage. Most of the wild species of genus *Oryza* collected and acquired from different sources are conserved *ex situ* in *Oryza* Garden, a new site of field gene bank to prevent spread of shattering seeds of wild rices. More than 2261 accessions of rice germplasm were supplied to researchers within the institute for screening and evaluation. Besides this, another 1929 accessions of rice germplasm were supplied to different researchers throughout the country with a Material Transfer Agreement.

Characterization and maintenance of landraces, identified donors and pre-breeding lines for upland ecosystem

Molecular characterization of 104 upland rice germplasm comprising of traditional cultivars and released varieties, was carried out using 43 SSR markers which were polymorphic across the genotypes. A total of 109 alleles were detected with an average of 2.53 alleles per locus and 10 were found to be rare alleles. Out of 43 primers, only one marker (RM23) showed four alleles, 21 primers showed three alleles and remaining 21 primers showed two alleles (Fig. 1). Dendrogram constructed using UPGMA resulted in 7 clusters at 1.5 linkage distances. Cluster I consisted of RR345-2, Clsuter II consisted of Salumpikit, Cluster III consisted of Abhishek, RR218-65 and Vanaprabha, Cluster IV consisted of Sadabahar, RR158-24, RR348-2 and NDR 1045-2, Cluster V consisted of DDR 105, Birsadhan 101, CT 13370-12-2-M UPLRi-7 and VLDT-1, Cluster VI consists of RR20-5 and Azucena, Lalnakanda and Cluster VII consists of P 0013, IAC25, B6144F-MR-6, Palawan and Tulasi. The same set of genotypes was evaluated for 23 morphological characters (Table 1).

Table 1. Distribution of genotypes into different classes for different characters studied

Leaf sheath colour		Leaf blade colour		Leaf pubescence		Panicle exsertion	
Green	71	Light green	8	Glabrous	15	Well exserted	61
Purple lines	2	Green	70	Intermediate	67	Moderately exserted	20
Light purple	24	Dark green	25	Pubescent	22	Just exserted	15
Purple	7	Purple margin	1	Partly exserted	8		
Stigma colour		**Epiculus colour**		**Panicle type**		**Awning**	
White	73	White	57	Compact	97	Short and partly awned	96
Yellow	2	Straw	19	Intermediate	5	Short and fully awned	7
Light purple	17	Brown	2	Open	2	Long awned	1
Purple	12	Red	17				
		Red apex	1				
		Purple	5				
		Purple apex	3				

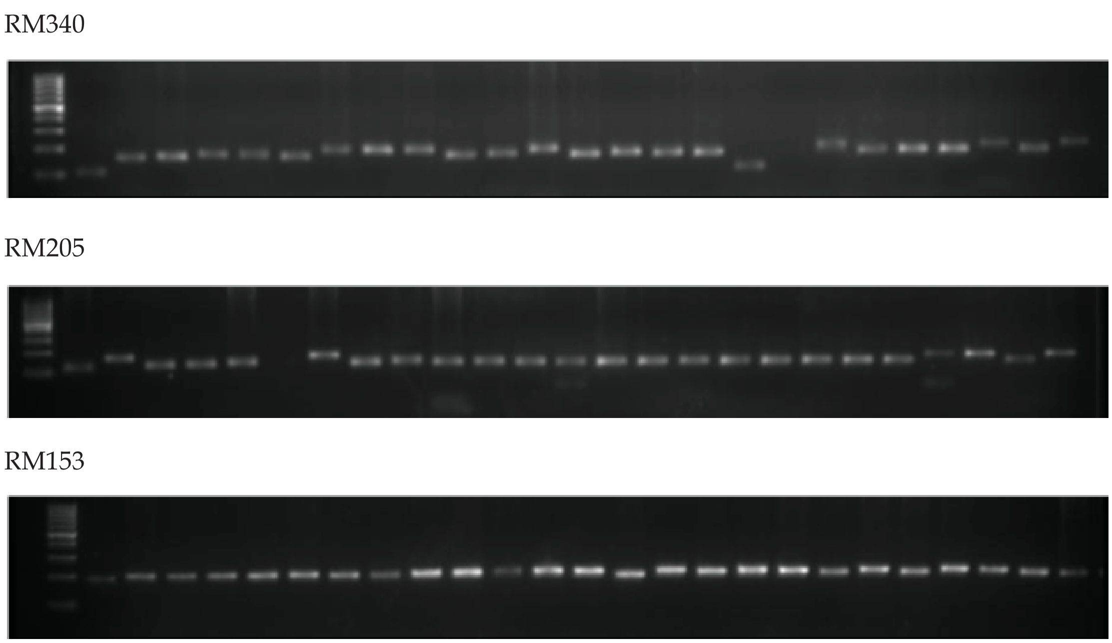


Fig. 1. Molecular profiling of different genotypes using SSR primers RM340, RM205 and RM153

Seed Research

Maintenance breeding and production of nucleus and breeder seed

Nucleus and breeder seed production during the wet season, 2011 (Table 2).

Variety	Nucleus seed production in quintals	Breeder seed production in quintals
CRDhan 70	0.90	4.20
Durga	0.90	6.90
CRDhan 10	1.50	10.20
CRSugandhdhan 3	1.20	1.50
Lunishree	1.50	3.00
Moti	0.90	3.00
Savitri	1.50	39.00
CR1014	0.60	18.00
Utkal Prava	1.20	8.10
Geetanjali	0.90	1.80
Sarala	1.20	25.00
Pooja	1.50	180.00
Tulasi	0.90	1.50
Ketekijoha	0.60	6.00
Nua Kalajeera	0.60	1.80
Padmini	0.90	3.60
Varshadhan	1.20	12.60
Swarna-Sub 1	1.80	170.00
Tapaswini	0.60	3.60
Gayatri	1.20	28.00
Nua Chinikamini	0.90	4.20
Dharitri	1.20	4.50
IR 20	0.60	3.00
CRDhan 402	0.90	0
CRDhan 501	0.90	0
CRDhan 503	0.90	0
Jaldidhan 6	0	1.50
Dhanarasi	0	5.70
Ranjit	0	5.40
Total	27.00	552.10

Studies on seed invigoration for improving rice productivity

Interactions among seed rates, fertility levels and invigoration techniques were found to be statistically non-significant. Seeding density of 100 seeds m^{-2} proved the best, as biological and economic yield were higher than the seeding density of 300 seeds m^{-2}. Likewise, tiller count and effective tillers were more in 100 seeds m^{-2} than the higher planting density. Both the Seed priming and priming agent's spray (spray of aqueous extract of *Syzygium cumini*) showed good response in terms of growth improvement and productivity of upland rice. Sterility of the grain was reduced due to priming and tillers or panicle bearing tillers were affected more than other growth parameters and yield attributes. Thermal hardening using alternate temperatures (43/ 28^{o} C) produced maximum tillers and panicle bearing tillers. Seed treatment proved better than the spray of priming agent.

Use of molecular marker technology for testing purity of parental lines and hybrids and development of markers

Thirty seven selective microsatellite primers were used to amplify genomes of seven CMS (CRMS 10A, CRMS 17A, CRMS 24A, CRMS 31A, CRMS 32A, CRMS 45A and CRMS 64A) and seven maintainer lines (CRMS 10B, CRMS 17B, CRMS 24B, CRMS 31B, CRMS 32B, CRMS 45B and CRMS 64B). A total of 71 alleles/ bands were amplified with an average of 1.92 alleles per primer. Eighteen out of 37 primers amplified 46 polymorphic alleles. Based on the amplification pattern, each genotype could be identified and differentiated from other and were grouped into two major groups at 73% of genetic similarity. Nine markers, hvSSR2-14, RM26, RM210, RM407, RM444, RM475, RM5752, RM10017, RM22506 were found to be useful for differentiating all the CMS lines, CRMS10A, CRMS17A, CRMS 24A, CRMS 31A, CRMS 32A, CRMS 45A and CRMS 64A, respectively from corresponding maintainer lines (CRMS10B, CRMS17B, CRMS 24B, CRMS 31B, CRMS 32B, CRMS 45B and CRMS 64B).

Management of seed micro-flora for quality seed production and storage

Fungal endophyte effective against rice pathogens

The endophytic *Dendryphiella* isolated from rice landrace *Bora Saruchina* collected from Jajpur district of Odisha promoted seedling vigour. It had ability to protect the seedlings from pathogenic *Fusarium* as well as from rice blast infection.

Bipolaris sorokiniana and B. oryzae coming up as threat to rice production

Heavy incidence of 'Brown spot' disease of rice was observed. Brown spots were found to be produced by *Bipolaris oryzae*/*Cochliobolus miyabeanus* and also by *Bipolaris sorokiniana* (teleomorph *Cochliobolus sativus*). *B. sorokiniana* was recorded for the first time as a rice pathogen from this part of India. Seed borne inoculums of brown spot was observed from rice landrace '*Mahipal*' collected from Bolangir district of Odisha. *Paspalum scrobiculatum* was observed as a collateral host of pathogenic *Curvularia spp*. causing leaf spots and seedling mortality of rice. Twenty four, out of 28 isolates studied were Fumonisin producers.

Genetic Enhancement of Yield

New Varieties Released/Identified

Sumit (CR662-22-1-1-1-1; IET19913)

Developed from the cross IR32/IR13246 was released for rainfed lowlands of Odisha. It has maturity duration of 150 days, plant height of 108-115 cm and long bold grain. The average yield of the variety is 5.2 t ha^{-1} and has resistance to leaf blast, stem borer, leaf folder, glume discoloration and has moderate tolerance to neck blast, brown spot, bacterial leaf blight, sheath blight, sheath rot, green leaf hopper, gall midge, rice thrips and has tolerance to submergence for one week.

Satyabhama (CR2340-11; IET20148)

Developed from the cross IR31238-350-3-2-1/IR41054-102-2-3-2 was released for favourabe uplands of Odisha. It has maturity duration of 110 days with semi-dwarf (100-105 cm) and non-lodging plant type moderate tillering, long panicle with medium slender grain. The average yield of the variety is 4.7 t ha^{-1}, while under drought situation it has yield potential of 2.3 t ha^{-1}. It has moderate resistance to stem borer, leaf folder and whorl maggot attack and moderate tolerance to white backed planthopper, gall midge, hispa, thrips and moderate tolerance to leaf blast, rice tungro virus disease and glume discoloration.

Jalamani (CR2282-1-2-5-1; IET20214)

Developed from the cross Panikekoa/Ambika was released for deepwater rice areas of Odisha. It has maturity duration of 160-165 days, tall plant type (150 cm), moderate kneeing ability, phenotypic acceptability and elongation ability moderate tillering with medium slender grain. The average yield of the variety is 4.6 t ha^{-1}. The variety is moderately resistant to leaf folder, green leaf hopper, leaf blast, neck blast, brown spot, gall midge, dead heart, stem borer, whorl maggot and rice thrips.

Jayanti (CR2080-169-3-2-5-2; IET20706)

Developed from the cross Samson Polo/Jalanidhi was released for deepwater rice areas of Odisha. It has maturity duration of 165-170 days, tall plant type (170 cm), moderate kneeing ability, phenotypic acceptability and elongation ability moderate tillering, compact panicle with medium slender grain. The average yield of the variety is 4.6 t ha^{-1}. The variety is moderately resistant to leaf blast, neck blast, sheath bight, sheath rot, rice tungro virus and gall midge biotype1 while resistant to stem borer, leaf folder, rice thrips, and whorl maggot.

Pyari (CR2624-IR55423-01; IET21214)

Developed from the cross UPL RI 5/IR12979-24-1 (Brown) was released for aerobic/water limiting rice areas of Odisha. It has maturity duration of 115-120 days, semi dwarf, non-lodging plant type, moderate tillering with compact panicle and short bold grain. The average yield of the variety is 4.5 t ha^{-1}. The variety is moderately resistant to leaf blast, neck blast, brown spot, stem borer, whorl maggot, gall midge and leaf folder attack.

Hue (CRK26-1-2-1; IET19351)

Developed from the cross IR42/Rahaspanjar was released for mid duration irrigated ecosystem of Odisha. It has maturity duration of 130-135 days, long slender grain and average grain yield capacity of 4.5 to 5.5 t ha^{-1}. The variety has resistance to gall midge and moderately resistant to sheath rot.

Luna Sankhi (CR2577-1; IET21237)

Developed from the cross IR31142-14-1-1-3-2/IR71350 was released for dry season cultivation in coastal saline area of Odisha. It has maturity duration of 105-110 days, plant height of 105 cm, medium slender grain and has average grain yield capacity of 4.6 t ha^{-1}. This variety is tolerant to leaf blast and has moderate tolerance to sheath blight.

Luna Barial (CR2092-158-3; IET19472)

Developed from the cross Jaya/Lunishree was released for wet season cultivation in coastal saline area of Odisha. It has maturity duration of 150-155 days, plant height of 120 cm, medium slender grain and has average grain yield capacity of 4.1 t ha^{-1}. This variety is tolerant to leaf blast and has moderate tolerance to leaf folder and sheath blight.

Improved Lalat (CRMAS2621-7-1; IET21066)

Developed from the cross Lalat/IRBB60 was released for bacterial bight endemic areas in Odisha. It has long sender grain, high HRR with intermediate amylose content having 130 days duration. It is resistant to major pest like gall midge and moderately resistant to stem borer. The average yield under is 4.5 to 5.0 t ha^{-1}.

Improved Tapaswini (CRMAS2622-7-6; IET21070)

Developed from the cross Tapaswini/IRBB 60 was released for bacterial bight endemic areas of Odisha. It has short bold grain, high HRR with intermediate amylose content having 130 days duration. It is resistant to major pest like BPH, YSB and WBPH and moderately resistant to stem borer. The average yield under normal condition is 4.0 to 5.0 t ha^{-1}.

Poorna Bhog (CRM2203-4; IET18008)

Developed from Pusa Basmati-1 through mutation breeding was released for irrigated areas of Odisha. This aromatic variety has 100 cm plant height, 140-145 days to maturity with long slender grain and grain yield capacity of 4.5-5 t ha^{-1}. Its grains are translucent without chalkiness with desirable cooking and eating qualities. The variety is resistant to neck blast, gall midge and moderately resistant to sheath rot and stem borer.

CR Dhan 907 (IET21044)

It is an aromatic short grain culture developed from Pusa44/Dubraj with semi dwarf stature giving a yield of 4.0 t ha^{-1} was identified for CVRC release in four states viz., Odisha, Chhattisgarh, Gujarat and Andhra Pradesh. This is the first semi dwarf aromatic short grain high yielding genotype recommended for central release.

CR Dhan 303 (CR2649-7; IET21589; IC593938)

It derived from the cross between Udaya/IET16611 was identified for irrigated areas of Madhya Pradesh, Uttar Pradesh and Odisha under mid-early duration by Variety Identification Committee. In region III (Eastern India), it stood 1st among all the inbred lines tested for three years (2009-11) with overall yield advantage of 16.4%, 11.6% and 5.3% over National check, Local check and Regional check, respectively. Quality wise it has 62.2% head rice recovery (HRR) with intermediate alkali spreading value (4.0) and amylose content (24.5%). This culture was also found to be promising for drought stress in AICRIP trial, 2010 for drought tolerance under rain out shelter at Coimbatore. This culture is moderately resistant to leaf blast, neck blast, sheath rot and rice tungro disease.

Varietal Improvement for Rainfed Uplands

Development of varieties suitable for uplands including drought tolerance

Promising lines identified

CRR616-B-2-66-B (IET 20859) derived from the cross Vandana/Apo, with 66 days to 50% flowering and short bold grains ranked 1st in AVT-VE under national coordinated trials during 2011 with a mean yield of 2.50 t ha^{-1} on overall mean basis. It showed 30.1, 36.8 and 36.4% yield superiority over the national, regional and local checks, respectively. This entry is resistant to brown spot, moderately resistant to leaf blast and drought. It has high head rice recovery (64.4%), intermediate Alkali Spreading Value (ASV) (4.0), amylose content (22.01%) and soft GC (39). Based on three years of testing this entry has been found promising for direct seeded uplands of Madhya Pradesh and Gujarat.

Entries promoted and new nominations in AICRIP trials

Based on their performance in initial trials, six entries namely, CRR451-1-B-2-1, CRR505-14-B-D1-RR1-B, CRR635-3-2, CRR 616-B-2-54-1, CRR617-B-47-3 and CRR617-B-3-3 were promoted for advanced testing (AVT-VE) under AICRIP trials. Twelve promising entries developed at CRRI Regional Station, Hazaribag have also been nominated for initial varietal testing under AICRIP trials.

AICRIP trial (IVT-VE)

In this trial, 19 entries along with 3 checks of very early duration were evaluated under rainfed uplands. There was deficient rainfall only in the month of July and rest of the growth period experienced normal rains. The top yielding entries in the trial are CRR616-B-2-54-1 (3.42 t ha^{-1}) and CRR451-1-B-2-1 (3.42 t ha^{-1}) significantly better than highest yielding check Anjali (2.50 t ha^{-1}).

Preliminary yield trial

Thirty entries including checks were evaluated under red soil of unfavourable uplands following recommended package of practices (NPK- 40:20:20). There was near normal rainfall during the season, hence the trial did not experience any drought. There were significant differences among genotypes for grain yield and other traits. The top yielding entries are CRR676-

1(1.80 t ha^{-1}), CRR676-11 (1.77 t ha^{-1}) and CRR507-12-B-1 (1.71 t ha^{-1}) but statistically at par with the best check Vandana (1.58 t ha^{-1}) (Table 3).

Hybridization, selection and evaluation of breeding materials

Fifteen new crosses were made to improve drought tolerance, blast resistance, early vigour and grain quality in upland varieties for varietal development in rainfed uplands. During 2011 wet season, in the pedigree nursery for unfavourable uplands, 2394 progenies were grown and 860 single plants and 20 uniform bulk selections were made from 109 crosses (Table 4). In F_3 generation 531 single plant progenies were selected from 16 crosses. Based on plant type, panicle characters, reaction to abiotic and biotic stresses, in F_4, F_5, F_6, F_7 and F_8 generations 113, 73, 15, 100 and 28 single plants were selected from 15, 11, 7, 28 and 32 crosses, respectively. Besides, 20 uniform bulks were multiplied to obtain seed for preliminary yield testing.

Table 3. Performance of the entries under preliminary yield trial- unfavourable upland

Entries	Days to 50% flowering	Plant height (cm)	Grain yield (t ha^{-1})
CRR676-1	69	94.3	1.80
CRR676-11	69	96.4	1.77
CRR507-12-B-1	72	93.0	1.71
CRR417-B-68-B-1-1-2-B-B	68	89.0	1.63
CRR418-B-6-B-1-1-2-1-B	69	88.4	1.48
CRR451-11-B-1	76	89.1	1.46
Vandana	67	87.9	1.58
Anjali	70	76.6	1.56
Brown gora	65	91.0	1.45
Mean	74	87.5	1.07
CD (P=0.05)	2	8.6	0.38

Table 4. Selections from segregating populations under unfavourable uplands at Hazaribag 2011wet season

Generation	Cross	Progenies grown	SP selected	Bulk selected
F_3	16	1946	531	
F_4	15	137	113	
F_5	11	111	73	
F_6	7	46	15	
F_7	28	92	100	
F_8	32	62	28	20
Total	109	2394	860	20

At Cuttack, seven new crosses were made in 2011 wet season using Mahulata, DPS 3 and Naliakhura as parents to improve drought tolerance, weed competitiveness and earliness with blast resistance. Backcross population of a cross between Lalat/*O.nivara* (AC100374)//Lalat were evaluated for blast resistance and two lines were found resistant. A total of 102 breeding lines from ten crosses (F_2 to F_7) including 30 fixed lines were evaluated along with check varieties Lalat and Khandagiri. Six genotypes significantly outyielded the checks and were identified as promising lines.

Development of Aerobic Rice for Favourable Soil Condition

Development of rice lines for water limiting environment

Eleven lines from CR143-2-2/Naveen and twelve fixed lines from Salumpikit/Naveen in F_7 generation have been selected for further advancement. Similarly, in F_8 generation, 12 lines from APO/PS (1086), four lines from Salumpikit/Lalat; 10 lines from CR143-2-2/Swarna; 43 lines from IR 20/Dandi; six lines from CR143-2-2/APO; five lines from CR143-2-2/IR20; eight lines from Dandi/APO; seven lines from Naveen/CR143-2-2; six lines from Salumpikit/Naveen; five from lines Salumpikit/APO; two lines from Naveen/Vandana and 15 lines from Naveen/APO were found promising and selected for further testing. In F_9 generation, five lines from APO/PS (1086), nine lines from Naveen/Salumpikit and 18 lines from IR20/APO were found promising.

New Nominations for AICRIP Trial 2012

Six promising lines *viz.,* CR2902-22-2-4, CR2890-3-2, CR2993-5-1 and CR3425-11-2 with flowering duration ranging from 94-98 days were nominated for IVT-IME and another two entries, CR3420-4-1and CR2902-22-2-1 were nominated to IVT-IM under AICRIP for evaluation.

Development of breeding materials for rainfed semi-aerobic/favourable uplands

AICRIP trials

In case of favourable uplands coordinated trials were conducted in two duration groups i,e. early and mid-early. In AVT2-E none of the entries were better than the national check Sahbhagidhan (2.65 t ha^{-1}) in the trial. Among the test entries, TJP 48 (2.48 t ha^{-1}) was the highest yielder which also performed very well at

Hazaribag during 2010. In IVT-E, top yielding entries were KKMBRNS 2 (2.71 t ha^{-1}) and MAULS-11 (2.67 t ha^{-1}) but statistically at par with the best check Sahbhagidhan (2.64 t ha^{-1}).

There was no significant difference among the entries tested under AVT2-IME for grain yield, however, top performing entries were all hybrids. The highest yielding hybrid 27P31 (6.37 t ha^{-1}) was also the best entry at Hazaribag in the previous year and could be a promising hybrid for Jharkhand. In AVT1-IME, hybrid KPH-371 (7.49 t ha^{-1}) was the best entry and significantly out-performed the hybrid check PA6201 (6.17 t ha^{-1}). Other promising entries were UPR3425-11-1-1(6.93 t ha^{-1}) and HRI-171(6.50 t ha^{-1}). In IVT-IME trial, OR2324-25-1 (6.78 t ha^{-1}), CR2641-30 (6.22 t ha^{-1}), and TM07275 (6.11 t ha^{-1}) were the top yielding entries, out yielded the best check, Lalat (5.72 t ha^{-1}).

IR 64 NILs with drought tolerance

Near isogenic lines (NILs) have been developed at IRRI in the background of IR64 by introgressing QTLs for grain yield under stress (DTY) using marker assisted selection. Individual QTLs were pyramided to increase the level of tolerance. Four such lines (NILs), three lines with two QTLs (DTY2.2 and DTY4.1) and one line with three QTLs (DTY2.2, DTY4.1 and DTY10.1) along with recurrent parent IR64 were evaluated with and without drought stress. In the rainout shelter stress trial, two replications were severely stressed (50 to 53 –kpa) as indicated by the tensiometer reading and analysed separately under severe stress condition. Other two replications were moderately stressed (39 to 41 –kpa at 30 cm depth). Top performing NIL IR87707-445-B-B-B outyielded the recurrent parent IR64 by 67% under severe stress, 27% under moderate stress and no yield difference under control (Table 5). Under severe stress, the NIL also had lower canopy temperature (31.95°C) and lower Drought Severity Index (0.94) as compared to IR64 (CT- 33.3°C and DSI-1.09) indicating higher level of drought tolerance.

Preliminary yield trial

In preliminary yield trial for favourable uplands 40 entries including checks were evaluated and significant differences were observed among test entries for grain yield and other traits. CRR459-52-1-1-1 (2.81 t ha-

Table 5. Performance of IR64 NILs (AICRIP) with and without stress at Hazaribag during wet season 2011

Designation	Days to flower	Grain yield (t ha^{-1})			Drought Susceptibility Index (DSI)	
		Control	Moderate stress	Severe stress	Moderate stress	Severe stress
IR87706-215-B-B-B	89	5.31	1.72	0.92	1.02	1.09
IR87707-182-B-B-B	88	4.45	1.88	1.50	0.87	0.87
IR87707-445-B-B-B	89	5.69	2.19	1.60	0.93	0.94
IR87707-446-B-B-B	91	5.71	1.31	1.23	1.16	1.03
IR64	89	5.61	1.83	0.95	1.02	1.09
Mean	89.0	5.35	1.79	1.24		
SED	0.72	0.47	0.29	0.42		
CV%	1.15	12.23	15.64	32.24		

Table 6. Performance of entries in Preliminary Yield Trial (favourable uplands)

Entries	Days to 50% flowering	PlantHeight (cm)	Yield (t ha^{-1})
CRR459-52-1-1-1	78	107.7	2.81
CRR536-7-1-1	78	114.8	2.60
CRR451-11-B-1	73	118.1	2.29
CRR446-6-1	75	118.6	2.08
CRR635-3-2	78	113.1	2.08
CRR632-34-1	79	78.3	2.06
CRR507-12-B-1	70	113.9	2.06
CRR473-5-1-1-1	68	105.2	2.02
Sadabahar	76	99.4	2.05
CR Dhan 40	73	112.7	1.96
Mean	73	110.6	1.77
CD (P=0.05)	1.7	7.5	445

[1]) and CRR 536-7-1-1 (2.60 t ha^{-1}) were the top yielding entries in the trial, significantly superior to other entries and checks (Table 6). Other promising entries identified are CRR451-11-B-1 (2.29 t ha^{-1}), CRR446-6-1 (2.08 t ha^{-1}) and CRR635-3-2 (2.08 t ha^{-1}).

Hybridization, selection and evaluation of breeding materials

Ten new cross combinations were attempted involving parents *viz.*, Sahbhagidhan, Sadabahar, RR51-1, Annada, Abhishek, ARB7, TJP48, CT9993-5-10-1-M, CR2340-11 and IR64-*glaberrima* introgression lines for the improvement of drought tolerance, weed competiveness and blast resistance besides yield potential under favourable uplands. Segregating populations of different generations were evaluated and selections were made based on maturity duration, plant height, panicle length, number of grains panicle^{-1}, sterility percentage and disease, and pest reaction. During 2011 wet season, 1223 single plant progenies were raised for evaluation under direct seeded condition. In segregating generations, from F_3 to F_8, 616 single plant progenies were selected from 118 crosses for further evaluation (Table 7). Besides these, 16 uniform progenies were bulked for preliminary yield evaluation in the next season.

Varietal improvement for shallow favourable lowland and irrigated ecosystems

Development of varieties with wider adaptability

Out of sixty germplasm lines maintained and evaluated, Shatabdi, a semi-dwarf, non-lodging early rice cultivar and Phalguni were found promising for *boro* condition. They were also found promising for Odisha under direct seeded wet land condition. They are adaptive to *boro* season with grain yield of 5.0- 6.0 t ha^{-1} in 110 days duration. WITA12 has been observed to possess basal pigmentation and white panicle.

Two hundred and seventy three progenies (F_4-F_7) along with checks, Swarna, Lalat, Naveen, WITA8 and WITA12 were evaluated and 273 SSPs were selected. Out of forty fixed cultures evaluated earlier, six were multiplied and nominated for AICRIP trials. Out of 24 fixed (AICRIP Trials) cultures evaluated, CRK26-1, Phalguni, CRAC2224-533, Satyakrishna and CRK22 found to be promising. Yield potential did not differ under direct seeded and transplanted condition but duration was early by 7-10 days under direct seeded condition.

Under direct seeded and transplanted conditions elite cultures *viz.*, CRAC2222-533, CRK22, CRK26-1-2-1, WITA12, Lalat, Naveen, IR64, Phalguni and Satyakrishna were evaluated in both *boro* and wet seasons. In both the seasons, duration of the varieties got reduced by 7-10 days under direct seeded condition with little difference in yield. In AYT for irrigated ecosystem, 30 advanced cultures were evaluated under two replications along with checks Naveen, Lalat and IR 64. The promising cultures were CRK18, CRAC2222-533, CRAC2221-43, CRAC2224-1041, CRK26-1-2-1 (IET 19351) and CRK26.

Table 7. Single plant (SP) selections made for favourable uplands during 2011 wet season

Generation	No. of Cross	No. of Progenies grown	No. of SP selected	No. of bulk selected
F_3	22	818	380	
F_4	6	87	56	
F_5	19	96	53	
F_6	25	99	61	
F_7	22	56	31	
F_8	24	67	35	16
Total	118	1223	616	16

Development of Varieties with High Nitrogen Use Efficiency

Evaluation of rice genotypes for high nitrogen use efficiency

Thirty one rice genotypes were evaluated under irrigated condition during dry season 2011 for nitrogen use efficiency at N_0, N_{120} and N_{200} level. Based on Agronomic N use efficiency (AE_N) at moderate N level i.e. 120 kg ha^{-1} Birupa found to be most efficient with AE_N value of 24.4, followed by Tapaswini (23.8), Indira (23.4), Surendra (22.6) and Pusa 44 (22.4). Almost similar trend was observed when high dose of N (200 kg ha^{-1}) was used. The most efficient genotypes at high N rate were Tapaswini with AE_N of 18.4, Birupa (18.2), IR8 (17.6), Indira (17.2) and Pusa 44 (17.0). N_{120} level, the highest yield of 6.2 t ha^{-1} was recorded in Tapaswini followed by Surendra (5.8 t ha^{-1}), Indira (5.5 t ha^{-1}) and IR8 (5.4 t ha^{-1}) whereas, N_{200} level the highest yield was obtained in Tapaswini (6.8 t ha^{-1}) followed by IR8 (6.4 t ha^{-1}), Pusa 44 (6.3 t ha^{-1}) and Indira (6.0 t ha^{-1}).

Evaluation of performance of promising F_5 population in wet season 2011

Sixty promising F_5 populations were evaluated to assess their performance at lower (N_{40}) and moderate

N level (N_{80}) with 7 popular varieties as checks *viz.,* IR 36, IR64, Vijetha, Pusa44, Tapaswini, Surendra and Indira. At N_{40} level, entry No. 4 (Lalat/Tapaswini 3-1-1) and entry No. 1 (Vijetha/N22 8-2-8) were the superior yielders with 4.38 t ha^{-1}. Entry No. 24 (Lalat/Supriya 1-2-1) and entry No. 3 (Lalat /IR 36 -15-1-1) yielded 4.31 t ha^{-1} and 4.27 t ha^{-1}, respectively that were either at par or better than the checks.

At N_{80} level, entry No. 109 (IR-36/Vijetha-3-1-1) gave a yield of 4.50 t ha^{1} followed by entry No.86 (IR-36/Vijetha 20-2-1) with 4.47 t ha^{-1} and Entry No. 60 (IR-36/Pusa 44 12-1-1) with 4.42 t ha^{-1} were better than checks.

Evaluation, selection and advancement of breeding materials of F_4, F_5 and other segregating generations

Around 1200 promising lines of F_4 and F_5 generations were evaluated under low nitrogen level (N_{30}) and also at moderate N level i.e. N_{60} and selected 1600 promising single plants with desirable features like high yield, long panicles, high grain number, long slender and long bold grain with high grain weight. Similarly, around 20 F_2 crosses from mid duration group and 35 F_2 crosses of long duration group were evaluated at low nitrogen level and selected around 600 single plants for further evaluation based on yield and other desirable features.

Breeding for Fe toxicity and zinc deficiency tolerance

Evaluation of around 420 F_5 single plant progenies at zinc deficient site of Ranital farm involving crosses of IR36, Ratna, Abhaya and Gajapati (Zinc deficient tolerant genotypes) with popular irrigated genotypes like Tapaswini, Surendra, Vijetha, Pusa44 was conducted and selected around 280 single plants for further advancement based on non-bronzing symptom and higher yield. Also evaluated 19 crosses of F_2 generation and selected around 150 single plants for further evaluation based on tolerant to zinc deficiency i.e. non appearance of leaf bronzing at 15-30 DAT with SES score 1 and 3. In iron toxicity tolerance evaluation around 480 single plant of F_4 generations and 18 F_2 generation crossed with tolerant genotypes Gitanjali, Surendra, Swarna and Lalat, with Savitri, Ranjit, Salivahana, Pooja and Sambha Mahsuri and selected 320 F_5 plants and 160 F_3 plants without bronzing symptom under iron toxic soil of Central Farm, Bhubaneswar for further evaluation. The same set of breeding materials was grown at CRRI to evaluate their performance under non stress environment and selected 100 plants based on yield and other agronomic criteria only.

Breeding for High Temperature Tolerance in Irrigated Rice

Evaluation of germplasm and genotypes for heat stress tolerance

Seventy four germplasm accessions evaluated and shortlisted earlier for heat stress tolerance were reevaluated by staggered sowing and planting so as to expose them to heat stress at reproductive stage along with susceptible checks (Satabdi, Naveen and Lalat) and tolerant check (N22, Annapurna and Dular). Out of these, 14 genotypes showed high spikelet fertility an indicator of reproductive stage heat stress tolerance even when flowered at higher temperature period. The most tolerant genotypes with high spikelet fertility, percentage were AC39843 (88.36%), AC39123 (88.07%), AC607 (87.74%) and AC39940 (87.25%) and N22(87.25).

Evaluation, selection and advancement of breeding materials for heat stress tolerance

Around 450 single plant selections of F_4 lines involving promising irrigated cultivars like Tapaswini, Lalat, Surendra, Pusa44, Vijetha, Shatabdi, IR36, Sasyasree and heat tolerance genotype N22, Annapurna, ADT43 and Dular were selected for heat stress situation by delayed sowing and planting. Based on high spikelet fertility, higher grain yield, high harvest index (HI) and other agronomic features 530 single plant selections were made for further advancement. The same 530 materials were evaluated during wet season 2011 for their performance and selected around 480 single plants of F_6 generation for further advancement.

Varietal Improvement for Rainfed Unfavorable Lowlands

Development of varieties of medium and mid-late duration with major biotic and abiotic stress tolerance (drought) for unfavorable shallow lowlands

Ten new crosses were made with Savitri, Gayatri, Swarna, Pooja and Lalat as ovule parents and drought tolerant lines CR143-2-2, Mahulata, Kalakeri, Bramani Nakhi and Naliakhura as pollen parents to improve drought tolerance, blast resistance and panicle characters for unfavorable lowland ecosystem. More than 30 bulks were selected and more than 300 single plant selections possessing desirable characters were made.

Reproductive stage observations were recorded from the fixed lines and promising selections *viz.*,CR2993, CR2882-1, CR2908, CR2875, CR2899, CR2881, CR2882-1-1, CR2907, CR2881-1, CR2902, CR2903, CR2890, CR2877, CR2902-1, CR2875-1, CR2902-1 were identified from cross CR143-2-2/Swarna, Salumpikit/Dandi, Dandi/APO, Salumpikit/APO, Salumpikit/Naveen for yield and yield traits and were retested against blast for its resistance.

Breeding for submergence prone and medium deep waterlogged areas

Development of breeding material suitable for submergence prone situation

One hundred and eighty single plant progenies from 19 cross combinations developed for submergence tolerance were evaluated under controlled submergence conditions during the wet season, 2011 and 64 lines showed more than 60% survival. Out of these lines, 114 single plant selections were made at the time of flowering and maturity on the basis of submergence tolerance, plant and panicle characters.

Development of breeding material suitable for medium deep waterlogged conditions

One thouse five hundred and twenty-two (F_3-F_8) single plant progenies along with 22 F_2 bulks were grown under medium deep waterlogged situation. Out of this material, 1000 single plants and 76 uniform progenies were selected on the basis of tolerance to water logging, plant and panicle characters (Table 8).

Evaluation of elite breeding lines in Advance Yield Trial (Station trial)

Twenty promising genotypes along with five check varieties (Purnendu, Sabita, Jal-lahari, Sarala and Varshadhan) were grown in a replicated trial under semi-deep water logged situation during wet season, 2011. Among the 25 entries tested only one culture CR2416-27-2-1-2-2-1 gave better yield (4.08 t ha^{-1}) than the best check variety Varshadhan (3.86 t ha^{-1}) followed by CR2415-43-1-1-1-1-1 (3.51 t ha^{-1}) and CR2416-15-2-2-7-1 (3.31 t ha^{-1}). Most of the entries flowered between last week of October and second week of November.

Table 8. Breeding materials evaluated and selections made during wet season 2011

Generation	No. of crosses/ bulks/ progenies grown	No. of selections	
		Single plants	Uniform bulks
F_2 bulks	22	138	-
F_3	462(74)*	375	-
F_4	385(47)	416	-
F_5	128(11)	71	-
F_6-F_8	547(79)	-	76
Total	1522 (233)	1000	76

*Number in parentheses indicates no. of crossses

AICRIP trials and performance of entries nominated during 2011

Three AICRIP trials *viz.,* NSDWSN (48 entries including three checks), IVT-SDW (18 entries including three checks), AVT 1-SDW (seven entries including three checks) were conducted under semi-deep water conditions during wet season 2011.

All the seven entries *viz.,* CR2416-13-1-1-1, CR2439-B-12-1-1, CR2416-6-1-1-1, CR2436-B-8-1-1, CR2378-13-1-1-1, CR2377-21-5-1-1 and CR2389-11-2-1-1 nominated to NSDWSN under AICRIP trials have been found promising and promoted to IVT-SDW. Two entries CR2389-5-2-1-1 and CR2378-13-4-1-1 tested under IVT-SDW have been promoted to AVT1-SDW testing during wet season, 2012.

Development of suitable varieties for delayed monsoon/early flooding situation

Seventeen advanced cultures were evaluated in replicated transplanted condition in 2011 wet season for yield and yield attributing characters with three check varieties Pooja, Gayatri and Varshadhan with both normal and aged seedlings. Sowing for aged seedlings trial was done on 8th June and transplanted on 26th August 2011 using more than 70 days old seedlings. CR2750-154 (4.10 t ha^{-1}) could give better yield than the best check Gayatri (3.81 t ha^{-1}) followed by CR2753-264 (3.90 t ha^{-1}) and CR2304-5-7 (3.80 t ha^{-1}). Sowing for delayed seeding was done on 20th July and transplanting was done with 35 days old seedlings. The genotype CR2565-674-292 (4.0 t ha^{-1}) was observed to be the highest grain yielder closely followed by CR2750-382 (3.80 t ha^{-1}) and CR2304-5-7 (3.70 t ha^{-1}) superior to the check varieties Varshadhan (3.40 t ha^{-1}) and Gayatri (3.30 t ha^{-1}). After twelve days of transplanting both the trials came under complete submergence for five days.

In general, planting with aged seedlings delayed the flowering by more than forty days resulting into reduced grain yield. CR2750-154, CR2753-264, CR2304-5-7, CR2565-674-292 and Gayatri were found suitable with aged seedling whereas, CR2565-674-292, CR2304-

5-7, CR2750-382 were promising in delayed seeding condition. The genotype CR2565-674-292 was observed to be stable in both the conditions.

Based on the overall performance of the cultures in station trial, CR2565-288, CR2543-83, CR2458-72-6, CR2767-5-1, CR2573-264, CR2008-4-8, CR2750-154 were nominated for NSDWSN; CR 2565-278, CR2565-352 and CR 2551-417 to IVT Late; CR2565-297, CR2565-348, CR2750-382, CR2565-549 CR2573- CR2008-111-4-16 and CR2565-674-292 to IVT rainfed shallow lowland trial of AICRIP. The promising genotype CR2459-12-8 was promoted to AVT 1 RSL for third and final year of testing along with CR2547-62-316 which was also promoted to final year of testing in AVT 2-SDW. Two other promising genotypes CR2573-621, CR2983-48 were promoted to second year of testing in semi-deep water and shallow lowland trials, respectively.

Generation advancement of 356 plant progenies belonging to 26 cross combinations in different generations was made and 314 single plants were selected for further evaluation, whereas 28 lines were bulked based upon their uniformity, grain yield and plant type.

Development of short duration (100 -110 days) and salt tolerant variety for coastal saline areas in dry season

Twenty one new crosses and nine back crosses were attempted during wet season 2011. One hundred eighty four BC_1F_3 short duration salt tolerant lines were planted for generation advancement in target area and 32 bulk populations were selected. Thirty two BC_1F_4 short duration salt tolerant lines were planted for generation advancement and two hundred fifty (250) single plant populations were selected. One hundred twenty seven F_3 multiple crosses for long duration were planted for generation advancement and four hundred fifty one single plants were selected.

Evaluation of breeding materials at target site

Thirty eight fixed lines along with three checks (IR72046-B-R-3-3-3-1, FL478 and Patitapaban) were evaluated in farmers' field at Padmapur, Ersama with soil ECe (1:2) and field water EC 7.7-10.8 and 3.4-11.7 dSm^{-1}, respectively. Five genotypes including susceptible check were completely dead. Highest yield recorded was 7.37 t ha^{-1} in CR2815-5-1-3-5-1-2-1 followed by 7.22 t ha^{-1} in CR2815-4-26-2-1-1-1-1 whereas, checks IR72046-B-R-3-3-3-1, FL478 (*Saltol*) and Patitapaban produced 3.50 t ha^{-1}, 1.60 t ha^{-1} and 0.00 t ha^{-1}, respectively. Five cultures gave more than 7.00 t ha^{-1}, six cultures yielded more than 6.00 t ha^{-1} and seven cultures produced more than 5.00 t ha^{-1}.

Evaluation of breeding materials in simulation tank

The same set of 38 lines from Annapurna/FL478 and Naveen/FL478 crosses were evaluated at vegetative and reproductive stage (SES, IRRI) for salinity tolerance in simulation tank at an EC of 10-14 dSm^{-1} in a replicated trial. Most of the genotypes were more tolerant than FL478 (*Saltol*) check. Highest yield was recorded in CR2815-4-23-5-S-2-1-1 (243 g m^{-2}) with 92 per cent survival followed by CR2815-4-26-1-S-5-2-1 (218 g m^{-2}) with 90 per cent survival. Some of the promising cultures were CR2815-2-4-2-1-1-1, CR2815-5-1-3-S-1-2-1, CR2814-2-4-3-1-1-1, CR2815-4-27-4-S-2-1-1, CR2815-4-23-2-1-1-1, CR2815-4-26-1-S-5-1-1 and CR2815-4-27-4-S-1-1-1 with 80-90 per cent survival. FL478, IR72046-B-R-3-3-3-1 and IR29 yielded 133 g m^{-2}, 89 g m^{-2} and 22 g m^{-2} with 84, 70 and 17 per cent survival, respectively (Table 9).

Varietal Development for Coastal Saline Areas for Wet Season

Hybridization and selection for high yielding salt tolerant lines

F_1 seeds were developed from 62 single, three way and double crosses in wet and dry season. In wet season, from salinity micro-plot (with ECe=12 dSm^{-1}), 1226 and 1330 seedlings belonging to F_5 and F_6 generation,

Table 9. Promising entries under simulation tank and farmers' field conditions

Genotypes	Simulation tank Survival (%)	Simulation tank Yield (g m^{-2})	Farmers' field Survival (%)	Farmers' field Yield (g m^{-2})
CR2815-4-23-5-S-2-1-1	92	243	90	662
CR2815-4-26-1-S-5-2-1	70.4	218	86	507
CR2815-2-4-2-1-1-1	91.4	207	95	700
CR2814-2-4-3-1-1-1	91.4	202	100	703
CR2815-4-27-4-S-2-1-1	89.5	202	100	595
CR2815-5-1-3-S-1-2-1	89.5	192	100	737
CR2815-4-23-1-S-4-1-1	94.4	177	95	435
IR72046-B-R-3-3-3-1 (check)	70.9	89	51	105
FL478 (*Saltol*) (check)	84.2	133	79	160
IR29/Patitapaban (check)	17.3	22	30	0
LSD (P=0.05)		10.2		15.6

respectively have been selected for their tolerance and transferred to non-saline fields. In dry season, six out of sixteen populations could regenerate after salinity stress (ECe=12 dSm^{-1}) at seedling stage. Around 253 single plants and 172 bulk population ranging from F_2 to F_7 generation have been harvested considering plant type and yield potentiality under non-saline condition. Fifty two single plants and eight bulk population have been selected from farmers' fields under saline situation (ECe= 7-8 dSm^{-1}).

AICRIP and INGER Trials conducted

IET 22636 (KMR3/*O. rufipogon;* BC_2F_1 -6) ranked first with 3.93 t ha^{-1} grain yield in NSASN under medium saline situation (ECe = 2-6 dSm^{-1}) while no entry could exceed the check variety Nona Bokra (3.40 t ha^{-1}) in IRSSTN module-1 for wet season 2011 under ECe of 6-8 dSm^{-1}.

Evaluation for seedling stage tolerance

Lower Na^+ concentration (ug mg^{-1}) and Na^+/K^+ ratio of shoot were found associated with tolerance. Under the evaluation of seedling stage salt tolerance of 62 accessions, highly (score 3) and moderately (score 4-5) salt tolerant accessions such as FL478, Korgut, Chettivirippu (AC39389), Chettivirippu (AC39394 Talmugur (AC43228), Kamini, Matchal (AC43232), Rupsal, Marisal, Gitanjali (AC43238), Agniban (AC43219), Matla, Patnai (AC43220), Chettivirippu (AC39388) and Hasawi contained very low Na-K ratio (0.18-0.30) in shoot. Higher potassium content in shoot per plant (18.9 mg as against 12.52 mg) contributed positively towards less Na^+/K^+ ratio and therefore, towards more tolerance in F_2 lines derived from Savitri/FL496 as compared to Savitri/SR26B.

Development of mapping population for analysis of salt tolerance

One BC_3F_3 population from IR64/Pokkali (AC41585) was developed. Another eight backcrosses (BC_1F_1) were generated using different salt tolerant donors.

Breeding high yielding varieties for deepwater rice with tolerance to major biotic and abiotic stresses

During 2011 wet season, selection and evaluation of segregating materials were taken up in F_2-F_6 generations in deepwater rice breeding programme. Selections were made within the segregating population of a cross in F_2 generation. More than two thousand plants were transplanted in pedigree nursery per cross and twenty five crosses were raised during the season. One hundred eighty promising single plants were selected from 25 cross combinations on the basis of moderate elongation ability, good kneeing ability, high panicle and grain number, photo sensitiveness, plant height, field tolerance to bacterial blight disease and stem borer and leaf folder attack. During the season, selection of superior progenies from the F_3 segregating generation was made from the F_3 pedigree nursery. Around two hundred plants comprising four rows were raised and selections were made within and between lines for advancement to F_4 generation. A total of 130 promising single plants were selected from thirty cross combinations.

Two hundred twenty F_4 lines and one hundred ninety F_5 lines were grown under typical deepwater situation and selections were made within and between lines to obtain promising plants. Among the F_4 populations, one hundred twenty promising single plants were selected from the derivatives of thirty cross combinations. Similarly, seventy promising single plants were selected from the 190 single plant progenies of F_5 generation segregating materials of twenty five crosses. During the season, uniform plant progenies of 45 F_6 lines were bulked and 30 single plant selections were made for further evaluation and advancement.

The performances of 23 elite fixed lines were promising as compared to the three check varieties. During the year, two high yielding rice varieties, *viz*., Jalamani and CRDhan 502 were released for deepwater areas of Odisha. Two deepwater rice cultures, CR2682-4-2-2-2-1 and CR2683-28-45-1-5 are in final year of testing under national trial and exhibiting superiority for many states. Seeds of forty five promising cultures were multiplied for nominations to various national and international trials and release purposes.

During wet season 2011, generation advancement of the F_3 population was taken up to develop recombinant inbred lines for mapping population. Progenies of the crosses, Durga/AC38480 and Durga/AC38999 were advanced to F_4 generation to develop the population. Single seed descent method was followed for generation advancement. From each line, single seed was grown and also 2-3 seeds were maintained for next generation and individual lines were kept separately.

National (AICRIP) and International (INGER) trials for lowland ecosystem

Initial variety trial-deepwater rice

Seeds of entries under initial deepwater rice trial were direct seeded during 2011 wet season to evaluate the promising entries nominated from different locations of the country. IET 22298 was top yielder (6.50 t ha^{-1}) followed by IET22314 (5.30 t ha^{-1}) and IET 22312 (5.20 t ha^{-1}).The mean grain yield ranged from 1.50 to 6.50 t ha^{-1}. IET 22306 and IET 22312 were observed to be having high seedling survival and at par with check varieties, Jalmagna and Dinesh.

Advance variety trial 1-deepwater rice

Seeds of entries under advance deepwater rice trial were direct seeded during 2011 wet season to evaluate the promising entries promoted from initial variety trial tested at different locations of the country. Eleven test entries were in second year of testing. IET 21719 was top yielder (5.60 t ha^{-1}) followed by IET 21716 (5.10 t ha^{-1}). The mean grain yield ranged from 3.00 to 5.60 t ha^{-1}. IET 21716 and IET 21706 were observed to be having high seedling survival and at par with check varieties, Jalmagna and Dinesh.

Breeding for Flood Prone Ecosystems

Development of varieties for pre-flood (*ahu*), post flood *(sali)* and flash flood situations

Generation of breeding materials

Sixteen uniform lines were selected from F_7 progeny derived from nine crosses for evaluation in station trial under rainfed shallow lowland situation. Three hundred seven F_6 progenies derived from fourteen crosses were evaluated and a total of 95 uniform lines (27 for rainfed shallow lowland, 43 for semi deep water and 25 for deepwater ecosystem) were selected for further evaluation in replicated yield trial. For the development of pre-flood *ahu* rice, F_1s of 16 single crosses (using traditional *ahu* rice and early maturing high yielding bases) were raised during *ahu* 2011 and 570 single plants were selected for further evaluation and selection.

Evaluation of pre-flood ahu rice

Twenty four early maturing rice including 10 varieties received from VPKAS, Almora were evaluated to assess their suitability as pre-flood *ahu* crop during *ahu* 2011. Rice Nilagiri (3.79 tha^{-1}), Kalyani-2 (3.67 t ha^{-1}), BAU404-D2 (3.45 t ha^{-1}) Kalong (3.10 t ha^{-1}) and Anjali (2.93 t ha^{-1}) were the top yielding five genotypes with similar maturity duration of the local check Luit (2.88 t ha^{-1}). The rice genotypes from VPKAS, Almora were inferior in grain yield compared to the local check.

Evaluation of post-flood sali rice

Eighteen rice varieties were evaluated during wet season 2011 under post-flood situation. Twenty five days old seedlings were transplanted on 9th September. CRM49 (2.88 t ha^{-1}), Manoharsali (2.62 t ha^{-1}), Dikhow (2.39 tha^{-1}) and Dichang (2.35 t ha^{-1}) were the top yielding varieties.

Development of varieties for *boro* season

Generation of breeding material

One hundred and eighty progenies (in F_4 nursery) derived from six crosses for development of *boro* rice varieties were evaluated during *boro* 2010-11 and 142 single plants were selected based on plant type, panicle characteristics and reaction to pest and disease under field condition. F_2 nursery of another set of 35 crosses for development of *boro* rice varieties was also raised and 390 single plants were selected for further selection in the next generation.

Preliminary yield trial for boro

Thirty three uniform *boro* rice cultures were evaluated during *boro* 2010-11. Four promising cultures from the trial (*viz.*, CRL1-1-3-3-1-1-1, CRL1-27-4-3-1-1-3, CRL2-41-6-3-1-1-1 and CRL2-41-6-3-1-1-13) were nominated to AICRIP under IVT-*Boro.*

Germplasm, seed maintenance and genotype evaluation through national and international trials

A total of 57 deepwater rice germplasm were collected from Kamrup, Nalbari, Dhemaji, Lakhimpur, Sonitpur and Jorhat districts of Assam in collaboration with NBPGR Regional Station, Thrissur during 2011 wet season. Seven hundred thirty accessions of lowland rice germplasm during wet season 2011 and 480 accessions of traditional *boro* rice during *boro* 2010-11, were grown and observed for days to 50% flowering, plant height, EBT and grain yield.

Hybrid Rice Technology

Production and evaluation of test cross hybrids

Five hundred and forty five test crosses involving seven CMS lines were grown in TCN for evaluation during dry season and wet season, 2011 and 25 heterotic combinations with >80% spikelet fertility were identified besides 30 promising sterile combinations. Around 300 new test crosses were made and evaluated in dry season, 2012. Test crosses for some of the fertile combinations with high spikelet fertility and good yield potential were repeated and flowering behavior of the parental lines for synchronization were studied. A few long duration, short statured plants were selected from anther culture derived plants of the cross combinations, CRMS31B/CRMS24B and CRMS32B/CRMS24B and test crosses were made to develop usable CMS lines in the late duration.

Maintenance, evaluation and multiplication of CMS lines

Twelve CMS lines including six CRRI bred CMS lines were evaluated for agro-morphological and floral characteristics and were maintained through manual hand crossing. CRMS31A and CRMS32A were multiplied in larger quantity both during wet season and dry season, 2011 (>100 kgs each). Five CMS lines from other sources (APMS6A, RTN12A, RTN6A, PMS10A, and PMS15A) were taken up for small scale multiplication for further utilization. Six CMS lines including the widely used lines, CRMS31A and CRMS32A were grown for purification and seed multiplication during dry season, 2012.

Transfer of characters into CMS lines

Hybrids were developed with donors for exserted stigma and BLB resistance with CRMS31B, CRMS32B and IR42266-29-3R, to transfer these traits into the promising CMS and restorer backgrounds. BC_3F_2 and BC_2F_2 progenies of these crosses were grown and were tested for presence of genes of interest. Test crosses with some promising BC_2F_2 single plants having resistance genes and without fertility restorer genes were made and the resultant hybrids were found to be sterile and backcrosses were initiated on these sterile F_1s.

Backcrosses were continued with exserted stigma segregants by using them as male parents on two CMS lines, CRMS31A and CRMS32A to transfer exserted stigma trait and develop improved CRMS31A and CRMS32A.

Status of back crossing to develop new CMS lines

Sixty nine backcross derived lines in 105-140 days duration were evaluated and carried forward based on pollen/spikelet sterility. Some of the short duration advanced lines involving drought tolerant recurrent parents like Virendra and Sahabhagidhan were quite stable for pollen and spikelet sterility. Some of the promising lines with stable male sterility, out crossing, good floret opening, and panicle and stigma exsertion are listed in Table 10.

Seed production of hybrids

Hybrid seeds of 13 combinations were produced including the three released hybrids during wet season, 2011 and dry season, 2011. Flowering behavior and synchronization of nine long duration hybrid combinations were studied. Production of eight hybrid combinations was taken up during dry season, 2012. Flowering behavior and synchronization of six long duration hybrid combinations studied during wet season, 2011 was also taken up during dry season, 2012. Three long duration hybrid combinations were nominated for evaluation in SLHRT-2011 at sixteen locations during wet season, 2011.

Restorer and maintainer breeding

About 1200 single plant progenies from both population improvement and recombination breeding (42 cross combinations) were grown in pedigree nursery and single plant selections with desirable features were made to develop improved parental lines.

Doubled haploid breeding

A total of 495 regenerants were produced from the anther culture of Rajalaxmi and they were transferred to pots and were grown in the green house in the A_0 generation. The ploidy analysis of the regenerants revealed that of the 495 derivatives, 243 double haploids and 221 were halpoids while the rest were polyploids.

Table 10. Promising sterile backcross derived lines advanced during 2011

BCN No.	Recurrent parent	Characteristics
$BCN^5$12A	HR-26-73	-
$BCN^5$17A	HR-34-7	-
$BCN^5$39A	CR-2234-75	-
$BCN^4$52A	PS 92B(69) (Kalinga)	Purple leaf
$BCN^4$71A	CRMP 2-1-614(79)	-
$BCN^4$166A	Shatabdi	Short duration
$BCN^4$206A	Abhishek	Short duration, drought tolerant
$BCN^4$199A	CR2234-1020 (WA)	Good floret opening
$BCN^4$200A	CR2234-1020 (Kalinga)	Good floret opening
$BCN^2$99A	A-180-12-1(87)	Short duration, drought tolerant
$BCN^4$187A	Sahabhagidhan	Short duration, drought tolerant
$BCN^4$180A	CR2234-834(WA)	Good floret opening and stigma exsertion

All the 243 doubled haploids were grown in the field for morpho-agronomic characterization and preliminary yield evaluation in A_1 generation. More than 97% of the doubled haploid lines showed 100% uniformity for all the six agronomical characters studied i.e. duration, plant height, tiller numbers, panicle length and 1000 grain weight. Based on the yield evaluation of the DH's in the A_1 generation, 20 promising doubled haploid lines from CRHR 5 were identified. The yield levels of some of the promising doubled haploids of Rajalaxmi are CR5-19 (7.23 t ha^{-1}), CR5-49 (7.23 t ha^{-1}), CR5-61 (7.23 t ha^{-1}), CR5-85 (7.03 t ha^{-1}), CR5-129 (7.23 t ha^{-1}) and CR5-10 (6.87 t ha^{-1}) while the hybrid parent recorded a yield of 7.35 t ha^{-1} and the two standard checks Lalat and Tapaswini recorded 5.52 t ha^{-1} and 5.53 t ha^{-1}, respectively.

Evaluation of Hybrids

National hybrid rice trial–shallow lowland hybrid trial (SLHRT)

The SLHRT to identify suitable hybrids in Swarna duration for coastal shallow lowland areas was constituted by CRRI and conducted at sixteen locations in ten states during wet season, 2011. A total of seven test entries including three long duration hybrids from CRRI along with four entries from private sector and five checks were evaluated in SLHRT trial. Only one hybrid, CRHR-34 showed the required yield advantage on overall mean basis and was promoted to AVT-1(L). One more hybrid, NK9316 showed yield advantage on zonal basis and was promoted.

Release/Notification of hybrids

Two hybrids, Ajay and Rajalaxmi were submitted for registration with PPV&FR Authority. CRDhan-701 (CRHR-32), a long duration hybrid developed and released for the 1st time in the country through CVRC was notified for cultivation in shallow lowlands of Gujarat and Bihar.

Development of Super Rice for Different Ecologies

Development and evaluation of super rice for irrigated /shallow lowlands

Critical investigations on morpho-physiological traits

Two hundred and fifty tropical *japonicas*, their derivatives and other lines were screened for key morpho-physiological traits supposed to act as donor/parental lines for development of super rice with four checks (Annada, Naveen, IR64 and Swarna).

Three genotypes *viz*., CR2667-3-1-1-1-2, CR2695-5-1-1-1 and CR2667-3-1-5-1 were found promising with intermediate height (138.6-142 cm) and lodging resistance, whereas, CR2687-13-5-7(39.2 cm), CR2687-5-1-1(36.0 cm), TJ-67(34.0 cm) and CR2683-36-1-1-1-1-3(33.6 cm) had long panicle. Tropical *japonicas* were shy tillering types in general; however, cultures with high EBT (e"9.0) *viz*., CR2672-13-1-1-3, CR2679-1-2-2-2 and CR2667-3-1-5-1 may contribute to the effective tiller number m^{-2}. CR2683-36-1-1-2, CR2687-5-1-1-1and CR2683-46-4-1 were recorded with high top three leaves TTL (>65.0 cm). Among other prominent cultures, CR2691-2-1, CR2688-6-1, CR2688-6-4 and CN 65-5 with good quality or fine grains; CR661-236-2 and CR2687-13-4-1 with ideal plant architecture, CR2781-2-1 with high LAD and AC38999, CR2687-16-4-1, CR2667-9-2-6 and CN 65-5 with good grain filling (chaff d" 12%) have been identified. It is important that, five genotypes *viz*., TJ 20-1, CR2672-13-1-1-3, CR2683-18-1-1, CR2695-9-1-1-1 and CR2683-10-9-1 were recorded with heavy panicle (more than 400 fertile grains) and three genotypes *viz*., UN-14, TCA 282 and CR2687-13-4-1 with high grain yield (10 t ha^{-1}) and these genotypes could be utilized as parental lines in the breeding programme.

Evaluation of new plant type/advance generation under irrigated/ shallow lowland condition

One hundred and seventy five fixed lines were tested under OYT and 48 fixed lines under AYT during dry season, 2011 and wet season, 2011-12 in the field. In dry season (AYT) five genotypes were found with high grain yield (CR3299-11-1-1 and CR3299-11-1-3 >10.00 t ha^{-1} and IR 73931-40-9-2-3-2-20-2, IR77700-84-2-2-2 and CR3300-1-2-2 >9.50 t ha^{-1}) against four checks (Annada, Naveen, IR 64 and Swarna). It was concluded that, there were appreciable number of ear bearing tillers, long panicles and longer and wider top three leaves which contributed to higher grain yield in comparison to checks. Apart from grain yield, CR3299-11-1-1 with long panicle and long top three leaves, IR73930-31-3-2-2 with heavy panicle, IR72158-148-4-2-6-2-3-1 with high tiller, IR-73898-71-2-6-3-1 with long top three leaves and IR73933-8-2-2-3 for better overall performance, were identified with better morpho-physiological traits.

During wet season 2011-12 (AYT), the same set of genotypes was evaluated. The best five genotypes found with enhanced grain yield were CR3299-11-1-3(8.27 t ha^{-1}) followed by CR 3300-2-1-1(8.12 t ha^{-1}), IR77700-

F_2 population under moderate stress during wet season 2011 at CRRI Regional Station, Hazaribag

84-2-2-2-1(8.03 t ha^{-1}), CR3300-3-1-1(7.8 t ha^{-1}) and IR 72158-68-6-3-3-1(7.39 t ha^{-1}). Apart from grain yield, CR3299-11-1-3 with long panicle, IR 73930-41-5-3-1-5-2 and IR71700-247-5-3-2-1-22-1with long top three leaves; IR71701-28-1-4 -1 and IR77700-84-2-2-2 with higher leaf breadth; IR77298-5-6 and IR78585-98-2-2-1 with compact panicle with good grain filling; and IR73896-51-2-1-3-2 with overall superior performance.

Seven elite cultures *viz.*, CR3299-11-1-1-1, IR72158-26-3-CR3624-3-1-1, CR3300-1-2-1-1, CR3299-2-1-1-1, IR77700-84-2-2-2-CR3623-2-2-1, CR3299-10-1-3-1, CR3624-4 were nominated for AICRIP trials and CR2996-1-14-29-3-1(IET-22731) was promoted to AVT 1.

Development and evaluation of superior plant types for unfavourable ecosystems

Seventy two F_7 generation superior single plant progenies of forty five inter sub-specific derivatives were grown along with three check varieties for observational yield evaluation. In the inter sub-specific crossing programme, three high yielding varieties of lowland were used as female parents and fifteen tropical *japonica* lines possessing traits like more spikelets panicle^{-1}, thick upright and broad leaf, long panicle and high seed test weight used as male parents for generating forty five F_1 hybrids. CR2683-15-5-3-1-1, CR2683-7-2-3-1-1, CR3608-1-2-1-1-1, CR2690-2-2-1-1-1 and CR3611-1-1-2-1-1 were observed to be very promising in the observational yield evaluation trial. CR2683-15-5-3-1-1 is in the final year of testing in national trial under rainfed shallow lowlands.

Development and evaluation of superior plant types to raise yield ceilings in uplands

F_2 population of 28 crosses was raised during wet season 2011 under transplanted condition at CRRI Regional Station, Hazaribag. Based on the performance of the crosses, a total of 704 single plant selections were made from 19 crosses. All these selections were generation advanced at Cuttack during 2012 dry season. Selection was not done in F_3 and progenies were harvested as bulks. Selection will be made in F_4 generation that will be grown at Hazaribag under direct seeded condition during 2012 wet season.

DNA Fingerprinting of Rice Varieties, Hybrids and other Elite Germplasm and Development of Database

DNA fingerprinting and evaluation of genetic relatedness in aromatic landraces

A total of 56 (nine aromatic varieties and 47 landraces) including five non-aromatic landraces were characterized using SSR and ISSR markers for fingerprinting and assessing the genetic variation among them. A pre-screening of 32 SSR primers pairs was performed out of which only 29 SSR primers produced a total of 68 bands of which 35 bands (51.47%) were polymorphic in nature. The PIC values varied from 0.0645 for primer RM431 to 0.919 for primer RM144 with a mean of 0.618. Similarly, a total of 35 ISSR primers were employed out of which 14 primers could produce clear and reproducible bands. A total of 84 bands were amplified, of which 42 and six were polymorphic and unique respectively.

The four microsatellite primer pairs such as RM152, RM312, RM433 and RM144 were able to identify and discriminate the aromatic landraces Sunabasmati, Lajkulibad, Kalajeera and one non-aromatic landraces Premanjalli. Likewise the six ISSR primers could also identify and differentiate six aromatic rice landraces *viz.*, Mohanbhog, Kalkati, Kapurkanti, Bindli, Bishnubhog and Jaigundi collected from different districts of Odisha along with one non-aromatic rice Gotikiamali and another CRRI released aromatic rice variety Nua Chinikamini.

Dendrogram constructed from combined SSR and ISSR data segregated two landraces (Ganjeijata and Badsabhog) and Nua Chinikamini from rest of the released aromatic rice varieties, landraces and non-aromatic landraces sharing a node at 36% level of similarity revealing presence of high diversity. Mantel Z-test reflected correlation between SSR and ISSR from which Jaccard's similarity coefficient value showed maximum correlation for ISSR (r=0.8529) as compared to SSR (r=0.7962). Similarly, combined SSR and ISSR exhibited significant correlation (r=0.7923) between them.

DNA fingerprinting and evaluation of genetic relatedness in released varieties for lowland

A total of 26 CRRI released varieties for lowland were characterized using SSR for fingerprinting and assessing the genetic relatedness among them. A prescreening of 60 SSR primers pairs (five from each chromosome) was performed out of which only 53 SSR primers produced a total of 126 bands of which 102 bands (80.95%) were polymorphic in nature. The PIC values varied from 0.474 for primer RM 28034 to 0.983 for primer RM 20096 with a mean of 0.581.

The three microsatellite primer pairs like RM27487, RM5443 and RM10167 could identify and discriminate Hanseswari, Nua Chinikamini and Nua Kalajeera, respectively. However, five microsatellite primer pairs RM25679, RM25817, RM5443, RM306 and RM23146 showed uniqueness for identification and differentiation of Nua Dhusura from all 26 varieties. The set of microsatellite markers used here provides a positive assessment to the ability of SSR marker to produce unique DNA profiles of rice varieties.

Dendrogram constructed using 53 pooled SSR data clearly segregates the aromatic rice varieties such as Ketakijoha, Nua Kalajeera and Nua Chinikamini from rest of the 23 released lowland rice varieties, sharing a node at 41% level of similarity revealing presence of high variability among them. The Jaccard's similarity coefficient showed that Dharitri and Gayatri were most closely related with a similarity value of 0.842. However, Ramakrishna and Nua Chinikamini were most remotely placed with the similarity coefficient of 0.287. The Mantel Z-test coefficient was 0.843 indicating a moderate fit between the dendrogram cluster and the original similarity matrix.

Maintenance and Use of Wild Relatives

Collection and maintenance of wild rice species and backcross derivatives

Fifteen wild rice species like *O. rufipogon* (AA), *O. nivara* (AA), *O. longistaminata*(AA), *O. barthii* (AA), *O. officinalis* (CC), *O. eichingeri* (CC), *O. rhizomatis* (CC), *O. latifolia* (CCDD), *O. alta* (CCDD), *O. australiensis* (EE), *O.brachyantha* (FF), *O. meyeriana* (GG), *O. ridleyi* (HHJJ), *O. longiglumis* (HHJJ) and *O. coarctata* (HHKK) were maintained in the net house. Generation of wide hybrid lines derived from inter-specific crosses namely, *O. brachyantha*/*O. sativa* cv. 'Savitri' and 'Swarna', *O. ridleyi*/*O. sativa*. cv. 'Swarna' and 'Udaya', *O. sativa* cv. 'Swarnaprava'/*O. grandiglumis*, *O. minuta,* and *O. latifolia, O sativa cv.* 'Neela'/*O. latifolia,* SCF_1s of *O. sativa,* cv. 'Swarnaprava'/*O. eichingeri, O. sativa' cv.* Ratna'/*O. officinalis* were maintained in the net house by repeated sub-culturing of stubbles.

Out of 152 PAU WH lines from crosses between elite rice cultivar PR114 with *O. glaberrima* and wild species like *O. rufipogon* and *O. nivara*, grown during wet season 2011, three lines were found suitable for irrigated medium duration with yield level above 6.50 t ha^{-1}. Five of them were nominated for IME-Aerob., having yield level in the range of 6.60-5.50 t ha^{-1}.

Introgression of alien genes tolerance to abiotic stresses and its utilization

Generation advance and evaluation of thirty interspecific back cross progenies (BC_2F_1), 1500 populations of F_4-F_5 and 20 interspecific back cross (BC_2F_2) derivatives of Lalat and Naveen with their parents were grown under field condition and single plant selections were made. Wide crosses were attempted using Savitri and Swarna as ovule parents and *O. australiensis* as pollen parent using hormonal treatment to transfer drought tolerant genes from more distant species *O. australiensis* (EC 384082). Out of 6045 pollinations twenty fertilized embryos were inoculated in 1/4th MS medium employing embryo rescue technique and only three hybrids of *O. sativa* cv. Savitri/*O. australiensis* and Swarna/*O. australiensis* could be obtained and grown to flowering for its true hybrid identity through morphological and cytological analysis. The F_1 plant was an alloploid with genome AE. It was intermediate between the parental species morphologically and completely sterile. Its primordial panicles, about 1.5 cm long, were cultured and after several cycles of subculture, the SC_1 plants were obtained which could be classified into two categories; those similar to the F_1 plant morphologically and sterile, and those showing characteristics of *O. sativa* and with increased 0.1% pollen fertility. The entire wide cross F_1s were analyzed cytologically to study chromosome pairing between cultivated rice and *O. australiensis*. At metaphase-I auto-syndetic bivalents with no chiasmata were found. At anaphase-1 distribution of both *O. australiensis* and *O. sativa* chromosomes to poles were highly irregular. Partial fertile hybrids were further back crossed with recurrent parents and

30 BC_1F_1 embryos were inoculated successfully in ¼ MS medium. The crossability (%) ranged from 0.33-0.42. The seeds of F_4, F_5 and BC_1F_2 and BC_2F_2 generations of the cross Naveen/*O.nivara*, Lalat/*O. nivara* were collected for next generation testing. New crosses have been effected using female parents such as Savitri with male parents such as *O. nivara* (AC100476, AC100374). More than 10 promising selections were made of which CR2892-14-3, CR2892-21-5, CR2892-30-1-1 were having desirable plant type with high degree of tolerance to drought.

The BC_1F_1 hybrids of *O. sativa* cv. Savitri/*O. brachyantha* were backcrossed with recurrent parents employing embryo rescue technique with hormonal treatments before and after pollination. Out of over 10,000 pollinations, 12 BC_2F_1 hybrids recovered following embryo rescue and were grown in pots. The chromosome numbers of BC_2F_1 plants ranged from 24 to 36. Three plants were 24 normal but differed from each other as well as from the normal disomic sibs in several morphological and reproductive features including slow growth habit. Sibs with 25 chromosomes were isolated. One disomic plant exhibited moderate resistance (MR) against yellow stem borer (YSB).

Studies on Gene Flow from Cultivated to Wild Species

Detection of gene flow using anthocyanin pigmentation of rice as morphological marker

A field experiment on gene flow from cultivated rice *O. sativa* 'Crossa' (as pollen source) to wild rice *O. nivara* (pollen receiver), was conducted during the wet season of 2011. The purple plant color of 'Crossa' was used as morphological marker. The 'Crossa' plants at the centre were surrounded by plants of *O. nivara* in a square design at every meter distance from the source up to 10 meters. The mature seeds of the receiver plants were allowed to shatter and fall in the same field to grow naturally in the next wet season on its own. It was expected to get purple hybrids from the 3rd year on and the extent of which will be an index of gene flow.

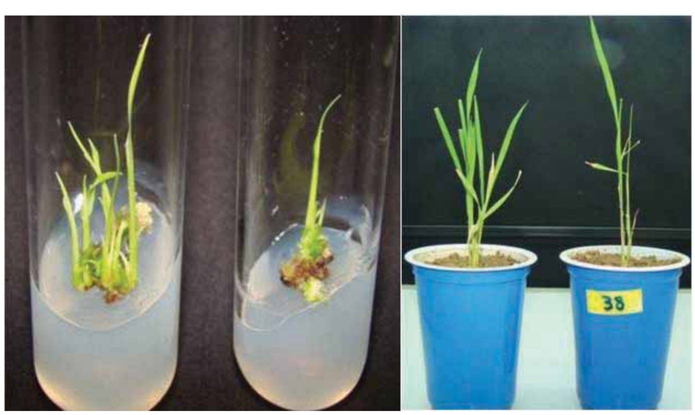
Tracing of gene flow using CMS lines and molecular markers

A field experiment was conducted to study the gene flow of rice in the wet season of 2011 using the CMS line as pollen receiver and rice varieties 'Lalat' and 'Tapaswini' with gene pyramids of *Xa5, Xa13 and Xa21* series as pollen source in a square design. This method was designed to provide a double check on pollen flow from the designated source. The percentages of fertile spikelets, representing the pollen flow in the CMS lines were highest at 5 m than those at 10 m. There were also differences in the percentage of fertile spikelets with different directions studied. The highest percentage of pollen flow, in terms of % of fertile spikelets was 2.74% in north-east direction at 5m distance followed by 2.4 %, 2.14 %, in north, and north-west direction, respectively. The lowest pollen flow of 0.71% was observed in eastward direction. Overall, the pollen flow values were found to vary with different distances and directions.

Improving Biochemical/Physiological Efficiency of Varieties

Transformation of rice variety Naveen using NADP-Malate dehydrogenase

Rice variety Naveen was transformed with NADP-Malate dehydrogenase using seed derived callus. Surface-sterilized seeds were allowed to germinate and cultured on 2N6 media for four weeks; callus was harvested and further cultured on 2N6 media for 10 days. The Calli were then incubated for 20 minutes in bacteria re-suspended (OD_{600}=1.0) in AAM media, drained, dried on sterile filter paper and then co-cultured with bacteria (*S. meliloti*) for seven days on 2N6AS media. After co-culture, rice calli were assayed for GUS activity and transferred to selective media (2N6TCH) for four weeks and proliferating calli were selected and transferred to regeneration media (RGH6). Shoots arising from calli on regeneration media were transferred to rooting media (½ MSH media: ½ strength MS major, MS minor salts, N6 vitamins; 10 g l^{-1} sucrose, 2.5 g l^{-1} Phytagel, pH 5.8, 50 mg l^{-1} hygromycin-B). After root formation, plants were transferred to soil for further analysis (Fig. 3).



Rice plants transformed with maize MDH

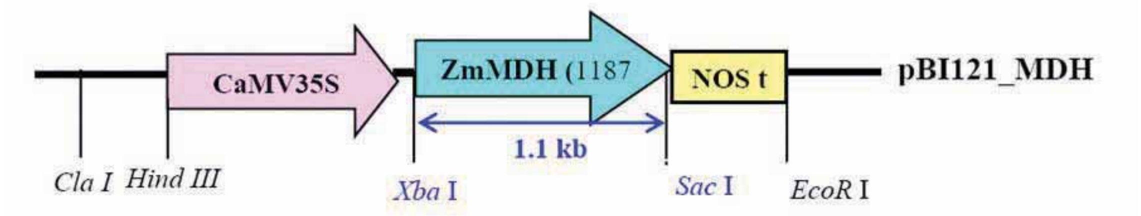


Fig. 3. Schematic diagram of *ZmMDH*, cloned in pPBI121 by replacing the GUS gene

Physiological characterization of NPT lines

Twenty NPT lines with 4 HYVs (Naveen, Shatabdi, Khitish and IR72) were tested in field condition. Highest leaf area index (LAI) at flowering was recorded in IR73896-51-2-1-3 followed by IR 73895-33-1-3-2, while highest photosynthetic rate (43.95 µmole CO_2 $m^{-2}s^{-1}$) was observed in IR 73895-33-1-3-2 followed by IR73907-75-3-2-3 (41.4 µmole CO_2 $m^{-2}s^{-1}$). Yield potential varied from 4.0 to7.0 t ha^{-1} with yield advantage of 0.5 to 1.0 t ha^{-1} over the check IR72. Nine genotypes recorded grain yield >6.00 t ha^{-1}. IR73895-33-1-3-2 recorded highest grain yield (7.02 t ha^{-1}) followed by IR73907-75-3-2-3 (6.85 t ha^{-1}) and IR73896-51-2-1-3 (6.48 t ha^{-1}). Grain yield was significantly correlated with biomass and photosynthetic rate. Apparent contribution of current photosynthesis to grain filling was highest in IR73896-51-2-1-3, while from stem to grain filling was highest in IR72 and from leaves to grain filling was highest in IR72969-143-5-3-6. However, higher pre-flowering contribution (more than 30%) in high yielding genotypes indicates that these genotypes possess the capacity to translocate pre-flowering photosynthetic carbohydrate to the storage organ, leading to high translocation efficiency. Highest grain yield in IR73895-33-1-3-2, IR73907-75-3-2-3 and IR73896-51-2-1-3 with yield advantage of 0.5 to 1.0 t ha^{-1} over the check IR72, might have been contributed by higher LAI (5.0-6.3), high photosynthetic rate (40-43 µmole CO_2 $m^{-2}s^{-1}$), higher biomass (13-15 t ha^{-1}), high HI (0.42-0.50), higher panicle no. (316-400), and higher translocation efficiency with high grain filling percentage (>80%).

Influence of boron on spikelet fertility under varied soil conditions

Mechanistic studies were done with three varieties grown in pots in wet season 2011. Boron (0.4 ppm) was sprayed at 50% flowering. Biochemical studies were undertaken in developing grains after seven and twelve days of spray. IET 20979 appeared to be more responsive to boron with respect to head rice recovery (HRR), plant height and 1000 seed weight. It showed higher amount of total starch in grains after seven and twelve days of spray (0.49 and 0.97 mg $grain^{-1}$) compared to untreated control (0.36 and 0.51 mg $grain^{-1}$) significant changes have been shown in bold digits. It also had higher activity of soluble invertase (8.7 and 9.0 n mol sucrose hydrolyzed min^{-1} rice $grain^{-1}$) in treatment than the control (6.2 and 7.4 n mol sucrose hydrolyzed min^{-1} rice $grain^{-1}$). The activity of sucrose-ADP glucosyltransferase was very low and changes were insignificant (Table 11).

Table 11. Effect of boron spray on some agronomical and grain quality characteristics of rice

Variety	Treatment	H%	M%	HRR%	Plant height (cm)	1000 Seed weight (gm)	AC%	Total carbohydrate (%)
IET20979	Control(C)	76.0.	64.0	57.5	88.0	18.2	20.1	76.0
	Treatment (T)	77.0.	67.0	63.0	99.4	19.5	20.5	77.4
Rasi	Control	78.0	69.0	68.0	96.3	19.7	23.4	78.0
	Treatment	77.0	67.0	65.0	95.2	18.9	24.1	80.3
Vandana	Control	76.0	63.5	54.5	149.8	20.5	19.6	78.4
	Treatment	75.0	64.5	53.0	146.9	19.9	19.8	77.5

(H=Hulling, M=Milling, HRR=Head Rice Recovery, AC= Amylose Content)

Improvement of Grain and Nutritional Quality

Breeding for Quality Rice

Evaluation and improvement of yield of aromatic varieties using conventional and molecular approaches

Evaluation of 135 purified aromatic landraces collected from Odisha indicated wide variation for different traits *viz.,* plant height (97 -189 cm), panicle length (20.3-33.5 cm), DFF (90-115 days) and grain yield (3.01 – 4.73 t ha^{-1}). Similarly, rich genetic diversity was detected at both morphological and molecular level in the 124 Kalanamak collections from different districts of UP.

Forty four promising aromatic, semi dwarf, high yielding breeding lines having medium slender grain developed from the crosses Swarna/Geetanjali (CR2937), CR689-116-2/Kalanamak (CR2938), Tillak Chandan/Kalanamak (CR2936), IR36/Basmati-370 (CR-2939),CRM 2203-4/Dubraj (CR2947) and BPT-5204/Kalanamak (CR2941) were evaluated under Advance Yield Trial with Kalanamak and Badshabhog as checks and five cultures gave more than 5.00 t ha^{-1} (Table 12). Three promising aromatic genotypes CR2947-1, CR2738-2, CR2713-35, CR2934-39 and CR2934-35 having desirable quality traits were nominated for evaluation under IVT-ASG as new short grain entries for all India testing.

Table 12. AYT- Promising aromatic selections

Varieties	Plant ht (cm)	Panicle length (cm)	EBT m^{-2} (nos)	Yield t ha^{-1}
CR2934-35	107.8	29.1	186	5.05
CR2938-1	118.0	30.0	308	5.60
CR2937-10	119.7	28.8	237	5.35
CR2947-15	109.3	24.7	222	5.11
CR2937-37	117.7	26.6	250	5.32
Badshabhog	171.6	30.0	210	2.97
Kalanamak	180.8	28.4	180	2.57
Expt. Mean	116.45	28.05	215	4.08
LSD (P=0.05)				0.31
CV (%)				3.8

Advancement of breeding materials

Development and selection of breeding materials resulted in selection of 796 single plant progenies from 45 crosses for further evaluation, while seeds from 253 F_2 plants belonging to 20 crosses were collected and 12 new crosses attempted during wet season. Mapping population for aroma and Fe were advanced from F_4 to F_5 generation and parental polymorphism for aroma with 240 SSR (RM) markers was completed. Four cultures *viz.,* CR2713-11(IET 21840), CR2713-179, (IET 22648), CR2947-18 (IET 22650) and CR2713-180 (IET 22649) were found promising and promoted to next year of testing under AICRIP.

Aromatic AICRIP Trials

Aromatic short grain trials ASGON, IVT- ASG and AVT-1-ASG were conducted in which genotypes IET 22651(5.3 t ha^{-1}), IET21850 (7.1 t ha^{-1}) and IET 21053 (5.8 t ha^{-1}) stood first. Three Basmati trials IVT-BT, AVT-1-BT and AVT-2-BT were also conducted at CRRI.

Development of high yielding varieties for grain quality, organic and nutritional enrichment

Hybridization

Selections of 243 single plants having slender grain were made from segregating populations (F_3-F_7) while F_2 single plants seed collected from 12 crosses and 10 new cross combinations were attempted during wet season. Fixed lines of Padmakeshari mutants with slender grain were grown for seed increase and further testing.

Evaluation of promising slender grain selections

Under Advance yield trial 33 promising slender grain selections belonging to two crosses (BPT 5204, Swarna with Banskathi) were evaluated along with Swarna, Gayatri and Pooja as checks and five cultures were found to have grain yield capacity more than 5.40 t ha^{-1} *(Table 13).*

Table 13. Promising slender grain selections in advance yield trial

Varieties	DFF (days)	Plant ht (cm)	Panicle length (cm)	EBT m^{-2} (nos)	Yield (t ha^{-1})
CR2942-116	111	101.1	25.8	275	6.03
CR2942-112	111	94.2	21.9	221	5.74
CR2942-109	112	102.9	24.1	313	5.64
CR2942-27	115	117.4	26.5	236	5.44
CR2942-11	110	96.6	23.5	297	5.43
Pooja	126	116.8	26.9	252	6.50
Gayatri	136	121.7	25.7	299	6.63
Swarna	116	105.9	25.2	261	5.62
Mean	115	105.9	24.7	265.9	5.06
LSD (P=0.05)					0.47
CV (%)					11.40

Breeding for High Protein Rice

Hybridization and selection for high yielding lines with high seed protein content

One hundred single plants and 26 bulk populations belonging to F_5-F_7 generations have been harvested in wet season. Duration of those lines varied from 120-150 days. Average single plant yield was 40 g. Mean seed protein content of these genotypes was significantly higher (11.1%) than high yielding parents (9%). F_1 seeds from ARC10075/Swarna and ARC10075/Naveen contained 14.5% crude protein. Highest seed yield/plant (71 g) was recorded in a line derived from Naveen/ARC10063 cross, but its protein content was low (8.85%). On the other hand highest seed protein content (15.18%) was recorded in a line derived from ARC10075/Swarna cross with 36g seed yield. High protein yield/plant were recorded in CPL-C-2 (7.49 g), a line derived from IR64/ARC10063 and CPL-H-11 (7.29 g), a line derived from Naveen/ARC10063 as compared to Swarna (4.27 g). Some genotypes such as CPL-H-4 (5 and 12.04%) and CPL-B-3 (6 and 11.8%) were observed to have good alkali spreading value as well as high crude protein content. They could be preferred for their good cooking and nutritional quality.

Study of parental polymorphism for QTL analysis

Parental polymorphism was studied among high yielding genotypes such as Swarna, IR64, Naveen and high protein donors such as ARC10075 and ARC10063. Nineteen polymorphic loci were detected using nine SSR primers (RM297, RM240, RM282, RM218, RM253, RM214, RM234, RM1375 and RM229) associated with QTLs for seed protein in rice. They could be utilized in genetical analysis for seed protein content in rice using advanced backcross population derived from ARC10075/Naveen, ARC10075/Swarna and ARC10075/IR64.

Capitalization of Prominent landraces of rice in Odisha through Value Chain Approach

Kalajeera

During the third cycle of purification, 153 panicle to row progenies of Kalajeera (three lines each) transplanted in 2011 wet season and no morphological variation was observed in the population. Six uniform Kalajeera pure lines with more than 19% amylose content were identified for seed production purpose

Machhakanta

During 2011 wet season, 227 panicle to row progenies were grown for purification and selection. Variation noted in maturity period (120-128 days), plant height (158-200 cm), panicle length (22.7-29.9 cm), panicle type (open-compact), grain shape (medium slender and medium bold), awning ability (awnless-partly-full) and grain yield (1.80–4.90 t ha^{-1}).

Haladichudi

Two hundred thirty four panicle to row progenies were grown for further purification and selection. Variation in panicle length (21.6-26.6 cm), grain shape (MS, MB), apiculus colour (purple/purple apex) and yield (1.80 - 5.40 t ha^{-1}) was recorded.

Molecular characterization

Molecular analysis of 227 lines of Machhakanta and 234 lines of Haladichudi was done with 24 highly variable Rice Microsatellite (RM) markers. Out of 24 markers, fifteen and seven markers could detect polymorphism in Machhakanta and Haladichudi populations, respectively (Fig. 4).

Grain Quality and Biochemistry

Agronomic and grain quality studies of *soak n eat* rice

The seeds of the *soak n eat* rice variety Aghoni was obtained from RARS, Titabar, Assam and grown at CRRI research farm, Cuttack in wet seasons of 2010, 2011 and dry seasons of 2009-10 and 2010-11 under standard cultivation practices (NPK 80:40:40 kg ha^{-1}). The crop duration in wet season 2010 and 2011 was about 143 days, with plant height around 91 cm. In dry season 2009-10, the crop duration was reduced to 130 days and the plant height to 62-64 cm. While the grain yield

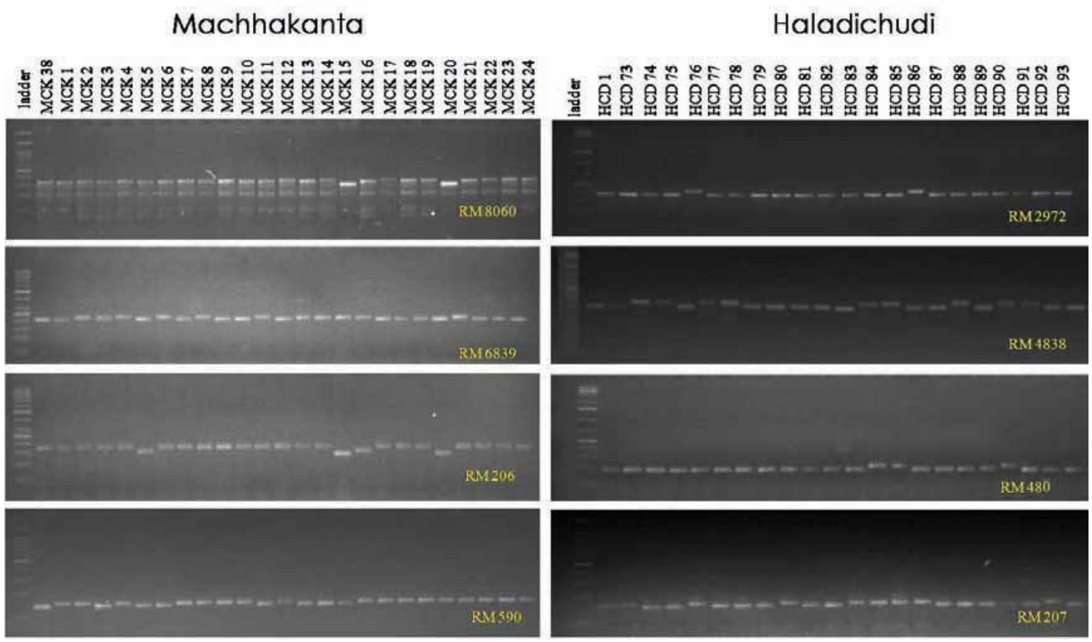


Fig. 4. SSR Variation among the lines of Machhakanta & Haladichudi

was 5.30 t ha^{-1} in the wet season, it was reduced to about 2.20 t ha^{-1} due to stunted growth, reduction in panicle length, grains per panicle and 1000 seed weight; another reason for the reduced yield could be the shorter crop duration observed during the dry season. This indicates that the rice Aghoni is not suitable for cultivation at Cuttack in dry season.

The data on quality of milled rice of Aghoni indicated that the grains were medium slender type with good head rice recovery (64.5%). The alkali spreading value (6.0) and water uptake value (310 ml $100g^{-1}$) were a little on the higher side whereas, the amylose content was quite low (4.65%), which classifies Aghoni as a very low amylose rice (2-9% amylose). The grain characteristics remained largely unchanged when grown in wet/dry season.

The soaking time (time required by parboiled grains to become as soft as cooked after soaking in water of normal temperature) of Aghoni increased from 40 min in 2008 to 90 min in 2011 indicating that the climatic/soil conditions at Cuttack do not suit it at least with respect to maintaining the soaking time.

Standardization of a laboratory method for quantifying total carbonyl content of rice as an indicator of aroma

A small arrangement was set up to measure the total carbonyl content of scented rice grains by a titrimetric method. The carbonyl compounds released by digestion of grain starch were driven to a flask containing alkaline $KMnO_4$. The unreacted $KMnO_4$ was treated with iodine solution and titrated against 0.02N $Na_2S_2O_3$. Though lesser volumes of $Na_2S_2O_3$ solution were required for scented grains (Basmati and Dubraj) compared to the non scented types (Vandana and Gayatri), however, the data on volume of $Na_2S_2O_3$ solution required were not reproducible.

Biochemical basis of grain quality enhancement through organic management practices

The rice variety Geetanjali was grown with different organic sources of nutrients. The treatments were control, FYM, green manure (*Sesbania aculeata*), FYM + green manure (1:1 on N basis), FYM + *Azolla* (1:1 on N basis), crop residue (5 t ha^{-1}) + *Sesbania aculeata*, *Azolla* + *Sesbania aculeata* (1:1 on N basis), crop residue (2.50 t ha^{-1}) + *Sesbania aculeata*. The 2, 2-diphenyl-1-picrylhydrazyl free radical (DPPH) scavenging activity varied from 68.42 % to 129.48% and was higher (129.48%) in organic rather than conventional treatment (68.42%). There was very little difference between antioxidant activities of cooked rice and raw brown rice. The treatment crop residue + GM application resulted in high oil content (3.72%) followed by FYM + GM (3.22%) as compared to conventional one (2.19%).

Studies on quality characteristics of parental lines and hybrids

Grain quality was analysed for multi location trial of different hybrids. The hulling % varied between 75.5 to 80.5% and HRR between 53.5 to 61.5% among all the 17 hybrids tested. Amylose content varied between (15.03 to 25.35%). CRHR32 (short bold), CRHR33 (medium slender), CRHR35 (long bold) and CRHR42 possessed good quality characters.

Biochemistry of high protein rice

Two high protein rice cultivars *viz.*, ARC10063 (16.41%) and ARC10075 (15.27%), were studied for key enzymes of nitrogen assimilation in rice plants. The two were found to have higher activities of glutamine synthetase (GS) and glutamate oxo-glutarate aminotransferase (GOGAT) at the maximum tillering stage compared to the low protein cultivar ARC 10069 (10.96%) (Fig. 5). The maximum activity of GS and GOGAT was observed in the developing grains of these cultivars on the 10th day of panicle emergence (Fig. 6).

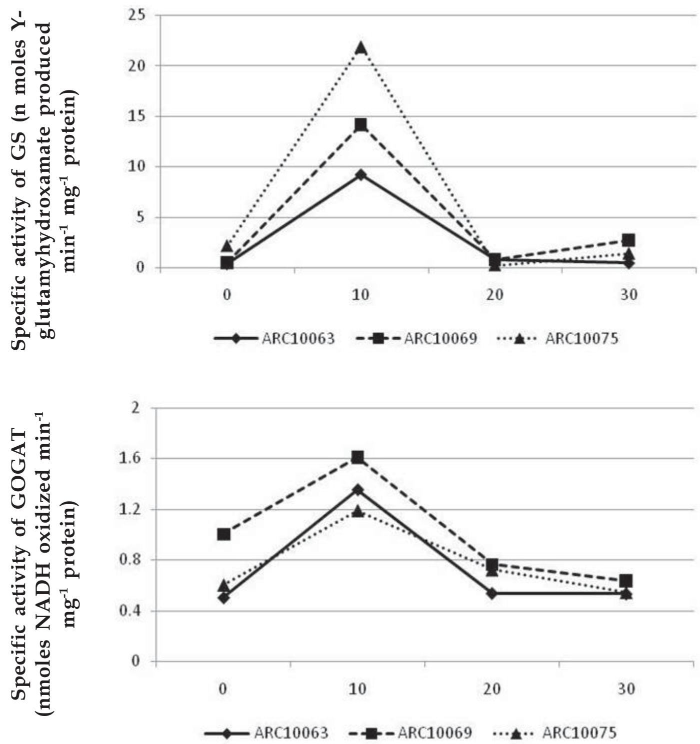


Fig. 6. Glutamine Synthetase and GOGAT activities in the developing grains of high protein cultivars

Biochemistry of micronutrients in rice

Two hundred and fifty rice germplasm accessions were assessed for Fe and Zn content of grain. Some of them were found to contain more than 15 ppm Fe and 50 ppm Zn in brown rice kernels. *Biroin* rice collections from Assam were found to be low in Fe content but were high in Zn content.

Accumulation of ferritin protein was found to be under the control of physiological Fe concentration of the plant. High iron containing cultivars contained high amount of ferritin in different plant parts. The optimum concentrations of Fe for maximum ferritin accumulation were different in high and low Fe containing cultivars. While, for high Fe containing cultivar, Sharbati, the optimum concentration was found be 2 ppm, for Lalat, a low Fe containing cultivar, maximum ferritin

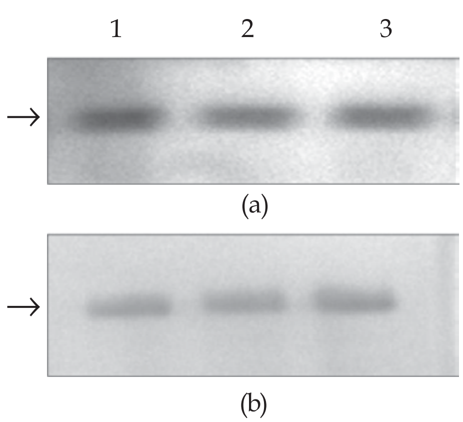


Fig. 5. Native-PAGE showing GS (a) and GOGAT (b) activities in the leaf extract of high protein cultivars. Lane 1, 2, 3 denote ARC 10063 (high GP), ARC 10069 (low GP for comparison) and ARC 10075 (high GP), respectively

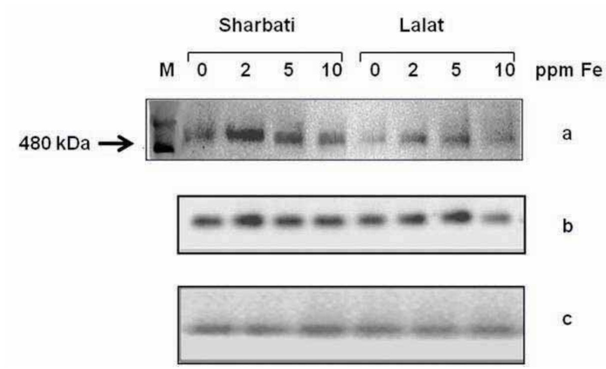


Fig. 7. Effect of Fe level on ferritin accumulation (a) and ferritin gene expression (b) in the leaves of 14 days old rice seedlings of two *indica* rice cultivars (*Sharbati* and *Lalat*) grown in hydroponics. â-tubulin (c) was used as loading control in RT-PCR

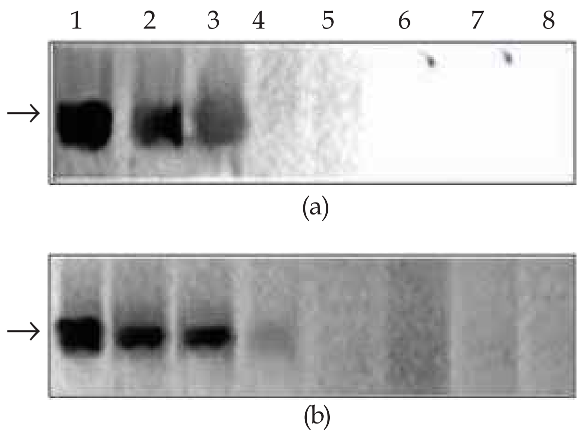


Fig. 8. Native-PAGE showing ferritin level in different parts of field grown plants of the two rice cultivars [*Sharbati (a)* and *Lalat* (*b*)] at mid grain filling stage. Lanes 1, 2, 3, 4, 5, 6, 7 and 8 denote flag leaf, 2nd leaf, 3rd leaf, leaf sheath, apical spikelet, basal spikelet, stem and root, respectively

accumulation was observed at 5 ppm Fe indicating that the former was more efficient at absorbing and accumulating iron in grain (Fig. 7).

As compared to high Fe containing cultivar, the low Fe containing cultivar was also found to absorb and accumulate lower amount of Fe from the growing medium and this was reflected in the lower level of ferritin accumulation in different parts of the plant, including seeds (Fig. 8).

Evaluation of rice germplasm and advanced breeding lines for grain quality and aroma (AICRIP trial)

Twenty two IVT-BT, eleven AVT-1-BT and seven AVT-II-BT cultures were analyzed for grain quality. In the IVT-BT trials, IET 2510 was found to be the best followed by 2504, 2522, 2521 and 2516; in case of AVT-I-BT, IET assessed as best followed by 2411 and 2406. In AVT-II-BT, all cultures (IET 2301 to 2307) possessed good grain quality characters with IET 2305 as the best followed by 2306 and 2301.

Breeding for Resistance/ Tolerance to Biotic, Abiotic and Environmental Stresses

Identification of New Sources of Resistance/Tolerance to Pests and Diseases

Identification of new sources of resistance/ tolerance against BPH, *Nilaparvata lugens* and mechanism of resistance

Three hundred twenty varieties from CRRI genetic resources, 140 released varieties and 100 lines evolved from resistance breeding in Salkathi and Dhobanumberi background were screened against net house reared BPH as per the standard procedure of SES scoring. CRAC42668, CR3005-77-2, CR3005-230-5, CR3005-11-3, CR3005-226-7 and CR3006-8-2 were found highly resistant with score 1. CRAC42687, 42715, WGL32183, IC356419, IC267428, IC283262, IC384159 and IC279374 showed moderate resistance of score 3. Out of the improved lines promoted to multiple resistance screening trial (MRST) of AICRIP, DRR during wet season 2011, CR3005-77-2, CR3005-230-5 and CR3006-8-2 were found most promising.

The antibiosis study against BPH showed low rate of oviposition and low survivality of 1^{st} and 2^{nd} instar nymphs on resistant variety Salkathi and Dhobanumberi against susceptible variety TN1. Biochemical analysis of stem of resistant donor showed less sugar, more ash content and less feeding of BPH on resistant donor Salkathi than in TN1.

Identification of new sources of resistance against WBPH, *Sogatella furcifera*

Ninety five rice genotypes were evaluated against WBPH under net house condition at Cuttack during 2011-12. The genotypes *viz.*, IR64 and TN1 were used as WBPH resistant and susceptible check, respectively. The genotype PSS32 and PSS74 were found moderately resistant against WBPH.

Identification of new sources of resistance against rice leaf folder, *Cnaphalocrocis medinalis*

Sixty eight entries from CRRI genetic resources were screened against leaf folder in field condition of Central Rice Research Institute, Cuttack during 2011-12. The cultivar Nadia phula was found moderately resistant to the leaf folder.

Identification of new sources of resistance against rice rootknot nematode (RRKN), *Meloidogyne graminicola*

Ninety five accessions from CRRI genetic resources were screened in net house condition against RRKN. CRAC43019 and 43020 were resistant with 0.7 and 0.3 GI, respectively whereas, CRAC41374, 42403, 42403, 42462, 42540, 42611, 42634, 43003, 43012, 43013, 43024 and 43022a showed moderate resistant reaction against the pest.

Identification of new sources of resistance/ tolerance to major diseases

Screening for blast resistance

One thousand nine hundred eight (1908) and 1575 rice germplasm collections from different sources (NSN-1, NSN-2, NHSN, NSNH, DSN, VMS etc.) were screened against blast disease during wet season 2011 and dry season 2012 respectively along with HR 12 and B 40 as susceptible checks and Zenith and Tadukan as resistant checks. Fifty four entries (CR2873-17-1, CR2873-30-5, CR3420-10-5-1, CR3420-15-3-1, CR3420-20-2-1 etc.) were identified as highly tolerant to blast disease showing disease score 0-1 in the SES scales against susceptible checks HR12 and B40 showing score 9 and location severity index > 5.

Screening for Bacterial blight resistance

Three thousand one hundred seventy four (3174) germplasm collections from different sources were screened against bacterial blight disease in the field during wet season 2011. One hundred forty two tolerant lines (CB05-031, CB09-138, TNRH 244, Ajay, CR2421-1, CR2421-9, Rasi, CR2437-31, CR2428-9, RP Bio 26 etc.) were identified showing disease score 1-3 in the SES scale against susceptible checks TN 1 and Tapaswini showing score 9 and location severity index > 5.8.

Screening for Brown spot

One thousand eight hundred (1800) entries comprising NSN 1, NSN 2, NHSN, DSN, Germplasm, advance breeding lines and some resistant donors were screened for brown spot resistance. Thirteen hundred entries were susceptible, 354 moderately resistant and 146 (CR2641-26-1-2-2, CR2644-2-6-4-3-2, CR2652-14, CR2683-15-5-3-1-1, CR2389-5-2-1-1, CR758-16-6, CR2643-1-4-3-1, CR2429-5 et.) showed resistant reaction to brown spot in the nursery. Out of 244 entries from the F_6 population of the cross Kalinga III/ Moroberekan, 26 entries showed resistance reaction, 96 entries were rated as moderately resistant and 122 were susceptible against brown spot.

Breeding for Resistance to Major Insects

Breeding for multiple pest resistance with emphasis on brown planthopper (BPH), yellow stem borer (YSB) and gall midge (GM)

Hybridization for new cross combinations

In order to incorporate both BPH and YSB resistance, five uniform advanced breeding lines for BPH resistance *viz.,* CR2711-76 (Tapaswini/Dhobanumberi), CR2711-114 (Tapaswini/ Dhobanumberi), CR2711-139 (Tapaswini/Dhobanumberi), CR2711-149 (Tapaswini/ Dhobanumberi) and CR2712-12 (Samba Mahsuri/Salkathi) which were found to be promising in AICRIP PHS trial, were used in the crossing programme with Nalihazra and Ramaboita as resistant donors for YSB resistance.

Cross seeds of multiple cross combinations involving elite cultivars *viz.,* Swarna, Samba Mahsuri, Tapaswini, Pusa 44, Pooja and Naveen, resistant donors for BPH *viz.,* Salkathi and Dhobanumberi; and resistant donors for YSB *viz.,* Nalihazra and Ramaboita were grown and F_2 seeds were harvested.

Observational yield trial

Thirty two selected uniform advanced breeding lines for BPH resistance and 24 selected uniform advanced breeding lines for gall midge resistance were grown with suitable checks under observational yield trial. Data relating to yield attributing characters were recorded. The lines were harvested and post harvest processing data recording was done. From the breeding lines for BPH resistance, three lines belonging to Tapaswini/Salkathi and Pooja/Dhobanumberi crosses performed better compared to the checks whereas, from breeding lines for gall midge resistance four lines belonging to Tapaswini/Phalguna and Swarna/Sarasa crosses performed better as compared to the checks.

Generation advancement and further selection

From the breeding lines grown for generation advancement, 20 and 15 single plants were selected from BPH and gall midge resistance crosses, respectively basing on the desired agro-morphological traits and yield attributing characters. The lines were harvested with recording of agro-morphological data.

Screening for BPH and gall midge resistance

For confirmation of resistance 60 advanced breeding lines from the crosses for BPH resistance and 43 advanced breeding lines from the crosses for gall midge resistance were screened in the net house for BPH and gall midge resistance respectively under artificial insect pressure. Five lines showed high degree of resistance for BPH and eight lines showed high degree of resistance for gall midge as per IRRI SES scale. Resistant plants were recovered from the screening and were grown in the net house. The seeds of these recovered resistant plants were collected separately.

Development of molecular markers linked to genes for resistance to brown plant hopper

In order to identify molecular markers linked to BPH resistance, the mapping population (F_2) is being developed from the cross between resistant parent, Salkathi and susceptible parent, Swarna. Selfed seeds were collected from 200 individual F_2 plants during December, 2011. Phenotyping of the 125 F_3 population was done under artificial infestation during March-April, 2012. Percentage of survival was counted on 5^{th}, 6^{th} and 7^{th} day after release when 100% TN1, the susceptible check, died. Six F_3 lines showed resistant reaction with SES score of three while 17 showed moderately resistant reaction with SES score of five. Thirty seven lines showed susceptible reaction with SES score of seven while 65 showed highly susceptible reaction with SES score of nine. Salkathi showed SES score of three and TN1 showed SES score nine. A total of 518 microsatellite primers from twelve chromosomes of rice were used to scan genomes of susceptible cultivar, Swarna and resistant cultivar, Salakathi. One hundred fourteen primers (22%) revealed polymorphism between parents. The polymorphic primers varied from 8.82% (Chromosome 9) to 33.33% (Chromosome 11).

Performance of resistant cultures in AICRIP Multiple resistance screening trial (MRST)

Out of the nine entries included in the AICRIP Multiple Resistance Screening Trial (MRST), evaluation in 11 greenhouse and 39 field tests against 10 pests revealed that four entries CR3005-230-5 (Samba Mahsuri/Salkathi), CR2711-76 (Tapaswini/Dhobanumberi), CR3005-77-2 (Samba Mahsuri/Salkathi) and CR3006-8-2 (Pusa 44/Salkathi) were found promising in 7-12 tests against 5-6 insect pests with a per cent promising reaction (PPR) of 9.6-14.4%. These entries were found to have major resistance to plant hoppers.

Breeding for Resistance to Major Diseases

Breeding for resistance to Bacterial blight and Blast

During wet season 2011, four hundred and fifteen F_4 progenies from nine cross combinations developed for bacterial blight and blast resistance were grown. All the lines were artificially inoculated with a virulent field isolate at maximum tillering stage. At flowering and maturity, 383 single plants were selected on the basis of resistance to bacterial blight and blast diseases and other plant and panicle characters. These selected plants were generation advanced during dry season, 2012. From 383 F_5 progenies grown during dry season, 241 single plants were selected. Besides, maintenance and seed multiplication of 35 lines developed for bacterial blight and blast resistance including the lines developed through MAS have also been taken up during both wet and dry seasons.

Marker assisted backcrossing for transfer of durable bacterial blight resistance into elite deepwater rice

CRMAS2232-85 (bacterial blight pyramided line containing BB resistance genes; *xa5, xa13 and Xa21)* exhibited resistant reaction to the disease while, Jalmagna (recipient variety) showed susceptibility reaction to the disease through artificial inoculation method. Hybridization was carried out in forty panicles of Jalmagna as male and CRMAS2232-85 as female parent. Seven hundred twenty two F_1 hybrid seeds were harvested during the wet season.

Parental Polymorphism

Genomes of CRMAS2232-85 and Jalmagna were amplified in PCR with 413 rice microsatellite markers. The amplified products were separated on 2.5% agaroge gel and photograph was taken using Gel documentation system. Based on the amplification pattern, polymorphic microsatellite markers were selected. Sixty eight, out of 413 were found to be polymorphic between parents which will be used for back ground selection.

Two hundred eighty BC_1F_1 plants were grown in three staggered dates while one date for Jalmagna during dry season, 2012. Six BC_1F_1 plants were found to be selfed based on the amplification pattern by RM336 primers. Genomes of two hundred seventy four BC_1F_1 plants were amplified with primers pTA248, RG136 closely linked to BLB resistance genes, *Xa21* and *xa13,* respectively. Similarly, multiplex PCR amplification was done with resistance gene specific primers, *xa5S* and *xa5R* for *xa5* resistance gene. The amplified products of pTA248 for *Xa21* and multiplex PCR products for *xa5* were resolved on a 1.2% and 2.5 % agarose gel, respectively. The amplified products of RG136 were restricted with *HinfI* redistricting enzyme. Then the products were separated on a 1.5% agarose gel.

Only fourteen plants showed the amplification of three resistance genes (*Xa21, xa13* and *xa5)* specific bands, indicating the presence of BLB resistance genes, *Xa21*, *xa13* and *xa5* in these 14 BC_1F_1 plants.

Breeding for resistance to Sheath Blight

The foundation population of the crosses involving genetic male sterile line and 13 sheath blight resistant donors IET 17885, IET 17886, IET 19346, Jogen (AC40922), Mansarovar (AC40844), Manoharsali (AC40509) and ASD 18 (AC40865), IET 20755, IET 20737, IET 20443, IET 20553, IET 19140 and IET 20230 were grown in wet season, 2011 for male sterility facilitated recurrent selection approach. In this population, 250 male sterile segregants were identified, tagged and out-crossed seeds from the sterile plants were harvested upon maturity to form the random mating population for the next cycle.

The male fertile segregants and progenies of resistant plants selected last year were screened in sheath blight screening nursery under artificial inoculation. Observations on disease progress were recorded periodically and 146 sheath blight resistant plants were selected for further testing. Those resistant lines were grown in dry season, 2012 under normal condition to select plants with high yield and good plant types.

Breeding for resistance to Rice Tungro Disease

Twenty fixed cultures, eight segregating populations of crosses involving elite varieties like Swarna, Gayatri, Naveen and RTD resistant donors like AC290, AC6078, LPR 106-19 and CB 98002 and 55 donors were screened against rice tungro disease under simulated tungro epiphytotic conditions. Among the cultures CR2654-17, CR2482-5, CR2482-10, CR2652-14, CR2649-7, CR2653-16 and CR2647-5 were found to be highly resistant to RTD. From the segregating generations of eight crosses, 152 resistant plants were selected. Among the donors, BJ 1, Purnendu, PTB 18, PTB 21, Pankhari 203, Chinikamini, Dhusara and AC6029 were found to be resistant to RTD.

Cultures found to be promising in All India Co-ordinated Trials

CR2644-2-6-4-3-2 (IET 22117) derived from the cross of Tapaswini and tungro resistant donor IET 16611 was promoted to AVT-2-IME based on its overall performance under irrigated mid-early situation. This culture is moderately resistant to RTD, sheath blight and brown spot.

CR2652-14 (IET 21346) derived from a cross of Sarala/CR682-165-1 has shown yield superiority in AVT 1-SDW trial of AICRIP, 2011 along with moderate resistance to multiple diseases i.e., RTD, sheath blight, brown spot, bacterial blight and sheath rot.

CR2643-1-4-3-1 (IET 22118) derived from the cross between Tapaswini and tungro resistant donor Vikramarya ranked fourth in Western region in IVT-IM trial of AICRIP, 2011 and was promoted to AVT-1-IM.

CR2641-26-1-2-2 (IET 22116) a cross from Tapaswini/CR101PKT was promoted to AVT2-IME on the basis of its yield superiority in AVT1-IME trial of AICRIP, 2011. This variety is moderately resistant to sheath blight and brown spot. IET 22116 also has shown good drought tolerant parameters under rainout shelter at Coimbatore.

CR2647-5(IET 22477) from the cross of Swarna and tungro resistant donor Vikramarya was promoted to AVT 1- Late based on its overall performance in IVT-L trial of AICRIP, 2011.

Three cultures CR2652-14 (IET 21346), CR2656-11-3-4-2 (IET 21713) and CR2644-2-6-4-3-2 (IET 22117) were found to be resistant to RTD with low susceptibility index less than 4.0 in NSN 1 and NSN 2 trial of AICRIP, 2011.

Physiology of Abiotic Stress Tolerance

Mechanism of multiple abiotic stress tolerance in rainfed lowland rice

Testing of cultivars for submergence tolerance under different levels of salinity

The experiment was conducted with 10 cultivars, which differed in submergence as well as salinity tolerance. Swarna is susceptible to both salinity and submergence, whereas Swarna-Sub1 is tolerant to complete submergence. Two cultivars namely Pokkali and Rashpanjar are tolerant to salinity. The rest of the cultivars may possess both *Sub1* and *Saltol* QTL. The data revealed that the cultivars without *Sub1* showed susceptibility under complete submergence. Survival % of Swarna-Sub1 decreased greatly under greater salinity (~12 ds m^{-1}). Irrespective of salinity of the flood water, two cultivars namely, IR84649-260-28-1-B and IR84649-21-15-1-B showed greater survival compared to other cultivars/fixed breeding lines (Table 14).

Table 14. Survival (%) after 12 days of submergence with different levels of saline water

Cultivars	Normal water	Saline water (~6 ds m^{-1})	Saline water (~9 ds m^{-1})	Saline water (~12 ds m^{-1})
Swarna	17	10	10	7
Swarna-Sub1	90	90	58	29
Pokkali (AC39416-A)	20	13	15	4
Rashpanjar	23	13	13	0
IR84649-130-5-1-1-1	100	87	44	14
IR84645-34-9-1-B	95	64	33	7
IR85212-73-1-1-1	40	25	0	0
IR84649-81-4-B-B	100	78	71	20
IR84649-260-28-1-B	100	77	80	67
IR84649-21-15-1-B	100	93	88	62

Photosynthetic characteristics and its association with salt tolerance

The experiment was conducted in hydroponics with four rice cultivars namely, IR42, FR13A, Rashpanjar and an accession of Pokkali (AC39416). FR 13A is a submergence tolerant line and susceptible to salinity. IR42 is susceptible to both salinity and submergence, whereas Rashpanjar and AC39416 are both tolerant to stagnant flooding. The genotype AC39416 is tolerant to salinity. Physiological characteristics changed greatly with salinity. Accumulation of greater quantities of H_2O_2 increased lipid peroxidation as malondialdehyde (MDA) accumulation showed highly significant association with H_2O_2 content (Table 15). Greater quantities of Na+ in shoot caused increase in H_2O_2 production, whereas greater quantities of K+ caused reduction in H_2O_2, which resulted in lower production of MDA. Highly significant negative association was noticed between photosynthesis (Pn) and H_2O_2 content and Pn and Na:K ratio. However, the association between Pn and K+ content was positive. The data showed that under saline conditions accumulation of greater quantities of K is beneficial.

Nutrient management (Phosphorous) in relation to submergence tolerance of *Sub 1* introgression cultivars

The experiment was conducted with three *Sub 1* cultivars namely Swarna-Sub1, IR64-Sub 1 and Savitri-Sub 1 with four levels of phosphorous i.e. 20, 40 60 and 80 kg P ha^{-1} with fixed dose of N (60 kg ha^{-1}) and K (30 kg ha^{-1}). Phosphorous and potash were applied as basal doses; N was applied in three split doses. Among the three Sub1 cultivars, survival (%) was greater in IR64-Sub1, followed by Swarna-Sub1. Survival (%) greatly increased with higher doses of phosphorous mainly in Savitri-Sub1 (Table 16). In other two cultivars, greater phosphorous application did not show either any positive or negative effects on plant survival due to complete submergence. Grain yield in general decreased due to submergence. Additional doses of phosphorous increased the yield significantly only in Savitri-Sub1.

Table 15. Correlation coefficients among different physiological parameters

Parameters	H_2O_2	MDA	Na	K	Na:K ratio	Photosynthesis (Pn)
Malondialdehyde (MDA)	0.967**	–-				
Na	0.753*	0.595ns	–-			
K	-0.768*	-0.899**	-0.238ns	–-		
Na:K ratio	0.981**	0.975**	0.729*	-0.827*	–-	
Photosynthetic rate (Pn)	-0.895**	-0.923**	-0.621	0.801*	-0.888**	–-
Shoot Dry weight	-0.656ns	-0.584ns	-0.802*	0.420ns	-0.698	0.681

*, ** = significance at <0.05 and <0.01 level, respectively at 6 degrees of freedom (d.f.); ns- non-significant.

Table 16. Effect of phosphorous on plant survival under complete submergence and grain yield

Cultivars	Phosphorous (kg ha^{-1})	Survival (%)	Grain Yield (t ha^{-1})		
			Control	Submergence	Stability (%)
Swarna-Sub1	20	79	6.57	5.14	78.2
	40	79	6.68	5.22	78.1
	60	86	6.91	5.38	77.8
	80	78	7.24	5.54	76.5
IR64-Sub1	20	95	2.32	1.79	77.1
	40	95	2.21	1.98	89.6
	60	93	2.18	1.90	87.1
	80	96	2.05	2.21	107.8
Savitri-Sub1	20	49	7.16	2.62	36.5
	40	51	7.28	2.65	36.4
	60	79	7.61	3.61	47.4
	80	82	7.76	3.77	48.6
LSD (P=0.05)	9	0.72	0.29		

Physiological basis of salt tolerance in rice with reference to coastal saline ecosystem

Physiological basis of salt tolerance was studied in eight landraces from Odisha and West Bengal found tolerant in earlier studies. After 10 days of salt stress (EC 12 dS m^{-1}), Kamini with 90% plant survival was comparable to Pokkali and *Saltol* donor FL478. The three cultivars survived under salt stress for 16 days while the remaining entries died completely between 10 and 16 days. Salinity significantly reduced the area and fresh weight of the 2nd top most leaf seven days after stress in all the genotypes, but the reduction over the control was lowest (22.0 & 30.7%) in Kamini and highest (71.8% & 71.2%) in IR29. In FL478, the corresponding reduction in the leaf area and leaf weight was 41.1% and 44.5%, respectively. Total chlorophyll content per unit leaf area in 2nd leaf at seven days after the stress increased under salinity for all the genotypes, except Marisal. The increase was lowest in IR29 and highest in Ravana followed by Kamini. The increase in chlorophyll content was generally due to an increase in chlorophyll b content. Total dry matter production at seven days after salt stress was also lowered by salinity in all the genotypes, but again the reduction was lowest (24.5%) in Kamini and highest (56.6%) in IR 29. Distribution of dry matter in different plant parts (root, leaf and stem) was also affected by salt stress and the response varied with the genotypes. While Kamini and IR29 showed similar reduction in root dry matter, reduction in leaf and stem dry matter was relatively much lower for Kamini. As a result, shoot:root ratio in salt stress treatment was significantly increased in Kamini but decreased in IR29. For the remaining genotypes, shoot: root ratio was either maintained to the same level as in the control or decreased. After seven days of salt stress, tolerant genotypes recorded significantly higher K content in leaf (22.7-27.9 mg g^{-1}dry weight) and stem (15.2-29.9 mg g^{-1} dry weight) compared to IR29 (18.5 & 11.1 mg g^{-1} dry weight) while reverse was true for Na content. The Na content in leaf and stem was 24.9 and 31.0 mg/g dry weight for IR29, as against 11.3-21.5 and 19.7-27.9 mg g^{-1} dry weight for the remaining cultivars. The Na:K ratio in leaf and stem was much higher in IR29 (1.35 & 2.79) than in tolerant varieties (0.44-1.02 & 0.66-1.80). Among the tolerant cultivars, Marisal and Talmugra recorded higher Na:K ratio both in leaf and stem.

Identification of rice varieties tolerant to different growth stage drought stress

Seedling stage

Thirty two entries out of 100 genotypes for seedling stage drought stress recorded SES score '1' at Soil Moisture Content (SMC) 10-12%, while under severe stress (SMC 1.2-2.0 %), nine entries IC568024, IC-568009, IC568114, IC568060, IC568016, IC568030, IC568083, IC568112 and IC568065 survived having more than 50% RWC and recovered fast after re-irrigation.

Vegetative stage

Two hundred eighty seven entries out of 970 genotypes for vegetative stage drought stress recorded SES score '1' at SMC 12-14%. Promising entries R-RF-45 (1.79 t ha^{-1}), IR72667-16-1-B-B-3 (1.56 t ha^{-1}), IR84882-B-120-CRA-1-1-1 (1.51 t ha^{-1}); CB5-754 (3.5 t ha^{-1}), Lalat (3.20 t ha^{-1}) and IR83388-B-B-108-3 (2.80 t ha^{-1}); IR83614-643-B (2.90 t ha^{-1}) and IR36 (2.60 t ha^{-1}) under vegetative stage stress recorded higher grain yield compared to other entries.

Reproductive stage

Thirty four entries out of 56 genotypes for reproductive stage stress were observed to be tolerant with SES score'1'. Under reproductive stage stress (10 days before flowering to 10 days after flowering), RR345-2 recorded highest grain yield of 2.50 t ha^{-1} followed by RR2-6 (2.30 t ha^{-1}), CR143-2-2 (1.80 t ha^{-1}) and IET 18817 (1.15 t ha^{-1}) with high moisture retention capacity (> 80%) and low DSI (drought susceptibility index) values (about 0.60) with high grain filling percentage (>70%).

Evaluation of drought tolerant genotypes for yield potential under control and rainfed upland condition (along with AICRIP entries)

Forty entries including 14 entries from AICRIP were evaluated under rainfed upland condition at KVK, Santhpur and controlled irrigated condition at CRRI, Cuttack for their yield potential. The crop experienced two mild stresses of six days duration in seedling stage and of 15 days duration during reproductive stage (54 days old seedling) at KVK Santhpur. Out of 40 entries tested, RR 270-5, RR345-2, Kalakeri and IET 18717, IET 20859, IET 21620, IET 21627, IET 22020, IET 22051, IET 22026, Anjali and Sahabhagidhan had yield potential of more than 4.0 t ha^{-1}under controlled irrigated condition at CRRI farm, while RR383-2, RR 2-6, CR143-2-2, Zhu11-16, RR443-2, IET 21620, IET 22026, IET 22032, Kalakeri and Sahabhagidhan had yield potential of > 1.50 t ha^{-1} with > 50% grain filling percentage under rainfed condition even after getting exposed to stress at both the stages.

Physiological basis of drought stress tolerance

Six rice varieties *viz.,* Bala, Peta, Dular, Mahsuri, Safri17 and IR20 grown in pots were exposed to vegetative stage stress consecutively for six days (upto 6 DAS) till the leaves were rolled and morpho-physiological and biochemical traits were recorded on before stress, 2, 4, 6 days after stress and recovery period.

Photosynthetic pigments chlorophyll 'a', 'b' and total chlorophyll was gradually decreased with the increase in severity of stress which is due to the degradation of pigments during limited water supply to the cell and Bala followed by Dular recorded maximum accumulation at all the stages. Proline accumulation an indicative response to stress at the cellular level increased on increasing the magnitude of the higher accumulation was recorded in Dular and Peta. Dular maintained high turgidity on the 6th day showing higher RWC value followed by Peta indicating their tolerant characters towards moisture stress. Soluble protein content in the fresh leaves decreased in all the varieties with maximum decrease in the susceptible variety IR20. But a marginal increase observed in Bala and Dular indicates the over expression of some stress tolerant proteins. The activity of antioxidative enzymes catalase, peroxidase and superoxide dismutase increased in relation to severity of moisture stress, while soluble sugar decreased significantly in all the varieties and maximum accumulation was recorded in Bala followed by Dular. Based on these physiological and biochemical traits, the varieties Bala, Peta and Dular were considered to be most tolerant varieties among the six varieties tested.

Physiological basis of grain yield under Aerobic/AWD condition

Effect of Aerobic and alternate wetting and drying (AWD) condition on growth and yield of rice varieties

Out of 10 varieties grown under Aerobic and AWD conditions, Rajalaxmi recorded highest yield of 6.0 t ha^{-1} under AWD followed by Ajay and AP-09-3, while Ajay recorded highest grain yield (5.30 t ha^{-1}) under Aerobic condition followed by CRHR 32 and Jaya. However, Ajay had a stable yield of 5.30 t ha^{-1} under both the conditions indicating its adaptation to water limited conditions. Higher grain yield observed in the above varieties might have been contributed by high biomass both at flowering and harvest, high LAI (> 4.22) higher moisture retention capacity (> 70%) during dry cycle, high chlorophyll content (> 3.0 mg $gfwt^{-1}$), and high photosynthetic rate (30.2-35.6 µ mole CO_2 m^{-2} s^{-1}).

Mechanism of anaerobic/underwater seedling establishment in rice

Impact of seed priming on yield and yield attributes under anaerobic seeding conditions

Seed priming even with simple tap water improved the grain yield of both IR64 and IR64-Sub1 under anaerobic seeding conditions. This is mainly due to the improvement of panicle numbers m^{-2} and panicle weight (Table 17). Numbers of plants per unit area were less under anaerobic seeding compared to the controlled conditions. Seed priming improved the underwater seedling establishment, yet the plant stand was not sufficient to produce similar grain yield as under normal condition. Effect of seed priming either with tap water or 2 % Jamun leaf extract had the same effect on seedling establishment, yield and yield attributes in IR64 and IR64-Sub1.

Table 17. Effects of seed priming on yield and yield attributes of two rice cultivars sown in aerobic and flooded soils

Yield and its attributes	IR64			IR64-Sub1			LSD(P=0.05)
	CNP	PNW	PLE	CNP	PNW	PLE	
A. Non-stressed conditions							
Panicle number m^{-2}	304	311	313	305	308	307	NS
Single panicle weight (g)	1.45	1.51	1.52	1.37	1.50	1.43	0.12
Fertile Spikelet (%)	13.9	12.6	12.1	12.0	12.7	10.8	NS
Grain yield (t ha^{-1})	4.20	4.37	4.28	3.73	4.32	3.91	0.25
B. Under anaerobic germination							
Panicle number m^{-2}	228	240	302	238	260	267	18
Single panicle weight (g)	1.29	1.33	1.43	1.24	1.42	1.44	0.09
Fertile Spikelet (%)	22.3	21.4	23.3	24.5	18.2	21.9	NS
Grain yield (t ha^{-1})	2.75	2.98	3.50	2.59	3.30	3.35	0.33

CNP- control no priming; PNW- priming with normal tap water; PLE- priming with 2 % leaf extracts of *Syzygium cumini*.

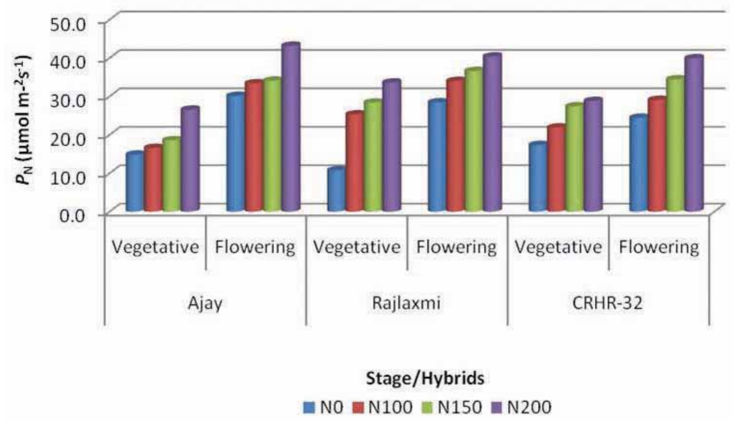


Fig. 9. Photosynthetic efficiency of rice hybrids grown under four nitrogen levels both at vegetative and flowering stage

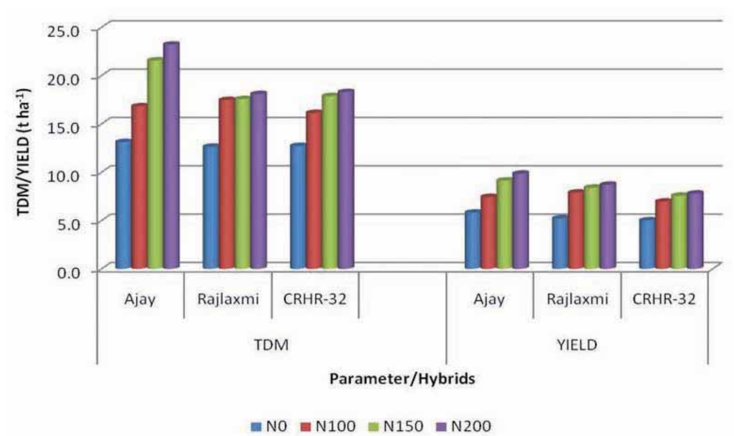


Fig. 10. Total dry matter (TDM) and grain yield of rice hybrids grown under four nitrogen levels

Photosynthesis and yield of rice hybrids grown under four nitrogen levels

Photosynthetic characteristics in relation to biomass production and yield were investigated using three rice hybrids *viz.*, Ajay, Rajalaxmi and CRHR32. The result indicated that the photosynthetic rate linearly increased in all the hybrids when the nitrogen level increased from N_0 (No nitrogen) to N_{200} (200 kg N ha^{-1}) irrespective of the stage of the crop (Fig. 9). The P_N per chlorophyll (P_N Chl^{-1}) was higher in all the hybrids grown under N_{200} at vegetative stage and there was a significant increase in the P_N Chl^{-1} value under flowering stage irrespective of the rice hybrids and *N* levels. The grain yield of all the rice hybrids was influenced by the nitrogen level with highest grain yield was recorded in Ajay (9.85 t ha^{-1}) followed by Rajalaxmi (8.70 t ha^{-1}) and CRHR32 (7.79 t ha^{-1}) under N_{200} (Fig. 10). There was a significant positive correlation between total dry matter and grain yield with P_N in all the hybrids showing interdependence of parameters under different nitrogen levels (Fig. 11).

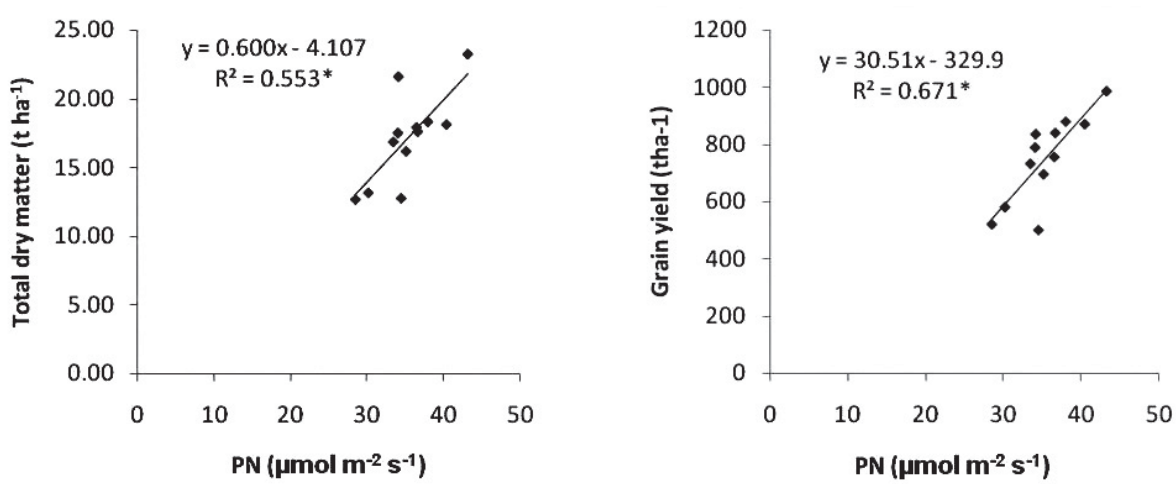


Fig. 11. Correlation coefficient between total dry matter and grain yield with photosynthetic rate in rice hybrids grown under four nitrogen levels

Biophysical Studies on Global Climate Change and Rice Production

Impact of elevated CO_2 on rice cultivars using FACE technology

Biochemical and Grain quality parameters of harvested grain of rice variety Naveen using Free Air CO_2 Enrichment (FACE) technology and Open Top Chamber (OTC) were studied. Study showed a significant increase in the grain quality under FACE. Elevated CO_2 generally accelerate the growth of rice crop and also flowering commenced earlier, which contributed to the higher grain yield and change in the chemical composition of the rice grains in FACE technology, as compared to OTC. Elevated CO_2 brought about significant increase in grain quality parameters in FACE grown plants as compared to plants grown under ambient conditions. It can be seen that the HRR%, WU and AC increased considerably (Table 18).

National Initiative on Climate Resilient Agriculture

Evaluation and improvement for salinity tolerance in rice

Analysis of Saltol locus for seedling stage tolerance

Principal component analysis employing eight SSR markers in *Saltol* region of chromosome 1 depicted that highly salt tolerant accessions at seedling stage such as Pokkali (AC41585) and Chettivirippu (AC39389) were distantly located in 2D plot in respect of another highly tolerant group comprising FL478 and Pokkali (AC39416). RM10745 and RM3412 markers could able to identify tolerant phenotypes in derivatives from FL478 and Pokkali in *Saltol* locus.

Reproductive stage tolerance

Under the evaluation for reproductive stage salt tolerance, considering least yield reduction and other related traits under salinity stress, Pokkali (AC41485) was found tolerant at flowering stage. Chettivirippu (AC39389) and Chettivirippu (AC39394) were also found moderately tolerant.

Selection of salt tolerance plants

Nine hundred twenty six seedlings were selected from 73 salt-tolerant and moderately tolerant populations after imposing salinity stress at seedling stage in simulation tank (ECe= 12-14dS m^{-1}) and transplanted to experimental blocks.

Towards Development of Single Cell C_4 Photosynthesis System in Rice

Identification of genes involved in transition from C_3 to C_4 taking Suaeda fruticosa, a C_3-C_4 intermediate Chenopod

An experiment was conducted for identifying genes involved in transition from C_3 to C_4 by taking *Suaeda fruticosa,* a C_3-C_4 intermediate Chenopod. There were no anatomical changes in the leaf of *S. fruticosa* sub-

Table 18. Impact of elevated CO_2 on the quality of rice grain (Naveen)

FACE	Hull	Mill	HRR	KL	KB	L/B	Al-val	WU	VER	KLAC	ER	AC
Amb FACE	75.33	68.33	48.03	5.06	2.1	2.4	5.5	80.33	4	9.2	1.76	23.27
Elev FACE	79.6	73.53	60.3	5.35	2.42	2.23	6	102	4	9.2	1.83	24.33
CD	2.54	3.94	6.95	N.S.	0.17	N.S.	N.S.	5.56	N.S.	N.S.	N.S.	N.S.
SE(d)	0.54	0.85	1.5	0.18	0.03	0.09	0.57	1.2	0.57	0.2	0.04	0.25
SE(m)	0.38	0.6	1.06	0.13	0.02	0.07	0.4	0.85	0.4	0.14	0.03	0.18
CV	0.86	1.46	3.39	4.31	2.08	5.21	12.29	1.61	17.67	2.66	2.89	1.31
OTC	Hull	Mill	HRR	KL	KB	L/B	Al-val	WU	VER	KLAC	ER	AC
Amb OTC	75.66	66.06	56.92	5.27	2.13	2.35	4	79.32	4	10.43	1.96	23.97
Elev OTC	76.44	67.26	62.66	5.2	2.21	2.48	4	80.0	5	10.73	2.15	24.24
Elev+TempOTC	74.0	64.66	55.66	4.97	2.12	2.34	4	70.0	4	9.76	1.87	23.87
CD	N.S	N.S	1.72	N.S	N.S	N.S	N.S	15.04	N.S	0.2	0.21	NS
SE(d)	0.36	0.6	0.6	0.16	0.1	0.09	0.47	5.27	0.47	0.07	0.07	0.29
SE(m)	0.25	0.42	0.42	0.11	0.07	0.06	0.33	3.73	0.33	0.05	0.05	0.2
CV	1.17	2.25	2.54	3.84	5.81	4.96	28.86	12.95	13.32	0.85	4.52	1.49

HRR=Head Rice Recovery; KL=Kernel Length; KB=Kernel Breadth; L/B=Length Breadth ratio; Alk-Val=Alkali Spreading Value; WU=Water Uptake; VER=Volume Expansion Ratio; KLAC=Kernel Length After Expansion; ER=Elongation Ratio; AC=Amylose Content jected to different levels of sodium chloride solution (Fig. 12), however, the $^{C}\delta$ value at high salinity environment shows indication of C_4 ness of *S. fruticosa* (Table 19).

One month old seedlings of the same germplasm accessions were exposed to vegetative stage moisture stress under field condition with similar checks as that of seedling stage stress. Soil moisture content varied from 2.6 to 9.7% under 30 cm soil depth with soil moisture tension of more than 60 kPa. Leaf death score was recorded when most of the entries showed leaf rolling symptom and the score was taken following IRRI SES '0' to '9'scale. Out of 525 entries, 75 entries were observed to be highly tolerant with drought and recovery score SES '1' followed by 188 as moderately tolerant with SES score '3', 92 relatively less tolerant with SES score '5', 134 with SES score '7' and 36 as susceptible with SES score '9'. The tolerant checks performed better with SES score ranging between '1-5', whereas susceptible check (IR-20) was observed with SES score in the range of '7-9'.

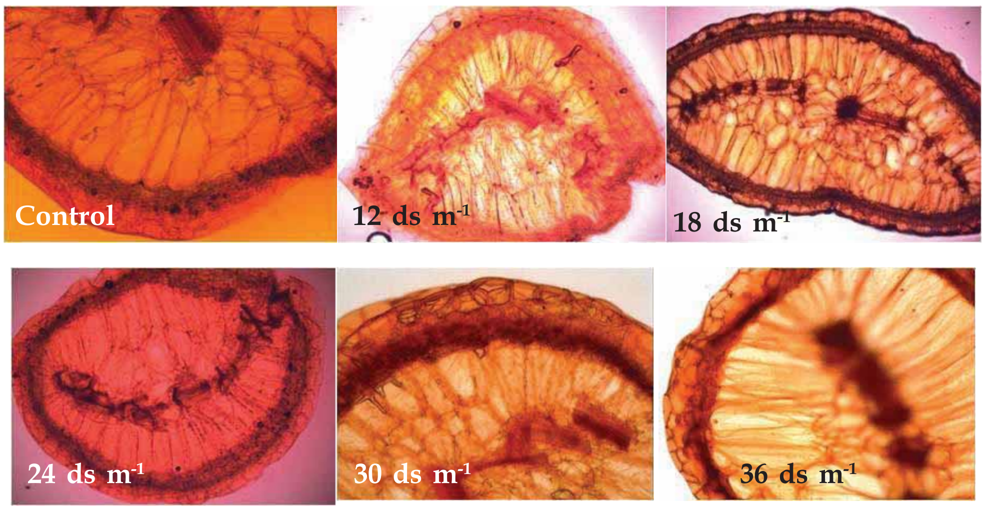


Fig. 12. Anatomy of *S. fruticosa* under different salinity level

Table 19. $^{C}\delta$ value of *Suaeda fruticosa* subjected to different salinity levels

	$^{C}\delta$ value control	12 ds m^{-1}	18 ds m^{-1}	24 ds m^{-1}	30 ds m^{-1}	36 ds m^{-1}
Suaeda fruticosa	14.543	16.721	15.125	14.659	13.876	8.698

Phenomics of moisture deficit and low temperature stress tolerance in rice

Fifteen days old seedlings of 525 germplasm accessions were exposed to seedling stage/ early vegetative stage moisture stress under field condition with four blocks and five checks (tolerant and susceptible). Soil moisture content was 2.38 to 11.20% and soil moisture tension was 50- 60 kPa during the stress period under 15 cm soil depth. Leaf death score was recorded following IRRI SES '0' to '9'scale. Out of 525 entries, 37 entries were observed to be tolerant with drought and recovery score SES '1', 33 as moderately tolerant with SES score '3', 108 relatively less tolerant with SES score '5', 236 with SES score '7' and 111 as susceptible with SES score '9'. The tolerant checks (Vandana, Vanaprabha, Salumpikit and CR143-2-2) performed better with SES score ranging between '1-5', whereas susceptible check (IR20) was observed with SES score in the range of '7-9'.

Bioprospecting and Allele Mining Against Abiotic Stresses

Phenotyping under salt stress and genotyping using QTL linked markers

A total of 825 lines were sown at CRRI and thirty day old seedlings were transplanted in the field at

Kankana, Erasama, a costal saline area along with the check varieties SR26B and IR29. The scoring against salinity stress was done at vegetative stage and also at maturity and observations were recorded on plant height, panicle length, panicle bearing tillers and spikelet fertility (%). Panicles from single plants were collected. The same set were also grown at CRRI under normal conditions. Out of eight hundred twenty five, 452 lines showed stress scoring of 3-5 and 239 lines showed > 70 % fertility as well as stress score of 3-5, thus demonstrating the wide variability for this trait in the germplasm studied.

Forty two lines along with check varieties were directly sown in salinity screening tank at CRRI. These lines were exposed to salt stress from 21 day seedling stage to flowering. Salinity stress scoring was done at vegetative stage according to IRRI guidelines and also 15 qualitative character data were taken according to descriptors for rice (IRRI, 1980). After harvesting total germplasm, fertility percentage of the surviving lines was calculated. Twelve out of the 42 lines evaluated were found to have more than 70 per cent fertility and stress scoring of 3-5.

Genotyping was done with fifty rice accessions through PCR analysis using gene specific and also microsatellite markers such as AP3206, AP3206f, SKC1, SKC1b, SKC2a, SKC10, RM3412, RM10745, RM10748, Pect4, RM493, RM10793, Salt1, RM8094, and RM562 for the prospecting of genes that confer tolerance to salt stress. Polymorphism was observed with some of the markers like AP3206, AP3206f, Pect4, RM3412, SKC2a, SKC10, RM10745, RM10748, RM10793, RM493, RM8094 and *Salt1*.

Phenotyping for submergence tolerance

Thirteen rice genotypes including highly tolerant variety FR13A and susceptible variety IR42, FR13B, FR43B, Sabita, AC38575, Atiranga, Kusuma, Gangasiuli, Kalaputia, CR780, Khoda and IR64-Sub1 were evaluated for the identification of submergence tolerance. Molecular analysis of these thirteen genotypes with allele specific and intragenic marker in *Sub1* locus, along with RM219, along with PDC and gene specific markers for submergence tolerance was carried out. Out of the all primers, Sub1BC2, Sub1BC3, SubLCI73 and RM219 showed clear polymorphism.

Phenotyping under drought stress

Two thousand and seven hundred accessions were direct seeded in the experimental farm of CRRI at Santhapur during the wet season and were subjected to severe drought stress starting from 30 day old crop. The results indicated that 270 accessions were identified as promising based on drought scoring and morphological symptoms.

Seventy eight rice accessions were screened at vegetative stage under field condition along with two drought tolerant checks Vandana and CR143-2-2 and one drought susceptible check IR20. The drought scores recorded as per IRRI SES scoring in 1 to 9 scales. Results indicated that, from the total lines, 30 lines were identified as best vegetative stage drought tolerant lines with early recovery by SES score '0' and '1', out of which 12 entries recorded SES score '0' and 18 entries recorded SES score '1' compared to the tolerant and susceptible checks. The same set of genotypes was evaluated under artificial conditions in the lab. The germination rates using five day old seedling were tested under Poly Ethylene Glycol 6000 mediated moisture stress. Higher degree of correlation was observed between the results of the field screening and the PEG experiments with eight genotypes being common to both PEG and field evaluation.

Phenotyping under heat stress

Seven hundred genotypes were screened under transplanted field conditions using staggered sowings (early, normal and delayed sowing) for high temperature tolerance to identify donor genotype(s). From heat tolerance screening trials of germplasm during dry season of 2011, three genotypes found highly tolerant to heat stress with SES score 1 were AC39843, AC39834 and AC39969 with more than 80% spikelet fertility that were at par /better than check Annapurna and N 22.

Mapping population of Naveen/Annapurna and Shatabdi/Annapurna, Shatabdi/N 22 and Lalat/N22 are in F_4/F_5 generation by SSD method. Few others genotypes showing moderate degree of tolerance are AC39975, AC11069, AC10925 and AC39935 showed moderately resistance with more than 75% spikelet fertility. The most susceptible genotypes was AC39880 with 56% fertility.

Identification of QTLs for Yield and Major Biotic and Abiotic Stresses

Identification of QTLs for yield and BPH resistance

The mapping populations (F_4 and F_5) from different crosses were developed for identification of QTLs associated with yield and BPH resistance (Dhobanambari/TN1) during wet season, 2011. Parental polymorphism survey with additional 116 hyper variable microsatellite primers indicated that 69 were polymorphic between WAB 50-56 and CR662-2211-2-1 (*per se* yield), 37 were polymorphic between PDKV Shriram and Heera (grain number) while 64 were polymorphic between AC 38562 and Pimpudibasa (1000 grain weight).

QTL associated with root-knot nematode resistance in the rice variety Ramakrishna

Phenotyping and genotyping of 109 F_9 recombinant inbred lines from the cross Annapurna/Ramakrishna identified three QTLs associated with root-knot nematode resistance in the rice variety Ramakrishna with a LOD score>3.0 (Table 20).These loci were designated as QMg1 (t), QMg2 (t) and QMg3 (t). QMg1 (t), located at 13.7cM on short arm of Chromosome1, control production of galls on roots, production of eggs by the pathogen and compensatory mechanism of the host, together explaining 41.24% of phenotype variance. QMg2 (t), located at 23.7cM on short arm of chromosome2, involved in production of galls by the pathogen on roots, contributing 7.05% to phenotype variance. QMg3 (t), located on short arm of chromosome3 at 21cM was involved in gall and egg production by the nematode, explaining 78.73 % of phenotype variance for the two traits together. All the three traits were highly correlated.

Identification and deployment of genes imparting phosphate utilization in upland rice

Fourteen rice varieties such as IR36, Kalinga III, Vandana, Virendra, UpLPi7, Anjali, Rasi, Annada, CRDhan 40, Sadabahar, Hazaridhan, Sahabhagidhan, Abhishek andAzucena were screened for phosphorus deficiency tolerance using sand culture. The plants were subjected to stress (nutrient solution containing 4 and 8 ppm of P) and non-stress (nutrient solution with 16 ppm of P) conditions. Reduction was observed for all the four traits (i.e. plant height, root length, number of roots/plant and dry weight/plant) at low P (4 ppm) and medium P (8 ppm) as compared to normal P (16 ppm). Least reduction was observed for all the traits in Rasi and Abhisek while reduction was highest for all the traits in IR36 and UPLPi7. Based on the four agronomic traits, Rasi and Abhisek were found to be phosphorus deficiency tolerant.

Identification of QTLs associated with blast resistance and development of QTLs -NILs

The cycle of backcrossing (BC_3F_1) for transfer of two blast resistance genes, *Pi2* and *Pi9* in the background of Vandana and BPT5204 was completed and confirmed plants were selected for selfing. Simultaneously, polymorphic flanking markers on either side of the gene based SSR marker AP5930 were used for recombinant selection for the both resistance genes, *Pi2* and *Pi9*. Five out of 30 hyper variable SSR markers on chromosome 6 were found polymorphic between the recurrent and donor, and were used for background selection. Among the five confirmed plants, four were similar to the recurrent parent based on amplification pattern.

Identification of QTLs associated with drought tolerance

Parental polymorphism survey with 206 microsatellite primers indicated that 81 were polymorphic between Kalinga III and Salumpikit while 68 were polymorphic between Kalinga III and Moroberekan. Two hundred and thirty recombinant inbred lines of the cross Kalinga III/ Salumpikit were evaluated for reproductive stage drought tolerance under uplands under rainout shelter. The parents showed statistically significant differences at higher probability level for the traits like grain yield, plant height, panicle length, filled grains per panicle, per cent spikelet sterility and drought score but not for biomass and canopy temperature (Table 21). The phenotypic distributions in the RIL lines for the traits mentioned did not show discrete classes but approximately fitted a normal distribution, indicating that all measured traits were quantitatively inherited in nature. Transgressive segregation in both directions was observed for most traits, indicating that both parents transmitted favorable alleles for each trait. Highly significant positive correlation (r=0.77) between grain yield and filled grains per panicle was found, indicating that genetic improvement in grain yield

Table 20. QTLs associated with root-knot nematode resistance in the rice variety Ramakrishna

QTLs	Associated traits	Chromosome	Flanking marker	Map position (cM)
QMg1(t)	Production og galls, eggs and eggs/gm root	1	RM495-RM428	13.7
QMg2(t)	Production of galls	2	RM233A-RM14149	23.7
QMg3(t)	Production of galls and eggs	3	RM231-RM7	21.0

Table 21. Trait mean values, ranges, standard deviation and F-statistic from analysis of variance of grain yield and its components of RIL population of Kalinga III/Salumpikit

Trait	Kalinga III	Salumpikit	RILs Range	Mean	Standard Deviation	F- Statistic
Days to flower	63	93	53-105	78.9	10.6	35.11**
Plant height (cm)	84.1	118.4	52.9 - 145.5	103.4	13.1	1.854**
Biomass (g./plot)	150.3	154.4	30 - 450	233.7	87.4	1.221
Panicle length (cm)	18.9	20.3	14.7 - 27.3	20.0	2.2	2.019**
Filled grains per panicle	14	59	0 - 90	27.2	18.0	2.29**
Percent spikelet sterility (%)	78.4	35.9	11.4 - 100	62.2	22.2	2.906**
Canopy temp. (ºC)	35.1	33	27.2 - 38.6	32.6	2.7	0.958
Drought score (SES)	7	3	1 - 7	4.0	1.6	2.99**
Grain yield (kg ha^{-1})	69.1	539.2	0 - 1181	331.3	258.8	3.622**

Table 22. Correlation matrix among different traits under stress condition

Trait	Days to flower	Plant height (cm)	Biomass	Grain yield kg ha ^{1}	Drought score (SES)	Canopy temperature (ºC)	Panicle length (cm)	Filled grains panicle^{-1}
Plant height (cm)	0.15							
Biomass	0.10	0.24						
Grain yield (kg ha ^{1})	0.23	0.34*	0.28					
Drought score (SES)	-0.11	-0.19	-0.18	-0.45**				
Canopy temp. (ºC)	0.03	-0.10	-0.05	-0.07	0.10			
Panicle length (cm)	0.16	0.21	0.12	0.22	-0.19	-0.16		
Filled grains per panicle	0.27	0.35	0.16	0.77**	-0.34*	-0.04	0.25	
Percent spikelet sterility (%)	-0.29	-0.34	-0.10	-0.74**	0.30*	0.01	-0.14	-0.92**

would likely be accompanied by improvement of filled grain number (Table 22). Negative correlations (r=-0.74) between grain yield and per cent spikelet sterility and between grain yield and drought score (r=-0.45) were also highly significant, though the magnitude of the later is not very high.

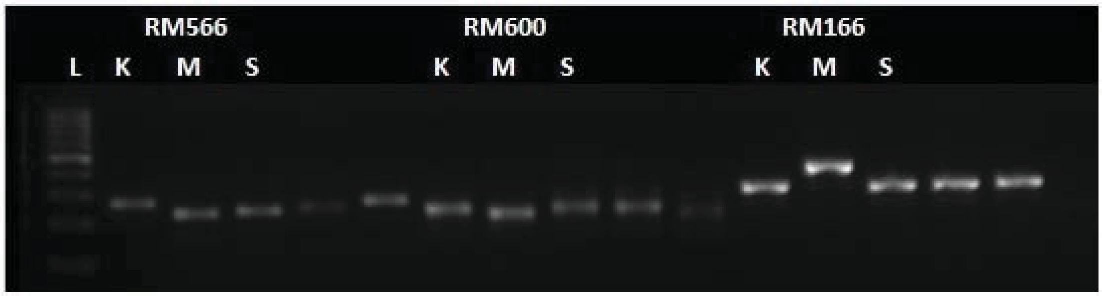
Identification of QTLs associated with traits conferring weed competitiveness

Heera and Browngora have been screened for parental polymorphism with 204 SSR markers, of which 85 were found to be polymorphic. The mapping population of the cross Heera/Browngora was advanced from F_7 to F_8 during wet season 2011. One hundred nine recombinant inbred lines (RILs) along with parents were evaluated for traits associated with weed competitiveness under once weeded and weed free conditions. Reduction in grain yield under weedy condition in red soil was 68% whereas, it was 28% under clay soil. In red soil, grain yield under once weeded condition ranged from 0.007 to 1.06 t ha^{-1}, whereas under weed free condition it ranged from 0.10 to 2.21 t ha^{-1}. In clay soil, grain yield under once weeded condition ranged from 0.35 to 1.92 t ha^{-1} whereas, under weed free condition it ranged from 0.53 to 2.35 t ha^{-1}. However, days to 50% flowering was not influenced by weeds in both red soil and clay soil conditions.

QTL-NIL development–Blast

The cycle of backcrossing for transfer of two genes (*Pi2* and *Pi9*) in the background of Vandana was advanced and confirmed plants (Fig. 13) selected for selfing. Simultaneously, flanking markers on either side of the gene based SSR marker AP 5930, used for both *Pi2* and *Pi9* and polymorphic between the parents have been identified for recombinant selection on the target chromosome. Around 30 HV SSR markers selected from chromosome 6 were used for background selection out of which five HV SSR were polymorphic between the recurrent and donor and situated on either side of the target gene. Among the five confirmed plants (Fig. 14), four were similar to the recurrent parent based on these polymorphic plants.

A population of 266 RILs of Kalinga /Moroberekan, developed by single seed descent, for abiotic and biotic stress tolerance was evaluated for blast and brown spot



Legend: L- Ladder (100bp) K- Kalinga III M- Moroberekan S- Salumpikit

Fig. 13. Parental polymorphism survey with SSR markers

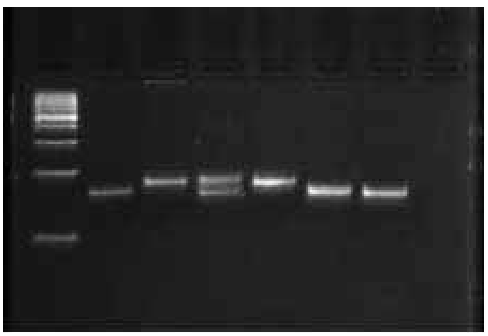


Fig. 14. Gel photo showing marker AP 5930 showing confirmed (C) BC3F1 plant of Vandana/*Pi2* (C 101 A 51)

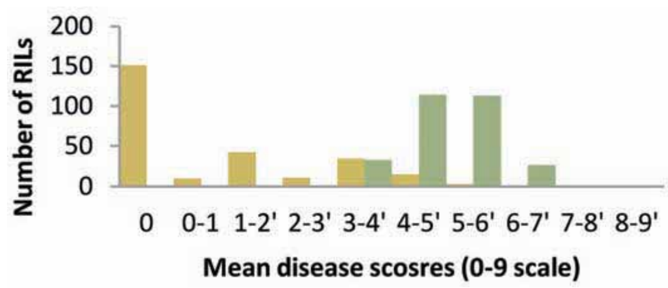


Fig. 15. Distribution of reaction types in the population of Kalinga III/Morobereman for blast and brown spot

in nurseries during wet season 2011. Majority of the RILs showed blast resistance (Table 23) but most were susceptible to brown spot (Fig. 15) obviously due to the moderate reaction of parents to brown spot.

Table 23. Range, mean and standard deviation of blast and brown spot intensity in the RILs of Kalinga III/ Moroberekan

	P1	P2	Range	Mean	Std dev
Bl. Score	0	4.5	0-6	1.28	1.72
Bl. DLA	0	5	0-14	1.12	2.68
B.sp. Score	4.9	6.4	3.0-6.8	4.99	0.79

Identification of major QTLs for grain yield under drought stress in 'Jhum' rice varieties of North Eastern Region for use in marker assisted breeding to improve yield under drought

Eighty three Jhum rice germplasm from north-eastern region were screened for drought tolerance under rain-out shelter facility. Based on leaf rolling one genotype was scored (SES) as 1, 35 genotypes as 3, 39 genotypes as 5, six genotypes as 7 and two as 9. Grain yield was negatively correlated with drought score, canopy temperature, chaffs panicle^{-1} (sterility) and positively correlated with grain number panicle^{-1} and biomass. Based on grain yield and other traits, the promising drought tolerant genotypes identified are RCPL1-128, Bhalum 3, Berain 2 and Kataktara. Mapping population will be developed using these donors to identify the QTLs for grain yield under stress.

Marker Assisted Breeding of Abiotic Stress Tolerant Rice Varieties with Major QTLs for Drought, Submergence and Salt Tolerance

Introgression of $DTY_{2.1}$ and $DTY_{3.1}$ QTLs in Swarna-Sub1 through marker assisted backcrossing

Backcross population (BC_1F_1s) of the cross Swarna-Sub1/IR81896-B-B-195 was grown during 2011 wet season. Six markers (RM324, RM521, RM6374, RM3549, RM327, RM13211) linked to QTL $DTY_{2.1}$ and three markers (RM16032, RM416, RM520) linked to QTL $DTY_{3.1}$

were selected for foreground selection. Among these primers RM521 and RM520 have given clear polymorphism for DTY $_{2.1}$ and DTY $_{3.1}$ QTLs, respectively. Two plants found positive for both the QTLs (DTY$_{2.1}$ & DTY$_{3.1}$) were used for backcrossing with Swarna-Sub1. Seventy two crossed seeds (BC_2F_1) have been harvested. During 2012 dry season, seventy-two BC_2F_1 plants were subjected to foreground selection. Gene specific markers RM521, RM520 and Sub1BC$_2$ were used for identifying positive plants with DTY$_{2.1,}$ DTY$_{3.1}$ and Sub1 QTLs respectively. Eleven positive plants were obtained with both drought QTLs (DTY$_{2.1}$ and DTY$_{3.1}$) along with Sub1 locus. Selected 11 BC_2F_1 plants were subjected tobackground selection with polymorphic STMS markers present across 12 Chromosomes in the rice genome. Selected plants were used for back crossing. One hundred and seventy crossed seeds (BC_3F_1) were harvested.

Introgression of *Sub1* QTL into Pooja and Pratikshya for flooding tolerance

During the wet season 2011, F_1 plants of two crosses *viz.*, Pooja/Swarna-Sub1 and Pratikshya/Swarna-Sub1 were grown along with the respective parents. Four primers *viz.*, IYT1, IYT3, Sub1A203 and AEX used for confirmation of *Sub1* QTL presence in F_1 plants showed dominant nature of these markers. Two primers RM8300 and Sub1BC2 showed co-dominant nature and seedlings with *Sub1* locus showed heterozygous condition. Confirmed plants were used for backcrossing with the recurrent parents, Pooja and Pratikshya (Fig. 16 & 17). Based on PCR results selected F_1 plants of the both the crosses, Pooja/Swarna-Sub1and Pratikshya/Swarna-Sub1 were used for backcrossing with the respective recurrent parents. More than one thousand seeds (BC_1F_1) of each cross were harvested.

Introgression of *Saltol* QTL into Gayatri for salt tolerance

During the wet season 2011, F_1 plants of the cross Gayatri/FL478 were grown along with parents. Out of the ten primers used for identifying the F_1 plants with '*Saltol*', three gene specific markers (RM8094, AP3206 and RM3412) and two flanking markers (RM493 and RM7075) showed co-dominant/heterozygous condition, whereas, other primers did not show any polymorphism. Primer, RM493 was used for selecting the F_1 plants with *Saltol* QTL, which showed a clear polymorphism between plants with and without '*Saltol*'. On the basis of PCR analysis, selected F_1 plants with '*Saltol*' were used for backcrossing with the recurrent parent Gayatri and about 600 BC_1F_1 seeds were obtained.

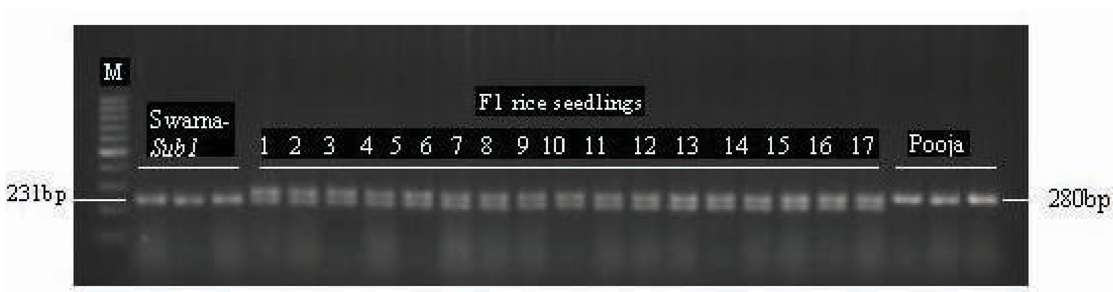


Fig. 16. Presence of *Sub 1* locus in heterozygous condition in F_1 plants (Pooja/Swarna-Sub 1) in PCR amplification with *Sub 1* QTL spcific marker *Sub 1 BC2* primer; M=100bp DNA ladder

Fig. 17. Presence of *Sub 1* locus in heterozygous condition in F_1 rice plants (Pratikshya/Swarna-Sub1) in PCR amplification with *Sub 1* QTL spcific marker *Sub 1 BC2*

Introgression with $DTY_{1.1}$ and $DTY_{2.2}$ QTLs into IR64-Sub1 for drought tolerance

Backcross populations (BC_1F_1s) of two crosses *viz.*, IR64-Sub1/IR88287-367-B-B and IR64-Sub1/ IR86918-B-305 were raised during 2011 wet season at CRRI Regional Station, Hazaribag. A total of 50 plants from each cross phenotypically similar to recurrent parent were selected for foreground selection. Two markers (RM279 and RM236) linked to QTL DTY $_{2.2}$ and four markers linked to QTL $DTY_{1.1}$ (RM3825, RM315, RM212 and RM431) were selected for foreground selection. Among these primers RM3825 and RM279 have given clear polymorphism for $DTY_{1.1}$ and $DTY_{2.2}$, respectively. Out of 50 plants selected for foreground selection, 8 plants of IR64-Sub1*2 /IR88287-367-B-B and 10 plants of IR64-Sub1*2/ IR86918-B-305 have been confirmed for the target marker.

Stress Tolerant Rice for Poor Farmers of Africa and South Asia (STRASA)

Drought prone rain-fed rice areas

Observational yield trial (OYT)

The trial was conducted under rainfed upland condition consisting of 105 entries and five checks (Kalinga III, Vandana, Anjali, CRDhan 40 and Brown gora). The promising entries identified were CRR423-2-2-1-1, IR83929-B-B-132-3, IR87756-20-2-2-3 and CRR660-2.

Advance Yield Trial (80-100 Days)

Twenty five genotypes along with check varieties Anjali, Vandana and Brown gora (local check) were evaluated under two fertility conditions (low and high) following alpha-lattice design with three replications under rainfed uplands. The low fertility treatment received a fertilizer dose of NPK @ 40:30:20 and for high fertility treatment fertilizer dose is NPK @ 60:30:20. All other crop management factors were applied uniformly to both trials and manual weeding was done twice to control the weeds. During the season, the crop was not limited by moisture due to normal and uniform distribution of rainfall. Average grain yield across all cultivars was 27% lower in low fertility than in high fertility condition (1871 vs. 2573 kg ha^{-1}). Six advanced breeding lines were significantly better than traditional variety Brown gora in low fertility condition. The promising entries across the fertility levels based on yield and maturity duration are CRR617-B-3-3, CRR646-B-93-6-B-3, CRR428-237-1-3-1, BAU446-06 and IR78908-193-B-3-B.

Advanced Yield Trial (100-120 Days)

A set of varieties, advanced lines (75) of 100-120 days maturity duration group were evaluated under rainfed natural stress (RNFDS), rainy season managed drought stress (RSMDS) and also under control condition in three reps trial following alpha-lattice design. Drought intensity index (DII) was 0.41 for the rainfed trial and 0.54 for the managed stress trial, which indicates moderate level of stress. The breeding lines IR84899-B-182-CRA-12-1, IR83381-B-B-137-3, IR83387-B-B-40-1, CB-05-753 and CRR626-B-41-4-4-B yielded about 3.0 t ha^{-1} under stress and more than 6.0 t ha^{-1} under control condition. These lines combine yield potential at par with the widely grown irrigated varieties like MTU 1010, IR 64 and perform much better reproductive stage stress.

Drought OYT or collaborative nursery

To provide a rapid preliminary evaluation of drought tolerance a set of 225 promising breeding lines were evaluated under managed stress and control conditions. IR87751-20-3-2-1 (2.23 t ha^{-1}), CRR625-B-88-3-4 (2.0 t ha^{-1}), IR87753-11-2-1-2 (1.77 t ha^{-1}) and IR87761-48-1-3-2 (1.77 t ha^{-1}) performed well under very severe stress l conditions, and promoted for advanced yield testing. Out of 14 potential donors evaluated for reproductive stage drought tolerance, Kalia (1.95 t ha^{-1}) and Djogolon (1.99 t ha^{-1}) were promising.

Drought Breeding Network- Phase 2

Evaluation of Vandana NILs for drought

Seven *qDTY12.1* NILs in the Vandana background along with parents were evaluated under managed stress (rain-out shelter) and normal field condition in direct seeded uplands. In the trial conducted under rain-out shelter stress was imposed at 50 days after seeding and in normal field there was no stress because of uniform rainfall distribution. There was severe stress in the rainout shelter (-70 kpa at 15 cm and -30 kpa at 45 cm depth) as indicated by the tensiometer reading. Best NIL, IR84984-83-15-481-B out yielded the recurrent parent Vandana by 27% under stress condition and difference was non-significant under non-stress condition (Table 24).

Submergence and Flood prone areas

Evaluation of entries under Observational Yield Trial (OYT)

Eighty entries from different cooperating centers under Eastern India Rainfed Lowland Shuttle Breeding Network (EIRLSBN) were evaluated for grain yield and its associated components in an augmented block

Table 24. Performance of Vandana NILs (*$qDTY_{12.1}$*) with and without drought stress at CRRI Regional Station, Hazaribag 2011 wet season

Designation	Days to flower		Grain yield (t ha^{-1})		Harvest index	
	Stress	*Control*	*Stress*	*Control*	*Stress*	*Control*
Way Rarem	90	86	0.10	0.86	0.21	0.11
IR84984-83-15-110-B	62	60	1.46	2.09	0.26	0.34
IR84984-83-15-481-B	61	61	1.68	2.34	0.21	0.32
IR84984-83-15-862-B	62	61	1.58	2.14	0.23	0.31
IR90019:17-159-B	60	59	1.48	2.26	0.23	0.38
IR90019:17-15-B	59	59	1.49	1.87	0.24	0.33
IR90020:22-265-B	62	61	1.27	2.16	0.22	0.33
IR90020:22-283-B	60	59	1.58	2.41	0.24	0.39
Vandana	60	61	1.32	1.79	0.22	0.31
Mean	64	63	1.33	1.99	0.23	0.31
CD 0.05	2.3	2.3	0.49	0.92	0.1	0.1
CV (%)	2.21	2.27	22.73	28.07	13.34	21.82

design with five checks (Savitri, Sabita, Swarna, Swarna-Sub1 and Sarala) under transplanted conditions in semi-deep water situation. Among the different entries, NDR 9460 performed best with an average yield of 7.88 t ha^{-1} follow by CR2415-3-2-1-1-1-1 (7.14 t ha^{-1}) and CR2416-27-2-1-2-2-1 (5.81 t ha^{-1}) against the best check Savitri (4.38 t ha^{-1}).

Evaluation of OYT entries for submergence tolerance

Eighty entries from observational yield trial (OYT) were screened for submergence tolerance under controlled conditions during wet season, 2011. Among the 80 entries, fifteen *viz.,* OR2340-19, OR2331-11, OR2407-KK-5, NDR9467, NDR9460, NDR9479, LPR1103, LPR1110, RAUSB 98301351, RAU640-204-15, RAU1407-7-1-3-3, RAU1415-12-7-6-4-8-1, RAU1415-12-7-6-4-3-2, CR2754-18-6 and Swarna-Sub1 showed more than 90% survival after 12 days of submergence. Elongation ability of these lines was comparable to FR13A.

Development of breeding material

During 2011 wet season, 1073 single plant progenies (F_3-F_7) developed under EIRLSBN have been grown. A selection activity has been organized at CRRI, Cuttack during November 18-19, 2011, where ten breeders from different cooperating centers and also from IRRI, Philippines have participated. Breeders selected single plants from the segregating material according to their location specific requirement. About 1350 single plant selections were made by different breeders. The selected lines will be supplied to all the corresponding centers for location specific evaluation.

Evaluation of promising genotypes in on-farm PVS trials

The researcher managed PVS (mother) trials were conducted at two sites *viz.,* village Nuagaon of Puri district, and Kalakha of Cuttack district during 2011 wet season. A set of twelve genotypes selected for evaluation including one local check (Bhandi/Kalashree). The trials at both the locations were direct seeded during third and fourth week of June. The trial at Nuagaon, Puri district was completely submerged for 10 days during September 20-29. Among the 12 entries tested at Nuagaon, LPR09003 gave the highest grain yield (2.41 t ha^{-1}) followed by CR2008-111-4 (2.23 t ha^{-1}) and CR2336-1 (2.16 t ha^{-1}) against the local check Kalahree (2.15 t ha^{-1}). However, the trial at Kalakha, Cuttack was normal but it was affected by terminal drought. Among the 12 entries tested LPR 09003 gave the highest grain yield (6.43 t ha^{-1}) followed by Savitri-Sub1 (5.78 t ha^{-1}) and CR2336-1 (5.68 t ha^{-1}) against the high yielding check Savitri (4.57 t ha^{-1}) and local check Bhandi (4.59 t ha^{-1}).

Saline prone areas

Evaluation of promising salt-tolerant rice varieties/elite lines through participatory varietal selection (PVS)

During the dry season, a set of 10 promising salt-tolerant rice varieties/elite lines (three from CRRI, two from Vietnam and five from IRRI, Philippines) along with two tolerant checks (FL 478 and IR72046-B-R-3-3-3-1) and a farmer's variety (Patitapaban/Khandagiri) were evaluated in on-farm trials at Ersama, Astaranga and Mahakalpada blocks. The crop in Astarang and Mahakalpada was completely damaged under high salinity due to shortage of irrigation water. In Ersama also, in two replications, all the genotypes died due to high salinity (soil ECe 9.3-18.3 dS m^{-1} and field water EC 4.4-7.2 dS m^{-1}). In one replication, where salinity was relatively low (soil ECe 9.4-14.4 dS m^{-1} and field water EC 4.1-6.1 dS m^{-1}), IR72046-B-R-3-3-3-1 produced the highest grain yield of 2.22 t ha^{-1}, followed by CR2472-1-6-2 and IR71895-3R-60-3-1 (grain yield around 1.50 t ha^{-1}), as against 1.26 t ha^{-1} for Patitapaban and 1.14 t ha^{-1} for FL478. During the wet season, 12 elite lines along with two salt-tolerant checks (SR 26B and Luna Suvarna) and a farmer's variety (Bhaluki/Panikoili) were evaluated in Ersama and Astarang blocks. At Ersama with high salinity (soil ECe 7.3-12.6 and field water EC 1.4-6.6 dS m^{-1}), all the entries produced lower grain yield as compared to Astarang (Fig. 18). The grain yield of CR 2468-1-319-3-1 and CR2464-1-203-1-1 was comparable to SR26B but 32% higher than the farmer's variety Bhaluki. At Astarang with low-medium salinity (soil ECe 4.6-8.3 and field water EC 1.1-3.4 dS m^{-1}), CR2092-141-2 gave significantly higher (21.6%) grain yield than SR26B, while the remaining entries were comparable to SR26B.

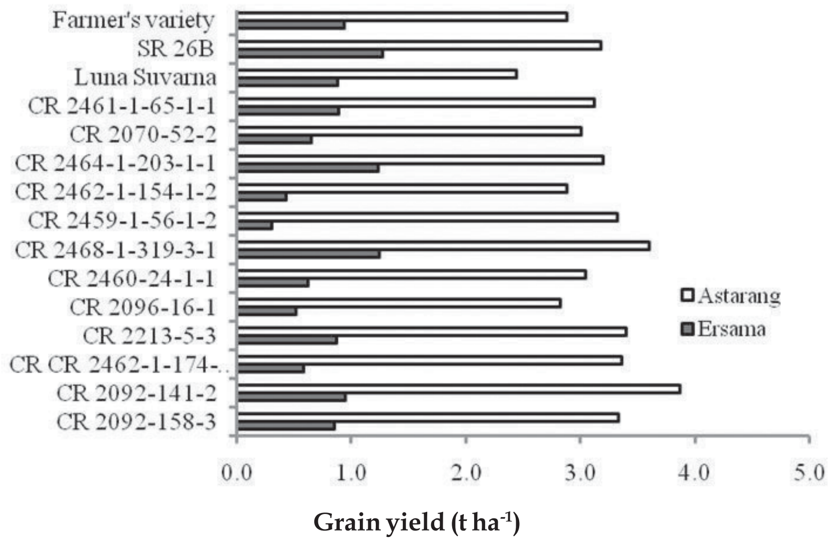


Fig. 18. Grain yield of promising salt-tolerant rice lines in farmer's fields at Ersama (Jagatsinghpur) and Astarang (Puri) blocks, Odisha during the wet season

Farmer-managed baby trials

In the dry season, performance of two CRRI lines (CR2472-1-6-2 and CR2485-7-3-45-1) and a Vietnam variety (OM6051) selected from the previous year's PVS trials was evaluated under farmer's management at 17 locations in Ersama, using IR72046-B-R-3-3-3-1 and a farmer's variety as checks. CR2472-1-6-2 recorded the highest mean grain yield of 3.70 t ha^{-1}, followed by OM6051 (mean grain yield 3.40 t ha^{-1}) and CR2485-7-3-45-1 (mean grain yield 3.10 t ha^{-1}). IR72046-B-R-3-3-3-1 recorded the mean grain yield of 3.60 t ha^{-1}, whereas the yield of farmer's variety was 3.10 t ha^{-1}. On an average, the test lines gave a yield advantage of about 20% over the farmers' variety. However, none of them was superior to IR72046-B-R-3-3-3-1. In the wet season, 18 baby trials were conducted in Ersama, where grain yield of SR26B, Luna Suvarna and CR2092-141-2 was 3.0-4.3, 2.9-4.7 and 3.5-5.0 t ha^{-1}, respectively, as against 2.1-3.4 t ha^{-1} for the farmer's variety Bhaluki. Improved varieties gave yield advantage of 0.8-1.5 t ha^{-1} over the farmer's variety.

Evaluation of promising breeding lines

Out of 10 most promising entries with 90-100% plant survival and grain yield of 702-818 g m^{2}, nine were from Annapurna/FL 478 cross and only one from Naveen/FL478 cross. The tolerant checks FL478 and IR72046-B-R-3-3-3-1 showed 51 and 35% survival and produced grain yield of 178 and 117 g m^{2}, respectively. Farmer's variety recorded 30% survival but did not produce any grain.

Rice-based cropping system

Effects of different spacing (1.5 x 1.5 m and 1.0 x 1.0 m) and irrigation schedules at 4, 6 and 8 day intervals on the yield of watermelon (cv. Sugar baby) were studied in farmer's field at Ersama under medium salinity. The EC of soil (saturation extract), groundwater and irrigation water was 4.9-10.0, 3.0-4.8 and 1.1-1.9 (beyond 30 days after sowing) dSm^{-1}, respectively. The yield was significantly higher under 1.5x1.5 m (6.6-8.5 t ha^{-1}) than under 1.0x1.0 m (6.1-7.7 t ha^{-1}) spacing, irrespective of the irrigation schedule. Further, the yield was the highest when the crop was irrigated at 4 days intervals and increasing the irrigation interval had a detrimental effect. Besides, sweet potato planting materials were supplied to 25 farmers in Ersama. A large variability in tuber yield was noticed depending on salinity levels and farmer's management and average yield was about 6.0 t ha^{-1}. Total 60 kg groundnut, 50 kg sunflower, 2 kg watermelon and 2 kg okra seeds were distributed to 150 farmers in Ersama, Astaranga and Mahakalpada blocks for popularization of non-rice crops.

Enabling Poor Rice Farmers to Improve Livelihoods and Overcome Poverty in South and Southeast Asia Through the Consortium for Unfavorable Rice Environments (CURE)

Identification of better sources of tolerance to stagnant flooding

Seventy four advanced breeding lines received from IRRI, Philippines along with two check varieties (Swarna-Sub1 and Varshadhan) have been evaluated in a cemented tank by maintaining the water level of 30-40 cm from 25 days after planting to dough stage during wet season, 2011. None of the entries performed better than the best check Varshadhan. However, among the different entries *viz.,* IR85085-SUB17-3-3-2, IR85078-39-3-1-3, IR85041-SUB18-3-2-1, IR85078-42-2-2-2, IR85078-14-1-2-1, IR49830-7-1-2-3, IR85083-SUB 1-1-2-2, IR85042-SUB 3-3-2-3, IR85086-SUB 20-2-1-2 were found promising and better than the Swarma-Sub1.

Seed and seedbed management for DS rice

The experiment was conducted with two cultivars namely, Swarna and Swarna-Sub1 under direct seeding condition with three different seed rates (60 kg ha^{1}, 90 kg ha^{1}and 120 kg ha^{1}). Complete submergence for 15 days after 25 days of sowing resulted 67, 79 and 87 per cent survival in Swarna-Sub1 under 60 kg ha^{1}, 90 kg ha^{1} and 120 kg ha^{1} seed rate, respectively. The survival % was significantly greater under higher seed rate. Survival percent was below 2 % in case of Swarna. From the present findings higher seed rate (120 kg ha^{1}) was found beneficial especially under submergence to realize greater yield in Swarna. However, in the submergence tolerant cultivar Swarna-Sub1 seed rate @ 60 kg ha^{1} found optimum either for control or submerged conditions. Farmers' can save up to 60 kg of seed materials in cultivating Swarna-Sub1 compared to Swarna with guarantee against damage of flooding.

Nursery management practices for TP Rice

The experiment was conducted with two rice cultivars *viz.,* Swarna and Swarna-Sub1. Seedlings were raised under two seed rates (*viz.,* 30 g m^{-2} and 50 g m^{-2}) with three fertilizers doses (N:P:KH" 20:0:20; 20:20:20 and 20:40:20 kg ha^{-1}). Twenty-five days old seedlings were transplanted and after 10 days of transplanting complete submergence under 80 cm depth of water was given for 15 days. Survival percentage varied from 1 to 12 % and 57 to 73 % in Swarna and Swarna-Sub1, respectively. In general, grain yield and yield attributing parameters *viz.,* straw yield and harvest index were non-significant under different methods of crop rising in seed bed. The present findings indicated that the crop rising with different rates of seed and phosphorous application at seed bed did not improve the chances of survival under submergence as well as excess grain yield under control condition.

Natural Resource Management and Input Use Efficiency for Improved Crop Production

Enhancement of the Resource Use Efficiency

Development of management strategies for sustainable crop and soil productivity in irrigated and favourable rainfed lowland ecosystems

A field experiment was conducted during 2011 with the objective to develop improve N management practice for enhancing N use efficiency under irrigated condition.Three improved methods of N management, *viz.,* LCC based, USG based and Sabant's Improved Rice Agro-technology (SIRA) were compared with recommended practice of N management (N:P:K: @120:60:60 kg ha^{-1}) along with controls (no N, no NPK) using the variety 'Swarna'. Nitrogen was applied @ 120 kg ha^{-1} in USG based and SIRA treatments, where as 90 kg ha^{-1} was applied in LCC based management, in these three treatments P and K was applied at recommended dose of 60 kg ha^{-1}. Among all the three methods of N management, no significant difference in grain yield was observed; however, NUE was highest in LCC based N management (41.1 kg $grain^{-1}$ kg N) followed by SIRA (29.58 kg grain kg^{-1} N).

In another experiment, feasibility of zero tillage vis-à-vis incorporation of residuary organic matter of preceding legume crop was studied under rainfed lowland rice system. The treatments included tillage practices (conventional tillage and zero tillage), residue incorporation (no residues and with residues) and two doses of NPK (100% RFD and 50% of RFD) which were replicated thrice in split-split plot design. Application of 50% NPK along with crop residues resulted higher yield over 100% NPK treated plots.

Simulation approach for optimization of nutrient use

A field experiment was conducted with medium-long duration rice varieties *viz.,* Pooja and Pratiksha in wet season during 2011 under varying nitrogen dose and application schedule. The result revealed that across the treatments, the mean leaf area index (LAI) of Pooja ranged from 2.8 at active tillering (AT) stage to 4.5 at flowering stage. Effect of treatment on LAI was non-significant. Across the treatments and variety the cumulative N uptake upto AT stage ranged from 15.1-22.7 kg ha^{-1} which is about 20-40% of total uptake; 53-70% of total uptake took place between AT and flowering stage. Among all the treatment combinations, yield, AE_N and RE_N ranged from 3.2-4.8 t ha^{-1}, 6.7-16.7 kg kg^{-1}, and 30.5-40.7%, respectively (Table 25). Reduction of basal dose of N from 50 to 33% enhanced both N use efficiency and yield.

Table 25. Effect of N application strategy on Yield, AE_N and RE_N

	Yield (t ha^{-1})			AE_N (kg kg^{-1})			RE_N (%)		
Treatments	Pooja	Pratiksha	Mean	Pooja	Pratiksha	Mean	Pooja	Pratiksha	Mean
T1	3.3	3.2	3.2	-	-		-	-	
T2	3.9	4.0	4.0	6.7	9.0	7.8	32.5	32.3	32.4
T3	4.3	4.2	4.3	11.1	11.2	11.2	40.7	38.4	39.6
T4	4.8	4.6	4.7	16.7	14.6	15.6	32.6	30.5	31.6
Mean	4.0	4.0	4.0	11.5	11.6	11.5	35.3	33.7	34.5
C.D.(5%)Variety (V)	0.24			3.5			5.6		
Treatment(T)	0.45			5.3			7.4		
VXT	0.7			7.5			14.6		

T1: N 0; T2: N 90 kg ha^{-1}(50%. 25% and 25% at transplanting, maximum tillering (MT) and panicle initiation (PI); T3: N 90 kg ha^{-1}(33%, 33% and 33% at 15 days after transplanting, MT and PI); T4: 120 kg ha^{-1}(50%, 25% and 25% at transplanting, MT and PI)

Standardization of management practices for System of Rice Intensification

A field experiment was conducted during the dry season of 2010-11 with the objective to estimate the nutrient requirement through organic and inorganic sources for realizing higher yield under System of Rice Intensification (SRI). Twelve days old seedling of Naveen rice variety was transplanted with a spacing of 25 cm x 25 cm under different treatments i.e., SRI with organic source of nutrient (FYM @ 5t ha^{-1}), SRI with 50% RDF + 50% organic source, SRI with chemical fertilizer (RDF: 80: 40: 40 NPK kg ha^{-1}), SRI with chemical fertilizer (120 % of RDF), 25% of RDF + 75% organic source, T6- SRI with 75% of RDF + 25% organic source, Conventional method (15 x 15 cm with recommended management practice). Results revealed that application of chemical fertilizer @ 120% of RDF produced significantly higher grain yield (6.18 t ha^{-1}) which was 38.3% and 26.1% more than treatment with nutrients supplied through 100% organic sources and traditional method of cultivation, respectively. This was evident by significantly higher panicle weight (3.32 g), grains per panicle (146.4), leaf area index (5.02) and harvest index (0.49).

In another experiment, conducted during the dry season of 2010-11, different weed management options were evaluated under SRI method of rice cultivation. Twelve days old seedling of rice variety Naveen was transplanted with a spacing of 25 cm x 25 cm under different treatments *i.e.,* Azimsulfuron 35 g *a.i.* ha^{-1} (Low dose high efficacy), weed free check (weeding at 20, 40, 60 DAT)/(15, 30, 45, 60 DAT), two hand weedings (15 and 30 DAT), weeding by cono-weeder,weeding by finger-weeder and no weeding. Results showed that among the different weed control practices, weed free check produced maximum grain yield of 5.21 t ha^{-1}. The herbicide Azimsulfuron 35 g *a.i*. ha^{-1} (Low dose high efficacy) was found to be effective for controlling the pre dominant weeds *viz., Cyperus difformis, Sphenoclea zeylanica, Fimbristylis miliacea, Marsilea quadrifolia, Ludwigia parviflora* etc. and produced comparable yield with cono weeder (twice at 12 and 25 DAT) and hand weeding (twice at 15 and 30 DAT). Yield reduction due to weed competition in weedy plots was 48%.

Standardization of management practices for organic rice production

In a field study, the efficacy of different nutrient management options involving combinations of FYM (at 5 t ha^{-1}, dry weight basis), *Sesbania* (5 t ha^{-1}, fresh weight basis) and rice straw (5 t ha^{-1}) was evaluated for organic rice production. The combination of rice straw and *Sesbania* produced highest yield. In another study, efficacy of botanical *i.e.* neem oil @ 5ml lit^{-1} of water with 2 ml labolene against major insect pests in two promising quality rice variety, 'Katrani' and 'Chinikamini' was evaluated against control (No protection). The experiment was laid out in a split-plot design with 4 replications. The neem oil application resulted in 8-10% higher grain yield and higher yield was observed in 'Chinikamini' (4.20 t ha^{-1}) compared with 'Katrani' (3.34 t ha^{-1}).

Evaluation of new herbicide molecule on wet direct seeded rice

A field trial was conducted to evaluate the efficacy of Penoxsulam + Cyhalofop-butyl at two different doses along with Bispyribac sodium and was compared with recommended practice of hand weeding twice at 20 and 40 days after sowing and weedy check. The rice *cv.* 'Moti' was established by sowing under puddled condition in four replications. Significantly higher yield (5.08 t ha^{-1}) was recorded in recommended practice of hand weeding twice. Among the tested herbicide, Penoxsulam + Cyhalofop-butyl at 135 g ha^{-1} controlled the weeds effectively but recorded comparable yield with Penoxsulam + Cyhalofop-butyl at 120 g ha^{-1}. The yield reduction due to weed competition in weedy plot was 43%.

Rhizosphere effect on soil chemical environment and nutrient use efficiency for sustainable rice production

Exudation of organic acids by the roots of two rice cultivars grown in three different soils with different P-status, and their impact on the rhizospheric P-dynamics and P-uptake by the rice plants was investigated. Root exudates from all the rice cultivars were significantly greater at 21 days after transplanting than at maximum tillering, panicle initiation, flowering and grain filling stages. Malic acid was the most predominant organic acid present in the rice root exudates (9.1 to 103.2 µmol $plant^{-1}d^{-1}$), followed by tartaric, citric and acetic acids. Greater exudation of organic acids from rice grown in P-deficient soil by all the rice cultivars suggested response of rice plant to P-stress. The differential response on individual genotypes to nutrient deficiency based on the type and quantity of organic acids exuded suggests a genotype and nutrient-spe-

Table 26. Rhizosphere P concentrations (mg kg^{-1}) of the rice cultivars planted to the soils of different P status grown under flooded conditions

Rice Cultivars	NaHCO$_3$-P* 21 DAT	NaHCO$_3$-P* Panicle initiation	NaHCO$_3$-P* Flowering	NaOH-P* 21 DAT	NaOH-P* Panicle initiation	NaOH-P* Flowering
Khuntuni soil (P-deficient)						
IR28	7.4 ab	5.7 c	5.3 b	25.5 b	19.0 b	17.0 b
IR36	7.8 a	7.8 a	6.6 b	28.0 ab	23.0 a	20.6 a
Dular	7.0 b	6.6 b	6.2 a	30.2 a	23.6 a	22.5 a
Ranital soil (P-medium)						
IR28	13.9 a	12.1 b	12.3 a	30.6 b	28.6 a	24.5 a
IR36	14.2 a	13.3 a	11.7 a	34.3 a	26.8 a	23.0 a
Dular	13.8 a	12.5 b	11.7 a	32.3 ab	23.8 b	22.8 a
CRRI soil (P-sufficient)						
IR28	28.6 b	25.6 a	23.6 a	71.7 a	54.1 b	49.7 a
IR36	30.0 a	25.5 a	23.6 a	66.2 b	57.0 a	50.3 a
Dular	26.7 c	24.5 b	22.3 b	61.6 c	52.4 b	45.7 b
CV (%)	2.6			4.8		
Comparison	S.E.D.	LSD (P=0.05)		S.E.D.	LSD (P=0.05)	
2-G×S×V	0.3	0.7		1.4	2.8	

* Mean of four replicate observations

In a column under each soil type, mean followed by the common letter are not significantly different (*P*< 0.05) by Duncan's Multiple Range Test (DMRT). DAT: Days after transplantation; G: Growth stage; S: Soil type; V: Variety

cific regulation of biosynthesis and release of root exudates. Results showed that rice cultivars releasing tartaric, malic, citric and acetic acids could extract P from strongly absorbed soil P fraction, thereby increasing native soil P utilization efficiency. In all the three soil, Olsens P were more (ranged from 7.0 to 30.0 mg kg^{-1}) at 21 DAT when the acid secretion in the root exudates were maximum (Table 26).

Nitrogen-Variety trials

In order to find out the production potential of selected AVT-2 rice cultures and their response to varying levels of nitrogen *viz.,* 50, 100 and 150 percent of recommended dose of N, two trials were conducted in different rice ecosystems during wet season 2011. In AVT-2 (Early) transplanted trial, two early cultures IET 21401 and IET 21637 were tested against standard checks Sahbagidhan and Tulasi along with local check Vandana. The culture IET 21367 gave highest grain yield of 4.24 t ha^{-1} and was comparable to other tested cultures including checks. These tested cultures responded significantly up to 60 kg N ha^{-1}.

In AVT-2 (ME) aerobic, the tested culture IET 21680 produced significantly higher yield (4.52 t ha^{-1}) over the checks Rasi (4.02 t ha^{-1}) and IR-64 (3.34 t ha^{-1}) and responded significantly up to 80 kg N ha^{-1}.

Development of Production Technologies for Aerobic Rice

Development of agro-management practices for enhancing crop and water productivity in aerobic rice

A field experiment was conducted with three irrigation water (IW) depths (25, 50 and 75 mm) in main plots and three IW/CPE ratios (0.8, 1.0 and 1.2) in subplots and replicated thrice to optimize the irrigation schedule in aerobic rice *cv.* Apo. Grain yield of aerobic rice reduced significantly with increase depth of irrigation from 25 to 75 mm but increased with increase in IW/CPE ratio from 0.8 to 1.2 (Fig. 19). However, irrigating the crop with higher IW depth and IW/CPE ratio recorded significantly higher grain yield over lower IW depths and IW/CPE ratio. Highest grain yield of 3.34 t ha^{-1} with irrigation water productivity of 0.61 kg grain m^{-3} of water was recorded when aerobic rice was irrigated with 25 mm of water at IW/CPE ratio of 1.2. The number of effective tillers decreased by 21.2% with increase in irrigation water depth from 25 to 75 mm but a

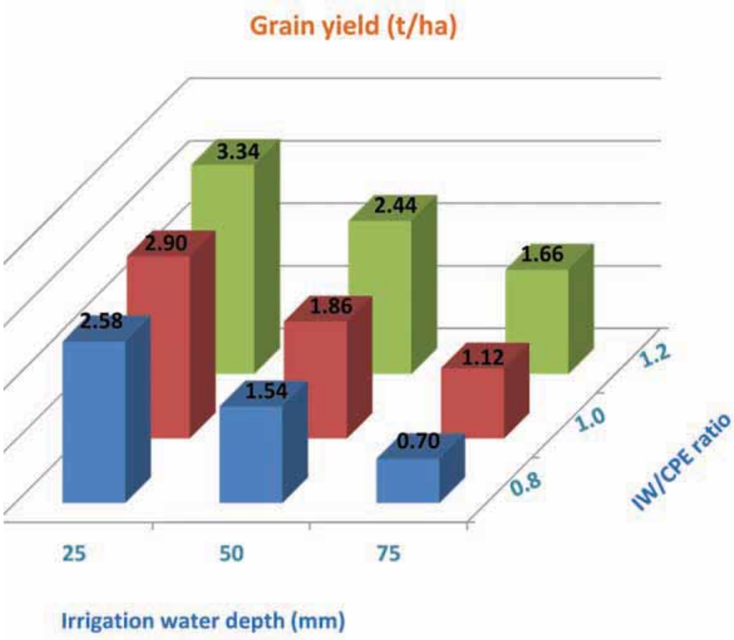


Fig. 19. Performance of aerobic rice (Apo) under varied moisture regimes

reverse trend was observed with IW/CPE ratio from 0.8 to 1.2.The sterility percentage of spikelets almost doubled with increase in IW depth from 25 to 75 mm but decreased with increase in IW/CPE ratio.

Transformation and availability of N in aerobic rice soils under different Nitrogen management strategies

A field trial was conducted in dry season during 2011 with aerobic rice variety Apo under different N management practices *viz.,* control, LCC based N application (30 kg Nha^{-1} at 20 days after sowing (DAS), 45 kg N ha^{-1} between 30-50 DAS as and when LCC reading < 4.0, 15 kg Nha^{-1} between 50-80 DAS as and when LCC reading < 4.0), SPAD meter based N application 30 kg N ha^{-1} at 20 days after sowing (DAS), 45 kg N ha^{-1} between 30-50 DAS as and when SPAD reading < 35.0, 15 kg N ha^{-1} between 50-80 DAS as and when SPAD reading < 35.0), Recommended dose (60 kg N ha^{-1} at sowing, 30 kg N ha^{-1} at maximum tillering, 30 kg N ha^{-1} at panicle initiation). Results revealed that use of LCC and SPAD could ensure equal level of yield as that of recommended dose with 25 % less fertilizer application. Both LCC based and SPAD meter based recommendation resulted higher agronomic N use efficiency (17-18%) and N recovery efficiency (26-30 %) over the recommended dose (Fig. 20).

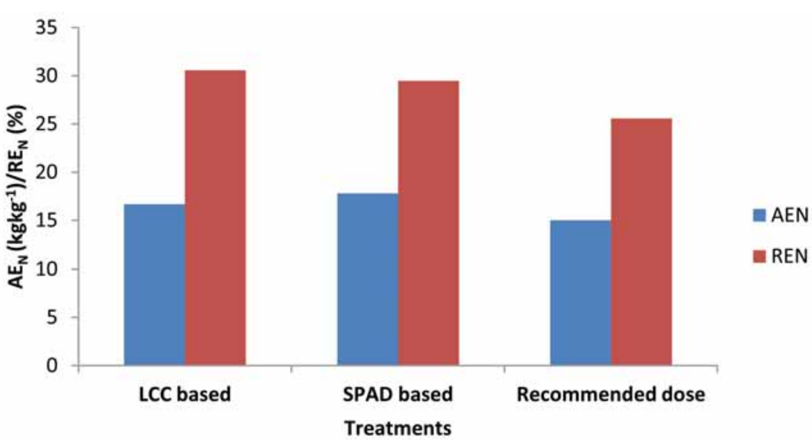


Fig. 20. Agronomic N use efficiency (AE_N) and N recovery efficiency (RE_N) under different N application strategy in aerobic condition

Transformation and availability of Zn under aerobic rice system

A laboratory incubation experiment was carried out to study the transformation of applied zinc in paddy soil under aerobic and submergence moisture regimes with three sources of Zn applications *viz.,* control (no Zn applied), Zinc Sulphate (5 kg Zn ha^{-1}) and Zinc Oxide (5 kg Zn ha^{-1}). The study on transformation of added zinc indicated that all the zinc fractions except crystalline sesquioxide and residual zinc fractions showed an increased trend with zinc application at aerobic and submergence moisture regimes during the incubation period. The days of incubation had significant effect on different zinc fractions under aerobic and submergence moisture regime at 15, 30, 60 and 120 days after incubation. With increasing incubation period, water soluble plus exchangeable zinc, organically bound zinc, crystalline sesquioxide bound zinc and available zinc fraction decreased in both the moisture regimes. The magnitude of decrease was more in submergence moisture regimes. Manganese oxide bound zinc, amorphous sesquioxide zinc and residual zinc showed an increasing trend with increasing incubation period. The water soluble plus exchangeable zinc, organically bound zinc and crystalline sesquioxide bound zinc were higher under aerobic moisture regimes while the submergence helped to increase the manganese oxide bound zinc, amorphous sesquioxide bound zinc and residual zinc. The field study with same treatments revealed that 7% reduction in yield was observed under aerobic than the submergence condition under no Zn applied conditions. However, under Zn fertilized condition no significant yield difference was observed. Averaged over the sources of Zn application, the yield penalty of 8% was observed under aerobic condition compared to flooded condition.

Microbial Resource Management and Diversity Analysis

Microbial diversity of tropical soils

Characterization of PGPR microbes

The potent ACCdeaminase producing bacteria *viz.*,*Bacillus* (n=2), *Microbacterium*, *Arthrobacter*, *Microbacterium* and *Paenibacillus* spp. induced drought tolerance in rice and increased seed germination by about 10% under anaerobic condition. Cellular protein and RAPD analysis profiles of 20 *Bacillus* (B) and 23 *Pseudomonas* (Ps) strains produced 22-41 and 30-61 protein fractions, and 2-4 and 2-6 amplicons, respectively which ascertained molecular diversity of the PGPR microbes (n=680). Further more, the *Bacillus* spp. were more effective than the *Pseudomonas* spp. Among the PGPRs, 40 were osmotolerant (7-18% NaCl), 110 were HCN producer and 87 had biocontrol properties. Only 2 Bt isolates fixed nitrogen and 3 produced IAA, whereas, 14 potent Bt strains solubilized P and cellulose, and produced NH_3.

Microbial activity under different rice based cropping system

In soil, microbial diversity in terms of fluorescein diacetate hydrolase (FDH), dehydrogenase (DH), β-glucosidase (GS), and urease, alkaline (ALP) and acid phosphatases (ACP) activities was more in rice-sesamum-rice rotation compared to rice-groundnut-rice, green gram-rice-maize and cowpea-rice-maize cropping systems. However, DH (125.06 µg g^{-1} h^{-1}), GS (102.12 µg g^{-1} h^{-1}) and FDH (8.41 µg g^{-1} h^{-1}) activities were maximum in rice-groundnut and minimum in rice-cowpea crop; Urease (71.12 mg g^{-1} h^{-1}), ACP (67.53 µg g^{-1} h^{-1}) and ALP (98.22 µg g^{-1} h^{-1}) were maximum in rice-sesamum and minimum in rice-greengram cropping systems.

In another study, effect of different treatments viz. FYM (5 t ha^{-1}) with *Sesbania aculeata*, urea (60 kg N ha^{-1}), rice straw (5 t ha^{-1}) with urea (60 kg N ha^{-1}) (RSU), FYM (5 t ha^{-1}) with *Sesbania aculeata* (FYMS), FYM with *Azolla* (5 t ha^{-1}) (FYMA), rice straw with *Sesbania aculeata* (RSS) on soil enzymatic activities was evaluated. The treatment RSU resulted higher DH (135.86 µg g^{-1} h^{-1} at panicle initiation (PI) stage), GS (135.86 µg g^{-1} h^{-1} at PI) and urease (84.01 mg g^{-1} h^{-1}at maximum tillering (MT) stage) activities followed by FYM Sand only urea; while FDH (11.70 µg g^{-1} h^{-1} at MT), ALP (108.72 µg g^{-1} h^{-1} at PI) and ACP (87.35 µg g^{-1} h^{-1} at PI) were more in FYMS treatment.

Characterization of pesticide degrading bacteria

Nine chlorpyrifos degrading bacteria were identified as *Achromobacter xylosoxidans* sub sp. *xylosoxidans, Xanthobacter flavus, Stenotrophomonas maltophilia, Inquilinus limosus, Bacillus sp.* and *Sphingobium fuliginis*. After Phenotyping and phylotyping *Methylobacterium* sp was identified as α, β, γ and δ-HCH degrader, which degraded β-HCH from onset of growth and optimum at stationary phase. β-HCH degradation was a novel record.

Diversity analysis of entomopathogenic microorganisms in rice ecosystem

Seventeen *B. thuringiensis* and 59 *Pseudomonas* strains isolated from different rice ecology produced siderophore, HCN and salicylic acid, effective against insect pests and plant pathogens. The Bt (n=12) isolates tolerated 8-18% osmotic stress. The osmolytes like amino acids rendered tolerance to 3 and proline to 11 isolates but the osmozymes SOD and catalase rendered stress tolerance to all Bt isolates. The *ect*C and *ect*ABC osmotolerant genes were identified in the isolates.

Out of 49 Bt strains isolated, 4 strains had the LC_{50} values as $3.16x10^6$ - $1.25x10^9$ spore-crystals ml^{-1} against LF in the field grown with rice *cv.* Sarala, Lalat, Naveen and Swarna. The commercial strains *i.e.* TB70 of bactospeine and TB73 of biolep were less effective than the indigenous strains. Four potent native entomopathogenic Bt against LF were formulated for mass field application.

Five *cry* genesamplified by CJI1/CJI2, CJ4/CJ5, V(-)/V(+), gral-nem(d)/gral-nem(r), gral-cyt(d)/gral-cyt(r) amplimers, effective against the lepidopteran and coleopteran pests of rice were identified from 67 out of 321 Bt isolates.

Improving Nutrient Use Efficiency of Upland Rice through Native Beneficial Soil Microorganisms

Integration of Arbuscular Mycorrhiza (AM)-based bio-fertilizer with rice based cropping systems

The AM-supportive crop management components *viz.*, (i) crop rotations (ii) application of AM inoculum and (iii) P sources (DAP and Purulia rock phosphate) were integrated for possible additive effects on enhanced AMF activity mediated efficient P nutrition of upland rice. In the first rotation (2010 and 2011), AMF inoculum under partially slow released P condition (DAP 50%+PRP 50%) significantly enhanced AMF population in soil, mycorrhizal colonization in rice, P uptake and grain yield in all rotations with highest in maize-horse gram (1^{st} yr)/rice (2^{nd} yr) rotation.

Effects of rainfall pattern on efficiency of native AMF

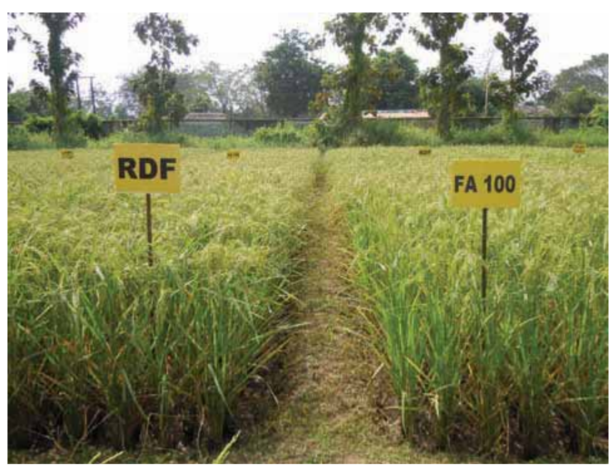
Analysis of long term data (6 alternate years between 1999 to 2009) revealed that mycorrhizal advantage to rice under AM-supportive crop rotation (maize-horse gram/rice), in terms of P acquisition efficiency (PAE) was negatively correlated with rainfall amount, indicating higher mycorrhizal efficacy under moisture stress. The observation emphasized potential of exploiting native AM-fungi as climate resilient component technology in rainfed ecology under present climate change scenario leading to reducing moisture availability.

Confidence building and facilitation of large scale use of fly ash as an ameliorant and nutrient source for enhancing rice productivity and soil health

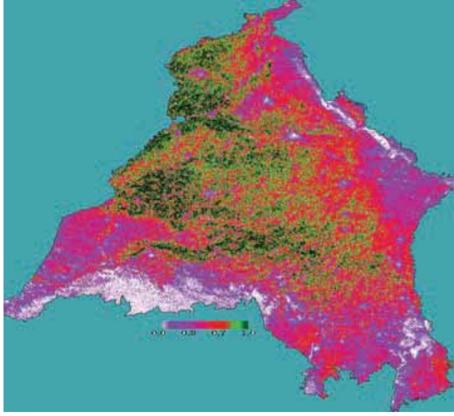
Fly ash is a mineral residue resulting from combustion of coal at high temperature that enters the flue gas streams. It is particulate in nature, contains most of the plant nutrients except nitrogen and having higher pH. Field experiments were conducted to evaluate the efficacy of bulk application of fly ash (@ 50 and 100 t ha^{-1}) either alone or in combination with FYM and inorganic fertilizers, as soil ameliorant and nutrient source for rice based cropping system under irrigated (transplanted and wet direct seeded) and rainfed (dry direct seeded) conditions from 2010-11 and the residual effects on rice were studied during 2011-12. The treatments comprised of different combinations of fly ash, FYM and chemical fertilizers *viz*., FP (farmer's practice -40:20:0 kg N:P:K ha^{-1}); RDF (recommended dose of fertilizer-80:40:40 kg N:P:K ha^{-1}); Lime + RDF; FA_{50} (Fly ash @ 50 t ha^{-1}); FA_{100}(Fly ash @ 100 t ha^{-1}); FA_{50} + $RDF_{75\%}$ + $FYM_{25\%}$(25% of RDF through Farm Yard Manure on N basis); FA_{100} + $RDF_{75\%}$ + $FYM_{25\%}$; FA_{50} + FYM @ 12.5 t ha^{-1} and FA_{100} + FYM @ 12.5 t ha^{-1}. As per the treatment combinations, fly ash and lime were applied and incorporated manually 20 days before transplanting/ sowing of rice with the help of a spade into the top 15 cm depth of soil during wet season 2010 as one time application.

The result s revealed that application of fly ash alone @ 50 t ha^{-1} and 100 t ha^{-1} resulted decrease in yield over farmer's practice and significantly lower yield than the 100% recommended dose of fertilizers (RDF) under all three situations. However, application of fly ash @ 50 t ha^{-1} along with 75% RDF and 25% through FYM on N basis has recorded on par yield with that of Lime + 100% RDF under transplanted as well as direct seeded conditions.

The field demonstrations were conducted in 12 farmers' fields across three districts of Odisha broadly covering the major soil groups of the state also revealed that application of fly ash @ 50 t ha^{-1} along with 100% RDF increased the rice yield by 12.9 to 35.4% over the farmer's practices across the locations, with an average of 24.02%.



Wet direct seeded rice crop at maturity stage in different fly ash treated plots



Enhancing and Sustaining the Productivity of Rice Based Farming Systems

Development of Integrated Nutrient Management Technolo-gies for System Productivity and Quality

Zero, reduced and optimum tillage for improved soil physical condition and producti-vity of rice based cropping system

A field experiment was conducted during wet season, 2011 to assess the effect of tillage practices under different water regimes and tillage depth on soil physical properties. The treatment consisted of dry (direct seeded) and wet tillage (transplanted) in main plots; shallow (tillage depth up to 10 cm) and deep (tillage depth up to 18-22 cm) as sub plot treatment and FYM and no FYM in sub-sub plot treatments in a split split plot design with rice *cv.* Tapaswini.

Wet tillage recorded significant yield advantage of 0.6 t ha^{-1}over the dry direct seeded practice. The yield was also significantly higher (0.14 t ha^{-1}) in FYM treated plots over no FYM. However, tillage depth had no significant effect on yield. During dry season, greengram *cv.* PDM 54 produced 48% higher yield in the plots where dry direct sown rice was grown in the preceding season.

In another experiment, the effect of zero tillage with straw mulch was evaluated for establishment of dry season crops in rainfed lowland. The treatment consisted of three crops in main plots with three mulch rates (rice straw at 0, 5 and 10 t ha^{-1}) in sub plots. Mulching at 5 and 10 t ha^{-1} significantly increased the yield of greengram, groundnut and cowpea as compared to no mulch treatment. It was also found that rice straw mulch facilitated pod development of ground nut under zero tillage condition and resulted higher seed yield.

Optimization of organic and inorganic sources of nutrients for enhancing productivity and GHGs emission

Effects of inorganic and organic nitrogen (N) management on the emission of three major greenhouse gases (GHGs) *viz.*, methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O), carbon equivalent emission (CEE) and carbon efficiency ratio (CER) were investigated in a flooded rice field. The treatments included an unfertilized control, inorganic nitrogen fertilizer, rice straw + inorganic nitrogen fertilizer and rice straw + green manure. Maximum global warming potential (GWP) (10188 kg CO_2 equivalent ha^{-1}) and CER was recorded in the field applied with rice straw and green manure. The combined application of rice straw and inorganic fertilizer was most effective in higher grain yield and reduction of GHG emission (Table 27).

Table 27. Greenhouse gas emissions on seasonal basis and related parameters after the application of inorganic fertilizers and organic manure to flooded soil planted with rice (*cv.* Gayatri)

Treatment	CH_4 emission (kg ha^{-1})	CO_2-C emission (kg ha^{-1})	N_2O-N emission (kg ha^{-1})	GWP of rice system (kg $CO_2 ha^{-1}$)	Carbon equivalent emission (CEE) (kg C ha^{-1})	Yield (Mg ha^{-1})	Carbon efficiency ratio (CER)
Control	69.7a	1100.3a	0.23a	5862a	1599a	3.53a	0.95b
Urea	92.6b	1447.7b	1.00d	8084b	2205b	5.13b	1.00b
Rice straw + Urea	115.4c	1680.6c	0.84c	9418c	2568c	5.57b	0.93b
Rice straw + Green manure	122.7c	1858.5d	0.72b	10188d	2779d	5.30b	0.82a

[Note: In each column the mean values followed by common letters are not significantly ($p<0.05$) different between treatments by Duncan's multiple range test (DMRT)].

Long term–assessment of soil quality and resilience in rice-rice system

The long term effect of nutrient management practices on soil physical, chemical and biological properties was studied for proper interpretation of the yield changes and development of soil quality indices. Keeping this, in view after 41 years of rice-rice system, the detailed soil analysis was conducted to find out the effects of nutrient management practices on soil properties in a subtropical rice–rice system.To determine a soil quality index, sustainable yield index was taken as the goal. The minimum data set (MDS) of indicators that best represent soil function were selected and scoring of MDS indicators based on their performance of soil function was done. Finally indicator scores were integrated into a comparative index of soil quality. The value of the dimensionless soil quality index varied from 1.46 in control plot to 3.50 in NPK +FYM plot. Six soil quality indicators such as DTPA Zn, SOC, available N, CDI, DHA and available K contributed 21.4, 20.4, 18.0, 19.5, 16.6 and 4.1% to the soil quality index estimation, respectively under NPK +FYM treated plot (Fig. 21). By considering NPK+FYM as an ideal treatment, the relative soil quality explained that if there were exclusion of FYM, the soil quality would decline by 31.4%; similarly if no manure and fertilizers were applied, the soil quality would decline by 61.4%. Similarly when compared with NPK treatment, soil quality declined by 47.3, 35.8, 5.7 and 14.0% in control, N, NP and NK treatments. This indicated that N and FYM are the important interventions which maintain and improve the soil quality.

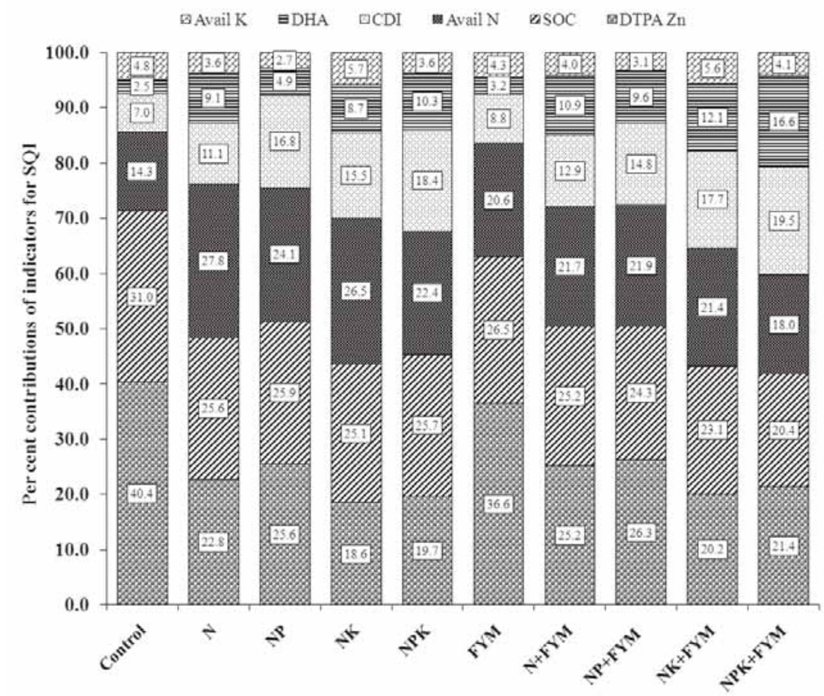


Fig. 21. Relative contribution of soil quality indicators to the soil quality index of long term rice–rice soil under different nutrient management systems

Management of Problem Soils

Management of coastal saline soils

Soil samples were collected during post monsoon period from Ersama block, Jagatsingpur district of Odisha during 2011-12 in a grid size of 4 km x 4 km. The soil pH, EC (1:2), available N, Available P, available K and micronutrients were determined. Crop cutting experiments were conducted in wet season at some places proximity to the grid point to determine the yield of rice under N applied and no N applied plots, the grid points where crop cutting was not possible secondary data from the farmers were collected. Taking the soil properties, salinity status and historical data *i.e.* waterlogged and non waterlogged conditions; the agronomic N use efficiency was assigned for each grid points. The site specific fertilizer N (SSFN) required was calculated using the formulae SSFN = $(Y_{Target} - Y_0N)/AEN$, Y_{Target} = Yield target, Y_0N = N-limited yield, AEN = Expected plot grain yield increase per unit of fertilizer N applied. The data of soil EC and site specific fertilizer N required were subjected to analysis of classical statistics and the data fitted well to normal distribution. The EC value ranged from 0.25 dSm^{-1} to 6.04 dSm^{-1} with average value of 1.43 dSm^{-1}. The SSFN ranged from 66-100 kg ha^{-1} with an average of 80 kg ha^{-1}. Using appropriate semivariograms, the EC (1:2) and SSFN value were interpolated by kriging with the given grid size; the map generated (Fig. 22) provided the regions and loops of EC and with distinct values and explains the quality and heterogeneity in the region.

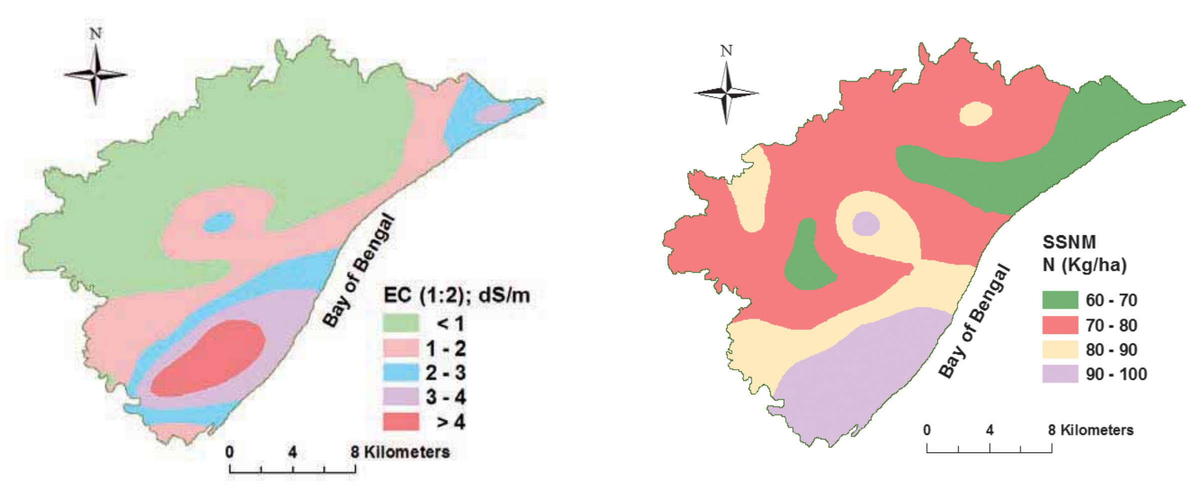


Fig. 22. Post monsoon EC (1:2) and site specific fertilizer recommendation (SSFN) map of Ersama Block of Jagatsinghpur District, Odisha

Mapping of saline rice growing areas of east coast of India using RS and GIS

To assess the salinity in Balasore and Bhadrak districts of Odisha, soil sampling was done in five blocks, *viz.*, Bhograi, Baliapal, Balasore, Remuna and Bahanaga of Balasore district and two blocks Basudebpur and Chandbali of Bhadrak district during pre-monsoon period of 2011. Soil samples were analyzed for soil electrical conductivity (EC_e) and pH. Soil EC_e varied from 0.80 to 17.9 dS m^{-1}. The data was subjected to geo-statistical analysis, using appropriate spherical variogram, pre-monsoon salinity map of the seven blocks was generated in the GIS platform using ArcGIS 10. Landsat satellite data synchronizing with the soil sampling was procured from USGS data centre. Satellite data was pre processed before its final utilization. Georectification and radiometric corrections of satellite data was performed. DN values were converted to top of atmospheric reflectance by standard procedures specified for landsat bands. Maps for salinity were generated based on regression fitting of these indices and soil EC_e values (Fig. 23).

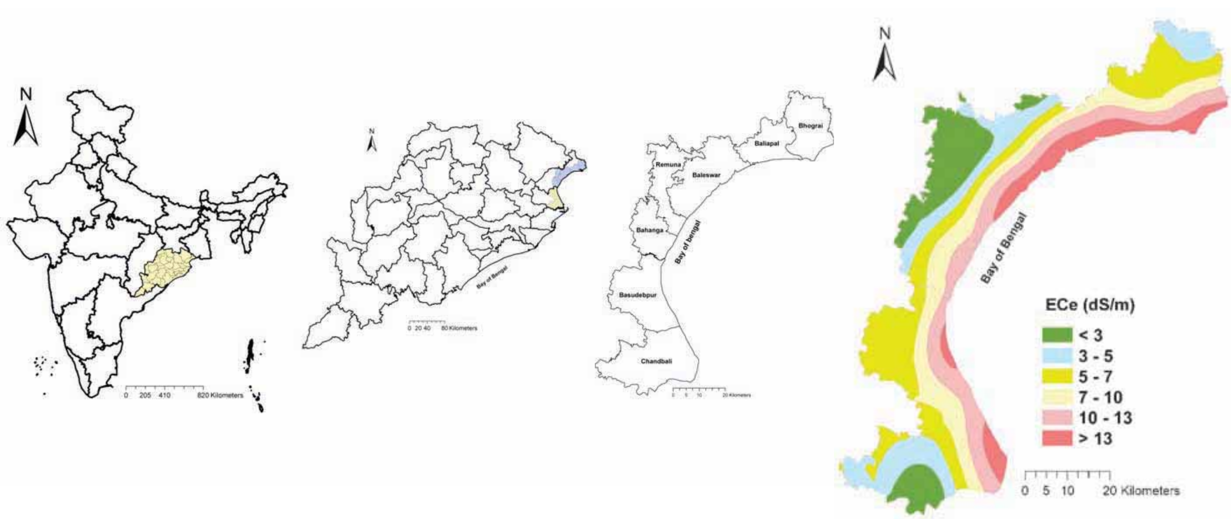


Fig. 23. (a) Coastal Blocks of Balasore and Bhadrak with highlighted Blocks used for this study. (b) Pre-monsoon salinity map generated using ArsGIS.

Management of Fe toxicity and Zn deficiency in rice

A field experiment was conducted at OUAT farm, Bhubaneswar with four cultivars (two each susceptible and tolerant) with different soil management options in Fe toxic soil to study the tolerance mechanism. It was found that the tolerant cultivar, Lalat produced the highest grain yield followed by Naveen. The lowest yield was obtained with Pusa 44 across the soil management treatments. However, susceptible cultivars responded better under different Fe toxicity management practices as compared to tolerant cultivars. The tolerant cultivars retained much of the Fe in the roots and translocated less to the shoots as compared to susceptible cultivars.

Another experiment was conducted at OUAT farm, Ranital to quantify the relative effects of different physiological mechanisms of Zn efficiency in four rice genotypes *viz.*, tolerant (IR36 and Tapaswini) and susceptible (IR64 and Pusa 44). The level of Zn application were 0, 2.5, 5 and 10 kg Zn ha^{-1}. The grain yield was significantly affected by zinc application and varied from 3.25 to 3.82 t ha^{-1}across different doses of Zn (Table 28). Maximum grain yield (3.82 t ha^{-1}) was recorded in IR-36. The results indicated that application of zinc enhanced the yield of all the four cultivars, which might be due to root proliferation and higher uptake.

Table 28. Grain yield (t ha^{-1}) of rice genotypes under different doses of Zn

	Level of Zn, kg ha^{-1}				
Genotypes	0	2.5	5	10	Mean
IR36	3.51	3.71	3.92	4.13	3.82
Tapaswini	3.42	3.63	3.76	3.91	3.68
Pusa 44	3.11	3.32	3.55	3.67	3.41
IR64	2.83	3.17	3.45	3.53	3.25
Mean	3.22	3.46	3.67	3.81	

LSD (P=0.05); Genotypes=0.17; Zn=0.21; GxZn=NS

Development of Cropping Systems for Different Rice Ecologies

Development and evaluation of rice based cropping systems for soil sustainability and productivity

A field experiment was carried out in split plot design with three rice-based cropping systems (RBCSs) *viz.*, Rice–Potato–Sesame, Rice–Maize–Cowpea and Rice–Groundnut–Green gram in main plots and three nutrient management options *viz.*, Recommended dose of fertiliser (RDF), INM (25% N based substitution with FYM) and RDF + Crop residue incorporation of previous crop) in sub plots to improve productivity and different nutrient management options under RBCS.

Experimental results revealed that grain yield of rice did not differ significantly with respect to cropping system in wet season. However, the highest rice equivalent yield (REY) was achieved with potato (7.58 t ha^{-1}) grown after rice which was significantly higher over groundnut but was at par with maize. Among the three summer crops, sesame produced significantly highest REY (2.51 t ha^{-1}). The total productivity of the rice-potato-sesame cropping system (14.91 t ha^{-1}) was found to be highest among the systems with 15.6 and 29.8% higher yield over Rice-Maize-Cowpea and Rice-Groundnut-Greengram cropping system, respectively. The lowest land utilization efficiency but highest production efficiency was observed in rice-potato-sesame cropping system although rice-maize-cowpea was found to be the most economical system. The highest REY of 13.65 t ha^{-1} was recorded with RDF + crop residue incorporation of preceding crop which was significantly higher than RDF alone. At the 2nd cycle of the cropping system rice-groundnut-greengram system recorded highest available nitrogen of 216.0 kg ha^{-1}and available potassium (113.7 kg ha^{-1}) which was significantly higher over other two systems. Among the nutrient management treatments at the end of the 2nd cycle of cropping sequence highest available nitrogen, potassium and organic carbon was found in RDF + crop residue incorporation treatment which was at par with INM treatment (RDF with 25% nitrogen based substitution) but significantly higher than RDF alone.

Assessing the impact of climate variability on rice productivity and developing adaptation strategies for rice based cropping system of Eastern India

Water balance analysis of Cuttack which falls under hot moist sub humid ecological sub region indicated a water surplus of 1046 mm in a normal rainfall year (2005) and during excess rainfall year (2003) it is around 1555 mm during the crop growing season (23–46 MSW). Even during a deficit rainfall year like 1996, there was a water surplus of 146 mm during the crop growing season indicating the opportunity for water harvesting and storage. The harvested water can be used for supplemental irrigation to mitigate the drought, extend crop growing season and irrigation for the dry

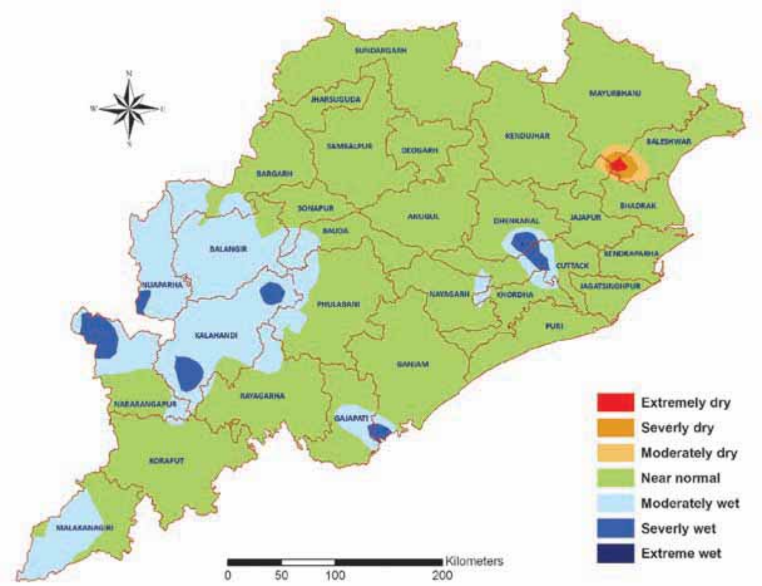


Fig. 24. Three months (July, August and September) SPI map of 2003

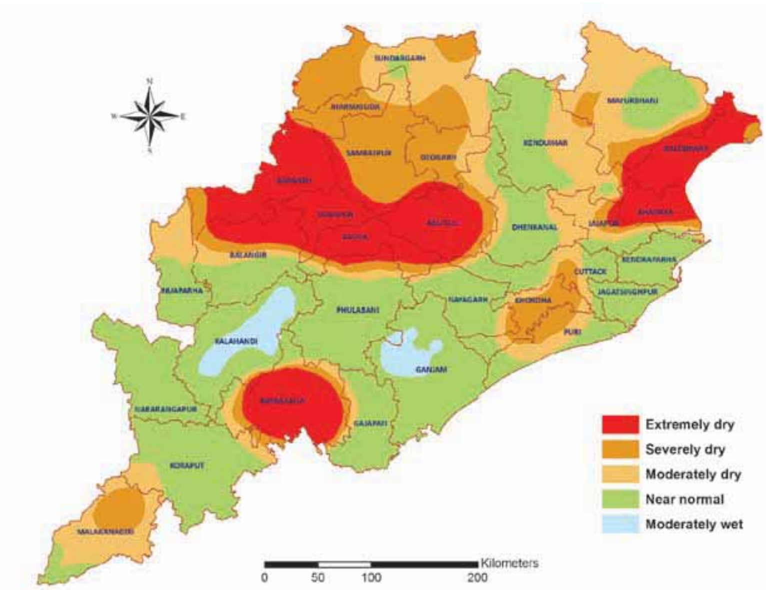


Fig. 25. Three months (July, August and September) SPI map of 2008

season crops. Similarly, water balance components of Odisha districts were also worked out to aid in formulating adaptation strategies for rice based cropping system.

The Standardized Precipitation Index (SPI) is an index based on the probability of recording a given amount of precipitation. Therefore, the probability of rainfall being less or more than a certain amount can be determined. Drought event means a particular rainfall event gives a low probability on the cumulative probability function. Using this index, the severity and pattern of wetness/dryness in Odisha were examined at block level. Daily rainfall data from 168 rain gauge stations were collected for the period 1982-2008. Different time scales of SPI *viz*., SPI for one, two, three, six, nine and twelve months were worked out. SPI spatial maps were generated by Kriging interpolation method using Spatial Analyst tool of ArcGIS and the spatial pattern were categorized into extremely wet (SPI >2.0), severely wet (1.5 -2.0), moderately wet (1.0-1.5), near normal (-1.0 to 1.0), moderately dry (-1.0 to -1.5), severely dry (-1.5 to -2.0) and extremely dry (<-2.0). The one-month SPI was closely related with short-term soil moisture and crop stress, especially during the growing season while the three-month SPI reflects short- and medium-term moisture conditions and provided a seasonal estimation of precipitation. The three month SPI maps of Odisha for September 2003 and 2008 were presented in Fig. 24 and 25 for comparison of normal and drought conditions. The frequency, area extent and severity of drought assessed from SPI will be useful in developing mitigation strategies of drought events in the region.

Development of agro-techniques for direct-sown summer rice

A field experiment was conducted to study the effect of different N-scheduling on performance of rice (Naveen) in wet direct-sown summer rice. The treatments were control (no fertilizer); rice-*Azolla* dual cropping at three levels *viz., Azolla* + 50:40:40; *Azolla* + 70:50:50 and *Azolla* + 90:60:60 N, P_2O_5 and K_2O kg ha^{-1}; FYM + chemical fertilizer at three level *viz.,* FYM + 50:40:40, FYM + 70:50:50 and FYM + 90:60:60 N, P_2O_5 and K_2O kg ha^{-1}; chemical fertilizer alone at three levels *viz.,* 80:40:40, 100:50:50 and 120:60:60 N, P_2O_5 and K_2O kg ha^{-1} which replicated thrice in randomized complete block design with four replications. The crop was established by spot seeding with pre-germinated seeds at 15 cm x 15 cm spacing during second week of January. Experimental results revealed that the highest yield (5.78 t ha^{-1}) was recorded in the treatments where rice + *Azolla* dual cropping was practiced with a fertilizer dose of 90:60:60 kg N, P_2O_5 and K_2O ha^{-1} along with *Azolla* (1 t ha^{-1}) applied 12 days after transplanting (DAT). However, it was comparable (5.67 t ha^{-1}) with *Azolla* (1 t ha^{-1}) + 70:50:50 kg N, P_2O_5 and K_2O ha^{-1}. About 121% yield enhancement was recorded in *Azolla* + 90:60:60 N, P_2O_5 and K_2O kg ha^{-1} over control plots where no fertilizer was applied. The benefit : cost (B:C) ratio was higher in the treatments where chemical fertilizer was applied than the rice +*Azolla* dual cropping.

Another field experiment was conducted to evaluate the efficiency of different weed control practices in wet direct-sown rice. The treatments consisted of different herbicides *viz.,* Pretilachlor + Safener (800 g ha^{-1}), Pyrazosulfuron ethyl (20 g ha^{-1}), bensulfuron methyl (60 g ha^{-1}), Almix (metasulfuron methyl + Chlorimuron ethyl at 4 g ha^{-1}), Almix + Pretilachlor (4+450 g ha^{-1}) and bensulfuron methyl + Pretilachlor (50+450 g ha^{-1}). These treatments were compared with mechanical weeding (finger weeder) + hand weeding; hand weeding twice (20 and 40 days after sowing) as recommended practice, weed free and weedy check. The major weed flora in weedy plots at 45 days after sowing(DAS) were *Cyperus difformis, Sphenoclea zeylanica, Leptochloa chinensis* and *Marsilea quadrifolia*. Grassy weeds constituted 26%, sedges 45% and broad leaf weeds 29% of the total weed population at this stage. Tank-mix application of bensulfuron methyl+ pretilachlor (applied as post-emergent 18 DAS at 50 + 450 g a.i.ha^{-1}) was found to be most effective for controlling the predominant weeds (WCE 91%) and produced comparable yield (5.67 t ha^{-1}) with hand weeding twice (5.77 t ha^{-1}). The highest net return (Rs. 21,298 ha^{-1}) and B:C ratio of 2.30 was also recorded with the treatment of bensulfuron methyl+ pretilachlor. There was more than 43% reduction in the grain yield of rice due to competition with weeds in weedy plots.

Cropping system analysis for Eastern India using remote sensing and GIS

Prediction of rainfall surfaces from point data is necessary for generating alternate rice based cropping pattern maps. Deterministic interpolation techniques create surfaces from measured points, based on either the extent of similarity or the degree of smoothing. In this study, geo-statistical interpolation methods were used to estimate monthly (June-December), seasonal (South-West and North-East Monsoon seasons) and annual rainfalls of Odisha. Historical daily rainfall data (1982 - 2008) were collected from 168 rain gauge stations of Odisha for the preparation of spatial rainfall maps.The spatial rainfall maps were generated using ordinary kriging method and the Ganjam district spatial map of South West Monsoon (SWM) rainfall is presented in Fig. 26.

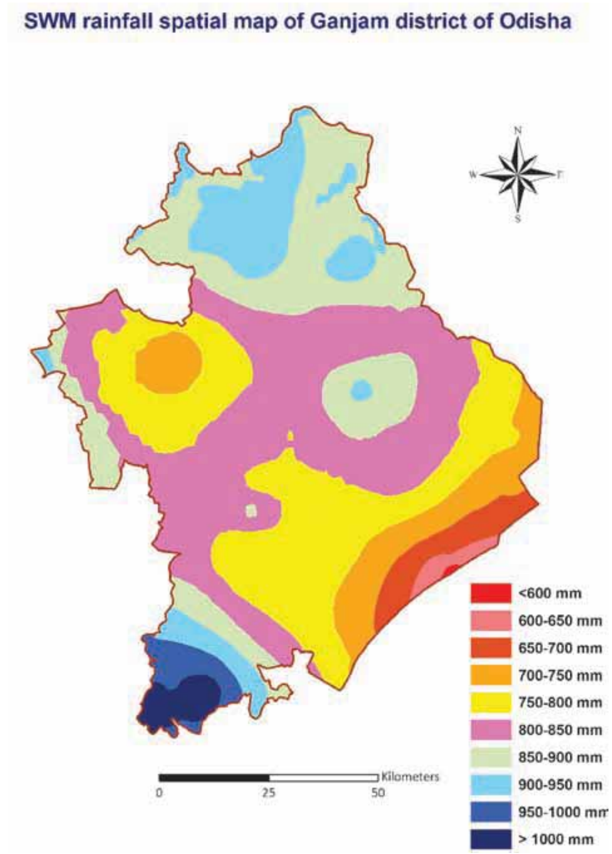


Fig. 26. South-west monsoon rainfall spatial map of Ganjam district of Odisha

Evaluation of site specific management in rice and rice based cropping system

Yield spatial variability study was conducted during the dry and wet season in 4.8 acres of land in CRRI farm. The site was marked by difference in gradient with variable level of standing water due to rain (10 cm to 30 cm). The rice-rice system was followed with variety “Naveen” during dry and “Gayatri” during wet season. The yield was recorded in the grids size of 20 m x 20 m (total 48 grids), during the dry season the rice grain yield varied from 2.95 to 8.20 t ha^{-1}, straw yield from 3.45 to 7.75 t ha^{-1}, effective tillers from 139 to 388 and panicle weight from 1.68 to 3.64 g whereas during the wet season grain yield varied from 9.10 to 17.70 t ha^{-1}, straw yield from 12.95 to 31.50 t ha^{-1}, effective tillers from 255 to 457 and panicle weight from 2.90 to 7.13 g. The soil samples were collected from the same grid point, processed and analysed for soil pH, OC, P and K. The geo-spatial maps for yield and nutrient status were developed using GIS software. It was found that the low fertility loops in the map is matching with low rice yield indicating a yield improvement if variable fertilizer application is made matching with low and high fertility zones.

Ecologically based integrated weed management in rice

Population dynamics, biology and management of weeds through low-dose high-efficacy novel herbicides, bio-agents and allelopathic effects

In direct-sown rainfed lowlands, the grassy weed, *Echinochloa colona* was prevalent (63% of total weed population) at early vegetative stage i.e., at 30 days after sowing (DAS) while at 60 DAS, the *Leptochloa chinensis* along with sedges *viz.*, *Cyperus iria* and *Fimbristylis miliacea* and broad leaf weeds *viz.*, *Ludwigia octovalvis* and *Cleome viscosa* were predominant (89% of total weed population). In medium deep (intermediate) lowlands, the major weed species at 30 DAS were *Echinochloa colona, Cyperus iria* and *Fimbristylis miliacea* (81% of total population). However, at 90 DAS, there was prevalence of *Leersia hexandra,* C*yperus haspan, Ludwigia octovalvis* and *Commelina benghalensis* (87% of total population). The predominant weed floras in transplanted rice were *Echinochloa colona*, *Fimbristylis miliacea, Ludwigia octovalvis , Marsilea quadrifolia* and *Sphenoclea zeylanica*. The mean relative density of major weed species in wet direct-sown summer rice were *Echinochloa colona* (8.7%), *Cyperus difformis* (26.1%), *Fimbristylis miliacea* (14.5%), *Sphenoclea zeylanica* (27.5%), *Marsilea quadrifolia*(23.2%) at 30 days after sowing (DAS). In case of transplanted rice, it was observed that *Cyperus difformis* was the most prevalent weed species (33% of total weed population) followed by *Sphenoclea zeylanica* (25%) at early vegetative stage (30 DAT). But the dominance of *Leptochloa chinensis* (21%) was recorded maximum at tillering stage (60 DAT).

An experiment was conducted to study the allelopathic effect of *Lantana camara* leaf extract on germination and seedling growth of three predominant weeds of irrigated rice field *viz.*,*Echinochloa colona, Cyperus difformis* and *Sphenoclea zeylanica*. It was found that the aqueous extract suppressed seed germination in all the three associated weeds and the suppressive effect increased with an increase in percentage of extract. The effect was more pronounced in *Cyperus difformis* (43% germination in 10% extract against 73% under normal condition). In case of seedling growth, it was found that the root elongation was affected more than shoot elongation in all the weeds after one week of germination, with the suppressive effect being most pronounced in *Cyperus difformis* followed by *Echinochloa colona* and *Sphenoclea zeylanica*. Shoot growth was significantly suppressed at higher concentration in *Cyperus diformis*. It was also observed that there was inhibition of total biomass in all the three weeds after three weeks of germination and the inhibition effect was highest in 10% of extract. The reduction was highest (86%) for *Cyperus difformis* followed by *Echinochloa colona* (81%) and *Sphenoclea zeylanica* (70%) by application of 10% aqueous extract of *Lantana camara* leaves.

The efficacy of two new low-dose high-efficacy herbicides *viz.*, Bispyribac sodium and Penoxulam and herbicide mixture, Penoxulam + Cyhalofop in conjunction with recommended herbicides were tested in wet direct- sown rice. Bispyribac sodium (at 30 g ha^{-1}) was found effective for controlling *Echinochloa colona* with weed control efficiency (WCE) 83% and Penoxulam + Cyhalofop (at 135 g ha^{-1}) found effective for contolling major weeds with WCE 86%. Except Azimsulfuron, other herbicides could not be found effective against *Leptochloa chinensis*. Azimsulfuron at 35 g ha^{-1} and Azimsulfuron + Metsulfuron methyl (30 + 2 g ha^{-1}) found most effective in controlling weeds (WCE 88 and 90%, respectively) and produced comparable yield with recommended practice of hand weeding twice at 20 and 40 DAS. There was 45% reduction in the grain yield of rice due to competition with weeds in the weedy plots.

Integrated weed management in upland rice

A field experiment was conducted at CRRI Regional Station, Hazaribag to study integrated weed management in rainfed upland rice during wet season, 2011 in factorial randomized complete block design combining weed management practices with different intercrop row ratios of rice and black gram (BG). Four row ratios of rice and BG (1:1, 2:1, 3:1 and 4:1) were sown using uniform base and intercrop spacings of 15, 20 and 25 cm. Pendimethalin alone or in combination with one hand weeding formed the treatments for weed management practices. Rice + BG (3:1) sown at uniform spacing of 20 cm coupled with pendimethalin alone produced comparable yield with pendimethalin supplemented with one hand weeding. Sole rice crop had higher weed biomass than the intercrop system under herbicide treated plots.

Another field experiment was conducted during the wet season, 2011 to evaluate the performance of different weed management practices in rainfed upland rice at KVK, Santhapur. There was predominance of grassy weeds along with sedges at early stage (30 DAS) and broad leaf weeds at later stage (45 DAS). Among the different weed management treatments, better control of weeds was recorded in the plots where stale seed bed technique was adopted followed by post emergence application of Azimsulfuron @ 35 g a.i. ha^{-1} at 20 DAS (3.43 t ha^{-1} with weed control efficiency 86%) and it produced the comparable yield with twice hand weeding (3.52 t ha^{-1}) while weed free check produced the highest yield of 3.73 t ha^{-1}.

Integrated Farming Systems in Different Rice Ecologies

Diversified rice farming systems for favourable and unfavourable upland ecologies

To evaluate crop component based farming system in rainfed uplands, sesame (Shekhar and Tarur), black gram (BU-1) and fingermillet (JWM 1 and A-405) were sown with upland rice as intercrops with two ratios (1:1 and 2:1) at uniform base and intercrop spacings of 15 and 20 cm. Experimental results revealed that all intercrop combinations were more productive in terms of rice equivalent yield and LER. Rice intercropped with fingermillet showed better performance when combined with fingermillet *cv.* A-405 due to different growth behavior of rice and fingermillet.

Improvement and popularization of integrated farming system model for small and marginal farmers under irrigated condition

The multi-enterprise integrated rice based farming system model was developed at CRRI, Cuttack with the potential integration of fishery, poultry, duckery, beekeeping, vermin-composting, horticulture and agroforestry with rice and rice based crops to improve water, nutrient and energy use efficiency in 1 acre area under irrigated condition. In its present form, the model has full potential to earn regular livelihood for small and marginal farmers by ensuring food and nutritional security besides its socio-economic and ecological benefits. With the aim of further improvement of the model; mushroom, nutritional garden and nursery raising enterprises were integrated during the year 2010-11 in the model and found compatible and feasible.

In this system,after an early crop of rice *cv.* Apo, submergence tolerant rice variety Swarna Sub-1 was transplanted in the last week of June. During the dry season rice *cv.* Naveen was grown. Three rice crops together (Swarna Sub-1, Naveen and Apo) produced a total grain yield of 12.8 t ha^{-1}. On the bunds more than 1.5 tones of vegetables and fruits were produced. Around 1.5 q of fish and 15,000 fingerlings were harvested in the system and generated an income of Rs. 20,000.

As a whole the system could produce about 14.3 q of food crops, 1.5 q of fish, 1.8 q of meat, 10 q of vegetables and 5 q of fruits besides 13 to 14 q of rice straw (used for animal feed) annually to ensure food and nutritional security, stable income on short and long term basis and year round employment of farm family.

Development of rice-fish farming systems for waterlogged and deep water areas and studies on rice-fish environment and interactions

Rice-fish-prawn-livestock horticultural crop based irrigated farming system for medium deep water lowlands

In the rainfed lowland rice-fish integrated farming system in one hectare area components like high yielding rice varieties (Varshadhan and Durga) followed by moong bean and okra in the dry season in the field and horticultural crops, poultry, duckery and agroforestry etc. were taken up. The productivity of wet season rice crop ranged between 3.0 – 3.5 t ha^{-1} (Durga) and 4.0 – 4.5 t ha^{-1} (Varshadhan), and the same for dry season crops after rice were 0.6 t ha^{-1}(greengram) and 7.0 t ha^{-1} (okra).

Rice-fish-horticultural crops-agro forestry based integrated farming system model for deepwater ecosystem

Rice-fish-horticulture based diversified farming systems with the integration of various crops and animal components were taken up in rainfed waterlogged and deepwater ecologies, besides studies on rice-fish environment and interactions. The grain yield of wet season rice (var.Pooja, Gayatri) was in the range of 4.3-5.0 t ha^{-1} in rainfed lowland and 3.8-4.6 t ha^{-1} (var.Durga, Varshadhan) in deepwater situation. The yield of various dry season crops grown with harvested rainwater were 0.53 t ha^{-1} in greengram (PDM 54), 3.3-5.9 t ha^{-1} in vegetables (Bottle gourd, cucumber, okra) and 5.0 tha^{-1} in rice (*cv.* Naveen). The productivity of other field crops in upland (Tier I and II) was in the range of 3.5-11.9 t ha^{-1} in vegetables during dry season and 7.9-12.7 t ha^{-1}

during wet season, 6.2-47.6 t ha^{-1} in tuber crops and 8-30 kg fruits per plant in fruit crops. The fish yield was 0.94 t ha^{-1} at a stocking density of 7,000 fingerlings ha^{-1}. Among the fish species, *Catla* attained maximum growth (0.88 kg) followed by *Rohu* (0.84 kg) and *Mrigal* (0.77 kg). Among the bird components, poultry birds (Vanaraja) attained average weight of 2.1 kg in 90 days, while ducks (Khaki Campbell) recorded average weight of 1.4 kg per year. The average net income of the multitier rice-fish-horticulture based farming system for deepwater areas was around Rs 1,00,000 ha^{-1}.

Studies on rice-fish environment and interactions

The possibility of using insectivorous fish (*Kou*, *Anabas testudinues*) as a component of IPM was studied under rice-fish farming during dry season. Culture of fish (*Kou*) reduced the infestation of yellow stem borer (YSB) of rice crop (Naveen) by 40.9% at the heading stage resulting marginal increase in grain yield. Use of insecticide (Chlorpyriphos) as seedling root dip (0.04% a.i ha^{-1}) reduced the YSB infestation at vegetative stage by 57.3% and later integration of fish (*Kou*) reduced the YSB infestation at heading stage by 25.5%. However, spray of Imidacloprid at 0.01% at heading stage gave comparable control of YSB with that of seedling root dip followed by release of fish. The grain yield of rice ranged from 4.6- 5.2 t ha^{-1}. The yield of fish fingerlings was in the range of 41.1-54.4 kg ha^{-1} in 75 days. The green house gases (CH_4 and N_2O) emission and their interaction with different fish species (catla, rohu, mrigal, and common carp) was studied under rainfed waterlogged rice-fish farming during wet season using rice variety, Varshadhan. The methane emission varied from 0.69 to 10.6 mg m^{-2} hr^{-1} during the crop growth stages with a peak flux at 102 DAT (after PI stage). The methane emission was found higher under rice-fish farming compared to rice alone and among the fish species common carp emitted maximum methane (0.72-10.6 mg m^{-2} hr^{-1}) due to more bioturbation because of its scavenger feeding habit followed the other species as catla, rohu and mrigal, respectively. The CH_4 emission was also found 32% higher in the flowering stage of the dry season rice (var.Naveen) under rice-fish culture. The N_2O emission varied from 13.2-55.2 N_2O-N µg m^{2} hr^{-1} with peaks values after the N fertilizer applications. The N_2O emission was higher during rice farming alone compared to rice-fish farming and there was no effect of fish species in the case of N_2O emission. The grain yield of rice was 4.55 t ha^{-1} in rice-fish farming compared to 4.10 t ha^{-1} in rice alone. The fish yield was 195-238 kg of fingerlings ha^{-1} in 90 days.

Development of Integrated Farming Systems for flood-prone areas

Performance of integrated rice-fish farming system at CRRI regional station, Gerua

Rice constituted the main component of rice-fish farming system model which covered 60 % of the total area. Five rice varieties, i.e., Swarna, Swarna-sub1, Ranjit, Pooja and Sabita were tested in RBD with four replications during wet season 2011. Swarna recorded significantly higher grain yield of 5.26 t ha^{-1} followed by Swarna-sub1 (4.97 t ha^{-1}) and Ranjit (4.93 t ha^{-1}) (Table 29).

Vegetable crops were cultivated on the pond dyke throughout the year. Interventions made were lady's finger (var. Arka Anamika) and yardbean (var. Harirani), brinjal (*cv.* PK-123) during pre-wet season and wet seasons, green chilli (var. Surajmukhi) during wet season and post-wet seasons. French bean (var. Anupam) and cabbage (var. Shaan) during dry season.

Interventions made on the hanging platforms were of pumpkin (var. Arjun) during wet seasons and bottle gourd and country bean (var. Kartika Seem) during dry season. Red amaranth was grown on pond bunds as wet season and post-wet season leafy vegetable while spinach was grown as leafy vegetable during dry season.

Gross income from the various components of the integrated farming system was calculated to be Rs. 80,650 from 0.5 ha of area. The major contribution in terms of production and income was highest from horticulture component (43.95%, followed by fish (24.80%) and rice (21%).

Table 29. Performance of rice varieties under integrated rice-fish farming system during wet season 2011

Variety	EBT/sq m	No. of filled grains panicle^{-1}	Test wt (gm)	Grain (t ha^{-1})	Straw yield (t ha^{-1})	HI
Swarna	273.07	153.30	19.60	5.26	6.45	0.45
Swarna sub-1	272.25	152.80	19.05	4.97	6.25	0.44
Ranjit	249.97	153.05	20.05	4.93	7.01	0.41
Pooja	338.25	104.00	20.16	4.25	6.10	0.41
Sabita	243.37	122.56	34.13	4.39	7.95	0.36
CD (P.05)	22.42	9.91	0.26	0.30	0.40	0.09

EBI: Ear bearing tillers, HI: Harvest index

Mechanization for Rice Production and Post-harvest Systems

Development of Cost Effective Machines

Design, fabrication and testing of self propelled paddy hill seeder, power tiller operated multi-crop seed drill

A five row power tiller operated seed drill was fabricated for sowing of rice and groundnut with furrow opener spacing of 25 cm. It was tested for sowing the rice variety Naveen and TMV variety of groundnut in dry season, 2011.The field capacity of 0.14 and 0.15 ha hr^{-1}, skidding percentage of 28.4 and 26.3 and cost of planting of Rs.1240 ha^{-1} and Rs. 1200 ha^{-1} was observed for rice and groundnut, respectively.

Power tiller operated seed drill for rice and groundnut

Development, evaluation and improvement of bullock/power tiller and power operated weeder for rice and rice based crop

Seven row bullock drawn weeder, eight row power tiller operated weeder and two row self propelled power weeder were tested with Naveen variety in dry season during 2011.The bullock and power tiller operated weeders were tested in a row spacing of 20 cmwhereas, power weeder was tested in row spacing of 25 cm. The seven row bullock drawn weeder was found to perform better than the others because of its higher field capacity, low energy use and low cost of operation (Table 30).

Seven row bullock drawn weeder

Design, fabrication and testing of power operated three row rice transplanter using mat type and root washed seedlings

A manual three row rice transplanter for using root washed seedlings was developed for 20 cm row spacing. Fixed fork type fingers were designed to pick up the seedlings from the tray. Arrangement was made to change the length of the fingers. The finger assembly was attached to a handle. The to-and-fro motion of the handle enables the finger to pick up the seedlings from

Table 30. Performance of various weeders in dry season rice

Weeder	Field capacity (ha hr^{-1})	Weed destruction % age in 1 pass	Cost of operation (Rs. ha^{-1})	Energy utilized for weeder operation (MJ ha^{-1})
Seven row bullock drawn weeder	0.16	30	780	68.0
Eight row power tiller operated weeder	0.1	32	1610	630.0
Two row power weeder	0.05	66	2200	879.0

the tray and plant them in the field. A mechanism was designed for the reciprocating motion of the seedling tray. The tray moves a little after each picking of the seedlings and moves in the reverse direction when the tray compartment reaches to a side. There is a mechanism to feed the seedlings in the tray to the fingers. Plant to plant distance is adjustable as per requirement of hill spacing. Field testing results revealed that the transplanter had field capacity of 0.011 ha hr^{-1} with missing hills ranging from 18-20%. This would be suitable for small size field.

Development and evaluation of power operated pre-germinated paddy seeder

An eight row, engine operated, pre-germinated paddy seeder having hyperboloid shape was designed with an aim to reduce the human drudgery in transplanting of paddy and reduce cost of cultivation. The machine comprised of a 2.94 kW light weight diesel engine, power transmission system, seed drum, main frame, float, ground wheel and tail wheel. This was field tested in wet season during 2011 and its performance was compared with the engine operated (8 rows) seeder having cylindrical shape, manual drum seeder having hyperboloid shape (8 rows), self propelled 8 rows transplanter and manual transplanting (Control). The field capacity of the developed seeder was 0.235 ha hr^{-1}which was more than other tested seeders and rice transplanters(Table 31).

Enhancing productivity, water use efficiency and profitability of rice cultivation system by use of CRRI planters and weeders

The field performance of CRRI planters were evaluated during wet season with rice variety Gayatri. The study showed that sprouted drum seeder is the best technique to reduce the cost of wet land rice-planting where standing water condition allows its use (within 2-5 mm). In case of higher water depth, mat type transplanters could be used with productivity advantage of 3.3%). Maximum net returns (Rs. 21, 410 ha^{-1}, Table 32) from rice cultivation was obtained by use of the self propelled transplanter.

The CRRI weeders were evaluated during dry season with rice variety Naveen. Among all the weeders, weed destruction was highest in case of cono weeder, followed by finger weeder and manual weeding. Average grain yield (3.85 t ha^{-1}) and WUE (0.57 kg m^{-3}) in mechanically weeded plots were twice the un-weeded plots. Highest net returns were obtained by using star-conoweeder followed by power weeder.

Table 31. Performance of different sowing and planting implements

Treatments	Effective field capacity (ha hr^{-1})	Field efficiency (%)	Ear bearing tillers m^{-2}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Engine operated (8 rows) seeder having hyperboloid shape	0.235	85.0	347.70	6.75	8.70
Engine operated (8 rows) seeder having cylindrical shape	0.230	83.5	323.00	6.37	8.47
Manual Drum seeder having (8 rows) hyperboloid shape	0.097	70.2	332.5	6.60	8.37
Self propelled 8 rows transplanter	0.190	72.4	331.3	6.75	8.32
Manual transplanting	-	-	321.5	6.72	8.97

Table 32. Effect of planting methods on productivity, water use efficiency (WUE) and net returns

Implements	Area (ha hr^{-1})	Planting cost * (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Grain yield (t ha^{-1})	WUE (kg m^{-3})	Net return (Rs. ha^{-1})
CRRI drum seeder	0.12	520	27,325	5.12	0.618	19,635
CRRI manual transplanter	0.032	1611	29,100	5.26	0.635	19,460
Self propelled transplanter	0.205	1052	28,510	5.32	0.643	21,410
Traditional	0.0036	5250	36,482	5.26	0.635	13,118
LSD (p=0.05)	-	76.40	668.69	0.574	0.07	1148.92

* Excluding cost of seed and nursery operations

Product Diversification, Value Addition and Post-harvest Technology

Development and evaluation of solar and bio-mass fuelled dryer for grain and food production

A batch dryer of 300 kg paddy holding capacity was designed and developed. Its main components are drying chamber (LSU type), solid fuel fired furnace with heat exchanger and blower. The bottom sheet of the drying chamber is hinged at one end so that it can be lowered at the other end for removal of the grain after drying. Provision is made to connect solar air heaters at the suction end of the blower to supplement with solar heat. One side of the drying chamber is provided with a door for placing trays over the inverted 'V' troughs so that it can also work as a tray dryer for drying other food materials. The bio-mass fuelled dryer was evaluated for drying of raw and parboiled paddy. The drying time for raw and parboiled paddy varied from 5-7 hrs having initial moisture content in the range of 19-26 %, where as open sun drying takes 3-4 days for drying the same. The cost of the dryer is estimated as approx. Rs. 40,000. The payback period of the dryer was computed as less than one year.

Development and evaluation of greenhouse type fish drying system for coastal region

A greenhouse type solar cabinet fish dryer was designed for drying 15-20 kg of small to medium size (10-15 cm long) fish. The structural frame is made of mild steel square bars, angle and flat. Over all dimension of the dryer is 157 x 87 x 150 (L x B x H) in cms. There are two stainless steel sliding trays (75 x 95 cm each) which were used for drying of fish. The aperture area is 1.44 m^2. The glazing material is UV stabilized polyethylene sheet. Perforations were made at the bottom of the front wall for entry of air and two chimneys of 15 cm diameter and 84 cm height were made for exit of hot humid air after drying. Two sizes of marine fish, 8-10 cm and 15-20cm were used for drying in March and May respectively. The fish was salt treated (1 kg salt for 10 kg fish) for overnight, then thoroughly washed, rinsed and dried in the dryer.Under no-load condition, the stagnation temperature of the dryer at 12.30 pm was 63^0C in Nov-Dec and 70^0C in April-May. In both the cases of fish drying, the total drying time to bring down the moisture from around 65% to around 14% was around 12 hrs (spread over 2 days) as compared to 3 days in open sun drying. The dryer temperature was in the range 50-62^0C. The ambient temperature was in the range 30-35^0C in March and 34-39^0C in May. The yield of dry fish was in the range 40.5% to 48%. Cost of drying and value addition per kg of fish was computed to be Rs. 2.12 and Rs. 17.90 if dried near the seashore. The payback period of the dryer was calculated to be 132 days.

Field evaluation of 30 m^3 fixed dome type biogas plant for power generation

Construction of a biogas plant of 30 m^3 capacity with R.C.C fixed dome was made during 2011 at Shree Gopal Krishna Goshala, Cuttack. Diameter and depth of digester of the plant was 5.0 m and 3.06 m, respectively. Dung mixing chamber was provided at the top of the inlet pipe. The PVC inlet pipe of 250 mm was laid at angle of 70^0 with the horizontal. The lower end of the pipe was kept at a height of 70 cm. Outlet chamber having dimension of 482 cm x 283 cm x 272 cm was constructed for slurry disposal. The plant was commissioned on November 23, 2011 and charged initially with fresh cowdung @ 2000 kg per day and water in 1:1 ratio for fifteen days. Subsequently, 1500 kg fresh cowdung with same quantity of water was fed to the biogas plant for 20 days. After stabilization, normal gas production was started from 26th December, 2011. Presently fresh cowdung @ 750 kg per day with 25-30% less water is being fed daily. Digested slurry is being used for making of vermi-compost.

During testing, the gas pressure was recorded as 57.0 mb at full capacity of slurry formation, as slurry level decreased by 40 mm, the gas pressure decreased from 57.0 mb to 3.0 mb. Biogas based generator was used for generating power, the voltage varied from 220 to 450 V and current varied between 5-8 A. Power generated from biogas based engine was also utilized to operate a chaff cutter (with electric motor of 5.0 hp), a submersible pump (with electric motor 2.0 hp) for irrigating the crops. The power was also used to illuminate 40 tube lights each of 40 W for 3.0 hrs. Biogas generator consumed biogas @ 4.90 m^3 hr^{-1}. The total cost incurred towards the construction of biogas plantalong with generator, H_2S scrubber, moisture removal from biogas, control panel, energy meter and generator shed was Rs. 5,55,173. The methane production varied between 43.8 to 48.7% of total gas emission.

Strategic Research on Pathogens/ Pest Population Dynamics, Crop Losses and Forecasting

Studies on Pest/Natural Enemy Population Dynamics

Studies on off-season biology and resurgence of major rice insect pests

White backed planthopper (WBPH) was found to complete its life cycle successfully on the ratoon plants of rice variety TN1 and succeeded to next generation in the harvested field having stagnate water and served as its off-season habitat. WBPH completed two generations in 35 days in ratoon rice recording more than 90 % survival. Off-season biology of WBPH studied on eight weeds, indicated that nymphs could develop only on *Echinocloa colona* and become adults.

Three granular insecticides *viz.,* Carbofuran, Cartap, Phorate and three microbial insecticides involving *Verticillium lecani, Metarhizium anisoplae* and *Beauveria bassiana* were tested under field condition for their possible role in inducing leaf folder (LF) resurgence. A maximum of 34.5% leaf damage was observed under carbofuran treatment compared to 23.3% in control indicating resurgence of LF. Application of Cartap significantly reduced LF incidence to 8.2% leaf damage.

Seasonal prevalence of rice insect pests recorded through light traps

YSB population reached a small peak of 774 moths in 14th standard meteorological week (SMW) of 2011 and remained low throughout the wet season. It reached a small peak of 384 moths week^{-1} in the 40th SMW and another with 434 moth week^{-1} in the 44th SMW and declined thereafter. This population was too small as compared to other years (excepting 2011). Based on the duration of life cycle it may be presumed that the parent brood emerges about six weeks before the peak emergence pesticide application during 34th and 38th SMW can protect rice crop from the attack of the peak brood.

Population of *Chilo* sp. followed a similar pattern and reached a peak of 265 moths in the 6th SMW and another peak of 42 moths in the 44th SMW. Population of YSB was predominant (95.00%) while *Chilo* species represented 4.0% and other stem borers only 1.0%. Leaf folder population increased in January-2011 and reached a peak in 7th SMW with 152 moths week^{-1} and then declined. During wet season, it reached another peak of 90 moths week^{-1} in 40th SMW in October.

Case worm population during dry season started increasing from the 1st week of January and reached peak of 312 moths week^{-1} in the 6th SMW. It appeared in good numbers in the wet season and reached a peak of 580 moths week^{-1} in the 39th SMW. Green leaf hopper population started increasing from September (32nd SMW), remained high throughout September and October. It reached a peak of 28,449 in the 43rd SMW.

Light trap catch of *Cnaphalocrocis medinalis* (Guenee) at Central Rice Research Institute; Cuttack from 1990 to 2009 was analyzed to study the population trend of the pest over the years. During 1990 – 1999, a major peak was observed at 19th SMW with two small peaks at 10th and 16th SMW. In the wet season, the peak pest population was observed at 42nd SMW and two small peaks at 38th SMW and 46th SMW. During 2000-2009, in the dry season, one major peak was observed at 7th SMW with two small peaks at 14th and 18th SMW. In the wet season, the major peak was observed during 45-46 SMW and another three small peaks were observed corresponding to 38-39, 42-43, 49-50 SMW. The mean annual leaffolder population from 1990 to 1999 and 2000 to 2009 indicated that over the past few years, the magnitude and number of peaks in the season has increased. Earlier (1990 to 1999), there were two peaks of leaffolder population in the dry season and grossly two peaks in the wet season, whereas, in the recent years three small peaks in the dry season and four peaks in the wet season were evident. The study indicated that leaffolder population has increased in recent years.

Life table and virulence of rice planthoppers and their management through induced resistance

Under field condition, about 75%, 70 % and 88 % of eggs of BPH developed into 1st instar nymph stage, respectively on PTB33, Udaya and TN1 generated by each of the cohort population investigated while, hatching percentage was higher recording 85%, 92% and 93%, respectively under natural enemy free condition. The trend index was low 0.72, 2.11 and 2.15 in field for PTB33, Udaya and TN1, respectively. There was a gradual decrease in life expectancy in the BPH populations on all three varieties tested under natural enemy free condition. Mortality survival ratio (MSR) was highest for the 1st and 2nd instar BPH and as the insect grows, MSR values were gradually falling and again at 5th instar stage there was a rise. Indispensable mortality (IM), at egg stage was recorded maximum at early instar stages in all the three varieties examined and was the minimum during late instars and adult stages. Under field condition, the mortality factors during early growth stages included mainly mesovellid bugs, spiders and unknown factors (environmental and host plant) but in later stages it largely included a wide array of spiders *(viz., Lycosa* sp., *Marpissa* sp., *Cheiracanthium* sp., *Paradosa* sp., *Oxyopes* sp., *Neoscona* sp. and *Tetragnatha* sp.).

Virulence studies of BPH continuously reared for 15 generations on selected rice varieties *viz.*, PTB33, IR64, Udaya, Ramaboita and TN1 indicated that biology of BPH in 0th, 5th, 10th and 12th generation on that particular variety when compared to 0th generation, a slight variation in survival percentage and developmental period was noticed in 10th and 12th generation insects reared continuously on resistant varieties.

Role of micronutrients and microbes in inducing resistance against rice BPH

Eight treatments *viz.*, rice bran, *Azospirillum*, *Pseudomonas fluroscens*, Calcium silicate, *Azospirillum* + *Phosphobacteria*, Ferrous sulphate, Salicylic acid along with control were tested in the net house to study their effect on BPH resistance. Three rice cultivars namely TN1, Udaya and Ramaboita were used for this purpose and nymphal survival of BPH was studied. Among the different treatments application of silica resulted in nymphal survival of 50%, 73% and 60%, respectively on TN1, Udaya and Ramaboita. In the control it was 76%, 66% and 65%, respectively on TN1, Udaya and Ramaboita indicating that mortality was more on the susceptible check TN1.

Quantitative and Qualitative Disease Severity Assessment

Survey for the incidence of major rice diseases and pests in Assam and other North East Region

The survey on occurrence of major rice diseases and insect pests was undertaken in Baksa, Kamrup, Nalbari, Barpeta, Darrang, Sonitpur districts of Assam and Ri Bhoi district of Meghalaya during wet season, 2011 at different stages of crop growth. In all the districts surveyed, variety Ranjit & Baisamuthi was the popular varieties grown, besides several other varieties like Swarna Mahsuri, Mahsuri (Aijung), Bahadur, Mong Bardhan, Barni, Kola joha and Tengre. Among the diseases brown spot (up to disease scale of 7), bacterial leaf blight and sheath blight (at disease scale 5) were commonly observed, besides neck blast, bacterial streak and sheath rot. Among the insect pests stem borer and leaf folders were commonly prevalent in all the districts while, hispa was also recorded from Baksa district.

At the research station, Gerua brown spot at disease scale 7 and sheath blight at disease scale 5 were found to be common followed by sheath rot, bacterial leaf blight, and false smut. Important insect pests were leaf folder and stem borer at moderate damage scale followed by rice hispa and gundhi bug.

Analysis of Population of Dynamics of Blast, Brown Spot and BLB

Development of monogenic differentials and characterization of *P. grisea* populations

Forty one monoconidial isolates *M. oryzae* of Eastern India prepared from 240 samples collected from several districts of Assam, Arunachal Pradesh, Jharkhand, Odisha, Meghalaya and Tripura over a period of three years (2009-11) was pathotyped on 26 monogenic differentials to determine their composition and virulence structure of the population and identification of broad spectrum resistance genes and their combination as decision making tool for resistance breeding. Virulence ranged from 23% (Mo-ei-205, 6 genes defeated) to 85% (MO-ei-5, 22 genes defeated). *Pi9* and *Pi ta2* were infected by the least number of isolates, the most virulent isolate being one of them. A combination of *Pi9* and *Pi ta2*, however, would provide broad spectrum resistance to all isolates evaluated.

Morpho-physiological and Molecular Characterization of Microflora and Development of Database

Polymorphism in *Fusarium* isolates associated with seeds of rice cultivars

Polymorphic bands were observed by RFLP of Inter-geneic spacer (IGS) region of ribosomal DNA of *Fusarium* isolates, associated with seeds of rice cultivars. Fumonisins producing and non- fumonisins producers clustered in different groups (Fig. 27).

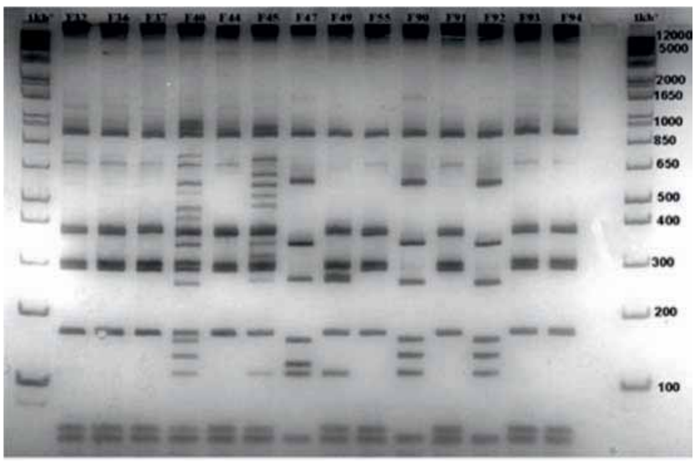


Fig. 27. Restriction digestion and PAGE of IGS region of seedborne Fusarium by *EcoRI* and *HhaI*.

RAPD primers ap12h, P-160, PU-1, P-117, R3, R-108, R-1,R-2, PU-2, PU-3,P-54, OPB-10 and 3B were used to amplify seed borne *Fusarium* isolated from various rice cultivars. High degree of polymorphism was observed among *Fusarium* isolates (Fig. 28).

Evaluation of toxins/other metabolites produced by fungi on host genotypes

Endophytic *Penicillium* from salt tolerant rice cultivar Lunisree protected rice seedlings against seedling mortality caused by *Fusarium* spp. This isolate was also effective against virulent isolates of 'rice blast pathogen' *in vitro*. First spray of cell free aqueous extract of false smut balls on rice cultivar Ranjit at active tillering stage and second spraying just before panicle emergence were effective. About 10% increase in yield was recorded.

Characterization and development of database for bacterial blight

One hundred isolates of bacterial leaf blight collected from different locations in Odisha *viz.*, Bolangir, Sonepur, Kalahandi, Nawapara, Keonjhar, Malkangiri, Nawarangpur,

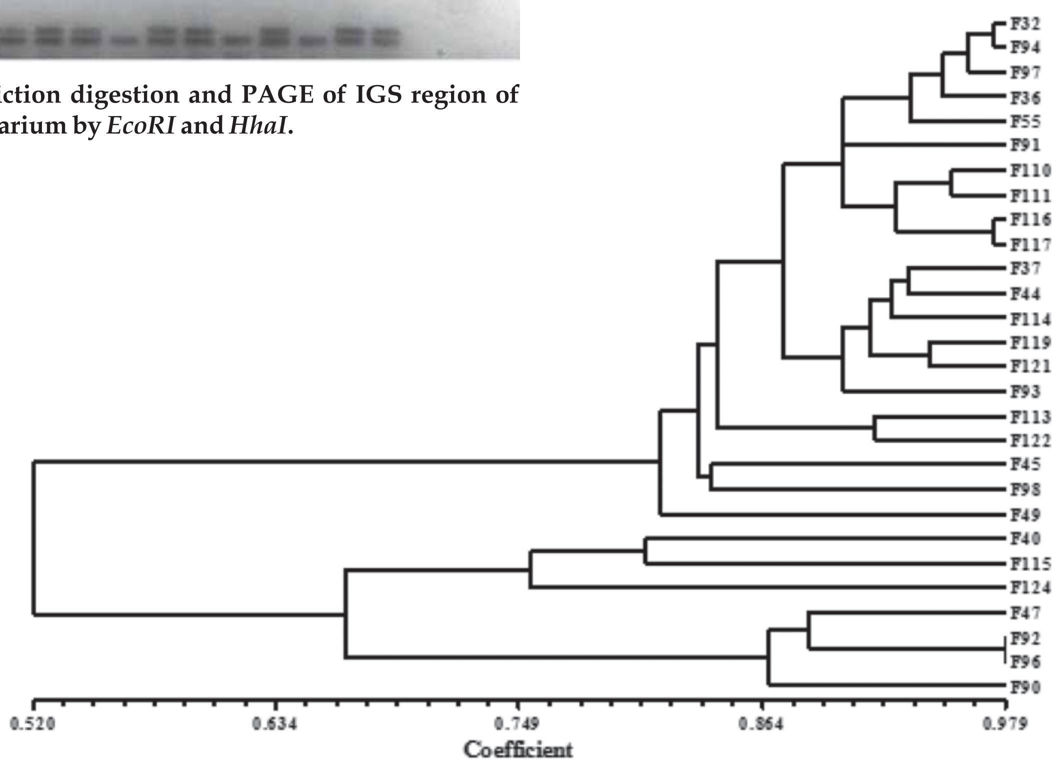


Fig. 28. Polymorphism in Fusarium isolates amplified by 13 RAPD primers

Mayurbhanj, Phulbani, Boudh, Puri, Sambalpur, Bargarh, Deogarh and Sundergarh were morpho-physiologically characterized by testing their pathogenicity on the differential cultivars IR 8(*Xa11*), IR 20(*Xa4*), BJ 1(*xa13*), DV 85(*xa5*+*Xa7*), Cemposelak (*Xa3*) and Java 14 (*Xa1*+*Xa3*) under field conditions. Nine pathotypes *viz*., *xa1* (42 isolates), *xa2* (18 isolates), *xa3* (14 isolates), *xa5* (seven isolates), *xb1* (four isolates), *xb5* (five isolates), *xb4* (three isolates), *xb14* (two isolates), *xf1* (five isolates) were identified based on their reaction on the differentials. Among the pathotypes, *xa1* was the most virulent one which produced the susceptible reaction on all the differential cultivars and the pathotype *xf1* was the most avirulent type showing susceptible reaction only on one variety. The pathotypes *xa2, xa3, xa5, xb1* and *xb5* were the moderately virulent types producing susceptible reaction on 5 and 4 differential cultivars, respectively. The virulence study of the isolates revealed that there was wide variability in the population structure of *Xanthomonas oryzae pv. oryzae* and both the virulent and avirulent types coexisted in the population of the pathogen in a locality.

Morpho-physiological, molecular characterization and development of database for the microflora

The nucleotide sequences of different microflora isolates were submitted to NCBI-Gen Bank and accession numbers were obtained (Table 33).

Table 33. NCBI Gen Bank accession numbers of microbes

NCB I-GenBank accession number	Organism	Description
Endophytes from rice seeds		
JQ039898	*Dendryphiella*	Endophyte associated with seeds of rice landrace Bora Saruchina collected from Jajpur district of Odisha
JQ039897	Unclassified Fungus	Endophyte associated with seeds of rice landrace Rajmali collected from Jajpur district of Odisha
JQ814883	*Leptosphaeria*	Endophytic fungal cultures associated with rice landrace Sanrasi from Mayurbhanj district of Odisha
JQ753708	Unclassified endophytic Fungus	Endophytic fungus growth promoter for rice seedlings and -antagonistic to rice pathogens
Rice pathogens		
JQ753703	*Curvularia spp.*	*Curvularia spp*. causing leaf spots on *Paspalum scrobiculatum* and seedling mortality of rice
JQ039899	*Bipolaris sorokiniana*	*Bipolaris sorokiniana* causal organism of brown spots on scented rice cultivars in Odisha
JQ753704	*Bipolaris sorokiniana*	Seedling mortality in hybrid rice parental lines caused by *Bipolaris sorokiniana*
JQ753705	*Cochliobolus miyabeanus*	Brown leaf spot on rice var. Kalajeera
JQ753706	*Cochliobolus miyabeanus*	Brown leaf spot on rice var. Nua Dhusara
JQ753707	*Cochliobolus miyabeanus*	Seedling mortality in hybrid rice caused by *Cochliobolus miyabeanus*
Biocontrol agents-antagonistic bacteria from cowshed		
JQ753710	*Bacillus vallismortis*	Cowshed bacteria *Bacillus vallismortis* antagonistic to molds and *Fusarium* species
JQ753711	*Bacillus amyloliquefaciens subsp. planta*	Cowshed bacteria *Bacillus amyloliquefaciens subsp. Planta* antagonistic to molds and *Fusarium* species

Quick diagnosis of Rice Tungro Disease (RTD) through molecular marker and other techniques

Six rice cultivars (*viz.,* Annada, IR64, TN1, Jaya, Tapaswini and Shatabdi,) were tested on three different dates of sowing and transplanting during the season . Observations based on visual symptoms were corroborated by insect transmission and the diagnostic was confirmed through PCR test involving specific primers for 'Rice Tungro Bacilliform virus'.

Characterization of sheath blight isolates

The sheath blight disease was artificially inoculated in 1025 test entries on to the sheath of seven plants in each row of in entries. Observations revealed that 55 entries namely, NSN-2 150, 191, 210, 249, 271, 273, 318, 369, 393, 444, 467, 487, 495, 507, 519, 542, 545; HSN27, 71, 84, 90, 114; NSN-H 2, 13, 14, 30, 36, 38, 68, 69, 74 and DSN 6, 39, 42, 60, 67 showed sheath blight symptom in SES score of 0-3.

Molecular characterization of insect pest populations

The genetic variability among 70 yellow stem borer (YSB) populations was assessed using molecular markers. These 70 YSB populations were collected from fifteen districts of Odisha namely, Khurda, Balasore, Puri, Kendrapara, Cuttack, Jagatsinghpur, Mayurbhanj, Deogarh, Sambalpur, Sonepur, Bolangir, Phulbani, Nayagarh, Boudh and Dhenkanal. Ten microsatellite and fifteen rDNA specific markers were used to amplify genomes of the YSB populations. A total of 122 bands were amplified, all being polymorphic. Twenty eight unique bands were identified which will be useful for developing diagnostic marker. Genetic similarity among YSB populations varied from 0.08 to 0.97 with an average of 0.50, indicating that wide genetic variation exists between YSB populations. YSB population in Srikhandpur of Balasore district showed highest genetic similarity with YSB population of Soro in Balasore district while YSB population from Ersama, Jagatsinghpur district showed least genetic similarity with Vellipadia, Balasore district. Cluster analysis using UPGMA, dendrogram classified all the 70 rice YSB populations into three major clusters at 30% level of genetic similarity. All the individual populations of YSB included in the study could be distinguished precisely from each in pair wise comparison over all the 25 primers.

Developing IPM Technologies for Different Rice Ecologies

Studies on Components of IPM

Control of field pests by chemicals and its long term effect in rice environment

Long term pesticide trial

Four formulations of pesticides *viz.*, Cartap @ 1 kg. a.i. ha^{-1} @, Chlorpyrifos @ 0.5 kg a.i. ha^{-1}, Carbendazim @ 1%, and Pretilachor @ 0.75 kg. a.i. ha^{-1} along with untreated control were screened against insect pests of rice during dry season, 2011. Result of the experiment revealed that Cartap (Critap 4G) treatment recorded lowest percentage (4.05%) of dead heart (DH), white ear head (WEH)(4.0%), gundhi bug damage (9.25%), leaf folder (LF) damage (3.12%) and highest grain yield of 5.73 t ha^{-1} in variety Naveen followed by Chlorpyrifos (Suban 1.5% dust).

Result of the experiment during wet season, 2011 also revealed that Cartap treatment recorded lowest percentage of DH (3.87%),WEH (3.62%), gundhi bug damage (8.75%), LF damage (3.0%) and highest grain yield of 5.25 t ha^{-1} in variety Naveen followed by Chlorpyrifos. All other insecticides were found effective against yellow stem borer, LF and gundhi bug. (Table 34). Spider population was highly affected by the application of Pretilachlor (0.5 spider sweep^{-1}) as compared to control (3.0 spiders sweep^{-1}).

Root knot nematode was reduced by 84.3% in Cartap treated plots followed by Chlorpyrifos (81.6%) whereas, rice root nematode was reduced by 69% in Chlorpyrifos treated plots followed by Cartap treated plots (66.3%) compared to control.

Enumeration of microbial population during wet season, 2011 indicated that plots treated with Cartap showed ~20% inhibitory effect to copiotrophs and ~5-10 % to other microbial population with respect to control. Other pesticides *viz.*, Chlorpyrifos, Bavistin and the herbicide Pretilachlor did not affect more than ~5% microbial population.

Testing of new insecticides against insect pests

Eleven of insecticide formulations *viz.*, Imidacloprid 17.8% @ 300g ha^{-1}, Sulfoxaflor 24% @375g ha^{-1}, Sulfoxaflor 24% @313 g ha^{-1}, Thiamethoxam 25%@100g ha^{-1}, Applaud (Buprofezin) 25% @ 700ml ha^{-1}, Acephate 95% SG @ 592 ml ha^{-1}, Dinotefuron 20% @ 200 ml ha^{-}

Table 34. Long term effect of pesticides on insect pest of rice during dry and wet season, 2011

Treatment with % a.i. and dose g ha^{-1}	%DH dry season	%DH wet season	%WEH dry season	%WEH wet season	%LF dry season	%LF wet season	% Gundhi bug damage dry season	% Gundhi bug damage wet season	Yield ha^{-1} dry season	Yield ha^{-1} wet season
Cartap@1kg a.i. ha^{-1}	4.05 (11.60)	3.87 (11.35)	4.00 (11.52)	3.62 (10.97)	3.12 (10.15)	3.00 (9.95)	9.25 (17.69)	8.75 (17.19)	5.73	5.25
Chlorpyrifos @0.5kg a.i. ha^{-1}	4.72 (12.54)	4.12 (11.71)	4.75 (12.58)	4.00 (11.53)	4.00 (11.52)	3.70 (11.08)	9.95 (18.38)	10.12 (18.55)	5.42	5.20
Carbendazim @0.1%	7.27 (15.64)	6.35 (14.59)	7.15 (15.50)	6.30 (14.53)	6.12 (14.32)	5.65 (13.74)	13.0 (21.13)	12.87 (21.02)	5.31	4.88
Pretilachlor @0.75kg a.i. ha^{-1}	7.37 (15.75)	6.50 (14.72)	7.25 (15.61)	6.67 (14.97)	6.50 (14.76)	6.10 (14.30)	13.95 (21.93)	13.30 (21.38)	5.21	4.53
Control	8.32 (16.76)	8.00 (16.42)	8.27 (16.71)	7.90 (16.32)	7.50 (15.88)	7.97 (16.39)	15.42 (23.11)	14.87 (22.68)	4.53	4.26
CD (P=0.05)	0.67	0.39	0.47	0.31	0.83	0.55	0.75	0.76	0.81	0.72

[1], Dinotefuron 20% @ 150 ml ha^{-1}, Acephate 75 SP, @ 800 ml ha^{-1}, Triazophos 40% @ 625g ha^{-1} with Monocrotophos (Monocrown) 36 % a.i. i.e. @ 1390 ml ha^{-1} were screened against insect pest of rice during dry and wet seasons of 2011 on variety Jaya. Results of the experiment revealed that Imidacloprid treatment recorded lowest percentage of DH (3.3%), WEH (3.33%), gundhi bug damage (7.16%) and highest grain yield of 5.28 t ha^{-1} in variety Jaya followed by the treatment Sulfoxaflor 24% @ 375g ha^{-1} with yield of 4.96 t ha^{-1}. All the insecticides were found effective against yellow stem borer (YSB) and gundhi bug. In control, YSB damage was 7.5% DH, 7.63% WEH, gundhi bug damage was 15.43% and the grain yield was 3.25 t ha^{-1} (Table 35).

Sulfoxaflor was also tested against BPH, LF and gall midge under controlled condition. No immediate knock-down effect or persistent toxicity was observed against BPH or leaf folder. However, there was low silver shoot (SS) formation (27%) in comparison to untreated control (82%) but higher SS in comparison to Sutathion and Hostathion (Triazophos). When tested under field condition during dry season of 2012, insecticide application at high brood emergence (15 DAT) reduced DH formation initially to a range of 0.2-0.9% in all the treatments such as Sulfoxaflor (313 and 375 ml ha^{-1}), Hostathion (750 and 1250 ml ha^{-1}), Sutathion (750 and 1250 ml ha^{-1}) and the check insecticide Imidacloprid as against 18% DH in untreated control as evident from the observation at 30 days after transplanting (DAT). But increasing DH formation towards 50 DAT necessitated another foliar application followed by one more foliar spray at panicle initiation stage coinciding with the second brood emergence. Highest yield advantage of 32 and 37% was obtained at both

Table 35. Testing of new insecticide against insect pests of rice in dry and wet seasons of 2011

Treatment	% a.i.	Dose g ha^{-1}	%DH dry season	%DH wet season	%WEH dry season	%WEH wet season	% Gundhi bug damage dry season	% Gundhi bug damage wet season	Yield ha^{-1} dry season	Yield ha^{-1} wet season
Imidacloprid	17.8	300	3.3 (10.46)	3.6 (1093)	3.33 (10.52)	3.6 (10.93)	7.16 (15.52)	6.5 (14.76)	5.28	5.18
Sulfoxaflor	24	375	3.5 (10.78)	4.06 (11.62)	3.5 (10.78)	3.8 (11.24)	7.43 (15.82)	7.33 (15.70)	4.96	4.61
Thiamethoxam	25	100	3.7 (11.09)	4.2 (11.82)	3.7 (11.09)	4.1 (11.68)	7.73 (16.14)	8.16 (16.60)	4.9	4.58
Triazophos	40	625	3.8 (11.14)	4.3 (11.97)	3.86 (11.34)	4.3 (11.97)	8.03 (16.46)	8.66 (17.12)	4.78	4.56
Monocrotophos	36	1390	4.1 (11.68)	4.6 (12.38)	4.1 (11.68)	4.3 (11.96)	8.4 (16.84)	9.16 (17.62)	4.65	4.36
Buprofezin	25	700	4.2 (11.82)	4.7 (12.52)	4.2 (11.82)	4.6 (12.38)	8.4 (16.84)	9.4 (17.85)	4.36	4.23
Acephate	95	592	4.26 (11.92)	4.93 (12.83)	4.46 (12.20)	4.86 (12.74)	8.7 (17.15)	9.6 (18.05)	4.28	4.18
Dinotefuron	20	200	4.5 (12.24)	4.93 (12.81)	4.7 (12.52)	5.2 (13.18)	8.86 (17.32)	10.0 (18.43)	4.26	4.11
Acephate	75	800	4.7 (12.52)	5.5 (13.56)	4.9 (12.79)	5.4 (13.43)	9.2 (17.66)	10.4 (18.81)	4.18	4.00
Dinotefuron	20	150	4.8 (12.65)	5.6 (13.68)	5.26 (13.26)	5.6 (13.68)	9.5 (17.95)	10.63 (19.03)	4.11	3.95
Sulfoxaflor	24	313	5.1 (13.05)	6.1 (14.3)	5.5 (13.56)	5.8 (13.93)	10.13 (18.56)	11.2 (19.55)	3.9	3.91
Control	Water		7.5 (15.89)	8.53 (16.96)	7.63 (16.04)	8.43 (16.87)	15.43 (23.12)	14.93 (22.73)	3.25	3.13
CD (P=0.05)			0.23	0.69	0.27	0.37	0.40	0.34	0.61	0.66

the doses of Hostathion followed by higher dose of Sutathion (31%) over grain yield of 4.83 t ha^{-1} in untreated control.

Chemical control of rice mites

Seven pesticides/miticides have been evaluated against the rice panicle mite, *Steneotarsonemus spinki* Smiley (Tarsonemidae) under field conditions during wet season 2011. Results showed (Table 36) that Profenphos proved to be the best pesticide to manage the panicle mite under field condition. Milbemenctin was found to be the next best pesticide against this mite followed by Diafenthiuron.

Testing the bio-efficacy of new molecules of chemicals against bacterial leaf blight

The bio-efficacy of a new molecule Bactinas 200 (2-bromo-2-nitropropane-3-diol) was tested @ 0.6g ltr^{-1} against bacterial leaf blight on the susceptible variety Tapaswini in wet season 2011 along with two other recommended chemicals – Plantomycin + Copper oxychloride (1 g + 1 g ltr^{-1}) and Streptocycline+Copper oxychloride (150 mg + 1 g ltr^{-1}). After artificial inoculation with a virulent strain of *Xanthomonas oryzae* at the active tillering stage, the chemicals were sprayed just after appearance of the disease symptoms and thereafter two times at weekly intervals. The results showed that the bacterial blight incidence was 37.6%, 33.73% and 32.1%, respectively in the plots applied with Bactinas 200, Streptocycline + Copper oxychloride and Plantomycine + Copper oxychloride compared to the control (93%) with grain yield of 4.77 t ha^{-1}, 5.12 t ha^{-1} and 5.2 t ha^{-1}, respectively as compared to 3.58 t ha^{-1} in the control.

Evaluation of new molecules of fungicides against rice leaf blast

Evaluation of new molecules of fungicides against blast disease of rice was carried out on a susceptible rice variety HR 12. Spraying of the four molecules of the fungicides *viz*., Tricyclazole 75%WP @ 0.6 g, and 1 g; Carbendazim 50%WP @ 2 g Propiconazole 25%EC @1, 2, and 2.5ml and Hexaconazole 5%EC @ 2.5 ml ltr^{-1} of water was carried out thrice at seven days interval. Foliar blast disease was reduced to a minimum of 5% in Propiconazole EC spray @ 2.5 ml ltr^{-1}, and a maximum of 8.5% in Tricyclazole WP treatment @ 0.6 g ltr^{-1}, compared to 80% disease in untreated check. However,

Table 36. Efficacy of certain pesticides against rice panicle mite during wet season, 2011

Treatment	Dose (g a.i. ha^{-1})	Mite population 100 $spikelets^{-1}$*	Per cent grain sterility**	Yield (t ha^{-1})
Milbemectin 1 EC(Milbeknock)	4.5	10.0	16.0	4.5
Abamectin 1.9 EC(Vermectin)	9	22.4	30.6	3.8
Profenphos 50 EC(Curacron)	500	5.4	6.3	4.8
Ethofenprox 10 EC (Treban)	75	15.2	24.0	4.0
Propargite 5.7 EC(Omite)	400	12.1	18.6	4.2
Diafenthiuron (Polo) 50WP	450	10.5	16.2	4.3
Control	-	26.0	35.6	3.4
CD (P=0.05)	-	10.0	14.3	0.66

* = $X^{1/2}$+0.5 transformation of original data; ** =angular transformed value

Table 37. Evaluation of new molecules of fungicides against rice leaf blast

New fungicide	Dosage ltr^{-1}	Foliar Blast (%)	Grain yield t ha^{-1}
Tricyclazole75%wp(Blasto Off)	0.60 g	8.50 (16.9)	2.65
Tricyclazole 75%wp (Blast Off)	1.00 g	8.00 (16.4)	2.70
Carbendazim50%WP (Bavistin)	2.00 g	6.00(14.2)	2.72
Propiconazole25%EC (Tilt)	1.00 ml	5.80(13.9)	2.60
Propiconazole25%EC (Tilt)	2.00 ml	5.50(13.5)	2.65
Propiconazole25%EC (Tilt)	2.50 ml	5.00(12.9)	2.68
Hexaconazole5%EC (Contaf)	2.50 ml	7.00(15.3)	2.70
Control	-	80.00(63.5)	1.21
CD (P=0.05)		2.6	0.20

Data in parentheses are angular transformed values of % blast infection.

grain yield was recorded highest (2.72 t ha^{-1}) in Carbendazim 50%WP @2 gm ltr^{-1} treated plot compared to 1.21 t ha^{-1} in the control plot (Table 37).

Synthesis and characterization of bio-degradable polymer-pesticide composites

Chitosan-formaldehyde (2.5% Chitosan solution in 100 ml of distilled water + 100 g commercial grade Furadon-3G) cross linked compounds were prepared by taking 5.00%, 7.50% and 10.00% formaldehyde. The jelly like mass was dried at 60° C to form coated carbofuran (Furadon 3G) granules. The absorbance maxima of furadon 3G was confirmed by UV spectroscopy and was found to be l_{max} = 238 nm. Preliminary release studies revealed that the formulation CF-F10 (Chitosan+Furadon+Formaldehyde 10%) exhibited a prolonged release compared to that of the other formulations.

Faunal diversity and utilization of predators, parasites and pathogens for management of insect pests of rice

Three bio-pesticides, based on *Verticillium lecani, Metarhizium anisopliae, Beauveria bassiana* and three granular insecticides *viz*., Cartap, Carbofuran, Phorate were applied in the rice field to study its effect on faunal diversity. It was observed that nine species of arthropods were observed in plots treated with Cartap compared to eleven species in control. In other treatments the species richness varied from six to eight. Maximum number of spiders (3.7 spiders sweep^{-1}) were also observed in plots treated with Cartap and on par with control. Phorate affected species abundance negatively. Results in the field testing of the bio-pesticides indicated that formulation of *M. anisopliae* could reduce the larval population of *Cnaphalocrocis medinalis* (Guen.) to two larvae hill^{-1} compared four larvae hill^{-1} in control. The population of predatory spiders and odonates were least affected under this treatment. Under green house condition nymphal survival of WBPH was minimum (60%) five days after the treatment of *M. anisopliae* formulation.

Faunal diversity under SRI and extent of egg parasitism of yellow stem borer

Faunal diversity was studied on variety Lalat in the field during both the season with emphasis on pests and predators. During wet season yellow stem borer attack was 6.68% DH at vegetative stage under SRI, while it was 9.12% in the non-SRI plot. During dry season, DH was 10.16% under SRI and 20.95% in conventional plot indicating prevalence of unfavourable conditions for YSB attack under SRI.

Eighteen species of arthropods were observed on Lalat under conventional method of cultivation compared to 13 species under SRI during wet season. GLH population was 22 insects sweep^{-1} under conventional method of cultivation compared to 12 insects under SRI. Among the predators average spider population was 5.5 spiders sweep^{-1}, 4.5 damselflies sweep^{-1} under SRI as compared to 3.5 spiders sweep^{-1} and 3.3 damselflies sweep^{-1} under conventional method of cultivation.

During 4th week of October 48% egg mass wise parasitism due to *Telenomus dignoides* (Nixon) was observed in the field followed by 25% parasitism by *Tetrastichus schoenobii* (Ferr.). By the end of November the extent of parasitism declined. During wet season in the 2nd week and 3rd week of February, parasitism due to *T. dignoides* was as high as 65% on egg mass basis followed by *Trichogramma japonicum* (Ashm.)(12.5%), *T. dignoides* was the dominant parasitoid during both the seasons.

Pheromones and botanical grain protectants against rice storage insects

In the CRRI Farm godown (Dry season -2011 harvest) having about 200 paddy bags, pheromone for *Sitotroga cerealella* (Oliv.) [(Z6-E11)16Ac] was evaluated using greased plastic trays to trap and kill purpose during August-2011. There were seven traps at equal distance. Number of male moth trapped ranged from 128-496 trap^{-1} within 24 hrs of placement. Periodical observations showed that there was a sharp decline in moth population after one week and moth catch reduced by 96.48% on 20th day of the trappings (Table 38).

Greased plastic trays as pheromone trap for Sitotroga cerealella

Table 38. Population of the paddy moth collected in different traps

Date	Trap 1	Trap 2	Trap 3	Trap 4	Trap 5	Trap 6	Trap 7	Total Catch*
07/08/2011	136	102	76	93	107	112	84	710
08/08/2011	121	97	71	87	99	103	77	655
09/08/2011	113	88	66	82	87	95	71	602
10/08/2011	102	71	63	76	81	84	69	546
11/08/2011	86	63	57	69	76	76	63	490
14/08/2011	73	56	51	61	67	61	52	421
15/08/2011	67	48	43	57	61	57	47	380
16/08/2011	61	32	37	48	56	48	43	325
17/08/2011	49	24	31	42	43	41	39	269
18/08/2011	43	19	31	37	37	39	33	239
21/08/2011	37	16	24	31	29	33	28	198
22/08/2011	34	16	19	24	23	27	24	167
23/08/2011	29	13	16	21	19	22	19	139
24/08/2011	21	09	11	18	13	17	13	102
25/08/2011	13	03	07	10	09	09	07	58
27/08/2011	09	01	03	03	02	03	04	25
Total catch **	993	658	604	759	809	827	673	5306

*- Date-wise total catch, **-Trap-wise total catch

Eight botanical oils *viz*., Til (*Sesamum indicum* L.), Karanja (*Pongamia glabra* Vent.), Bael (*Aegle marmelos* Corr.), Castor (*Ricinus communis* L.), Citronella (*Cymbopogon citratus* DC. Stapf.), Crown oil (resin of *Shorea robusta* Roth.), Mustard (*Brassica campestris* L.) and Groundnut (*Arachys hypogea* L.) were extracted using Clevenger oil extraction apparatus and tested against paddy moth, *Sitotroga cerealella* under controlled conditions on variety Ratna. The oil of citronella and crown oil could effectively protect the stored paddy from this pest for six months (Table 39).

Management of root-knot nematode using botanicals

Leaves of 50 plants were tested against rice rootknot nematode @ 5 and 10 t ha^{-1}. These were incorporated in to soil in pot culture experiment. Number of galls per gram of root was counted to compute the gall index. Based on the gall index the plants were categorized to highly effective, effective and ineffective. *Argimone mexicana* L., *Calotropis procera* Aitan, *Tamarindus indica* L. and *Strychnos nux vomica* L. were found to be highly effective. In the nematode infected fields fresh leaves of

Table 39. Evaluation of botanical oils against paddy moth *Sitotroga cerealella*

Treatment	Moth population 45 DAR		Moth population 90 DAR		Moth population 180 DAR	
Til	169.5	(13.03)	710	(27.75)	2010	(44.83)
Karanja	54.50	(07.41)	240	(15.50)	650	(25.50)
Bael	79.50	(08.94)	326	(18.06)	870	(29.50)
Castor	110.5	(10.51)	450	(21.22)	1170	(34.21)
Citronella	20.50	(04.58)	93	(09.66)	201	(14.19)
Crown	22.00	(04.74)	110	(10.51)	316	(17.79)
Groundnut	163.50	(12.78)	723	(26.89)	1650	(40.62)
Mustard	160.50	(12.64)	650	(25.50)	1390	(37.28)
Control	220	(14.84)	880	(29.67)	2800	(52.91)
SD at 5%		4.67		7.98		11.73

DAR= days after release; Initial grain moisture-16%
Data in parenthesis are "X+0.5 transformation of original value
Dose @ 0.5% v/w; Initial release 5 pairs of moths

Table 40. Effect of botanicals on management of blast disease

Variety & Treatment	% leaf area affected	Yield (t ha^{-1})
Dry Season 2011		
Chandrama & Bael leaf extract	28.92 (32.53)	4.08
Chandrama & Tulsi leaf extract	27.16 (31.41)	4.14
Chandrama & Blast Off	31.80 (34.33)	4.01
Chandrama (Control)	63.24 (52.68)	3.42
Mahsuri & Bael leaf extract	38.75 (38.50	4.16
Mahsuri & Tulsi leaf extract	40.22 (39.36)	3.88
Mahsuri & Blast Off	42.17 (40.50)	3.77
Mahsuri (Control)	67.38 (55.17)	3.11
Joymati & Bael leaf extract	28.82 (32.47)	4.12
Joymati & Tulsi leaf extract	34.56 (36.01)	3.40
Joymati & Blast Off	30.24 (33.36)	3.47
Joymati(Control)	70.12 (56.86)	2.98
CD 5% (Variety)	11.85	0.78
CD 5% (Treatment)	10.95	0.52
Wet season 2011		
Mahsuri & Bael leaf extract	27.61 (31.70)	4.18
Mahsuri & Tulsi leaf extract	30.44 (33.49)	3.96
Mahsuri & Blast Off	33.67 (35.47)	3.83
Mahsuri (Control)	71.28 (57.59)	3.10
Panchanan & Bael leaf extract	42.63 (40.76)	4.21
Panchanan & Tulsi leaf extract	39.76 (39.09)	4.38
Panchanan & Blast Off	44.52 (41.85)	3.92
Panchanan (Control)	68.16 (55.56)	3.48
Pratikshya & Bael leaf extract	29.92 (33.16)	3.83
Pratikshya & Tulsi leaf extract	35.10 (36.33)	3.64
Pratikshya & Blast Off	32.84 (34.96)	3.77
Pratikshya (Control)	66.77 (54.80)	3.52
CD 5% (Variety)	9.56	0.71
CD 5% (Treatment)	10.66	0.82

these plants can be incorporated in to soil @ 5 t ha^{-1} at the time of final land preparation to reduce galling.

Management of blast and sheath blight diseases through botanicals

Bio-efficacy of two botanical products namely leaf extracts of bael (*Aegle marmelos*) and tulsi (*Ocimum sanctum L.*) with standard fungicide Blast Off (Tricyclazole 75% W.P) for management of blast disease was tested on rice varieties Chandrama, Mahsuri and Joymati during wet/*boro* season, 2011 and on varieties Mahsuri, Panchanan and Pratikshya during wet/*sali* season 2011. Out of four treatments including control, extract of fresh leaves of bael @ 25g fresh leaves ltr^{-1} of water (by grinding to a paste), extract of fresh leaves of tulsi (by boiling) @ 25 g ltr^{-1} of water and fungicide Blast Off @ 0.6 g ltr^{-1} of water were sprayed two times at 15 days' interval starting from 10 days of disease appearance.

Results indicated that bael leaf extract in varieties Mahsuri and Joymati, and Tulsi leaf extract in Chandrama reduced the foliar blast and increased the grain yield significantly than the untreated check (Table 40). During wet season, the treatment bael leaf extract in Mahsuri and Pratikshya and Tulsi leaf extract in Panchanan significantly reduced the foliar blast and increased the grain yield than the untreated check.

Standardization and development of botanical formulations and assessment of new plant sources as fungi toxicant

Aegle marmelos ethanolic mother extract (EME) in combination with a biodegradable formulating agent from Merck, FA (B+) , at 0.1% concentration with EME in all combinations and 0.0001% to 0.1% of EME concentration exhibited complete inhibition (2%) of *Pyricularia grisea* conidial germination (Table 41) and at 1% in *Helminthosporium oryzae* and *Curvularia lunata*, respectively with all tested combinations of EME. Varying degree of fungitoxic pattern such as, complete inhibition, reduction and granulation in germ tube, highly branched, elongated, and thickened germ tube. Control registered normal 98% conidial germination (Fig. 29).

a. Distortion in *C. lunata* coinidia

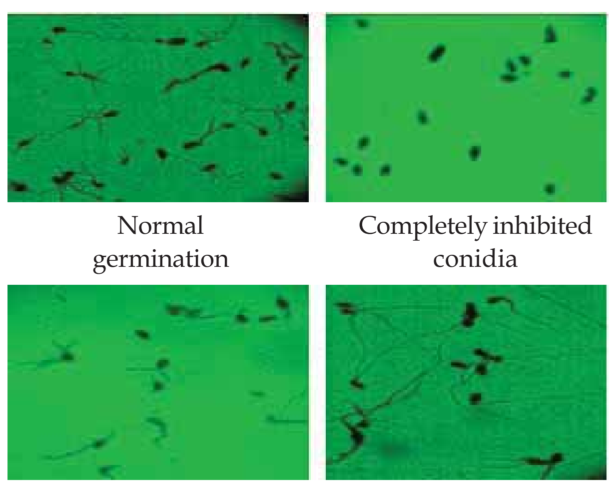


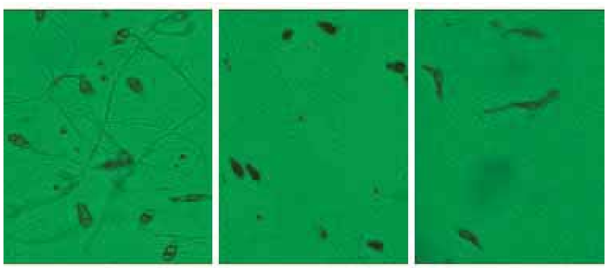
Fig. 29. Varying degree of fungitoxic pattern in *(a) C. lunata* conidia, ***(b) P. grisea*** and ***(c) H. oryzae***

Table 41. Fungitoxicity of aqueous extract of *Aegle marmelos*, mother extract (AME)/in combination with formulating agent FA(B^+) on conidial germination of *Pyricularia grisea*

Treatment (FA/AME)	Concentration (%)						
	10%	1%	0.1%	0.01%	0.001%	0.0001%	Control(FA)
	Conidial germination (%)						
10%	2 (8.13) *	2 (8.13) *	2 (8.13) *	2 (8.13) *	2 (8.13) *	2 (8.13) *	2 (8.13) [a]
1%	2 (8.13) [a]	2 (8.13) [a]	2 (8.13) [a]	2 (8.13) [a]	2 (8.13) [a]	2 (8.13) [a]	2 (8.13) [a]
0.1%	2 (8.13) [a]	2 (8.13) [a]	2 (8.13) [a]	2 (8.13) [a]	2 (8.13) [a]	2 (8.13) [a]	2 (8.13) [a]
0.01%	2 (8.13) [a]	2 (8.13) [a]	30 (33.21)[bg]	55 (47.57) [bg]	65 (53.73) [b]	70 (56.79) [b]	80 (63.44) [b]
0.001%	30 (33.21)[bg]	70 (56.79) [c]	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)
0.0001%	50 (45.00) [c]	95 (77.08)[c]	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)
Control(AME)	2 (8.13) *	2 (8.13) [a]	50 (45.00) [bg]	70 (56.79) [C]	98 (81.87)	98 (81.87)	
Control(sterilized d.w.)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	
C.D. 5%-0.21							

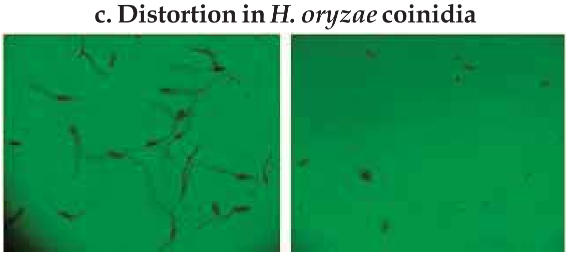
Data in parentheses represents angular values; Complete inhibition is represented as 2%; *=complete bursting; a= ungerminated conidia; b= reduced germ tube; g= granulated germ tube; c= longer germ tube; AME=aqueous mother extract; FA= formulating agent

b. Distortion in *P. grisea* coinidia

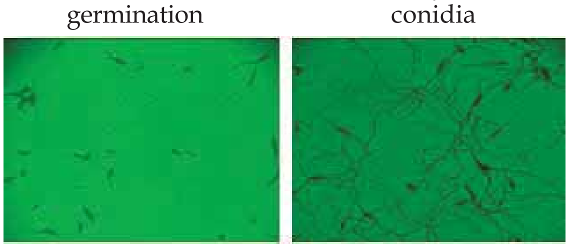


Normal germination — Ungerminated coinidia — Reduced & granulated germ tube

c. Distortion in *H. oryzae* coinidia



Normal germination — Completely inhibited conidia



Reduced germ tube — Excessively longer and highly branched germ tube

Fungitoxic spectrum of twelve new plants *viz*., *Thevetia peruviana* L., *Mollugo pentaphylla* Linn., *Moringa oleifera* Lam., *Vitex negundo* L., *Citrus limon* L., *Murrya koenigii* L., *Callistemon viminalis* Gaertn., *Phyllanthus emblica* L. was tested in ethanolic extract (1:4 w/v) and *Euphorbia hirta* L., *Ageratum conyzoides* L., *Physalis minima* L., *Phyllanthus niruri* L. was tested as a series of solutions ranging from 0.001 to 100% concentration in aqueous extract (1:4 w/v) against the primary inoculum, conidia of *P. grisea*, *H. oryzae, C. lunata* and *Fusarium moniliforme,* respectively. All the treatments drastically reduced conidial germination at and above 0.1% concentration and from 1% concentration in except *C. limon* and *C. viminalis*, ethanolic extract which displayed higher reduction in *P. grisea*. Critical fungi toxic pattern such as granulation, reduction/elongation, thickening, coiling, bulbular structure at the base of germ tube and highly branched germ tube was observed in treated conidia compared to normal germination in control.

Identification of effective botanicals and their evaluation against blast

Six plant extracts of commonly occurring grasses and weeds (Australian Grass, *Cynodon dactylan* with and without roots, *Parthenium, Lantana and Ipomea*) along with control as chemical check were evaluated under field condition against brown spot of rice in upland. Preliminary study on the efficacy of the fresh plant extracts revealed that they have potential to control brown

Table 42. Effect of bio-control agents on sheath blight disease during dry and wet seasons, 2011

Variety & Treatment	Disease incidence (%)	Yield (t ha^{-1})
Dry Season 2011		
Jaya & *T. viride*	29.81 (33.09)	3.96
Jaya & *P. fluorescens*	37.65 (37.85)	3.82
Jaya & Sheathmar-3	44.90 (42.07)	3.91
Jaya (Control)	72.42 (58.32)	3.28
Joyamati & *T. viride*	31.63 (34.22)	3.88
Joyamati & *P. fluorescens*	27.30 (31.50)	4.05
Joyamati & Sheathmar-3	44.88 (42.06)	3.56
Joyamati (Control)	74.51 (59.68)	3.02
Chandrama & *T. viride*	30.76 (33.68)	4.23
Chandrama & *P. fluorescens*	38.50 (38.35)	4.18
Chandrama & Sheathmar-3	42.92 (40.93)	3.97
Chandrama (Control)	71.28 (57.59)	3.66
CD 5% (Variety)	(11.87)	0.81
CD 5% (Treatment)	(10.97)	0.57
Wet season 2011		
Tapaswini & *T. viride*	36.47 (33.09)	4.54
Tapaswini & *P. fluorescens*	39.65 (37.85)	4.28
Tapaswini & Sheathmar-3	45.71 (42.07)	4.06
Tapaswini Control)	80.72 (58.32)	3.52
Mahsuri & *T. viride*	32.54 (34.22)	3.91
Mahsuri & *P. fluorescens*	28.80 (31.50)	4.26
Mahsuri & Sheathmar-3	46.63 (42.06)	4.20
Mahsuri (Control)	78.44 (59.68)	3.58
Pratikshya & *T. viride*	34.42 (33.68)	4.35
Pratikshya & *P. fluorescens*	37.26 (38.35)	4.28
Pratikshya & Sheathmar-3	42.51 (40.93)	4.11
Pratikshya (Control)	72.60 (57.59)	3.61
CD 5% (Variety)	(12.29)	0.77
CD 5% (Treatment)	(12.49)	0.69

spot under field conditions to an extent of 20% over control. The plant extracts were non-significant with each other but significant with the control. Minimum disease intensity ranged from 15.09-26.89% within the plant extracts compared to disease intensity of 32.22% in the control plot.

Evaluation of bio-control agents for management of sheath blight

The efficacy of bio-control agents, *Trichoderma viride* and *Pseudomonas fluorescens* along with standard fungicide Sheathmar-3 (Validamycin 3%) was tested in a field trial for the management of sheath blight during dry season, 2011 on the varieties Jaya, Joymati and Chandrama, and during wet season, 2011 on varieties Tapaswini, Mahsuri and Pratikshya. Treatment of *T. viride* on varieties Jaya, Chandrama and *P. fluorescens* on Joymati during dry season, significantly reduced the sheath blight disease incidence and increased the grain yield. But during wet season, treatment of *T. viride* on Tapaswini and Pratikshya significantly reduced the sheath blight incidence and increased the grain yield (Table 42).

Development, Evaluation and Validation of IPM Modules for Different Rice Eco-systems

Insect pest management under rainfed upland situation at Cuttack

A field trial was conducted for insect pest management in upland rice during wet season 2011 at village Banipada, Tangi-Chaudwar block, Cuttack. Two varieties, one local variety and a high yielding variety Anjali were grown in the trial. IPM practices involved seed treatment with Chlorpyrifos 20EC @ 3.75 lit $100kg^{-1}$ seed, herbicidal application of Pretilachlor @ 0.75 kg a.i. ha^{-1} at 3 days after sowing and application of Monocrotophos 36EC @ 0.5 kg a.i. ha^{-1} at ETL, fixing of

Table 43. Testing of IPM module in rainfed upland during Wet season, 2011

Treatment	% Dead heart	% White ear head	% Gundhi bug damage	% Termite damage	Yield t ha^{-1}
Anjali with IPM	4.05 (11.60)	4.5 (12.24)	8.75 (17.19)	5.3 (13.028)	2.85
Anjali without IPM	7.5 (15.88)	7.67 (16.07)	14.75 (22.58)	9.75 (18.18)	1.90
Brown Gora with IPM	4.42 (12.13)	4.75 (12.57)	7.87 (16.29)	5.25 (13.52)	2.10
Brown Gora without IPM	8.0 (16.42)	7.87 (16.29)	16.00 (23.57)	10.25 (18.66)	1.15
CD (P=0.05)	0.95	0.90	0.78	1.37	0.42

Value in parentheses indicate angular transformed values pheromone traps 20 ha^{-1} for mass trapping of YSB and release of *Trichogramma japonicum* @ 100,000 ha^{-1}. The results of the trial revealed that least incidence of dead heart (DH) 4.05 %, WEH 4.5%, gundhi bug damage 8.75% and termite damage 5.3% were recorded under IPM practice in variety Anjali with highest grain yield of 2.85 t ha^{-1}. This treatment was found to be better than that of farmer practice/non-IPM in reducing the insect damage and increasing the grain yield in both the varieties (Table 43). The increased benefit cost ratio was found to be highest (2.65) for Anjali (IPM) vs. Brown gora (non-IPM), whereas, it was 1.66 in Anjali under IPM vs. Non-IPM and 1.55 in Brown gora IPM vs. Non-IPM.

IPM in upland rice at Hazaribag and Chatra

Integrated pest management was conducted in village- Sigrawan, District Hazaribag in an area of 20 acres involving 32 farmers with IPM interventions, five acres Non IPM (farmers' practice) and six acres in village Pandani, District Chatra. IPM interventions were, application of pre-emergence herbicides, seed dressing with fungicides and need based spray of fungicides and insecticides. Variety Anjali was taken for the IPM interventions in both the villages with the local variety Dhusari for Non IPM (farmers practice). Average yield under IPM interventions was 3.58 t ha^{-1}, whereas, under farmers' practices yield was 1.86 t ha^{-1} in village Pandani with benefit cost ratio of 1.89 (IPM) and 1.73 (Non IPM). In Sigrawan the yield was 2.21 t ha^{-1} in IPM and 1.32 t ha^{-1} in Non IPM with benefit cost ratio of 1.24 (IPM) and 1.19 (Non IPM). In IPM fields, gundhi bug infected panicles were 4 m^{-2} while it was 10 m^{-2} in Non-IPM fields. Weed infestation was 46 g m^{-2} in IPM and 132 g m^{-2} in Non IPM, respectively at Pandani. In general, the yield was higher in Pandani due to normal rainfall and better soil fertility with good water holding capacity in comparison to Sigrawan.

Bio-intensive IPM for irrigated rice

Under irrigated ecosystem, variety Naveen was transplanted during dry seasons of 2011 and 2012. Experiments were designed for IPM and insecticide treatments along with untreated control. Yellow stem borer (YSB) was the major pest during both the years. Pheromone trapping of male moths indicated two broods during 2011 with peak emergence at 7th standard meteorological week (SMW) and 14th SMW. During 2012, brood emergence with three peaks was observed at 3rd, 6th and 13th SMW (Fig. 30). The early brood (3rd SMW) caused severe infestation to the initial crop stage whereas, continuous YSB population up to last week of April (17th SMW) damaged later stage of the crop.

Need-based application of 0.5% neem oil as foliar spray along with standing water application of bio-mixtures (Neem, Karanj and Kochila seed powder in the proportion of 3:2:1) @25 kg a.i. ha^{-1} at 20 DAT coinciding with brood emergence could reduce the dead heart (DH) formation up to 35.7% and 29.3% during 2011 and 2012, respectively. Second application of bio-mixture at PI stage reduced white ear head formation to about 50% as compared to 100% in untreated control. Yield advantage of 25% was achieved through bio-intensive IPM over untreated control. The efficacy was on par with the treatment of seedling root dip (SRD) in 0.02% Chlorpyrifos solution followed by a foliar spray of Chlorpyrifos @ 0.5 kg a.i. ha^{-1} at 20 DAT + Cabofuran at PI stage (2012) but was inferior to SRD + granular application of Carbofuran @1 kg a.i. ha^{-1} both at 20 DAT and at PI stage of the crop (2011). Observations on spider population at reproductive stage indicated 4 spiders $sweep^{-1}$ in IPM plot, 3.0 spiders $sweep^{-1}$ in control plot and 1.0 spider $sweep^{-1}$ in insecticide treated plots.

IPM package in rainfed shallow favourable lowland rice with emphasis on botanicals

Variety Pooja was grown with 3 treatments such as IPM (two foliar sprays of 1% neem oil, one at 20 DAT

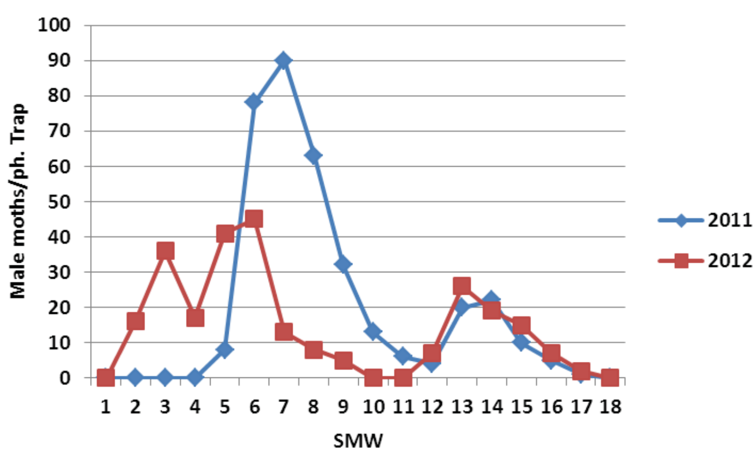


Fig. 30. Population of male yellow stem borer moths in pheromone trap during dry season

Experimental field showing severe YSB damaged and protected plots during dry season, 2011

for hispa and another at 75 DAT for leaf folder and standing water application of bio-mixture (Neem, Karanja & Kochila seed powder @ 25 kg ha^{-1} at the PI stage for YSB) and insecticide along with untreated control. Pest incidence comprised of low incidence of hispa during last week of July to 3rd week of August, moderate to severe incidence of leaf folder during 1st-last week of October and low but continuous incidence of YSB during 3rd week of September-last week of November. Hispa and YSB damage (WEH) were negligible in IPM plots whereas, damage due to leaf folder was 11% as against 45% in untreated control. A yield advantage of 23.6% was realized under IPM treatment over untreated control.

During wet season 2011, scented variety Ketkijoha was grown for evaluation of botanicals against insect pests. Severe infestation of hispa was recorded with 90.7% leaf damage $hill^{-1}$ in untreated control towards 2nd week of September. Coinciding with the initiation of hispa infestation at 30 DAT foliar spray of 1% neem oil provided maximum protection of 26.9% leaf damage.

IPM package for hybrid rice

Seed treatment with carbendazim 2 g kg^{-1} and need based chemical control were made during the season. Leaffolder incidence on rice hybrid Rajalaxmi was 9.6% leaf damage, whereas on Lalat it was 8.5% under protected condition compared to 16.2% and 18.0% on Rajalaxmi and Lalat, respectively under unprotected condition. Indoxacarb @ 30 g a.i. ha^{-1} successfully controlled the damage due to leaf folder. Whorl-maggot damage to the extent of 8.0% was observed on Rajalaxmi compared to 2.5% on Lalat. Incidence of white ear head caused by stem borer was 4.5% only, which was below ETL. The crop was under flood water for four days during September. Grain yield recorded was 6.4 t ha^{-1} and 4.9 t ha^{-1} in Rajalaxmi and Lalat, respectively under protected condition compared to 6.1 t ha^{-1} and 3.8 t ha^{-1} in Rajalaxmi and Lalat, respectively under no protection.

Dissemination of rice IPM technologies in farmers' field

An IPM trial under CRRI-NCIPM collaborative project was conducted in the farmers' paddy fields on variety Pooja during wet season of 2011 at village Sighmapur, district Cuttack having 35 acres of land area, where 5 acres plot was kept as control. IPM interventions were seed treatment with Bavistin @ 2g kg^{-1} seed, followed by another scheduled granular application of Cartap 4 G @ 1 kg a.i. ha^{-1} at 30 DAT. Foliar application of Bavistin 2 g ltr^{-1} was also given one week before panicle initiation stage as a prophylactic measure against false smut. Plantomycin 1g ltr^{-1} along with copper oxychloride 2 g ltr^{-1} was sprayed just at the appearance of BLB symptoms during active tillering stage.

Periodical survey for pests and diseases revealed that the incidences of YSB, LF, false smut and BLB were ranging from 1-5% in IPM fields except for BLB, where it was 5-8% as against 5-25% disease and pest incidence under farmers' practice. Grain yield recorded under IPM was 1.3 t ha^{-1} more than the non-IPM field (Table 44). The B:C ratio was also more under IPM (3.14) as compared to farmers' practice (2.37).

Table 44. Pesticide application, yield and economics under IPM and farmers' Practices

Variables	IPM	FP
No. of Pesticide sprays	2	Nil
Total cost (Rs. ha^{-1})	17320.00	13960.00
Mean Yield (t ha^{-1})	5.3	4.0
Total returns (Rs. ha^{-1})	54399.00	33113.00
Net returns (Rs. h^{-1})	37079.00	19153.00
Benefit Cost Ratio (Total returns/total cost)	3.14	2.37

(Rate of paddy Rs.1080 - per q)

Socio-economic Research for Sustainable Development

Database Creation

Creation of database on rice related information

Analysis of data on area, production and yield during ninth, tenth five year plans and for the period 2005 to 2009 revealed that the production growth at all India level has declined in tenth plan as compared to ninth plan. However, the growth has regained during the period 2005-2009. This production growth has largely contributed to growth in yield. The states like Andhra Pradesh, Haryana, Punjab have performed better than other states during the period. The states like Assam, Bihar, Kerala, Tamil Nadu and Uttar Pradesh did not perform well during tenth plan in comparison to other periods due to reduction in area and/or negative growth in yield. The growth rate in production of states like Gujarat, Karnataka, Madhya Pradesh and Odisha was more than seven per cent during tenth plan due to excellent yield improvement. Although the states like Maharashtra and West Bengal performed better during tenth plan period in improving production growth rate. During 2005-09, the production growth decelerated due to decrease in yield growth rate (Table 45).

Impact Analysis and Adoption Strategies for Various Ecosystems

Extent of adoption of rice production technologies, their appropriateness and constraints as perceived by growers

A representative sample consisting of 100 farmers having rice in the irrigated shallow to semi-deep lowland ecosystem and exposure to CRRI rice varieties was constituted from the Salipur block of Cuttack district. The extent of adoption of CRRI rice varieties and their appropriateness were studied on four selected parameters i.e., social, economical, environmental and technological. For each parameter, farmer's response was taken. Scores were assigned accordingly which were used to get final mean appropriateness score. The mean appropriateness score of all the selected parameters for each individual were further averaged to arrive at overall mean appropriateness score. Based on the mean

Table 45. State-wise growth rate of area, production and yield of rice

States	Area during			Production			Yield		
	IX plan	X plan	05-09	IX plan	X plan	05-09	IX plan	X plan	05-09
Andhra Pradesh	1.61	0.72	4.46	5.20	2.16	6.54	3.54	1.44	2.00
Assam	1.18	-2.36	-0.04	4.14	-3.52	1.66	2.92	-1.19	1.71
Bihar*	0.02	-2.30	1.89	0.94	-6.05	9.22	0.93	-3.84	7.20
Gujarat	-0.01	5.09	2.24	-4.24	17.15	1.91	-4.23	11.47	-0.32
Haryana	5.63	1.34	3.11	7.27	2.81	3.86	1.56	1.45	0.73
Karnataka	2.32	1.23	3.03	3.58	10.11	-2.56	1.23	8.77	-5.42
Kerala	-5.47	-4.02	-5.22	-3.00	-2.58	-2.61	2.61	1.50	2.75
Madhya Pradesh*	0.31	-0.61	-0.62	-0.26	7.23	-1.07	-0.57	7.89	-0.46
Maharashtra	0.42	0.06	0.14	-1.18	3.40	-0.06	-1.60	3.34	-0.20
Odisha	0.11	0.43	-0.30	-0.44	7.69	1.69	-0.56	7.24	1.99
Punjab	4.23	1.08	0.68	5.06	3.81	1.84	0.79	2.70	1.15
Tamil Nadu	-0.35	1.37	0.55	4.22	-0.65	3.27	4.59	-1.99	2.70
Uttar Pradesh*	2.55	-0.59	0.48	2.80	-1.79	2.32	0.25	-1.21	1.83
West Bengal	-0.02	-0.30	-0.11	2.10	0.91	0.10	2.13	1.21	0.21
All India	0.96	-0.26	0.80	2.55	1.79	2.35	1.58	2.06	1.54

* - Undivided states

Table 46. Extent of adoption of CRRI rice varieties by the farmers

Name of Variety	Farmers adopted under different categories (f)				Total rice area of the responders, wet season 2011 (ha)	Area under different varieties, wet season 2011(ha)	Extent of adoption in terms of Area
	Small (n=58)	Medium (n=30)	Large (n=12)	Total (N=100)			
Pooja	36 (90.00)	48(92.31)	4 (50.00)	88 (88.00)	86.02	39.55	45.75%
Sarala	28 (70.00)	48 (92.31)	8(100.00)	84(84.00)		34.59	40.21%
Durga	4 (10.00)	12 (23.08)	8 (100.00)	24 (24.00)		12.08	14.04%

(Figures in the parentheses indicate percentage)

appropriateness score three categories of appropriateness were developed *viz.*, 'very appropriate' (score more than 2.4), 'somewhat appropriate' (score 1.8 – 2.4) and 'less appropriate' (score less than 1.8).

The data relating to the extent of adoption of CRRI rice varieties by the farmers revealed that majority (88%) of farmers adopted rice variety Pooja followed by Sarala (84%) and Durga (24%). The extent of adoption in terms of area was highest for Pooja (45.97%) followed by Sarala (40.21%) (Table 46).

The findings on appropriateness of CRRI rice varieties revealed that rice variety Pooja was found to be most appropriate with score 2.83 among the three widely adopted lowland varieties as perceived by the rice growers (Table 47).

Further analysis revealed that the rice variety Pooja was found to be 'very appropriate' as perceived by highest percentage of farmers (89) followed by 11% as 'somewhat appropriate'. Regarding the perceived appropriateness of rice variety Sarala it was found to be 'very appropriate' by highest percentage of farmers (86) whereas, in case of rice variety Durga highest percentage (60) of farmers perceived it as 'somewhat appropriate' for their land situation. The variety Pooja was found to be most appropriate CRRI variety as perceived by the farmers under study.

Table 47. Appropriateness of CRRI rice varieties as perceived by the rice growers (N=100)

Parameters of Appropriateness	CRRI rice varieties		
	Pooja	Sarala	Durga
Social appropriateness	2.35	2.55	2.25
Economic appropriateness	3.00	2.80	2.50
Environmental appropriateness	3.00	2.75	2.35
Technological appropriateness	3.00	2.80	2.45
Total	2.83	2.72	2.38

Prediction of requirement of quality seeds of rice by the farmers of different ecosystems in India

In the second phase, the study was conducted by gathering data on indirect preferences of farmers of Chhattisgarh and Jharkhand under different ecosystems for rice seeds.

Chhattisgarh State

During dry season, the single most preferred variety of rice by the farmers was MTU 1010. During wet season 2011-12, the preferred upland varieties of rice by the farmers of Chhattisgarh in decreasing order of preference were MTU-1010, IR-36, Danteswari, Samaleswari, Narendra Dhan-97 and Poornima. The preferred medium land varieties of rice in decreasing order of preference were MTU-1001, Mahamaya, IR-64, Bamleshwari, HMT, KRH-2(Hybrid), Shatabdi, Tapaswini, Chandrahasini, Anjali, Indira Sona, Indira Sugandhit Dhan and Pusa Basmati-1. The lowland rice varieties in decreasing order of preference were MTU-7029, Karma Mahsuri, BPT-5204, MTU-1032, Kasturi, Mahsuri, BPT-3291 and Krishna Hamsa. CRRI rice varieties *viz.*, Shatabdi, Tapaswini, Anjali were found to be prominent in the seed chain.

Jharkhand State

During dry season, out of 24 districts, rice was grown only in fourteen districts of Jharkhand. However, the preferred varieties in decreasing order of demand were IR-64, Naveen, MTU-7029, Rajender Mahsuri, MTU-1010 and IR-36. During wet season 2011-12, the upland varieties of rice by the farmers of Jharkhand in decreasing order of preference were Birsa dhan-108, Birsa Vikas-109, Birsa Vikas-110 and Vandana. The medium land varieties of rice in decreasing order of preference were IR-64, IR-36, Lalat, Naveen, MTU-1001, Abhisek, Sahabhagidhan and Hazaridhan. The preferred lowland rice varieties in decreasing order of preference were MTU-7029, Rajendar Mahsuri and MTU-1010. A good number of CRRI varieties *viz.*, Naveen, Vandana, Abhishek, Sahabhagidhan and Hazaridhan were found in the seed chain of Jharkhand.

Developing entrepreneurial modules of selected CRRI technologies for training potential entrepreneurs-a process study

A five week duration Trainer's Training Module for entrepreneurship development on CRRI Rice Technology (TED-CRiT) on commercial (50 acre), medium (7.5 acre) and small (0.5 acre) rice-fish integrated farming systems models was developed which contained sub modules such as entrepreneurial motivation, general management, finance management, production management, labour management, marketing management and business plan. Each sub modules contained ELC based sessions. A detailed lesson plan was developed for each session which was further refined and finalized. The business plans were based on the data validated during the last year. The total costs of these projects were Rs.38.8 lacs, Rs.22.6 lacs and Rs.1.26 lacs, respectively while the total working capital requirements were Rs. 10.5 lacs, Rs. 3.5 lacs and Rs. 0.85 lacs, respectively. The training module on integrated rice-fish farming was refined and tested with a group of 15 farmers and farmwomen. The Trainer's Training Module for entrepreneurship development on CRRI Rice Technology (TED-CRiT) can be utilized by various extension agencies to disseminate the CRRI technology.

Simulation of adoption of rice production technology

In order to simulate adoption of rice production technology, Pooja rice variety was selected as technology and data was collected from 81 respondents of Arada village of Cuttack district. CRRI/KVK staff (74.1%), fellow farmers (17.3%) and extension workers (8.6%) were the main sources of information regarding Pooja while, the mass media exposure of the majority of respondents (82.7%) was low. Similarly, about 46.9% of respondents had no exposure to technology demonstration. However, more than 88.9% of respondents had good to excellent perception of technological characteristics of Pooja and 59% of respondents belonged to middle and high income group.

Various linear and non-linear models were fitted to the above data set to obtain mathematical models for different segments of simulation programme including mathematical relationship between adoption and independent variables. Both logit and probit models were tested with the data for its suitability and probit model was found to be more suitable for developing simulation model. The simulation model developed based on the data analyzed using SPSS and probit model was refined to suit the real life data. The 1:1 plot of simulation adoption quotients and real world adoption quotients showed that maximum observations fell in the 5% zone. The simulated distribution and observed distribution was statistically tested using Kolmogorov-Sminrov two-sample test. The result was non-significance showing that there was no difference between simulated and observed distributions (Table 48 & Fig. 31).

The model shows that the perception about the technological characteristics has a greater role in adoption of the technology besides the income level. This model can be used by the researchers and extension workers to experiment further and see the effect of the increasing the number of demonstration and using other medium of information and predict the rate of adoption.

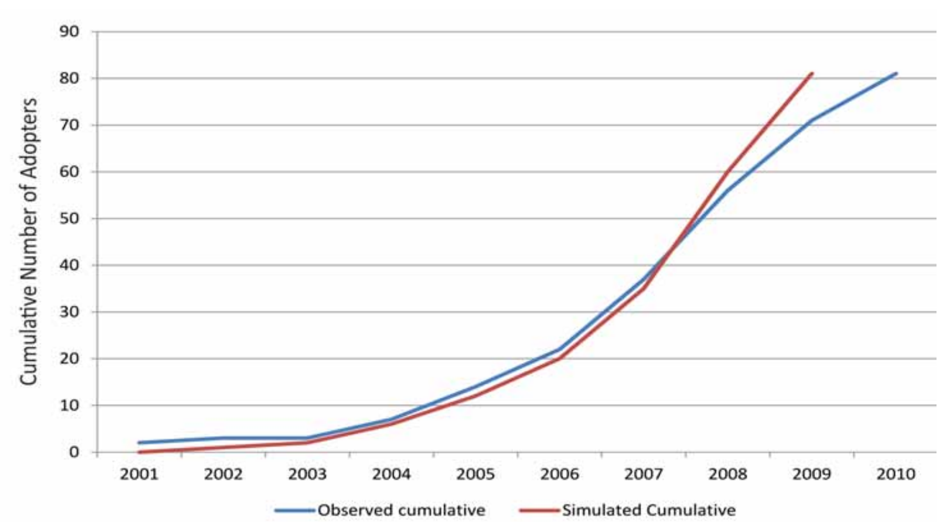


Fig. 31. Cumulative graph of observed and simulated adoption of Pooja

Table 48. Kolgomogorov-Sminrov two sample test between simulate and observed values

	Observed $S_m(x)$	Simulated $S_m'(x)$	$\|S_m(x)-S_m'(x)\|$
2001	0.02	0.00	0.02
2002	0.04	0.01	0.02
2003	0.04	0.02	0.01
2004	0.09	0.07	0.01
2005	0.17	0.15	0.02
2006	0.27	0.25	0.02
2007	0.46	0.43	0.02
2008	0.69	0.74	0.05
2009	0.88	1.00	0.12 max
2010	1.00		

Market and Policy Research

Impact of WTO on global rice exports with particular reference to India

The country wise export and import data on rice for the period 1961 to 2008 were analyzed. The analysis revealed that the share of world rice trade in total rice production has expanded from 4.3% during 1960s to 7.0% during the recent period. The rice trade volume has increased from 7.5 m tonnes per year during 1960s to 28.6 mt during the last decade. Though India was a major importer during 1960s, it has turned out to be a major exporter after the 1994 GATT agreement and occupies third position next to Thailand and Vietnam. China was the second largest exporter during 1970s and its position has been relegated to sixth during the recent period. Myanmar, which was a major exporter during 1960s (fourth position), lost its importance and relegated to tenth place during the recent years. Other countries which also emerged with small amounts of exports are Uruguay, Argentina, Spain and Guyana. The Herfindahl index, which measures the degree of concentration, indicates that the concentration of exports has reduced marginally from 0.165 to 0.156 during the last five decades. The emerging major importers during the period 1961 to 2008 were Philippines, Nigeria, Iran, Iraq, Cote d'Ivoire, Senegal, South Arabia, South Africa, UAE, USA and Brazil. Bangladesh, Malaysia and Indonesia have increased their import volume over years. The Herfindahl index for imports has substantially reduced from 0.170 to 0.040, because of the entry of large number of importers over the last five decades.

The total rice export from India has increased more than 4 times i.e. from Rs. 2653 crores during pre-WTO period (1990-94) to Rs. 11500 crores (Fig. 32) during post-WTO period (2005-09).

India could expand its rice export to 169 countries after the agreement, which were 103 before the agreement. Government of India imposed ban on exports of non-basmati rice from October, 2007 with exceptions (government to government agreements) to contain food price inflation in domestic market. As a result, the export of non-basmati rice has reduced drastically during 2008-09 (0.93 mt), 2009-10 (0.14 mt), and 2010-11 (0.10 mt), from the peak level obtained during 2007-08 (5.29 mt). In spite of restrictions imposed on basmati rice export in terms of minimum export price and export tax, government took a decision to include Pusa-1121 variety for export under basmati rice category from October, 2008. Therefore, the average export of basmati rice per year has increased from 0.83 mt (2000-04) to 1.39 mt per year in post-WTO period (2005-09) and has crossed 2 mt during 2009-10. The average triennium value of export per year after inclusion of Pusa–1121 under basmati category was Rs. 11141 crores (2008-10) and the figure before inclusion was Rs. 4405 crores (2005-07) *i.e.* an increase of 153%. Due to increased access of countries to basmati rice, India

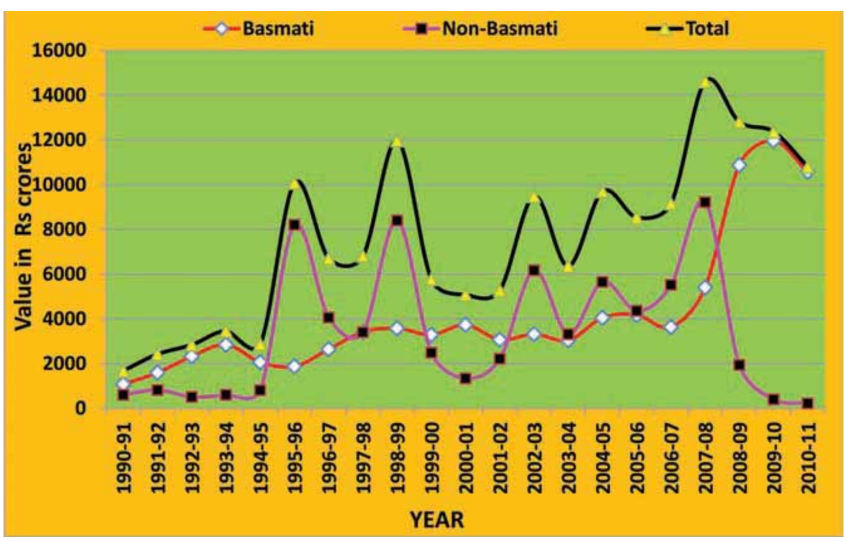


Fig. 32. Rice exports from India during 1990-91 to 2010-11 (at constant prices of 2010-11)

has increased basmati rice exports by 289% in quantity and 264% in value terms in the post-WTO period (2005-09) over the pre-WTO period (1990-94). The basmati export volume has reached more than 21.8 lakh tons valuing Rs. 10,578 crores in the year 2010-11. In absolute terms, the average export value has increased from Rs. 1983 crores during pre-WTO period to Rs. 7212 crores during 2005-09 and reached a peak of Rs. 11,969 crores during the year 2009-10 after inclusion of Pusa-1121 under basmati category.

The non-basmati export has increased significantly during post-WTO period (2003-07) over pre-WTO period (1990-94). The market access for non-basmati has doubled during post- WTO period in terms of number of countries (pre-WTO = 76; post-WTO = 151). The export has increased by 1014% in volume and 739% in value terms. Among non-basmati types, parboiled and white grade rice accounted for more than 94% in volume and value terms as per the quinquennial figures ending 2003-07. The export of parboiled rice during pre and post WTO period has increased from 0.70 lakh tons to 25.2 lakh tons in volume and Rs 142 crores to Rs 3893 crores in value terms i.e. an increase of 3500% and 2642% respectively over the pre-WTO period. Major export destinations of parboiled rice were West Africa (33.5%) followed by South Asia (29.7%), Southern Africa (12%), Middle East (11.9%) and Eastern Africa (5.5%) during post-WTO period. Disaggregated by regions, the major destinations of white rice were to South Asia (39.6%) and Middle East (35.9%) during post-WTO period. The other export destinations were to Southern Africa (8.6%), West Africa (7.4%), and East Africa (2.6%).

Participatory Extension and Training Methodology Development for Various Groups

Dissemination of rice production technologies through model village and other programmes and their evaluation

Based on PRA and consultation with the farmers of the model village-Gurujang, Tangi-Choudwar, Cuttack, dissemination of production technologies was taken up in a systematic and co-odinated manner. Besides holding trainings and method demonstrations for the farmers, result demonstrations on the production potential of newly released rice varieties were conducted. Data on yield and other related information were gathered which provided the following findings.

Field evaluation of Swarna sub-1

Field studies of Sahabhagi Dhan

The rice variety, Sahabhagidhan had an average yield of 3.29 t ha^{-1}. The variety being grown in the rainfed upland ecosystem could provide a great relief to the farmers. The farmers had previously no suitable variety for upland for which the land remained almost fallow. The farmers expressed great satisfaction because the variety could help them to find a solution for better income from the land. The farmers appreciated the variety for good yield, quality grain and straw and pest and disease resistance. They took a decision to grow Sahabhagidhan in a bigger way through seed exchange programme.

The hybrid rice variety Rajalaxmi was demonstrated with an objective to popularize hybrid rice and understand farmers' reactions. The variety produced a yield of 5.87 t ha^{-1} which was found to be 49.98% higher than that of Swarna grown in the locality and considered as a local check. Farmers expressed their happiness and desired that new and good hybrid rice seed should be supplied in the seed chain. In order to find appropriate substitution to the old variety Swarna, demonstrations were conducted to show the yield potential of Pooja, Satyakrishna and Swarna Sub-1. The average yield per hectare as found out were 5.55 t ha^{-1}, 4.37 t ha^{-1} and 5.30 t ha^{-1} for Pooja, Satyakrishna and Swarna Sub-1, respectively. The variety Swarna as reported from the adjacent local plots yielded less than the said varieties by 44%, 16.66%, and 16.67%, respectively. Evaluations made by farmers on the varieties revealed that the grains of Satyakrishna did not remain intact after milling which was a cause of concern for the farmers. The rubber sheller facility was not available for the farmers of the locality. Although Swarna Sub-1 is recommended for flash flood situations, its performance in the rainfed situation was taken up basing on the demand of the farmers. Farmers expressed their satisfaction on the performance of the variety due to its higher yield over Swarna and less susceptibility to pests and diseases.

Assessment of effectiveness of KVK programmes on sustainable development of farmers

A study was conducted in two KVK adopted villages i.e., Sanimula and Garada in Jagatsinghpur district of Odisha to assess the impact of OFTs on rice in effecting changes in knowledge level of farmers. The study was taken up in a before-after experimental design with no control group. Efforts were made to ensure effective participation of farmers in the trials conducted by KVK, Jagatsinghpur. Out of farmers having participation in the OFTs, 30 respondents were selected randomly. The knowledge level of the respondents wasassessed on three major aspects *viz*, crop management, insect pest and disease management and weed management before and after the trials.

The findings revealed that there were remarkable changes in knowledge level of farmers in all the three aspects due to their participation in the on-farm trials (Table 49). The pre-participation mean knowledge level increased from 26.5% to 86.1% indicating an overall gain of 59%. A tangible impact of the OFT was that the rice variety 'Varshadhan' – the technology tested in the OFT, was subsequently adopted by cent percent of the respondents.

Gender Issues in Rice Farming

Income generating opportunities for tribal and disadvantaged farmwomen through entrepreneurship development on rice-based farming system

An action research on empowerment of tribal women engaged in rice-based farming activities was conducted in Balasore district of Odisha. One hundred twenty farmwomen from three villages were selected through random sampling. They were organized into twelve Self Help Groups consisting of 10 members in each group. Eight income generating activities in rice-based farming systems were selected for empowering women depending on the capacities and opportunities they had. Extension methods *viz*., group approach, training, demonstration and advisory services were organized for the group on the identified interventions.

The results of major income generating activities taken up by the farmwomen revealed that most of the respondents had taken up 'integration of other crops *viz*., oilseeds, pulses and vegetables after rice' which ranked first. The other income generating activities taken up by the respondents in descending order were 'preparation of different value added products from rice' 'fish farming along with other crops', 'kitchen gardening', 'livestock rearing', 'dal making', 'extraction of oil from available oilseeds' and 'mushroom cultivation' (Table 50).

An index to measure the extent of empowerment was developed by identifying nine relevant indicators *viz*., education, land ownership, ownership of other assets (other than land), control over income contributed by her to the family, control over the income of the

Table 49. Distribution of respondents according to their mean knowledge level before and after participation in OFTs

Areas	Pre-exposure mean knowledge	Post-exposure mean knowledge	Change in mean knowledge
Crop management(0-25 score)	7.0 (28.0)	22.5 (89.9)	15.5 (61.9)
Insect pest & disease management(0-13 score)	3.0 (23.3)	10.7 (82.3)	7.6 (58.7)
Weed management(0-12 score)	3.2 (26.9)	9.9 (82.2)	6.6 (55.3)
Overall knowledge levels(0-50 score)	13.3 (26.5)	43.0 (86.1)	29.8 (59.5)

(Figures in the parentheses indicate percentage)

Table 50. Major Income generating activities taken up by the respondents (N=120)

Activities	Frequency	Rank
Integration of other crops after rice i.e., pulses, oilseeds, vegetables	89 (74.16)	I
Livestock rearing	39 (32.5)	V
Fish farming along with other crops	56 (46.67)	III
Preparation of value added products from rice	79 (65.83)	II
Mushroom cultivation	2 (1.67)	VIII
Kitchen Gardening	52 (43.33)	IV
Dal Making	16 (13.33)	VI
Extraction of oil from available oil seeds	8 (6.67)	VII

Table 51. Extent of empowerment of farmwomen through Income generating activities

Villages	Average empowerment Inde x (before)	Average empowerment Inde x (after)	Average gain in empowerment	't' value
Harichandanpur	14.71	41.41	26.7	18.66**
Sutanati	18.81	44.81	26.0	29.41**
Kudia	16.11	40.21	24.1	26.66**
Mean	16.54	42.14	25.6	39.14**

family, savings, access to credit, social participation and cash income earned from income generating activities (Rs. Month^{1}) in consultation with experts. Based on the score obtained from these nine variables, extent of empowerment was calculated by computing the empowerment index in percentage. Gain in empowerment was calculated by finding the difference between empowerment index value before and after the project activities.

The overall gain in empowerment was found to be 25.6 per cent which was mainly due to expansion of income generation activities (Table 51). Hence, capacity building programmes *viz.*, training, demonstration and advisory services would enable them to increase income, reduce drudgery and enhance their status in the society.

Transfer of Technology

Demonstration of CRRI Rice Varieties

During dry season 2011-12, an on-station demonstration of 26 CRRI rice varieties was conducted.The rice hybrid Ajay gave the highest yield of 7.8 t ha^{-1}, while Geetanjali gave the lowest yield of 3.8 t ha^{-1}. The varieties Rajalaxmi, Tapaswini MAS, Swarna MAS, Lalat MAS, Chandan yielded more than 6 tha^{-1}.

During wet season 2011-12, out of 26 varieties demonstrated, rice hybrid Ajay gave the highest yield of 7.3 t ha^{-1} while Rajalaxmi gave the yield of 7.0 t ha^{-1}. Among the aromatic varieties Ketekijoha gave the highest yield of 4.4 t ha^{-1} followed by Geetanjali and Nua Chinikamini. Among the upland varieties Sahabhagidhan gave the highest yield of 5 t ha^{-1} followed by Virendra, Abhisek, Sadabahar, Hazaridhan and Kamesh. Among the medium and lowland rice variety Swarna *sub-1* gave the highest yield of 6.3 t ha^{-1}.

Gender issues in rice-based production system and refinement of selected technologies in women perspective

An on-farm trial was conducted in Purbakachha village of Salipur block of Cuttack District to evaluate selected technologies with women perspective in rice based production system. Four treatments *viz.*, Farmers practice, Planting by CRRI two rows manual rice transplanter with hand weeding, Planting by transplanter with mechanical weeding by finger weeder, Manual planting in rows with hand weeding were

Two-rows CRRI manual rice transplanter-a drudgery reducing implement for women

CRRI finger weeder- a women friendly implement

planned. A group of 30 farm women who participated in the trial and worked with two rows transplanter and finger weeder as well as in traditional method gave their qualitative assessment. The farm women favoured the CRRI two rows transplanter on account of 'quick in doing job', 'socially acceptable' and 'prestigious' very strongly (score above 2.5 out of 3 in the rating scale). The other positive points which were endorsed strongly (score 2-2.5) were on 'generation of higher income', 'easy in doing the transplanting' and 'bright future of the machine'. The negative points on 'fear of accident' and 'more mistakes in operation' were strongly denied. The feedback provided by women farmers on the technologies had led to draw useful recommendations for refinement of programmes on farm implements for women. The highest net return (Rs. 25,880 ha^{-1}) and benefit: cost ratio (2.30) were recorded in the plots where the crop was established by transplanter and mechanical weeding by finger-weeder (20 DAT) followed by manual removal of weeds within rows. This could be due to reduction in the labour cost in mechanical transplanting and weeding.

Development and maintenance of rice knowledge management portal

CRRI as consortium partner of NAIP (Component 1) funded project developed a digital photo library on rice related information such as various stages of rice plant growth, insect pests of rice, diseases of rice, implements/machineries used for production and post-harvest of rice, varieties and other general photographs. Besides, documents of Government schemes and extension programmes on rice were collected, digitized and sent for uploading in rice portal. Sixty one-minute spot films and one 17 minute documentary film were made by CRRI which are available on the portal. The shooting of the film was done at Cuttack, Hazaribag, Almora, Gerua, Ludhiana and Kochi. In order to make the portal popular, a capacity building workshop was organized for 60 participants from Odisha, Bihar, Jharkhand and Chhattisgarh at CRRI, Cuttack. The participants were exposed to the Rice Knowledge Management Portal and its utility in disseminating rice related information to farming community.

Krishi Vigyan Kendras

Santhapur, Cuttack

Front Line Demonstrations (FLD)

Rice**:** In wet season 2011, forty six demonstrations on six ecology specific rice varieties were conducted. In upland situation Sahabhagidhan gave highest yield of 3.85 t ha^{-1} followed by Annada (3.56 t ha^{-1}) and Anjali (3.44 t ha^{-1}). In shallow lowland the variety Reeta gave 4.56 t ha^{-1}, while, scented rice Nua Kalajeera gave 3.64 t ha^{-1}. In medium deepwater situation the variety Varshadhan gave 4.83 t ha^{-1}.

Arhar**:** In wet season 2011, FLD on variety UPAS-120 was conducted in three hectare land in Karanji village of Tangi Choudwar block involving ten number of farmers. The average yield of 0.86 t ha^{-1} was recorded in demonstrated plots which was 38.7 % higher than local check (0.62 t ha^{-1}) and B:C ratio was found to be 2.4.

Blackgram: In dry season 2011-12, FLD of variety Shekhar-2 was conducted in five hectare land involving 12 farmers of Chadheipada village of Tangi-Choudwar. The average yield of 0.82 t ha^{-1} was recorded in demonstration plots which was 41.3% higher than the local check (0.58 t ha^{-1}) with a benefit cost ratio of 2.36.

Green Gram: Front line demonstration of green gram was conducted covering five hectare land in Ganeshwarpur village involving 12 farmers. The average yield of demonstrated variety TARM-01 was 0.93 t ha^{-1} which was 44.1 % higher than local check (0.65 t ha^{-1}).

On Farm Testing (OFT)

Seventeen on-farm trials (OFT) were conducted on farmers field representing different disciplines *viz.* crop production, horticulture, plant protection, home science and soil science. In OFT of okra and brinjals, 20 t ha^{-1} and 46 t ha^{-1} yields were recorded, respectively. Application of boron in cauliflower resulted in 30 t ha^{-1} yield with good quality compact curd.

Training

During 2011-12, thirty eight off and on-campus vocational training programmes were organized for 1310 farmers/farm women/rural youths and extension functionaries. The programmes were on Scientific nursery raising of paddy, Pest management in paddy nursery, Integrated nutrient management in paddy, Integrated weed management in paddy, Water management in rice in rainfed situation, Method of increasing Nitrogen use efficiency, Management of nutritional garden, Method of planting and fertilizer management in rice, Mechanical rice production, Farmers club formation and its benefits, Production technology of grafting, budding and layering for nursery management, Fertilizer management and method of planting in pointed gourd, Use of biofertilizer in vegetable production, Insect pest management in tomato, brinjal and cole crops, Role of micro-organism in agriculture production, Method of soil sample collection, Value addition in tomato and other vegetables, Basin management in coconut garden, Integrated weed management in rabi pulses, Acid soil management, Formation and management of farmers' club, Mushroom production technology, Leadership development, INM in banana, INM in rabi rice and IWM in rabi rice.

A total of ten training programmes, sponsored by Project Director, ATMA, Cuttack, were conducted in areas like Vermicomposting, Value addition of tomato, Mushroom production technology, IWM in rice, IPM in field crops, INM in field crops and Importance of balance nutrient in vegetables.

Jainagar, Koderma

On Farm Testing (OFT)

Replacement of popular variety (IR36) in rainfed bunded uplands with Anjali and crop and nutrient management (direct seeding, additional dose of P from 20 to 30 kg and addition of K @ 20 kg ha^{-1}) increased rice yield by 45.7% (3.50 t ha^{-1}) with a net return of Rs. 25,600 and benefit cost ratio of 2.97. Brown mulching with Sesbania @ 40 kg ha^{-1} followed by 2, 4 D at 25 DAS instead of farmers' practice of using available FYM improved rice yield by 40.3% and provided a net return of Rs. 30,100. Replacement of transplanted Sita with Sahbhagidhan allowed the farmers to increase the cropping intensity (rapeseed var. PT 303 after rice harvest) and securing a net return of Rs. 30,500.

Balanced fertilizer application (NPK: 120:100:90 over farmers practice of 60:30:00) improved the tuber size and the yield in potato by 34% resulting into a net return of Rs. 83,600 besides, reducing the incidence of disease/insect pests. Application of Azotobacter and PSB @ 25 kg ha^{-1} and 5 kg ha^{-1}, respectively in conjunction with 75% of the recommended dose of fertilizer (NPK 100:50:25) in wheat (var. UP 262) yielded 37.4% more (3.73 t ha^{-1}) over farmers' practice (2.73 t ha^{-1}). OFT of new varieties of capsicum (Indra), wet season onion (Arka Niketan) and papaya (Pusa Nanha) were also conducted. Deworming thrice in a year to increase the body weight of goat, calcium @ 30 ml per day for 60 days to increase milk production in cows, zero energy cool chambers to reduce weight loss and spoilage of fresh vegetables, bamboo platform for housing of goats were the other technologies evaluated under OFT and were found suitable for the district.

Front Line Demonstrations (FLDs)

Front line demonstrations of transplanted Sahbhagidhan in rainfed conditions recorded 37.2% more yield (3.5 t ha^{-1}) as compared to the local check. Farmers reported higher number of tillers hill^{-1}, spikelets panicle^{-1} and higher filled grain percentage. Pigeon pea variety Maruti was liked by the farmer as it had bold grains that fetched higher price in the market but occasional incidence of wilt (upto 10%) was noticed in the FLDs. Birsa Niger 1 and rapeseed variety Shivani were also demonstrated after rice harvest.

Training and Seed Production

KVK conducted 72 on and off campus training programes in areas like Technique of seed treatment in rice, Nursery management of *kharif* season vegetable, Management of milch cattle in summer season, Care and management in goat, Scientific method for preservation of seasonal fruit, Improved paddy cultivation for different farming situation, IPM in okra, technique of seed treatment in *kharif* pulses, Technique for increasing cropping intensity in rice-fallow system, Making different types of *papad* and chips, Lac cultivation, Formation of self-help group, Technique of micro-irrigation in vegetable crops, Establishment of layout technique in orchard and Scientific cultivation of *kharif* onion during 2011-12 benefiting 1736 farmers. Farmers produced 40.4 q of seeds of rice varieties Abhishek, Anjali and Sahbhagidhan (seed village), while, KVK produced good quantity of planting materials of various crops and vermicompost in the technology demonstration farm.

Publications

Papers in Research Journals

Bhattacharyya, P. Mandal, D., Bhatt, V. K. and Yadav, R. P. (2011). A quantitative methodology for estimating soil loss tolerance limits for three states of northern India. *Journal of Sustainable Agriculture*. **35**(3): 276-292.

Chakraborty, K., and Rath, P. C. (2011). Efficacy of Selected Biopesticides against Rice Leaf Folder, *Cnaphalocro medinalis*. *Indian Journal of Plant Protection*. **39**(2):151-152.

Chattopadhyay, K., Das, A. and Das, S. P. (2011). Grain protein content and genetic diversity of rice in north eastern India. *Oryza* **48**(1): 73-75.

Chattopadhyay, K., Das, Avijit and Das, S. P. (2011). Grain protein content and genetic diversity of rice in north eastern India. *Oryza*. **48**(1):73 -75.

Das, Avijit and Sharma, Srigopal (2011). Alcohol dehydrogenase activity may not be an indicator of submergence tolerance in rice. *Oryza*. **48**(1): 86-89.

Das, Gitishree, Reddy, J. N., Das, K. M., Thatoi, H. N. and Rao, G. J. N. (2011). Pyramiding of biotic and abiotic stress genes in rice. *Oryza*, **48**(3): 267-269.

Das, Lipi, Sadangi, B. N., Mishra, S. K. and Kar, M. K. (2011). Extent of adoption of CRRI rice varieties for lowland and their appropriateness as perceived by growers. *Oryza*. **48**(4): 370-374.

Dash, S. K., Pradhan, S. K., Mall, A. K., Singh, O. N. and Rao, G. J. N. (2011). Screening of potential donors for development of New Plant types in irrigated rice (*Oryza sativa* L.) in Eastern India. *Journal of Crop and Weed Science*. **7**(2):74-79

Datta, A., Rao, K. S., Santra, S. C., Mandal, T. K. and Adhya, T. K. (2011). Greenhouse gas emissions from rice based cropping systems: Economic and technologic challenges and opportunities. *Mitig. Adapt. Strateg. Glob. Change*. **16**:597-615.Dhua, Urmila, Dhua, Sudhiranjan, Chhotaray, Apurba (2011). Identification of rice endophytes and their impact on host cultivars in coastal Orissa. *Oryza*. **48**(3) :244-249.

Ghosh, A. (2011). Improved crop and nutrient management for efficient use of residual soil moisture and nutrients under rainfed lowland rice fallow conditions. *International Rice Research Notes*. **36**: 1-5.

Ghosh, A. (2011). Intercropping rice (*Oryza sativa* L.) with jute (*Corchorus capsularis* L.) and its impact on total productivity and profitability under rainfed lowland ecology. *Indian Journal of Agronomy*. **56** (3): 25-30.

Ghosh, A. and Suman, K. K. (2011). Exploring seedling vigour for post-flood stand establishment of rice (*Oryza sativa* L.) under flood prone waterlogged deepwater condition. *Indian Journal of Agricultural Sciences*. **81** (4): 62-64.

Jena, Mayabini and Dani, R. C. (2011). Evaluation of insecticides against rice hispa, *Dicladispa armigera* Oliver (Coleoptera:Chrysomelidae). *Oryza*. **48** (3), 255-257.

Kumar, A., Verulkar, S. B., Mandal, N. P., Variar, M., Shukla, V. D., Dwivedi, J. L., Singh, B. N., Singh, O. N., Swain, P., Mall, A. K., Robin, S., Chandrababu, R., Jain, A., Haefele, S., Piepho, H. P. and Raman, A. (2012). High-yielding, drought-tolerant, stable rice genotypes for the shallow rainfed lowland drought-prone ecosystem. *Field Crops Res*.**133**: 37-47.

Kumar, Anjani, Nayak, A. K., Shukla, Arvind K., Panda, B. B., Raja, R., Shahid, Mohammad, Tripathi, Rahul, Mohanty, Sangita and Rath, P. C. (2012). Microbial biomass and carbon mineralization in agricultural soils as affected by pesticide addition. *Bull. Environ. Contam. Toxicol*. **88**: 538–542.

Lenka, S. and Bhaktavatsalam, G. (2011). Management of rice sheath blight through new fungicidal formulations in field. *Indian Phytopathology*. **64**(2): 201-202.

Lenka, S., Bhaktavatsalam, G., Singh, S. K. and Medhi, B. (2011). Imidacloprid, a promising insecticide for prevention of rice tungro disease. *Journal of Plant Protection and Environment*. **8**(11): 131-136.

Lenka, S., Mishra, S. K., Mohanty, S. K., Rath, N. C. and Das, K. M. (2011). Reaction of wild rice species to sheath blight caused by *Rhizoctonia solani* Kuhn. *Oryza*. **48**(1): 81-82.

Maiti, D., Toppo, Neha Nancy and Variar, M. (2011). Integration of crop rotation and arbuscular mycorrhizal (AM) fungal inoculum application for enhancing native AM activity to improve phosphorus nutrition of upland rice (*Oryza sativa* L.). *Mycorrhiza* **21** (8): 659-667.

Maiti, D., Variar, M. and Singh, R. K. (2012). Rice based crop rotation for enhancing native arbuscular mycorrhizal (AM) activity to improve phosphorus nutrition of upland rice *(Oryza sativa* L.). *Biol. and Fert. of Soils*. **48**: 67-73.

Mall, A. K., Swain, P. and Singh, O. N. (2011). Genetic divergence for drought promising rice genotypes based on quality characters. *Indian Journal of Plant Genetic Resources*. **24** (2): 172-176.

Mall, A. K., Swain, P., Das, S., Singh, O. N. and Kumar, A. (2011). Effect of drought on yield and drought susceptibility index for quality characters of promising rice genotypes. *Cereal Research Communications*. **39** (1): 22-31.

Mandal, B., Vijayanandraj, S., Shilpi, S., Pun, K. B., Singh, V., Pant, R. P., Jain, R. K., Varadarasan, S. and Varma, A. (2012). Disease distribution and characterization of a new macluravirus associated with chirke disease of large cardamom. *Ann. Appl. Biol*. **160** : 225-236.

Marric, Elsa and Reddy, J. N. (2011). Studies on DNA polymorphism and genetic diversity among rainfed lowland rice genotypes. *Oryza*, **48**(3): 206-210.

Mishra, R. R., Prajapati, S., Das. J., Dangar, T. K., Das, N., Thatoi, H. (2011). Reduction of selenite to red elemental selenium by moderately halotolerant *Bacillus megaterium* strains isolated from Bhitarkanika mangrove soil and characterization of reduced product. *Chemosphere* **84**: 1231–1237.

Mohanty, Amruta , Panda, Binay Bhusan, Marndi, B. C., Sharma, Srigopal and Das, Avijit (2011). Two traditional rice (*Oryza sativa* L.) cultivars from Assam Rice Collections contain high grain protein content. *Oryza*. **48**(2): 171 – 174.

Mohapatra, P. C., Din, M., Parida, B. C., Patel, S. P. and Mishra, P. (2012). Effect of mechanical planting and weeding on yield, water-use efficiency and cost of production under modified system of rice intensification. *Indian Journal of Agricultural Science*. **82** (3): 280-4, 2012.

Nayak, A. K., Gangwar, B., Shukla, Arvind K., Mazumdar, Sonali P., Kumar, Anjani, Raja, R., Kumar, Anil, Kumar, Vinod, Rai, P. K. and Mohan, Udit (2012). Long-term effect of different integrated nutrient management on soil organic carbon and its fractions and sustainability of rice–wheat system in Indo Gangetic Plains of India. *Field Crops Research*. **127**: 129–139.

Nedunchezhiyan, M., Laxminarayana, K., Rao, K. R. and Satapathy, B. S. (2011). Sweet potato *(Ipomoea batatas* L.) based strip intercropping: Interspecific interactions and yield advantage. *Acta Agronomica Hungarica*. **59** (2): 121-131.

Panda, B. B., Sharma, S. G., Mohapatra, P. K. and Das, A. (2012). Iron stress induces primary and secondary micronutrient stresses in high yielding tropical rice. *Journal of Plant Nutrition*. **35**: 1359-1373.

Panda, D. and Sarkar, R. K. (2011). Improvement of photosynthesis by Sub1 QTL in rice under submergence: probed by chlorophyll fluorescence OJIP transients. *Journal of Stress Physiology and Biochemistry*. **7**: 250-259.

Patel, S.P. (2011). Development of power tiller operated seed drill for rice and pulse. *Oryza*. **48** (1): 52-55.

Pradhan, S. K., Singh, S., Singh, O. N., Rao, G. J. N., Dash, S. K., Behera, L., Pande, K., Bose, L. K., Meher, J., Mall, A. K., Das, K. M., Dhua, S. R. and Baig, M. J. (2012). A deepwater rice variety, CR Dhan 500. *Indian J. Genet*. **72**(1):107-108.

Raja, R., Ravisankar, N., Ghoshal Chaudhuri, S., Ambast, S. K., Chand, Subhash, Din, M., Meena, Babu Lal, Subramani, T. and Ahmed, Zamir (2012). Effect of supplemental irrigation on yield and water productivity of dry season crops in Andaman and Nicobar Islands. *Indian Journal of Agricultural Sciences.* **82** (2): 122-126.

Rath, P. C. (2011). Testing of some new insecticides against insect pest of rice. *J. Plant Prot. Environ.* **8** (1): 31-33.

Rath, P. C. and Subudhi, H. N. (2011). Greenhouse Evaluation of selected rice varieties against white backed plant hopper *Sogatella furcifera* (Horvath) *Oryza.* **48**(2): 188-189.

Roy, D. K., Kumar, Rakesh and Kumar, Anjani (2011). Production potentiality and sustainability of rice-based cropping sequences in flood prone lowlands of North Bihar. *Oryza.* **48** (1); 47-51.

Roy, S. K., Haque, S., Kale, V. A., Asabe, D. S. and Dash, S. (2011). Variability and character association studies in rapeseed-mustard (*Brassica sp.*). *Journal of Crop and weed Science*. **7**(2):108-112.

Sahoo, D., Sahoo, S., Das, J., Dangar, T.K., Nayak, P. L. (2011). Antibacterial activity of chitosan cross linked with aldehydes and blended with cloisite 30 B. *Nano Trends: A J Nanotech its Applica.* **10**: 1-9.

Samal, P. (2011). Slutsky Curvature and Nutrition Policy: The Case of Orissa. *Orissa Economic Journal*. **43** (1): 211-220.

Samal, P. and Pandey, S. (2011). Labour migration and livelihood analysis in rainfed rice based farming systems of coastal Odisha. *Oryza,* **48**(2): 175-180.

Samal, P. and Patra, R. N. (2012). Natural calamities, rice production loss and risk coping strategies: Evidence from Odisha. *The IUP Journal of Agricultural Economics.* **9** (1) :7-19.

Samal, P., Pandey, S., Kumar, G.A.K. and Barah, B.C. (2011). Rice ecosystem and factors affecting varietal adoption in rainfed coastal Odisha: A multivariate probit analysis. *Agricultural Economics Research Review*. **24**(1):161-167.

Sarkar, R. K. and Mohanty, P. (2010). An overview on submergence tolerance in rice: farmers' wisdom and amazing science. *Journal of Plant Biology.* **37**: 191-199.

Sen, H.S., Sahoo, N., Sinhababu, D. P. and Behera, K. S. (2011). Improving agricultural productivity through diversified farming and enhancing livelihood security in coastal ecosystem with special reference to India. *Oryza*, **48** (1): 1-21.

Subudhi H.N., Das, Sanjukta, Swain, D. and Singh, O.N. (2011). Variability correlation and path analysis for quality characters in rice. *Oryza.* **48** (4):319-323.

Subudhi, H. N., Das, S. and Sharma, S. G. (2011). Evaluation of upland rice cultivars for physic-chemical and cooking quality characteristics. *Indian Agriculture.* **55** (1&2):59-61.

Tripathi, Rahul, Sahoo, Rabi N., Sehgal, Vinay K., Tomar, R. K., Chakraborty, Debashish and Nagarajan, S. (2012). Inversion of PROSAIL Model for Retrieval of Plant Biophysical Parameters. *Journal of Indian Society of Remote Sensing*. **40** (1), 19-28.

Verulkar, S. B., Mandal, N. P., Dwivedi, J. L., Singh, B. N., Sinha, P. K., Mahato, R. N., Dongre, P., Singh, O. N., Bose, L. K., Swain, P., Robin, S., Chandrababu, R., Senthil, S., Jain, A., Shashidhar, H. E., Hittalmani, S., Veracruz, C., Paris, T., Raman, A., Haefele, S., Serraj, R., Atlin, G., Kumar, A. (2010). Breeding resilient and productive genotypes adapted to drought-prone rainfed ecosystem of India. *Field Crop Research*. **117** (2):197-208.

Books

Bhattacharyya, P., Nayak, A. K., Raja, R. and Rao, K. S. (Eds). (2012). *Climate Change: Greenhouse Gas Emission in Rice Farming and Mitigation Options*. Central Rice Research Institute, Cuttack-753006, Odisha, India. 165 p.

Kumar, G.A.K. and Mohanty, A.K.(2011). *Extension Research Methodology: Basics to Advances.* Agrotech Publishing Academy, Udaipur. 216 p.

Sharma, D. K., Rathore, R. S., Nayak, A. K. and Mishra, V. K. (2011). *Sustainable management of sodic land.* CSSRI Regional Research Station, Lucknow. 416 p.

Singh, R. K., Mandal, N. P., Singh, C. V. and Anantha, M. S. (Eds.) (2011). *Upland Rice in India.* Scientific Publishers, Jodhpur, India. 389 p, ISBN: 978-81-7233-728-5.

Booklets

Das, Lipi and Sadangi, B. N. (Eds.). (2012). *Baigyanika Padhhatire Dhana Utpadana Pranali (2nd edition)* in Odia Central Rice Research Institute, Cuttack, Odisha, India. 52 p.

Das, Lipi, Jambhulkar, N.N. and Sadangi, B.N. (Eds.) (2012). *Rice Production Technology*, Central Rice Research Institute, Cuttack, Odisha, India. 204 p.

Das, Lipi, Jambhulkar, N.N. and Sadangi, B.N. (Eds.) (2012). *Unnat pranali me dhan ki kheti*, Central Rice Research Institute, Cuttack, Odisha, India. 106 p.

Das, Lipi, Jambhulkar, N.N. and Sadangi, B.N. (Eds.) . (2012). *Chawal utpadan ke liye unnat pranali*, Central Rice Research Institute, Cuttack, Odisha, India. 106 p.

Das, Lipi, Jambhulkar, N.N. and Sadangi, B.N. (Eds.). (2012). *Hybrid Rice Production Technology*, Central Rice Research Institute, Cuttack, Odisha, India. 150 p.

Das, Lipi, Jambhulkar, N. N. and Sadangi, B. N. (Eds.). (2011). *Chawal Utpadan Proudhogiki* in Hindi Central Rice Research Institute, Cuttack, Odisha, India. 77 p.

Book Chapters

Baig, M. J. and Swain, Padmini (2012). C_4 Rice : Meeting food security in the era of climate change. *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp.149-158.

Bhattacharya, P., Manna, M. C., Roy, K. S., Neogi, S., and Mohammad Shahid (2012). Climate change feedback and temperature sensivity of soil organic carbon and its degradation kinetics. *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp. 91-98.

Bhattacharya, P., Neogi, S., Roy, K. S., Rao, K. S., Nayak, A. K. and Bajpai, R. K. (2012). Greenhouse gas emission from rice: Issues, monitoring and budgeting. *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp.1-16.

Bhattacharya, P., Roy, K. S., Neogi, S., Mohanty, Sangita, Adhya, T. K. and Srinivas, D. (2012). Gaseous carbon emissions from rice and rice based cropping systems. *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp. 33-49.

Bhattacharyya, P. and Adhya, T. K. (2011). Soil carbon sequestration, GHGs emissions and productivity of rice based system in eastern India. *In*. Rao, Srinivasa, Venkateswarlu, Ch. B.,Srinivas, K., Sumanta, Kundu and Singh, A.K.(Eds). *Soil carbon sequestration for climate change mitigation and food security.* Central Research Institute for Dryland Agriculture, Hyderabad, India.

Das, J., Dangar, T. K. (2011). *Bacillus thuringiensis*: biodiversity to biotechnology. In: Mishra, B.B. and Thatoi, H. (Eds.) *Microbial Biotechnology: Methods and Applications*. Narosa Publishing, New Delhi, India. pp. 68-95.

Mandal N. P., Anantha, M.S., Singh, R.K. and Variar, M. (2011). Upland rice in Jharkhand. In: Singh, R.K., Mandal, N.P., Singh, C.V. and Anantha, M.S. (Eds.) *Upland Rice in India.* Scientific Publishers, Jodhpur, India, pp.142-167.

Manna, M. C., Bhattacharya, P., Adhya, T. K. and Rao, A. Subba (2012). Soil organic carbon pools and productivity in rice based cropping system. *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp. 73-82.

Mishra, S. K. and Das, Lipi (2012). Communication Approaches for Effective Transfer of Technologies. *In:* Mahapatra, B.K., Pailan, G.H., Munilkumar, S., Datta, S. and Mishra, S.K. (Eds.) the Reference Manual on Model Training Course on "Fish Nutrition and Feed Formulation". CIFE Kolkata Center, Kolkata, pp. 131-138.

Mishra, S. K., Ojha, S. N., Immanuel, Sheela, Sharma, Arpita, Prakash, Swadesh, Sinha, Archana and Das, Lipi (2011). A study on the performance appraisal of Non-Governmental Organizations in fisheries development in India, in the 'Compendium of Lectures' (Ed. by M. Krishnan, P.S. Ananthan, R.S. Biradar and W.S. Lakra) of the CIFE Golden Jubilee Mini Symposium Series No.-1 on "Farmers as Stakeholders in Commercial Aquaculture", held at CIFE, Mumbai on 30th April, 2011, published in June 2011, pp 95-104.

Mohanty, Sangita, Nayak, A. K., Bhattacharya, P., Kumar, Anjani, Thilgam, V. Kasthuri and Poonam, Annie (2012). Nitrous oxide emission from rice and rice based production system and its mitigation strategy. *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp. 51-62.

Nayak A. K., Shahid, Mohammad, Kumar, Anjani, Tripathi, Rahul and Mohanty, Sangita (2012). Nutrient Management in Hybrid rice. *In:* Das, Lipi, Jambhulkar, N. N. and Sadangi, B. N. (Eds.). *Hybrid Rice Production Technology.* Central Rice Research Institute, Cuttack. pp. 69-81.

Nayak, A. K., Raja, R., Kumar, A., Shahid, M., Tripathi, R., Mohanty, S., Bhattacharya, P. and Panda, B. B. (2012). Soil organic carbon sequestration in rice based cropping system in Indo-Gangetic Plains. *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp.63-71.

Nayak, A. K., Shahid, Mohammad, Shukla, A. K., Kumar, Anjani, Raja, R., Tripathi, Rahul and Panda, B.B. (2012). Soil organic carbon sequestration in agriculture: Issues and priopities. *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp. 17-32.

Pathak, A. R., Mehta, Atul M., Vashi, R. D., Parmar, D. B., Mandal, N. P., Singh, R. K. and Anantha, M.S. (2011). Upland rice in Gujarat. *In:* Singh, R.K., Mandal, N.P., Singh, C.V. and Anantha, M.S. (Eds.) *Upland Rice in India.* Scientific Publishers, Jodhpur, India. pp. 91-106 .

Raja, R., Panda, B. B. and Nayak, A. K. (2012). Agro-climatic analysis for understanding climate change and variability. *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp.99-107.

Rath, N. C. and Das, Lipi (2012). *Dhan pradarshan karyakram me kisano ki pratibhagita*. *In:* Das, Lipi, Jambhulkar, N.N. and Sadangi, B.N. (Eds.) *Chawal utpadan ke liye unnat pranali*, Central Rice Research Institute, Cuttack, Odisha, India. pp. 105-106.

Sadangi, B. N. and Das, Lipi (2012). *Dhan prodhougiki ke prasar me krushi mukhia ki bhumika*. *In:* Das, Lipi, Jambhulkar, N.N. and Sadangi, B.N. (Eds.) *Unnat pranali me dhan ki kheti*, Central Rice Research Institute, Cuttack, Odisha, India. pp. 102-104.

Sadangi, B. N. and Das, Lipi (2012). Role of opinion leaders in dissemination of rice technologies. *In:* Das, Lipi, Jambhulkar, N.N. and Sadangi, B.N. (Eds.) *Rice Production Technology*, Central Rice Research Institute, Cuttack, Odisha, India. pp. 200-204.

Sadangi, B. N. and Das, Lipi (2012). Constraints in hybrid rice production. *In:* Das, Lipi, Jambhulkar, N.N. and Sadangi, B.N. (Eds.) *Hybrid Rice Production Technology*, Central Rice Research Institute, Cuttack, Odisha, India. pp. 148-150.

Saha, Sanjoy (2011). Weed management in organic farming – Recent developments. *In:* Gulati, J.M.L. and Barik, T. (Eds.) *Recent development in organic farming.* Orissa University of Agriculture and Technology, Bhubaneswar. pp 648-665.

Saha, Sanjoy (2011). Weeds are not enemies always – can indicate some hidden characters of soil. *In:* Gulati, J.M.L. and Barik, T. (Eds.) *Recent development in organic farming.* Orissa University of Agriculture and Technology, Bhubaneswar. pp. 666-676.

Saha, Sanjoy (2012). Integrated weed management in rice under different ecosystem. *In:* Das, Lipi, Jambhulkar, N.N. and Sadangi, B.N. (Eds.) *Rice Production Technology*, Central Rice Research Institute, Cuttack, Odisha, India. pp. 61-68.

Saha, Sanjoy (2012). Weed management in hybrid rice. *In:* Das, Lipi, Jambhulkar, N.N. and Sadangi, B.N. (Eds.) *Rice Production Technology*, Central Rice Research Institute, Cuttack, Odisha, India. pp. 82-87.

Sarkar, R. K. (2012). Climate resilient rice cultivars adapted to excess water, *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp.141-148.

Sharma, S. G. (2012). Rice quality : A matter of concern in climate change scenario, *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp.159-165.

Shukla, A., Nayak, A. K., Raja, R., Shahid, M. and Panda, B. B. (2012). Management strategies for improving nitrogen use efficiency in rice based system under various rice ecologies. *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp.129-139.

Singh, N. P., Chattopadhyay, K. and Das, S. P. (2011). Upland rice in Tripura. In: Singh, R.K., Mandal, N.P., Singh, C.V. and Anantha, M.S. (Eds.) *Upland Rice in India.* Scientific Publishers, Jodhpur, India.

Tripathi, Rahul, Shahid, Mohammad, Nayak, A. K. and Pal, S. S. (2012). Resource conservation technologies in rice based cropping systems: A climate change mitigation option. *In*: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). *Climate change: Green-house Gas Emission in Rice Farming and Mitigation Options.* Central Rice Research Institute, Cuttack, Odisha, India. pp. 117-128.

Extension Bulletins/Popular Articles

Ghosh. A. (2012). Improve natural resource management in rainfed lowland conditions-towards higher system productivity of rainfed rice production system. *Indian Farming.* 61 (10). 14-16.

Kumar, G.A.K., Das Lipi, Sinhababu, D.P., Sadangi, B.N., Rath, N.C., Din, M., Chaudhury, A.K., Rao, R.N., Sharma, S.G and Tewari, S.N. (2012). Role of entre (Agri) preneurship development in bringing second green revolution in eastern India. *In:* Souvenir CRRI-Eastern Zone Regional Agriculture Fair, 2012. pp.42-52.

Mohapatra, T**.,** Rao, K. S. and Saha, Sanjoy **(**2012). Bringing green revolution in eastern India (BGREI). *In:* Souvenir CRRI-Eastern Zone Regional Agriculture Fair, 2012 pp. 53-57.

Mohapatra, T**.,** Rao, K. S. and Saha, Sanjoy **(**2012). *Purbi bharat mai harit Kranti arambh korne ke paripreksh mai.* Souvenir CRRI – Eastern Zone Regional Agriculture Fair, 2012 pp. 113-117.

Panda, B. B. and Nayak, A. K. (2012). Swalpa jaliye dhan chashe *In:* Das, Lipi and Sadangi, B. N. (Eds.). (2012). *Baigyanika Padhhatire Dhana Utpadana Pranali (2nd edition)* in Odia Central Rice Research Institute, Cuttack, Odisha, India. pp 47-49.

Panda, B. B., Nayak, A. K., Kumar, Anjani and Raja, R. (2012). Simit jal ke dwara dhan ki kheti (In Hindi) *In:* Das, Lipi, Jambhulkar, N.N. and Sadangi, B.N. (Eds.) . (2012). *Chawal utpadan ke liye unnat pranali*, Central Rice Research Institute, Cuttack, Odisha, India. pp 46-48.

Pun, K. B., Lenka, S., Bhakta, N. and Satapathy, B. S. (2011). RRLRRS, Gerua in the service of rice farmers of Eastern India. CRRI Regional Station, Gerua, Hajo, Assam, Information Bull., August 2011.

Sah, Rameswar Prasad, Kumar, Anjani and Gupta, Mithilesh Kumar (2011). Allele Mining through Tilling and Eco-Tilling. AGROBIOS *Newsletter, Volume X, Issue No. 6,* November, *2011.*

Saha, Sanjoy (2012). Dhan ki bivinya paritanta mai samanita kharpatwar prabandhan. *In:* Das, Lipi, Jambhulkar, N.N. and Sadangi, B.N. (Eds.) . (2012). *Chawal utpadan ke liye unnat pranali*, Central Rice Research Institute, Cuttack, Odisha, India. pp. 29-32.

Satapathy, B. S, Pun, K. B and Lenka, S. (2012). Aerobic rice – an efficient water management strategy for sustainable rice production *In*: Training manual on water management, AICRP on Water Management, Assam Agricultural University, Jorhat.

Technology/Technical Bulletins

Bhattacharyya, P., Rao, K. S. and Adhya, T. K. (2011). Advance Technology for Greenhouse Gas Monitoring in Rice and Rice-based Cropping Systems. CRRI Technical Brief-01, 4 p.

Mohanty, Sangita, Bhattacharyya, P., Swain, P., Kumar, Anjani, Singh, O. N., Chattopadhyay, K. and Sarkar, R. K. (*2012*). *Netrajan ke prabhavi prabandhan main LCC ka prayog*. Central Rice Research Institute, Cuttack (India). 4 p.

Mohanty, Sangita, Bhattacharyya, P., Swain, P., Singh., O. N., Chattopadhyay, K., Sarkar, R. K. and Kumar, Anjani (*2012). Leaf color chart: Dhana chasare jabakshara jana ra upyogita badhaebara eka utkrusta madhyama.* Central Rice Research Institute, Cuttack (India). 4 p.

Mohanty, Sangita, Bhattacharyya, P., Kumar, Anjani, Swain, P., Singh, O. N., Chattopadhyay, K. and Sarkar, R. K. (2012). *Leaf color chart (LCC) for effective nitrogen management and reduction of N_2O from rice field*. Central Rice Research Institute, Cuttack (India). 4 p.

Nayak, A. K., Raja, R., Rao, K. S., Panda, B. B. and Shukla, A. K. (2011). Fly Ash Utilization in Rice Production: A Success Story. Central Rice Research Institute, Cuttack (India). 6 p.

Nayak, A. K., Raja, R., Rao, K. S., Panda, B. B. and Shukla, A. K. (2011). *Dhan chash re fly ash ra sadupayog*. Central Rice Research Institute, Cuttack (India). 6 p.

Nayak, A. K., Raja, R., Rao, K. S., Panda, B. B., Mohammad Shahid and Anjani Kumar (2011). *Fly ash ka chawal utpadan main prayog*. Central Rice Research Institute, Cuttack (India). 6 p.

Poonam, A., Baig, M. J., Rao, K. S. (2012). *Dhan ki saghan krishi pranali* (SRI) (Hindi). CRRI Technology Bulletin-*78*, 4 p.

Poonam, A., Rao, K. S. and Sanjoy Saha (2011). System of rice intensification. CRRI Tech. Bull. 77 (CRRI). 4 p.

Reddy, J. N., Patnaik, S. S. C., Ghosh, A. and Mayabini Jena (2011). *Varshadhan – tatiya Odisha ke barshashrit aardh gahre nichli bhumi khetron ke liye adhik upaj dene bali dhan ki kisam* (Hindi) CRRI Technology Bulletin-*75*, 4 p.

Reddy, J. N., Patnaik, S. S. C., Ghosh, A. and Mayabini Jena (2011). *Varshadhan – Odishara upkulabarti anchalare barshashrit majhiaali khalua gami panie eka adhika amalakhyma dhana kisam – utpadana o chasa padhati* (Odia) CRRI Technology Bulletin-*76*, 4 p.

Reddy, J. N., Patnaik, S. S. C., Sarkar, R. K. and Rao, K. S. (2011) Swarna-Sub1: A promising high yielding rice variety for flood-prone rainfed shallow lowlands of coastal Odisha (English). CRRI Technology Bulletin-*73*, 4 p.

Reddy, J. N., Patnaik, S. S. C., Sarkar, R. K. and Rao, K. S. (2011) Swarna-Sub1: *Tatiya Odisha ke barshashrit nichlibhumi bale kum gahre badha praban khetron ke liye adhik upaj dene bali ek asajanak dhan kisam* (Hindi). CRRI Technology Bulletin-*72*, 4 p.

Reddy, J. N., Patnaik, S. S. C., Sarkar, R. K. and Rao, K. S. (2011). *Odisha upakulabarti barshajala plabita khalua gami panie udista adhika amalakhyma dhana kisama : Swarna sub-1* (Odia). CRRI Technology Bulletin-*74*, 4 p.

Sinhababu, D. P., Pandey, V., Nedunchezhiyan, M., Mahata, K. R., Nayak, P. K. and Sahu, P. K. (2012). Multitier Rice-Fish-Horticulture Based Farming System for Deepwater Areas (English). CRRI Technology Bulletin-*80*, 12 p.

Research Bulletins

Mayabini Jena (2012). *Botanical-based indigenous technical knowledge (ITK) for rice pest management-with emphasis on tribal farming system.* CRRI Research Bulletin No. 5, Central Rice Research Institute, Cuttack, Orissa, India, 80 p.

Rao, K. S., Sanjoy Saha, Panda, B. B., Poonam, A. and Ghosh, A. (2012). *Cropping system research under rainfed and irrigated rice ecology.* CRRI Research Bulletin No. 6, Central Rice Research Institute, Cuttack, Orissa, India, 28 p.

Saha, Sanjoy and Rao, K. S. (2011). *Major weeds of rice.* CRRI Research Bulletin No. 4, Central Rice Research Institute, Cuttack, Orissa, India, 63 p.

Other publications

Annonymous (2011) *CRRI Annual Report 2010-11*. Central Rice Research Institute, Cuttack (India).

Annonymous (2011-12) *CRRI Newsletters viz.,* April-June'11, July-September'11, October-December'11, January-March'12. Central Rice Research Institute, Cuttack (India).

Sinhababu, D.P., Sharma, S.G., Jena, Mayabeni, Kumar, G.A.K., Saha, Sanjoy, Das, Avijit, Lal, Banwari and Gautam, Priyanka (2012) A multi lingual *Souvenir on Technologies and Programmes for Second Green Revolution in Eastern India.* Central Rice Research Institute, Cuttack (India). 156 p.

Events and Activities

QRT, RAC, IMC, IJSC, IRC and SAC Meetings

Quinquennial Review Team

The Quinquennial Review Team (QRT), under the Chairmanship of Dr. E.A. Siddiq reviewed the research and other achievements of CRRI for the period from 2005 to 2011 by holding five discussions with different stakeholders *viz*., scientists, development agencies and farmers. The other members are Drs P. Raghava Reddy, V. Balasubramanian, N. Ramakrishnan, A.N. Mukhopadhyay and Prof Anil K. Gupta. Dr. J.N. Reddy is the Member Secretary of QRT. The team visited various facilities at the CRRI, Cuttack. They also visited CRRI Regional Station, Hazaribag, Jharkhand from 3 to 7 September, 2011and CRRI Regional Station, Gerua, Assam from 25 to 26 November, 2011.

Dr. E.A. Siddiq, Chairman QRT addressing the scientists

Research Advisory Committee

The XVIIth Meeting of the Research Advisory Committee (RAC) was held at CRRI, Cuttack from 24 to 25 September, 2011 under the Chairmanship of Dr. R.B. Singh. The other members were Drs C.L. Acharya, Shailaja Hittalmani, R. Sridhar, M.L. Lodha, S.L. Intodia, T.K. Adhya, Shri Digambar Mohapatra and Dr. S.S. Rahangdale with Dr. R.N. Rao as the Member Secretary. Dr. B.C. Viraktamath, Director, DRR, Hyderabad attended the meeting as a special invitee. The RAC reviewed the progress of work from 2010-2011. The Members also visited the experimental fields, the laboratories and *Oryza* Museum.

Chairman and members of RAC visit the experiment on methane emission

Institute Research Council

The 28th meeting of the Institute Research Council (IRC) was held from 16 to 24 May, 2011 under the Chairmanship of Dr. T.K. Adhya, Director, CRRI. Results of experiments conducted under different research programmes and externally-aided projects were presented and discussed. The 29th meeting of the IRC was held from 12 to 14 December, 2011 under the Chairmanship of Dr. Anand Prakash, Director (Acting), CRRI. Progress of research work during wet season 2011 was discussed and an action plan for dry season 2011–12 was outlined. Proposals for the XIIth Five Year Plan were also discussed. The 30th meeting of the IRC was held from 22 to 30 March, 2012 under the Chairmanship of Dr. T. Mohapatra, Director to finalize the research projects proposals for the XIIth Five Year Plan.

Institute Joint Staff Council

The 4th IJSC meeting (2009–2012) was held on 29 June, 2011 at CRRI, Cuttack and its 5th meeting at

Hazaribag on 17th September 2011 under the Chairmanship of Dr. T.K. Adhya, Director, CRRI. Various administrative and financial matters were discussed and finalized.

SAC meetings of Krishi Vigyan Kendras

KVK, Santhapur

The 13th Scientific Advisory Committee meeting of Krishi Vigyan Kendra, Cuttack was held on 28 March, 2012 under the Chairmanship of Dr. T. Mohapatra, Director, CRRI, Cuttack, and Dr. S. S. Nanda, Dean, Extension Education, OUAT, Bhubaneswar and other SAC members, farmers' representative and farmwomen's representative were present. Heads of the Division of CRRI, Cuttack and many progressive farmers of Santhapur also attended the SAC meeting as special invitees. Dr. S.M. Prasad, P.C., KVK, presented overall achievements of 2011-12 and action taken report. All subject matter specialists (SMSs) presented their brief achievements and annual action plan for April 2012 to March, 2013. In course of presentation, the Chairman and other members provided their valuable suggestions.

Dr. T. Mohapatra, Director, CRRI, Chairing the SAC of KVK, Santhapur

KVK, Koderma

The Scientific Advisory Committee of Krishi Vigyan Kendra, Jainagar, Koderma, Jharkhand was held on 03 April, 2011 under the Chairmanship of Dr. Mukund Variar, OIC, CRRI Regional Station, Hazaribag. The meeting was attended by SAC members, farmers' representative, farmwomen's representative and the staff of KVK, Koderma. Dr. V.K.Singh, P.C., KVK presented achievements of KVK and annual action plan for April 2011 to March 2012.

Participation in Symposia/Seminars/Conferences/Trainings/Visits/Workshops

Name of symposium/seminar	*Personnel Attended*
ICAR –IRRI interaction meeting at New Delhi on 4 April, 2011	Dr.T.K.Adhya
Inception meeting and planning workshop of the Stress Tolerant Rice for Africa and South Asia (STRASA, phase-2) and IFAD at NASC Complex, New Delhi from 5 to 7 April, 2011.	Drs T.K. Adhya, Mukund Variar, V.D. Shukla, N.P. Mandal, J.N. Reddy, D.P. Singh, Padmini Swain, P. Samal, R.K. Sarkar, S.S.C. Patnaik and B.C. Marndi
46th Annual Rice Group Meeting at DRR, Hyderabad from 7 to 11 April, 2011.	Drs T.K. Adhya, K.S. Rao, S.G. Sharma, Mukund Variar, V.D. Shukla, S.R. Dhua, R.N. Rao, N.P. Mandal, J.N. Reddy, A. Patnaik, S.K. Pradhan, Padmini Swain, R.K. Sarkar, S.S.C. Patnaik, C.V. Singh and N. Bhakta
Meeting of the Harvest Plus at ICRISAT, Hyderabad on 12 April, 2011.	Dr. S.G. Sharma
10th Review and Steering Committee Meeting of the Consortium for Unfavorable Rice Environments (CURE) from 18 to 20 April, 2011 at Kathmandu, Nepal.	Drs T.K. Adhya, Mukund Variar, D.P. Singh and J.N. Reddy
The Sectional Committee Meeting of the Indian National Science Academy at New Delhi on 27 April, 2011.	Dr. T.K. Adhya
Meeting on 'Promotion of Rice Strategies developed by IRRI' under the ongoing programme 'Extending Green Revolution to Eastern India (BGREI)' at Krishi Bhavan, New Delhi on 30 April, 2011.	Dr. Mukund Variar
26th Annual Group Meeting of AICRP National Seed Project (Crops) held at CSK Himachal Pradesh Agricultural University, Palampur from 2 to 4 May, 2011.	Dr. S.R. Dhua
20th Meeting of the ICAR Regional Committee No. III held at the ICAR Research Complex for North-eastern Hills Region, Umiam, Meghalaya from 5 to 6 May, 2011.	Drs KB. Pun and N. Bhakta
18th Zonal workshop of KVKs of Zone VII at RVSKVV, Gwalior from 6 to 8 May, 2011. He presented the Annual Progress Report 2010-11 and Action plan for 2011-12.	Dr. S.M. Prasad
National Seminar on 'Fly Ash-based Amendments for Amelioration of Degraded Soils to Increase Crop Production in the Gangetic Plains' at the CSSRI Regional Research Station, Lucknow from 7 to 8 May, 2011.	Drs A.K. Nayak and R. Raja
36th Zonal Research and Extension Advisory Committee Meeting 2011-12 for the Lower Brahmaputra Valley Zone of Assam held at the Horticultural Research Station, Assam Agricultural University, Kahikuchi on 9 May, 2011.	Dr. K.B. Pun

Name of symposium/seminar	Personnel Attended
Training programme on 'Employer's perspective on Labour Related Laws' at NAARM, Hyderabad from 10 to 11 May, 2011.	Dr. T.K. Adhya, Shri D. Moitra and Shri D.S. Meena
Meeting with DG, ICAR on 'Major Priority Areas of XII^{th} Plan' at New Delhi on 12 May, 2011.	Dr. T.K. Adhya
5^{th} Review Meeting of AMAAS Projects at the NBAIM, Mau on 14 May 2011.	Dr. T.K. Adhya
Review meeting of the programme 'Bringing Green Revolution to Eastern India' at Raipur on 17 May, 2011.	Dr. T.K. Adhya
Consortium Implementation Committee (CIC) meeting of the NAIP (C-3) project 'Developing Sustainable Farming System Models for Prioritized Micro Watersheds in Rainfed Area of Jharkhand' at BAU, Ranchi on 25 May, 2011.	Dr. R.K. Singh
FLD workshop of Oilseed and Pulses of Zone VII at OUAT, Bhubaneswar on 29 May, 2011.	Dr. S.M. Prasad
Meeting of the National Academy of Agricultural Science at New Delhi on 5 June, 2011.	Dr. T.K. Adhya
Meeting of the TIFAC Eastern Region at the Bose Institute, Kolkata from 6 to 7 June, 2011 to prepare its Vision Document 2035.	Dr. T.K. Adhya
Training programme on "Women Friendly Tools and Equipments for Drudgery Reduction" by AICRP on Ergonomics and Safety in Agriculture at College of Agricultural Engineering & Technology, OUAT, Bhubaneswar from 9 to 10 June, 2011.	Smt. Sujata Sethy
Meeting-cum-workshop of the Head of the Divisions and Regional Stations at CIAE, Bhopal from 14 to 15 June, 2011.	Drs K.S. Rao, O.N. Singh and Mukund Variar
'Orientation Programme on Approved Uses of Pesticides' organized by National Institute of Plant Health Management, Hyderabad on 18 June, 2011.	Dr. Sanjoy Saha
60^{th} Meeting of the Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops at the NBPGR, New Delhi on 28 June, 2011.	Dr. T.K. Adhya
Directors' Conference and Foundation Day Ceremony of ICAR from 14 to 16 July, 2011.	Dr T.K. Adhya
'NKN-GARUDA Partners Meet' organized by C-DAC, Knowledge Park, Bangalore from 15 to 16 July 2011.	Dr. G.A.K. Kumar and Shri S.K. Sethi
Training programme on Using Hindi in computers at NPTI, Durgapur from 18 to 22 July 2011.	Shri Daniel Khuntia and Miss Sandhya Rani Dalal
Training course on "Mushroom Production Technology" at National Research Centre for Mushroom, Solan, Himachal Pradesh from 21 to 27 July, 2011.	Smt. Sujata Sethy
Seminar 'Jalavayu Parivartan Aaur Krishi Vyavasthapana' organized by Krishi Vigyan Kendra, Nalbari on 29 July, 2011.	Dr. K.B. Pun
Meeting convened by the Director, Department of Agriculture, Government of Assam, on 30 July, 2011 for implementing BGREI in Assam and to plan for the BGREI programme for dry season 2011-12.	Dr. K.B. Pun

Name of symposium/seminar	*Personnel Attended*
Brainstorming session on 'Prioritization of Plant Physiology and Biochemistry Research for XII[th] Five Year Plan Period' at IARI, New Delhi from 5 to 6 August, 2011.	Drs S.G. Sharma, R.K. Sarkar and Avijit Das
Crop Seminar under the 'Mass Media Support to Agricultural Extension' of Doordarshan Kendra, Guwahati at CRRI Regional Station, Gerua on 6 August, 2011.	Dr. T.K. Adhya
National Consultation on 'Gender Prospective in Agriculture', organized by the ICAR, New Delhi from 8 to 9 August, 2011.	Drs B.N. Sadangi and Lipi Das
Scientific team survey of the rice field affected areas nearby Hindusthan Aluminium Company at Hirakud in Sambalpur district of Odisha from 9 to 10 August, 2011.	Drs P.C. Rath, A.K. Nayak and Shri S.K. Singh
3[rd] State Seed Sub-Committee meeting, convened by the Director, Department of Agriculture, Govt. of Assam on 11 August, 2011.	Drs K.B. Pun and N. Bhakta
Meeting on 'Regional Agriculture Fair' at Department of Agriculture and Cooperation, Ministry of Agriculture at Krishi Bhawan, New Delhi on 23 August, 2011.	Drs B.N. Sadangi and N.N. Jambhulkar
Workshop on 'Agriculture, Food Security and Green House Gas (GHG) Accounting Workshop' at San Diego, California, USA from 07 to 09 September, 2011.	Dr. T.K. Adhya
Workshop on "Genetic Challenge Program (GCP): Targeting drought avoidance root traits to enhance rice productivity under water-limited environment" at IRRI, Philippines from 12 to 16 September, 2011.	Dr. M.S. Anantha
International Symposium on "Plant Biotechnology towards tolerance to stress and enhancing crop yield" at BIT, Ranchi from 28 September to 2 October, 2011.	Dr. M.S. Anantha
31[st] Rabi Research Council meeting of the Birsa Agricultural University, Ranchi on 25 October, 2011.	Dr. S.G. Sharma
Training programme on "Phenotyping for Abiotic Stress in Rice" at IRRI, Philippines from 27 October to 11 November, 2011.	Drs K. Chattopadhyay and B. Bhattacharya
71[st] Annual Conference of the Indian Society of Agricultural Economics at University of Agricultural Sciences, Dharwad from 3 to 5 November, 2011.	Dr. P. Samal
Annual Meeting of the eastern chapter of Indian Phytopathological Society organized by Department of Botany, Guwahati University from 4 to 5 November, 2011.	Dr. S. Lenka
General body meeting of Indian Society of Genetics and Plant Breeding and meeting on Phenomics in New Delhi from 3 to 5 November, 2011.	Dr. O.N. Singh
Meeting on 'Possibility to Explore the Collaboration of JNKVV and CRRI' at Jabalpur from 6 to 7 November, 2011.	Dr. O.N. Singh
Brain Storming Session on 'Health Food platform' at IASRI, New Delhi on 17 November, 2011.	Dr. S.G. Sharma
Meeting on "Impact Assessment of International Trainings in Frontier Areas of Agricultural Sciences" at the NASC Complex, New Delhi from 28 to 30 November, 2011.	Drs. S.K. Pradhan, M.K. Kar and Shri R.K. Sahu

Name of symposium/seminar	*Personnel Attended*
The GRiSP workshop on "Developing New Generation Climate Adapted Varieties" at IRRI, Philippines from 28 to 30 November, 2011.	Drs M. Variar and N.P. Mandal
National Symposium on "Biology, Immunity and Disease Control in Pathogen-Plant Interactions" at University of Hyderabad, Hyderabad from 2 to 4 December, 2011.	Dr. Dipankar Maiti
Sixth National Conference of KVKs at JNKVV, Jabalpur, from 3 to 5 December, 2011.	Dr. S.M. Prasad
Technology week meeting organized by the KVK Holly cross, Hazaribag on 9 December, 2011.	Drs M. Variar and V.D. Shukla
International Symposium on '100 years of Rice Science and Looking Beyond' at TNAU, Coimbatore from 9 to 10 January, 2012.	Dr. Anand Prakash, Drs K. Pande, B.C. Patra, S.K. Dash, A.K. Nayak, R. Raja, B.B. Panda, Rahul Tripathy, Upendra Kumar, Anjani Kumar
3rd Global conference on 'Plant Pathology for Food Security' at Maharana Pratap University of Agriculture & Technology, Udaipur, Rajasthan from 10 to 13 January, 2012.	Dr. S.R. Dhua
12th SABRAO Congress on 'Plant Breeding Towards 2025: Challenges in a Rapidly Changing World' in Thailand from 13 to 16 January, 2012.	Dr. J.N. Reddy
Research Advisory Committee meeting of the Directorate of Rapeseed Mustard, ICAR, Bharatpur on 31 January, 2012.	Dr. T. Mohapatra
Partners' meeting on Health Foods at CIPHET, Ludhiana from 2 to 3 February, 2012.	Dr. S.G. Sharma
Stakeholders Consultation Meeting at the DRR, ICAR, Hyderabad on 10 February, 2012.	Dr. T. Mohapatra
Training programme on 'Phenotyping and Molecular Breeding for Drought Adaptive Traits' at University of Agricultural Sciences, Bangalore from 13 to 22 February 2012.	Dr. S.K. Dash
Directors' Conference at IARI, ICAR, New Delhi from 17 to 18 February 2012.	Dr. T. Mohapatra
The Results-Frame-Works Documents meeting at Krishi Bhawan, New Delhi on 21 February, 2012.	Dr. N.N. Jambhulkar
National Symposium on 'Rice-based Farming System for Livelihood Security under Changing Climate Scenario' at the College of Agriculture, Chiplima, Sambalpur on 29 February, 2012.	Drs. T. Mohapatra, A.K. Nayak, R. Tripathy, R. Raja, B.B. Panda, S.G. Sharma, D.P. Sinhababu, B.C. Patra and P. Bhattacharya
Research Advisory Committee meeting at the DWR, ICAR, Karnal on 5 March, 2012.	Dr. T. Mohapatra
Institute Management Committee meeting at the NBFGR, ICAR, Lucknow on 6 March, 2012.	Dr. T. Mohapatra
Meeting on "Genetic Improvement of Rice with Special Reference to Eastern India" at the Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi on 12 March, 2012.	Dr. G.J.N. Rao

Name of symposium/seminar	*Personnel Attended*
Global Conference on 'Women in Agriculture' organized by ICAR and APARI at NASC Complex, New Delhi from 13 to 15 March, 2012.	Drs B.N. Sadangi and Lipi Das
NAIP Annual Workshop at New Delhi from 19 to 20 March, 2012.	Dr. T. Mohapatra
ICAR-IRRI meeting at the NASC, New Delhi on 21 March, 2012.	Dr. T. Mohapatra
2nd Annual review meeting of the DBT funded research project entitled "Establishment of National Rice Resource Database at National Institute of Plant Genomic Research (NIPGR), New Delhi on 31st May, 2011	Dr. B.C. Patra
NBPGR-NAGS Workshop to formulate a National Network project on PGR at New Delhi during 29-30 July, 2011.	Dr. B.C. Patra
Group Meeting at NBPGR, New Delhi on 17 November, 2011 to finalise the draft proposals for the National Network Project on PGR for XII Plan (Agro-biodiversity platform).	Dr. B.C. Patra
Meeting on Registration of Farmers' varieties in the state of Odisha at State Seeds Testing Laboratory, Govt. of Odisha, Bhubaneswar on 28 April, 2011.	Dr. B.C. Patra
Training-cum-workshop on "Seed production of Farmers' varieties for the state of Odisha" at CRRI, Cuttack on 28 June, 2011 and delivered a lecture entitled "Management of field plots for seed production of varieties and characterization by DUS guidelines".	Dr. B.C. Patra
Group Meeting at NBPGR, New Delhi on 17 November, 2011 to finalise the draft proposals for the National Network Project on PGR for XII Plan (Agro-biodiversity platform).	Dr. B.C. Patra
Review and planning meeting of DBT India-IRRI Network Project "*From QTL to variety: marker assisted breeding of abiotic stress tolerant rice varieties with major QTLs for drought, submergence and salt tolerance*" held at NRCPB, New Delhi on 8 November, 2011.	Dr. J.N. Reddy
"Phenotyping for abiotic Stresses in Rice", held at International Rice Research Institute, Los Banos, Philippines during 27 October to 11 November, 2011.	Dr. K. Chattopadhyay
National conference on "Applied Zoological Research For National Food Security and Environmental protection" held on 15-16, February, 2012.	Drs Anand Prakash, Mayabini Jena, K.S. Behera, P.C. Rath, S. Pokhare and Berliner J.

Participation in Exhibitions

The institute participated in following exhibitions for showcasing the CRRI technologies.

- IVRI Kisan Mela 2011 at IVRI, Izatnagar, UP during 18-20 October, 2011.
- Krushak Sampark Mela at Jalakeli, Narasinghpur, Cuttack on 24 December, 2011.
- Regional Agricultural Fair 2012 at CRRI, Cuttack during 21-23 February, 2012.
- Krushi Mohotsav at Januaryata Maidan, Chandrasekharpur, Bhubaneswar during 25-28 March, 2012.

CRRI Stall at IVRI Kisan Mela 2011 at Izatnagar

Dr. T. Mohapatra, Director addressing to the audience during Krushi Mohatsav

Organization of Events, Workshops, Seminars and Farmers' Day

CRRI Foundation Day

The 65th CRRI Foundation Day of CRRI was celebrated on 23 April, 2011 at CRRI, Cuttack. Dr. C.D. Mayee, Chairman, Agricultural Scientists Recruitment Board (ASRB), New Delhi and Chief Guest of the programme spoke on the developments in agriculture and the efforts of the ASRB to identify talent. Dr. S.K. Datta, Deputy Director General (Crop Sciences), ICAR, New Delhi and Guest of Honour of the function outlined the role of rice in food security and to evolve new strategies in the plant breeding programmes. Shri U.P. Singh, IAS, Principal Secretary (Agriculture), Government of Odisha, gave an overview of rice production in Odisha. A documentary film "Golden Panicle" on CRRI and an Oriya booklet "Method of Scientific Rice Production" were released. Ten progressive farmers were felicitated. Shri Ashirbad Pradhan, Shri Saswat Lenka and Kumari Somika Nayak were awarded cash prize for their academic achievement in Std.-X from Best Institute award fund.

On the eve of the foundation day, Dr. C. D. Mayee delivered the 2nd Foundation Day lecture on "Do GM crop regulations aid or abate farm or farmers".

Eastern Zone Agricultural Fair

Central Rice Research Institute organized the Eastern Zone Regional Agricultural Fair 2011-12 sponsored by Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India from 21 to 23 February 2012 on the theme "Technologies and Programmes for Second Green Revolution in Eastern India". The fair was organised under the chairmanship of Dr. T. Mohapatra, while Dr. B.N. Sadangi acted as co-chairman and Dr. G.A.K. Kumar as Organising Secretary.

The fair attracted 1250 farmers and farmwomen from from Eastern India and provided opportunities to research institutes, extension agencies, govt. and non-govt. organizations to showcase their technologies, programmes and policies meant for agriculture development of the region. The events started with an inauguration function which was attended by Dr. R. P. Dua, ADG, Crop Science as Chief Guest, Dr. A. K. Padhee, IAS, Director Special Project, Panchayati Raj Department, Govt. of Odisha, Shri R. S. Gopalan, IAS, Director of Agriculture & Food Production, Govt. of Odisha as Guest of Honour, Shri Kshetrabasi Behera, a renowned agripreneur of Odisha as Guest. The inauguration was presided by Dr. T. Mohapatra, Director, CRRI. A multi lingual souvenir, extension booklets and technology bulletins were released on this occasion.

The final day was marked by a valedictory function which was attended by eminent guests, Shri G. C. Pati, IAS, Additional Secretary, Ministry of Agriculture, Govt. of India as Chief Guest and Prof. D. P. Ray, Vice Chancellor, OUAT as Guest of Honour. The guests lauded the potentiality of eastern India in agriculture sector and elaborated the concerns of the Central and State Govt. to harness the potentiality. Dr. T. Mohapatra, Director, CRRI while summarizing the efforts of CRRI in the said direction, called upon the participating farmers to disseminate their experiences and play a catalytic role in their micro situations. Eleven farmers and three farm women from different states were felicitated by the Chief Guest for their innovative behavior in farming.

Women in Agriculture Day

The KVK, Santhapur celebrated "Women in Agriculture Day" at village Budukunia in Mahanga block of Cuttack district in Odisha on 4 December, 2011. Farmwomen interacted with the Director (Acting), CRRI and chief guest of the programme Dr. Anand Prakash,and other scientists from the CRRI and the KVK, Santhapur. In this programme, 150 farm women, school dropout girls, rural youths and farmers from Budukunia and nearby villages participated . One quiz programme was conducted for farm women and prizes were distributed by the Chief Guest.

Release of KVK Newsletter on the ocasion of Women in Agriculture Day

World Food Day

The World Food Day was celebrated on 16 October, 2011 at village Rudrapur of Tangi-Choudwar block. More than 200 farmers of villages Chadaipada, Ganeshwarpur, Rudrapur and Jaripada participated in the programme that was organized by the KVK, Santhapur. Dr. Anand Prakash, gave away awards to two progressive farmers and certificates to school children who participated in a quiz competition.

Dr. Krishna Srinath, Director, DRWA inagurating the 20th Gopinath Sahu Memorial Lecture

Gopinath Sahu Memorial Lecture

The 20th Gopinath Sahu Memorial Lecture was delivered on the topic "Gender Issues in Rice Farming" by Dr. Krishna Srinath, Director, Directorate of Research on Women in Agriculture, Bhubaneswar on 1 November, 2011 at CRRI, Cuttack.

Hindi Fortnight

The Hindi Fortnight was celebrated at CRRI, Cuttack as well as at CRRI Regional Station, Hazaribag from 14 to 30 September, 2011. Various competitions were conducted during this occasion among the staff of CRRI and the winners were awarded with cash prize and certificate.

Hindi Workshop

A one day Hindi workshop on "General Provident Fund and its Advances and Withdrawal: Noting and Drafting in Hindi" was organized at CRRI, on 24 November, 2011. Fourteen employees from the CRRI participated in the workshop. Shri G. Kalundia, Assistant Director (Official Language), CRRI, Cuttack spoke on the efforts at the CRRI in using Hindi for official noting and drafting.

Vigilance Awareness Week

The Vigilance Awareness Week was observed from 31 October to 5 November, 2011 at CRRI, Cuttack and its regional stations at Hazaribag and Gerua. Shri Santosh Upadhyay, IPS, IGP (Vigilance), Govt. of Odisha and Chief Guest of the occasion addressed the staff of CRRI and gave certificate for participating in a debate competition in Hindi, English and Odia on 'Participative Vigilance'.

Workshop on Fly-ash

A one day workshop under the DST funded project 'Confidence Building and Facilitation of Large scale Use of Fly-ash as an Ameliorant and Nutrient Source for Enhancing Rice Productivity and Soil Health' was

organized at CRRI, Cuttack on 20 November, 2011. More than 50 farmers from the adopted villages of the project participated and gave their experience in using fly-ash in their fields with rice Gayatri and Swarna.

Kisan Diwas

The Kisan Diwas was organized by the CRRI Regional Station, Hazaribag at village Chauria in Hazaribag on 4 November, 2011. On this occasion farmers spoke on their experience of growing the varieties of the station.

Farmer's Field Day

A Farmers' Field Day and training programme was organized at the KVK, Koderma on 4 November 2011 which was inaugurated by Dr. Anand Prakash, Director (Acting), CRRI. Dr. Prakash listed out the new research activities to tackle emerging problems of growing rice. Dr. V.K. Singh, PC, KVK, Koderma, spoke on the objectives. Dr. M. Variar outlined the research programmes. He also spoke on the new rice varieties brought out by CRRI Regional Station, Hazaribag. Farmer's shared their experiences. The KVK demonstrated the zero till machine and the reaper to the farmers.

Training Programmes

The following State and National level training programmes were organized during the year 2011-12.

Training Programme on Rice Production Technology sponsored by DAO, Purnea, Bihar during 26 to 30 April, 2011.

Capacity building programme for KVK personnel of Odisha and Chhattisgarh on Rice Production technology sponsored by ZPD, Zone-VII, Jabalpur during 30 to 31 May, 2011.

Training Programme on Rice Production Technology sponsored by ATMA, Begusarai, Bihar during 17 to 23 January, 2012.

Training Programme on Hybrid Rice Production Technology sponsored by SIMA Rahmankhela, Lucknow during 27 to 31 January, 2012.

Training Programme on Rice Production Technology sponsored by BTC Kokrajhar, Assam during 1 to 7 March, 2012.

Training Programme on Rice Production Technology sponsored by ATMA, Koderma, Jharkhand during 20 to 24 March, 2012.

Above the training programmes were coordinated by Dr. Lipi Das.

Farmers training workshop on 'Awareness of Conservation, Cultivation & Commercialization of Landraces

A moment of accomplishment during the training programme of Rice' at CRRI was organised during 1 to 2 February, 2012 in which fifteen farmers participated. Dr. Ashok Patnaik coordinated the programme.

Mid-term progress review meeting of the DBT sponsored network research project entitled 'Establishment of National Rice Resource Database' was organised on 19h November, 2011 at CRRI, Cuttack. Dr. B.C. Patra coordinated the programme.

A twenty one day Field Experience Training was conducted from 8 to 28 November, 2011 for the scientists of 84th FOCARS batch at CRRI. The programme was coordinated by Drs G.A.K. Kumar and J.R. Mishra.

A training programme on 'Seed Production and Characterisation of Farmers' Varieties was organised by CRRI in collaboration with the State Seed Testing Laboratory, Govt. of Odisha on 28 june, 2011 for personnel of selected NGOs and state department officials.

Exposure Visits

A total of 4370 visitors including farmers (3411), farmwomen (214), students (442), agriculture officers (295) and scientists (8) from Odisha, Andhra Pradesh, Jharkhand, Tripura, West Bengal, Tamil Nadu, Kerala, Madhya Pradesh, Punjab, Chattishgarh, Uttar Pradesh, Assam and Bihar have visited CRRI experimental plots and *Oryza* Museum and were addressed by the rice experts of the institute.

Distinguished Visitors

Dr. C.D. Mayee, Chairman, Agricultural Scientists Recruitment Board, New Delhi visited CRRI, Cuttack on 22 April, 2011.

Dr. S.K. Datta, Deputy Director General (Crop Sciences), ICAR, New Delhi visited CRRI, Cuttack on 23 April, 2011.

Shri P.K. Basu, IAS, Secretary and Shri M. Khullar, IAS, Joint Secretary, Department of Agriculture and Cooperation, Government of India, New Delhi, visited CRRI, Cuttack on 19 May, 2011.

Dr. Inacio Calvino Maposse, Chief of Delegation and President of Scientific Council of Agriculture, Government of Mozambique, Professor Vasco J. Lino, National Director for Research, Innovation and Technology Development, Mozambique and Sergio Pereira, Engineer, Department of Agriculture, Mozambique visited CRRI, Cuttack on 8 June, 2011.

Shri G.C. Pati, IAS, Additional Secretary, (DAC), Government of India, New Delhi, visited CRRI, Cuttack on 20 June, 2011.

Dr. Emerlinda R. Roman, Chairman, IRRI Board of Trustees, Dr. Robert S. Zeigler, Director General, IRRI, Philippines and Achim Dobermann, Deputy Director General (Research), IRRI, Philippines visited on 10 October, 2011.

Dr. G. Kalloo, Vice-Chancellor, JNKVV, Jabalpur visited on 21 October, 2011.

Dr. K.C. Bansal, Director, NBPGR (ICAR), New Delhi visited CRRI on 4 January, 2012.

Dr. R. P. Dua, ADG, Crop Science, Dr. A. K. Padhee, IAS, Director Special Project, Panchayati Raj Department, Government of Odisha and Shri R. S. Gopalan, IAS, Director of Agriculture & Food Production, Government of Odisha visited CRRI on 21 February, 2012.

Shri G.C. Pati, IAS, Additional Secretary, Dept. of Agriculture & Cooperation, Ministry of Agriculture, Government of India, New Delhi and Shri R.L. Jamuda, IAS, Principal Secretary (Agriculture), Government of Odisha visited CRRI on 23 February, 2012.

Dr. Wais Kabir, Executive Chairman, Bangladesh Agriculture Research Council visited CRRI on 15 March, 2012.

Dr. Inacio Calvino discussing with the Director, CRRI

Dr Wais Kabir visiting the Biotechnology Lab at CRRI

Awards/Recognition

The Times of India and Tefla's "Think Odisha Leadership Award for Educational Institute of Excellence 2011" was awarded to CRRI for its path-breaking rice research that led to the development of various technologies involved tapping genetic resources for breeding rice varieties with higher yield potential, better grain quality and increased tolerance to diseases and pests. Dr. T.K. Adhya, Director, CRRI received the Award from Shri Naveen Patnaik, Hon'ble Chief Minister of Odisha on 27 August, 2011 in Bhubaneswar.

Dr. T.K. Adhya received the ICAR Norman Borlaug Award 2010 from Shri Sharad Pawar, Hon'ble Union Minister of Agriculture, Government of India during the ICAR Foundation Day on 16 July, 2011 at New Delhi. Dr. T.K. Adhya was given this award for his outstanding studies on "Methane Production in Paddy Fields" that involved "Significant contributions in the frontier areas of agro-environmental science and natural resource management with tropical rice soil as the model ecosystem."

Dr. T.K. Adhya, Director receiving the Think Odisha Leadership Award from Hon'ble Chief Minister of Odisha

Dr. Anand Prakash was awarded the Honorary Fellowship of the Society of Biological Sciences & Rural Development, Allahabad, for his outstanding contribution in the field of Plant Protection on 11 November, 2011.

Dr. Dipankar Maiti, Principal Scientist, CRRI Regional Station, Hazaribag was awarded the Prof. MJ Narasimhan Medal for the best paper published in the journal *Indian Phytopathology* titled "Enhancing Native Arbuscular Mycorrhizal Association to Improve Phosphorus Nutrition of Rainfed Upland Rice through Cropping Systems" in joint authorship with Drs V.K. Barnwal, Sulochona K. Rana, M. Variar and R.K. Singh. Dr. Maiti was given the award during the 64th Annual Meeting of the Indian Phytopathology Society held at University of Hyderabad, Hyderabad on 4 December, 2011. Dr. Dipankar Maiti was also nominated as a Fellow of the society for 2011.

During the 65th Foundation Day the 'Best Worker' awards were given to the following CRRI staff.

Longest Service: Shri A. Pattnaik (Principal Scientist); Shri B.V. Das (T-5); Shri K.B. Agasti (PS) and Shri Bulu Naik (SSS).

Best Worker: Dr. G.J.N.Rao (Principal Scientist); Dr. S.K.Pradhan (Senior Scientist); Shri Prakash Kar (T 7-8); Shri Arun Kumar Mishra (T-5); Shri Brundaban Das (T-3); Shri Basant Kumar Sahoo (AAO); Shri Janardan Nayak (PA); Shri Sanjay Kumar Sahoo (Assistant); Kumari Jali Das (LDC), CRRI Regional Station, Gerua and Shri P. Bhoi (SSS).

M.Sc. degree awarded after completing dissertation work at CRRI

Discipline	Number of Students
Biotechnology	20
Microbiology	5
Bioinformatics	1
Food Science and Technology	2

Ph.D. degree awarded

Name of the student	Thesis Title	University	Name of the guide
Binay Bhusan Panda	Biochemical studies on iron metabolism in rice plant (*Oryza sativa* L.)	Sambalpur University Sambalpur	Dr. Avijit Das
Jyotirmayee Das	Phenotypic and molecular diversity of toxin and inhibitor producing bacteria in flooded soil and sediments from rice fields of coastal India	Utkal University Bhubaneswar	Dr. T. K. Dangar

CRRI lifts championship trophy in sports meet

CRRI, Cuttack lifted the overall Institute Championship Trophy during the ICAR Zonal Sports Tournament for Eastern Zone held at Indian Veterinary Research Institute, Izatnagar, from 7 to 11 April, 2011. CRRI got the first position in kabaddi, table tennis doubles (women) and 4 x 100 m relay race. It got the second position in volleyball shooting. Shri P.K. Parida, was judged as the best athlete (men) of the Zone.

The CRRI sports contingent was also adjudged the Champion in the ICAR Zonal tournament held at Patna from 19 to 22 March, 2012 by scoring 105 points in the tournament, a record for the eastern zone among 22 ICAR institutes from the eastern zone. Shri P.K. Parida and Kum. Sabita Sahoo of CRRI were declared as the Best Athlete (men) and Best Athlete (women), respectively.

CRRI-Champions in ICAR Inter-Zonal sports championship

For the third time, the CRRI lifted the ICAR Inter-Zonal Sports Championship held at CRIJAF, Barrackpore from 16 to 19 January, 2012 among 42 ICAR institutes in India. Shri P.K. Parida, CRRI was adjudged as the Best Athlete.

CRRI sports contingent with the championship trophy in the ICAR Inter-Zonal meet at Barrackpore

CRRI sports contingent with the champions trophy in ICAR Zonal meet at Patna

CRRI participates in Kabaddi Championships

The CRRI kabaddi team participated in the 59th Senior State Kabaddi Championship for Men held at Sambalpur, Odisha from 9 to 11 December, 2011. Shri P.K. Parida was selected from the CRRI to represent the Odisha Kabaddi team in the 59th National Senior Kabaddi championship held from 14 to 16 December, 2011 in Jamshedpur, Jharkhand.

Personnel

Staff strength as on 31st March 2012

Category	Posts at CRRI, Cuttack			Posts at KVK, Santhapur			Posts at KVK, Koderma		
	Sanctioned	*Filled*	*Vacant*	*Sanctioned*	*Filled*	*Vacant*	*Sanctioned*	*Filled*	*Vacant*
Scientist	114	86	28	4	1	3	1	1	-
Technical	179	116	63	11	7	4	11	7	4
Administrative	94	82	12	2	1	1	2	-	2
Skilled Support Staff	165	73	92	2	1	1	2	2	-
Others	5	5	-	-	-	-	-	-	-
RMP	1	1	-	-	-	-	-	-	-
Total	558	363	195	19	10	9	16	10	6

Dr. T. Mohapatra (from 13 January, 2012) ..... Director
Dr. A. Prakash (1 October, 2011 to 12 January 2012) .. .. Director (Acting)
Dr. T.K. Adhya (up to 30 September, 2011) .... Director

Division of Crop Improvement

Dr. O. N.Singh .... Principal Scientist & Head

Genetics and Plant Breeding

Dr. G.J.N. Rao .... Pr.Scientist
Dr. S.R. Dhua .... Pr.Scientist
Dr. K. Pande .... Pr.Scientist
Dr. R.N. Rao .... Pr.Scientist
Dr. J.N. Reddy .... Pr.Scientist
Shri A. Pattnaik .... Pr.Scientist
Dr. (Mrs.) Meera Kumari Kar .... Sr.Scientist
Dr. S.K. Pradhan .... Sr.Scientist
Dr. L.K. Bose .... Sr.Scientist
Dr. K.Chattopadhyay .... Sr.Scientist
Dr. Sushant Kumar Dash .... Sr.Scientist
Sri R.K. Sahu .... Scientist (SG)
Sri S.S.C. Pattanaik .... Scientist (SG)
Shri J.Meher .... Scientist (SS)
Dr. RamlakhanVerma .... Scientist
Sri B.S. Subramanian .... *Scientist
Dr. Ramesh Chandra .... T-6 (Jr. Tech. Asst.)
Sri A.V.G. Sharma .... T-6 (Sr.Mechanic)

Economic Botany

Dr. B.C. Patra .... Pr.Scientist
Dr. D. Swain .... Sr.Scientist
Dr. H. N.Subudhi .... Sr.Scientist
Sri B.C. Marndi .... Scientist (SG)

Biotechnology

Dr. (Mrs.) S. Samantaray .... Sr.Scientist
Dr. L. Behera .... Sr.Scientist
Dr. (Ms.) B. Bhattacharjee .... Sr.Scientist
Sri J.L. Katara, ... Scientist

Division of Crop Production

Dr. K.S. Rao .... Principal Scientist & Head

Agronomy

Dr. A. Ghosh .... Sr.Scientist
Dr. Sanjoy Saha .... Sr.Scientist
Dr.(Ms.) Annie Poonam .... Sr.Scientist
Dr. R. Raja .... Sr.Scientist
Dr. B.B. Panda .... Sr.Scientist
Sri Banwari Lal .... Scientist
Mrs. Priyanka Gautam .... Scientist

Soil Science

Dr. A.K. Nayak .... Pr.Scientist
Dr. P. Bhattacharyya .... Sr.Scientist
Dr(Ms.) Sangita Mohanty .... Scientist
Dr. Mohammad Shahid .... Scientist
Sri Anjani Kumar .... Scientist
Dr. Rahul Tripathi .... Scientist
Dr.(Mrs.) Kasthuri Thilangam. V .... Scientist

Microbiology

Dr. T.K. Dangar .... Pr.Scientist
Sri Upendra Kumar .... Scientist

Fish and Fisheries

Dr. D.P. Sinhababu .... Pr.Scientist

Dr. P.K. Nayak .... Pr.Scientist

Agricultural Engineering

Dr. P.C. Mohapatra .... Pr.Scientist

Er. B.C.Parida .... Pr.Scientist

.... (retired on 31 August, 2011)

Dr. P.N. Mishra .... Pr.Scientist

Dr. M. Din .... Pr.Scientist

Sri S.P. Patel .... Pr.Scientist

Division of Crop Protection

Dr. Anand Prakash .... Principal Scientist & Head

Entomology

Dr. S. Sasmal .... Pr.Scientist

Dr. K.S. Behera .... Pr.Scientist

Dr.(Mrs.) Mayabini Jena .... Pr.Scientist

Dr. P.C. Rath .... Sr.Scientist

Pathology

Dr.(Mrs.) Urmila Dhua .... Pr.Scientist

Dr.S.N.Tewari .... Pr.Scientist

Sri S.K. Singh .... Scientist (SS)

Nematology

Dr. S.C. Sahu .... Pr.Scientist

Sri Berliner J. .... Scientist

Sri S.S. Pokhare .... Scientist

Division of Biochemistry, Physiology and Environmental Sciences

Dr. S.G. Sharma .... Principal Scientist & Head

Physiology

Dr. D.P. Singh .... Pr.Scientist

Dr. R.K. Sarkar .... Pr.Scientist

Dr. (Mrs.) P. Swain .... Pr.Scientist

Dr. M.J. Baig .... Sr.Scientist

Dr. (Mrs.) N. Dwivedi .... Sr.Scientist

Biochemistry

Dr. Avijit Das .... Sr.Scientist

Sri T.B. Bagchi .... Scientist

Division of Social Science

Dr. B.N. Sadangi .... Principal Scientist & Head

Extension

Dr. N.C. Rath .... Pr.Scientist

Dr. G.A.K. Kumar .... Sr.Scientist

Dr.(Mrs.) Lipi Das .... Scientist (Sr.Scale)

Sri Prakash Kar .... T (7-8) (Sr.Photographer)

Sri P. Jana .... T (7-8) (Technical Officer)

Sri Ravi Viswanathan ....

.... T-6 (Editor-cum-Information Officer)

Economics

Dr. P. Samal .... Pr.Scientist

Statistics

Dr. N.N. Jambhulkar .... Scientist

Automobile Unit

Sri K.K. Swain .... T -9 (Mechanical Engineer)

CRRI Regional Station, Hazaribag

Dr. M.Variar .... Principal Scientist & O.I.C.

Dr.V.D. Shukla .... Pr.Scientist

Dr. R.K. Singh .. Pr.Scientist (retired on 30 June, 2011)

Dr.D. Maiti .... Pr.Scientist

Dr. N.P. Mandal .... Sr.Scientist

Dr.Yogesh Kumar .... Sr.Scientist

.... (Joined on 12 March 2012)

Sri C.V. Singh .... Scientist(SG)

Sri Anantha M.S. .... Scientist

Dr. V. Karunakaran .... Scientist

Sri J. Terom .... T(7-8) (Sr. Farm Asst.)

CRRI Regional Station, Gerua

Dr.K.B. Pun .... Principal Scientist & O.I.C.

Dr.Teekam Singh .... Sr.Scientist

Dr. Srikanta Lenka .... Sr.Scientist

Dr. N. Bhakta .... Scientist(Sr.Scale)

Sri B.S. Satapathy .... Scientist

Krishi Vigyan Kendra, Cuttack (Santhapur)

Dr. S.M. Prasad .... Sr.Scientist

Dr. J.R. Mishra .... T (7-8) STA (Agrl.Extn.)

Mrs. Sujata Sethy .... T-6 STA (Home Science)

Sri D.R. Sarangi .... T-6 STA (Soil Science)

Sri T.R. Sahoo .... T-6 STA (Horticulture)

Dr. Manish Chourasia .... T-6 STA (Plant Protection)

Krishi Vigyan Kendra, Jainagar, Koderma (Jharkhand)

Dr.V.K. Singh .... Sr.Scientist

Mrs. Chanchila Kumari, ... T-6, STA (Home Science)

Dr. Shudhanshu Sekhar, ... T-6, STA (Veterinary Sc.)

Sri Bhoopendra Singh .... T-6, STA (Horticulture)

Administration and Finance

Sri D. Moitra .... Chief Administrative Officer

.... (upto 9 December, 2011)

Sri B.K.Sinha .... Senior Administrative Officer

.... (from 17 January, 2012)

Sri S.R. Khuntia .... Senior Finance &Accounts Officer

Sri D.C. Sahoo .... Administrative Officer

Sri P.C. Naik .... Administrative Officer

.... (retired on 29 February, 2012)

* On deputation

Projects and Financial Resources

Work Plan for 2011-2012

Programme 1. Genetic resources and seed technology: Leader: S.R. Dhua/B.C.Patra

Principal Investigators (PIs)

B.C. Patra, H.N. Subudhi, B.C. Marndi, M.S. Anantha, S.R. Dhua, L. Behera, R.K. Sahu, U. Dhua and C.V. Singh

Co-Principal Investigators (Co-PIs)

H.N. Subudhi, B.C. Marndi, A. Patnaik, B.C. Patra, N.P. Mandal, R.K. Sahu, J.N. Reddy, S.S.C Patnaik, A. Prakash, S. Saha, U. Dhua, R.N.Rao, A.Poonam, S.R. Dhua, L. Behera and R.K. Singh

Programme 2. Genetic enhancement of yield: Leader: GJN Rao/R.N. Rao

Principal Investigators (PIs)

L.K.Bose, J.N. Reddy, S.S.C. Patnaik, B.C. Marndi, K.Chattopadhyay, S.K. Pradhan, N .Bhakta, R.N. Rao, S.K.Dash, S.K. Pradhan, S.Samantaray, B. Bhattacharya, L. Behera, N. Dwivedi, G.J.N. Rao, S.C. Sahu, D. Swain andM.J .Baig

Co-Principal Investigators (Co-PIs)

M.Variar, V.D. Shukla, L.K.Bose, O.N. Singh, P. Swain, L.Behera, K. Pande, S.K. Pradhan, A. Ghosh, M.J. Baig, K.M.Das, A. Prakash, C.D.Mishra, S.K. Das, C.V. Singh, R.K. Singh, M.S. Anantha, S.S.C. Patnaik, M. Kar, G.J.N. Rao, N. Bhakta, B.B.Panda, Md. Shahid, P.C. Rath, R.K. Sarkar, U. Dhua, S. Sasmal, J.N. Reddy, K. Chattopadhyaya, D.P. Singh , B.C.Marndi, K.B.Pun, J.L. Katara, R.L. Verma, R.N. Rao, R.K. Sahu, A. Patnaik, G. Bhaktavatsalam, S.C. Sahu, N.P.Mandal, K.Vanitha, S. Samantaray, A. Das, J. Meher, M. Jena, B. Bhatachharya, H.N. Subudhi, B.C.Patra and S.G.Sharma

Programme 3. Improvement of grain and nutritional quality: Leader: A Patnaik/S.G. Sharma

Principal Investigators (PIs)

A. Patnaik, K.Chattopadhyay, S .G. Sharma, T.B.Bagchi and A. Das

Co-Principal Investigators (Co-PIs)

G.J.N. Rao, L. Behera, S.G. Sharma, A.K. Nayak, T.B. Bagchi, K.S. Behera, P. Mishra, S.N. Tewari, Md. Shahid, A. Das, B.C. Marndi, P. Bhattacharya, H.N. Subudhi, J.N. Reddy, R.N. Rao, S.S.C. Pattnaik and S.C. Sahu

Programme 4. Breeding for resistance/tolerance to biotic, abiotic and environmental stresses: Leader: JN Reddy/RK Sahu

Principal Investigators (PIs)

M. Jena, K.M. Das, C.D. Mishra, R.K. Sahu, J.N. Reddy, M.K. Kar, R.K. Sarkar, D.P. Singh, P. Swain, M.J. Baig and N. Dwivedi

Co-Principal Investigators (Co-PIs)

K.S. Behera, P.C. Rath, K.Vanitha, S.K. Pradhan, R.K. Sahu,R.N. Rao, K.M. Das, U. Dhua, S.N. Tewari, S.K. Singh, M.K. Kar, B.C. Marndi, L. Behera, M. Jena, S.C. Sahu, A. Prakash, G.J.N. Rao, K.B. Pun, D.P. Singh, J.N. Reddy, R.K. Sarkar, B.C. Marndi, A.K. Nayak, M.J. Baig, O.N. Singh, N.P. Mandal, S. Saha, P. Swain, R.N. Rao and T.B. Bagchi

Programme 5. Natural resource management and input use efficiency for improved crop production: Leaders: A.K.Nayak/ A. Ghosh

Principal Investigators (PIs)

A. Ghosh, S. Mohanty, A. Poonam, K.S. Rao, P. Bhattacharyya, D.P. Singh, B.B. Panda, Md. Shahid, T.K. Dangar and D.Maiti

Co-Principal Investigators (Co-PIs)

K.S. Rao, P.C. Mohapatra, O.N. Singh, S. Mohanty, P. Bhattacharyya, A. Ghosh, S. Saha, M.J. Baig, S.P. Patel, M. Din, C.V. Singh, V.D.Shukla, R.K. Singh, B.S. Satapathy, K.S. Behera, K.M. Das, M. Jena, A. Patnaik, S.N. Tewari, T.B. Bagchi, A. Poonam, B.B. Panda, R.Raja, T.K. Adhya, U. Kumar, R. Tripathi, P. Samal, P. Swain, A. Kumar, A.K. Nayak and M.Variar

Programme 6. Enhancing and sustaining the productivity of rice based farming systems: Leader: K.S. Rao/S.Saha

Principal Investigators (PIs)

R. Tripathi, P. Bhattacharyya, A.K. Nayak, Md. Shahid, R. Tripathi, A. Kumar, B.B. Panda, R. Raja, S. Saha, B.S. Satapathy, A. Poonam, C.V. Singh, K.S. Rao, D.P. Sinhababu, C.V. Singh and S.M. Prasad

Co-Principal Investigators (Co-PIs)

B.C. Parida, K.S. Rao, T.K. Adhya, P. Battacharyya, R. Tripathi, Md. Shahid, R. Raja, A. Kumar, B.B. Panda, S. Mohanty, D.P. Singh, S. Saha, A.K. Nayak, J. Meher, K.S. Rao, A. Ghosh, S. Sasmal , A. Poonam, K.S. Behera, U. Dhua, P. Samal, S. Lenka, M. Jena, B.C. Patra, B.C. Marndi, S.P. Patel, R.K. Singh, P.K. Nayak, T.K. Dangar and K.B. Pun

Programme 7. Mechanization for rice production and post-harvest systems: Leader: P.C. Mohapatra / P.Mishra

Principal Investigators (PIs)

S.P. Patel, M. Din, P.C. Mohapatra and P. Mishra

Co-Principal Investigators (Co-PIs)

P.C. Mohapatra, K.S. Rao, B.C. Parida, S.P. Patel, M. Din and P. Mishra

Programme 8. Strategic research on pathogens/pest population dynamics, crop losses, forecasting: Leader: U. Dhua /S. Sasmal

Principal Investigators (PIs)

K.S. Behera, C.D. Misra, K.M. Das, S.K. Singh, S. Lenka, D. Maiti, S.N. Tewari, M. Variar, V. D. Shukla and U. Dhua

Co-Principal Investigators (Co-PIs)

M. Jena, K.S. Behera, S. Sasmal, S.N. Tewari, S.K. Singh, K.M. Das, N. Bhakta, K.B. Pun, S.C. Sahu, V. D. Shukla, B.C. Patra, D. Maiti, L. Behera, A. Das and B. Bhattachary

Programme 9. Developing IPM technologies for different rice ecologies: Leader: K.S.Behera/S.N.Tewari

Principal Investigators (PIs)

P.C. Rath, K.S. Behera, A. Prakash, C.D. Mishra, S. Sasmal, S.K. Singh, S. Sasmal, S. Lenka, P.C. Rath and M. Jena

Co-Principal Investigators (Co-PIs)

K.S. Behera, C.D. Mishra, M. Jena, S. Saha, U. Kumar, S.N. Tewari, A.K. Nayak, S. Sasmal, T.K. Dangar, P.C. Rath, V.D. Shukla, K.M. Das, M. Variar, M. Jena, A. Prakash, A. Das, K.B. Pun, P. Samal, G.A.K. Kumar, S. Sasmal, S.K. Singh, U. Dhua, A. Poonam and R.N. Rao

Programme 10. Socio-Economic Research for Sustainable Development: Leader: B.N.Sadangi/P. Samal

Principal Investigators (PIs)

N.N. Jambhulkar, L. Das, N.C. Rath, G.A.K. Kumar, P. Samal, B.N. Sadangi and V.K. Singh

Co-Principal Investigators (Co-PIs)

P. Samal, P. Kaushal, N.C. Rath, L. Das, G.A.K. Kumar, S.R. Dhua, D.P. Sinhababu, R.N. Rao, S.N. Tewari,B.N. Sadangi, N.N. Jambhulkar, S.M. Prasad, B.C. Parida, K.M. Das, M. Jena, S.S.C. Pattnaik and H.N. Subudhi

Ongoing Externally Aided Projects (EAPs)

Number	Title of the Project	Principal Investigator	Source of Funding
EAP 27	Revolving fund scheme for seed production of upland rice varieties at CRURRS, Hazaribagh	N.P.Mandal	AP Cess
EAP 36	National Seed Project (Crops)	S.R.Dhua	NSP
EAP 49	Revolving fund scheme for breeder seed production	S.R.Dhua	NSP/Mega Seed
EAP 60	Front line Demonstration under Macro-Management scheme of Ministry of Agriculture – New High Yielding Varieties	V.D.Shukla	DAC
EAP 99	Transgenic in crops	G.J.N.Rao	ICAR Network
EAP 100	Seed Production in Agricultural Crops and Fisheries– "Mega Seed Project"	S.R.Dhua	ICAR
EAP 104	Microbial diversity and identification	T.K.Adhya (CCPI –T.K.Dangar)	ICAR Network
EAP 105	Nutrient management	T.K.Adhya	ICAR Network
EAP 106	Microbial bioremediation	T.K.Adhya	ICAR Network
EAP 108	Developing and disseminating resilient and productive rice varieties for drought prone areas on India - Hazaribagh	N.P.Mandal	IRRI (Rockfeller Foundation & Generation Challenge Program)- ICAR
EAP 119	Soil organic carbon dynamics vis'-a'-vis' anticipatory climatic changes and crop adaptation strategies	T.K. Adhya	ICAR (NAIP)
EAP 120	Towards development of a single cell C4 photosynthetic system in rice	M.J. Baig	ICAR (NAIP)
EAP 121	Developing Sustainable Farming System Models for Prioritized Micro Watershed in Rainfed Areas in Jharkhand	R.K. Singh	ICAR (NAIP)
EAP 122	Allele Mining and Expression Profiling of Resistance and Avirulence genes in Rice Blast Pathosystem for Development of Race Non-Specific Disease Resistance	M. Variar	ICAR (NAIP)
EAP 123	Enhancing and stabilizing productivity of salt affected areas through incorporation of genes for tolerance of abiotic stresses in rice	D.P. Singh	IRRI (BMZ) – ICAR
EAP 125	Stress tolerant rice for poor farmers of Africa and South Asia–Drought prone rain-fed rice areas of South Asia–Hazaribagh Centre	N.P.Mandal	ICAR- IRRI (STRASA)
EAP 126	Stress tolerant rice for poor farmers of Africa and South Asia- Drought prone areas- CRRI Centre	O.N. Singh P. Swain	ICAR– IRRI (STRASA)

Number	*Title of the Project*	*Principal Investigator*	*Source of Funding*
EAP 127	Stress tolerant rice for poor farmers of Africa and South Asia- Submergence and Flood prone areas	J.N.Reddy S.S.C.Patnaik	ICAR– IRRI (STRASA)
EAP 128	Stress tolerant rice for poor farmers of Africa and South Asia- Saline prone areas	D.P. Singh	ICAR – IRRI(STRASA)
EAP 129	Stress tolerant rice for poor farmers of Africa and South Asia- Socio-economic survey and impact assessment	P. Samal	ICAR-IRRI (STRASA)
EAP 130	All India Network Project on Soil Biodiversity- Biofertilizers	T.K. Adhya D.Maiti	ICAR Network Project
EAP 131	Research into development of decision support system for major insects pests or rice and cotton	Mayabini Jena	NAIP
EAP 132	Gender issues of rice based production system and refinement of selected technologies in women perspective	Lipi Das	ICAR Network Project
EAP 133	Capitalization of prominent landraces of rice in Orissa through Value Chain Approach	A. Patnaik	NAIP
EAP 134	Development and maintenance of rice knowledge management Portal	G.A.K. Kumar	NAIP
EAP 135	Bioprospecting of genes and allele mining for abiotic stress tolerance	G.J.N. Rao	NAIP
EAP 137	Establishment of National Rice Resources Database	B.C. Patra	DBT
EAP 138	Connecting performance under drought with genotype through phenotype association	P. Swain	IRRI-ICAR
EAP 139	Renewable Energy Sources for Agriculture and Agro-based Industries	P.N. Mishra	AICRP
EAP 140	Intellectual Property Management and Transfer/ commercialization of agricultural technology Scheme	S.R. Dhua	ICAR
EAP 141	DUS Testing and documentation	S.R.Dhua	PPV&FRA
EAP 143	Identification of molecular markers for enhanced *Arbuscularmycorrhiza* (AM) response and marker assisted selection of high am responsive varieties for efficient phosphorus nutrition of upland rice	D. Maiti A.Das BCKV R.K. Singh N.P. Mandal	DBT
EAP 144	Livelihood promotion through integrated farming system in Assam	N. Bhakta	NAIP
EAP 145	Identification and functional analysis of genes related to yield and biotic stresses	S.C. Sahu M. Jena L.Behera R.K.Sahu	DBT
EAP 146	Confidence building and facilitation of large scale use of fly ash as an ameliorant and nutrient source for enhancing rice productivity and soil health	K.S.Rao A.K. Nayak R.Raja	DST

Number	Title of the Project	Principal Investigator	Source of Funding
EAP 147	Agro-techniques for sustaining productivity of wet direct sown summer rice in flood prone lowlands	Sanjoy Saha K.S.Rao K.Pande K.S.Behera B.B. Panda, L. Das	DST
EAP 148	Strategies to enhance adaptive capacity to climate change in vulnerable regions	K.S.Rao, B.B.Panda S. Mohanty, A.Pandit	NAIP
EAP 149	Awareness cum surveillance programme for management of major pest in Paddy	Anand Prakash	Directorate of Agriculture & Food Production, Orissa, Bhubaneswar
EAP 150	Development, dissemination and popularization of location specific IPM strategies in different rice agro-ecosystems	Anand Prakash	NCIPM, ICAR
EAP 151	Hybrid Rice Research network	R.N.Rao	AICRP
EAP 152	Mapping and Marker Assisted selection for RTV resistant genes	M.K. Kar, GJN Rao J Rao	AICRP
EAP 153	Development of molecular markers linked to genes for resistance to Brown Planthopper	R.K. Sahu, M Jena L Behera	AICRP
EAP 154	Development of new plant type varieties with higher yield and resistance to major pest and diseases	S.K. Pradhan	AICRP
EAP 155	From QTL to Variety: Marker Assisted Breeding of Abiotic Stress Tolerant Rice Varieties with Major QTLs for Drought, Submergence and Salt Tolerance	T.K.Adhya J.N.Reddy ONSingh D.P.Singh, R.K.Sarkar P.Swain, N.P. Mandal B.C. Marndi	DBT, GOI
EAP 156	Marker–assisted backcrossing for transfer of durable bacterial blight resistance into elite deepwater rice varieties	S.C.Pradhan L.Behera K.M.Das, GJN Rao S.K. Das, P. Kaushal	DBT, GOI
EAP 157	CURE Salinity Project: Enabling poor rice farmers to improve livelihood and overcome poverty in South and Southeast Asia (A)-Salinity,(B)-Submergence	D.P.Singh (A) J.N.Reddy (B)	IFAD/ IRRI/-ICAR
EAP 158	National Initiative on Climate Resilient Agriculture for XIth Plan	T.K.Adhya	ICAR
EAP 159	"Diversity of osmotolerant and biochemical strains of endophytic microorganisms of rice"INSPIRE Fellowship under "Assured Opportunity for Research Career (AORC)"	Supriya Sahu (T.K.Dangar)	DST
EAP 160	Identification of Major QTLs for Grain Yield under drought stress in 'Jhum' rice varieties of North Eastern Region for use in marker assisted breeding to improve yield under drought	N.P.Mandal	DBT

Number	*Title of the Project*	*Principal Investigator*	*Source of Funding*
EAP 161	Bringing Green Revolution to Eastern India (BGREI)	T.K.Adhya K.S.Rao	Rashtriya Krishi Vikash Yojana" (DAC)
EAP 162	Stress tolerant rice for poor farmers of Africa and South Asia-Sub grant, Seed (CRURRS, Hazaribagh)	N.P.Mandal M.Variar V.D.Shukla	IRRI-ICAR(STRASA)
EAP 163	Stress tolerant rice for poor farmers of Africa and South Asia-Sub grant, Seed (CRRI, Centre)	S.R.Dhua	IRRI-ICAR(STRASA)
EAP 164	Technology dissemination and adoption of water saving rice production (Aerobic rice and AWD system) to improve rice farming rural livelihood in water shortage regions	A.K.Ghosh	DST

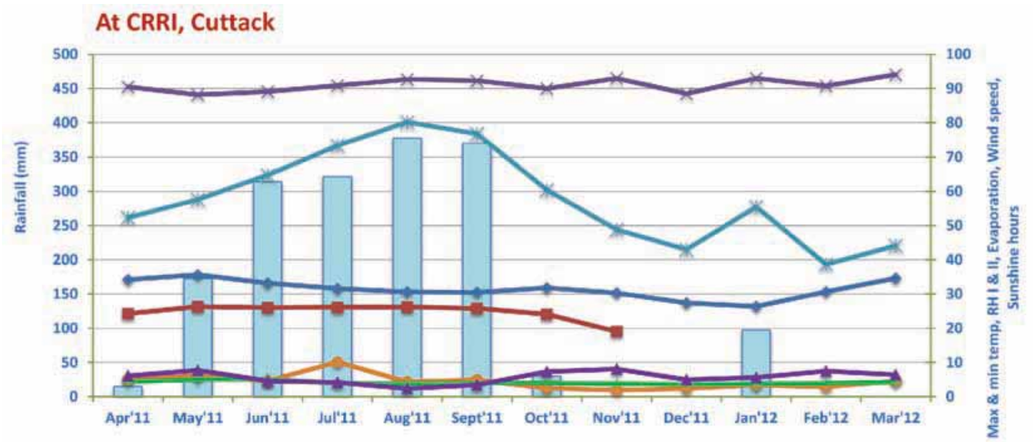
Financial Statement for 2011-12

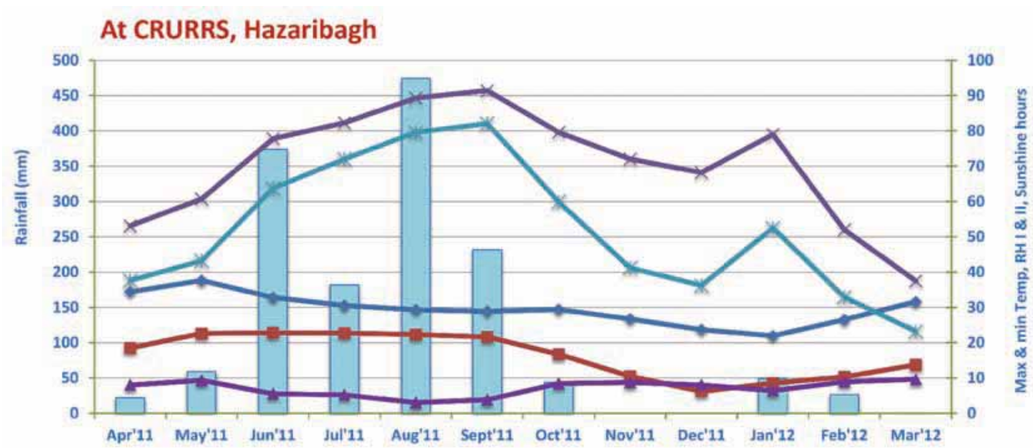
(As on 31 March 2012)

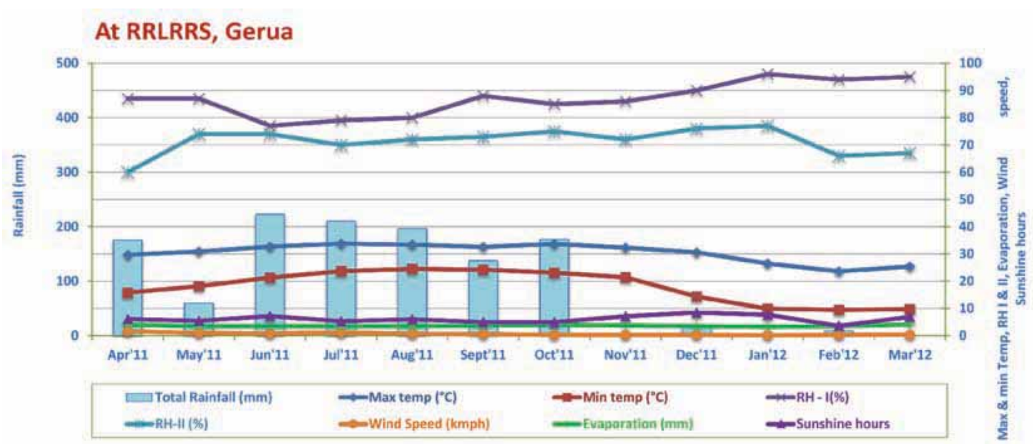
(Rs. in lakh)

Sl. No	**Head of Account**	**PLAN(2011-12)**		**NON-PLAN(2011-12)**	
		Allocation	**Expenditure**	**Allocation**	**Expenditure**
1	Estt. Charges(Including Wages)	--	--	2,326.00	2,326.00
2	TA(Including (HRD)	17.52	17.52	10.00	10.00
3	OTA	--	--	0.40	0.40
4	Other Charges(Including IT)	70.54	70.54	436.00	436.00
5	**Works**				
	I)Office Building	--	--	30.00	29.92
	II)Residential Building	--	--	14.00	13.99
	III)Minor works	--	--	10.00	9.96
6	**Capital**				
	I)Furniture & Fixture	--	--	4.50	4.50
	II)Minor works	--	--	2.00	1.99
	III)Equipment	7.36	7.36	5.00	5.00
	IV)Library Books	10.00	10.00	--	--
	V)Plan works	209.58	209.29	--	--
7	Pension	--	--	410.00	410.00
8	P Loan & Advances	--	--	20.00	20.00
	TOTAL	**315.00**	**314.71**	**3,267.90**	**3,267.76**

Weather







Mean monthly weather parameters recorded at CRRI and its sub stations

Acronyms

AAU : Assam Agricultural University
ADG : Assistant Director General
AICRIP : All India Coordinated Rice Improvement Project
AIR : All India Radio
AMAAS : Application of Microorganisms in Agri culture and Allied Sectors
ANGRAU : Acharya N.G. Ranga University
ARIS : Agricultural Research Information Service
ASG : Aromatic Short Grain
ASGON : Aromatic Short Grain Observation Nursery
ASRB : Agricultural Scientists Recruitment Board
ASV : Alkali Spreading Value
ATMA : Agricultural Technology Management Agency
AVT : Advanced Varietal Trial
AWD : Alternate Wetting and Drying
AYT : Advance Yield Trial
BB/BLB : Bacterial Leaf Blight
BMGF : Belinda and Bill Gates Foundation
BPH : Brown Planthopper
Bt : *Bacillus thuringiensis*
CAC : Consortium Advisory Committee
CIAE : Central Institute of Agricultural Engineering
CIC : Consortium Implementation Committee
CIFA : Central Institute of Freshwater Aquaculture
CMS : Cytoplasmic Male Sterile/Sterility
CRIDA : Central Research Institute for Dryland Agriculture
CRIJAF : Central Research Institute for Jute and Allied Fibres
CRRI : Central Rice Research Institute
CRURRS : Central Rainfed Upland Rice Research Station
CSIR : Council of Scientific and Industrial Research
CURE : Consortium for Unfavourable Rice Environment
DAC : Department of Agriculture and Cooperation
DAF : Days after Flowering
DAH : Days after Harvest
DAO : District Agricultural Officer
DARE : Department of Agriculture Research and Education
DAS : Days after Sowing
DBN : Drought Breeding Network
DBT : Department of Biotechnology,
DFF : Days to 50 % Flowering
DH : Dead Hearts
DNA : Deoxyribonucleic Acid
DRR : Directorate of Rice Research
DRWA : Directorate of Research for Women in Agriculture
DS : Dry Season
DSN : Dry Season Nursery
DSR : Directorate of Seed Research
DST : Department of Science and Technology
EAP : Externally Aided Projects
EC/ECe : Electrical Conductivity
EIRLSBN : Eastern India Rainfed Lowland Shuttle Breeding Network
FLD : Frontline Demonstration
FYM : Farmyard Manure
g : Gram
GLH : Green Leafhopper
GM : Green Manuring / Gall Midge
h : Hour
ha : Hectare
HI : Harvest Index
HRR : Head Rice Recovery
HYV : High Yielding Variety
IARI : Indian Agricultural Research Institute
IASRI : Indian Agricultural Statistics Research Institute
ICAR : Indian Council of Agricultural Research
ICRISAT : International Crops Research Institute for the Semi-Arid Tropics
IDM : Integrated Disease Management
IET : Initial Evaluation Trial
IFAD : International Fund for Agricultural Development
IGAU : Indira Gandhi Agricultural University
IGKVV : Indira Gandhi Krishi Vishwavidyalaya
IINRG : Indian Institute of Natural Resins and Gums
IISS : Indian Institute of Soil Science
IIVR : Indian Institute of Vegetable Research
IJSC : Institute Joint Staff Council
IMC : Institute Management Committee
INGER : International Network for Genetic Evaluation of Rice
INM : Integrated Nutrient Management
INSA : Indian National Science Academy
IPM : Integrated Pest Management

IPR	:	Intellectual Property Rights
IPS	:	Indian Police Service
IRRI	:	International Rice Research Institute
IVRI	:	Indian Veterinary Research Institute
IVT	:	Initial Varietal Trial
Kg	:	Kilogram
KVK	:	Krishi Vigyan Kendra
L /l/ltr	:	Litre
LB	:	Long-bold
LCC	:	Leaf Colour Chart
LF	:	Leaf folder
LS	:	Long-slender
LSI	:	Location Severity Index
MAS	:	Marker-assisted Selection
MB	:	Medium Bold
MLT	:	Multi location Trial
MS	:	Medium Slender
NAARM	:	National Academy of Agricultural Research Management
NAAS	:	National Academy of Agricultural Sciences
NAIP	:	National Agricultural Innovation Project
NARES	:	National Agricultural Research and Extension Research
NARS	:	National Agricultural Research System
NASC	:	National Agricultural Science Complex
NBAIM	:	National Bureau of Agriculturally Important Microorganisms
NBPGR	:	National Bureau of Plant Genetic Resources
NDRI	:	National Diary Research Institute
NDUAT	:	Narendra Dev University of Agriculture and Technology
NFSM	:	National Food Security Mission
NGO	:	Non Governmental Organization
NHSN	:	National Hybrid Screening Nursery
NIL	:	Near-isogenic Lines
NIPGR	:	National Institute for Plant Genome Research
NIWS	:	National Invasive Weed Surveillance
NPK	:	Nitrogen, Phosphorous, Potassium
NPT	:	New Plant Type
NRC	:	National Research Centre
NRCPB	:	National Research Centre for Plant Biotechnology
NSN	:	National Screening Nursery
NSP	:	National Seed Project
OFT	:	On-farm Trials
OUAT	:	Orissa University of Agriculture and Technology
OYT	:	Observational Yield Trial
PAU	:	Panjab Agricultural University
PDCSR	:	Project Directorate for Cropping System Research
PE	:	Panicle Emergence
PI	:	Panicle Initiation
PMYT	:	Preliminary Multilocational Yield Trial
PVS	:	Participatory Varietal Selection
PYT	:	Preliminary Yield Trial
q	:	Quintal
QTL	:	Quantitative Trait Loci
RAC	:	Research Advisory Committee
RAPD	:	Random Amplification of Polymorphic DNA
RARS	:	Regional Agricultural Research Station
RBC	:	Rice-based Cropping System
RBD	:	Randomized Bock Design
RCC	:	Reinforced Cement Concrete
RFLP	:	Restriction Fragment Length Polymorphism
RH	:	Relative Humidity
RIL	:	Recombinant Inbred Line
RRLRRS	:	Regional Rainfed Lowland Rice Research Station
RTV/RTD	:	Rice Tungro Virus/ Disease
SAC	:	Scientific Advisory Committee
SATVT	:	Saline Alkaline Tolerant Varietal Trial
SAU	:	State Agricultural University
SB	:	Short-bold
SBN	:	Salinity Breeding Network
SES	:	Standard Evaluation System
SRI	:	System of Rice Intensification
STRASA	:	Stress Tolerant Rice for Poor Farmers in Africa and South Asia
t	:	Tonne / Ton
UBN	:	Uniform Blast Nursery
URSBN	:	Upland Rice Shuttle Breeding Network
WBPH	:	White-backed Planthopper
WCE	:	Weed Control Efficiency
WEH	:	White Ear Heads
WS	:	Wet Season
WTCER	:	Water Technology Centre for Eastern Region
WTO	:	World Trade Organization
WUE	:	Water-use Efficiency
YMV	:	Yellow Mosaic Virus
YSB	:	Yellow Stem Borer
ZPD	:	Zonal Project Directorate

All good wishes to the Rice Institute — first of its kind in India, in Asia and in the world. May it solve the problems that afflict us in equal Trice.

Jawaharlal Nehru

April 13. 1948

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