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2016-17

ICAR-CENTRAL SOIL SALINITY RESEARCH INSTITUTE
KARNAL-132001 (INDIA)

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A saline landscape at Moon Land, Ladakh (J&K) formed due to geogenic processes (top right); barren saline-sodic land in Abohar (Fazilka, Punjab) (middle left); wheat variety KRL-210 in a sodicity affected farmers' field (bottom left) (Photo: Dr. Ranjay K. Singh); and agro-forestry plantation under saline shallow watertable conditions of Nain Experimental Farm, Panipat (bottom right) (Photo: Dr. Rakesh Banyal)

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PREFACE

Recently the twin menaces of soil salinity and waterlogging have grown by leaps and bounds in several irrigated and rainfed areas of the world. Available evidences suggest that salinity has gradually unfolded into a severe environmental hazard in most of the affected countries. Climate change impacts, *inter alia*, high temperature, erratic rainfall, and water scarcity will further exacerbate the problem; especially in marginally productive arid and semi-arid areas. Despite reclamation efforts, destructive impacts of secondary salinity in the new agricultural areas are worrisome. While salinity and other land degradation processes continue to diminish the soil productivity, global food demand has consistently risen over time. As further agricultural expansion into new areas is virtually impossible, global attention has increased to harness the potential of degraded lands to meet the growing food needs while lessening the pressure on prime farm lands. Consistent with the global trends, Government of India is committed to achieve the goal of being a 'land degradation neutral country' by 2030 by arresting the desertification of about 81 Million ha area including the salt-affected lands through sustainable management of soil, water and biodiversity. Taking a cue from these developments, we are leaving no stone unturned to provide handsome returns to the farmers in the salinity affected areas of the country. Recent advances in salinity management such as precise soil characterization, identification of alternative soil reclaimants, development of multiple stress tolerant cultivars and conservation agriculture in reclaimed lands have captured our imagination. In order to effectively respond to the emerging challenges, we are embarking upon the latest developments in these fields to accelerate the rate of soil restoration projects in saline areas. We stay focussed on research collaborations with other national and international agencies working in the similar areas, acquisition of research grants and the quick dissemination of salinity management technologies to the farmers' fields.

The Annual Report for the period 2016-17 highlights the noteworthy accomplishments in the areas of research, technology transfer and capacity development of the farmers. Major research outcomes and thrust areas during the period under report were: release of promising new salt tolerant Indian mustard variety CS 58, utilization of biodegradable municipal solid waste for enhancing crop productivity in salt affected soils, techniques for the sustainable use of alkali waters at farmers' field, development of novel alternative amendments for sodic soils, impact assessment of subsurface drainage technology in Karnataka, identification of salt tolerant rootstock and scion genotypes in fruit crops, cropping systems intensification in salt affected coastal zones and the development of cost effective drainage solutions for waterlogged saline Vertisols. During the year, Institute produced 14.01 tonnes of breeder seeds of rice, wheat mustard and gram for distribution among various agencies. Different capacity development programmes were organized to enhance the knowledge and skills of the farmers and farm women.

A pre-Rabi Kisan Mela was organized on 7th October, 2016 in village Budhmor of Distt. Patiala Punjab to address the varied problems being faced by the local farmers. About 500 farmers and extension workers were present. A total of 13 pre-Rabi and 12 pre-Kharif *Kisan Gosthis* were organized under '*Mera Gaon Mera Gaurav*' programme in salinity affected parts of Haryana, Uttar Pradesh, West Bengal and Gujarat states witnessing the presence of over 2600 farmers. Similarly, 256 front line demonstrations on salt tolerant crop varieties were also conducted in different villages during 2016-17. The 132nd birth anniversary of late Dr. Rajender Prasad, the First President of India, was celebrated as 'Agricultural Education Day' on 3rd December, 2016. Rabi Kisan Mela was organized on 8th March, 2017 at Karnal. Prof. Vijay Paul Sharma, Chairman, CACP was the Chief Guest. About 1500 farmers, school students and extension workers attended the Kisan Mela and benefitted by exposure to different technologies. As the Mela coincided with the World Women's Day, 100 women farmers also enthusiastically participated and shared their success stories in farming. During 2016-17, a total of 9 exhibitions were organized at different research institutions and developmental agencies.

'*Swachh Bharat Abhiyan*' was organized in different villages *viz*., Bhudmor (Patiala), Sampli Kheri (Kaithal), Zarifa Viran (Karnal), Sikander Kheri (Kaithal) as well as at the Main Campus and Regional Stations of the Institute during the period under report to encourage the villagers for maintaining cleanliness in homes, community lands and farms for the health and environmental benefits. A seminar on subject '*Swachhta, Samgatishilta and Paryawaran*' was also organized at Karnal on 28th October, 2016. 'World Soil Health Day' was organized in Mundri village of Kaithal district on 5th December, 2016 to sensitize the farmers about the importance of soil health, crop residue management, integrated nutrient management and efficient water management in salt affected soils. 'National Productivity Week' was celebrated during 13-18 February, 2017 during which students and farmers gained knowledge on different environmental issues, crop and kitchen waste management, biogas production and composting. Institute celebrated its 48th Foundation Day on 1st March, 2017 by organizing a Foundation Day lecture delivered by Dr. K. Alagusundaram, DDG (AE & NRM), ICAR, New Delhi.

The XXIV meeting of the ICAR-Regional Committee V was organized at New Delhi during 03-04 October, 2016 under the Chairmanship of Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR, New Delhi to discuss the constraints hampering sustainable agricultural production in the food basket states of Punjab, Haryana and Delhi. Agricultural Scientists Recruitment Board, New Delhi organized its 43rd Foundation Day at ICAR-CSSRI, Karnal on 3rd November 2016. Prof. Ramesh Chand, Member, NITI Ayog was the Chief Guest on this occasion. Biennial workshop of AICRP on SAS & USW was organized at SKRAU, Bikaner from 19-20, January 2017. Further, 5th National Seminar on 'Climate Resilient Saline Agriculture: Sustaining Livelihood Security' was organized at Bikaner from 21-23 January 2017, in association with SKRAU, Bikaner. Dr. Gurbachan Singh, Chairman, ASRB was the Chief Guest.

The Institute celebrated Hindi Pakhwara during September, 14-28, 2016. An 8-days model training course on 'Quality seed production, processing and certification of selected field and vegetable crops in salt affected area" was organized from 15-22 December, 2016 at ICAR-CSSRI, Karnal. Two capacity building programmes for ber growers of Haryana (RKVY funded) were organized during 09-12 May, 2016 and 02-07 January, 2017, respectively.

I express my gratitude to Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR, New Delhi, Dr. K. Alagusundaram, DDG (AE & NRM), ICAR, New Delhi and Dr. S. K. Chaudhari, ADG (SWM) for their continued guidance and support. The efforts of Dr. Anshuman Singh and Shri Madan Singh for the compilation, editing and timely printing of the Annual Report are commendable. I thank my colleagues for providing the material for the timely publication of the report.

I am convinced that the information furnished in this report will provide valuable insights to the readers about the current R&D efforts, trends and constraints in salinity management in agriculture. Suggestions/inputs from the readers are invited to help us further improve the quality of the Annual Report in the future.

(Parbodh Chander Sharma)
Director

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केन्द्रीय मृदा लवणता अनुसंधान संस्थान

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सारांश

वर्ष 1969 में करनाल (हरियाणा) में स्थापित केन्द्रीय मृदा लवणता अनुसंधान संस्थान देश के विभिन्न कृषि पारिस्थितिकीय क्षेत्रों में लवणता प्रबंधन एवं कृषि में निम्न गुणवत्ता वाले जल के प्रयोग पर बहुविषयक अनुसंधान कार्यों के लिए समर्पित है। मुख्यालय में बहुविषयक अनुसंधान कार्यक्रम चार विभागों–मृदा एवं फसल प्रबंध, सिंचाई एवं जलनिकास अभियांत्रिकी, फसल सुधार और प्रौद्योगिकी मूल्यांकन एवं प्रसार द्वारा संचालित किये जाते हैं। विभिन्न कृषि जलवायु क्षेत्रों की विनिर्दिष्ट अनुसंधान आवश्यकताओं को पूरा करने के लिए संस्थान के तीन क्षेत्रीय अनुसंधान केन्द्र–कैनिंग टाउन (प. बंगाल), भरूच (गुजरात) और लखनऊ। (उत्तर प्रदेश) क्रमशः समुद्र तटीय लवणता, लवणग्रस्त वर्टीसोल और सतही जल स्तर वाली मध्य एवं पूर्वी सिंधु–गंगा के मैदानों की क्षारीय मृदा संबंधी समस्याओं के निदान हेतु कार्यरत हैं। संस्थान में लवणग्रस्त भूमियों के प्रबंधन और लवणीय जल के कृषि में प्रयोग हेतु अखिल भारतीय समन्वित परियोजना भी कार्यरत है। संदर्भित अवधि के लिए विभिन्न महत्वपूर्ण क्षेत्रों में संस्थान की कुछ प्रमुख अनुसंधान उपलब्धियाँ निम्नलिखित हैं :

सरसों की अधिक उत्पादक लवण सहिष्णु प्रजाति 'सीएस 58' का विमोचन

उत्तर पश्चिमी भारत के कई हिस्सों में लवण तनाव सरसों की निम्न उत्पादकता का एक मुख्य कारण है। लवणीय दशाओं में सरसों की उपज बढ़ाने हेतु लवण सहिष्णु प्रजातियों का विकास एक कारगर उपाय माना जाता है। इस दिशा में किए गए ठोस प्रयासों से हाल ही में भारतीय सरसों की आशाजनक लवण सहिष्णु किस्म 'सीएस 58' का चिन्हीकरण एवं विमोचन संभव हुआ। यह प्रजाति जोन 2, जिसमें हरियाणा, पंजाब एवं उत्तर प्रदेश के लवण प्रभावित क्षेत्र आते हैं, में व्यावसायिक खेती हेतु संस्तुत की गई है। यह प्रजाति लगभग 132 दिनों में पककर तैयार हो जाती है। पौधों की ऊंचाई लगभग 180 सेमी. होती है और उनमें अन्य स्थानीय प्रजातियों की तुलना में अधिक जैवभार उत्पादन एवं 1000 बीज भार (5.5 ग्रा.) होता है। सामान्य मृदाओं में यह प्रजाति लगभग 2.6–2.8 टन/हे. बीज उपज देती है। लवण प्रभावित मृदाओं में इसकी उपज 2.0–2.2 टन/हे. होती है। बीज में लगभग 40 प्रतिशत तेल होता है । सीएस 58 प्रजाति के पौधे अल्टरनेरिया झुलसा के प्रति सहिष्णु होते हैं और उनमें सफेद रतुआ, चूर्णिल आसिता, रोमिल आसिता, स्टैग हेड एवं सरसों माहू का बहुत कम प्रकोप होता है।

लवणीय मृदाओं में फसल उत्पादकता बढ़ाने के लिए बायोडिग्रेडेबल नगरीय ठोस अपशिष्ट का प्रयोग

इस तथ्य को ध्यान में रखते हुए कि पारंपरिक विधि से नगरीय ठोस अपशिष्ट का निस्तारण करने से कई पर्यावरणीय समस्याएं उत्पन्न होती है, फसलों में नगरीय ठोस अपशिष्ट आधारित कम्पोस्ट का प्रयोग एक सतत पुनः चक्रण रणनीति के रूप में देखी जा रही है। लवणीय मृदा में सरसों–बाजरा फसल चक्र में विभिन्न जैविक सुधारकों का तीन वर्षों तक प्रयोग किया गया। आंकड़ों ने यह दर्शाया कि नगरीय ठोस अपशिष्ट कम्पोस्ट, धान पुआल कम्पोस्ट, जिप्सम समृद्ध कम्पोस्ट एवं उर्वरकों की 25 प्रतिशत संस्तुत मात्रा के एकीकृत प्रयोग से जैविक सुधारको एवं रासायनिक उर्वरकों के एकल प्रयोग की तुलना में मृदा में सूक्ष्मजीव जैवभार कार्बन की मात्रा में प्रभावी वृद्धि, लवणता में कमी एवं फसल उपज में वृद्धि हुई। रासायनिक उर्वरकों की संस्तुत मात्रा (100 प्रतिशत) की तुलना में जैविक सुधारकों एवं 25 प्रतिशत उर्वरक मात्रा के प्रयोग से मृदा में 32 प्रतिशत अधिक सूक्ष्मजीव जैवभार कार्बन देखा गया। इसी प्रकार संयुक्त प्रयोग उपचार में नियंत्रण उपचार (100 प्रतिशत रासायनिक उर्वरक) की तुलना में औसत विद्युत चालकता में कमी देखी गई। नगरीय ठोस अपशिष्ट कम्पोस्ट (16 टन/हे.) से उपचारित मृदा की संतृप्त घोल विद्युत चालकता 3.6 डेसी सीमन प्रति मी. जबकि नियंत्रिण उपचार में विद्युत चालकता 4.8 डेसीसीमन/मी थी। तीन वर्षों के औसत आंकड़ों के आधार पर यह पाया गया कि जैविक सुधारकों एवं 25 प्रतिशत उर्वरक मात्रा के संयुक्त प्रयोग से 100 प्रतिशत रासायनिक उर्वरकों की तुलना में सरसों एवं बाजरा में लगभग 25 प्रतिशत अधिक दाना उपज प्राप्त हुई। यह परिणाम लवण प्रभावित मृदाओं में नगरीय ठोस अपशिष्ट के सुधारक के रूप में प्रयोग करने से होने वाले आर्थिक एवं पर्यावरणीय लाभों को दर्शाते हैं।

कृषक प्रक्षेत्रों पर क्षारीय जल का सतत प्रयोग

धान–गेहूँ फसल चक्र में क्षारीय जल का सतत प्रयोग सुनिश्चित करने हेतु एक प्रक्षेत्र प्रयोग संचालित किया गया। इस प्रयोग में लवण सहिष्णु प्रजातियों के निष्पादन एवं क्षारीयता उदासीनीकरण सुधारकों (जिप्सम एवं प्रेसमेड) के एकीकृत अथवा एकल प्रयोग के प्रभाव का मूल्यांकन किया गया। चयनित अनुसंधान प्रक्षेत्र हरियाणा के कैथल जिले में स्थित है और मृदा क्षारीयता व सिंचाई जल में अवशिष्ट सोडियम कार्बोनेट की अधिक मात्रा (5.0–7.0 मिली समतुल्य प्रति ली.) की समस्या से प्रभावित है। जिप्सम एवं प्रेसमड के विभिन्न संयोजनों को मुख्य भूखंड उपचार तथा लवण सहिष्णु प्रजातियों (बासमती धान सीएसआर 30 एवं गेहूँ केआरएल 210) व स्थानीय प्रचलित प्रजातियों (धान पूसा 1121 एवं गेहूँ एचडी 2967) को उप–भूखंड उपचारों के रूप में प्रयुक्त किया गया। सिंचाई जल में क्षारीयता बढ़ने के साथ बासमती सीएसआर 30 ने पूसा 1121 की तुलना में बेहतर प्रदर्शन किया। अनुसंधान क्षेत्र में क्षारीयता से होने वाली उपज हानि को रोकने और प्रणाली उत्पादकता को बढ़ाने हेतु गेहूं की लवण सहिष्णु प्रजाति केआरएल 210 के अंगीकरण की भी अनुशंसा की जाती है। एचडी 2967 की तुलना में लवण सहिष्णु केआरएल 210 में लगभग 11.9 प्रतिशत अधिक उपज प्राप्त हुई। प्रचलित किस्मों की तुलना में बासमती सीएसआर 30

एवं गेहूँ प्रजाति केआरएल 210 ने लवण तनाव अनूकूलन हेतु अधिक कार्यिकी दक्षता प्रदर्शित की जो कि पत्तियों में अधिक सापेक्ष जल मात्रा व सापेक्ष पर्णहरित तथा कम झिल्ली क्षति एवं तनों/जड़ों में कम सोडियम/पौटेशियम अनुपात के कारण थी। जिप्सम एवं प्रेसमड के एकल अथवा एकीकृत प्रयोग से क्षारीय जल का उदासीनीकरण करने पर 11.6–17.4 प्रतिशत अधिक प्रणाली (गेहूँ) समतुल्य उपज प्राप्त हुई।

क्षारीय मृदाओं हेतु नवीन वैकल्पिक सुधारकों का विकास

भारत के कुल लवण प्रभावित क्षेत्र का 50 प्रतिशत से अधिक भाग (3.77 मिलियन हेक्टेयर) क्षारीयता से ग्रसित है। हरियाणा, पंजाब, उत्तर प्रदेश एवं देश के अन्य भागों में जिप्सम–आधारित तकनीक द्वारा लगभग 1.95 मिलियन हेक्टेयर क्षारीय मृदाओं का सफलतापूर्वक सुधार किया जा चुका है। हाल में गुणवत्तायुक्त जिप्सम की सिकुड़ती आपूर्ति के कारण अवक्रमित क्षारीय मृदाओं की उत्पादकता बढ़ाने हेतु निम्न लागत वैकल्पिक सुधारकों के चिन्हीकरण पर अधिक ध्यान दिया जा रहा है। आद्यौगिक सल्फर एक ऐसा ही मृदा सुधारक है जिसके कार्यक्षम प्रयोग में बाधाओं जैसे धीमा आक्सीडेशन व धूल एवं आग जैसे जोखिमों को दूर करने हेतु एक प्रयोग प्रारंभ किया गया है। इस दिशा में भा.कृ. अनु.प.–केन्द्रीय मृदा लवणता अनुसंधान संस्थान एवं रिलायंस इण्डस्ट्रीज लिमिटेड के बीच एक समझौता ज्ञापन के माध्यम से क्षारीय मृदा सुधार हेतु अयौगिक सल्फर की दक्षता बढ़ाने हेतु अनुसंधान किया जा रहा है। खनिज जिप्सम के विकल्प के रूप में समुद्री जिप्सम की व्यहार्यता के मूल्यांकन हेतु भी प्रयास प्रारंभ किए गए हैं। समुद्री जिप्सम सामान्य खाने के नमक (सोडियम क्लोराइड) की उत्पादन प्रक्रिया का एक उपोत्पाद (बायप्रोडक्ट) है। समुद्री जिप्सम में सोडियम क्लोराइड, मैग्नीशियम क्लोराइड एवं मैग्नीशियम सल्फेट अपमिश्रण के रूप में पाए जाते है जो जलीय विलयन का सक्रियता गुणांक घटाकर आयनिक शक्ति बड़ा देते हैं जिससे खनिज जिप्सम की तुलना में समुद्री जिप्सम की घुलनशीलता एवं परिणामस्वरूप मृदा सुधारक कार्यदक्षता अधिक होती है। प्रयोगशाला परीक्षण समुद्री जिप्सम आधारित फार्म्यूलेशन में कैल्शियम की अत्यधिक (30.5 मिली समतुल्य/मी.) मात्रा पायी गई जो वस्तुतः एनालिटिकल ग्रेड जिप्सम के समतुल्य थी।

कर्नाटक में उपसतही जलनिकास तकनीक के प्रभाव का मूल्यांकन

कर्नाटक प्रदेश के बेलगाम जिले में स्थित उपसतही जलनिकास परियोजना क्षेत्र में एक प्रभाव मूल्यांकन अध्ययन किया गया। उगार बुडरूक गांव की 925 हेक्टेयर जलाक्रांत लवणीय भूमियों में उपसतही जलनिकास प्रणाली स्थापित की गई है जिससे 644 किसान लाभान्वित हुए हैं। उपसतही जलनिकास प्रणाली द्वारा लवणीय मृदा सुधाई की प्रति इकाई लागत रूपये 52,000 प्रति हेक्टेयर आंकी गई। सुधारी गई भूमियों की फसल सघनता में लगभग 24 प्रतिशत वृद्धि देखी गई जो मुख्यतः मृदा लवणता में हुई गिरावट के कारण थी। सुधार पूर्व औसत मृदा लवणता 6.63 डेसीसीमन/मी. जबकि सुधार पश्चात 2.52 डेसीसीमन/मी. थी। सुधारी गई मृदाओं में शुद्ध लाभ में 161.81 प्रतिशत की वृद्धि हुई जबकि लाभःलागत अनुपात 0.54 से बढ़कर 1.21 हो गया। शुद्ध लाभ एवं लाभःलागत अनुपात में बढ़ोत्तरी का मुख्य कारण फसल उपज में हुई वृद्धि थी। उपसतही जलनिकास प्रणाली के क्रियान्वयन के 2–3 वर्ष पश्चात ही सुधारी गई मृदाएं उच्च मूल्य वाली फसलों की खेती के उपयुक्त हो गई।

फल फसलों में लवण सहिष्णु किस्मों का चिन्हीकरण

ऐसी लवण प्रभावित मृदाएं जो आंशिक एवं मध्यम लवण सांद्रता रखती हैं, में उच्च मूल्य वाली फल फसलों द्वारा विविधीकरण की अपार संभावनाएं हैं। उथले जलस्तर वाली मृदाओं में किए गए प्रयोगों ने इंगित किया है लवणीय जल सिंचित (3–4 डेसी सीमन/मी.) लवणीय मृदाओं में अमरूद प्रजाति इलाहाबाद सफेदा एवं बेल प्रजाति नरेन्द्र बेल–5 की व्यावसायिक खेती संभव है। ऐसी लवणीय मृदाओं में मेड़ों पर पौधरोपण करने और रोपण गड्ढों में जैविक खाद का प्रयोग करने पर पौधों की लवण सहिष्णुता में वृद्धि होती है। विभिन्न स्रोतों से एकत्र की गई अनार एवं बेर की प्रजातियों ने भी ऐसी दशाओं में अच्छा प्रदर्शन किया है। इसके अतिरिक्त, दक्षिण अण्डमान द्वीप से एकत्र किए गए आम के बहुभ्रूणीय मूलवृंतों एमएल–2, एमएल–3, एमएल–6, जीपीएल–1, जीपीएल–3 एवं जीपीएल–4 का चेक मूलवृंत '13–1' के साथ क्षारीय मृदा में परीक्षण किया गया। दो मूलवृंतों (एमएल–2 एंव एमएल–6) ने उच्च क्षारीय तनाव में भी अच्छा प्रदर्शन किया और उनमें लवण तनाव के लक्षण उत्पन्न नहीं हुए। इन मूलवृंतों की अधिक लवण सहिष्णुता का कारण पोटैशियम आयनों एवं संगत विलेय पदार्थों एवं एण्टी आक्सीडेण्ट किण्वकों का अधिक संचयन था।

पश्चिम बंगाल के लवण प्रभावित तटीय क्षेत्रों में फसल पद्धति सघनीकरण

पश्चिम बंगाल के लवणीय तटीय क्षेत्रों में ,विशेषकर शुष्क रबी मौसम में एकीकृत मृदा जल एवं फसल प्रबंधन द्वारा फसल सघनता एवं उत्पादकता बढ़ाने के लिए प्रयास किए जा रहे हैं। धान की विभिन्न उन्नत रोपण विधियों एवं प्रजातियों के महत्व को प्रदर्शित करने हेतु कृषक प्रक्षेत्रों पर अनुसंधान कार्यक्रम प्रारंभ किए गए हैं। खरीफ मौसम में अम्लीय लवणीय मृदाओं (पीएच 4.6–4.8) में धान की अमलमन प्रजाति का परीक्षण किया गया। आगामी रबी मौसम में उन्हीं खेतों में विभिन्न फसलों जैसे मक्का, आलू, प्याज, मूंग एवं खेसरी का परीक्षण किया गया। खरीफ धान की कटाई के उपरोत आलू की प्रजाति पोखराज पंरपरागत एवं शून्य जुताई विधियों द्वारा रोपी गई। आलू के कन्दों की नम भूमि में सीधे बिजाई द्वारा उगाई गई फसल में सिंचाई मांग में सार्थक कमी देखी गई। आलू के कन्दों को सूखे

कम्पोस्ट एवं धान के पुआल की 30–45 सेमी. मोटी परत द्वारा ढका गया। परम्परागत जुताई में आलू की उपज 7.5–26.9 टन प्रति हे. जबकि शून्य जुताई में 12.4–32.1 टन प्रति हे. थी। शून्य जुताई पद्धति में आलू के कन्दों की गुणवत्ता भी अच्छी थी। आलू की फसल की शीघ्र कटाई के कारण भूखंड में दूसरी रबी फसलों जैसे मक्का, मूंग एवं प्याज की खेती संभव हुई। इस प्रकार सुन्दरबन क्षेत्र की बरानी निचली भूमियों में फसल सघनता 300 प्रतिशत तक बढ़ाई जा सकती है। खेसरी की बुआई से खरीफ धान के निचले खेतों में अवशिष्ट मृदा नमी का प्रयोग संभव हुआ। मूंग की बुआई या तो राइजोबियम उपचार के साथ अथवा बिना उपचार की गई। प्याज प्रजाति सुखसागर की खेती मृदा नमी संरक्षण उपचारों ;धान की पुआल की पलवार एवं चूने के प्रयोग के साथ की गई।

जलग्रस्त लवणीय वर्टिसोल में लागत दक्ष जलनिकास

गुजरात प्रदेश के कई सिंचित क्षेत्रों में जलभराव एवं लवणता की समस्याएं कृषि भूमियों पर प्रतिकूल प्रभाव डाल रही हैं। यह प्रयोग लागत दक्ष एवं विश्वासप्रद जलनिकास तकनीकियों के विकास एवं प्रदर्शन हेतु प्रारंभ किया गया है। ऐसी जलग्रस्त लवणीय मृदाओं के सुधार हेतु मुख्यतः उपसतही जलनिकास तकनीक का अंगीकरण किया जाता है। इसी प्रकार मानसून के समय लवण प्रभावित काली मृदाओं में जलभराव की समस्या को दूर करने के लिए मुक्त सतही जलनिकास एवं मोल (पाइप रहित) जलनिकास विकल्प भी उपलब्ध हैं। परन्तु ऐसी कई स्थानीय समस्याएं है जो इन जलनिकास तकनीकियों के अंगीकरण एवं क्रियान्वयन में बाधा उत्पन्न करती है। भरूच जिले के दो जलग्रस्त लवणीय स्थानों (संतृप्त घोल विद्युत चालकता 3.4–41.0 डेसीसीमन/मी.) पर उपसतही जलनिकास प्रणाली स्थापित की गई। इनमें दो अंतराल (35 मी. एवं 40 मी.) पर 1.2 मीटर गहराई पर पाईप डाली गयी। इन स्थलों पर गुरूत्वाकर्षण आधारित निकास उपलब्ध है। एक परियोजना स्थल के एक छोर पर प्राकृति जलनिकास नाली भी उपलब्ध है। तकनीकी प्रयासों के अतिरिक्त स्थानीय समुदाय को जागरूक करने का भी प्रयत्न किया जा रहा है जिससे इन जलनिकास परियोजनाओं का सफल क्रियान्वयन किया जा सके।

पुरस्कार एवं मान्यता

- डा. अजय कुमार भारद्वाज व डा. सुभाशीष मंडल को भारतीय कृषि अनुसंधान परिषद के लाल बहादुर शास्त्री उत्कृष्ट युवा वैज्ञानिक अवार्ड, 2015 से सम्मानित किया गया।
- डा. रंजय कुमार सिंह, प्रधान वैज्ञानिक (कृषि विस्तार) को यूनाइटेड किंगडम के लीड्स विश्वविद्यालय के लिये लाल बहादुर शास्त्री अवार्ड विजिटिंग फेलोशिप से सम्मानित किया गया।
- डा. प्रवेन्द्र श्योराण, डा. अंशुमान सिंह एवं डा. भास्कर नर्जरी को 5–25 फरवरी, 2017 के मध्य खाद्य सुरक्षा के लिये खेतों में सिंचाई जल क्षमता बढ़ाने के लिये अंतर्राष्ट्रीय प्रशिक्षण कार्यक्रम में भाग लेने के लिये आस्ट्रेलिया सरकार द्वारा आस्ट्रेलिया अवार्ड फेलोशिप प्रदान की गई।
- डा. डी. के. शर्मा, प्रधान वैज्ञानिक को इण्डियन सोसायटी आफ एग्रोनोमी, नई दिल्ली द्वारा स्वर्ण पदक (2016) से सम्मानित किया गया।
- डा. आर. के. यादव, अध्यक्ष, मृदा एवं फसल प्रबंधन व डा. प्रवीन कुमार, प्रधान वैज्ञानिक इण्डियन सोसायटी ऑफ एग्रोनोमी नई दिल्ली द्वारा वर्ष 2016 के लिए फेलो चुने गए।
- डा. आर. के. यादव को 2016 में भारतीय मृदा लवणता एवं जल गुणवत्ता सोसाइटी का फेलो चुना गया।
- डा. टी. दामोदरन, प्रधान वैज्ञानिक को फल विज्ञान में उत्कृष्ट योगदान के लिये भारतीय उद्यान सोसाइटी का फेलो चुना गया।
- डा. राजकुमार, वैज्ञानिक को कृषि एवं प्रौद्योगिकी में मार्च 19–20, 2017 के मध्य सोसाइटी आफ हयुमन रिसोर्स तथा इनोवेशन द्वारा आगरा में आयोजित अग्रिम विश्व अनुसंधान की पहली राष्ट्रीय संगोष्ठी, में युवा वैज्ञानिक अवार्ड–2017 से सम्मानित किया गया।
- डा. आर. राजू, वैज्ञानिक (कृषि अर्थशास्त्र) को 25–26 जून, 2016 के मध्य नई दिल्ली में अंतर्राष्ट्रीय जर्नल आफ एग्रीकल्चर तथा सिरियल पब्लिकेशन, नई दिल्ली द्वारा आयोजित तृतीय कृषि, उद्यान एवं पौध विज्ञान अंतर्राष्ट्रीय संगोष्ठी में उत्कृष्ट युवा वैज्ञानिक अवार्ड 2016 से सम्मानित किया गया।
- डा. एस.के. झा, वरिष्ठ वैज्ञानिक को 25–26 जून, 2016 के मध्य में नई दिल्ली में आयोजित कृषि उद्यान एवं पौधा विज्ञान पर भारतीय जर्नल ऑफ ट्रोपिकल एग्रीकल्चर की तृतीय अंतर्राष्ट्रीय संगोष्ठी में उत्कृष्ट वैज्ञानिक अवार्ड 2016 से सम्मानित किया गया।
- डा. वी. के. मिश्रा, अध्यक्ष, क्षेत्रीय अनुसंधान केन्द्र, लखनऊ को माननीय श्री राम नाईक, राज्यपाल, उत्तर प्रदेश द्वारा 18 दिसम्बर 2016 को ग्रामीण विकास समिति एवं भारतीय गन्ना अनुसंधान संस्थान, लखनऊ द्वारा आयोजित राष्ट्रीय संगोष्ठी में उत्तर प्रदेश में क्षारीय भूमि के प्रबंधन के लिये सम्मानित किया गया।
- डा. आर. राजू, वैज्ञानिक (कृषि अर्थशास्त्र) को महात्मा फूले कृषि विद्यापीठ में 10–11 फरवरी, 2017 को आयोजित महाराष्ट्र कृषि अर्थशास्त्र समिति द्वारा द्वितीय अंतर्राष्ट्रीय कृषि अर्थशास्त्र संगोष्ठी–2017 में श्री बानू पनाजी हिले मेमोरियल अवार्ड से सम्मानित किया गया।
- डा. अरीजीत बरमन, वैज्ञानिक को आईसीएआर–एनबीएसएस एंड एलयूपी में 10–13 नवंबर, 2016 के मध्य आयोजित इंटरनेशनल कान्फ्रेंस आन इंटैगरेटीड लैंड यूज

प्लानिंग फॉर स्मार्ट एग्रीकल्चर–एन एजेंडा फार सस्टेनएबल लैंड मैनेजमेंट के दौरान उत्कृष्ट पोस्टर अवार्ड से सम्मानित किया गया।

- डा. यशपाल सिंह, प्रधान वैज्ञानिक को ग्रामीण विकास तथा जलवायु परिवर्तनशील कृषि के लिये शुष्क तथा अर्द्धशुष्क वातावरण में प्राकृतिक संसाधन प्रबंधन पर 25वें राष्ट्रीय सम्मेलन में सर्वोत्तम पत्र पुरस्कार–2016 से सम्मानित किया गया।
- डा. एस.के. सारंगी, प्रधान वैज्ञानिक को 21–23 जनवरी, 2017 के मध्य स्वामी केशवानंद राजस्थान कृषि विश्वविद्याल, बीकानेर में आयोजित जलवायु सहनशील लवणीय कृषि : सतत् सुरक्षा जीविका पर पांचवी संगोष्ठी में उत्कृष्ट पोस्टर अवार्ड से सम्मानित किया गया।
- डा. मधु चौधरी, वैज्ञानिक को 21–23 जनवरी 2017 के मध्य में आयोजित स्वामी केशवानंद, राजस्थान कृषि विश्वविद्यालय, बीकानेर में जलवायु सहनशील लवणीय कृषि : सतत् सुरक्षा जीविका पर पांचवी संगोष्ठी में उत्कृष्ट पोस्टर अवार्ड से सम्मानित किया गया।
- डा. अजय कुमार भारद्वाज, वरिष्ठ वैज्ञानिक को 21–23 जनवरी के मध्य में यूएएस बेंगलौर में आयोजित कृषि विज्ञान सभा में उत्कृष्ट पोस्टर अवार्ड से सम्मानित किया गया।

कार्यशाला, सेमिनार, प्रशिक्षण कार्यक्रम, स्थापना दिवस एवं किसान मेला का आयोजन

- स्वच्छता पखवाड़ा एवं स्वच्छ भारत अभियान के अन्तर्गत स्वच्छता, समगतिशीलता एवं पर्यावरण' विषय पर 28 अक्टूबर 2016 को संस्थान में सेमिनार आयोजित किया गया।
- दिनांक 12 अगस्त, 2016 को लाल बहादुर शास्त्री अवार्ड परियोजना (आईसीएआर) के अंतर्गत जलवायु परिवर्तन प्रतिरोधी समगतिशील जैविक खेती पर गांव सिकन्दर खेड़ी (कैथल) में एक किसान गोष्ठी का आयोजन किया गया। इस गोष्ठी में हिसार से आये 10 कृषकों ने भाग लिया।
- संस्थान में 14 से 29 सितम्बर 2016 तक हिन्दी पखवाड़ा आयोजित किया गया।
- भारतीय कृषि अनुसंधान परिषद की क्षेत्रीय कमेटी न. 5 की उच्च स्तरीय दो दिवसीय 24वीं बैठक का आयोजन दिनांक 3–4 अक्तूबर 2016 को संस्थान द्वारा भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली में किया गया। इस बैठक में लगभग 150 विशिष्ट प्रतिभागियों ने भाग लिया जिसमें हरियाणा, पंजाब व दिल्ली सरकार के कृषि सचिव/आयुक्त, कृषि–विश्वविद्यालयों के कुलपति, उच्च अधिकारीगण, भारतीय कृषि अनुसंधान परिषद के सभी उपमहानिदेशक, सहायक महानिदेशक, भारतीय कृषि अनुसंधान परिषद, नई दिल्ली के अंतर्गत आने वाले संस्थानों के निदेशक/परियोजना निदेशक/परियोजना समन्वयक, गैर सरकारी संस्थाओं के अधिकारी तथा प्रगतिशील किसान सम्मिलित हुए।
- 3 नवम्बर 2016 को कृषि वैज्ञानिक चयन मंडल, नई दिल्ली के 43वें स्थापना दिवस का आयोजन किया गया।
- लाल बहादुर शास्त्री चैलेंज पुरस्कार परियोजना के अन्तर्गत 8 नवम्बर, 2016 को गांव चिड़ौद (हिसार) में एक किसान गाष्ठी का आयोजन किया गया।
- संस्थान में 3 दिसम्बर, 2016 को भारत के प्रथम राष्ट्रपति डा. राजेन्द्र प्रसाद के जन्म दिवस को 'कृषि शिक्षा दिवस' के रूप में मनाया गया।
- लवणग्रस्त मृदाओं का प्रबंध एवं लवणीय जल का कृषि में उपयोग पर अखिल भारतीय समन्वित अनुसंधान परियोजना की द्विवर्षीय कार्यशाला का आयोजन 19–20 जनवरी 2017 को स्वामी केशवानन्द राजस्थान कृषि विश्वविद्यालय बीकानेर में हुआ।
- भारतीय मृदा लवणता एवं जल गुणवत्ता समिति, करनाल, स्वामी केशवानन्द राजस्थान कृषि विश्वविद्यालय, बीकानेर व केन्द्रीय मृदा लवणता अनुसंधान संस्थान, करनाल के संयुक्त तत्वावधान में पांचवें राष्ट्रीय सेमिनार ''जलवायु अनुकूल लवणीय कृषिः सतत् आजीविका सुरक्षा में सहायक'' का आयोजन दिनांक 21–23 जनवरी 2017 को स्वामी केशवानन्द राजस्थान कृषि विश्वविद्यालय, बीकानेर में हुआ।
- भारत सरकार की फार्मर फर्स्ट परियोजना के अंतर्गत "लवणग्रस्त मैदानी क्षेत्रों के किसानों के लिये डेरी उत्पादन में वैज्ञानिक तौर–तरीकों का समावेश विषय पर तीन दिवसीय प्रशिक्षण कार्यक्रम आयोजित किया गया। इसमें कैथल जिले के किसानों ने भाग लिया।
- मेरा गांव, मेरा गौरव कार्यक्रम के अंतर्गत हरियाणा, पंजाब, उत्तर प्रदेश, पश्चिम बंगाल एवे गुजरात प्रदेशों के अंगीकृत गांवों में प्री–रबी किसान गोष्ठियों का आयोजन किया गया। इन गोष्ठियों के दौरान 2000 से अधिक किसानों ने वैज्ञानिकों/विशेषज्ञों के साथ विचार–विमर्श किया।
- संस्थान ने 1 मार्च, 2017 को अपना 48वां स्थापना दिवस समारोह आयोजित किया जिसमें डा. अलगुसुन्दरम उपमहानिदेशक (प्राकृतिक संसाधन प्रबंधन) भारतीय कृषि अनुसंधान परिषद, नई दिल्ली मुख्य अतिथि द्वारा स्थापना दिवस व्याख्यान प्रस्तुत किया गया।
- संस्थान परिसर में 8 मार्च, 2017 को रबी किसान मेले का आयोजित किया गया जिसका उद्घाटन प्रो. विजय पाल शर्मा चेयरमैन, कृषि लागत एवं मूल्य आयोग भारत सरकार ने किया। इस मेले में 1500 से अधिक किसानों एवं स्कुली

छात्रों ने भाग लिय व 53 सरकारी संस्थानों एवं निजी कम्पनियों द्वारा प्रदर्शित की गई कृषि प्रौद्योगिकियों से लाभान्वित हुए। इस अवसर पर एक किसान गाष्ठी का अयोजन भी किया गया।

क्षेत्र प्रदर्शनी व भ्रमण

वर्ष 2016–17 के दौरान कृषि में लवणग्रस्त मृदा के सुधार और प्रबंधन व निम्न कोटि जल के उपयोग पर विभिन्न अनुसंधान संस्थानों और विकास अभिकरणों में 9 प्रदर्शनियां लगाई गई। 105 समूहों में आये 2897 हितधारकों ने संस्थान के सूचना प्रौद्योगिकी केन्द्र व प्रायोगिक फार्म का दौरा किया। 2897 हितधारकों में 36 समूहों में आये 1537 किसान, 11 समूहों में आए 139 प्रसारकर्मी और वस्तु विशय विशेषज्ञ, 19 समूहों में आए 1135 विद्यार्थी, 15 समूहों में आए 86 भारतीय व विदेशी वैज्ञानिक 36 समूहों में आए थे।

किसान सलाहकार सेवा

किसानों की मृदा लवणता, क्षारीयता व जल गुणवत्ता संबंधित समस्याओं के त्वरित और समुचित समाधान हेतु संस्थान 18001801014 नम्बर पर निःशुल्क फोन सेवा शुरू की है। वर्ष 2016–17 के दौरान देश के विभिन्न क्षेत्रों से कृषि संबंधित समस्याओं संबंधित 914 कॉल प्राप्त हुई और संस्थान के वैज्ञानिकों द्वारा इन समस्याओं के निदान हेतु वैज्ञानिक उपाय सुझाए गए।

अंतर्राष्ट्रीय सहयोग

- अफ्रीका और दक्षिण एशिया के गरीब किसानों के लिए तनाव सहिष्णु धान (आईआरआरआई व वीएमजीएफ द्वारा प्रायोजित)।
- नवीन आनुवांशिकी स्टॉक्सः धान में विभिन्न लक्षणों के लिए जीन खोज की सुविधा के लिए विविध जीनोटाइप के बीच मल्टी–पेरेंट इंटर–क्रस से अधिक उत्पादन बढाना (आईआरआरआई)।
- जलवायु परिवर्तन, कृषि एवं खाद्य सुरक्षा (सीसीएएफएस) (सिमिट, मैक्सिको)
- सैद्धांतिक और एप्लाइड भौतिक रसायन विज्ञान संस्थान (आईएनआईएफटीए), ला प्लाटा अर्जेन्टीना (यूनेस्कोटी डब्ल्यू एएस–कोनीसटेस द्वारा वित्त पोषित) से सहयोगात्मक अनुसंधान।
- चावल में फसल और पोषक तत्व के प्रबंधन के तरीकों का विकास (आईआरआरआई द्वारा पोषित) ।
- दक्षिण एशिया में शहरी बाड़ को कम करने तथा ग्रामीण क्षेत्रों में पानी की सुरक्षा में सुधार के लिये भूगत नवप्रवर्तनकारी परीक्षणात्मक को बढ़ावा देना (आईडब्ल्यू एमआई)।
- बांग्लादेश एवं पश्चिम बंगाल, भारत के लवण प्रभावित तटीय क्षेत्रों में फसल प्रणाली सघनीकरण (सीएसआईआरओ एवं मुडोर्क विश्वविद्यालय, आस्ट्रेलिया द्वारा वित्त पोषित)

प्रकाशन

संस्थान द्वारा प्रमुख जरनलों में 114 अनुसंधान आलेख, 54 पुस्तक अध्याय, 7 पुस्तक/मैनुअल, 6 बुलेटिन/फोल्डर, 13 प्रचलित आलेख, तकनीकी प्रतिवेदन छपवाये गये और 113 आलेख सेमीनार/सिमपोसिया और कानफ्रेन्सों में प्रस्तुत किये गये।

वैज्ञानिकों का विदेश भ्रमण कार्यग्रहण व सेवानिवृत्ति

ज्ञान व कुशलता को बढ़ाने हेतु संस्थान के 12 वैज्ञानिकों ने विभिन्न देशों जैसे नेपाल, फिलीपीन्स, ईग्लैंड, बांग्लादेश, श्रीलंका, आस्ट्रेलिया और अर्जेन्टिना का दौरा किया। इस अवधि में 6 वैज्ञानिकों ने कार्यभार संभाला।

EXECUTIVE SUMMARY

ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal, Haryana is an internationally recognized premier research organization dedicated to multi-disciplinary research on salinity management and use of poor quality irrigation water in different agro-ecological regions of the country. Multi-disciplinary research programmes at the main institute are conducted through four divisions: Soil and Crop Management, Irrigation and Drainage Engineering, Crop Improvement, and Technology Evaluation and Transfer. The institute has also established three Regional Research Stations at Canning Town (West Bengal), Bharuch (Gujarat) and Lucknow (Uttar Pradesh) to deal with the problems of coastal salinity, salt-affected vertisols and alkali soils of the central and eastern Indo-Gangetic plains, respectively. The Coordinating Unit of All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture is also located at the main institute and is functioning through 12 research centres at Agra (Uttar Pradesh), Baptala (Andhra Pradesh), Bikaner (Rajasthan), Gangawati (Karnataka), Hisar (Haryana), Indore (Madhya Pradesh), Kanpur (Uttar Pradesh), Tiruchirapalli (Tamil Nadu), Bathinda (Punjab), Panvel (Maharashtra), Port Blair (A&N islands) and Vyttila (Kerala) representing different agro-ecological regions of the country. For the period under report, some of the major research achievements of the institute in different thrust areas are as under:

High yielding salt tolerant mustard variety CS 58 released

Salt stress is a major cause of low mustard productivity in many salinity affected pockets of north-western India. Development of salt tolerant cultivars is seen as a viable means of mustard productivity enhancement under saline conditions. Concerted efforts in this direction have led to the identification and release of a promising salt tolerant variety of Indian mustard 'CS 58' for the salinity affected mustard growing regions of Zone-II comprising the states of Haryana, Punjab and Uttar Pradesh. This new variety matures in about 132 days. Plants attain a height of approximately 180 cm and higher 1000 seed weight (5.5 g) as compared to the locally grown varieties. Seed yield ranges from 2.6-2.8 t ha^{-1} in normal soils and from 2.0-2.2 t ha^{-1} in salt affected soils. Seeds contain about 40% oil. Plants of CS 58 show resistance to *Alternaria* blight and have very less incidence of white rust, powdery mildew, downy mildew, stag head, *Sclerotinia* stem rot and mustard aphid under field conditions.

Development of novel alternative amendments for sodic soils

Sodic soils occupy more than 50% (3.77 m ha) of the total salt-affected area of India. Around 1.95 M ha sodic lands have been successfully reclaimed using the gypsum-based package in Haryana, Punjab, Uttar Pradesh and other parts of the country. Recently, owing to dwindling supplies of good quality gypsum, interest has considerably increased in identifying low cost alternative amendments for reviving the productivity of degraded sodic soils. One such amendment, *i.e.*, elemental sulphur, is being tested with the aim to overcome the constraints such as slow oxidation, dustiness and fire hazard that limit its potential use. A memorandum of understanding has been signed between ICAR-CSSRI and Reliance Industries Limited (RIL) for improving the efficacy of the elemental sulphur in sodic soil reclamation. Efforts are also underway to assess the feasibility of marine gypsum as a substitute for the mineral gypsum. Marine gypsum, a by-product from the manufacturing process of common salt (NaCl), contains NaCl, $MgCl_2$ and $MgSO_4$ as impurities which may increase the ionic strength of the aqueous solution by decreasing its activity coefficient, and thus increased solubility of gypsum resulting in the enhanced reclamation efficiency compared to the mineral gypsum. Laboratory experiments revealed very high calcium content (30.5 meq l^{-1}) in marine gypsum based formulation that is in fact comparable to the pure analytical grade gypsum ($CaSO_4.2H_2O$).

Utilization of biodegradable municipal solid waste for enhancing crop productivity in saline soils

Considering the fact that traditional method of municipal solid waste disposal creates several environmental problems, use of municipal solid waste compost (MSWC) in crops is increasingly being seen as a sustainable recycling strategy. In a field experiment conducted for three consecutive years in mustard-pearl millet cropping system in a saline soil, integrated use of organic amendments *viz.*, MSWC, rice straw compost (RSC) and gypsum enriched compost (GEC) along with 25% recommended dose of fertilizers (RDF) resulted in significant increase in microbial biomass carbon (MBC), decrease in soil salinity and increase in crop yields than use of organic amendments and mineral fertilizers alone. Combined use of MSWC, RSC and GEC and 25% RDF resulted in 32% higher MBC than solitary use of 100% RDF. Mean electrical conductivity (EC) declined in all treatments compared to control but the decline was highest in organically treated soil than in 100% RDF. Soil saturation extract salinity decreased to 3.6 dS m^{-1} with MSWC @ 16 t ha^{-1} relative to control (4.8 dS m^{-1}). Mean data for three years indicated that combined application of MSWC, RSC, GEC and 25% RDF resulted in about 25% higher yield in both mustard and pearlmillet than 100% RDF. These results point to the economic and environmental benefits of using municipal solid waste as an ameliorant in salt affected soils.

Sustainable use of alkali waters at farmers' field

A field experiment was conducted to evaluate the performance of salt tolerant varieties and RSC neutralizing ameliorants *viz.*, gypsum and pressmud applied either individually or in combination for the sustained use of alkali water in rice and wheat crops. Study sites, located in Kaithal district of Haryana, suffer from the problems of soil sodicity and high residual sodium carbonate in irrigation water (RSC_{iw} 5.0-7.0 meq L^{-1}). Different combinations of gypsum and pressmud were taken in the main plots while salt tolerant (Basmati CSR 30 in rice and KRL 210 in wheat) and the popular varieties (Pusa 1121 in rice and HD 2967 in wheat) were taken as the sub-plot treatments. With the increase in RSC_{iw}, Basmati CSR 30 performed relatively better than Pusa 1211. Adoption of salt tolerant wheat variety KRL 210 is also suggested to overcome the yield reduction as well as improving the system productivity in the study area. Overall, yield superiority of 11.9% was recorded with salt tolerant KRL 210 in comparison to HD 2967. Both Basmati CSR 30 and wheat KRL 210 showed better physiological efficiency for salt stress adaptation in terms of lower Na^+/K^+ ratio in shoot and root tissues compared to the popular cultivars. Neutralization of RSC water through amendments (gypsum/pressmud) either individually or in combination resulted in 11.6-17.4% (mean 14.7%) higher system (wheat) equivalent yield.

Cropping systems intensification in salt affected coastal zones of West Bengal

Efforts are being made to increase the cropping intensity and productivity in the saline coastal zones of West Bengal, especially in the dry (*Rabi*) season, through integrated soil, water and crop management. Experiments are being conducted at farmers' fields to demonstrate the potential of different establishment methods and improved cultivars of rice. While rice variety Amal-Mana was grown on acid saline soils (pH 4.6-4.8) in the *Kharif* season, maize and other *Rabi* season crops like potato, onion, green gram and grass pea were also evaluated in the on-farm trials. Potato variety Pokhraj was grown under conventional and zero tillage (direct sowing of potato tubers to the wet soil) immediately after harvesting of *Kharif* rice. Zero tillage significantly decreased the irrigation requirement. Tubers were covered with dry compost and 30-45 cm thick layer of paddy straw. Tuber yield varied from 7.5-26.9 t ha^{-1} in conventional tillage and 12.4-32.1 t ha^{-1} in ZT cultivation. Tuber quality in zero tillage was better and due to early harvest it was possible to take other *Rabi* crops like maize/green gram/onion in the same plot. Therefore, cropping intensity can be increased to 300% in rainfed low lands of

Sundarbans. Grass pea (*Lathyrus*) was cultivated as *paira* crop with *Kharif* rice. This system of cultivation helped in utilization of residual soil moisture in the low land paddy fields. Green gram was grown with and without *Rhizobium* culture treatments. Onion variety Sukhsagar was grown with soil moisture conservation treatments (with and without paddy straw mulching) and liming.

Cost effective drainage solutions for waterlogged saline Vertisols

Waterlogging and soil salinity problems are adversely affecting agricultural lands in many irrigation commands of Gujarat state. This project was initiated to develop and demonstrate the cost effective and convincing models of drainage including subsurface drainage. This system (SSD) is basically adopted for reclamation and management of soils affected by waterlogging and salinity. Similarly, to get rid of waterlogging situation during monsoon season in salt affected black soils, open surface drainage and mole drainage (pipe less drainage) options are also available. Yet, there are several location specific problems that pose difficulties in the implementation and operation of such drainage interventions. SSD system was installed in waterlogged saline soils (EC_e 3.4-41.0 dS m^{-1}) at 2 locations of Bharuch district of Gujarat. SSD was installed with two different lateral spacings (35 m and 40 m) at 1.2 m depth. These sites have gravity outlet condition and natural drainage channel was present along the boundary of one site. Local communities are being sensitized for the active participation for the successful operation of these projects.

Identification of salt tolerant cultivars in fruit crops

Salt affected soils, especially those suffering from low to moderate limitations, offer ample scope for diversification through high value fruit crops. Experiments conducted under shallow saline watertable conditions have shown the possibility of commercial cultivation of guava (cv. Allahabad Safeda) and bael (cv. NB-5) in saline soils irrigated with saline water (EC_{iw} 3.0-4.0 dS m^{-1}). Simple agronomic practices such as planting on raised beds and the amelioration of planting pits with FYM considerably enhance the salt tolerance in young plants. Different germplasm lines of pomegranate and ber (Indian Jujube) have also given encouraging results under the similar conditions. Further, polyembryonic mango rootstocks collected from the South Andaman Islands (ML-2, ML-3, ML-6, GPL-1, GPL-3, GPL-4) were screened in sodic soils along with the standard check '13-1' at CSSRI RRS Lucknow. Two accessions, ML-2 and ML-6 endured high sodicity without any salt induced injury symptoms that seemed to be due to preferential K^+ uptake and the higher accumulation of compatible solutes and anti-oxidant enzymes in these genotypes.

Impact assessment of subsurface drainage technology in Karnataka

An impact assessment study was conducted in the subsurface drainage (SSD) project area of Belgaum District in Karnataka state. Subsurface drainage system has been installed in waterlogged saline lands of village Ugar Budruk over an area of 925 ha covering 644 farmers. The per hectare cost of saline land reclamation through SSD installation was estimated at Rs. ₹ 52,000. There was about 24% increase in the cropping intensity in the post-SSD phase mainly due to the reduction in soil salinity from average 6.63 dS m^{-1} during pre-SSD to 2.52 dS m^{-1} in post-SSD period. Net returns increased by 161.81%, and the B: C ratio increased from 0.54 to 1.21 in the reclaimed soils. The increase in net income and B: C ratio was largely due to increase in crop yield. Owing to considerable improvement in the soil properties within 2-3 years of SSD installation, soils became suitable for growing the high value crops.

AWARDS AND RECOGNITIONS

- Dr. A. K. Bhardwaj and Dr. S. Mandal received 'Lal Bahadur Shastri Outstanding Young Scientist Award 2015' of ICAR, New Delhi.
- Dr. Ranjay K.Singh, Principal Scientist (Agril. Extension) received 'Lal Bahadur Shastri Award Visiting Fellowship' to University of

Leeds, United Kingdom.

- Dr. Pavender Sheoran, Dr. Anshuman Singh and Dr. Bhaskar Narjary received the 'Australia Awards Fellowship' of the Government of Australia to attend the international training programme entitled 'Enhancing private sector capability in on-farm irrigation for food security (Indo-Gangetic Plains)' held in Australia from 5-25 February, 2017.
- Dr. D. K. Sharma was bestowed with the 'Gold-Medal' of the Indian Society of Agronomy, New Delhi.
- Dr. R. K. Yadav and Dr. Parveen Kumar were elected 'Fellow' of the Indian Society of Agronomy, New Delhi.
- Dr. R. K. Yadav was elected the 'Fellow' of the Indian Society of Soil Salinity and Water Quality, Karnal.
- Dr. T. Damodran was elected Fellow, Horticultural Society of India for the year 2016.
- Dr. Rajkumar was awarded the 'Young Scientist Award 2017' in the '1st National Conference on Advances in Global Research in Agriculture & Technology' organized by the Society of Human Resource and Innovation Agra, India during 19-20 March, 2017.
- Dr. R. Raju, Scientist (Agril. Economics) received the 'Best Young Scientist Award-2016' in the '3rd International Conference on Agriculture, Horticulture, and Plant Sciences' organized by International Journal of Tropical Agriculture (IJTA) and Serials Publications Pvt. Ltd. New Delhi, India during 25-26 June, 2016.
- Dr. S.K. Jha received Outstanding Scientist Award and Best Paper Presentation Award 2016 in IJTA 3rd International Conference on Agriculture, Horticulture & Plant Sciences, New Delhi.
- Dr. V.K. Mishra, Head RRS Lucknow received the Dr. M.S Swaminathan Award -2016 for his significant contribution in management of sodic soil in Uttar Pradesh by Hon. Governor Uttar Pradseh Sri Ram Naik during national seminar jointly organised by Gramin Vikash Samiti, Lucknow and Indian Institute of Sugarcane Research Lucknow .
- Dr. R. Raju, Scientist (Agril. Economics) was awarded for Best Paper Presentation (Male) in the memory of Shri. Bhau Punaji Hile Memorial Award in the '2nd International Conference of Agricultural Economics-2017' of Maharashtra Society of Agricultural Economics held at MPKV, Rahuri during 10-11 February, 2017
- Dr. Arijit Barman received the 'Best Poster Award' in the 'International Conference on Integrated Land Use Planning for Smart Agriculture- An Agenda for Sustainable Land Management' held at ICAR-NBSS & LUP Campus, Nagpur during 10-13November, 2016.
- Dr. Y.P Singh received the 'Best Paper Award' in 25th National conference on Natural Resource management in Arid and Semi-arid ecosystem for climate resilient agriculture and rural development 2016.
- Dr. S. K. Sarangi received the 'Best Poster Award' in the '5th National Seminar on Climate Resilient Saline Agriculture: Sustaining Livelihood Security' held at Swami Keshwanand Rajastahan Agricultural University, Bikaner during 21-23 January, 2017.
- Dr. Madhu Chaudhary received the 'Best Poster Award' in the '5th National Seminar on Climate Resilient Saline Agriculture: Sustaining Livelihood Security' held at Swami Keshwanand Rajastahan Agricultural University, Bikaner during 21-23 January, 2017.
- Dr. A. K. Bhardwaj was bestowed the 'Best Poster Award' in the 'XIII Agricultural Science Congress held during 21-24 February, 2017 at UAS, Bengaluru.

Workshops, Seminars, Trainings, Foundation Day and Kisan Mela organized

- Annual Review Meeting of All India Coordinated Research Project on "Management of Salt Affected Soils and Use of Saline Water in Agriculture" was organized during 06-07 May,

2016 at ICAR-CSSRI, Karnal.

- Brainstorming session on "Coastal saline soils-problems, solutions, and future research strategies" was organised by AICRP on SAS&PQW, Panvel, Maharashtra (Volunteer Centre) and Dapoli Chapter of ISCAR, Canning Town, West Bengal on 13th June 2016 at Khar Land Research Station, Panvel.
- A number of programmes were organized on *Swachh Bharat Abhiyan* in different villages *viz*; Bhudmor (Patiala), Sampli Kheri (Kaithal), Zarifa Viran (Karnal), Sikander Kheri (Kaithal) and at the Main Campus of the Institute.
- A total of 13 pre-rabi and 12 pre-kharif *Gosthis* were organized under MGMG during the period under report in which 2670 farmers participated and benefitted by interacting with the scientists and officials of the state development departments, KVKs, etc.
- The XXIV meeting of the ICAR-Regional Committee V was organized at Indian Agricultural Research Institute, New Delhi during 03-04 October, 2016 to discuss the constraints hampering sustainable agricultural production in the food basket states of Punjab, Haryana and Delhi.
- A *Kharif Kisan Mela* was organized on 7th October, 2016 in village Budhmor of Patiala district (Punjab) in which around 500 farmers participated.
- Agricultural Scientists Recruitment Board, New Delhi organized its 43rd Foundation Day at ICAR-CSSRI, Karnal on 3rd November 2016.
- World Soil Health Day' was organized in Mundri village of Kaithal district on 5th December, 2016.
- An 8-days model training course on 'Quality Seed Production, Processing and Certification of Selected Field and Vegetable Crops in Salt Affected Area" was organized from 15th-22nd December, 2016 at ICAR-CSSRI, Karnal. A total of 29 participants from line department, KVKs and ICAR institutes representing 4 states attended the training programme.
- A 3-days training programme on 'Dairy Management for Livelihood Security' was organized under Farmers FIRST Project during 27-29 December, 2016. Thirty farmers of Mundri, Kathwar, Geong, Sampli Kheri and Bhaini Majra villages of Kaithal district participated in this training programme.
- A 3-days training programme on 'Agriculture Management in Sodic Environment: Challenges and Remedies' was organized under Farmers FIRST Project during 11-13 January, 2017. Thirty three farmers of Mundri, Kathwar, Geong, Sampli Kheri and Bhaini Majra villages of Kaithal district attended this training programme.
- Biennial workshop of AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture was organized at SKRAU, Bikaner from 19-20 January 2017.
- 5th National Seminar on 'Climate Resilient Saline Agriculture: Sustaining Livelihood Security' was organized at Bikaner from 21-23 January 2017, in co-ordination with ISSSWQ, and SKRAU, Bikaner.
- National Productivity Week' was celeberted during 13-18 February, 2017 in which 35 students, 45 farmers and about 80 scientists and officials of CSSRI participated.
- ICAR-CSSRI, Karnal celebrated its 48th Foundation Day on 1st March 2015 by organizing a Foundation Day lecture delivered by Dr. K. Alagusundaram, DDG (AE), ICAR, New Delhi.
- ICAR-Central Soil Salinity Research Institute, Karnal organized *Rabi* Kisan Mela on 8th March, 2017. In which about1500 farmers, school students, extension workers and NGOs participated and benefitted by visiting

different ongoing research experiments on CSSRI campus.

Field Exhibition and Visit

During 2016-17, a total of 9 exhibitions were organized at different research institutions and developmental agencies which portrayed the technological achievements of CSSRI in reclamation and productive management of salt-affected soils and poor quality waters in agriculture. Out of 2897 stakeholders, 1537 farmers in 36 groups, 1135 students in 19 groups, 139 extension workers in 11 groups and 86 scientists in 15 groups from India and abroad have visited CSSRI technology information centers and research farmers to learn about the technologies being developed.

Farmers' Advisory Services

During 2016-17, a total of 914 advisories on soil testing, salinity and alkalinity management, salt tolerant varietal selection in rice, wheat & mustard and management in salt affected areas, crop production, animal husbandry, horticultural crop management and nutrient management were provided to the farmers through Institute Toll Free Number 1800 180 1014.

International Collaboration

- Stress Tolerant Rice for Poor Farmers of Africa and South Asia (IRRI-BMGF)
- Climate Change, Agriculture and Food Security (CCAFS, CIMMYT, Mexico)
- Novel Genetics Stocks: Multi-parent advanced generation inter-crosses (MAGIC) among diverse genotypes to facilitate gene discovery for various traits in rice (IRRI).
- Research Institute of Theoretical & Applied Physical Chemistry (INIFTA), La Plata, Argentina (funded by UNESCO-TWAS-CONICETS).
- Development of crop and nutrient management practices in rice(IRRI).
- Cropping system intensification in the salt affected coastal zones of Bangladesh and West Bengal, India (CSIRO, Murdoch University, Australia)
- Cropping system intensification in the salt affected coastal zones of Bangladesh and West Bengal, India (ACIAR, Australia).
- Piloting and up-scaling an innovative underground approach for mitigating urban floods and improving rural water security in South Asia (IWMI)

Publications

The Institute published 114 research papers in peer reviewed journals, 54 book chapters, 7 books/manuals, 6 bulletins/ folders/ leaflets/ technical reports, 13 popular articles and technical reports. Besides, 113 papers were presented in different National and International seminar/symposia and conferences.

Scientists' visits abroad and new scientists joined

To upgrade their knowledge and skills, 12 scientists of the institute visited different countries *viz.* Philippines, United Kingdom, Bangladesh, Sri Lanka, Australia and Argentina. 6 scientists joined the institute during period under report.

INTRODUCTION

Historical Perspective

ICAR-Central Soil Salinity Research Institute (ICAR-CSSRI) is a premier research institute dedicated to pursue interdisciplinary researches on salinity/alkalinity management and use of poor quality irrigation waters in different agro-ecological zones of the country. The Govt. of India constituted an Indo-American team to assist the Indian Council of Agricultural Research to develop a comprehensive water management programme for the country. As a follow up of these recommendations, Central Soil Salinity Research Institute was established under Fourth Five Year Plan period. The Institute started functioning at Hisar (Haryana) on 1st March, 1969. Later on, in October, 1969, it was shifted to Karnal. In February 1970, the Central Rice Research Station, Canning Town, West Bengal was transferred to CSSRI, Karnal to conduct research on problems of coastal salinity. Another Regional Research Station for carrying out research on problems of inland salinity prevailing in the black soil region of western parts of the country started functioning at Anand (Gujarat) from February, 1989. As per recommendations of the QRT, the station was shifted from Anand to Bharuch in April 2003. Keeping in view the need of undertaking research to manage alkali soils of Central and Eastern Gangetic Plains under surface drainage congestion, high water table conditions, relatively heavy textured soils, and indurated pan below, another Regional Station was established during October, 1999 at Lucknow. The Coordinating Unit of AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture is located at the Institute with a network of eight research centres located in different agro-ecological regions of the country (Agra, Bapatala, Bikaner, Gangawati, Hisar, Indore, Kanpur and Tiruchirapalli). Recently in 2014, four new centres have started functioning at Bathinda (Punjab), Panvel (Maharastra), Vytilla (Kerela) and Port Blair (Andaman & Nicobar Islands).

Over the years, Institute has grown into an internationally recognized esteemed centre of excellence in salinity research. Multidisciplinary research activities at the main institute are being strengthened through four research divisions. The major research activities in the Division of Soil and Crop Management include preparation and digitization of database on salt affected soils besides periodic assessment of state of soil resources, developing alternate amendments for the reclamation of alkali soils besides developing technologies for the optimal management of gypsum amended alkali soils and the use of high RSC and saline waters for crop production. In the post reclamation phase, focus is on developing resource conservation technologies and development of farming system models for resource poor farmers. Agro-forestry and horticulture on salt affected soils is another area of focus that includes multipurpose tree species, fruit plants, vegitables and seed spices. Development and propagation of individual farmer based groundwater recharge technologies, subsurface drainage for amelioration of waterlogged saline soils and decision support systems for ground water contaminations with fluoride and climate change are some of the major issues being addressed in the Division of Irrigation and Drainage Engineering. Development of high yielding genotypes tolerant to salinity, alkalinity and water logging stresses in rice, wheat, mustard and cheekpea through conventional breeding and modern molecular and physiological approaches are the major concerns of the Division of Crop Improvement. The Division of Technology Evaluation and Transfer is studying constraints in the adoption of land reclamation technologies and their impact on rural development.

The Institute has developed technologies for the reclamation of alkali soils in the country with the addition of chemical amendments, reclamation of saline soils through subsurface drainage, development and release of salt tolerant crop varieties of rice, wheat, mustard and chickpea and the biological reclamation of salt affected soils through salt tolerant multipurpose trees. A microbial consortia CSR BIO as a plant growth enhancer has been developed and commercialized to four different firms. Land shaping technologies

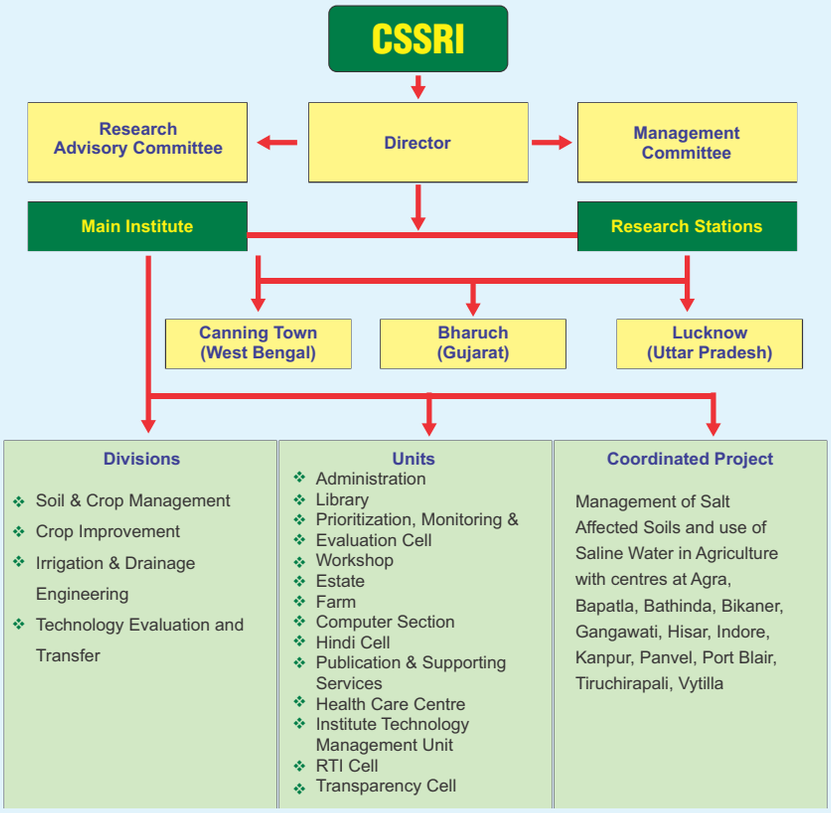
for the productive utilization of waterlogged sodic soils and coastal saline soils have also been developed. Nearly 2.0 million ha salt affected lands have been reclaimed using these technologies and put to productive use. It has been estimated that reclaimed area is contributing about 17 to 18 million tonnes food grains to the national pool. For waterlogged saline soils, subsurface drainage technology developed by the Institute initially for Haryana has been widely adopted and replicated in Rajasthan, Gujarat, Andhra Pradesh, Maharashtra and Karnataka. So far, about 70,000 ha waterlogged saline areas have been reclaimed, through institutional and private modes. Artificial groundwater recharge is another area of interest for the region with depleting water table. Besides, the technologies are also being developed for the salt affected areas of Vertisols and coastal regions of the country.

An International Training Centre to impart training at national and international level was established during 2001 under Indo-Dutch collaborative research programme. The Institute has developed Post Graduate Education programme in association with State Agricultural Universities (SAUs), Indian Institute of Technology (IIT) and other Universities, which has contributed to the growth of the Institute substantially. The Institute has several national and international projects to fund its research and development activities. The notable amongst them are: IRRI sponsored rice improvement programme, ACIAR sponsored programme for coastal saline soils, CIMMYT, sponsored programme on the improvement of cereal based systems and IWMI sponsored programme on training of underground flood water systems.

The institute has created state of the art facilities of sodic and saline micro-plots. Depending upon the objectives, desired stress levels of sodicity and salinity can be created in this facility for screening and better genotypic comparisons. Similarly, an environmentally controlled glass house facility is in place for growing crops and screening genetic resources during off-season. This allows precise screening under saline hydroponics and advancement of breeding generation. Transgenic green house facility has been created at CSSRI in the year 2008 under Indo-US program. A central laboratory with modern equipments has been established at the institute.

Organogram

The current organizational set up for implementing its research programmes is shown below



Mandate

The mandate of the Institute, as approved by the ICAR, is as follows:

- Developing technologies for reclamation and management of salt affected soils and use of poor quality irrigation waters in different agro-ecological regions of India.
- Evaluate and recommend strategies that promote adoption of preventive/ ameliorative technology.
- Coordinate/support the network of research for generating and testing location specific technologies.
- Centre for training in salinity researches in the country.

Research Farm, Karnal

Agricultural farm at CSSRI, Karnal has total area of 82 ha. A motorable road has been laid all along the boundary of this farm, for regular monitoring, upkeep and proper watch and ward. Whole of the farm area under cultivation has been divided and laid out in standard plot size of 1.0 ha size and each plot is connected with road for easy accessibility, underground water conveyance and lined channels for irrigation. Eight tube wells are installed in the farm to meet irrigation requirement of general agriculture, research experiments and water supply in the campus and laboratories. All essential farm machinery and implements *viz.*, laser leveler, multi-crop thresher, turbo seeder, zero till machines, laser leveler, tractors, hydraulic trolley, cleaner, shrub master, maize thresher, ride on lawn mower etc. are available; most of farm operations are mechanized. To achieve the optimization of water and other inputs, all the plots are precisely leveled with laser leveler at regular intervals. Combination of different cropping system is being practiced to optimize the land use in the farm. Experimental crops are grown on 20.5 ha area, while general crops are grown in 16.6 ha, which also includes the 9 ha area under seed production mainly of salt tolerant varieties of rice and wheat. During the period under report, the farm unit produced 8.3, 19.43 and 9.75 tonnes of the quality seed of wheat, rice and mustard, respectively. To reduce the emission of green house gases, most of area has been put under minimum tillage and residue burning is not practiced in the farm. Agro-forestry system is practiced on 5.2 ha area of the farm, where multipurpose tree species have been planted in combination with arable crops of the region. The area under fruit crops such as ber (*Ziziphus mauritiana* Lam.), aonla (*Emblica officinalis* L.), jamun (*Syzygium cumini* L.), guava (*Psidium guajava* L.), litchi (*Litchi chinensis* Sonn.) and mango (*Mangifera indica*) is 7.4 ha. An herbal garden consisting of 104 species of medicinal/ aromatic herbs, shrubs and trees has also been established and maintained in an area of 1.4 ha, besides fish are reared in ponds covering about 2.5 ha area. The 27.3 ha area of the farm is permanently covered under glass house, net houses, micro-plots, laboratories, offices, residences, oxidation pond, roads and landscape.

Productivity of crops at CSSRI farm

Crop	Variety	Average yield (t ha^{-1})
	Rabi 2015 - 16	
Wheat	KRL 210	4.49
	KRL 213	3.81
Mustard	CS 52	2.00
	CS54	2.40
	CS56	2.55
	CS 58	2.80
	Kharif 2016	
Paddy	CSR 30	3.55
	CSR 36	5.00
	CSR 43	5.25
	Pusa 44	5.63

CSSRI, Research Farm, Nain

The Nain experimental farm is located at Nain village, west of Panipat- Gohana road, 25 km from Panipat town (District Panipat) and is about 65 kms from Karnal. This farm covers an area of 10.8 ha. Initials the site had *Prosopis juliflora* and had some salt tolerant grasses and herbs as *Sporobolus marginatus*, *Saccharum spontanium* (Kans), *Cynodon dactylon* (Dub grass), *Suaeda fruticosa* (Noon khari), *Kochia indica* (Bui) and *Calotropis procera* (Aak) etc. A wide range of soil salinity (<4 to >30 dS m^{-1}) existed at surface and sub-surface. The soil reaction showed sodic nature ranging from <8.2 to 8.9. The

area has watertable at a depth of about 15 metres. The ground water showed neutral pH (7.7) and higher EC (13 dS m^{-1}) indicating high salinity with dominance of Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and HCO3-. Higher SAR (19.3 $mmol^{1/2}L^{-1/2}$) showed limitations for use during seed germination. Such water may be used in cyclic mode with good quality water preferably for salt tolerant crops and forestry/fruit plantations. Institute has initiated many experiments on forestry, horticulture, agro-forestry and sustainable management of such salt affected resources. Since no fresh water supply source is available on the farm, two ponds have been dug to harvest and store rain water and two tubwells have also been installed for supply of different quality water for experiments. Institute screens its mustard, wheat and rice germplasm for salinity tolerance. In addition some institutes like IARI and RRS of SBI also use this facility for screening of germplasm.

Finances

Summary of allocation and expenditure during the year 2016-17 under Plan and Non-Plan budget is presented below:

Budget (Lakh Rs.)	Sanctioned amount/receipts	Actual expenditure
Non-plan	3131.00	2952.40
Plan	260.00	242.97
AICRP (Non-plan)	41.00	40.80
AICRP (Plan)	495.00	494.42
Total	3927.00	3730.59

Staff

The total staff strength of the institute is 351. The category vise detail are :

Category	Sanctioned	In position
Scientific	81	65
Technical	117	99
Administrative	58	45
Skilled Supporting Staff	95	62
Total	351	271

Library

Library plays a crucial role in supporting the research and academic programmes of the Institute. It identifies, evaluates, procures, processes and then makes these learning resources available to the faculty and students for their teaching and research. Library has always been striving hard to meet the expectations of its users. CSSRI library is well furnished, fully air-conditioned and equipped with 4 computers, 01 server and 02 UPS. The Institute library has rare and large collection of Technical, Scientific books, Journals, Reports and other publications. The CSSRI Library possesses Indian and Foreign publications related to the fields of Water Management, Soil Salinity, Drainage, Alkalinity, Water Resources, etc. to achieve the mandate of the institute. Presently the library has total collection of 15568 books including Hindi books. A separate section is maintained for Hindi books. There are 8451 bound volumes of the Journals. It has a rich collection of special publications of FAO, IRRI, UNESCO, ILRI, ICID, IFPRI, ASA, ASAE which fulfill the needs of scientists, researchers, teachers and students. It subscribes 24 National Journals. 05 Journals are being received on gratis. About 162 theses on subjects relating to Soil Science, Agric. Engg., Water Management, etc. are available in the library. Annual Reports from the different Institutes, Agricultural Universities are being received from time to time.

e-Services

Online Journals: More than 3000 scientific research journals are available online through Consortium for e-Resources in Agriculture (CeRA) (Now jgateplus portal) on request.

CD-ROM Data Bases: World wide agricultural information retrieval services of published agricultural researches are available on CD-ROM data base where abstracts of the researches can be consulted. The research databases are available since 1972 of AGRIS, Plant Gene CD , Soil CD.

Online Public Access Catalogue (OPAC): Library book catalogue is available in online form which is a systematic record of the holding of a collection to find the physical location of information using LIBSYS software version 6.0. Now "KOHA" software has also been implemented and all the

data of Books, Journals, Theses, etc. has been migrated to "KOHA" to strengthen the digital resources of all Libraries under NARS (e-Granth). The Web OPAC of Library in "KOHA" may be accessed through http//egranth.ac.in

Institutional Digital Repository: Institute Library has a Digital repository i.e. "Krishikosh' which has been created through the digitized CSSRI documents including Institutional Publications, Annual Reports, Foundation day lecture notes, Technical Bulletins, rare and important books (150) by IARI, New Delhi centre. The digitized documents uploaded in "KrishiKosh" may be accessed online through the link http:// krishikosh.egranth.ac.in

Bar-code based Circulation: Library provides Bar-coded Electronic Membership Cards to its readers for easy circulation and to know the borrower status.

Documentation and other Services

Documentation Services: Under Documentation Services, Current Awareness Services (CAS) and Selective Dissemination of Information (SDI) are provided to users with the help of Fresh Arrivals display on board and in training, advertisement files, etc.

The library also works as a repository center where Institute's Publications such as Salinity News, Technical Bulletins, Annual Reports, Brochures, etc. are stocked and sent to Research Institutes, Agricultural Universities, NAAS members, QRT members, RAC members etc. and also distributed amongst the distinguished visitors, farmers, etc. We have a collection of 05 priced publications also which are supplied on cash or digital payment modes.

Laboratories

Well equipped laboratories for undertaking researches on various aspects of salinity management are in place with some of the advanced facilities like Atomic Absorption Spectrophotometer, Inductively Coupled Plasma (ICP), Carbon-Nitrogen-Hydrogen-Sulphur analyzer (CNHS), Ion Chromatograph, UV VIS Spectro Photometer, Ultra pure water system, PCR, Gel documentation, Radio meter, Kjeltek N-analyser, EM Salinity Probe, Neutron Moisture meter, Growth Chamber, Modulated flurometer, Dilutor, Hydraulic conductivity measurement apparatus, Pressure plate apparatus, etc. Large number of screen houses and micro-plots are also available for precision experimental works. The facilities of image processing and interpreting satellite imageries and geographical information system besides testing facilities of drainage filter materials are also available. Recently, a multimedia laboratory has also been established to cater to the need of photographic and image processing and power point presentation etc.

Allied Facilities

A conference hall, seminar room and an auditorium with modern facilities are available for scientific meetings and group discussions. The institute has a museum with exhibits depicting salient research findings and the latest technologies developed at the institute. The museum is being upgraded with addition of new exhibits and state of art display infrastructure/ material. An international guesthouse and scientists hostel with boarding facilities caters to the need of scientists and other visitors. A dispensary with physiotherapy unit is also available in the institute. A community center and sports complex consisting of playgrounds for football, hockey, cricket, volley ball, lawn tennis court etc. besides indoor facilities for table tennis, chess, carom and badminton are available. The staff recreation club functions to meet the recreational requirements of the staff. Besides this, a Staff Welfare Club is also functioning actively for the welfare of the CSSRI staff.

Research Achievements

केन्द्रीय मृदा लवणता अनुसंधान संस्थान

1969

CSSRI

ISO 9001:2008

DATABASE ON SALT AFFECTED SOILS

Mapping and characterization of salt affected soils in central Haryana using remote sensing and GIS (A. K. Mandal, Ranbir Singh, P. K. Joshi and D. K. Sharma)

Waterlogged and salt affected soils in Hisar district were characterized based on the IRS LISS III data of March, June and October 2010. High energy absorption from stagnated water in IRS imagery revealed waterlogging and reflectance of white salt crust indicated soil salinization in irrigated areas along the Bhakra canal command covering Narnaud, Hansi, Hisar, Barwala and Uklana blocks. Red to dark red tones for vegetation indicated scattered, discontinuous and mottled crop cover in the waterlogged areas and at places barren surface with patchy salt inflictions indicated soil salinization. High reflectance from sand with no vegetative cover indicated wastelands covering vast areas of Hisar, Agroha and Adampur blocks. As intermixing of sand and salty soils hamper the precise delineation of soil salinity using IRS data, inputs from ground truth studies are vital for such areas. Groundwater depth and quality data confirmed water over-exploitation in general. Ground truth observations indicated waterlogging along the canal irrigated areas of Narnaud, Hansi II and Hisar I blocks, use of poor quality groundwater in Barwala, Hansi I, Agroha, Hisar I and Hisar II blocks and vast stretches of wastelands in sandy plain and sand dunes areas in Adampur and Hisar blocks, respectively. Secondary salinization and crop failure are common problems in the irrigated areas of Uklana, Barwala, Narnaud and Hansi II (Bass) blocks. Secondary soil salinization (9.2%) occurs in areas affected by high water table depth and saline ground water.

Representative soil profiles were collected to appraise soil physico-chemical and physical properties such as pH_s, EC_e, ESP, CEC, cation and anion composition, $CaCO_3$ (< 2 mm size) content and soil texture. The results of four soil profiles of Hisar district are presented in Tables 1 and 2. The spatial extent of salinization in the study area is shown in Figure 1. P1, P2 and P3 are barren waterlogged (WTD <1.5 m) soils located in the Bhakra canal command. EC_e range of 21.1-44.3, 11.1-61.3, 9.7 to 39.3 and 5.5 to 12.3 dS m^{-1} in P1, P2, P3 and P4, respectively, indicated strong soil salinity. Salt composition indicated the dominance of Na^+ (243 to 508 me L^{-1} in P1, 103 to 663 meL^{-1} in P2, 58 to 90 me L^{-1} in P3and 25 to 50 me L^{-1} in P4) followed by Ca^{2+} and Mg^{2+} contents (35 to 126 me L^{-1} P1, 40 to 238 me L^{-1} in P2, 69 to 261 me L^{-1} in P3 and 35 to 93 me L^{-1} in P4). Availability of Cl^- and SO_4^{2-} contents suggested the presence of neutral salts. Mg^{2+} content exceeded Ca^{2+} content, apparently due to slightly alkaline nature of soils. $CaCO_3$ contents in P3 and P1 showed moderate to high calcareous soils and its presence in sub-surface depths caused poor drainage. Low CEC values in P1, P2 and P3 and medium in P4 are related to the coarse to medium soil texture. The particle size analysis revealed medium soil texture (loam to silt loam) in P1, very fine strata (loam to clay loam) in P2, coarse soil texture (sandy loam) in P3 and moderately coarse to finer soils texture (sandy clay loam to clay loam) in P4. Water dispersible un-aggregated soil particles (<50 μ) and $CaCO_3$ contents were studied to characterize natural aggregates and the cementing effects of carbonates (Table 2). The silt content varied abruptly (56 to 62%), apparently due to intermixing with fine sand and the increased contents at lower depths resulting due to higher alkalinity and calcareousness. Lower clay contents in soil aggregates indicated strong association with organic matter. $CaCO_3$ content was higher in fine-sand particles in P1 (8.8 to 10.0 %) and P3 (4.0 to 7.7%) and significant contents were noted in lower depths. The fine sand and $CaCO_3$ concretion favored formation of stable aggregates structures in P1 and P3. The two pedons are strongly saline soils, showed thick layer of $CaCO_3$, medium to coarse soil texture and the absence of natural drainage. These pedons need interventions through installation of SSD followed by salt leaching with good quality water. Pedon 2 showed severe soil salinity in finer texture strata at surface but much lower salinity in the subsurface depth. It needs surface salt removal through drainage or leaching and careful water management before

Table 1: Physico-chemical properties of soils of Hisar district of Haryana

Depth (cm)	pH_s	EC_e (dS m^{-1})	Na^+	K^+ Mg^{2+}	Ca^{2++}	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	OM	$CaCO_3$	CEC c mol $p^+ kg^{-1}$
			----------me L^{-1}----------						---------- (%)----------			
P1: Vil. Thurana Block Hansi I Dist Hisar 29°08'10.9" N, 76°07'57.0 "E Barren, Waterlogged (WT 1.5m)												
0-30	7.8	44.3	508	0.19	126	45	81	476	30.2	0.29	2.8	8.9
30-60	8.1	30.5	341	0.14	86	35	51	305	64.1	0.19	3.9	11.9
60-90	8.2	26.9	267	0.19	65	27	38	265	58.5	0.26	3.8	9.1
90-120	8.4	21.1	243	0.16	35	15	20	201	80.2	0.29	6.8	12.0
P2: Vil. Kumbha Block Hansi I Dist Hisar 29°08'02.3" N, 76°04'58.5 "E Waterlogged, highly saline												
0-30	7.6	61.8	663	0.21	238	55	183	720	25.4	0.44	1.0	13.8
30-60	7.7	19.1	173	0.09	80	35	45	176	33.1	0.31	0.9	16.8
60-90	7.2	13.9	125	0.10	60	30	30	101	33.9	0.28	1.1	21.1
90-120	7.8	11.1	103	0.07	40	17	23	71	27.7	0.31	1.0	11.9
P3: Vil. Kharkhara Block Narnaud Dist Hisar 29°05'33.1" N, 76°05'48.2 "E Waterlogged, saline soil												
0-30	8.3	39.3	90	0.19	261	27	234	281	20.8	0.31	3.0	10.1
30-60	8.1	13.1	92	0.14	86	30	56	86	26.4	0.22	11.0	10.5
60-90	8.1	9.10	53	0.19	70	30	40	52	5.10	0.19	10.8	8.7
90-120	7.9	9.70	58	0.16	69	27	42	54	25.8	0.20	10.2	8.7
P4:Vill. Bhataul Jatan Block Narnaud Dist Hisar 29°05'48.8" N, 76°07'14.6 "E support rice crop partially												
0-30	7.7	12.3	55	1.03	93	50	43	125	17.0	0.37	0.5	13.4
30-60	7.1	8.40	27	0.53	55	36	19	80	9.9	0.32	0.9	12.5
60-90	7.1	6.20	28	0.27	40	25	15	55	9.5	0.31	0.5	22.6
90-120	7.2	5.50	25	0.22	35	23	12	50	9.9	0.22	0.4	20.6

Table 2: Soil physical properties of Hisar district Haryana

Depth (cm)	CS	FS	Silt	Clay	Text-ure	Water dispersible soil separate (WDSS)			$CaCO_3$ (%) in WDSS				
	----------(%)----------					CS	FS	Silt	Clay	CS	FS	Silt	Clay
						----------%----------							
P1: Vil. Thurana Block Hansi II Dist Hisar 29°08'10.9" N, 76°07'57.0"E Barren, Waterlogged (WT 1.5m)													
0-30	15.5	18.9	48.4	17.4	l	25.1	13.9	56.8	4.3	0.9	9.5	0.9	0.5
30-60	11.3	31.1	40.6	17.0	l	23.4	13.7	58.3	4.6	1.3	8.3	1.3	0.3
60-90	10.8	18.2	48.7	22.3	l	21.1	13.4	61.9	3.5	1.5	10.0	1.5	0.1
90-120	7.3	22.7	60.1	9.9	Sil	15.1	8.4	72.1	4.4	5.3	9.8	5.3	0.8
P2: Vil. Kumbha Block Hansi II Dist Hisar 29°08'02.3" N, 76°04'58.5 "E Waterlogged, highly saline													
0-30	13.72	27.38	31.76	27.14	l	9.6	14.7	56.2	19.3	0.5	2.1	0.5	0.0
30-60	8.29	26.63	29.93	35.15	cl	8.1	8.8	54.9	16.3	0.4	4.0	0.2	0.6
60-90	8.13	19.12	32.65	40.09	c	12.9	5.9	56.1	24.9	0.4	3.5	0.2	0.3
90-120	8.77	18.89	31.58	42.76	c	11.4	5.3	58.1	25.2	0.3	1.4	0.2	0.2
P3: Vil. Kharkhara Block Hnais II Dist Hisar 29°05'33.1" N, 76°05'48.2 "E Waterlogged, saline soil													
0-30	42.57	22.27	30.11	5.05	Sl	12.8	37.8	34.8	14.4	1.5	4.0	0.7	0.6
30-60	25.45	32.78	34.21	7.56	Sl	22.8	21.8	51.1	4.6	2.0	7.2	3.5	0.0
60-90	25.33	30.41	35.51	8.74	Sl	21.7	22.8	51.3	4.1	2.6	7.7	3.1	0.0
90-120	31.82	22.90	40.79	4.79	Sl	22.5	28.8	41.9	6.6	5.3	6.0	3.2	0.0
P4:Vill. Bhataul Jatan Block Narnaud Dist Hisar 29°05'48.8" N, 76°07'14.6 "E support rice crop partially													
0-30	26.88	24.07	28.36	20.69	scl	21.0	24.6	44.0	10.3	0.2	0.5	0.2	0.0
30-60	20.97	32.46	23.54	23.03	scl	18.2	22.9	46.1	12.7	0.1	0.4	0.3	0.2
60-90	13.45	24.43	27.59	34.53	Cl	19.3	13.7	54.5	12.4	0.2	0.6	0.2	0.6
90-120	11.11	21.57	31.54	35.78	cl	16.4	13.3	56.8	13.6	0.1	1.0	0.1	0.2

CS= Coarse sand, FS = Fine sand, MC = Mechanical composition, WDSS = Water Dispersible Soil Separates

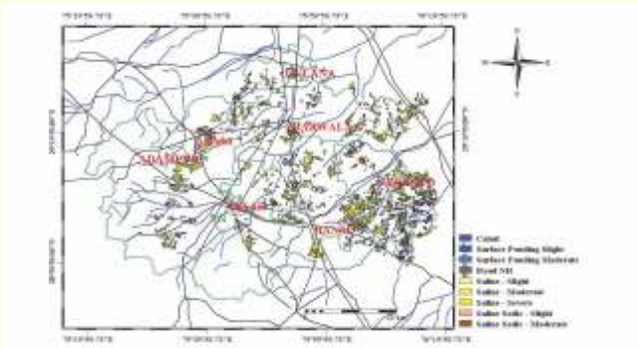


Fig. 1: Distribution of salt affected soils and waterlogged areas in Hisar district Haryana

putting under cultivation. Pedon 4 is a moderately saline soil and can be best utilized through the salt tolerant varieties.

Modelling salinity effects based on soil reflectance: A laboratory experiment (Arijit Barman, Rajeev Srivastava, M. Sethi and R. K. Yadav)

Soil salinization and alkalization are the major land degradation processes in arid and semi-arid regions of India. Conventional methods of detecting soil salinity based on saturation extract EC_e, pH_s, Na^+, K^+, Mg^{2+}, Ca^{++}, CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} entails additional time, labour and capital. Present study aimed to develop soil reflectance spectral models for rapid and cost-effective assessment of soil salinity and alkalinity. Visible-Near Infrared Reflectance (VNIR) spectroscopy provides information in a narrow (1 nm) bandwidth. In a laboratory study, spectral properties of main salt types (chlorides, sulphates and carbonates of sodium) at 0-10% salinity (on weight basis) levels from the alluvial soil of Haryana, India were examined using VNIR. The spectral regions with wavelengths of 1400, 1900 and 2200 nm were highly sensitive to the changes in salinity. The reflectance of Na_2SO_4 and Na_2CO_3 were higher in 1300 to 2450 nm wavelengths than control (Fig. 2). It was due to the development of sodicity with replacement of calcium and magnesium by sodium causing expansion of soil colloids and less retention of moisture in air-dried soil samples. However, due to high hygroscopicity of NaCl, reflectance value decreased than other two Na salts over the wavelength domain and there was the mixed effect of reflectance in the case of a mixture of these three salts of sodium. There was a shifting of higher wavelengths at 1900 nm with increase in salt concentration (Fig. 2b). Some models were assessed for predicting salinity and sodicity based on reflectance characteristics of alluvial soils. Higher coefficient of determination with low RMSE for all salinity related parameters was obtained during calibrations of PLS regression model (Table 3). Square root transformation of saturated extract potassium (R^2=0.90, RMSE= 0.24), calcium (R^2=0.90, RMSE= 0.75) and magnesium (R^2=0.92, RMSE= 0.74) were well calibrated in Partial Least Square Regression (PLSR) model due to existence of variation from lower to higher value among the samples suggesting that there was replacement of above cations by sodium ions. The coefficient of determination was > 0.93 for four anions and among them, square root transformation of saturated extract carbonate (R^2=0.96, RMSE= 1.03) and bicarbonate (R^2=0.97, RMSE= 0.96) fitted well in the calibration set.

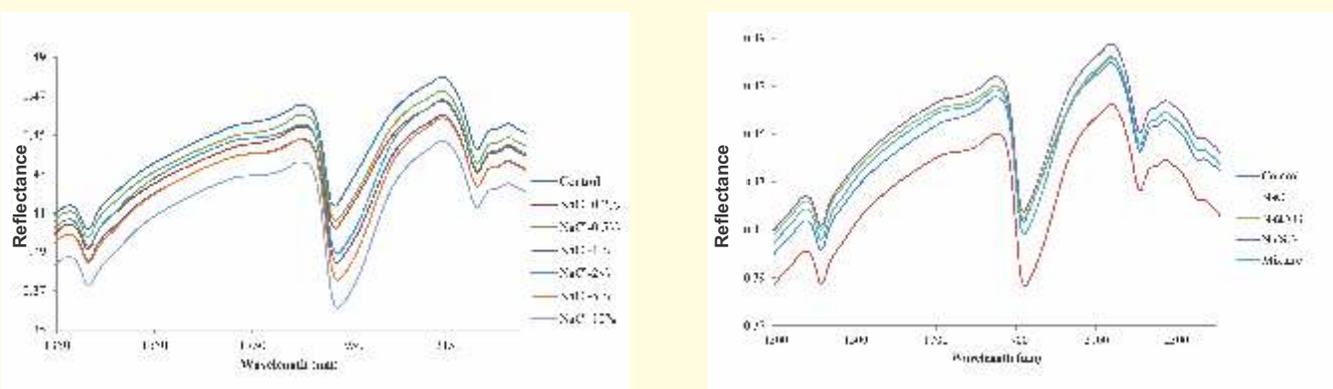


Fig. 2: Effects of (a) salt types (averaged spectra from six levels of salt contents) and (b) change of reflectance with different levels of NaCl contents on air-dried soil reflectance spectra

Saturated extract pH (R^2=0.93, RMSE= 0.23), EC_e (R^2=0.88, RMSE= 9.68) and SAR (R^2=0.95, RMSE= 1.31) were also in good agreement of calibration sets of PLSR model. PLS regression coefficient (B) values for EC_e, pH_s and SAR against wavelength helped find out the sensitive bands. Comparatively higher absolute B values at wavelength bands 470, 1400, 2020 and 2190 nm for pH_s, 1400, 1890, 1930 and 2180 nm for EC_e and 460,1400, 1910, 2180, 2340 and 2430 for saturated extract SAR pointed out that these bands are carrying more soil salinity and sodicity related information. The efficacy of the calibrated PLSR model when applied to a validation set of soil samples correctly predicted more than 87% variability in EC_e and other salinity and sodicity related attributes including saturated extract K^+, Na^+, Cl^-, CO_3^{2-} and HCO_3^-. The increased use and application of VNIR will aid in building a spectral library for salt affected soils and in conjunction with hyperspectral satellite data will provide real-time monitoring as well as rapid information enabling the farmers to deal with salt degradation more effectively and efficiently.

Table 3: Summary statistics of the hyperspectral partial least-square regression (PLSR) model

Soil parameters*	No. of Factors	Calibration set			Validation set				
		N	R^2	RMSE	N	SD*	R^2	RMSE	RPD
ECe (mS m^{-1})	3	98	0.88	9.68	50	28.86	0.87	10.49	2.70
pH_s	7	98	0.93	0.23	50	0.87	0.89	0.29	3.00
SE Cl^- (meq L^{-1})	5	98	0.93	2.73	49	10.70	0.92	3.00	3.57
SE HCO^{3-} (meq L^{-1})	6	98	0.97	0.96	49	5.84	0.93	1.51	3.87
SE CO_3^{2-} (meq L^{-1})	5	98	0.96	1.03	48	5.11	0.95	1.28	3.99
SE SO_4^{2-} (meq L-1)	11	98	0.94	1.06	41	4.27	0.77	2.25	1.90
SE Na+ (meq L^{-1})	4	98	0.88	4.39	50	12.93	0.86	4.88	2.65
SE K^+ (meq L^{-1})	6	98	0.90	0.24	50	0.76	0.87	0.28	2.71
SE Ca^{2+} (meq L^{-1})	9	98	0.90	0.75	49	2.41	0.79	1.06	2.27
SE Mg^{2+} (meq L^{-1})	11	98	0.92	0.74	50	2.65	0.85	1.08	2.45
SAR ([meq L^{-1}]0.5)	7	98	0.95	1.31	50	5.78	0.92	1.63	3.55

*Square root transformation was applied on all soil parameters except pH_s (no transformation)

RECLAMATION AND MANAGEMENT OF ALKALI SOILS

Productive utilization of reclaimed sodic soil through conservation agriculture under RWCS

(Ranbir Singh, Parvender Sheoran , D. K. Sharma, A. K. Rai and Aslam L Pathan)

Indo-Gangetic alluvial plains comprising of Punjab, Haryana and Uttar Pradesh contribute significant quantity of food grains particularly rice and wheat to the central pool. However, in the recent past, the productivity of rice-wheat cropping system (RWCS) in this region is either stagnating or decreasing with the associated problems of declining water table, decreasing organic matter in the soil, nutrient imbalances, deficiencies of secondary and micro nutrients and extensive tillage and residue burning practices. Problems multiply several folds in salinity affected areas. This calls for improving the water, nutrient and energy use efficiencies through better management of land and water resources to sustain agriculture in this region crucial to the food security of the country. Targeting different resource conserving technologies offer newer opportunities for sustained yields and better livelihood for the resource poor farmers of the region. Keeping these constraints in view, a field experiment has been continuing since 2011 to evaluate the effect of resource conservation strategies *viz.*, tillage and residue management and adoption of precise irrigation methods for enhancing crop productivity and sustaining the health of partially reclaimed sodic soils. Conventional practice (Cv) vis-à-vis eight resource conservation techniques were assessed. High yielding varieties of rice (Ariz-6129) a nd wheat (HD 2967) were used as the test crops. Rice grain

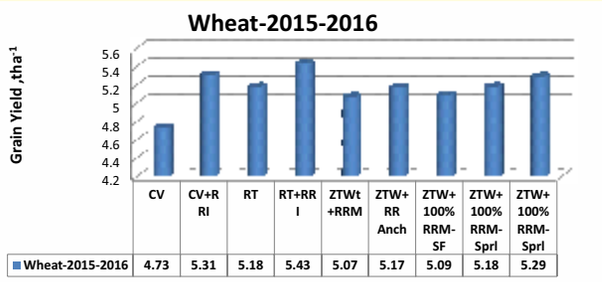


Fig. 3: Effects of different resource conservation techniques on wheat grain yield

(CV= Conventional tillage; RRI= Rice residue incorporation; RT= Reduced tillage; ZT= zero tillage; RRM=rice residue mulch and SPL= sprinkler irrigation)

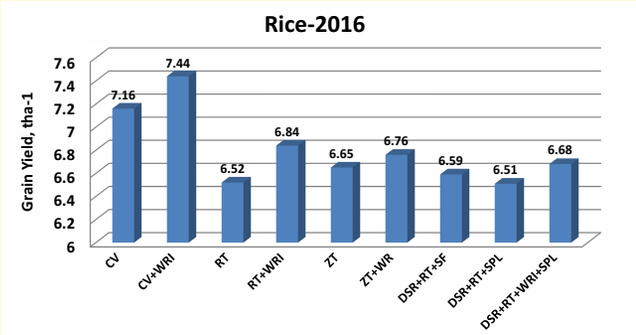


Fig. 4 : Effects of different resource conservation techniques on rice grain yield

(Cv = Conventional tillage;
WRI= wheat residue incorporation; RT= Reduced tillage;
ZT= zero tillage; WR= Wheat residue retention and SPL= sprinkler irrigation;
DSR= Direct seeded rice and SPL= sprinkler irrigation.

yield was the highest (7.44 t ha^{-1}) in Cv with wheat residue incorporation followed by 7.16 t ha^{-1} in Cv without crop residue. DSR with crop residue produced 6.84 t ha^{-1} grain yield, which was 4.91% higher than DSR without crop residue (Fig. 3). Weed infestation, especially *Cyperous rotundus* (motha), *Echinochloa crusgali* (Barta), *Echinochloa colonum* (Sanmak), *Dactyloctenium aegyptium* (Makra) and Kallar grass, etc. cause d a significant yield reduction in DSR.

A marginally higher wheat grain yield of 5.43 t ha^{-1} was recorded under 50% reduced tillage with rice residue incorporation compared to Cv (4.73 t ha^{-1}) and in 50% reduced tillage (5.18 t ha^{-1}), respectively (Fig. 4). Long term crop residue incorporation increased yield by ~14.80% under 50% reduced tillage. In case of conventional tillage, crop residue incorporation increased yield by 12.26% in comparison to without crop residue. Wheat in 50% tillage with crop residue incorporation yielded 5.84% higher grain in comparison to 50% tillage without crop residue. Under mini-sprinkler irrigation, irrigations were scheduled as per cumulative pan evaporation of previous 7 days with a 12960 lh^{-1} $acre^{-1}$ discharge rate at 2 $kgcm^{-2}$ pressure and 90% uniformity coefficient. Micro-irrigation system saved 33.82 and 8.15% of irrigation water and electricity consumption, respectively over the surface irrigation (Table 4) with 1.27 times higher wheat grain water productivity. Happy seeder/turbo seeded ZT wheat sown after DSR in 100% rice straw mulch produced highest grain yield (5.29 t ha^{-1}) under

Table 4. Effect of surface and mini sprinkler method on wheat yield (Cv. HD 2967), irrigation water requirement, water productivity, saving of water and electricity

RCTs	Conventional wheat sowing	Wheat sowing in ZT with100% rice mulch/ DSR without wheat residue	Wheat sowing in ZT with 100 % rice mulch/DSR without wheat residue	Wheat sowing in ZT with 100% rice mulch /DSR with wheat residue incorporation
Mode of irrigation	Surface T1	Surface T7	Mini –Sprinkler T8	Mini –Sprinkler T9
Irrigation criteria	Growth stages	Growth stages	(Previous 7 days CPE)	(Previous 7 days CPE)
Grain yields(t ha^{-1})	4.73	4.89	5.18	5.29
Total crop productivity (t ha^{-1})	12.43	11.82	10.77	10.74
Total irrigation water (ha-cm)	28.00	23.00	18.53	18.53
Total irrigation water (m^3ha^{-1})	2800	2200	1853	1853
Crop water productivity (kgm^{-3})	4.44	5.37	5.81	5.79
Grain water productivity (kgm^{-3})	1.79	2.22	2.24	2.28
Irrigation water saving (%)	-	21.43	33.82	33.82
Electricity saving (%)	-	27.77	8.15	8.15
NUE (kg kg^{-1} nitrogen)	31.53	32.60	69.07	70.53
Physiological observation	Yellowness-water stagnate after irrigation and rainfall	Greenness-water not stagnated	Greenness-water not stagnated	Greenness-water not stagnated
Rainfall = 46.2 mm and Pan evaporation=257.1 mm during November 2015 to March 2016 , CPE of 7 days used for irrigation through mini sprinkler system , CD (0.05) =0.32 and NUE= nitrogen use efficiency				

mini sprinkler irrigation. The highest NUE of 70.53 kg grain kg^{-1} N was observed in mini sprinkler fertigation, which saved ~50% N (75 kg N/162.0 kg urea), in comparison to lowest NUE (31.53 kg kg^{-1} N) under conventional wheat cultivation. In case of rice, mini sprinkler irrigation produced 6.59 t ha^{-1} grain yield in DSR with 50% reduced tillage and saved 59.10 and 28% irrigation water and electricity. DSR with 50% reduced tillage under surface irrigation saved 31.03% irrigation water as compared to conventional transplanting. N fertigation through mini sprinkler in rice saved 27% *i.e.*, 40 kg ha^{-1} nitrogen with increased NUE of 59.18 kg gain kg^{-1} N as compared to conventional transplanting.

Wheat crop under Mini Sprinkler irrigation

Wheat crop in Zero Tillage treatment

Nutrient management strategies for sustainable rice and wheat production in reclaimed alkali soils (A.K. Bhardwaj, Nirmalendu Basak, Parveen Kumar and D.K. Sharma)

Integrated nutrient management experiments were started with ten treatments replicated four times in randomized block design (Fig. 1). The treatments are- T_1=Control (without organic and inorganic fertilizer, O), T_2= $N_{180}P_{22}K_0Zn_5$ (Farmer's practice; FP), T_3= $N_{180}P_{39}K_{63}Zn_5$ (R), T_4= $N_{100}P_{16}K_{26}$+Moong (LE), T_5= $N_{100}P_{16}K_{26}$+GM(*Sesbania aculeate*) before rice transplanting (GM), T_6= $N_{100}P_{16}K_{26}$+FYM before rice transplanting (FYM), T_7=$N_{100}P_{16}K_{26}$+wheat straw before rice transplanting(WS), T_8= $N_{100}P_{16}K_{26}$+Rice straw before wheat sowing (RS), T_9= $N_{150}P_{26}K_{42}S_{30}Zn_7Mn_7$

(SMN) and T_{10}= $N_{150}P_{26}K_{42}S_{30}Zn_7Mn_0$(S).At the time of harvesting, 33% of the total rice stalk length was kept untouched and incorporated into the soil by power tiller before wheat (DBW-17) sowing only in T_8 treatment. Before rice transplanting, green gram seeds (SML 668) were sown in first fortnight of May in the specified plots and incorporated in situ after two pickings of pods. Similarly, dhaincha (*Sesbania aculeate*) as green manure crop was sown in May in the plots of T_5 treatment. At the age of 45 days, it was harvested, weighed and incorporated *in situ* in the specified plots before rice transplanting. Farm yard manure (FYM) and wheat straw (WS) were added in soil 15 and 30 days before rice transplanting, respectively. Rice (Pusa-44) seedlings (30 days old) were transplanted in first week of July at 20 cm × 15 cm spacing. One third of N and full doses of other macro and micro nutrients were applied at the time of sowing (in wheat) / transplanting (in rice) according to the treatment specifications. Remaining N was applied in two equal splits after 3 and 6 weeks of sowing (in wheat) / transplanting (in rice). Ion exchange resin (IER) membranes (cation, anion) were used as plant root simulators. The membranes are implanted in soil for 10-15 days intervals, through out the season, to determine daily nutrient availability in soil solution. The membranes were regularly installed-removed, and nutrients were extracted with 2M KCL and analyzed for micro nutrients-Zn, Fe, Cu, Mn over the full growing season.

Available Zn: Year to year variability indicated strong (linear) relationship between Zn availability and soil moisture/ rainfall. In rice, LE, GM, WS and RS matched availability with Zn fertilizer addition (R) (Fig.5). In wheat, under moisture stress, LE and FYM outperformed fertilizer added Zn availability. The availability of micro nutrients was lesser in dried periods, and organic management (FYM, LE) outperformed availability through fertilizer (R) during drier periods, especially in wheat crop (Fig. 6).

Available Iron (Fe): In rice, FYM treatment exceeded availability of iron followed by legumes based rotation (LE) (Fig. 7, 8). In wheat, all treatments had almost equal availability during wetter season. Yet, during a relatively drier season organic management had significant more availability of iron as determined using IER technique.

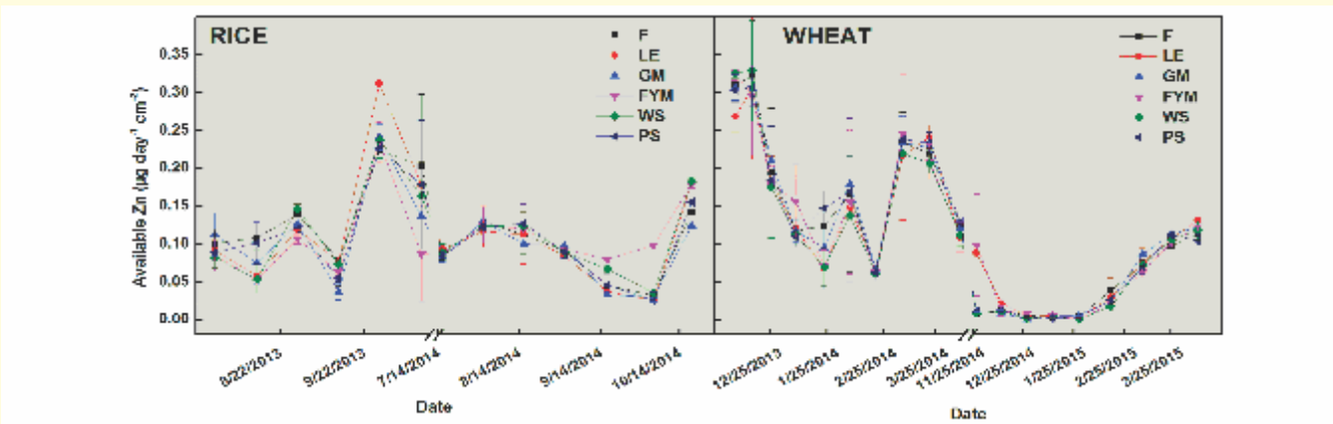


Fig.5: Temporal variations in daily plant available Zn under different integrated nutrient management in rice & wheat crop.

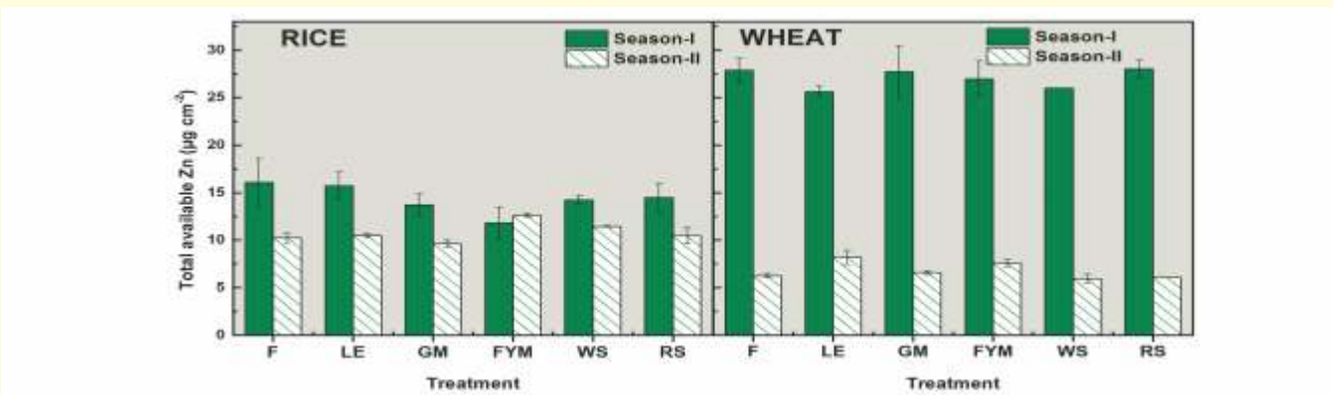


Fig. 6. Effects of different treatments on total plant available Zn during full season in rice and wheat crop.

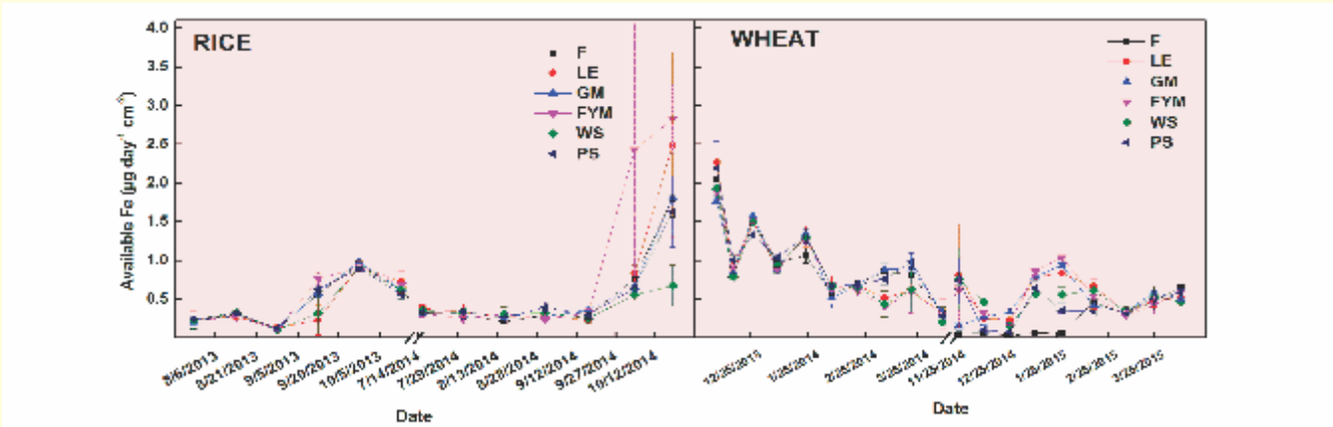


Fig. 7: Temporal variations in daily plant available Fe under different integrated nutrient management in rice and wheat crop

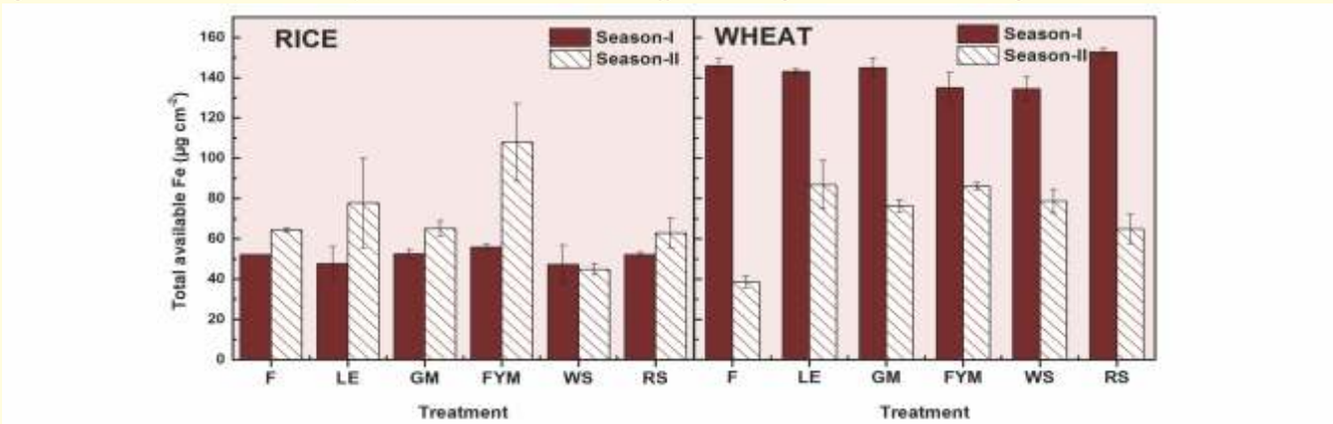


Fig. 8:Effects of different treatments on total plant available Fe during full season in rice and wheat crop

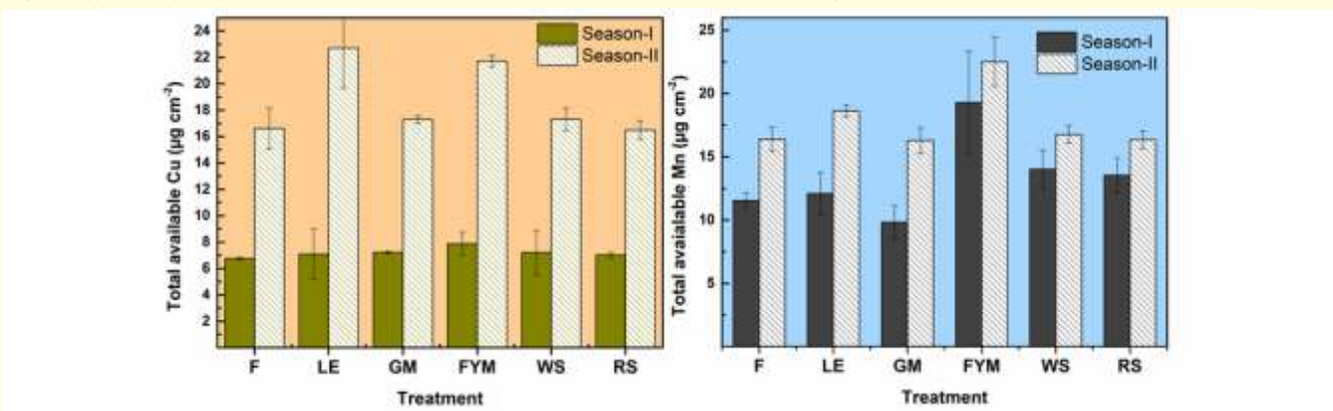


Fig. 9: Effects of different treatments on total plant available Cu and Mn during full season in rice and wheat crop.

Available Copper (Cu) and Available Manganese (Mn): For both Copper and Manganese, best availability scenarios were in the FYM and LE treatments, for both rice and wheat (Fig. 9). In general lower availability was evident in RS and WS treatments especially during early season.

Overall, Farmyard manure (FYM) and legume based (LE) management indicated higher availability of micronutrients (Zn, Fe, Cu, Mn) compared to other management practices. The micronutrients availability was strongly affected by the soil moisture and rainfall characteristics, especially during the wheat season. Dried seasons had better availability in organic residue/ manure added treatments.

Nutrient and residue management of ZT-DSR basmati rice-ZT wheat cropping system under partially reclaimed sodic soils (Parveen Kumar, D. K. Sharma, R. K. Yadav, A. K. Rai and Ashwani Kumar)

Direct seeding of rice has many tangible and non-tangible benefits, especially savings of labour and water and ultimately the low cost of cultivation

than conventional transplanted rice. But there are certain agronomic issues; especially weed, nutrient, residue and water management, that need to be resolved before its promotion as a farmer friendly technology. Considering these facts, a field experiment was conducted with eight nutrient management treatments with rice residue and without residue as control. Results indicated that residual effect of nutrient and residue management treatments of rice was non-significant on yield and yield attributes of wheat (KRL 210). After two years of experimentation, available N, available K and Zn status improved in soil with addition of rice mulch @ 5 t ha^{-1} than without mulch. Direct seeding of salt tolerant Basmati rice cv. CSR 30, was done on 16th June 2016. Physiological traits like photosynthetic rate, chlorophyll fluorescence, stomatal conductance, transpiration rate, relative water content and chlorophyll content (SPAD readings) were maximum with RDF + CSR-BIO with rice residues as mulch @ 5t ha^{-1}. Higher physiological efficiency under rice residue (Fig. 10) also resulted in the maximum grain yield of rice under recommended dose of fertilizers (RDF) + CSR-BIO treatment. However, under no-residue treatment the maximum rice grain yield was recorded with RDF + 20% higher N in top cutting (Table 1). Across residue management treatments, grain yield of zero-till direct seeded (ZT-DS) Basmati rice was the highest in treatment RDF + 20% higher N in top cutting (3.04 t ha^{-1}), at par with RDF+10% higher N (2.88 t ha^{-1}) and RDF + CSR-BIO (2.85 t ha^{-1}). Over nutrient management treatments, rice mulch did not affect yield and yield attributes in ZT-DS basmati rice (Table 5), but helped in bio-fortification of rice grains.

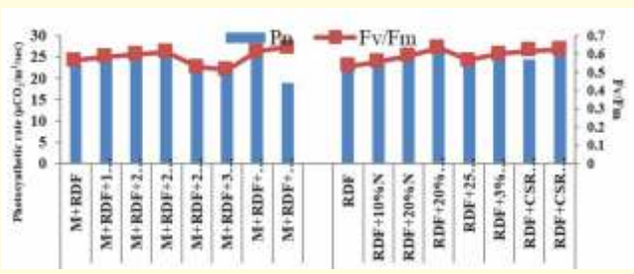


Fig. 10: Effect of nutrient and residue management on physiological efficiency of ZT-DSR(CSR 30

Developing the alternate strategies for reclamation of sodic soils (A. K. Rai, N. Basak, R. L. Meena, R. K. Yadav, P. C. Sharma, Parul Sundha, S. K. Jha, U. R. Khandkar, R. V. Jasra, Kalpana Gopalkrishnan, Prakash Kumar, Kalpesh Sidhpuria, Sachin Rawalekar, J.V. Narasimham, Hemant Katti)

Sodic soils occupy more than 50% (3.77 m ha) of the salt-affected area of India. As per the projections made, area will further increase in the irrigated

Table 5: Interaction of nutrient and residue management on grain yield of ZT-DSR (Basmati CSR 30)

Nutrient management/ Residue management	Grain yield (t ha^{-1}) Rice mulch (5 t ha^{-1})	Control	Mean
RDF*	2.62	2.74	2.68
RDF+10% N	2.86	2.91	2.88
RDF+20% N	2.65	2.64	2.64
RDF+20% N+ Cut	2.79	3.28	3.04
RDF+25 kg $ZnSO_4$	2.46	2.87	2.67
RDF+ 3% $FeSO_4$ (40, 60 d)	2.33	2.88	2.60
RDF+CSR-BIO	2.95	2.74	2.85
RDF+CSR-BIO+ Cut	2.29	3.06	2.68
Mean	2.62	2.89	-
LSD 0.05	NM=0.28;	RM=NS;	NM×RM=0.39

T1: *RDF (60 kg N+30 kg P2O5+30 kg K2O+25 kg $ZnSO_4$ ha^{-1}) + 5q ha^{-1} FYM (30 d); T2: RDF+10% higher N; T3: RDF+20% higher N: T4: RDF+20% higher N with top cutting; T5: RDF+25 kg ha^{-1} $ZnSO_4$; T6: RDF+foliar spray of $FeSO_4$ @ 3% (40 and 60 DAS); T7: RDF + CSR-BIO (Seed treatment with 3% liquid formulation + soil application @ 25 kg ha^{-1} with FYM @ 5 q ha^{-1} at 30 DAS); T8: RDF + CSR-BIO with top cutting

Table 6: Ranges of soil pH and EC in the samples collected from different locations

S. No.	State*	pH_2	EC_2 (dS m^{-1})
1	Haryana (15)	9.20-10.5	0.60-2.10
2	Punjab (5)	8.63-09.6	1.24-2.42
4	Rajasthan (10)	8.60-10.0	0.60-2.50
5	Uttar Pradesh (46)	9.40-10.4	0.60-2.70

*figures in parenthesis are no of samples collected.

commands of the country by 2030. Around 1.95 M ha sodic lands have been successfully reclaimed using the gypsum-based package in Haryana, Punjab, Uttar Pradesh and other parts of the country. Recently, interest in using elemental sulphur (S) for reclaiming the calcareous sodic soils has increased. However, the characteristics of the fine S (flower) make it unacceptable for reclamation due to dustiness and fire hazards, and oxidation rate of prilled sulphur has been reported to be slow limiting its use as a reclaimant for sodic soils. Apart from the particle size, S oxidation being biological in nature depends upon the soil physico-chemical properties and soil biological activity specially S oxidizing microorganisms. A memorandum of understanding has been signed between ICAR-CSSRI and Reliance Industries Limited (RIL) for improving the efficacy of the elemental S in sodic soil reclamation. Soil samples from different sodicity affected areas of Punjab, Haryana, Rajasthan and Uttar Pradesh states were collected for laboratory analysis (Table 6).

Improving productivity of salt-affected soils using biodegradable municipal solid waste and gypsum enriched composts in a mustard - pearl millet cropping system (M. D. Meena, Parvender Sheoran, P. K. Joshi and B. Narjary**)**

Recently municipal solid waste (MSW) is getting importance as an organic amendment for improving the physico-chemical properties of the salt affected soils. Considering the fact that landfilling with MSW creates environmental problems, composting of MSW is increasingly being considered as an important recycling strategy for the safe and sustainable managemenmt of MSW. Efficiency of different organic amendments in improving the biological and chemical properties of a salt affected soil was evaluated. A field experiment on mustard-pearl millet cropping system, started in November 2012, was continued during the year. Observations revealed that integrated use of organic amendments *viz*., municipal solid waste compost (MSWC), rice straw compost (RSC) and gypsum enriched compost (GEC) along with 25% recommended dose of fertilizers (RDF) resulted in the significant increase (mean of 3 years) in microbial biomass carbon (MBC) than use of organic amendments and mineral fertilizers alone. Application of MSWC @ 16 t ha^{-1} led to 52% higher MBC as compared to 100% RDF (Fig. 11). MSWC performed slightly better than both RSC and GEC with regard to MBC. MBC was more influenced in organically treated soils than those receiving mineral fertilizers. Combined use of organic amendments (MSWC, RSC and GEC) and 25% RDF resulted in 32% higher MBC than solitary use of 100% RDF. Three year mean electrical conductivity (EC) decreased in all treatments compared to control but the rate of decrease was higher in organically treated soil than 100% RDF. Soil EC decreased to 3.6 and 4.1 dS m^{-1} with MSWC @ 16 t ha^{-1} and RSC @ 14 t ha^{-1}, respectively, relative to the control (4.8 dS m^{-1}). However, the highest reduction in mean salt concentration was observed with combined use of organic amendments along with 25% RDF than other treatments. Treatment

Marwar , Pali Rajasthan
pH_2 10.0 EC_2 0.7 dS m^{-1}

Swarasati forest, Haryana
pH_2 9.9-10.2 EC_2 0.4-0. 7 dS m^{-1}

Ahamedpur, Kaithal, Haryana
pH_2 9.66 EC_2 1.28 dS m^{-1}

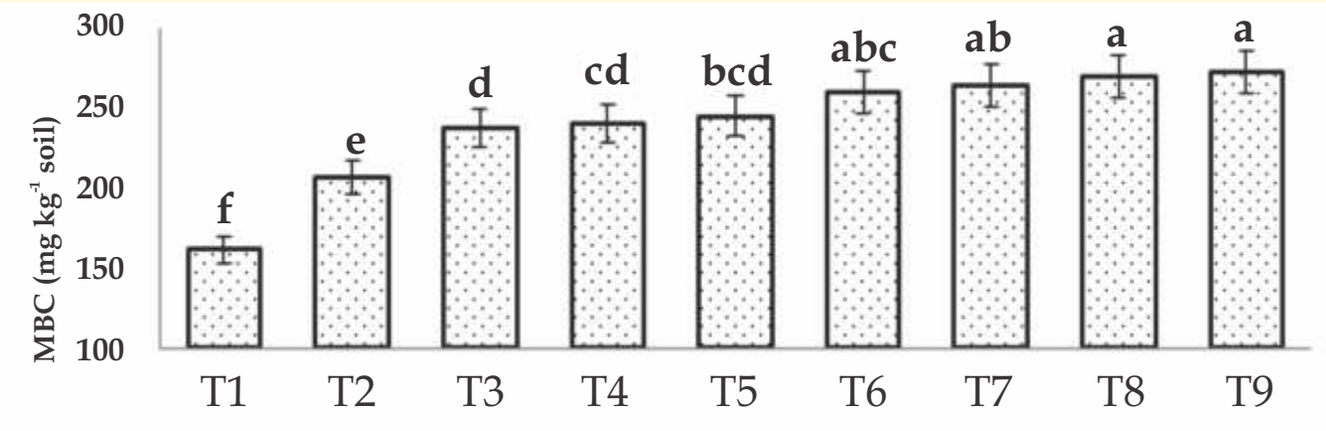


Fig.11: Effect of municipal solid waste compost vis-à-vis gypsum enriched compost and chemical fertilizers on three mean microbial biomass carbon (MBC) under mustard pearl millet cropping system

*(T1: Control, T2: Recommended dose of NPK fertilizers (100% RDF),T3: Rice straw compost @ 14 t ha^{-1} ,T4: Gypsum enriched compost @ 14 t ha^{-1} ,T5: Municipal solid waste compost @ 16 t ha^{-1} , T6: 50% RDF + Rice straw compost @ 7 t ha^{-1} ,T7: 50% RDF + Gypsum enriched compost @ 7 t ha^{-1},T8: 50% RDF + Municipal solid waste compost @ 8 t ha^{-1} ,T9: 25% RDF + RSC@ 3.5 + GEC @ 3.5 + MSWC @ 4 t ha^{-1} *For each parameter, different letters within the same column indicate that treatment means are significantly different at P<0.05 according to Duncan's Multiple Range Test for separation of means.)*

receiving organic amendments along with 25% RDF had significantly lower EC value than alone use of organic amendments except MSWC although, it was statistically similar with combined use of organic amendments plus 50% RDF.

Farmer participatory enterprise mix diversification on reclaimed sodic land (Gajender, R. Raju, A.K. Rai, Madhu Choudhary, Rajkumar, K.S. Kadian, R.K. Yadav and D.K. Sharma)

Integration of various farm enterprises in the form of diversified farming system may offer

Table 7: Income generated from multienterprise agriculture model during the year 2016

Sr. No.	Components	Area (ha)	Gross Income (Rs.)	Total Cost (Rs.)	Net Income (Rs.)	B:C ratio
1	Rice-Wheat-Moong	0.4	74875	41750	33125	1.79
2	Rice - Wheat	0.2	36675	22825	13850	1.61
3	Maize-Wheat-Moong	0.4	66150	34869	31281	1.90
4	Horticulture	0.2	54850	9590	45260	5.72
5	Vegetables	0.2	27170	24700	2470	1.10
6	Fodder	0.4	45200	28216	16984	1.60
	Sub Total-1		304920	161950	142970	1.88
7	Subsidiary Components	0.2				
	Milk, Compost, Biogas		93931	50820	43111	1.85
	Fish Production		0	0	0	
	Fruits/Veg. (Pond Area)		18430	9540	8890	1.93
	Poultry		8500	3050	5450	2.79
	Sub Total-2		120861	63410	57451	1.91
	Total	2	425781	225360	200421	1.89

sustainable solutions to the problems of present day agriculture especially for the smallholder farmers in the region. To improve the agricultural productivity and profitability per unit area, the studies on enterprise mix diversification were continued during 2016 at ICAR-Central Soil Salinity Research Institute Karnal, India on a reclaimed sodic land. The total gross income generated from 2 ha area was Rs. 425781 and net income was Rs. 200421 (Table 7). In grain production system, the highest net income of Rs. 33125 was recorded in rice-wheat-moong production system from 0.4 haarea with a B: C ratio of 1.79 followed by maize-wheat-moong (Rs. 31281) with a B: C ratio of 1.90. Whereas, the net return from 0.4 ha fodder production system was Rs. 16984 with a B: C ratio of 1.60. The net return from 0.2 ha horticulture production system was Rs. 45260 with a B: C ratio of 5.72. Among the subsidiary components, dairy generated a net income of Rs. 43111 with B: C ratio of 1.85. A net income of Rs. 8890 with B: C ratio of 1.93 was obtained from vegetables grown on pond dykes. Since fish pond was under major re-construction, no income was obtained from fish production.

Soil organic carbon (OC) in upper soil layers (0-15 cm) in maize-wheat-moong, fodder and horticulture components were 0.36, 0.42 and 0.77%, respectively. The higher OC in these systems may be due to higher biomass addition to the soil. Available nitrogen and phosphorous varied from 175.6 to 288.5 kg ha^{-1} and 19.81 to 37.83 kg ha^{-1}, respectively in various components (Table 8). The lower N in horticulture component was due to lesser application of chemical fertilizers in this component. The available K ranged between 201.8 to 303.7 kg ha^{-1} in various components. The diversified farming system can be an efficient and remunerative alternative to rice-wheat cropping system for small holders of salt affected areas in IGP.

Table 8: Soil fertility in various production systems of Multi-enterprise agriculture

Components/ Soil depth	OC(%)		N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Rice- Wheat- Moong	0.13	0.15	225.7	219.5	29.56	27.72	225.7	232.9
Maize-Wheat-Moong	0.36	0.35	238.3	224.1	26.45	13.57	208.2	217.7
Rice -Wheat	0.29	0.24	178.2	190.5	31.47	23.62	201.8	220.7
Fodder	0.42	0.35	288.5	251.1	28.37	17.45	227.2	262.9
Vegetable	0.36	0.25	213.2	200.7	19.81	12.61	257.2	280.0
Horticulture	0.77	0.38	244.6	206.9	36.62	37.91	288.8	377.8
Pond	0.37	0.31	175.6	200.7	37.83	21.99	303.7	320.6

MANAGEMENT OF WATERLOGGED/SALINE SOILS

Performance evaluation of subsurface drainage systems in Haryana and to implement interventions for improving operational performance and impact (D. S. Bundela, Bhaskar Narjary, Aslam Pathan, R. Raju, Parvender Sheoran, R. K. Singh, S.K. Kamra and D.K. Sharma)

Out of seven SSD projects, three sites namely, Jagsi (Sonipat), Siwana Mal (Jind) and Mokhra Kheri (Rohtak) were intensively studied for the performance evaluation and suitable interventions for improving the impact of technology. Jagsi site [430 ha area with 9 drainage blocks (S-25 to 33)], Siwana Mal site [295 ha area with 7 drainage blocks (JD-1 to 7)] and Mokhra Kheri site [520 ha area with 10 drainage blocks (RK-1 to 10)] implemented in May 2009, June 2012 and June 2012, respectively, were monitored for the reduction/build-up of soil salinity and waterlogging status during pre and post-project periods using Landsat OLI and ETM data. A Landsat imagery of 12th February, 2007 was processed using ERDAS Imagine version 10 software to assess the pre-project waterlogged saline affected area and it was found that 63-80% area in different drainage blocks was affected by waterlogging and salinity (water table < 1.5 m, soil salinity >8 dS m^{-1} and groundwater salinity > 2 dS m^{-1}). During post-project period, large patches of soil salinity at Jagsi site shrunk by 46% on Landsat imagery of 4th April 2011 and eventually disappeared from the Landsat data (28th May 2014 and 22nd February 2016). This is attributed to efforts of farmers for the timely and regular pumping of sump well during the monsoon season for effective salt leaching/flushing from the affected area. The pumped outlets were also modified to pump-cum-gravity outlets (Fig. 12) which were operated as pumped outlets during the monsoon season when the water level in open drains was high and as gravity outlet during non-monsoon season when the water level in open drains was low. The drainage water was re-used for irrigation of both rice and wheat crops in the project area. The yields of rice and wheat obtained from Jagsi site were at par with that of rice and wheat from normal soils in Haryana.

At Siwana Mal and Mokhra Kheri sites, large patches of soil salinity (32%) could be seen from the Landsat data during post-project period due to non-distribution of diesel pump sets and the sporadic response of farmers for pumping operation. Significant improvements observed in seven blocks (JD-1, 2, 5 and 6, and RK-8, 9 and 10) were due to farmers' efforts for the timely pumping. At Siwanamal site, notable increase in crop yields (35-110 % in rice and 25- 120% in wheat) in the post-project period was observed in the four selected blocks over pre-project period. The area under moderate and high salinity (ECe >8 ds m^{-1}) reduced from 56.4% in June 2012 to 28.3% in June 2016 whereas the area under slight salinity ECe (4-8 dS m^{-1}) increased from 6.6% in 2012 to 20.4% in 2016 at Siwana Mal site. Seven solar pump sets at Siwanamal site are to be shortly installed. At Mokhra Kheri site, significant increase in crop yields (35- 105 % in rice and 40- 110% in wheat) in the post-project period was observed in the three selected blocks over the pre-project period.

Fig. 12: (a) Modified pumped cum gravity outlet and (b) re-use of drainage water for irrigation in SSD site at Jagsi (Sonipat)

ICAR Extramural Project entitled 'Spatio-temporal monitoring of secondary salinization in the Indira Gandhi Canal Command using geoinformatics (D.S. Bundela, Bhaskar Narjary, R. L. Meena, A. K. Mandal, Madhurama Sethi and D. K. Sharma)

In order to assess the extent of secondary salinization in the Indira Gandhi Canal Command (IGNP), a spatial geodatabase of the IGNP Command was generated using ArcGIS version 10 from digitization of 1:50,000 OSM topographic maps, 1:500,000 soil map and 1:50,000 canal network maps and the attributes were tagged to GIS features. This database was updated with Landsat and Resourcesat data and was used in delineating various canal commands with their bio-physical conditions responsible for secondary salinization in the stage-I and II of IGNP command (Fig. 13a). Further more, analysis of the pre-monsoon water table data from 99 observation points in the IGNP stage-I area from 2005 to 2016 revealed that the water table was within 2 m (critical waterlogging) at three locations (Masitawali, Chohlinyawali, and Gandheli) only in 2016 (Fig. 13b).

Multi-temporal Landsat OLI and ETM data of four different years (21 February 1999, 19 February 2010, 19 February 2011 and 4 February 2016) were processed using the image enhancement models such as NDSI, NDWI, and NDVI and Gaussian algorithm to identify and assess the hot spots of soil salinization in the stages I and II. Three major hot spots in the stage-I and II areas were identified. The hot spots in the stage-I were located in the commands of Suratgarh branch, Naurangdesar distributary and Rawatsar branch. Soil samples from the hot spots in the stage-I were collected and their physico-chemical properties were input to the geodatabase. The area under waterlogging in the stage-I was monitored from 1999 to 2016 which decreased by 3.2 times (Fig. 14). The area under soil salinization also decreased by 43% from 2011 to 2016. These first estimates were verified through ground truth survey for the accuracy assessment.

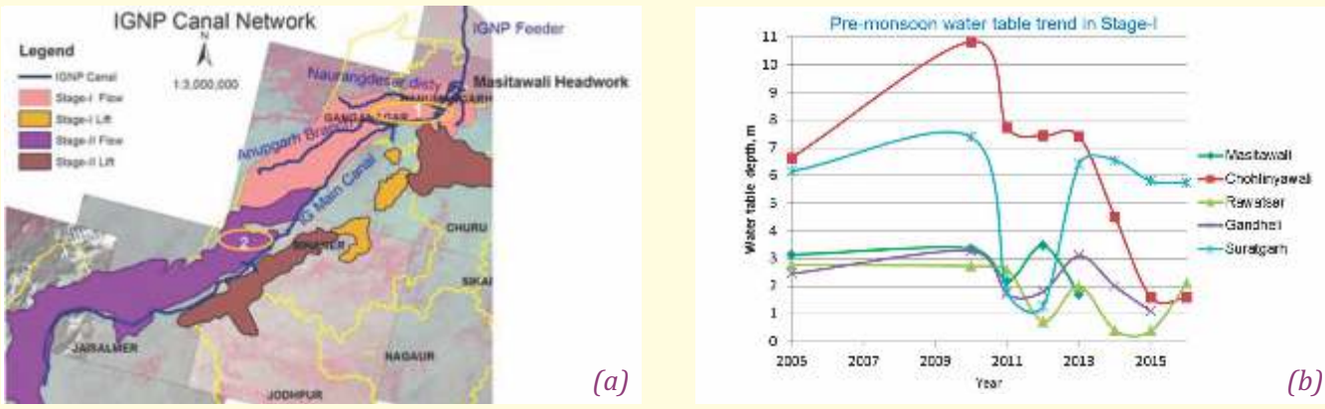


Fig. 13. Database of IGNP canal commands in western Rajasthan (a) and water table trend in stage-I from 2005 to 2016 (b)

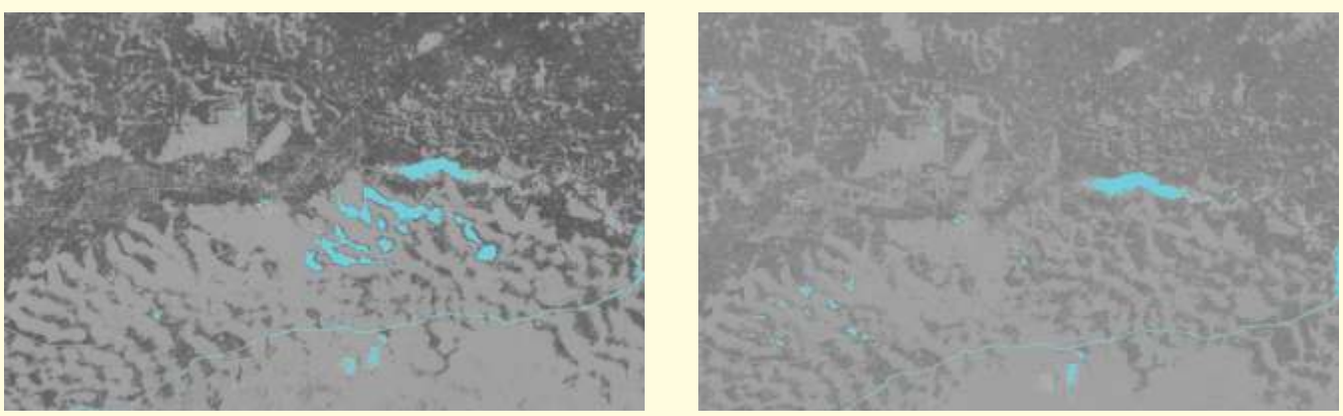


Fig. 14. Spatio-temporal change in waterlogged area from 1999 to 2016 in the IGNP Stage-I

HOPP Project on Technical guidance on new site identification and design of SSD system and monitoring and evaluation of newly implemented SSD projects under RKVY in Haryana (D. S. Bundela, Satyendra Kumar, Aslam L Pathan and P. C. Sharma)

A new Memorandum of Understanding (MOU) between ICAR-CSSRI and Haryana Operational Pilot Project (HOPP), Department of Agriculture and Farmers Welfare (DoAFW), Govt. of Haryana was signed in March 2017 for the next five years (2017-2022) for providing technical guidance and monitoring of Sub-Surface Drainage Projects operational in Haryana under Rashtriya Krishi Vikas Yojana as the HOPP projects have been closed since July 2017. The CSSRI team evaluates the detailed design of SSD projects proposed by HOPP team for seven identified sites covering 6,000 ha waterlogged saline area in Haryana (1,300 ha in Sirsa district, 200 ha in Sonipat, 1,200 ha in Jhajjar, 600 ha in Fatehabad, 1,500 ha in Rohtak, 100 ha in Faridabad and 1,100 ha in Bhiwani). These projects will be implemented during the next five years (2017-2022). Corrugated plastic drain pipes and woven and non-woven geotextile filter materials received from HOPP unit, consultancy firm and different drainage industries were tested in the CSSRI Drainage Material Testing Laboratory.

Consultancy on sub surface drainage for heavy soils in Maharashtra, Karnataka, Gujarat, Andhra Pradesh and Telangana (P. C. Sharma, D. S. Bundela and S. K. Kamra)

The consultancy project proposal was revised during 2016-17 to include two more states- Andhra Pradesh and Telangana. The consultancy now includes five states *viz*., Maharashtra, Karnataka, Gujarat, Andhra Pradesh and Telangana. A significant work on implementation of SSD projects for reclamation of waterlogged saline heavy soils in these five states has been executed by our consultancy partner, M/s Rex Polyextrusion Pvt Ltd, Sangli. Technical backstopping on SSD technology to the consultancy firm was provided by the institute team during 2016-17. Further, a few pilot scale SSD studies in Purna river valley of Maharashtra were proposed to assess the technical and socio-economic feasibility of SSD in Akola, Amravati and Buldhana districts. Technical guidance on SSD projects in Purna river valley was provided to the consultancy partner by the institute team. A visit to western Maharashtra is planned to interact with state government departments/agencies for promotion of SSD technology and to sort out cost norms and drainage guideline issues for the saline Vertisols.

Groundwater resource management to mitigate the impact of climate change in Punjab and Haryana (Satyendra Kumar, S. K. Kamra, Bhaskar Narjary and R. K. Yadav)

There is growing evidence that climate is changing. The increase in mean maximum and minimum temperatures has been projected which may influence crop water demand. More intense rains are also expected in the coming future that will affect the aquifer recharge. This study was conducted to assess the possible change in climate of Karnal and its impact on water requirement of the prevailing rice-wheat cropping system and groundwater resources. The derived daily future climatic data were used as input in CROPWAT model to estimate evapotranspiration, effective rainfall and net irrigation of rice and wheat cropping systems under changing climate. To quantify the changes in the future climate of Karnal under different representative concentration pathways (RCPs), change in monthly projected maximum (T_{max}) and minimum (T_{min}) temperatures and precipitation of the mid and end of century as compared to the base period are presented in Fig. 15. The climate data for base period (1981-2010) and future time periods of 2040-2069 (2050s, mid century), 2070-2099 (2080s, end century) were averaged monthly for 30 years. The change in mean annual temperature (T_{max}, T_{min}) and precipitation of Karnal are projected to be 1.8-2.9 ^{0}C, 1.9-3.2 ^{0}C and 85 -117 mm respectively, in the mid and end century under different RCPs. However, the maximum changes in the monthly maximum and minimum temperature were found during the period of January to May. Similarly, projected changes in the mean annual temperature (T_{max}, T_{min}) and precipitation of Hisar are 1.8-4.9 ^{0}C, 1.9-5.4 ^{0}C and 39-56 mm, respectively, in mid and end century under different RCPs.

To assess the impact of changing climate on crop water demand, projected daily T_{max}, T_{min} and

precipitation of RCP 4.5 were used as input data in CROPWAT computer program to compute the future crop water requirement. The model was run with different dates of sowing of wheat to find out the appropriate time for sowing of wheat to reduce crop water demand and groundwater pumping for irrigation. The estimated crop evapotranspiration (ET_c), effective rainfall (ER) and irrigation requirement (IR) of wheat for the base period, 2020, 2050 and 2080 (Table 9) indicated that ET_c will increase slightly in the coming future for the date of sowing of wheat of 5th November. However, IR would increase by 90 mm in 2050. In 2080, IR is expected to decrease as compared to 2020. It also emerged that date of sowing has significant impact on crop water requirement and irrigation demand. Delay in sowing of wheat from 5th November towards 5th December will result in increased irrigation demand for wheat production.

The scenario for studying the impact of rice-wheat cropping system on groundwater resources under changing climate was generated. The whole cultivable and non-cultivable land use of Karnal was considered one hydrological unit for this purpose. The different land uses such as cropped land, forest land, residential area, water bodies including canal network and other land (barren, pasture and waste land) were considered to represent whole district for calculation of different water balance components. The recharge component (return flow) and draft (groundwater pumping) were estimated separately for different land uses with the help of different models/ relationships and GEC 1997 methodology of estimating groundwater resources. The fluctuation in ground water table was calculated

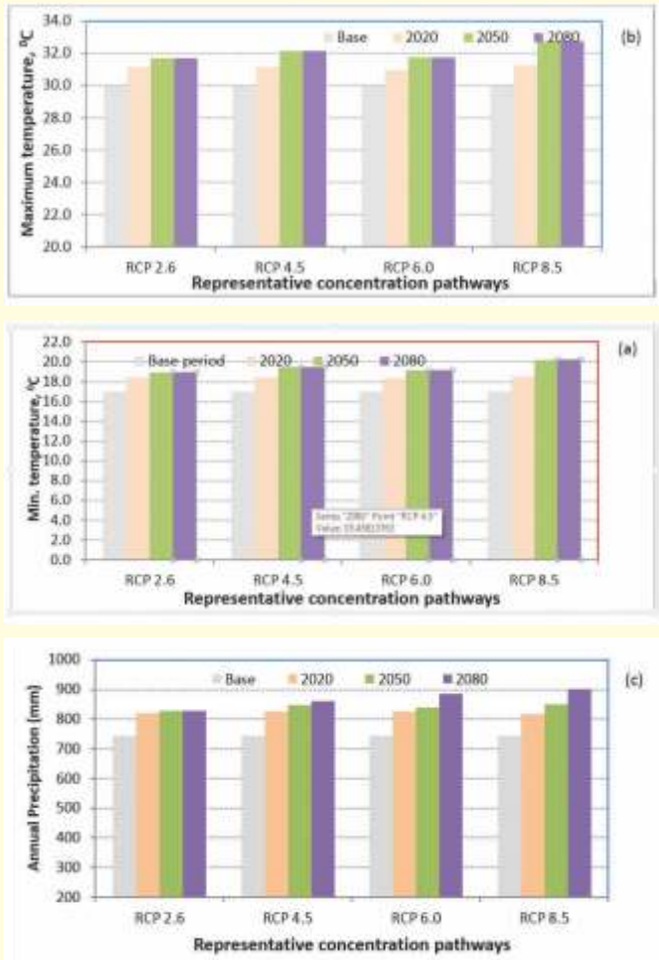


Fig. 15. Mean annual a) minimum temperature, b) maximum temperature and c) precipitation in base period (1980-2010), 2020, 2050 and 2080

by considering specific yield of aquifer as 0.12 and total study area as 0.246 M ha. The annual decline in water table was estimated by using deficit in groundwater recharge over draft and specific yield. Since prevailing date of transplanting of rice and sowing of wheat is 15 June and 15 November, respectively, in this region, these dates were taken

Table 9: Crop evapotranspiration (ET_c), effective rainfall (ER) and irrigation requirement (IR) of wheat as affected by date of transplanting under changing climatic scenario (RCP 4.5)

Period	Date of sowing											
	5 November			15 November			25 November			5 December		
	ET_c (mm)	ER (mm)	IR (mm)	ETc (mm)	ER (mm)	IR (mm)	ETc (mm)	ER (mm)	IR (mm)	ETc (mm)	ER (mm)	IR (mm)
Base period	402.4	116.4	278.6	433.5	118.9	371.4	471.3	123.1	371.4	514.3	126.6	464.3
2020	419.2	120.9	371.4	451.5	120.9	371.4	490.5	130.2	371.4	534.5	136.9	464.6
2050	433.9	119.5	371.4	467.0	121.4	371.4	506.8	126.9	464.3	551.7	133.9	464.3
2080	432.4	120.2	285.7	465.4	124.1	342.9	505.2	129.5	400.0	550.2	136.1	457.1

for estimation of return flow and ground water draft from cultivated land. The observed average groundwater table depth (15.47 m) of 2010 was taken as the base data for projecting water table depth for future years taking annual groundwater fluctuation. The observed groundwater table depth was taken from the Year Book of Central Ground Water Board. From the results, it was estimated that groundwater table will reach to 37, 52 and 73 m by the end of early century (2001-2039), the end of mid-century (2040-2069) and the end of end-century (2070-2099), respectively.

Efficient groundwater management for enhancing adaptive capacity to climate change in sugarcane based farming system in Muzaffarnagar district (Satyendra Kumar, Aslam Latif Pathan, S.K. Kamra and D.K. Sharma)

One of the objectives of this research project was to evaluate the impact of technological interventions on a pilot basis for sustainable use of groundwater for enhancing adaptive capacity to climate change. Of different interventions proposed, design and construction of groundwater recharging techniques have been entrusted to CSSRI. A recharge cavity was constructed by drilling a bore hole until a sandy layer (thickness > 10 m) was found below a clay layer. Blind PVC pipe of 22.5 cm diameter (9") with 10 kg/ m^2 pressure was inserted into the clay layer and sand was pumped out until a stable semi-spherical cavity developed below the clay layer. During the reporting period, two recharge structures were installed to meet out the specific objective of this project (Table 10). The cavity at 58 m (190 ft) was formed at Kutba and at 44 m (145 ft) at Nirmana village. In view of favourable sand strata in both the villages, additional strainer filter was provided above the cavity to further enhance the recharge rate. With this modification, these recharge structures are working as recharge cavity-cum-filter instead of only as recharge cavity. The specifications and design of a typical groundwater recharge cavity installed under this project is presented in Fig. 16.

The recharge structure was installed near the corner of the pond at Kutba village where pond receives water from the canal passing nearby. At Nirmana village, structure was constructed near the pond. At both the places, water comes first in the pond, which facilitates sedimentation and then enters into the recharge chamber. The analyzed

Table 10: Locations of installed recharge structures under the project in Muzaffarnagar

S. No.	Village	Block	Longitude & latitude	Recharge structure
1	Nirmana	Baghra	29°23′07.6′′N 077°36′58.7′′E	Village pond and recharge cavity
2	Kutba	Baghra	29.39984° N 077.54208° E	Canal distributary, village pond and recharge cavity

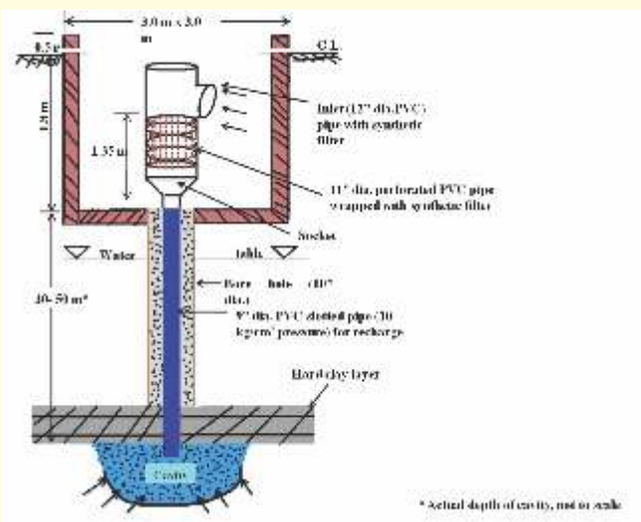


Fig. 16: Design specifications of a recharge cavity installed at Muzaffarnagar study site

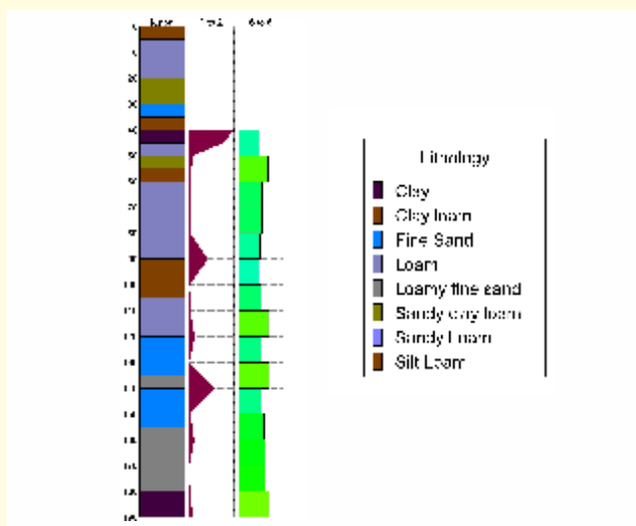


Fig. 17. Lithological details of drilled soil at recharge cavity site at Kutba

Table 11: Hydro-chemical analysis of groundwater collected from different depth at Kutba project site

Depth of log (feet)	$Ca^{+}Mg$ (meq l^{-1})	CO_3 (meq l^{-1})	HCO_3 (meq l^{-1})	Na (meq l^{-1})	K (meq l^{-1})	RSC (meq l^{-1})	SAR
40	1.5	0.46	1.84	0.76	0.15	0.8	0.88
45	3.5	0.46	2.07	0.79	0.11	0.0	0.60
50	40	0.92	4.60	1.52	0.16	0.0	0.34
60	3.5	0.23	2.53	0.69	0.14	0.0	0.52
70	2.5	0.46	2.30	0.85	0.14	0.3	0.76
80	3.5	0.46	2.30	1.65	0.15	0.0	1.25
90	2.0	0.23	2.30	1.87	0.18	0.5	1.87
100	4.5	0.46	1.15	1.45	0.15	0.0	0.97
110	2.0	0.46	1.38	1.03	0.17	0.0	1.03
120	2.0	0.46	1.84	1.92	0.14	0.3	1.92
130	3.5	0.92	2.76	2.44	0.13	0.2	1.84
140	3.5	0.92	3.22	1.48	0.13	0.6	1.12
150	3.0	0.92	1.38	1.24	0.12	0.0	1.01
160	2.0	0.23	2.30	1.38	0.12	0.5	1.32
170	2.1	0.92	1.38	1.28	0.11	0.2	1.25
180	3.0	0.46	1.84	2.72	0.15	0.0	2.22
185	3.5	0.46	0.92	2.85	0.13	0.0	2.16
During cavity development	2.5	0.46	2.53	2.62	0.15	0.5	2.34
	Nirmana site						
5	2.50	0.92	2.30	2.81	0.96	0.72	2.52
10	2.50	0.92	1.61	2.40	0.55	0.03	2.14
15	2.25	0.92	1.61	2.13	0.53	0.28	2.01
20	1.75	4.60	1.38	2.50	0.53	4.23	2.67
25	2.25	0.92	1.61	1.66	0.17	0.28	1.56
30	2.00	0.92	1.38	2.22	0.28	0.3	2.22
40	1.75	0.92	1.61	2.36	0.71	0.78	2.52
45	1.75	4.60	1.61	3.01	0.45	4.46	3.22
50	1.75	0.92	1.38	2.46	0.45	0.55	2.63
60	1.75	0.92	1.38	3.01	0.43	0.55	3.21
65	2.00	0.92	1.38	3.03	0.33	0.3	3.03
70	2.50	0.92	1.38	3.01	0.35	0	2.69
75	2.00	3.68	1.84	3.62	0.44	3.52	3.61
80	2.00	0.92	1.84	3.55	0.38	0.76	3.55
85	2.50	0.92	2.30	3.55	0.45	0.72	3.17
90	2.50	0.92	1.84	3.75	0.38	0.26	3.35
95	3.00	0.92	2.30	3.88	0.56	0.22	3.17
100	2.25	0.92	2.07	3.51	0.46	0.74	3.30
105	3.00	0.92	1.84	3.37	0.29	-0.24	2.76
110	2.25	0.92	1.61	3.14	0.26	0.28	2.96
115	2.00	0.92	1.61	2.60	0.26	0.53	2.66
120	2.75	0.92	1.84	2.50	0.24	0.01	2.13
During cavity	2.25	0.92	1.84	1.49	0.21	0.51	1.40

(a) *(b)*

Fig. 18:Installation of recharge structures at Kutba site (a) and Nirmana site (b)

lithology (well log) of recharge structure at Kutba village is presented in Fig. 17. Based on lithology, the design of recharge structure was formulated as a combination of a recharge cavity below 3 m (10 feet) thick clay layer between 180-190 feet depth at Kutba and 135-145 feet depth at Nirmana sites and a 3 m (10 feet) strainer well above the clay layer. It was seen that a 22.5 cm diameter PVC pipe was fitted in 30.4 cm diameter drilled hole up to 180 feet depth at a location near a pond that is linked with a distributary canal passing nearby for the disposal of excess canal water, whenever possible and particularly during rainy season into the village pond at Kutba *site* (Fig. 18 a). At 180 feet, the PVC pipe was inserted through a 10 feet (3 m) thick clay layer below which a semi-spherical cavity well of 5-6 m diameter was developed in an extensive coarse sand aquifer by standard methodology of continuously pumping out sand mixed water for 10-12 hours. In the medium sandy zone, a perforated section of 9 inch diameter PVC pipe, covered with conventional synthetic filter, was connected with upper blank pipe to enhance recharge from this section in addition to cavity. Recharge cavity at *Nirmana* site (Fig. 18b) was formed at 145 feet depth with similar design and using the same methodology as describe above.

A 3 m x 3 m x 3 m size brick masonry recharge chamber was constructed around the PVC pipe at soil surface to receive water from pond and to transfer it after filtration into the recharge structure. The non-perforated 9 inch diameter pipe was connected at 1 m height from the base of the chamber with a 2 m long and 12 inch diameter perforated and synthetic filter covered PVC pipe to recharge water being received in the masonry chamber into the recharge structure. The lower 1m pipe has not been perforated to provide space for settlement of sediments in the inflowing recharge water at the base of the chamber. The same design of filtering unit was adopted for both the locations. A recharge cavity was preferred at these two sites since it can also be used for occasional pumping with a 7.5- 10 HP submersible motor for cleaning and de-clogging sediments deposited over the sand surface of the cavity.

Water samples were collected from the ponds whose water is to be utilized for recharge and other water bodies at the locations and also during drilling of recharge structures at Kutba and Nirmana. The water and soil samples collected during drilling of recharge structures were chemically analyzed. A few water samples were also tested for micro-biological parameters. Some results of chemical analysis of water samples collected from ponds at 4 locations and collected during drilling are presented in Table 11. These data suggested that water collected during drilling coinciding with different depths did not have RSC problem. Similarly, pH and EC values are also within the permissible limits in almost all layers. It shows that geological strata of the sites are of good quality.

Hydro-physical evaluation of a rainwater harvesting system under saline soil and groundwater environment (Bhaskar Narjary, Satyendra Kumar, M.D. Meena, S.K. Kamra and D.K. Sharma)

Waterlogging and soil salinity are serious environmental problems adversely affecting the crop yield, soil health and socio-economic conditions of the farming community. It is important to characterize and map within-field variability in soil salinity in space and time. Monitoring the water table fluctuation and water quality both spatially and temporarily is also important to assess the adverse effect of waterlogging and salinity on crop production and environmental degradation. In order to study spatio-temporal variation in groundwater depth and salinity, a study was carried out at Nain Experimental Farm, Panipat situated in a depressional area having shallow and saline ground water conditions. A total of 27 observation wells were installed in such a way that few among them are near to the working tubewell for observing ground water fluctuation due to

Fig. 19c. Spatial map of water table depth in pre monsoon season in 2015 at Nain farm

Fig. 19d. Spatial map of water table depth in post monsoon season in 2015 at Nain farm

Fig. 20a. Spatial map of ground water salinity in pre monsoon season in 2013 at Nain farm

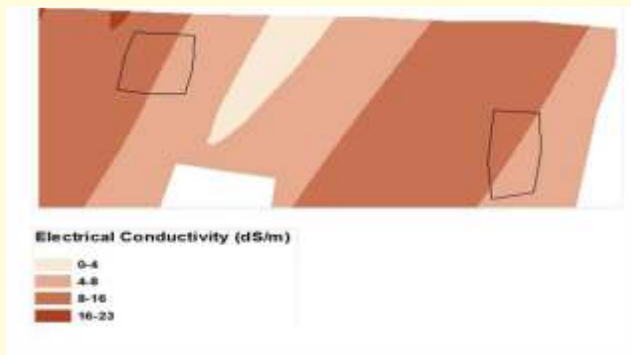


Fig. 20b. Spatial map of ground water salinity in post monsoon season in 2013 at Nain farm

Fig. 20c. Spatial map of ground water salinity in pre monsoon season in 2015 at Nain farm

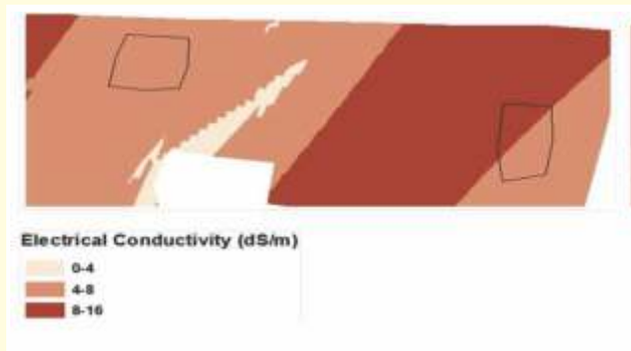


Fig. 20d. Spatial map of ground water salinity in post monsoon season in 2015 at Nain farm

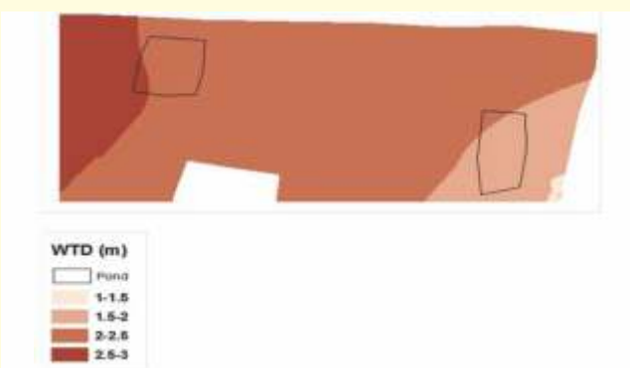


Fig. 19a. Spatial map of water table depth in pre monsoon season in 2013 at Nain farm

Fig. 19b. Spatial map of water table depth in post monsoon season in 2013 at Nain farm

pumping. Eight observation wells were installed near the pond and the remaining observation wells were installed in the area confined between pond and surface drains to observe the impact of natural recharge from water bodies on groundwater table fluctuation. Spatial variability maps of groundwater level in pre-monsoon season indicated 36% increase in area of shallow ground water level (< 2 m BGL) in the year 2015 as compared to the year 2013 (Fig. 19a-d). Observations on groundwater salinity over a period of two years between 2013 and 2015 revealed that area under low groundwater salinity (0-4 dS m^{-1}) increased from 0-17%. Conversely, area under high groundwater salinity (8-16 dS m^{-1}) reduced from 82.8 to 34 % (Fig. 20a-d). Increase in area of shallow ground water level (< 2 m BGL) and low salinity (0-4 dS m^{-1}) in 2015 as compared to 2013 indicated that considerable groundwater recharge took place from fresh groundwater sources. This may be due to runoff of fresh water from nearby open drains into the farm ponds which subsequently percolated and recharged the ground water and diluted its salinity over time.

Cost-effective, rapid, easy and less labor intensive geophysical electromagnetic induction method by using EM-38 instrument was used for characterizing and quantifying the soil salinity of Nain Experimental Farm both spatially and temporarily. Observations on soil salinity over a period of three years from 2013 to 2016 revealed that area under low soil salinity (4-8 dS m^{-1}) increased from 4 to 17%. Conversely, area under very high salinity (>16 dS m^{-1}) reduced from 74 to 30%. The sharp change in salinity within the field may be due to the continuous agricultural management practices within the field where large amounts of rain and fresh drainage water were applied to leach the salts into deeper soil layers

Impact of secondary salinization and other stressors on agricultural systems: constraint analysis in South-Western Punjab (Ranjay K Singh, Anshuman Singh, Satyender Kumar and Nirmalendu Basak)

This project is being implemented in the salinity affected villages of Abohar and Baluana developmental bocks of Fazilka district, Punjab. A total of 25 farmers were sampled of which 21 farmers participated in the focus group discussions (FGD) to complement the data recorded from the personal interviews. In addition, transect walks were also carried out in the study villages with the local farmers to understand the current state of salinization and its adverse impacts on crops and livelihoods. Secondary data were also collected from different sources for comparison with the primary information to reach to valid conclusions. Soil and water samples were also collected from the farmers' fields for laboratory analysis. Again, a total of 11 farmers from the Malout developmental block of Muktsar district were also interviewed to understand the recent trends in the adoption of CSSRI salt tolerant varieties (*e.g.*, wheat cv. KRL 210).

Analysis of stressors in the study area

Ecological stress

Data on soil properties from two depths *i.e.*, 0-15 cm and 15-30 cm (Table 12) indicated saline-sodic nature of the soils irrespective of the land use system. At 0-15 cm depth, the highest pH (9.40 ± 0.41) was recorded in the mustard fields and the lowest (8.51 ± 0.2) in case of Kinnow. Soil pH was marginally higher at 15-30 cm depth in all the crop fields studied.

Basically, there are three predominant production systems in the study area facing different levels of ecological stresses and constraints. The traditional Kinnow system (wheat/barseem crops grown as intercrops during the initial few years) is

Table 12: Soil salinity and organic carbon status in selected crop fields of Abohar developmental block

Crop	pH_2		EC_2 (dS m^{-1})		Organic C (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Rice	8.81 ± 0.10	8.85 ± 0.30	2.25 ± 0.30	0.61 ± 0.10	0.59 ± 0.10	0.39 ± 0.20
Wheat	8.86 ± 0.20	9.27 ± 0.35	1.13 ± 0.27	2.12 ± 0.44	0.49 ± 0.05	0.35 ± 0.03
Mustard	9.40 ± 0.41	8.95 ± 2.58	2.84 ± 0.44	1.59 ± 0.49	0.54 ± 0.09	0.31 ± 0.78
Kinnow	8.51 ± 0.20	9.05 ± 0.40	1.61 ± 0.25	1.25 ± 0.20	0.72 ± 0.15	0.33 ± 0.10

A declining Kinnow orchard in the Alamgarh village of Abohar block, Fazilka

threatened by the rising watertable, salinity and sodicity stresses. It was found that watertable currently lies very close to the surface (0.1-0.53 m) in most of the study area. Owing to permanent water inundation in the root zone, high salinity (EC_2 1.13 -2.84) and sodicity ($pH_2$8.51-9.05) stresses, Kinnow trees have either declined or on the verge of collapse. It has considerably enhanced the vulnerability of the local farmers who previously fetched remunerative returns from Kinnow production. Rice-wheat rotation, another predominant cropping system in the study area, is also exposed to serious waterlogging and salinity risks. Average rice and wheat yields in the study area, 3.8-4.5 t ha^{-1} and 3.5-4.0 t ha^{-1}, respectively, have shown declining trend the last few years. It was noted that climate change, loss of local agro-biodiversity (e.g., landraces in crops such as green gram, black gram, sesame, jowar and red gram) and other anthropogenic factors have compounded the adverse effects of salinity. Another traditional system, namely, cotton-wheat cropping system, also faces high threats due to continuous rise in watertable (0-2 m bgl), alkalinity (pH_2 8.86-9.27) and salinity (EC_2 1.13-2.12).

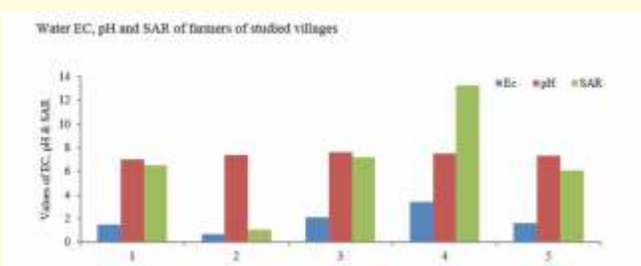


Fig. 21. Water quality parameters

Table 13: Impact of shallow saline watertable on crop productivity

Crops	Watertable depth (range in m)	Yield (t ha^{-1})
Rice	0.46-0.60 2.44-3.05	1.5-2.0 4-4.5.0
Wheat	0.46-0.61 2.44-3.05	2.5-3.0 3.0-3.5
Cotton	0.46-0.60 2.44-3.05	Not grown 0.2-2.5.0 (q ha^{-1})

Soil samples taken from rice, wheat and mustard fields and kinnow orchards indicated the deficiency of available micronutrients such as Zn, Mn and Fe necessitating integrated nutrient management and other agronomic interventions to enhance the availability of these nutrients. The groundwater table depth in the studied villages ranged from 1.0-7.0 feet. Groundwater is marginally to moderately saline (EC_{IW}= 0.7 to 3.43 dS m^{-1}) with SAR ranging from 1.08-13.28 (**Fig. 2b**). Depending on salinity and SAR values, only a few groundwater samples were found to be suitable for irrigation. The water salinity stress with high ground water table has different levels of impact on the productivity of rice, wheat and cotton (Table 13).

Socio-economic and policy related stressors

Results revealed that farmers experienced eight different socio-economic, market and policy stressors which along with soil and water salinity have considerably enhanced the overall livelihood risks of the farmers. Majority (98.0%) of the farmers experienced the problem of unassured procurement of Basmati rice followed by the high fluctuations in the market price of Kinnow fruits (95.0% farmers' response) Growing lack of interest among the rural youth for farming (90.0% response) has significantly enhanced rural-urban migration for gainful jobs. About 80.0% of the farmers reported that MGNREGA and PDS have reduced the availability of the local farm labours often compelling them to hire the labour at higher costs (Table 14).

Adaptations among the farmers

Planned adaptations

Results indicated that farmers facing waterlogging

Table 14: Socio-economic and policy related stressors as perceived by farmers

Stressors	Perception score (%)
Low market prices of Basmati rice in certain years (Rs. 17,500-20,000 ha^{-1}) together with high crop management costs in saline soils	98.0
Yearly fluctuations in the prices of major cash crop Kinnow (e.g., Rs. 5000 t^{-1} in 2014 and Rs. 8500 t^{-1} in 2015)	95.0
Declining interest of youth in farming	90.0
Gradually increasing labour costs, due in part to MGNREGA and PDS policies, putting the farmers at economic risks (currently Rs. 350-400 person-1day^{-1} against Rs. 150 in 2006)	85.0
Poor access to government subsidies ascribed to poor institutional network and lack of knowledge	75.0
Deposition of security money (Rs. 15,000) for free electricity, and high irrigation water charges (Rs. 300 ha^{-1}) enhance the economic vulnerability of small and marginal farmers	62.0
Labour shortages accentuate during drought years as local people migrate to cities for jobs coupled with the reduced availability of migrant labourers from Bihar state	58.0
High cultivation costs (e.g., Rs. 37,500-45,000 ha^{-1} for rice) and high land rental rates (Rs. 70,000-87,500 ha^{-1}) pose increased risks to the small farmers as they are often caught in debt trap	45.0

and salinity risks are being identified by the state government for the installation of sub-surface drainage systems for the land reclamation. About 35-40% farmers now adopt custom hired machines (*e.g.*, laser leveler for land leveling) to save the resources and irrigation water use. All the large scale farmers now use combines for the timely harvesting of crops and thereby minimizing the risks caused by shallow watertable or untimely rains. Only a few (15-20%) of the small and marginal farmers have adopted this practice. Despite resulting in reduced labour availability for large farmers, PDS and MGNREGA policies are important for the food security of small and marginal farmers (100.0%).

Fish culture in Saidawali village by a group of farmers

Autonomous adaptations

About 35% of the studied farmers have recently switched over from Kinnow and cotton-wheat systems to rice-wheat system. A total of 5 farmers in Siadawali village have adapted aquaculture in waterlogged saline lands to strengthen their livelihoods. Changes in the time of sowing (either early or late) depending on the timing of rainfall were also seen as a possible reactive measure among the farmers to tide over the twin problems of waterlogging and salinity (52% response). Adoption of zero tillage in wheat (25-35% farmers) and changes in the rice varieties (Pusa 1121, Pusa 1509 and CSR-30) (>70%) were also being tried to cope up with the salinity and economic stressors. Early harvesting of Kinnow fruits to reduce the post-harvest losses as well as to fetch better prices (15-30% response) and cultivation of white fly tolerant *desi* cotton in place of *Bt* cotton are being increasingly adapted by the small and marginal farmers.

Perceived climate variability and agricultural adaptations by material resource-poor farmers in salt affected agro-ecosystems-implications for food and livelihood security (Ranjay K. Singh, Anshuman Singh, Satyendra Kumar, Parvender Sheoran, K. Thimmappa and Dheeraj Singh)

In the recent past, increased climate variability has enhanced the risks in crop production; especially in rainfed and saline environments. Other

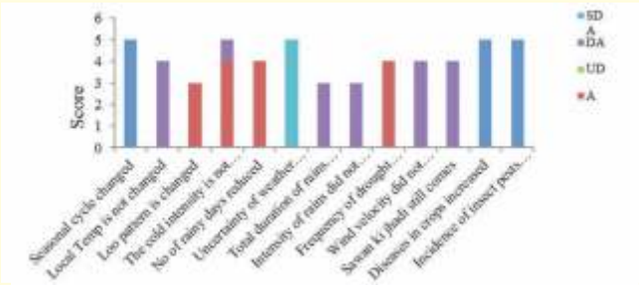


Fig. 22. Farmers percpetion about climate variability

ecological, economic and social stressors often compound such climate change induced risks. This project is being carried out with the small and marginal farmers of representing three contrasting agro-climatic regions, *viz.*, Pali district of Rajasthan (semi-arid to arid climate), Hisar district of Haryana (semi-arid to arid climate) and Jaunpur district of Uttar Pradesh (sub-humid climate) to understand the climate risks and adaptation strategies. A total of of 63 farmers; 23 from Jaunpur, 23 from Hisar and 17 from Pali district were randomly sampled for the study during 2016-17. Data were collected using personal interviews, focus group discussions and transect walk. Soil and water samples were also collected from the crop fields to gain insights into salinity/sodicity status of soil and irrigation water. Socio-economic and policy related variables were also recorded by applying socio-economic scales and measurement tools.

Soil and water salinity

Soil and water analysis data showed that irrigation water salinity (EC_{iw}) ranged from 1.8-17.9 dS m^{-1} while soil salinity (EC_e) ranged from 0.7-4.8 dS m^{-1} in Chidaud and Payal villages of Hisar-1 block of Hisar district. In Bhatol Jatan and Bhatol Rangada villages of Hansi block of Hisar EC_{iw} and EC_e ranged from 3.2-10.9 dS m^{-1} and 2.4-4.5 dS m^{-1}, respectively. In Hemawas, Rampura-1 and Rampura-2 villages of Pali district, EC_{iw} and EC_e ranged from 3.4-13.2 dS m^{-1} and 0.29-3.34 dS m^{-1}, respectively. In Hasanpur and Bibipur villages of Mariahu block of Jaunpur district, soil saturation paste *p*H (pH_s) and salinity (EC_e) varied from 8.7-10.1 and 0.3-1.8 dS m^{-1}, respectively. In Chakwa, Bhakura and Jamuhai villages of Karanjakala block of Jaunpur district, soil pH_s and EC_e ranged from 9.1-9.7 and 0.6-2.9 dS m^{-1}, respectively. Transect walks during the cropping season in Pali and Jaunpur district indicated that farmers obtained very poor crop yields due to the high salinity and sodicity stresses, respectively.

Perception about climate variability and compounding stressors

Farmers of Pali district perceived that climate variability has increased as evident from early withdrawal and delayed onset of monsoon (84% response) as well as increased frequency of droughts and erratic rainfall pattern (91.2%) which adversely affected crops and livelihoods. For other variables of climate variability including change in seasonal cycles, climate induced diseases and insect-pests incidence in crops, cold intensity and change in *Loo* pattern, farmers either 'stongly agreed' or 'agreed'' (Fig. 22).

It was also observed that certain socio-economic changes and anthropogenic factors have compounded the climate variability induced livelihood risks. About 67.5% farmers opined that increasing costs of cultivation posed relatively

Muskmelon crop on conserved soil misture in Hemawas village

Mixing of ponds clay in upper landscape of sandy and sodic soils to enhance soil fertility

View of a farmers' goshthi organized in Chidoud village of Hisar district

more risks to the material resource poor small landholders. Labour shortages arising due to MGNREGA policy and increased migration to cities for the wageful employment have further increased the economic risks for the farmers (71.6% response). About 85.5% farmers' perceived that lack of proper procurement policy for the crop produce, inadequate minimum support prices compared to the cost of cultivation and poor access to appropriate technologies for sustaining poor quality water use in agriculture were also reducing farm profits and posing risks to the livelihoods. About 45.5% of the farmers reported that climate variability has enhanced the risk of crop fauilures caused by the salinity. Salinity problem is further aggravated when polluted water discharged from the local textile industries enters into the open wells and crop fields (88.4% response).

Adaptation strategies

Results indicated that adaptation among the studied farmers of Pali district were mostly of autonomous or reactive in nature led by diversification, intensification, exchange, local innovation and the pooling and rationing of the resources. Farmers have diversified their income portfolio through crop diversification (Fig. 3), integration of dairy animals and migration to cities for the wage employment. Some of the farmers in Rampura-2 and Hemawas villages have adopted cumin and tomato cultivation for the higher income. Similarly, example of crop intensification was observed in Hemawas village where about 52% of the farmers have reduced acreage under bajra, guar and moth crops with corresponding increase in area under wheat and muskmelon crops grown on residual moisture in the local dam catchment area. Such farmers, in addition to extracting irrigation water from greater soil depth, also harvest water from the dam catchment, grow more than one variety in each crop and apply more agrochemicals than before to obtain higher crop yields. It was seen that about 85.7% of the studied farmers tend to strengthen their adaptive capacity by exchanging the resources such as seeds, machines and tractors, labour and irrigation water. Water harvesting during drought years, deploying labour for watchand ward of the crops (muskmelon, tomato and chilli) during night and draining out the excess flood water during heavy rains were seen as the characteristic examples of the pooling of resources (48.5% response). Rationing of resources including water, fodder, seeds and grains and animals was also a major adaptation strategy among 95.8% of the studied farmers. About 62.5% of the farmers have evolved local knowledge to restore the soil fertility (*e.g.*, by applying pond clay in the crop fields), nursery management in muskmelon crop, conservation of soil moisture and water harvesting to sustain their crops. To support the farmers' livelihoods under such adverse conditions, both technological interventions and capacity building interventions were carried out.

Technological interventions

After diagnosing the soil and water salinity and sodicity problems, seeds of crop varieties were provided to the farmers for front line demonstrations (FLDs). A total of 13 FLDs were conducted in Hisar block of Hisar district. These included FLDs on Bajra (cv. HHB-226) which recorded average yield of 2.15 t ha^{-1} under saline irrigation. A total of 13 farmers were provided seeds of guar cv. HG-2-20 giving average yield of 1.4 t ha^{-1} under saline conditions. The farmers of Bhatol Jatan and Bhatol Rangada villages of Hansi block affected by waterlogging and salnity were provided seeds of salt tolerant rice Basmati CSR 30 which recorded an average yield of of 2.43 t ha^{-1}. Even some of the farmers (*e.g.*, Mr. Seva Ram) obtained high yields of 4.3 t ha^{-1} in rice cv. CSR-43 in fields lying barren since the last 6 years. Selected farmers of Jaunpur district who cultivated Basmati rice CSR 30 got low yields than expected primarily

due to heavy damage caused by excess rainfall during the crop maturity stage. Although crop showed very good performance, very heavy rains in September and October months of 2016 caused heavy destruction. Excessive height of CSR-30 plants and inability of farmers to timely prune the excess growth resulted in lodging after the rains. Average CSR 30 yields in the studied villages ranged from 1.3-2.0 t ha^{-1}. Keeping these constraints in view, rice variety for 2017 season has been changed to CSR 43. In Pali district, 35 farmers were provided the seeds of moong cv. IPM-02-3 which produced average yield of 0.7 t ha^{-1} (0.67-1.17 t ha^{-1}), *i.e.*, an increase of about 22.8% over the local check with a B: C ratio of 4.3 compard to B: C ratio of 2.8 in the local check.

Capacity Building

A toal of 75 soil health cards along with complete agroadvisory was distributed to the farmers of three selected districts to enhance their adaptive capacity for planned adaptation and contingency (autonomous and planned) planning. A total of 9 farmers' goshthis were also organized in the selected districts (Hisar- 255 farmers, Jaunpur- 163 farmers and Pali- 135 farmers) to benefit the farmers by sensitizing them about different improved technologies for salt stress management. During these goshthis, the farmers were also informed about different government schemes, balanced nutrition of crops, upkeep of dairy animals and climate resilient agricultural practices to strengthen their livelihoods.

The data collected so far indicated that farmers in all the three selected districts suffer from salinity and sodicity risk to varying extents. Of late, factors such as fresh water scarcity, climate variability and socio-economic changes have further enhanced the vulnerability of farmers adversely impacting their livelihoods. Notwithstanding the fact that magnitude of salinity induced crop losses significantly varied in three districts representing distint agro-climatic conditions, most of the farmers still rely on autonomous adaptation strategies. However, in some cases, integration of planned adaptation activities such as adoption of improved crop varieties, agrochemicals and machinery have enhanced the farmers' resilience and adaptive capacity.

Impact assessment of subsurface drainage technology in canal command areas of Karnataka

(R. Raju, Thimmappa K. and Aslam L. Pathan)

This study was carried out in the subsurface drainage (SSD) project area of village Ugar Budruk located in Athani Taluk of Belgaum District in Karnataka state. The subsurface drainage system was installed during 2009-10 to 2011-12 in the waterlogged saline areas of village Ugar Budruk. The total area was 925 ha covering 644 farmers. The per hectare cost of saline land reclamation through SSD installation was estimated at Rs. 52,000. For impact assesment of the technology, both primary as well as secondary data were collected from different sources.

Impact on cropping pattern and cropping intensity

The cropping pattern in the study area during pre and post-SSD period reflected that the major crops grown in (Table 15) the project area were sugarcane followed by oilseeds and cereals, horticulture, vegetables and pulses .

Table 15: Cropping pattern and cropping intensity of the study area

Crops	Pre-SSD		Post-SSD		Per cent change	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Sugarcane	776.83	30.95	1745.87	69.55	969.04	124.74
Cereals	228.02	9.08	13.41	0.53	-214.61	-94.12
Pulses	46.00	1.83	0.00	0.00	-46.00	-100.00
Vegetables	12.72	0.51	17.53	0.70	4.81	37.81
Oilseeds	427.64	17.04	155.57	6.20	-272.07	-63.62
Horticulture	42.51	1.69	15.92	0.63	-26.59	-62.55
Uncultivated land	937.73	37.36	561.81	22.38	-375.92	-40.09
Total cultivable land	2510.00	100.00	2510.00	100.00	-	-
Cropping intensity	-	62.64	-	77.62	-	23.91

Table 16: Drain water salinity during pre and post-SSD installation

Water Quality	EC range	Outlets (Mean EC= 4.60 dS m^{-1})
Good	< 2	O & N
Marginally Saline	2-4	-
Saline	>4	P, B, F, H, H1, Q, A, R, CD-1, CD-2, OD-2, CD-3, DW
High-SAR Saline	>4	-

CD=Closed Drain, OD=Open Drain, DW=Drain Water

The cropping intensity of the drainage area has significantly increased during post-SSD period. Cropping intensity during pre-SSD was 62.64% and it has increased to 77.62% during the post-SSD period. The overall cropping intensity increased by 23.91% due to SSD installation. The increase in cropping intensity shows a positive impact of drainage technology on reclamation of saline soils.

Impact on soil and drain water salinity

It was observed that soil salinity in the study area varied between the locations and slope of the land. This variation was probably caused by the amount of irrigation and its distribution. The mean soil salinity of the project area was 6.63 dS m^{-1} during pre-SSD which reduced to 2.52 dS m^{-1} in post-SSD phase. Analysis of 30 soil samples from the project area showed that about 77% were normal (non-saline) and the rest 27% slightly to moderately saline during post-SSD. Analysis of the drain water indicated presence of salinity in most of the drainage outlets (Table 16).

Economic impacts

The study revealed that the cost of cultivation increased during post-SSD phase by 30.96% (Table 17) which is attributed to the better performance of crops after reclamation; crops demanded more inputs *viz.*, fertilizer, pesticides, irrigation management and labour for operation and maintenance. The net returns increased by 161.81%. During pre-SSD, the B: C ratio was 0.54 which increased to 1.21 in the post-SSD phase. The increase in net income and B: C ratio was largely due to increase in crop yield in the post-SSD phase. The unit cost (on per ton basis) of sugarcane production also reduced from Rs. 4116 to Rs. 1815 showing a significant reduction of 55.91% during post-SSD.

This study revealed considerable improvements in the soil properties within 2-3 years of SSD installation. As a consequence, soils became suitable for growing high value crops. In post-SSD phase, the area under different crops was increasingly put under sugarcane crop. Cropping intensity increased by 23.91% within a short span of 3 years after SSD installation. Average crop yields increased from 34 t ha^{-1} in pre-SSD to 100 t ha^{-1} in post-SSD period indicating an increase of 194.55%. Increase in the net returns by 161.81% and the higher B: C ratio during post-SSD phase indicated vast potential of this technology in enhancing the economic value of waterlogged saline lands.

Table 17. Economics of sugarcane cultivation during pre and post-SSD installation

Particulars	Pre-SSD	Post-SSD	Per cent change
Yield (t ha^{-1})	34	100	194.55
Gross Returns (Rs ha^{-1})	74718	220077	194.55
Cost of cultivation (Rs ha^{-1})	138119	180886	30.96
Net Returns (Rs ha^{-1})	-63402	39191	161.81
Cost of production (Rs t^{-1})	4116	1815	-55.91
Benefit-Cost Ratio	0.54	1.21	126.32

MANAGEMENT OF MARGINAL QUALITY WATER

Conjunctive water use strategies with conservation tillage and mulching for improving productivity of salt affected soils under limited fresh water irrigation. (A. K. Rai, R. K. Yadav, A. R. Chinchmalatpure, N. Basak, Satyendra Kumar, Bhaskar Narjary, Gajender, A. K. Bhardwaj, Madhu Chaudhary and D. K. Sharma)

In arid and semi-arid regions, limited availability of good quality water necessitates the conjunctive use of the saline and fresh water to sustain the crop yields. In the present study, conservation tillage, deficit irrigation and crop residue mulching approaches were employed for managing intra/inter seasonal root zone salinity for increased crop production of low water requiring cropping system under limited water supply. Data on wheat grain yield and fodder sorghum yield for 2015-16 are presented in Table 18. Tillage had no significant effect on the sorghum and wheat yield after three years of cropping cycle. Mulching with deficit irrigation showed significant effect on wheat yield compared to 100% water requirement application without mulching. Deficit irrigation with saline water (60% WRM) + mulching resulted in relatively higher soil organic carbon and low SAR in the soil solution. Irrigation and mulching had no effect on the sorghum grown as rainfed crop due to heavy rainfall in July 2016. In zero tilled plots (ZT-ZT), cumulative infiltration was relatively more (15.4-18.4 cm day^{-1}) compared to the conventional plot (CT-CT) (12.6 cm day^{-1}). Root zone salinity management is the key to the success of cropping in salt affected soils with limited fresh water irrigation. Therefore, assessment of *in situ* root zone salinity can help in developing proper soil-water-crop management practices. Current method of soil salinity estimation is empirical in nature and does not represent the salinity of the soil solution wetting the plant roots. Accordingly, the dynamics of electrical conductivity (EC_{SS}) and nutrient concentration in soil solution collected from soil at field capacity after 24 hrs of irrigation were analyzed using the centrifugal filters. Soil samples were drawn from the field experiment at Nain Experimental Farm, Panipat under sorghum-wheat cropping system since 2014. Soil solution in quasi-equilibrium with soil solid phase was

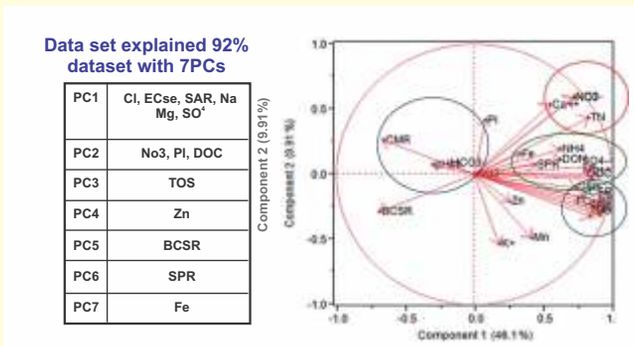


Fig.23: Effect of tillage and mulching on water infiltration rate and biplot of principle components of the soil solution indices of saline soils under saline irrigation

Table 18. Effect of tillage, mulching and deficit irrigation on the sorghum and wheat yield (Mg ha^{-1})

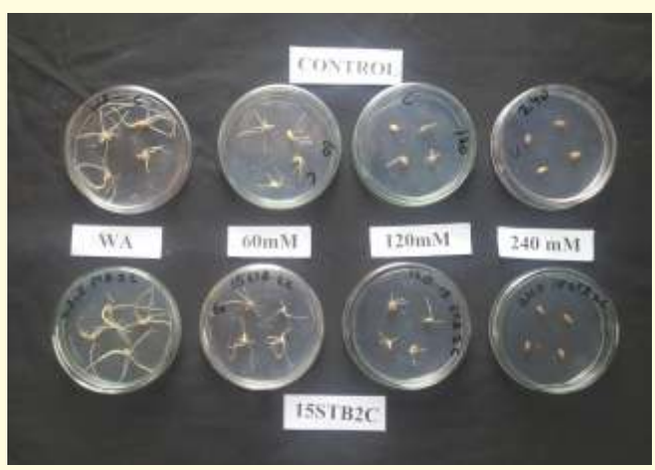
Treatment	Wheat (2015)	Sorghum GFY (2016)	Sorghum DFY	Dry matter (%)
Tillage				
RT-ZT	5.77a	57.2a	14.04a	24.7a
CT-CT	5.97a	51.1 a	12.06a	23.5a
ZT-ZT	5.60a	57.0a	13.75a	24.0a
Irrigation and mulching				
100 WR-no mulch	5.39b	53.89a	12.8 0a	23.8a
80 WR- no mulch	5.70ab	53.6a	13.51a	25.1a
60 WR - no mulch	5.76ab	55.3a	12.54a	23.7a
100 WR - mulch	5.89a	54.72a	13.07a	24.1a
80 WR - mulch	6.01a	56.94a	13.61a	23.6a
60 WR - mulch	5.94a	58.61a	14.18a	23.9a

Tillage × irrigation and mulch: ns

extracted and analyzed for different cationic and anionic constituents. All the cationic, anionic constituents and their indices were put under principal component analysis (Fig. 23). Seven principal components identified explained about 92% variability in data set. The EC_{Se} (EC of extracted solution) and pH_{Se} were in the range of 3.1-42.05 dS m^{-1} and 7.61-8.56, respectively. Soil pH_{se} was positively correlated with Ca/Mg ratio, HCO_3^- and HCO_3^- /(Cl^-+SO_4^{2-} ratio). The soil solution NO_3^- concentration was strongly correlated with Ca_2^+ concentration. CMR was negatively correlated with pH_2. EC and SAR play important role in determining soil pH but at micro level cationic and anionic ratio also modify the soil pH.

Development of effective salt tolerant microorganisms to mitigate salt stress for crop production in salt affected soils (Madhu Choudhary)

Plant growth promoting rhizobacteria (PGPR) are the soil rhizospheric bacteria which facilitates plant growth and development via production and secretion of various regulatory chemicals in the rhizosphere. These also aid in the adaptation to salt stress. In present study, 52 bacterial strains were isolated on the basis of salt tolerance at 20% NaCl. Twenty isolates showed better PGP traits like HCN production and *nif* H activity. These isolates were also checked for lipase, amylase and protease activities. STB 133 and 15STB5C showed positive response for HCN production. With respect to enzymatic activities, STB 80 possessed amylolytic and lipolytic activity; while 10STB7B, STB1 and 15STB2C showed positive results for amylolytic activity and STB 32 and STB 38 showed good proteolytic activity. STB 1, STB 38 and STB 32 isolates also showed positive results for *nif* H activity. Seed germination experiment was performed with selected 21 isolates at 0, 60, 120 and 240 mM NaCl. From the experiment, it was observed that wheat seeds germinated better at all NaCl levels as compared to mustard seeds. Isolates STB1, 10 STB 7B, STB 80, STB 32 and STB 133 showed better seed germination as compared to others. The best vigor index was obtained from seeds inoculated with STB80, 15STB2C and STB38 in wheat, while in mustard it was the maximum with STB1 followed by STB80 and STB32. All 21 isolates were inoculated further on mustard and wheat plants in pot house experiments. The initial EC_e of soil was 5.36 dS m^{-1} and pH was 7.02. Inoculation with isolates 10STB3C(2) and STB 55 increased the plant height of mustard and wheat by 10.27 and 5.83% as compared to uninoculated control. STB 32 inoculated wheat plants showed 33.3% more tillers while STB 24 treated plants recorded showed an increase of 62.7% in chlorophyll content. STB 32 and STB1 inoculated wheat and mustard plants recorded 27.08 and 10.46%, higher biomass over control, respectively. Inoculation of 5STB11B on wheat and 10STB3C(2) on mustard resulted in an increase of 29.9 and 20.78% in seed yield in the respective crops over control. Sodium and potassium contents in wheat and mustard decreased by 72.7 and 41.3%, respectively, over control. In rice field experiment, STB 80, STB 32 and consortium (STB 80+ STB 32 +STB 133) led to increase in plant height by 5.83,



Amylolytic activity exhibited by isolates 15STB2C, STB1 and STB80; Effect of isolate 15STB2C on wheat germination under salt stress

2.23 and 3.24%, respectively. STB 80 and STB 133 showed increase in chlorophyll content by 36.3 and 42.4%, respectively. Isolate STB80 and consortium (STB 80+ STB 32 +STB 133) reduced proline content by 41.56 and 12.69%, respectively as compared to control. Lipid peroxidation decreased by 77.5 and 27.5%, with STB 80 and STB 32, respectively.

Isolation, identification and evaluation of plant growth-promoting bacteria for mitigating salinity stress in crops (Madhu Choudhary, Gajender, M. D. Meena and Vineeth, T. V.)

Plant growth promoting bacteria (PGPB) are the root colonizing bacteria that exert beneficial effects on plant development. In addition to the use of salt tolerant verities and chemical amendments, the utilization of PGPB could be a viable strategy to improve plant growth in salt affected soils. For the isolation of bacteria, soil samples of rhizosphere and roots of plants were collected from the Nain Experimental Farm. Bacterial isolation was carried out from these samples on different types of media. A total of 84 phenotypically different bacteria were isolated; 30 from Nutrient Agar, 14 from Jensen's medium, 6 from Pikovaskaya medium, 24 from King' B and 10 from Ashby's medium. All these isolates were screened for ammonia excretion, production of indole acetic acid (IAA) and HCN and phosphate solubilisation. Some microbes showed capability to produce ammonia which is an important source of nitrogen for plants. IAA is the most common, naturally occurring, plant hormone of the auxin class. Indole acetic acid helps in the production of longer roots with increased number of root hairs and root laterals which are involved in the nutrient uptake. The microorganisms isolated from rhizosphere region of various crops have an ability to produce IAA as secondary metabolites due to rich supply of substrates. Some isolates showed high production of ammonia and some of IAA. Fifteen isolates showed both activities. Isolate PM2-2 showed the highest ammonia production (2.4 µg ml^{-1}) followed by KM1-8 (2.15 µg ml^{-1}) and KM2-1 (2.14 µg ml^{-1}).

Phosphate solubilisation by bacterial isolates

Table 19: Ammonia excretion and IAA production by bacterial isolates

Isolate	Ammonia excretion (µg ml^{-1})	IAA production (µg ml^{-1})
JKB1-7	1.07	5.27
JM3-3	0.94	9.28
KM1-2	1.35	5.27
KM1-8	2.15	6.31
KM2-1	2.14	5.7
KBD-1	1.19	5.04
KBD-3	1.64	6.62
KBD-4	1.78	6.35
KBD-5	1.95	9.51
KBD-6	0.91	12.6
NM3-2	1.31	5.24
PSB-1	1.55	5.66
PM2-1	1.9	5.97
PM2-2	2.4	5.16
PKB2-2	1.55	5.35

Production of IAA was the highest by isolate KBD-6 (12.6 µg ml^{-1}) followed by KBD-5 (9.51 µg ml^{-1}) and JM3-3 (9.28 µg ml^{-1}) (Table 19). Zone of phosphate solubilisation was also seen by some isolates.

Characterization and application of sewage sludge and municipal solid waste compost for reclamation of sodic soils (Parul Sundha, A. K. Rai, Gajender and N. Basak)

Application of organic amendments to agricultural soils provide essential nutrients (N, P, K and other secondary and micronutrients), improve soil physical and chemical properties and enhance the microbial populations and activities. With the declining availability of farmyard manure, utilization of municipal solid waste and sewage sludge could be the alternative options. Combined application of organic amendments and gypsum has also given encouraging results in overcoming the problem of soil sodicity. This project was initiated with an idea to harness the potential of organic wastes in land reclamation and systematic waste disposal. To achieve these objectives, municipal solid waste compost (MSWC) and sewage treatment plant (STP) sludge collected from different industrial and non-industrial cities, were characterized for their efficiency to reclaim the sodic soils. The contents of different macro- and micro-nutrients and heavy metals were also determined in the collected samples. Sewage sludge samples were collected from Faridabad, Panipat, Karnal, Yamunanagar, Gharaunda, and Indri in Haryana. MSWC was colllected from Delhi and Karnal. The sampling of sewage sludge was done on seasonal basis from Karnal, Yamunanagar and Faridabad. The physico-chemical characterization, contents of macro and micro-nutrients in sewage sludge and MSWC is presented in Table 20 and 21. The $pH_{(1:5)}$ of the samples was neutral and ranged from 6.17 to 7.79, except for acidic (5.55) in Yamunanagar sample. Electrical conductivity ($EC_{1:5}$) of compost and sewage sludge varied from 4.09 to 10.8 dS m^{-1}. The sewage sludge samples collected from Yamunanagar, Karnal and Faridabad were higher in total carbon and nitrogen. Composts of both the sites *i.e.*, Karnal and Delhi contained the lower amounts of C and N. Sewage sludge of Gharaunda, Indri and Panipat also contained lower concentration of C and N. Phosphorus load was greater in sewage sludge from Yamunanagar (1117.5 mg kg^{-1}). Lower level of C: N ratio was observed for sewage sludge of Indri, Panipat and composts of Karnal and Delhi (~15-16:1). The total micronutrient concentration in almost all the samples was in accordance to the FCO standards. Heavy metals characterization was also carried out. The sampling is being done on seasonal basis. Till now, post summer and post monsoon sampling has been completed. Sampling is in process for the winter season. Heavy metal analysis revealed higher Cr (4343 mg kg^{-1}) and Ni (1452.3 mg kg^{-1}) in the Yamunanagar sewage sludge. Lead was not detected and Cd was within

Table 20: Physico-chemical characterization of sewage sludge and compost

Site	pH (1:5)	EC (1:5) (dS m^{-1})	TOC(%)	Total N(%)	Total P (mg kg^{-1})	C:N Ratio
Karnal	6.17 ±0.01	6.13 ±0.03	24.10±5.12	0.65±0.02	649.6±76.4	35.2±1.4
Gharaunda	6.5 ±0.003	4.71 ±0.16	12.8±2.14	0.42±0.01	663.6±67.9	28.4±0.9
Indri	6.88 ±0.02	6.16 ±0.22	8.88±1.04	0.51±0.01	659.8±23.6	15.4±2.4
Panipat	7.47 ±0.01	4.09±0.11	9.14±1.54	0.64±0.03	393.9±12.5	16.47±2.8
Yamunanagar	5.55 ±0.02	8.63 ±0.01	28.74±4.35	0.74±0.04	1117.5±124	35.8±3.7
Faridabad	6.91 ±0.01	8.21±0.17	22.99±6.34	0.87±0.01	607.5±134	24.71±2.6
Karnal Compost	7.32±0.02	10.8±0.05	10.8±0.10	0.64±0.02	547.61±69	16.4±1.0
Delhi Compost	7.79±0.01	9.58±0.09	9.58±0.36	0.67±0.02	511.27±47	14.2±0.96
FCO Standard	6.5-7.5	<4	>16.0	>0.5	-	20 or less

Table 21: Total micro-nutrient content in sewage sludge and compost

Sampling site	Fe (g kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
Karnal	15.09±.076	214.4±3.38	782.9±9.02	139.27±0.18
Panipat	21.34±1.54	332.1±7.68	601.47±25.91	134.37±7.94
Indri	19.54±1.11	240.07±4.45	450.77±4.76	95.21±9.02
Yamunanagar	22.82±0.8	699.2±55.64	2880±56.96	3133.3±56.27
Gharaunda	17.68±.061	238.13±6.78	662.8±15.4	101.79±3.74
Faridabad	17.31±2.13	203.93±6.02	1296.5±101.0	192.4±12.71
Karnal compost	16.41±2.68	234.97±42.66	422.07±75.78	244.33±38.90
Delhi composting	20.88±1.16	335.13±76.24	826.97±53.35	614.23±69.43
FCO Standrad	-	-	<1000	<300

permissible limits of FCO.

Evaluation of salinity tolerance of seed spices (R. K. Yadav and R. L. Meena)

A collaborative research project between ICAR-CSSRI, Karnal and ICAR-NRCSS, Ajmer was continued at CSSRI, Karnal. One pot and two lysimeter experiments were carried out to assess the overall and stage dependent tolerance of seed spice crops to salinity and RSC levels in irrigation water under direct seed sowing and transplanting conditions. Fennel (*Foeniculum vulgare*), coriander (*Coriandrum sativum*), celery (*Apium graveolens*) and fenugreek (*Trigonellafoenum graecumL.*) were further assessed to verify overall and stage dependent (0-30, 31-60, 61-90 and 91-120 days after sowing/transplant) tolerance to irrigation water

Table 22: Effect of sowing methods and stage dependent salinity stress on seed production of seed spice crops

IR (DAS)	Fennel		Celery		Coriander		Fenugreek		Mean*	
	Direct Seeding									
	Biomass	Seed	Biomass	Seed	Biomass	Seed	Biomass	Seed	Biomass	Seed
Control	2.14	1.40	1.88	0.44	1.94	1.28	1.62	0.65	1.99	1.04
0-30	1.84	1.30	1.79	0.37	1.68	1.03	1.23	0.46	1.77	0.90
31-60	2.01	1.38	1.84	0.38	1.82	1.16	1.32	0.52	1.89	0.97
61-90	2.10	1.41	1.97	0.41	1.91	1.23	1.28	0.48	1.99	1.02
91-harvest	1.96	1.33	1.89	0.39	1.95	1.21	1.46	0.50	1.93	0.98
Cont. Saline	1.78	1.19	1.58	0.30	1.64	0.94	1.12	0.36	1.67	0.81
Mean	1.97	1.34	1.83	0.38	1.82	1.14	1.34	0.50	1.87	0.95
					Transplanting					
Control	1.97	1.26	1.71	0.42	1.80	1.19	--	--	1.83	0.96
Tr.-30	1.78	1.24	1.84	0.39	1.71	1.05	--	--	1.78	0.89
31-60	1.96	1.35	1.80	0.40	1.87	1.20	--	--	1.88	0.96
61-90	2.15	1.43	1.94	0.43	2.03	1.28	--	--	2.04	1.05
91-harvest	1.88	1.35	1.83	0.37	1.99	1.13	--	--	1.90	0.97
Continuous	1.69	1.14	1.47	0.27	1.56	0.83	--	--	1.57	0.75
Mean	1.91	1.30	1.77	0.38	1.83	1.11	--	--	1.83	0.93

CD (p=0.05) Bimass - Seeding Methods (SM) = NS; Irrig. Regimes (IR) = 0.18; Crops = 0.11; SM*IR = NS; SM *IR*Crop = 0.21, Seed - Seed Yield (SY): Seeding Methods (SM) = NS; Irrig. Regimes (IR) = 0.13; Crops = 0.21; SM*IR = 0.17; SM *IR*Crop = 0.14

salinity (6.0 and 4.0 dS m^{-1}). Fennel and coriander were also assessed for tolerance to RSC levels (0, 2.5, 5.0 and 5.0 meq L^{-1} + gypsum to neutralize to 2.5) in irrigation water. Anise (*Pimpinella anisum*), ajwain (*Trachyspermum ammi*) and dil (*Anethum sowa*) were evaluated for overall tolerance to irrigation water salinity (3, 6, 9, 12 dS m^{-1}). In all the three experiments, irrigations were scheduled at 1.2 ID/CPE ratio. Growth, development, yield parameters and yield of all the crops were recorded periodically and compared with normal (~0.6 dS m^{-1} EC_{IW} and nil RSC) water applied as per treatment in respective experiments.

Direct seeding and transplanting did not affect growth and yield, of fennel, coriander and celery, under saline (6.0dS m^{-1}) irrigation (Table 22). Under direct seeding, fennel, coriander and celery produced biomass/seed yields of 1.97/1.34, 1.83/0.38 and 1.82/1.14 t ha^{-1}, respectively. Continuous saline irrigation decreased seed yield of direct seeded fennel, celery, coriander and fenugreek by 15, 27, 32 and 44%, respectively. During initial 0-30 DAS and reproductive (>90 DAS) period these seed spice crops were more sensitive to salinity as the seed yield decreased by 8, 17, 20 and 29%, and 6, 11, 14 and 21% in fennel, celery, coriander and fenugreek, respectively in comparison to normal water irrigation.

Fennel and coriander were observed to be sensitive to RSC in irrigation water (Table 23). Germination and seed yield reduced by 32 and 25%, and 34 and 29%, respectively under RSC of 2.5 meq L^{-1}. Further increase in RSC to 5.0 meq L^{-1} reduced germination by 65 and 54% and seed yield by 26 and 62%, respectively. However, neutralizing RSC 5 to 2.5 meq L^{-1} using gypsum improved the germination and seed yield of two crops by 65 and 69%, and 48 and 85%, respectively. After germination, crops sustained even high (5.0 meq L^{-1}) RSC levels in irrigation water. Seed and biomass production of both fennel and coriander decreased significantly with increasing levels of RSC in irrigation water.

Other three seed spice crops *viz.*, anise, ajwain and dil, were also assessed for tolerance to salinity in irrigation water. Germination of dil, anise and ajwain was delayed by 2, 3 and 4 days, respectively under salinity stress of 6.0 dS m^{-1}. Increasing salinity in irrigation water from 3.0 to 6.0 and 6.0 to 9.0 dSm^{-1} reduced germination by 14, 12 and 12 and by 29, 26 and 25%, respectively in ajwain, anise, and dil. Irrigation water salinity > 6.0 dSm^{-1} had significant negative effect on seed yield of all the three crops.

Assessing use of press mud/press mud compost in gypsum beds for neutralization of RSC in irrigation water (R. K. Yadav, M. D. Meena, Satyendra Kumar, Madhu Chaudhary, Parul Sundha and D. K. Sharma)

To overcome the difficulty in passage of water through gypsum beds, this project was initiated to assess the effectiveness of mixing pressmud in gypsum beds on neutralization of RSC in irrigation water, optimizing ratio of gypsum and press mud for maximum neutralization of RSC in groundwater and understanding the improvement in soil physico-chemical and microbial properties and crop productivity with use of neutralized water. Pressmud collected from Panipat, Kaithal and Yamunanagar was characterised for pH (4.82-5.13), EC (0.79 – 1.24 dS m^{-1}), Ca (2.14- 2.40%) and S (1.18 – 1.26%). A column (75 cm height and 12 cm diameter) study (Plate 1), consisting of gypsum and pressmud from Yamunanagar in different ratios (gypsum, 5:1, 4:1, 3:1, 2:1 and pressmud), was conducted in triplicate. One litre of each of high

Table 23: Germination, biomass and seed yields (t ha^{-1}) of coriander and fennel under high RSC water irrigation

RSC levels (meq l^{-1})/ Crops	Germination (%)		Seed yield		Biomass yield	
	Fennel	Coriander	Fennel	Coriander	Fennel	Coriander
Nil	94	89	1.46	1.34	2.23	1.94
2.5	62	64	0.93	0.96	1.52	1.47
5.0	29	35	0.39	0.47	0.79	0.68
5.0 + gypsum	47	59	0.58	0.85	1.17	1.10
CD (p=0.05)	12	14	0.13	0.17	0.20	0.19

Table 24 :Volume of leachate collected (litres) from 1.0 litre water after saturation of columns at 2.0 hrs

Water RSC (meq l^{-1})	Gypsum + Pressmud					
	Gypsum	5:1	4:1	3:1	2:1	Pressmud
Nil	0.23	0.39	0.52	0.69	0.83	0.89
2.0	0.21	0.42	0.54	0.63	0.75	0.94
4.0	0.19	0.37	0.51	0.71	0.78	0.86
6.0	0.24	0.43	0.49	0.65	0.85	0.89
Mean	0.22	0.40	0.52	0.67	0.80	0.90

Table 25 : RSC neutralization with different mixtures of gypsum and pressmud at 2.0 hrs

Water RSC meq l^{-1}	Gypsum + Pressmud					
	Gypsum	5:1	4:1	3:1	2:1	Pressmud
Nil	--	--	--	--	--	--
2.0	1.42	1.44	1.38	1.14	0.76	0.35
4.0	3.17	3.26	3.10	1.76	1.28	0.42
6.0	4.25	4.34	3.84	2.67	1.17	0.38
Mean	2.95	3.01	2.77	1.86	1.07	0.38

Column set up to assess the effect of different mixtures of gypsum and pressmud on RSC neutralization

RSC (6, 4 and 2 me $L^{-1}$and nil) water was passed through a column and leachate was collected after 2 hrs and analysed for neutralization of RSC. The amount of leachate collected and neutralization of RSC is given in Table 24 and 25. Mixing of gypsum and pressmud in a ratio of 4:1 helped in improving the passage of water through beds by 136% with ~6% less neutralization of RSC.

Improving farm productivity through sustainable use of alkali waters at farmers' field in rice-wheat production system (Parvender Sheoran, R.K. Yadav, Nirmalendu Basak, Satyender Kumar, K. Thimmappa and R.K. Singh)

A field experiment was initiated in June 2014 with rice as the first crop to evaluate the performance of salt tolerant varieties and RSC neutralizing ameliorants *viz.*, gypsum and pressmud used either individually or in combination for sustained use of sodic water in crop production. A total of 4 treatments as RSC neutralizing ameliorants- T_1: RSC water/untreated (control); T_2: T_1 + gypsum @ 7.5 t ha^{-1}; T_3: T_1 + pressmud @ 10 t ha^{-1}; and T_4: T_1 + gypsum @ 3.75 t ha^{-1} + pressmud @ 5 t ha^{-1} were taken in the main plots while two varieties one each as salt tolerant (Basmati CSR 30 in rice and KRL 210 in wheat) and the most adopted ones (Pusa 1121 in rice and HD 2967 in wheat) in respective growing seasons were super imposed to the neutralization treatments at both locations. All other cultural practices including fertilization and plant protection measures were adopted as per the recommendations related to the respective crops. Two sites were selected for the experimental purpose in village Mundri, District Kaithal, having RSC_{iw}≈7.0 and 5.0 meq L^{-1}.

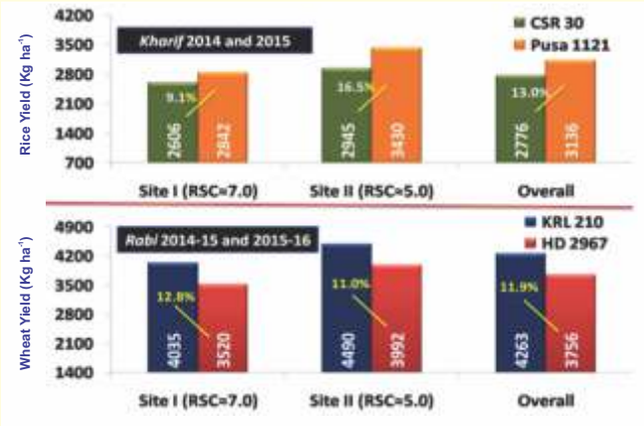


Fig. 24. Comparative performance of salt tolerant and traditional varieties irrigated with high residual alkalinity in irrigation water at farmer's fields in RWCS

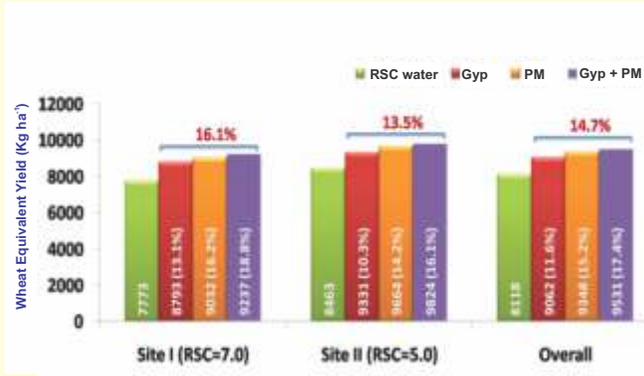


Fig. 25. Effect of RSCiw neutralization treatments on the system productivity in RWCS

With the increase in RSC_{iw}, Basmati CSR 30 performed relatively better than Pusa 1211 as evident from narrow yield gaps between two varieties from 16.5% at site I to 9.1% at site II (Fig. 1). Better physiological efficiency for salt stress adaptation were recorded in CSR 30 in terms of higher relative water content (RWC) and SPAD values and lower membrane injury and Na^+/K^+ ratio in shoot and root tissues compared to Pusa 1121. Varietal intervention through inclusion of salt tolerant wheat variety KRL 210 can be an important strategy to overcome the yield reduction as well as improving the system productivity (Table 26). Overall, yield superiority of 11.9% (11.0-12.8%) was recorded with salt tolerant KRL 210 in comparison to HD 2967 (Fig. 24).

Neutralization of RSC water through amendments (gypsum/pressmud) either individually or in combination resulted in 11.6-17.4% (mean 14.7%) higher system (wheat) equivalent yield (Fig. 25). Similar to rice, wheat plants grown on amendment treated soils showed higher RWC and SPAD values and lower membrane injury and Na^+/K^+ ratio in shoot and root tissues in comparison to untreated, RSC water irrigated plants. Better grain quality and economic returns were observed with neutralization treatments.

Table 26: Interactive effect of RSC_{iw} neutralization treatments and crop varieties on system productivity in RWCS (mean data of 2 locations and 2 years crop rotation)

Cropping sequence		Wheat equivalent yield (kg ha^{-1})			
		RSC water	Gyp	PM	Gyp + PM
Basmati CSR 30	HD 2967	7958	8887	9133	9336
	KRL 210	8283 (+4.1%)	9284	9647	9794
Pusa 1121	HD 2967	7905	8794	9022	9224
	KRL 210	8328 (+5.4%)	9283	9590	9769
Mean		8118	9062	9348	9531
		(+11.6%)	(+15.2%)	(+17.4%)	

CROP IMPROVEMENT FOR SALINITY, ALKALINITY AND WATER LOGGING STRESSES

Development of salt tolerant genotypes in rice-conventional and molecular breeding approaches (S. L. Krishnamurthy, P. C. Sharma, Ravikiran K. T., Vineeth T. V., Y. P. Singh and S. K. Sarangi)

This project aims at the development, evaluation and dissemination of better salt tolerant rice genotypes. To achieve the objectives, following trials were conducted and the breeding material was advanced during *Kharif* 2016.

A. National Trials:

IVT-Alkaline and Inland Saline Tolerant Variety Trial-2016

The IVT-Alkaline and Inland Saline Tolerant Variety Trial (IVT-AL&ISTVT) comprised of 20 entries including check varieties CSR 36, CSR 27 and yield check Jaya which were evaluated across six locations in RBD with three replications. Under salinity stress at Karnal (pH_2- 7.5; EC_e- 8 dS m^{-1}), 10 entries outperformed the national salinity check CSR 23. Entry 2204 showed the highest grain yield (3.747 t ha^{-1}) followed by 2205 (3.648 t ha^{-1}), and local check (2.6 t ha^{-1}). At Nain, Panipat (pH_2- 7.5; EC_e- 11.0 ds m^{-1}) 9 entries outperformed the local check. The grain yield ranged from 0.121 t ha^{-1} (2218) to 2.752 t ha^{-1} (2212). Entry 2212 showed the highest grain yield (2.752 t ha^{-1}) followed by 2216 (2.651 t ha^{-1}), and local check (1.987 t ha^{-1}). Under sodic stress at Karnal (pH_2- 9.6; EC_e- 1.2 dS m^{-1}), 15 entries performed better than the local check CSR 36. The entry 2216 showed the highest grain yield (4.18 t ha^{-1}) followed by 2204 (3.954 t ha^{-1}), and local check (3.145 t ha^{-1}). At Kurukshetra (pH_2- 9.6; EC_e- 2.0 ds m^{-1}), 15 entries performed better than the local check CSR 36. Entry 2202 showed the highest grain yield (3.925 t ha^{-1}) followed by 2204 (3.816 t ha^{-1}), and local check (3.015 t ha^{-1}). At Jind (pH_2- 9.7; EC_e- 2.0 dS m^{-1}), 15 entries performed better than the local check CSR 36. Entry 2209 showed the highest grain yield (3.925 t ha^{-1}) followed by 2204 (3.834 t ha^{-1}), and local check (2.969 t ha^{-1}). At Gautam Buddh Nagar (U.P.) (pH_2- 9.6; EC_e- 1.0 dS m^{-1}), eleven entries performed better than the local check CSR 36. The entry 2202 showed the highest grain yield (3.817 t ha^{-1}) followed by 2205 (3.788 t ha^{-1}) and local check (2.831 t ha^{-1}).

AVT-Alkaline and Inland Saline Tolerant Variety Trial-2015

In AVT-Alkaline and Inland Saline Tolerant Variety Trial (AVT-AL&ISTVT), 19 entries including check varieties CSR 36, CSR 27 and the yield check Jaya were tested across six locations in RBD with three replications. Under salinity stress at Karnal (pH_2- 7.5; EC_e- 8 dS m^{-1}), 7 entries outperformed the local check CSR 23. Entry 2101 showed the highest grain yield (3.684 t ha^{-1}) followed by 2105 (3.653 t ha^{-1}), and local check (2.935 t ha^{-1}). At Nain Experimental Farm, Panipat (pH_2- 7.5; EC_e- 11.0 ds m^{-1}) 10 entries outperformed the local check. The grain yield ranged from 0.125 t ha^{-1} (2108) to 1.657 t ha^{-1} (2101). Entry 2101 showed the highest grain yield (1.657 t ha^{-1}) followed by 2105 (1.453 t ha^{-1}), and local check (0.380 t ha^{-1}). Two entries 2110 and 2104 did not flower at the testing locations. Under sodic stress at Karnal (pH_2- 9.6; EC_e- 1.2 ds m^{-1}), 10 entries performed better than the local check CSR 36. Entry 2113 showed the highest grain yield (4.786 t ha^{-1}) followed by 2105 (4.77 t ha^{-1}), and local check (3.454 t ha^{-1}). At Kurukshetra (pH_2- 9.6; EC_e- 2.0 dS m^{-1}), 13 entries performed better than the local check CSR 36. Entry 2105 showed the highest grain yield (4.058 t ha^{-1}) followed by 2113(4.022 t ha^{-1}), and local check (2.992 t ha^{-1}). Entry 2105 showed the highest grain yield (4.185 t ha^{-1}) followed by 2113(4.154 t ha^{-1}), and local check (3.391 t ha^{-1}). At Gautam Buddh Nagar (U.P.) (pH_2- 9.6; EC_e- 1.0 dS m^{-1}), 6 entries performed better than the local check CSR 36. Entry 2105 showed the highest grain yield (4.022 t ha^{-1}) followed by 2115 (3.836 t ha^{-1}).

B. Station Trials

Monitoring, maintenance and development of breeding materials

Development of F_1's during *Kharif* 2016

Many salt tolerant lines were used in hybridization with high yielding varieties to enhance the genetic variation and to transfer the salt tolerance in high yielding varieties. 206 crosses were attempted during the season.

Table 27: List of F_7 populations advanced for the next generation under stress

S. No.	Crosses	S. No	Crosses	S. No	Crosses
1	NDR359 × FL478	9	NDR356 × CSR 27	17	Tar Bas × CSR 2K 262
2	FL478 × PR115	10	PB6 × CSR 2K-262	18	PR115 × FL-478
3	PR115 × CSR27	11	CSR86-IR-8 × FL478	19	PB 6 × CSR27
4	Sarjoo 52 × PB6	12	Sarjoo-52 × CSR27	20	BCW56 × CSR36
5	Tar Bas × CSR27	13	Sarjoo 52 × CSR36	21	Tar Bas × PB6
6	Bas370 × CSR 2K 262	14	Tar Bas × CSR36	22	PR115 × CSR10
7	Pusa 44 × CSR27	15	IR-60997A × FL478	23	PR115 × CSR 2K 262
8	IR 60997 ×CSR36	16	CSR27 × Indrasan	24	IR60997 × FL478

Table 28: Summary performance of promising entry IET 24537 during 2014 - 2016 in AL & ISTVT

IET No.	Year of testing	Yield improvement (%) over best check under alkalinity
CSR 56 (IET 24537)	I Year, 2014	10.66 (CSR 36)
	II Year, 2015	5.02 (CSR 10)
	III Year, 2016	13.57 (CSR 23)

Multiplication of F_3's during *Kharif* 2016

Different cross combinations (MTU 1010 × CSR 27, MTU 1010 × CSR 11, MTU 1001 × CSR 27, MTU 1001 × CSR 11, CSR 30 × Vandana, CSR 30 × CSR 11, CSR 30 × CSR 27, CSR 30 × PB 3, CSR 30 × Jaya, CSR 30 × HUBR 10-9, CSR 30 × CSR 8, Pusa 44 × CSR 27 and MAUB 13 × CSR 30) made during *Kharif* 2014 to combine the yield and salt tolerance in rice were screened during 2016 at Nain Experimental Farm.

Screening and selection of F_5 populations

A total of 43 segregating populations were screened under high salinity (EC_{iw} ~ 12 dS m^{-1}) in microplots and at Nain Experimental Farm. The top 10 progenies were selected from each segregating population for further screening/ evaluation in the next cropping season.

Screening and selection of F_7 populations

A total of 24 segregating populations (Table 27) were screened under high salinity (EC ~ 10.0 dS m^{-1}) in the saline micro plots. The top 10 progenies were selected from each segregating population by considering the yield, quality, tolerance and other traits for further screening/evaluation in the next cropping season.

Performance of CSR 56 (IET 24537) in AL & ISTVT Trial

The performance of IET 24537 was consistently high under alkalinity for three successive years in Haryana and Uttar Pradesh. It showed yield superiority of 25.16%, 20.10%, 77.15%, 17.96%, 17.10% than CSR 36, Local Check, Jaya, CSR 23, CSR 10, respectively (Table 28).

Production and maintenance of advanced bulks, segregating lines and germplasm

A total of 176 segregating lines derived from different crosses and a total of 655 genetic stocks including 276 IRRI lines were grown in the field for maintenance. Besides, 104 advance stabilized lines were maintained. A total of 100 different elite breeding lines were grown and maintained in the field. The demonstration trial was conducted with 43 elite rice breeding lines. Nucleus seed of rice varieties was produced for next year breeder seed production and 87 promising lines were also grown in field for multiplication and maintenance.

Breeder seed production

Breeder seed of the salt tolerant rice varieties *i.e.*, CSR 10 (0.16 t), CSR 13 (0.12 t), CSR 23 (0.1 t), CSR 27 (0.12 t), CSR 30 (2.97 t) CSR36 (1.95 t), CSR 43 (1.04 t) and CSR 46 (1.2 t) was produced to meet the demand of seed producing agencies as per DAC (Department of Agriculture and Cooperation) indent.

National project on transgenics in crops-salinity tolerance in rice: functional genomics component (ICAR funded) (S.L. Krishnamurthy, P.C. Sharma and Ravi Kiran, K.T)

The main aim of this project is to map the important genomic regions/QTLs controlling salt tolerance traits in rice. This involves collaborative work between CSSRI for phenotyping and NRC on Plant Biotechnology, New Delhi for genotyping.

Phenotyping of fine mapping population (CSR27/MI48) for spikelet fertility

A total of 225 genotypes including 220 RILs along with parents were phenotyped in randomized block design with two replications under 3 environments [normal, moderate salinity (EC_{IW}~6.0 dS m^{-1}) and high salinity (EC_{IW}~12 dS m^{-1}) microplots] during *Kharif* 2016. The mean and per cent reduction in different traits for RIL population were recorded during 2016 (Table 29). The grain yield ranged from 6.21 (RIL 112) to 36.76 (RIL 30), 0.48 (RIL 1) to 9.55 (RIL 209) and 0.07 (RIL 118) to 6.44 (RIL 44) under normal, moderate salinity and high salinity treatments, respectively. The spikelet fertility ranged from 63.62 (RIL 192) to 94.5 (RIL 35), 5.63 (RIL 118) to 87.29 (CSR 27) and 0.29 (RIL 216) to 72.88 (RIL 16) under normal, moderate salinity and high salinity treatments, respectively. RIL 216 registered the lowest spikelet fertility of 0.29 % under high salinity. Top 10 RILs with high spikelet fertility (%) under normal, moderate salinity and high salinity stresses are presented in Table 30. The top 10 lines based on grain yield under normal, moderate salinity and high salinity stress were identified. The top 10 lines showing the least per cent reduction for grain yield under moderate and high salinity stresses are presented in Table 31. The line RIL 200 registered its

Table 29: Mean and per cent reduction for different traits of homozygous recombinants derived from RIL 41 and RIL 44 of CSR 27/MI 48 RIL under normal, moderate and high salinity stresses

Traits	Mean			% Reduction	
	N	MS	HS	MS	HS
Days to 50% flowering	94.26	97.32	102.57	-3.24	-8.81
Plant Height (cm)	126.82	89.70	75.06	29.27	40.81
Panicle length (cm)	28.36	23.58	20.46	16.86	27.83
Total tillers/plant	9.32	7.81	6.54	16.20	29.87
Productive tillers/plant	8.29	6.59	5.14	20.49	38.03
Grains per panicle	112.66	59.45	25.09	47.23	77.73
Spikelet fertility (%)	84.06	65.82	32.10	21.69	61.81
Biological yield per plant (g)	48.95	19.98	14.29	59.19	70.81
Grain yield per plant (g)	16.82	5.24	1.57	68.88	90.67

Note: N- Normal soil; MS- Moderate Salinity (EC_{iw} ~ 6.0 dS m-1); HS- High salinity (EC_{iw} ~ 12.0 dS m^{-1}).

Table 30: Top 10 recombinants with high spikelet fertility (%) derived from RIL 41 and RIL 44 of CSR 27 x MI 48 RIL under normal, moderate and high salinity stresses

S. No.	N		MS		HS	
1	RIL 35	94.50	RIL 186	86.61	RIL 16	72.88
2	RIL 47	94.41	RIL 44	86.24	RIL 34	68.15
3	RIL 90	93.62	RIL 123	84.85	RIL 47	67.34
4	RIL 150	93.22	RIL 212	83.63	RIL 22	65.47
5	RIL 12	92.88	RIL 179	82.38	RIL 42	62.90
6	RIL 87	92.46	RIL 9	82.01	RIL 37	62.84
7	RIL 66	92.45	RIL 42	82.01	RIL 143	62.70
8	RIL 36	92.37	RIL 138	81.92	RIL 43	61.95
9	RIL 116	92.20	RIL 207	81.42	RIL 67	61.88
10	RIL 182	91.91	RIL 209	81.36	RIL 48	60.66
P1	CSR 27	93.40	CSR 27	83.99	CSR 27	68.24
P2	MI 48	80.29	MI 48	37.74	MI 48	3.31
P3	RIL 44	87.37	RIL 44	82.59	RIL 44	42.70
P4	RIL 41	81.97	RIL 41	37.32	RIL 41	1.08

Note: N- Normal soil; MS- Moderate Salinity (EC_{iw} ~ 6.0 dS m^{-1}); HS- High salinity (EC_{iw} ~ 12.0 dS m^{-1}).

Table 31: Top 10 RILs showing less per cent reduction for grain yield under moderate (EC_{iw} ~ 6 dS m^{-1}) and high (EC_{iw} ~ 12 dS m^{-1}) salinity stress

S. No.	MS		HS	
	Genotypes	% reduction	Genotypes	% reduction
1	RIL 199	0.67	RIL 22	56.14
2	RIL 112	7.70	RIL 24	59.44
3	RIL 126	16.13	RIL 107	62.06
4	RIL 107	16.30	RIL 21	64.30
5	RIL 200	26.38	RIL 44	66.59
6	RIL 83	27.57	RIL 132	67.10
7	RIL 93	30.78	RIL 42	67.37
8	RIL 114	35.08	RIL 112	67.54
9	RIL 219	35.99	RIL 72	69.13
10	RIL 188	36.14	RIL 19	69.46

Note: MS- Moderate Salinity (EC_{iw} ~ 6.0 dS m^{-1}); HS- High salinity (EC_{iw} ~ 12.0 dS m^{-1}).

Table 32: Mapping populations being maintained

S. No.	Mapping populations	Generation	Population size
1	Taraori Basmati / CSR 36	F8	400
2	Taraori Basmati / CSR-2K-262	F8	400
3	VSR 156 / CSR 20	F8	400
4	VSR 156 / CSR 10	F7	400
5	VSR 156 / CSR 36	F7	400
6	CSR 11 x MI 48	F14	216
7	CSR 27 x MI 48	F14	218
8	CSR 27 x CSR 11	F14	215
9	BPT 5204 x Kalanamak	F3	
10	CSR 30 x Kalanamak	F3	
11	PB 1 x Kalanamak	F3	

Note: MS- Moderate Salinity (EC_{iw} ~ 6.0 dS m^{-1}); HS- High salinity (EC_{iw} ~ 12.0 dS m^{-1}).

consistency on lesser per cent yield reduction in moderate as well as high saline stress. The mapping populations currently being maintained are shown in Table 32.

Molecular genetic analysis of resistance/ tolerance in rice wheat chickpea and mustard including sheath blight complex genomics (Sub-project 1: Rice component) (S. L. Krishnamurthy, P. C. Sharma and Ravi Kiran, K. T.)

The main aim of this project is to map the important genomic regions/QTLs controlling sodicity tolerance traits in rice. This is a network project involving various components with salinity/sodicity component being dealt by ICAR-CSSRI, Karnal and genotyping at IARI, New Delhi.

Phenotyping of mapping population (Trichy/Pusa Basmati 1) for sodicity tolerance

A total of 225 genotypes including 215 RILs derived from Trichy x Pusa Basmati 1 along with parents were evaluated in replicated Simple Lattice Design in 3 environments [normal, moderately sodic (pH_2 ~ 9.5) and highly sodic (pH_2 ~ 9.9 soil conditions] during *Kharif* 2016. The range, mean and per cent reduction of different traits for RIL population were recorded (Table 33). High mean grain yield and other related traits were noticed under normal soil as compared to moderate sodic and high sodic stresses. The grain yield and biomass were the most sensitive traits and reduced by 61.16% and 47.12% followed by grains per panicle, harvest index, plant height,

Table 33: Mean, range and per cent reduction for different traits of Recombinant Inbred Lines derived from Trichy x Pusa Basmati 1 under normal, moderate and high sodicity stress

Traits	Mean			Range			% Reduction	
	N	MS	HS	N	MS	HS	MS	HS
Plant (cm)	119.19	88.35	60.39	106 (RIL 188) - 139.20 (RIL 183)	66.70 (RIL 147) - 108.9 (RIL Height 33)	36.50 (RIL 48) - 87.33 (RIL 143)	25.87	49.33
Panicle length (cm)	27.17	22.26	15.95	23.44 (Trichy) - 31.0 (RIL 187)	17.0 RIL 63) - 27.80 (RIL 156)	8.50 (RIL 213) - 25.33 (RIL 143)	18.04	41.28
Total tillers /plant	8.38	6.42	4.76	5.6 (RIL 127) - 14.90 (RIL 215)	4.2 (RIL 26) - 11.35 (RIL 173)	2.0 (RIL 60) - 7.23 (RIL 129)	23.36	43.16
Productive tillers/plant	7.38	5.79	3.41	4.8 (RIL 197) - 13.90 (RIL 215)	3.0 (RIL 37) - 10.20 (RIL 129)	1.0 (RIL 85) - 6.04 (Trichy)	21.54	53.77
Grains per panicle	103.33	56.75	22.99	44.90 (RIL 45) - 165.9 (RIL 156)	22.5 (RIL 109) - 112.10 (RIL 156)	0.75 (RIL 194) - 71.8 (RIL 180)	45.08	77.75
Spikelet fertility (%)	77.20	61.41	32.86	25.93 (RIL 109) - 92.67 (RIL 107)	25.41 (RIL 109) - 79.79 (RIL 2)	1.06 (RIL 194) - 74.25 (RIL 93)	20.45	57.44
Biological yield per plant (g)	37.99	20.09	11.84	21.80 (RIL 5) - 73.80 (RIL 87)	9.35 (RIL 37) - 33.60 (RIL 84)	3.80 (RIL 123) - 26.60 (RIL 42)	47.12	68.84
Grain yield per plant (g)	9.88	3.84	1.51	3.50 (RIL 109) - 22.55 (RIL 31)	0.77 (RIL 150) - 8.40 (RIL 43)	0.10 (RIL 81) - 5.80 (RIL 42)	61.16	84.69
Harvest index (%)	25.91	18.56	12.69	12.95 (RIL 169) - 39.72 (RIL 156)	6.13 (RIL 150) - 30.37 (RIL 127)	1.56 (RIL 205) - 25.36 (RIL 97)	28.36	51.02

Note: N- Normal soil; MS- Moderately sodic (pH_2 ~ 9.5); HS- Highly sodic (pH_2 ~ 9.9)

Table 34: Top 10 RILs showing less % reduction for grain yield under moderate and high sodicity stresses

S. No.	Moderate Sodicity (pH_2 9.5)		High Sodicity (pH_2 9.9)	
	Genotypes	% reduction	Genotypes	%reduction
1	RIL 32	20.23	RIL 27	35.23
2	RIL 127	22.40	RIL 93	47.93
3	RIL 100	29.47	RIL 42	51.05
4	RIL 8	29.56	RIL 140	51.41
5	RIL 82	29.57	RIL 22	58.90
6	RIL 97	30.11	RIL 97	64.58
7	RIL 109	30.86	RIL 13	66.86
8	RIL 140	33.76	RIL 67	66.98
9	RIL 27	34.46	RIL 95	67.58
10	RIL 93	34.67	RIL 135	67.89

total tillers per plant, productive tillers per plant, spikelet fertility and panicle length under moderate sodicity stress. The grain yield reduced by 84.69% under high sodicity stress followed by grains per panicle, biomass, spikelet fertility, productive tillers per plant, harvest index, plant height, total tillers per plant and panicle length. The grain yield ranged from 3.50 (RIL 109) to 22.55 (RIL 31), 0.77 (RIL 150) to 8.40 (RIL 43) and 0.10 (RIL 81) to 5.80 (RIL 42) under normal, moderate and high sodicity, respectively. The spikelet fertility ranged from 25.93 (RIL 109) to 92.67 (RIL 107), 25.41 (RIL 109) to 79.79 (RIL 2) and 1.06 (RIL 194) to 74.25 (RIL 93) under normal, moderate and high sodicity, respectively. The top 10 lines based on grain yield under normal, moderate sodicity and high sodicity stresses were identified. The top 10 lines showing the least per cent reduction for grain yield under moderate and high sodicity stresses are presented in Table 34.

Stress tolerant rice for poor farmers of Africa and South Asia (STRASA phase 3) (S.L. Krishnamurthy, P.C. Sharma and Ravi Kiran, K.T.)

The experimental material comprised of 60 rice

genotypes collected from various national and international institutes to assess their performance under saline and sodic stresses. The genotypes were evaluated in augmented block design with 15 entries per block during *Kharif* 2016 under two environments *viz.*, high salinity stress (EC_{iw}~10 dS m^{-1}) and high sodicity (pH_2 ~9.9) in microplots at Karnal. Six checks were repeated across four blocks. The 35-day old seedlings from wet bed nurseries were transplanted @ two seedlings per hill with a spacing of 15 × 20 cm. Basal fertilizers for the main crop was 120-60-60 kg of NPK ha^{-1}. The recommended package of agronomic practices was followed to raise a healthy crop. Twenty one days after the transplanting, salinity was imposed by using 7 NaCl: 1 Na_2SO_4: 2 $CaCl_2$ on equivalent basis. Five randomly selected plants were tagged from each genotype and data were recorded for different traits: days to 50% flowering, plant height (cm), total tillers/plant, productive tillers/plant, panicle length (cm), stress score at reproductive stage and grain yield (kg ha^{-1}).

Under saline stress, days to 50% flowering ranged from 87 (KR 15006) to 131 (KS 12) with a mean of 106.48. Plant height (cm) varied from 22.4 (CR 2850-S-2B-12-1-2-1) to 91 (CSRC(S)47-7-B-B-1-1) with a mean of 58.42. Panicle length (cm) ranged from 7.8 (CSAR 1604) to 24 (CR3884-244-8-5-6-1-1) with a mean of 13.91. Total tillers varied from 2.2 (PAU 3835-12-1-1-1, CR3884-244-8-5-11-1-4 & CSR-2748-197) to 6.6 (IR84649-81-4-1-3B-CR3397-S-B-4B-1) with a mean of 3.62. Productive tillers ranged between 0.4 (CSR-2748-197) to 5.6 (IR84649-81-4-1-3B-CR3397-S-B-4B-1) with a mean of 1.85 and the grain yield (kg ha^{-1}) varied between 308.67 (CSR-2748-197) to 1577.21 (CSR-2748-4441-66) with a mean of 455.33 (Table 35). The best five genotypes under saline stress in terms of yield advantage were CSR-2748-4441-66, CSR-2748-4441-111, CR3884-244-8-5-6-1-1, CSR-2748-4441-115 and IR84649-81-4-1-3B-CR3397-S-B-4B-1. Thirteen genotypes did not flower. Under sodicity stress, days to 50% flowering ranged from 89 (KR 15006) to 130 (CR3903-161-1-3-2) with a mean of 104.55. Plant height (cm) varied from 29.2 (CR 2851-S-1-B-4-1-1-1-1) to 103.8 (CR3881-4-1-6-3-4-1) with a mean of 74.54. Panicle length (cm) ranged from 15 (RP-106-22-4-1-3) to 27 (CR3879-3-1-6-1-3-1 & TR 09027) with a mean of 19.69. Total tillers

Table 35. Mean performance of genotypes under saline stress (ECiw ~ 10 dSm^{-1})

Characters	Mean	Minimum	Maximum	S.D	S.Em
Vigour score	7.04	5.0	9.0	1.78	0.19
Days to 50% flowering	106.48	87	131	42.74	4.72
Plant height (cm)	58.42	22.4	91.0	15.34	1.67
Panicle length (cm)	13.91	7.8	24	7.25	0.79
Total tillers	3.62	2.2	6.6	0.95	0.10
Productive tillers	1.85	0.4	5.6	1.36	0.15
Grain yield (kg ha^{-1})	455.33	308.67	1577.21	514.93	56.18

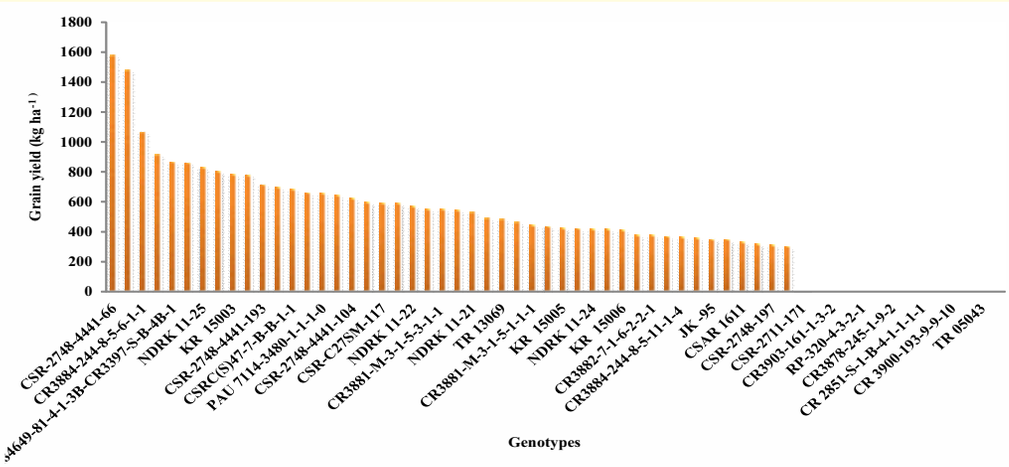


Fig. 26: Performance of STBN entries in high alkalinity (pH ~ 9.9)

varied from 3.2 (CR3882-7-1-6-2-2-1) to 7.6 (RP-320-4-3-2-1) with a mean of 5.07. Productive tillers ranged between 0.2 (CR3909-192-1-7-2) to 6.6 (CARI Dhan 6) with a mean of 3.67 and the grain yield (kg ha^{-1}) varied between 608.67 (RP-106-22-4-1-3) to 2203 (CSR-2748-4441-72) with a mean of 747.19. The best five genotypes in terms of yield advantage under sodic stress were CSR-2748-4441-72, IRRI-147, CSAR 1610, KR 15006 and CR3884-244-8-5-11-1-4 (Fig. 26). Five genotypes did not reach flowering stage and grain yield was not obtained from five other genotypes.

Novel Genetics Stocks: Multi-parent advanced generation inter-crosses (MAGIC) among diverse genotypes to facilitate gene discovery for various traits in rice (S.L. Krishnamurthy and P.C. Sharma)

The main aim of this project is to tag essential novel salinity, bacterial blight (BB) and brown spot QTLs using the MAGIC population through phenotyping and genotyping. This is a collaborative work between IRRI, Philippines, ICAR-CSSRI, Karnal (for salinity screening), ICAR-IIRR, Hyderabad and ANGRAU, Rice Research Station, Maruteru. A set of 395 genotypes received from IRRI, Philippines in 2015 along with 6 checks were phenotyped for reproductive stage salinity tolerance. The genotypes were evaluated in augmented block design with 72 entries per block during *Kharif* 2016 under two environments *viz*., moderate salinity (EC_{iw} ~ 6 dSm^{-1}) and high salinity (EC_{iw} ~ 10 dSm^{-1}) in microplots at Karnal. Six checks were repeated across six blocks. The 35-day old seedlings from wet bed nurseries were transplanted @ two seedlings per hill with a spacing of 15 × 20 cm. Basal fertilizers for the main crop was 120-60-60 kg of NPK ha^{-1}. The recommended package of agronomic practices was followed to raise a healthy crop. Twenty one

Table 36: Top 10 genotypes in terms of grain yield (kg ha^{-1}) under moderate saline and high saline conditions

S. No.	Moderately saline	Highly saline
1	IR93335:48-B-15-5-15-1RGA-2RGA-1-B-B	IR93341:9-B-19-10-4-1RGA-2RGA-1-B-B
2	IR93327:32-B-19-25-12-1RGA-2RGA-1-B-B	IR93347:5-B-7-3-10-1RGA-2RGA-1-B-B
3	IR93337:48-B-18-20-13-1RGA-2RGA-1-B-B	IR93350:37-B-10-16-4-1RGA-2RGA-1-B-B
4	IR93341:9-B-19-10-4-1RGA-2RGA-1-B-B	IR93342:37-B-21-18-8-1RGA-2RGA-1-B-B
5	IR93346:26-B-20-8-2-1RGA-2RGA-1-B-B	IR93349:31-B-4-11-21-1RGA-2RGA-1-B-B
6	IR93340:1-B-10-13-10-1RGA-2RGA-1-B-B	IR93354:14-B-9-8-6-1RGA-2RGA-1-B-B
7	IR93350:43-B-23-16-12-1RGA-2RGA-1-B-B	IR93349:14-B-6-5-4-1RGA-2RGA-1-B-B
8	IR93327:6-B-17-5-20-1RGA-2RGA-1-B-B	IR93353:14-B-8-12-8-1RGA-2RGA-1-B-B
9	IR93328:20-B-8-22-7-1RGA-2RGA-1-B-B	IR93335:10-B-12-16-9-1RGA-2RGA-1-B-B
10	IR 93349:14-B-6-5-4-1RGA-2RGA-1-B-B	IR 93337:36-B-14-20-13-1RGA-2RGA-1-B-B

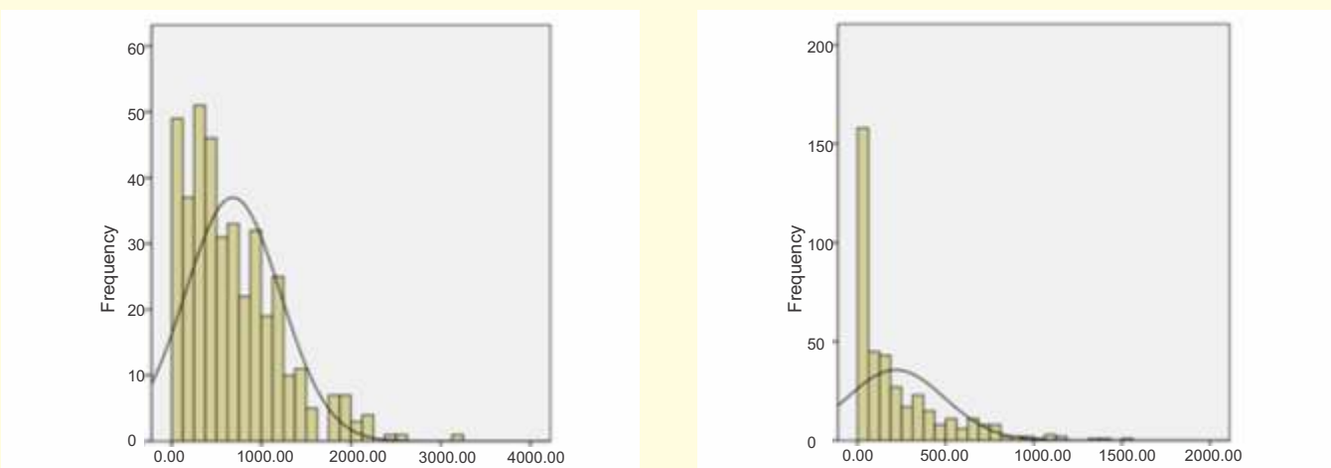


Fig. 27. Frequency distributions of genotypes for grain yield (kg ha^{-1}) under moderate saline (a) and high saline (b) conditions.

days after the transplanting, salinity was imposed by using 7 NaCl: 1 Na_2SO_4: 2 $CaCl_2$ on equivalent basis. Five randomly selected plants were tagged from each genotype and data were recorded for different traits: days to 50% flowering, plant height (cm), total tillers/ plant, productive tillers/plant, panicle length (cm), stress score at reproductive stage and grain yield (kg ha^{-1}).

The frequency distributions for grain yield under moderate and high saline stresses (Fig. 27a and 27b) showed that both these distributions were skewed towards low yielding side with majority of the genotypes suffering from yield loss due to stress. Grain yield (kg ha^{-1}) ranged from 20.00 (IR 93353:32-B-21-17-1-1RGA-2RGA-1-B-B & IR 93329:45-B-14-13-10-1RGA-2RGA-1-B-B) to 3139.69 (IR 93335:48-B-15-5-15-1RGA-2RGA-1-B-B) under moderate saline condition with a mean of 786.67 kg ha^{-1}. Sixteen genotypes did not give any grain yield. Under high saline condition, grain yield (kg ha^{-1}) varied from 6.67 (IR 93337:39-B-10-19-17-1RGA-2RGA-1-B-B) to 1519.85 (IR 93341:9-B-19-10-4-1RGA-2RGA-1-B-B) with a mean of 236.04 kg ha^{-1}. Nearly 122 genotypes did not give any grain yield under high salinity. Top 10 genotypes under moderate and high saline conditions are given in Table 36. Interestingly, one genotype (IR93341:9-B-19-10-4-1RGA-2RGA-1-B-B) was found in the top 5 under both moderate and high salinity treatments. It was ranked 4th under moderate salinity and 1st under high salinity treatment and can be a promising genotype for future use.

CRP on Agrobiodiversity - Evaluation of rice germplasm for salinity/sodicity (S. L. Krishnamurthy, P. C. Sharma and Ravi Kiran, K.T.)

A total of 1200 genotypes including two checks (IR 29- sensitive check and FL478- tolerant check) received from IIRI, Hyderabad were phenotyped for seedling stage salinity tolerance in 2016. Out of 1200 genotypes, 4 did not germinate. Screening for salt tolerance at seedling stage was performed in hydroponics using Yoshida culture solution under controlled conditions in the transgenic glasshouse having 29-35°C/21°C day/night temperature. The nutrient solution was salinized (EC ~ 12 dS m^{-1}) on 14th day after sowing by adding NaCl salt. Standard Evaluation Score (SES), root and shoot lengths were measured on 28th day after sowing. The mean, maximum and minimum values of the recorded traits during 2016 are presented in Table 37.

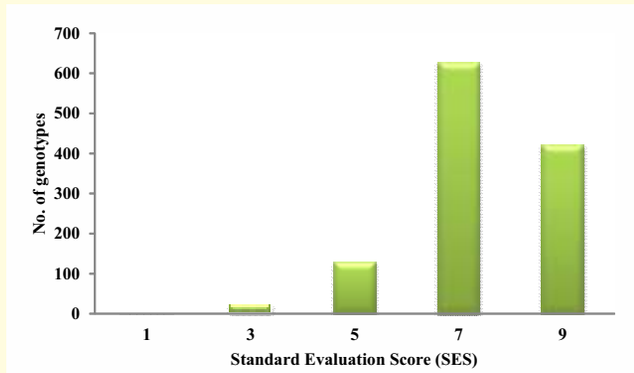


Fig. 28. Frequency distribution of genotypes for different standard evaluation scores (SES)

Shoot and root lengths reduced in the salinized plants. Vigour score (SES) ranged from 3 to 9 under saline conditions. A total of 22 genotypes were found tolerant (score-3), 127 genotypes were moderately tolerant (score-5), 626 were moderately sensitive (score-7) and 421 genotypes were highly sensitive (score-9) (Fig 28). Shot length ranged from 9.13 to 53.17 cm with a mean of 37.48 cm. The range of root length is from 3.73 to 52.93 cm with a mean of 16.03.

Evaluation of BAYER rice hybrids under salinity stress (Consultancy project) (P.C. Sharma, S.L. Krishnamurthy and D. K. Sharma)

Two hybrids, ARIZE 6444GOLD and INH 15126

Table 37: Summary statistics for root length, shoot length and SES recorded on 1200 rice gentoypes

Parameter	Vigour score	Root length	Shoot length
Mean	7.41	16.03	37.48
Maxiumum	9.00	52.93	53.17
Minimum	3.00	3.73	9.13
S.D.	1.04	5.04	6.48
S.Em	0.04	0.14	0.18

Table 38: Mean performance of BAYER hybrids along with checks under normal, moderately salinity, high salinity, moderate sodicity and high sodicity treatments

Genotypes	Mean yields in kg ha^{-1}				
	T1	T2	T3	T4	T5
ARIZE 6444GOLD	6942	2301	753	3137	1458
INH 15126	6726	2633	768	2748	1565
CSR 27	6697	2805	1241	3276	1730
CSR 36	6898	2496	834	3325	2472
VSR 156	3496	247	0	1117	340
CD (P=0.05)					
Genotypes (G)	70.56				
Salinity (S)	64.41				
G × S	157.78				

Note: T1- Normal soil, T2- Moderate salinity (EC_e- 6.0 dS m^{-1}), T3- High salinity (EC_e- 10.0 dS m^{-1}), T4- Moderate sodicity (pH_2- 9.5) and T5- High sodicity (pH_2- 9.9).

received from Bayer Crop Sciences, Hyderabad were tested under fives stress levels: normal (pH_2- 7.5; EC_e- 1.0 dS m^{-1}), moderately saline (pH_2- 7.5; EC_e- 6.0 dS m^{-1}), highly saline (pH_2- 7.5; EC_e- 10.0 dS m^{-1}), moderately sodic (pH_2- 9.5; EC_e- 1.0 dS m^{-1}) and highly sodic (pH_2- 9.9; EC_e- 1.0 dS m^{-1}) in the microplots at Karnal during *Kharif*, 2016. In normal soil, ARIZE 6444GOLD showed the highest grain yield of 6942.5 kg ha^{-1} (Table 38); while under moderate and high salinity conditions, entry CSR 27 topped among all the genotypes with a grain yield of 2805 kg ha^{-1} and 1241 kg ha^{-1}, respectively. Under moderate and high sodic conditions, CSR 36 performed best with mean grain yield of 3324 kg ha^{-1} and 2472 kg ha^{-1}, respectively. VSR 156 was the most sensitive genotype under all the stress levels and showed the highest yield reduction as compared to normal. The Bayer hybrids could give at par yield with the check only under moderate stress levels. Under higher stress levels, their performance was significantly lower than the respective checks. Among the hybrids, INH 15126 was found promising under stress conditions compared to others.

Establishment of National Rice Resource Database (S. L. Krishnamurthy and Joginder Singh)

Based on the evaluation of about nine thousand accessions of rice for 30 DUS characters during the previous years, a mini-core of 1503 accessions was selected for further evaluation and characterization in an augmented design under sodic condition (pH_2~ 9.6) during 2015-16 crop season at Karnal. Experiment was conducted in an augmented design and each accession was planted in three rows of 3.0 m length. Spacing of 20 x 15 cm was followed. Out of these 1503, only 994 accessions germinated. Data were recorded for the seven traits: vigour score, plant height (cm), panicle length (cm), grain yield (kg ha^{-1}), total tillers plant^{-1}, productive tillers plant^{-1} and biological yield plot^{-1} (g). Out of 994 genotypes, 18 (2%), 71 (7%), 836 (84%) and 69 (7%) were found to be tolerant, moderately tolerant, moderately sensitive and highly sensitive, respectively. The mean plant height among 994 genotypes was 99.02 cm with a range of 22.0 cm (IC 577109) to 163 cm (IC 554839). A range of 10 cm (IC 466460) to 37 cm (IC 467132) was observed for panicle length with the mean value of 20.15 cm. Total tiller plant^{-1} exhibited a wider variation ranging from 2 (IC 577874) to 17 (IC 267428) with an average value of 6.94. A range of 1.0 (IC 577874) to 15 productive tillers/plant (IC 267428) was observed for productive tillers plant^{-1} with the mean value of 5.8. Grain yield ha^{-1} exhibited a wider variation ranging from 24.24 (IC 554843) to 5454.0 kg ha^{-1} (IC 337555) with an average value of 1026.60. Harvest index (%) ranged from 0.17 (IC 300134) to 38.1 (IC 497113) with a mean of 15. Top ten genotypes showing the best trait values of yield and important yield contributing characters are given in Table 39. The genotypes, IC 337555, IC 491396, IC 337560, IC 260917, IC 579020, IC 413609, IC 463068, IC 298569, IC 335860 and IC 145594 were the best performers for grain

Table 39: Top ten best performing accessions based on various traits under sodic stress at Karnal

S. No.	IC NO.	Grain yield (Kg ha^{-1})	IC NO.	Panicle Length (cm)	IC NO.	Total Tillers per plant
1	337555	5.45	467132	37	267428	17
2	491396	5.43	382568	32	565307	16
3	337560	5.42	580399	31	580228	15
4	260917	5.22	577577	31	579042	14
5	579020	5.10	577807	31	497108	14
6	413609	4.84	335860	31	545419	14
7	463068	4.85	337614	31	98834	14
8	298569	4.69	267428	30	256522	14
9	335860	4.62	335396	30	450592	14
10	145594	4.62	449994	30	145420	14

yield. The dispersion of various characters was depicted using box plots (Fig. 5) and the maximum variation was found for harvest index while the least for panicle length. Significant numbers of outliers were found for the grain yield. Near normal distributions were obtained for plant height and panicle while the remaining characters showed skewed distributions.

Genetic enhancement of wheat with respect to salt and waterlogging tolerance (Arvind Kumar, P. C. Sharma, Y. P. Singh and Indivar Parsad)

Special Trial- Alkalinity/Salinity Tolerance (Irrigated- Timely Sown) 2015-16

During *Rabi* 2015-2016, the special trial on salinity/alkalinity comprising of 7 entries (DBW 216, NW 6094, WH 1310, DBW 215, KA 1427, DBW 217 and DBW 214) and three checks (KRL 19, KRL 210 and Kharchia 65) was conducted across three zones NWPZ, NEPZ and CZ at 11 locations (Bawal, HAU Hisar, IIWBR Hisar, CSSRI Karnal, CSSRI Nain Experimental Farm Panipat, Muktsar, Dalipnagar, Faizabad, Lucknow, Vanasthali and Bharuch). None of the new entry produced yield statistically at par with the check variety KRL 210 (3.0 t ha^{-1}, zonal mean). Therefore, no tested entry was promoted for the second year testing under salinity/alkalinity tolerance varietal trial 2016-17.

Salinity/Alkalinity Tolerance Screening Nursery (SATSN) trial 2015-16

The nursery comprising of 55 test entries, obtained from different wheat breeding centres of the country, was evaluated along with 3 salt tolerant checks (Kharchia 65, KRL-19 and KRL 210), one national check (HD 2967) and one sensitive check (HD 2009) in an Augmented Randomized Block Design having 5 blocks with plots of 2 m length having 3 rows spaced 20 cm apart. This nursery trial was conducted at 8 locations in three states *viz*., Haryana (CSSRI-Karnal, CSSRI-Nain Panipat, Bawal, HAU-Hisar, and IIWBR-Hisar), Uttar Pradesh (Faizabad, Dalipnagar and Lucknow) and Gujarat (CSSRI-Bharuch). On the basis of pooled analysis, KRL 377 was the highest yielding entry followed by WS 1505. Thirteen entries showed better performance for grain yield as compared to the best check KRL 210. However, 5 entries *viz*., WS 1505 (LR-ACI-23.2), KRL 373 (YR-ACI-15.1), WH 1315 (YR-ACI-15.3), KRL 389 (YR-ACI-21.9) and KRL 383 (YR-ACI-28.8) showed the high incidence of rust (Table 40).

Introgression of desirable traits for improving yield, disease resistance and salt tolerance

During the crop season, a total of 280 single crosses were attempted between 40 parents (25 salt tolerant lines developed by CSSRI and 15 higher yielding and disease resistant cultivars from different sources) primarily for improving the yield and adaptation to marginal lands (salt affected, waterlogged and elemental toxicities) and resistance to rusts. About 5-6 spikes were attempted for each cross. During this season, F_1 generations are to be grown and advanced. Shuttle breeding approach will be used to identify potential combinations for the high yield and adaptation to marginal lands and also to make site

Table 40: Pooled yield and rust reactions of promising test entries in SATSN 2015-16

S. No.	Entry	Yield (g plot^{-1})	Stem Rust		Leaf Rust (S)		Leaf Rust (N)		Strip Rust	
			HS	ACI	HS	ACI	HS	ACI	HS	ACI
1	KRL 377	586.2	5S	1.4	5S	1.2	10S	2.0	40S	12.8
2	WS 1505	576.9	15S	7.0	80S	23.2	40S	22.2	0	0.0
3	WS 1504	550.2	tR	0.1	30S	6.8	10MS	1.6	0	0.0
4	RWP 2015-17	537.0	30MS	11	20S	8.2	0	0.0	80S	11.3
5	KRL 370	535.5	10S	2.6	2MS	3.2	0	0.0	20S	5.6
6	KRL 373	534.8	5S	1.3	tR	0.1	0	0.0	40S	15.1
7	WH 1316	534.4	5S	1.3	20S	7.6	20S	4.8	10S	2.7
8	WH 1315	531.6	30MR	7.3	15MS	2.4	0	0.0	60S	15.3
9	KRL 389	523.9	5MS	1.6	15MS	4.0	0	0.0	60S	21.9
10	WS 1501	523.4	30S	11.6	10MS	3.4	40S	8.0	40S	12.5
11	KRL 383	520.7	5MS	1.6	tR	0.1	0	0.0	60S	28.8
12	KRL 384	519.0	15MR	1.6	20S	5.2	0	0.0	30S	8.8
13	KRL 386	518.0	10S	3.1	10S	4.2	0	0.0	40S	7.5
	Checks									
C1	KRL 19	459.6								
C2	Kharchia 65	459.2								
C3	KRL 210	516.8								
C4	HD 2009	430.8								
C5	HD 2967	501.5								

Note: HS- Highest Score; ACI-Average coefficient of infection, S- Susceptible, tR- Traces, MR- Moderately resistant, MS- Moderately susceptible

specific selections.

Screening of segregating and advanced generation crosses:

During the crop season, the breeding materials were evaluated with four checks namely KRL 210, KRL 213, KRL 283 and KRL 1-4 and selections were made on the basis of disease response and other desirable attributes (Table 41).

Breeder and nucleus seed production

Breeder seed of CSSRI varieties KRL 210 (2.1 t) and KRL 213 (2.71 t) was produced for distribution to various seed producing agencies and also for the production of TL seeds for further distribution to different agencies and farmers. Nucleus seed of 20

Table 41: Selections made in different generations at CSSRI

Generation	Cross combination	Selections made
F_1	280	85
F_2	81	50 single spikes
F_3	31	30 single spikes
F_4	41	20 single spikes
F_5	10	15 single spikes
F_6	42	10 single spikes
F_7	27	Bulk seed
F_8	13	Bulk seed
F_9	14	Bulk seed
F_{10}	13	Bulk seed
F_{11}	11	Bulk seed

lines (KRL entries) and of four released varieties (KRL 1-4, KRL19, KRL 210 and KRL 213) was also produced at CSSRI Experimental Farm for use in the next season.

Evaluation of advance generation bulks in CSSRI station Trial 2015-16

During the crop year 2015-16, 80 advance generation bulks were tested in Increased Block Design (Augmented Randomized Block Design) with 5 checks (KRL210, KRL 213, WH1105, HD3086, HD2967 and WH1310) with the plot size of 3 rows of 2 m length under normal (~pH2 <8.2), and two salt stress environments: saline (5.1- 16.2 dS m^{-1}) at Nain Experimental Farm and sodic (pH_2 >9.4) with waterlogging (WL) treatment in the field. The WL treatment was imposed at 21 days after sowing (DAS). Plants were watered weekly prior to WL treatment. When WL commenced, water was maintained 5-7 cm above the soil surface. Out of 80 advance bulks, 20 genotypes performed better than checks. On the basis of yield performance and other desirable traits, 20 bulks were selected for further evaluation in the Salinity/Alkalinity Tolerance Screening Nursery (SATSN) and Initial Plant Pathological Screening Nursery (IPPSN) 2016-17 (Table 42).

Evaluation of wheat varieties for salt stress in microplots

Thirty five wheat varieties were evaluated for their performances under different salt and waterlogging stresses *i.e.*, normal (pH_2 ~8.2), normal (pH_2 ~8.2) + 20 days waterlogging, saline (EC_e >5.9 dS m^{-1}), sodic (pH_2 9.3-9.6) and sodic (pH_2 9.2-9.4) + 20 days waterlogging in the microplots. Each genotype was replicated two times. The genotypes KRL 330, KRL 3-4, KRL 99, KRL 377, KRL 210, KRL 393, KRL 376, KRL 384, KRL 385 and BH 1146 were found to be tolerant whereas KRL 119, KRL 213, HD 2967 and KRL 351 were found to be moderately tolerant. DW 1, DW 3, HD 2009, Brookton, Ducula 4, HD 2851 and HD 4530 were ranked as the sensitive genotypes.

Table 42: Advanced entries selected from CSSRI station trial conducted during 2015-16

KRL line	Pedigree
KRL 390	HW2045/KRL99
KRL 391	AKW2662-2/Kharchia 65
KRL 392	KRL 99/ HD 2851
KRL 393	KRS 9382/PBW 621
KRL 394	VL486/BT Schomburgk
KRL 395	SOKOLL*2/4/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/STAR
KRL 396	KRL 99/HW 2045
KRL 397	QG4.37A/4/MILAN/KAUZ//PRINIA/3/BAV92/5/MILAN/KAUZ//PRINIA/3/BAV92
KRL 398	CNO79//PF70354/MUS/3/PASTOR/4/BAV92*2/5/HAR311
KRL 399	KRL 99/ PBW 525-88
KRL 400	KRL 210/BH 1146 F6
KRL 401	KRL 302/HD 2967
KRL 402	KRL 342/ KRL 304
KRL 403	KRL 302/KRL 337
KRL 404	KRL 99/FLW 4
KRL 405	ATTILA*2/PBW65*2/4/CROC_1/AE.SQUARROSA (205)//BORL95/3/2*MILAN
KRL 406	HW 2045/KRL 99
KRL 407	KVZ/PPR47.89C//FRANCOLIN #1/3/2*PAURAQ/5/BAV92//IRENA/KAUZ/3/HUITES*2/4/MURGA
KRL 408	TRCH/5/REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES/6/IWA8600211/ /2*PBW343*2/KUKUNA/7/PBW343*2/KUKUNA*2//FRTL/PIFED
KRL 409	INQALAB 91*2/TUKURU//T.SPELTA PI348599/3/2*INQALAB 91*2/KUKUNA/4/KINGBIRD #1//INQALAB 91*2/TUKURU

Table 43: Observed and Adjusted yield (g^{-m}) of common out yielder germplasm of bread wheat in rain fed and sodic stress conditions

S.No.	Germplasm name	Under rainfed condition		Under sodic condition	
		Observed Y_{ij}	Adjusted $\hat{Y}_{ij}$	Observed Y_{ij}	Adjusted $\hat{Y}_{ij}$
1.	KRS-611	458.60	418.63	215.00	211.70
2.	KRL-105	288.80	271.07	158.40	153.20
3.	IC535493	188.80	249.20	135.00	152.00
4.	EC463441	258.60	319.00	136.00	150.20

Bread wheat germplasm evaluation for salt tolerance under sodic condition (pH 8.8- 9.1)

Fifteen hundred and thirteen bread wheat germplasm lines were evaluated under sodic conditions (pH 8.8-9.2) with 5 checks (KRL 3-4, Kharchia 65, C-306, HD 2967, RAJ 3765) for salt tolerance through potential yield efficiency under mild salt stress. The experiment was conducted at CSSRI Experimental Farm, Karnal during the 2015-16 cropping season in an augmented design with seventeen blocks. The adjusted grain yields of 11 germplasm lines (IC405226, IC443722, IC279230, IC572928, IC554661, IC47550, IC416168, IC535493, EC463441, KRS-611, and KRL-105) were higher than salt tolerant check (Kharchia 65). These lines can be considered as an important source of genes for developing salt tolerant and high yielding wheat varieties. Four germplasm lines outperformed others under both sodic and rainfed conditions (Table 43). These selected germplasm can be considered as an important source for abiotic stress tolerance and to develop climate smart wheat varieties. Moisture and salt stress tolerant germplasm are under advance wheat yield trial for validation of grain yield against multiple stresses in comparison to salt tolerant checks.

Bread wheat germplasm evaluation for soil moisture stress tolerance under rainfed condition

A preliminary yield trial was conducted with 1358 bread wheat germplasm including four national checks (C-306, KRL 210, HD 2967 and Kharchia 65) for higher yield potential in order to incorporate the high yielding moisture stress tolerant genotypes as donor in the wheat improvement program. The experiment was conducted at CSSRI Experimental Farm, Karnal under rainfed conditions during 2015-16 cropping season. The new germplasm were compared against four standard varieties using an augmented design with fifteen blocks. The adjusted grain yield of 62 germplasm (38 accessions of NBPGR and 24 salt

Table 44 : Promising wheat germplasm for various traits identified in the germplasm pool under rainfed condition

Traits	Criteria*	Germplasm accessions
YLD	>Mean+2.576SD (>238 g)	EC463441, EC534443, EC609338, IC543290, IC321905, IC535493, IC547643, KRS-611, KRL-112, KRL-105, KRL-136, KRL-119, KRS-621, KRL2-10, KRL-340, KRL-90, KRL-35
NET	>Mean+2.576SD (>137)	IC534198, IC279060, IC564126, IC78926, IC279328, IC543290, IC542983,IC310071, ,IC430369, IC536339, IC533809, IC585637, IC138543, IC469480, IC393128 IC535350, IC542968, IC279030, IC543262, EC217847, EC575756, EC218116, EC575648, EC374915, EC534433, EC534528, EC557001, EC575737, EC575712, EC217899, KRL-136, KRL-112, KRL-2-22
DH	<Mean -1.96SD (<76 Days)	IC282300, IC539399, IC111959, IC111914, IC128388, IC398067, IC402048, IC543367, IC415861, IC524288, IC408334, EC578119

Note: YLD- grain yield m-1, NET- number of effective tillers, DH- Days to heading
*In normal distribution, 95% of the population is within 1.96 standard deviations of the mean
* In normal Distribution 99% of the population is within 2.576 standard deviations of the mean

tolerant lines of CSSRI) were higher than the best check (C-306). However, 17 genotypes (EC463441, EC534443, EC609338, IC543290, IC321905, IC535493, IC547643, KRS-611, KRL-112, KRL-105, KRL-136, KRL-119, KRS-621, KRL2-10, KRL-340, KRL-90 and KRL-35) were found to be the most desirable for yield potential. While 33 accessions had higher number of effective tillers than others, 12 accessions (IC282300, IC539399, IC111959, IC111914, IC128388, IC398067, IC402048, IC543367, IC415861, IC524288, IC408334 and EC578119) were outperformers with regard to earliness (Table 44). These germplasm lines can be considered as an important source of genes for earliness, higher number of effective tillers and higher grain yield for wheat improvement programmes for abiotic stress tolerance. Non-significant differences for grain yield between the salt tolerant (KRL 210 and Kharchia 65) and drought tolerant (C-306) checks showed co-existence of salt and water stress tolerance in KRL 210 and Kharchia 65. Although both the cultivars were developed for salt prone areas, they seem to be suitable for cultivation under low soil moisture conditions. These screened germplasm lines are under advance wheat yield trial for validation of grain yield against multiple drought tolerant checks.

Molecular genetic analysis of resistance/ tolerance to different stresses in Rice, Wheat, Chickpea and Indian mustard including sheath blight complex genomics (Rice) Wheat (Sub-project 2)- CSSRI, Karnal (P. C. Sharma, Arvind Kumar and Ashwani Kumar)

A fixed population of Recombinant Inbred Lines (280 RILs) of *T. aestivum* was developed from a cross between wheat varieties KRL 99 and PBW 525 by the single seed descent method. Phenotyping of KRL 99/PBW 525 RILs for salt tolerance parameters were commenced on the stabilized F_8 plants of 280 RILs along with two parents. The phenotyping was performed in *Rabi* 2015-16 under field conditions: high sodicity (pH ~ 9.3) and normal soil (pH ~ 7.89-8.10) at CSSRI Experimental Farm, Karnal. The desired level of sodicity (pH ~ 9.3) simulating the natural field conditions was created by adding required amounts of $NaHCO_3$ in the soil. The KRL 99/PBW 525 RIL population was phenotyped for grain yield response index (GYRI) and genotypic core and other salt tolerance parameters. Data were recorded for plant height (PH), ear length (EL), spikelets ear^{-1} (SLE), biomass (BM), ear weight (EW), harvest index (HI), ear filling rate (EFR%), chlorophyll content (SPAD) and ion contents (Na^+, K^+, Ca^+, Mg^+) on five culms from each RIL plot. However data on grain yield (g) and other component traits namely, days to anthesis (DA), days to maturity (DM), number of tillers and number of ear heads were recorded on per plot basis during *Rabi* 2015. Four salt tolerance indices, namely, Vegetative Growth Rate Index-VGI [= (biomass yield - grain yield)/days to anthesis), Grain Yield Response Index (GYRI) (= Average grain yield (Table 45) of the genotype/mean yield of the genotype), Tolerance Index (TI) (= Yield of the genotype in stress/yield of the genotype in non-stress condition) and Genotypic Score (GS)(=

Table 45: Top 10 and bottom 10 RILs based of grain yield response index (GYRI)

Based grain yield response index (GYRI)			
Top 10		Bottom 10	
RILs	GYRI	RILs	GYRI
SSD1-311	2.253	SSD1-31	0.304
SSD1-176	2.240	SSD1-37	0.288
SSD1-168	2.234	SSD1-129	0.283
SSD1-177	2.182	SSD1-247	0.262
SSD1-310	2.103	SSD1-35	0.257
SSD1-164	2.067	SSD1-17	0.220
SSD1-166	2.025	SSD1-22	0.205
SSD1-45	1.920	SSD1-36	0.205
SSD1-59	1.857	SSD1-16	0.173
SSD1-302	1.836	SSD1-23	0.168

GYRI x TI) were used for the screening of the stress tolerant RILs. Twenty each of the most tolerant and most sensitive RILs of KRL 99/PBW 525 mapping population were identified based on GYRI for GY .

Proprieties of the trait distribution were estimated by ANOVA analysis. According to Kurtosis and Skewness estimation, trait distribution reflects the variability observed between studied lines. Some RILs had more extreme values than the parental lines showing a transgressive segregation; this is obvious for all traits under salt-stressed conditions. All traits showed transgressive segregation and their phenotypic values exceeded the mean parental values (Table 46).

The stress intensity (SI) for grain yield under high sodicity (pH ~9.3) as compared to normal (pH ~7.80-8.10) was 0.62. KRL 99 x PBW 525RIL populations showed significant variability for the 15 salt tolerance parameters examined. RIL population showed mean grain yield of 101.75, and 38.13 under normal and high sodicity, respectively. Tolerant parent KRL 99 showed the mean yield of 107.42 and 67.76; whereas the sensitive parent PBW 525 expressed mean yield of 89.48 and 36.28 under normal and high sodicity, respectively. Tolerant parent KRL 99 showed significantly less grain yield reduction of 36.92% than the susceptible parent PBW 525 showing 59.45% yield reduction under high sodicity. Tolerant parent KRL 99 showed higher GYRI for yield under high sodicity (1.78) as compared to the sensitive parent PBW 525 showing GYRI of 0.95 under high sodicity (Table2). The GYRI for grain

Table 46: Traits means of parents and traits means, range, SD, CV, Skewness and Kurtosis parameters in RILs of KRL 99 X PB 525 in sodic soils (pH_2 9.4)

Variable	Parents		Recombinant Inbred Lines					
	KRL 99	PBW 525	Range	Mean	SD	CV(%)	S	K
DA	117.40	115.80	113-131	120.82	2.67	2.21	-0.05	0.41
PH	77.60	71.13	43.33-94.33	70.34	8.87	12.61	-0.04	0.00
CC	32.84	30.30	21.6-43.3	29.94	4.34	14.50	0.32	-0.11
T	72.40	48.80	10-94	44.62	15.86	35.53	0.55	0.37
EH	67.00	45.00	6-91	42.41	15.79	37.24	0.51	0.27
EL	9.80	9.00	6-11	8.66	1.01	11.61	0.04	-0.10
SE	19.40	17.80	11-23	18.75	2.06	10.96	-0.59	0.48
DM	144.40	145.00	141-165	146.43	3.41	2.33	0.77	2.30
GY	67.76	36.28	6.4-85.9	38.13	16.65	43.68	0.51	-0.13
BM	17.44	16.76	5.6-23.1	15.37	2.96	19.25	0.07	0.40
EW	10.08	9.88	1.6-13.6	8.72	1.90	21.76	-0.26	0.81
GW	7.58	7.24	0.85-10.4	6.29	1.55	24.62	-0.38	0.60
HI	0.44	0.43	0.15-0.75	0.41	0.06	13.89	-0.36	7.03
EFR	76.23	73.45	45.24-87.5	71.63	5.89	8.22	-1.42	3.65
Na^+ (%)	2.87	2.33	0.32-9.02	2.70	1.30	48.15	1.82	4.55
K^+ (%)	13.99	14.88	1.44-15.84	9.84	3.31	33.65	-0.33	-0.45
K^+/Na^+	5.53	6.68	0.35-14.19	4.54	2.46	54.18	0.56	0.59
Ca^+ ($mg\,l^{-1}$)	2.77	1.97	0.65-9.85	1.96	0.80	40.80	5.18	42.33
Mg^+ ($mg\,l^{-1}$)	0.60	0.48	0.09-4.93	0.34	0.37	108.42	9.24	104.08
VGI	0.08	0.08	0.03-0.12	0.08	-	-	0.25	0.48
GYRI	1.78	0.95	0.17-2.25	1.00	-	-	0.51	-0.13
TI	0.63	0.41	0.07-0.97	0.39	-	-	0.76	0.07
GS	1.18	0.41	0.725.08	2.67	-	-	0.40	0.60

Note: DA- Days to anthesis, PH- Plant height (cm), CC- Chlorophyll content (SPAD reading), T- Tillers m^{-1}, EH- Ear heads m^{-1}, EL- Ear length (cm), SE- Spikelets ear^{-1}, DM- Days to maturity, GY- Grain yield $plot^{-1}$ (g), BM- Biomass five $tillers^{-1}$ (g), EW- Ear weight five $tillers^{-1}$ (g), GW- Grain weight five $tillers^{-1}$ (g), Hi- Harvest index, EFR- Ear filling rate (%), VGI- Vegetative growth index, GYRI- Grain Yield Response Index TI- Tolerance index, GS- Genotyping score (GYRI/TI)

yield ranged from 2.253 (SSD-1-311) to 1.647 (SSD-1-55) for top 20 RILs whereas, for bottom 20 RILs it ranged from 0.441 (SSD1-102) to 0.168 (SSD1-23). Days to anthesis, plant height and chlorophyll content reduced under salt stress in comparison to normal soil. Analysis of correlation coefficients revealed the nature and magnitude of association of yield and yield component traits among themselves and with GYRI under different sodicity stresses. Grain yield per meter row length showed significant positive association with most of the recorded traits under high sodicity condition except days to heading and days to maturity which showed significant negative week association. As expected, the number of tillers was positively strongly associated with total number of ear heads per meter row length in both the environments. The ear filling rate showed significant positive correlation with grain yield per meter row length, biomass, ear weight, grain weight, and harvest index in highly sodic environment. Similarly, SPAD readings showed significant positive correlation with grain yield per meter row length, total tillers, K/Na ratio and Na content in salt stress environment. Correlation coefficients of morphological and physiological traits with GYRI showed significant correlation under high sodicity condition.

Improvement of salt tolerance in wheat using molecular approach (IIWBR-Network Project) (P.C. Sharma and Arvind Kumar)

The main aim of this project is to map the important genomic regions/QTLs controlling sodicity tolerance traits in wheat. This is a network project. Genotyping work is being conducted at the main centre (ICAR-IIWBR) while phenotyping is being dealt by ICAR-CSSRI, Karnal.

Phenotyping of the mapping population (Kharchia 65 x HD 2009)

A total of 132 genotypes including 120 RILs along with parents were evaluated in augmented randomized block design in two environments [normal and moderately sodic (pH_2 ~ 9.1)] during *Rabi* 2015-16. The *per se* performance of top 25 RILs under normal and moderately sodic conditions based on least percent reduction in grain yield under stress condition showed that norm of reaction of RILs population was highly variable (Table 47). In general, high mean for grain yield and other related traits was recorded on normal soils as compared to sodicity stress. The grain yield per plant ranged from 12.2 g (MP1- 26) to 176.6 g (MP1- 39) under normal and from 3.8g (MP1- 88) to 88.6g (MP1- 39) at moderate sodicity. Similarly, the Na^+ ion accumulation (%) ranged from 0.08% (MP1-75) to 1.23% (MP1-37) under normal and from 0.36% (MP1- 116) to 9.72 % (MP1- 65) at moderate sodicity. The grain yield and biomass were the most sensitive traits and were reduced up to 90.38% and 88.5%, respectively, followed by the productive tillers plant^{-1}, plant height and harvest index under moderate sodicity. All the morphological and physiological values in the whole population showed a relatively normal distribution around a population mean that lies between the parental values. Some RILs had more extreme values than the parental lines showing a transgressive segregation.

Wheat improvement for water logging, salinity and element toxicities in India (P.C. Sharma, Arvind Kumar and Nirmalendu Basak)

Sixty four wheat genotypes (38 varieties + 26 SSD advanced) were evaluated along with five checks (HD 2967, HD 2009, KRL 99, KRL-3-4, KH 65) under augmented randomized complete block design with five blocks under normal and high sodic (pH 8.9-9.3) conditions. Twenty days waterlogging treatment was applied after 21 days after sowing. Data were recorded for each entry on plot basis for days to anthesis (DA), days to maturity (DM), plant height (PH), tillers m^{-1} (T/M), grain filling duration (GFD), biological yield (BY), spike weight (SW) and grain yield (GY). Analysis of variance revealed highly significant variation among the entries for all the eight traits under the stress environment suggesting the presence of sufficient genetic variation and ample scope for the improvement of wheat for salt and waterlogging tolerance. Tolerant genotypes with least reduction in grain yield were KRL 99, KRL 3-4, HD 2733, HD 2967, WH 1102, NW 2036 and KH 65. Susceptible genotypes that suffered the maximum reduction were PBW 590, PDW 291, RAJ 4120, PBW 314, HD 2985 and HD 2824 etc. (Fig 29). These lines may also be utilized in hybridization programme for developing next generation mapping populations for identification of QTLs conferring waterlogging

Table 47: Top 25 RILs for high grain yield (g) per plot under normal, moderate sodicity and for least percent reduction in grain yield (g)

S. No.	Normal		Moderate Sodicity (pH_2 9.1)		Moderate Sodicity (pH_2 9.1)	
	RILs	GY (g)	RILs	GY (g)	RILs	% Reduction
1.	MP1-39	176.6	MP1-39	88.6	MP1-73	1.10
2.	MP1-33	145.6	MP1-5	88.2	MP1-55	1.54
3.	MP1-70	139.2	MP1-27	81.4	MP1-93	2.07
4.	MP1-35	132.4	MP1-75	79.0	MP1-108	2.24
5.	MP1-32	127.6	MP1-1	78.0	MP1-1	2.50
6.	MP1-13	123.4	MP1-9	76.8	MP1-117	2.50
7.	MP1-107	122.8	MP1-99	76.8	MP1-16	2.88
8.	MP1-95	114.6	MP1-32	76.4	MP1-98	4.91
9.	MP1-75	114.4	MP1-115	75.8	MP1-99	4.95
10.	MP1-9	106.6	MP1-102	75.0	MP1-53	5.22
11.	MP1-110	106	MP1-35	73.0	MP1-27	7.29
12.	MP1-19	104.2	MP1-107	72.2	MP1-104	8.15
13.	MP1-61	103.4	MP1-3	68.2	MP1-4	8.89
14.	MP1-86	99.8	MP1-17	67.8	MP1-115	9.55
15.	MP1-5	98.6	MP1-20	66.4	MP1-102	9.86
16.	MP1-65	94	MP1-72	66.0	MP1-5	10.55
17.	MP1-89	93.8	MP1-12	64.4	MP1-91	11.54
18.	MP1-48	92.8	MP1-68	63.4	MP1-29	12.03
19.	MP1-12	92.6	MP1-80	62.8	MP1-80	12.29
20.	MP1-112	92.4	MP1-48	62.4	MP1-46	12.68
21.	MP1-68	92.2	MP1-13	61.8	MP1-50	12.84
22.	MP1-43	91	MP1-105	58.4	MP1-77	13.25
23.	MP1-20	90.6	MP1-110	57.4	MP1-11	13.33
24.	MP1-6	88.8	MP1-112	57.2	MP1-45	15.22
25.	MP1-34	88.6	MP1-117	56.6	MP1-60	15.74

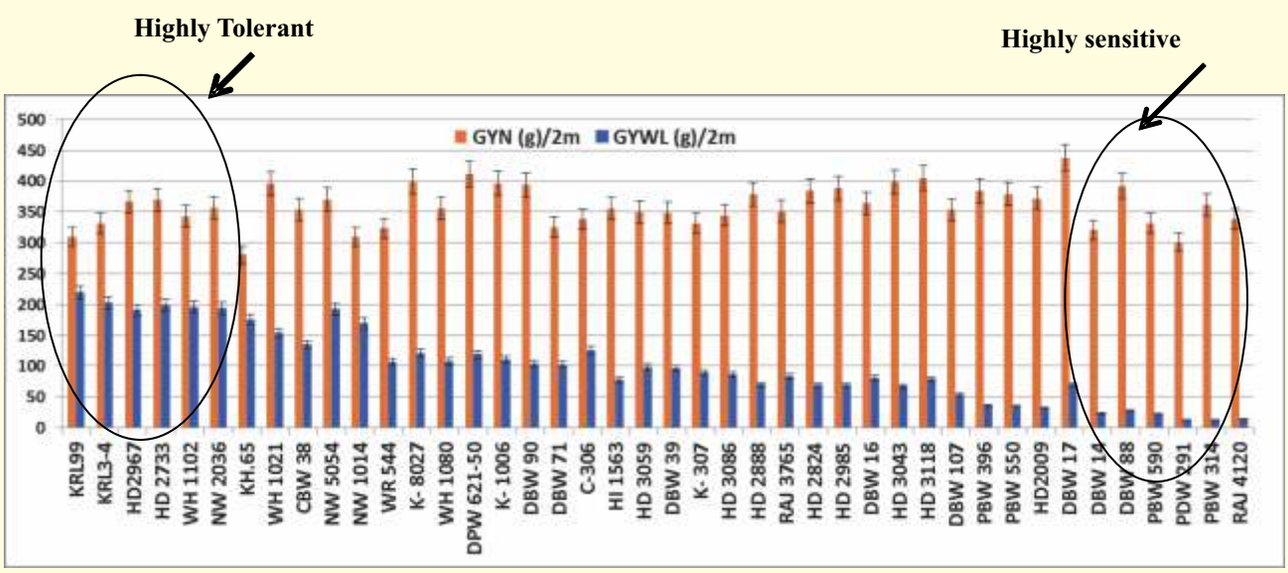


Fig 29: Effect of 20 day waterlogging after 21 DAS on released cultivars (for NEPZ) of wheat

tolerance.

In another experiment, 32 advanced wheat breeding lines developed by CSSRI and IIWBR were evaluated with five checks (HD 2967, HD 2009, KRL 99, KRL-3-4, KH 65) under Augmented Randomized Complete Block Design with five blocks under normal and high sodic (pH 8.9-9.3) conditions; 20 days waterlogging treatment was applied 21 days after sowing. Data were recorded for each entry on plot basis for days to anthesis (DA), days to maturity (DM), plant height (PH), tillers m^{-1} (T/M), grain filling duration (GFD), biological yield (BY), spike weight (SW) and grain yield (GY). Analysis of variance revealed highly significant variation among the entries for all the eight traits under the stress environment suggesting the presence of sufficient genetic variation and ample scope for the improvement of wheat for salt and waterlogging tolerance. Based on percent yield reduction and tolerance index selected crosses KRS 9301/ PBW 509, K 307/ Kh.65, FLW 2/ KRL 99// PBW 550, HD 2967/ Kh.65, KRL 210/ HD 2009 and WH 1105/ KRL 210 showed the least grain yield reduction and can be advanced through shuttle breeding to develop salt and waterlogging tolerant cultivars (Fig. 30). Per cent reduction in grain yield under waterlogged condition ranged from 52-72% for individual experiments (Table 48). Most of the studied traits such as DA, DM, PH, T/M, GFD, BY, SW and GY decreased in the waterlogging experiments. The overall comparisons revealed that lines in Exp-II (Pooled Crosses) showed comparatively superior performance over the Exp-I and III with respect to grain yield, spike weight and biological yield. Variability pattern depicted through box-plot (Fig. 31) showed that genetic gain and selection are more useful in advanced crosses in comparison to released cultivars and SSD population.

Summary

- Release proposal of the entry KRL 283 has been submitted to Central Sub-a Committee on Crop Standards, Notification and Release of Varieties, New Delhi.
- Four entries namely KRL 370, KRL 377, KRL 384, and KRL 386 were promoted form SATSN for testing in Special Trial -Salinity/Alkalinity Tolerance (AVT I) 2016-17.
- Ten entries (KRL 390-399) performed better than all the checks (Kh. 65, KRL 19 and KRL

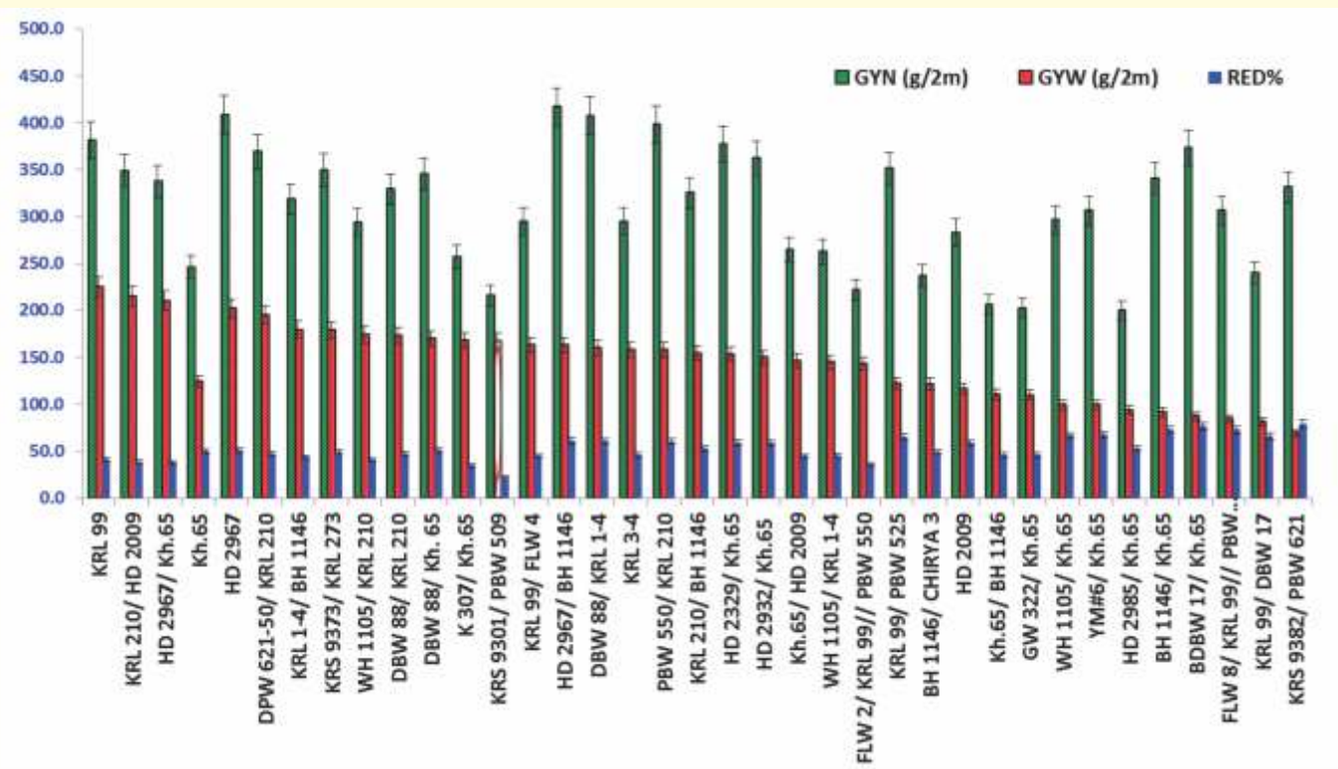
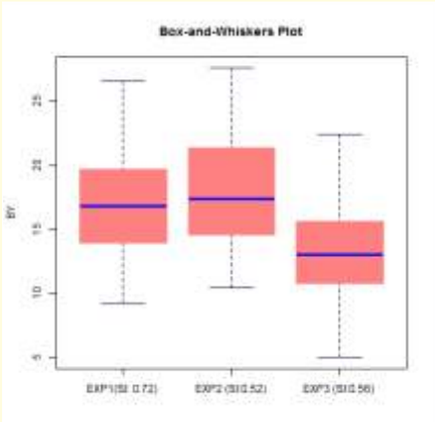
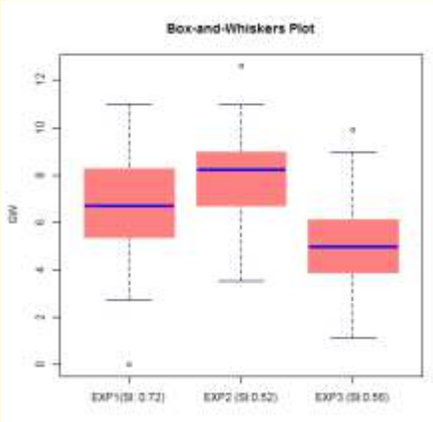


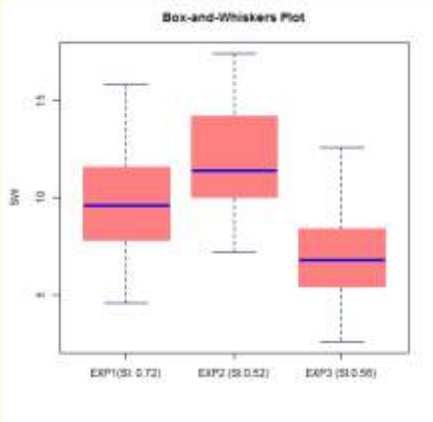
Fig 30: Effect of 20 day waterlogging after 21 DAS on advanced crosses of wheat under sodic high condition (pH: 9.21-9.62)



Effect of different stress intensity on biomass (g)



Effect of different stress intensity on grain yield (g)



Effect of different stress intensity on spike weight (g)

(Stress Intensity in Experiment 1: 0.72, Experiment 2: 0.52, Experiment 3: 0.56)

Fig: 31 Biomass, grain Yield and spike weight trait expression under different stress intensities of three experiments

Table 48: Effect of water logging on different traits in normal V/S sodic high soil conditions (Percent Reduction)

Parameters	Experiment 1	Experiment 2	Experiment 3
Days to heading	-11.60	-18.66	-7.31
Days to maturity	3.00	-0.67	-0.42
Plant height	23.50	13.66	21.79
Tillers/M	71.30	52.08	45.50
Grain filling duration	24.60	23.82	9.24
Biological yield	22.80	23.95	31.22
Seed weight (g)	28.80	24.85	33.20
Grain Yield (g) /Plot	72.10	52.35	56.46

210) under station trial (conducted in saline/alkaline conditions). These entries were sent for evaluation under Salinity/alkalinity nursery (SATSN) 2016-2017 and twenty entries ((KRL 390-409) were submitted for IPPSN 2016-17 for rust screening

- 4.8 t Breeder seed (2.1 t of KRL 210 and 2.71 t of KRL 213) and nucleus seed of salt tolerant wheat varieties KRL210, KRL213, KRL19, KRL1-4 and KRL 283 was produced at CSSRI Experimental Farm, Karnal farm for distribution to various seed producing agencies.
- Nucleus seed of 40 lines (KRL entries) and of four released varieties (KRL 1-4, KRL19, KRL 210 and KRL 213) was also produced at CSSRI Experimental Farm.
- 280 single crosses were attempted between 40 parents consisting of 25 salt tolerant lines developed by CSSRI and 15 higher yielding and disease resistant cultivars.

Development of Indian mustard (*Brassica juncea*) genotypes with improved salinity tolerance and higher seed yield (Jogendra Singh, P. C. Sharma and Vineeth, T. V.)

A new mustard variety released:CS58 (CS 1100-1-2-2-3)

A new variety of salt tolerant variety of Indian mustard identified through 23rd Annual AICRP (Rapeseed & Mustard) Group Meeting held at DUVASU, Mathura (U.P.) during 5-7 August, 2016 was subsequently released by CVRC for notification during 76th meeting held on 31st January, 2017 for the salinity affected areas of the mustard growing regions of Zone-II comprising of the states of Haryana, Punjab and Uttar Pradesh. It matures, on an average, in 132 days and takes 60 days to flower. The strain attains the height of approximately 180 cm and produces high number

of primary branches (6), secondary branches (9), main shoot length (85 cm) and 1000 seed weight (5.5g). The productivity of this variety under normal soils is about 2.6-2.8 t ha^{-1} which slightly decreases in salt-affected soils to 2.0-2.2 t ha^{-1}. Seeds contain about 40% oil. CS58 also showed resistance to *Alternaria* blight. It also shows much lesser incidence of white rust, powdery mildew, downy mildew, stag head, *Sclerotinia* stem rot and mustard aphid under the field conditions.

CS 1100-1-2-2-3

This genotype of Indian mustard has been registered in NBPGR (IC0511389 and INGR 15058) as National Genetic Stock for the unique traits: salinity tolerance up to EC_e 12 dS m^{-1}, alkalinity tolerant up to pH 9.4, high seed yield (2.09 t ha^{-1}) and oil content (39%) under salt stress condition.

Development and evaluation of advanced breeding lines (IVT and AVT) in semi-reclaimed alkali soils

Forty two breeding lines including three checks (CS 54, Kranti and CS52) were evaluated in IVT for seed yield in screening trial in reclaimed alkali soils (pH 8.1-9.5) at Karnal. Seed yield ranged from 1.18 to 3.08 t ha^{-1} (mean 2.03 t ha^{-1}). Twenty five lines gave significantly higher yield over the best check CS54 (1.97 t ha^{-1}) with CS 2009-265 (3.08 t ha^{-1}) followed by CS 900-1-2-2-1-3 (2.71 t ha^{-1}) recording the maximum seed yield (Table 1). Further, 48 breeding lines including 4 checks (CS 54, Kranti, CS 56 and Varuna) were evaluated in AVT for seed yield in screening trial in reclaimed alkali soils (pH 8.1-9.5) at Karnal. Seed yield ranged from 1.71 to 3.29 t ha^{-1} (mean 2.54 t ha^{-1}). Twenty five lines gave significantly higher yield over the best check CS 54 (2.57 t ha^{-1}) with CS2009-414 and CS 15000-1-1-1-4-2 (3.29 t ha^{-1}) followed by CS 15000-1-1-3-2-1 (3.22 t ha^{-1}) recording the maximum seed yield.

Development and evaluation of advanced breeding lines (IVT and AVT) in saline soils

Forty two breeding lines including three checks (CS 54, Kranti and CS52) were evaluated in IVT for seed yield in screening trial in saline soils (EC_e 9.2-15.4 dS m^{-1}) at Nain Experimental Farm, Panipat. Seed yield ranged from 0.38-2.66 t ha^{-1} (mean 1.11 t ha^{-1}). Twenty eight lines gave significantly higher yield over the best check CS 54 (0.78 t ha^{-1}) with CS1300-3-3-2-7-1 (2.66 t ha^{-1}) followed by CS2900-3-1-2-1 (2.43 t ha^{-1}) recording the maximum seed yield (Table 1). Further, in AVT, 48 breeding lines including 4 checks (CS 54, Kranti, CS 56 and Varuna) were evaluated for seed yield in saline soils (EC_e 9.2-15.4 dS m^{-1}) at Nain Experimental Farm. Seed yield ranged from 1.18-3.44 t ha^{-1} (mean 2.13 t ha^{-1}). Eighteen lines gave significantly higher seed yield over the best check Varuna (2.29 t ha^{-1}) with CS1100-1-1-1 (3.44 t ha^{-1}) followed by CS2009-335 (3.34 t ha^{-1}) recording the maximum seed yield.

Development and evaluation of segregating material (F_7 and F_9) of Mustard in semi-reclaimed alkali soils

Fifty four breeding lines including 8 checks (Pusa Bold, Pusa Jaggnath, CS 2007-25, CS 2007-6, Varuna, CS 54, Kranti and CS 56) were evaluated in F_7 generation for seed yield in reclaimed alkali soils (pH 8.1-9.5) at Karnal. Seed yield ranged from 0.92-2.07 t ha^{-1} (mean 1.60 t ha^{-1}). Forty lines gave significantly higher seed yield over the best check CS 56 (1.37 t ha^{-1}) with CS 2013-8 (2.07 t ha^{-1}) followed by CS 2013-66 (2.06 t ha^{-1}) giving the maximum seed yield. Sixty two breeding lines including 5 checks (Krishna, Kranti, CS 54 and CS 56) were evaluated in F_9generation for seed yield in reclaimed alkali soils (pH 8.1-9.5) at Karnal. Seed yield ranged from 1.15-2.32 t ha^{-1} (mean 1.70 t ha^{-1}). Thirty three lines gave significantly higher seed yield over the best check CS 54 (1.66 t ha^{-1}) with CS 2500-1-4 (2.32 t ha^{-1}) followed by CS 2009-204 (2.31 t ha^{-1}) outperforming the other lines. Top 10 best performing lines are given in Table 49.

Development and evaluation of segregating material (F_7 and F_9) of mustard in saline soils

Fifty four breeding lines including 8 checks (Pusa

Table 49: Development and evaluation of segregating material (F_9) 2015-16

S. No.	Genotype	F_9 Nain Yield (t ha^{-1})	F_9 Karnal Yield (t ha^{-1})	S. No.	Genotype	F_9 Nain Yield (t ha^{-1})	F_9 Karnal Yield (t ha^{-1})
1	CS2009-144	2.29	1.64	32	CS2009-227	1.36	1.53
2	CS2009-214	2.30	1.77	33	CS2009-156	0.88	1.17
3	CS2009-247	2.04	1.86	34	CS2009-208	1.01	1.59
4	CS2009-261	2.01	1.92	35	CS2009-151	0.60	1.41
5	CS2009-260	1.80	1.80	36	CS2009-253	0.52	1.67
6	CS2009-264	1.34	1.77	37	CS2009-256	0.46	1.49
7	CS2009-246	1.31	1.41	38	CS610-5-2-5-5	1.48	1.85
8	CS2009-224	0.67	1.79	39	CS609-51KP1	1.48	1.88
9	CS2009-346	0.59	1.58	40	CS2800-1-3-1-1	1.48	1.59
10	CS2009-118	0.54	1.72	41	CS600-3-3-6	1.33	1.60
	Mean					1.05	1.70
	CD 5%					0.21	0.40
	Range					0.41-2.30	1.15-2.32
	Best check					CS56 (0.98)*	CS54 (1.66)*
	No. of Superior lines over best check					33	33

*Figures in parentheses are yield (t ha^{-1})

Bold, Pusa Jaggnath, CS 2007-25, CS 2007-6, Varuna, CS 54, Kranti and CS 56) were evaluated in F_7 generation for seed yield in saline soils (EC_e 9.2-15.4 dS m^{-1}) at Nain Experimental Farm. Seed yield ranged from 0.32-2.24 t ha^{-1} (mean 1.05 t ha^{-1}). Seven lines gave significantly higher seed yield over the best check CS 56 (1.82 t ha^{-1}) with CS2013-22 (2.24 t ha^{-1}) followed by CS2013-3 (2.23 t ha^{-1}) recording the maximum seed yield. Further, 62 breeding lines including 5 checks (Krishna, Kranti, CS 54 and CS 56) were evaluated in F_9 generation for seed yield in saline soils (EC_e 9.2-15.4 dS m^{-1}) at Nain Experimental Farm. Seed yield ranged from 0.41-2.30 t ha^{-1} (mean 1.05 t ha^{-1}). Thirty three lines gave significantly higher seed yield over the best check CS 56 (0.98 t ha^{-1}) with CS 2009-214 (2.30 t ha^{-1}) followed by CS 2009-144 (2.29 t ha^{-1}) being the best performing lines (Table 49).

Comparative evaluation of promising genotypes of Indian mustard (*Brassica juncea* L.) under saline water irrigation

Performance of 8 promising genotypes of Indian mustard *viz.*, CS 52-SPS-1-2012, CS 2009-105, CS 245-2-80-7, CS 614-4-1-4-100-13, CS 1100-1-2-2-3, CS 8000-1-2-8 and CS 15000-2-2-2-1 along with salinity check CS 54 and one high yielding check Pusa Bold was evaluated under different irrigation salinity levels having EC_{IW} of 2, 12, 15 and 18 dS m^{-1} in four replications. Salinity stress was applied at sowing time and maintained throughout the experiment. The maximum mean shoot dry weight (g plant^{-1}) at seedling stage was recorded in CS 8000-1-2-8 (2.99) followed by CS 54 (2.88) and the minimum in Pusa Bold (1.77). The maximum root dry weight (g plant^{-1}) under similar conditions was recorded in CS 1100-1-2-2-3 (0.423) and CS 15000-2-2-2-1 (0.419) while the minimum in Pusa Bold (0.23). At harvesting stage, the minimum mean shoot Na^+/K^+ ratio was observed in CS 2009-105 (3.14) and CS 8000-1-2-8 (3.72) across all salinity levels. The maximum mean Na^+/K^+ ratio was observed in CS 54 (6.05) and Pusa Bold (6.02) across all the salinity levels. CS 614-4-1-4-100-13 (5.43) and CS 52-SPS-1-2012 (10.97) recorded the minimum and maximum mean root Na^+/K^+ ratio, respectively, amongst different genotypes evaluated (Table 50).

The maximum mean seed yield (g plant^{-1}) under different salinity levels was recorded by CS 614-4-1-4-100-13 (18) followed by CS 2009-105 (17.4). Genotypes CS 15000-2-2-2-1 and CS 8000-1-2-8 showed the minimum mean seed yield of 13.95 and 15.10, respectively, under salinity stress. Further, the minimum percentage reduction in seed yield at 15 dS m^{-1} compared to control was recorded in CS 52-SPS-1-2012 (23%) followed by CS 245-2-80-7

Table 50: Performance of nine mustard genotypes under varying salinity levels at harvesting stage

Genotypes	Mean across five salinity levels (2, 9, 12, 15 and 18 dS m^{-1})				
	Shoot Na^+ (mg g^{-1} DW)	Shoot Na^+/K^+	Root Na^+ (mg g^{-1} DW)	Root Na^+/K^+	Seed yield (g $plant^{-1}$)
CS 54	30.12	6.05	40.21	8.69	16.16
Pusa Bold	26.71	6.02	54.81	8.42	16.70
CS 52-SPS-1-2012	25.02	3.91	45.97	10.97	17.27
CS 2009-105	22.34	3.14	47.55	9.97	17.46
CS 245-2-80-7	25.61	3.81	45.27	9.92	15.10
CS 614-4-1-4-100-13	25.39	4.19	38.70	5.43	18.04
CS 1100-1-2-2-3	23.42	4.36	49.08	7.47	15.93
CS 8000-1-2-8	19.58	3.72	49.31	5.52	15.10
CS 15000-2-2-2-1	19.62	3.90	54.69	7.88	13.95
CD (P=0.05)					
Genotypes (G)	4.17	0.90	5.06	1.23	0.96
Salinity (S)	3.11	0.67	3.77	0.91	0.71
G x S	9.34	2.01	11.32	2.75	2.00

(25%) and CS 1100-1-2-2-3 (34%). High yielding check Pusa Bold recorded the maximum reduction (44%) in seed yield at this salinity. Better performing genotypes CS 2009-105 and CS 614-4-1-4-100-13 recorded improved seed yield along with the minimum accumulation of Na^+ in shoot and also the minimum Na^+/K^+ ratio in shoot across all the salinity levels. The minimum seed yield in genotype CS 15000-2-2-2-1 was not associated with Na^+/K^+ ratio in shoot at harvesting stage.

Monitoring and evaluation of promising salt tolerant strains of Indian mustard (*Brassica juncea*) in AICRP on Rapeseed Mustard Salinity/Alkalinity Trial -2014-15

Ten genotypes were evaluated in IVT under saline conditions at Nain Experimental Farm (EC_e 11.0 dS m^{-1}) and under alkaline conditions at Karnal (pH 9.3). Significant differences were observed in seed yield amongst the genotypes evaluated under both the stresses. Seed yield ranged from 1.42-2.49 t ha^{-1} (mean 1.73 t ha^{-1}) in saline soils at Nain and from 1.42-2.26 t ha^{-1} (mean 1.72 t ha^{-1}) in alkali soils at Karnal. Genotypes CSCN-15-4 (2.49 and 2.26 t ha^{-1}) followed by CSCN-14-7 (2.08 and 2.16 t ha^{-1}) showed the highest seed yield at Nain and Karnal, respectively (Table 51).

Strain out yielding the best check by margin of >10 % seed yield; KL- Karnal, PNP- Panipat.

Similarly, ten genotypes were evaluated in AVT-I+II under saline conditions (EC_e 11.0 dS m^{-1}) at Nain Experimental Farm and under alkaline conditions (pH 9.3) at Karnal. Significant differences were observed in seed yield amongst the genotypes evaluated under salinity and alkalinity stresses. Seed yield ranged from 1.41-2.04 t ha^{-1} (mean 1.67 t ha^{-1}) at Nain and from 1.44-2.27 t ha^{-1} (mean 1.77 t ha^{-1}) at Karnal. Genotypes CSCN-15-13 (2.04 and 2.27 t ha^{-1}) followed by CSCN-15-11 (2.03 and 2.23 t ha^{-1}) showed the highest seed yield at Nain and Karnal, respectively.

Monitoring and evaluation of salinity/alkalinity entries of Indian mustard as influenced by different fertility levels in All India Coordinated Research Project on Rapeseed Mustard Trial-2015-16

Four genotypes were evaluated in agronomy trial under alkaline conditions (pH 9.3) at Karnal with four nitrogen levels; 75%, 100%, 125% and 150% of the recommended dose. Significant differences were observed in seed yield amongst the genotypes evaluated. CS 15000-1-2-2-2-1 responded favourably to the additional doses of fertilizer. Further, 100% recommended dose (RD) was found suitable for this genotype (Table52).

Production of nucleus and breeder seeds of three salt tolerant varieties developed at CSSRI Karnal and released by CVRC

During the year 2015-16, breeder seed (graded) of

Table 51: Performance of mustard strains in IVT (saline/alkaline conditions)-2015-16

S. No.	Code	Strain	Seed yield (t ha^{-1})			1000-Seed wt. (g)		Oil Content (%)	
			KL	PNP	Mean	KL	PNP	KL	PNP
1	CSCN-15-1	CS 900-1-2-2-1-3	2.03	1.99	2.01*	4.85	5.43	39.21	38.80
2	CSCN-15-2	RH 749 (ZC)	1.42	1.42	1.42	4.97	5.13	38.08	37.78
3	CSCN-15-3	RH 0725	1.65	1.66	1.65*	5.12	5.30	39.17	38.14
4	CSCN-15-4	CS 700-2-1-4	2.16	2.49	2.33*	5.03	5.03	39.14	39.16
5	CSCN-15-5	Kranti (NC)	1.47	1.43	1.45	3.70	3.40	38.94	37.93
6	CSCN-15-6	CS 1600-1-1-1-1-1	1.87	1.91	1.89	5.02	4.77	38.12	38.99
7	CSCN-15-7	CS 54 (Salinity check)	1.44	1.43	1.44	4.93	5.03	38.19	37.71
8	CSCN-15-8	Giriraj (LR)	1.43	1.46	1.45	5.00	4.90	38.07	37.16
9	CSCN-15-9	CS 508-1 P2	2.26	2.08	2.17*	5.00	4.77	39.12	38.05
10	CSCN-15-10	RH 0761	1.46	1.46	1.46	4.97	5.03	38.22	37.55
		GM	1.72	1.73	1.73				
		CD (5%)	0.31	0.30					
		DOS	17/10	18/10					
		C.V.	10.49	10.03					
		ECe (dS m-1)/pH	9.30	11.00					

Indian mustard varieties CS 52 (0.10 t), CS 54 (0.30 t) and CS 56 (0.28 t) was produced for distribution to central and state govt. agencies. Similarly, nucleus seed of CS 52 (0.010 t), CS 54 (0.075 t) and CS 56 (0.030 t) was also produced.

Identification of new mutant CS 52-SPS-1-2012

A mutant 'CS52-SPS-1-2012' having higher 1000-seed weight (9-10 g), salt tolerance up to EC_e 14 dS m^{-1} and pH up to 9.5, better oil quality parameters

Table 52: Influence of different fertility level at different locations on promising entries in salinity/ alkalinity conditions-2015-16

Entries	Genotype	Fertility Levels				
		T1	T2	T3	T4	Mean Yield (t ha^{-1})
Ag 5	CS 54	1.68	1.88	2.07	1.87	1.68
Ag 6	RH 749	1.66	1.84	2.01	1.84	1.66
Ag 7	CS 15000-1-2-2-2-1	2.14	2.31	2.35	2.26	2.14
Ag 8	Kranti	1.72	1.96	2.06	1.91	1.72
	Mean	1.80	2.00	2.12	1.97	1.80
	CD					
	(P= 0.05)	Entries (E)= 0.06		Fertility (F)= 0.05	F at same level of E= N.S.	
					E at same level of F= N.S.	

Note: T1- 75% of RD, T2- 100% of RD, T3- 125% of RD and T4- 150% of RD.

Table 53: Different characteristics of mutant 'CS52-SPS-1-2012'

Genotype	PH	PB	SB	MSL	P	PL	S	SW	Y	Oil (%)	Pr	EA	CF
Kranti	209	5	11	75	45	5	14	5.0	1.67	38.2	18.2	46.0	11.2
CS 54	194	5	11	77	50	6	14	5.5	2.05	39.0	19.0	49.0	11.0
CS 52-SPS -1-2012	170	6	12	80	55	5	15	8.9	2.38	39.9	20.0	33.8	9.6

Note: PH- plant height (cm), PB- primary branches, SB- Secondary branches, MSL- Main shoot length (cm), Po- Pods on main shoot, PL- Pod length (cm), S- Seeds per pod, SW- 1000 seed weight (g), Y- Yield (t ha-1), Pr- protein (%), EA- Erucic acid (%), CF- Crude fibre (%).

and short stature than the national check CS 54 and Kranti was identified (Table 53).

Molecular approaches for mapping of novel gene(s)/ QTL(s) for resistance/ tolerance to different stresses in Rice, Wheat, Chickpea and Indian Mustard including sheath blight complex genomics and resistance mechanisms. Sub Project 4: Indian mustard (P.C. Sharma, Jogendra Singh and Vineeth TV)

Metabolite profiling of contrasting genotypes in stress induced and non- stressed plants

Metabolite profiling of 7 promising genotypes of Indian mustard (Giriraj, RH 749, CS 1100-1-2-2-3, CS 15000-2-2-2-1, CS 2800-1-2-3-5-1, CS 7003-3-2-6, CS 700-2-1-4) along with salinity check variety CS 54 and one high yielding check Krishna was studied. Plants were irrigated with different salinity waters (EC_{IW} 2, 12, 15 and 18 dS m^{-1}) in four replications. Salinity stress was applied at the time of sowing and maintained throughout the course of the experiment. At harvesting stage, the minimum mean Na^+ content in shoots was observed in CS 54 (17.49 mmol g^{-1} DW) and RH 749 (21.54 mmol g^{-1}) across all salinity levels. The maximum mean Na^+ content was noted in CS 700-2-1-4 (28.05 mmol g^{-1}) across all salinity levels. In root tissues, RH 749 (7.65 mmol g^{-1}) and CS 2800-1-2-3-5-1 (11.3 mmol g^{-1}) recorded the minimum and maximum mean Na contents, respectively, amongst the different genotypes evaluated. The minimum mean shoot K content was observed in CS 2800-1-2-3-5-1 (26.92 mmol g^{-1}) and CS 7003-3-2-6 (28.82 mmol g^{-1}) across all salinity levels. The maximum mean K content was observed in Giriraj (33.88 mmol g^{-1}) across all salinity levels. In roots, CS 700-2-1-4 (12.93 mmol g^{-1}) and CS 54 (18.1 mmol g^{-1}) recorded the minimum and maximum K contents, respectively (Table 54).

The maximum mean seed yield under different salinity levels was recorded in CS 700-2-1-4 (15.1 g $plant^{-1}$), followed by CS 7003-3-2-6 (13.9 g $plant^{-1}$). Genotype Krishna recorded the minimum mean seed yield of 9.01 g $plant^{-1}$ under salinity stress. Further, the minimum percentage reduction in seed yield at 15 dS m^{-1} compared to control was recorded in RH 749 (58%) followed by CS 54 (60%) and Giriraj (67%). In contrast, the high yielding check Krishna recorded the maximum percentage reduction (72%) at this salinity level. An assay of the primary metabolites was also carried out in all the genotypes with genotypes CS 1100-1-2-2-3, RH 749 and CS 54 accumulating the maximum proline in the leaf tissues *i.e.*, 1,193.29, 1,876.19 and 1,874.11 µg g^{-1} FW, respectively. Higher accumulation of proline, an osmoprotectant lowers the osmotic potential of the cell and there by improves the

Table 54: Cellular Na^+ and K^+ contents (mmol g^{-1} DW) and seed yield of promising mustard genotypes under varying salinity levels

Genotypes	Mean across five salinity levels (2, 9, 12, 15 and 18 dS m^{-1})				
	Shoot Na^+ (mg g^{-1} DW)	Shoot Na^+/K^+	Root Na^+ (mg g^{-1} DW)	Root Na^+/K^+	Seed yield (g $plant^{-1}$)
CS 54	17.49	28.91	8.87	18.10	9.97
Giri Raj	23.31	33.88	8.45	17.99	13.23
RH 749	21.54	31.27	7.65	16.98	12.14
CS 1100-1-2-2-3	24.94	31.62	8.03	16.64	11.59
CS 15000-1-2-2-2-1	25.46	27.80	10.19	17.06	13.05
CS 2800-1-2-3-5-1	25.08	26.92	11.30	15.60	13.09
CS 7003-3-2-6	26.42	28.82	10.30	14.25	13.94
CS 700-2-1-4	28.05	30.37	10.78	12.93	15.18
Krishna	28.01	29.35	10.51	13.89	9.01
CD (P=0.05)					
Genotypes (G)	1.58	1.44	0.91	1.00	3.39
Salinity (S)	1.18	1.07	0.68	0.75	2.52
G x S	3.55	3.22	2.04	2.24	N/A

Table 55: Estimation of primary metabolites associated with imposed salinity stress in promising Indian mustard genotypes

Genotypes	Mean across five salinity levels (2, 9, 12, 15 and 18 dS m^{-1})				
	Proline	Malondialdehyde	Total chlorophyll	H_2O_2	Protein
	(µg g^{-1} FW)	(nmol g^{-1} FW)	(mg g^{-1} FW)	(nmol g^{-1} FW)	(µg g^{-1} FW)
CS 54 1,874.11	18.669	4.88	20.66	515.53	
Giri Raj	1,672.36	19.313	4.544	18.86	434.91
RH 749	1,876.19	23.183	4.741	19.42	487.69
CS 1100-1-2-2-3	1,888.84	23.347	4.485	24.26	427.99
CS 15000-1-2-2-2-1	1,193.29	35.659	4.347	19.01	521.66
CS 2800-1-2-3-5-1	1,095.07	15.24	4.344	21.34	396.16
CS 7003-3-2-6	1,130.68	30.978	3.492	15.65	430.07
CS 700-2-1-4	1,095.11	36.379	4.111	22.54	419.31
Krishna	1,235.78	37.541	3.835	23.39	442.34
CD (P=0.05)					
Genotypes (G)	73.0	1.17	**0.114**	**1.41**	**10.32**
Salinity (S)	54.4	0.87	**0.085**	**1.05**	**7.69**
G x S	163.3	2.62	**0.256**	**3.16**	**23.08**

water intake in salt stressed plants. Among the genotypes, Krishna and CS 700-2-1-4 showed very high levels of malondialdehyde content (37.54 and 36.38 nmol g^{-1} FW respectively) that clearly indicated the susceptible nature of these genotypes to salinity stress. CS 2800-1-2-3-5-1, CS 54 and Giriraj displayed comparatively lower levels of malondialdehyde (15.24, 18.669 and 19.313 nmol g^{-1} FW, respectively) suggesting a far more stable cellular membrane system with lower peroxidation levels (Table 55). Statistical analysis of the data revealed that different salinity levels and the interaction between salinity and various genotypes had a significant effect on total chlorophyll content. Increase in salinity from 0 to 18 dS m^{-1} led to significant reductions in photosynthetic pigments. The maximum reduction was observed when plants were exposed to the highest salinity level of 18 dS m^{-1}. Mean values of data showed that CS 54 and RH 749 showed the minimum (4.88 and 4.741 mg g^{-1} FW, respectively) while CS 7003-3-2-6 and Krishna showed the maximum reductions (3.4 and 3.8 mg g^{-1} FW, respectively) in chlorophyll content under salinity. Leaf H_2O_2 levels significantly differed among the varieties, NaCl treatments and variety × NaCl interaction ($P < 0.001$). When plants were exposed to salt stress, especially high NaCl concentrations, CS 1100-1-2-2-3 and Krishna displayed the highest leaf H_2O_2 contents (24.2 and 23.3 nmol g^{-1} FW, respectively) compared to other genotypes. However, CS 7003-3-2-6 and Giriraj showed comparatively lower leaf H_2O_2 levels (15.6 and 18.8 nmol g^{-1} FW, respectively) under high salinity. The proteins, being capable of creating more stability in the presence of high concentration of Na^+ in the cytoplasm, are reported to be synthesized under a variety of stresses such as chilling, anoxia and salinity. Total protein content decreased with increasing NaCl concentrations. The lowest mean minimum protein content under stress was observed in CS 700-2-1-4 and Krishna (419.3 and 442.3 µg g^{-1} FW, respectively). CS 15000-1-2-2-2-1 and CS 54 maintained higher levels of total soluble protein (521.6 and 515.5 µg g^{-1} FW, respectively) even under elevated stress levels (Table 56).

Genetics of salt tolerance and allelic relationships of genes controlling tolerance

A total of 250 RILs along with their parents (CS56 and CS 614-1-1-100-13) were evaluated for seed yield and other yield contributing traits in normal soil at Karnal and saline soil (ECe 9.2-15.4 dS m^{-1}) at Nain Experimental Farm, Panipat. The yield performance of RIL population was compared with the parents. The plant height of the parental lines CS 56 and CS 614-1-1-100-13 was 202.67 cm

Table 56. Phenotyping of RILs

RILs	Plant Height (cm)				Pri. Branches				Sec. Branches			
	Control	Salinity	Mean Over Envt	%Reduction	Control	Salinity	Mean Over Envt	% Reduction	Control	Salinity	Mean Over Envt	% Reduction
RILs (CS56 × CS614-4-1-4-100-13)	213.46	198.15	205.81	7.17	5.87	5.48	5.67	6.64	10.21	6.34	8.28	37.90
CS 56 202.67	203.33	203.00	-0.33	5.00	4.67	4.83	6.66	10.33	6.33	8.33	38.71	
CS614-100-13	185.33	168.00	176.67	9.35	5.33	5.00	5.17	6.24	10.00	3.00	6.50	70.00
Mean 194.71	195.60	195.16	-0.46	5.40	5.05	5.22	6.51	10.18	5.22	7.70	48.68	
Range (RILs)	118.00 (R79)	122.33 (R130)	159.00 (R79)		4.00 (R237)	3.00 (R161)	4.00 (R230)		3.33 (R177)	1.33 (R219)	3.17 (R177)	
	257.67 (R133)	241.67 (R236)	235.50 (R106)		13.33 (R200)	11.00 (R5)	9.67 (R200)		18.00 (R200)	15.00 (R1)	14.00 (R1)	
CD (P=0.5)	**RILs (G)**	**Salinity (S)**	**G x S**		**RILs (G)**	**Salinity (S)**	**G x S**		**RILs (G)**	**Salinity (S)**	**G x S**	
	19.94	**1.78**	**28.2**		**1.23**	**0.11**	**1.74**		**2.29**	**0.21**	**3.24**	
RILs	**Siliqua on Main Shoot**				**Test Weight**				**Yield/Plant (g)**			
	Control	**Salinity**	**Mean Over Envt**	**% Reduction**	**Control**	**Salinity**	**Mean Over Envt**	**% Reduction**	**Control**	**Salinity**	**Mean Over Envt**	**% Reduction**
RILs (CS56 × CS614-4-1-4-100-13)	56.97	47.59	52.28	16.46	4.67	4.91	4.79	-5.16	22.55	12.85	17.70	43.01
CS 56	58.33	52.33	55.33	10.29	4.67	4.57	4.62	2.14	21.13	14.33	17.73	32.16
CS614-100-13	40.67	37.67	39.17	7.38	5.03	4.20	4.62	16.55	18.19	9.67	13.93	46.86
Mean 51.99	45.86	48.93	11.78	4.79	4.56	4.67	4.82	20.62	12.28	16.45	40.44	
Range (RILs)	38.33 (R115)	33.00 (R27)	40.00 (R121)		2.50 (R143)	2.87 (R148)	2.92 (R143)		7.81 (R230)	4.00 (R122)	6.24 (R230)	
	73.00 (R119)	64.00 (R4,11,208)	67.67 (R208)		6.53 (R61)	7.47 (R65)	6.75 (R65)		56.67 (R50)	32.00 (R11)	31.84 (R50)	
CD (P=0.5)	**RILs (G)**	**Salinity (S)**	**G x S**		**RILs (G)**	**Salinity (S)**	**G x S**		**RILs (G)**	**Salinity (S)**	**G x S**	
	7.44	0.66	10.52		0.29	0.03	0.41		3.77	0.34	5.33	

Main Shoot Length (cm)				
RILs	**Control**	**Salinity**	**Mean Over Envt**	**%Reduction**
RILs (CS56 × CS614-4-1-4-100-13)	82.68	68.15	75.42	17.58
CS 56	90.00	76.67	83.33	14.81
CS614-100-13	73.00	68.00	70.50	7.35
Mean	80.23	72.61	76.42	9.50
Range (RILs)	54.00 (R205)	48.67 (R6)	59.00 (R163)	
	112.33 (R169)	92.00 (R11)	94.00 (R203)	
CD (P=0.5)	**RILs (G)**	**Salinity (S)**	**G x S**	
	8.58	0.77	12.14	

and 185.33 cm, respectively under normal conditions. There was 10% reduction in plant height in the susceptible line CS 614-1-1-100-13 in saline soils. There was no significant reduction in height of CS 56 in saline soils. The height of RILs ranged from 118-257 cm under normal and 122.33-241.67 cm under saline soils, respectively, with 7 % mean reduction in height under saline conditions. The number of primary branches in RILs ranged from 4-13 and 3-11 in normal and saline soils, respectively, with 7 % mean reduction under saline conditions. There was no significant difference in the mean number of primary branches under normal and saline treatments. The number of secondary branches in RILs ranged from 3-18 and 1-15 in normal and saline soils, respectively, with 38 % mean reduction under saline conditions. The number of secondary branches of the parental lines CS 56 and CS 614-1-1-100-13 was 10 under normal conditions. There was 70 % reduction in secondary branches in the susceptible line CS 614-1-1-100-13 in saline soils as compared to 37% in the RILs. The main shoot length of RILs ranged from 54-112 cm in normal and 48-92 cm in saline soils, respectively, with 18 % mean reduction under saline conditions. Moreover, CS 56 and CS 614-1-1-100-13 displayed 14.8 and 7.3% reductions, respectively, in the main shoot length under saline conditions. The number of siliqua on main shoot of RILs ranged from 38-73 and 33-64 in normal and saline soils, respectively, with 16% mean reduction under saline conditions. There were 10% and 7% reductions in siliqua count under saline conditions in CS 56 and CS 614-1-1-100-13, respectively, as compared to 16% in the RILs. The test weight of RILs ranged from 2.50-6.53 and 2.87-7.47 in normal and saline soils, respectively, with 5% mean increase in test weight under saline conditions. CS 56 and CS 614-1-1-100-13 displayed 2% and 17% mean reductions in test weight under saline conditions. The RIL yield [yield plant^{-1} (g)] ranged from 7.81-56.67 and 4.0-32.0 in normal and saline soils, respectively, with 43% mean reduction under saline conditions. CS 56 and CS 614-1-1-100-13 displayed 32% and 47% reduction in mean yield under saline conditions .

Molecular approaches for mapping of novel gene(s)/QTL(s) for resistance/tolerance to different stresses in Rice, Wheat, Chickpea and Indian mustard including sheath blight complex genomics and resistance mechanisms. Sub Project 3: Chickpea (P. C. Sharma, Anita Mann and Jogendra Singh)

Refinement of screening techniques for tolerance to salinity

A total of 233 RILs along with their parents (ICCV-10 and DCP92-3) were evaluated for seed yield and other yield contributing traits under saline (EC_{iw} 6 dS m^{-1}) and alkali (pH 9.0) conditions at Karnal. The yield performance of RIL population was compared with the parents. Plant height of the parental lines ICCV-10 and DCP92-3 was 50.50 cm and 48.17 cm, respectively under alkali conditions whereas 22.0 cm and 31.0 cm, respectively under salinity. There was 56% reduction in plant height in both the parents under salinity compared to alkali condition. (Table 57) Plant height of RILs ranged from 13.33-56.17 cm under alkali and 11.50-42.00 cm under salinity treatments, respectively, with 50% mean reduction in height under saline conditions. The number of branches of the parental lines ICCV-10 and DCP92-3 was 9.0 and 7.83 under alkali conditions while 3.0 and 5.0 under salinity. There was 80% reduction in mean number of

Table 57: Phenotyping of 233 RILs and 50 advanced breeding lines under salinity (EC_{iw} 6.0 dS m^{-1}) and alkali (pH 9.0) conditions

RILs	Plant Height (cm)		No. of Branches		No. of Filled pods		100 seed Weight		Yield/Plant (g)	
	Alkali	Salinity	Alkali	Salinity	Alkali	Salinity	Alkali	Salinity	Alkali	Salinity
RILs (DCP92-3 × ICCV-10)	46.92	27.32	8.00	4.12	114.67	22.18	15.88	6.15	31.74	3.46
ICCV-10	50.50	22.00	9.00	3.00	67.83	10.00	21.85	10.20	30.88	1.04
DCP92-3	48.17	31.00	7.83	5.00	54.33	39.00	17.25	12.20	24.54	7.17
Mean	48.53	26.77	8.28	4.04	78.95	23.73	18.33	9.52	29.05	3.89
Range (RILs)	13.33 (R20,44)	11.50 (R107)	3.33 (R44)	1.00 (R107)	27.67 (R11)	3.50 (R10)	11.55 (R11,49)	4.20 (R126,139)	12.44 (R20)	0.29 (R107)
	56.17 (R152)	42.00 (R167)	19.33 (R160)	7.50 (R97,98, 228)	270.67 (R17)	67.00 (R83)	21.15 (R119)	15.70 (R71)	52.90 (R184)	11.79 (R201)
AB Lines	**Plant Height (cm)**		**No. of Branches**		**No. of Filled pods**		**100 seed Weight**		**Yield/Plant (g)**	
	Alkali	Salinity	Alkali	Salinity	Alkali	Salinity	Alkali	Salinity	Alkali	Salinity
Mean	46.57	31.92	6.01	3.54	64.63	12.19	23.91	13.15	19.90	4.39
Range	18.33 (S 20)	21.00 (PB 132)	2.00 (S 20)	2.00 (PB 9, PB 132)	15.00 (S 20)	4.00 (S 20)	12.85 (PB 19)	3.40 (PB 52)	5.98 (S 20)	0.84 (PB 141)
	61.17 (S 20)	44.50 (PB 19)	8.17 (S 3)	6.00 (S 26)	116.67 (S 11)	31.00 (S 7)	49.80 (S 21)	28.30 (PB 133)	37.55 (S 2)	9.14 (PB 8)

branches under salinity as compared to alkali treatment. The mean number of branches of RILs ranged from 3.33-19.33 and 3.0-11.0 under alkali and saline conditions, respectively, with 30% mean reduction under saline conditions. The number of filled pods of RILs ranged from 27.67-270.67 and 3.50-67.0 under alkali and salinity conditions, respectively. Number of filled pods in parental lines ICCV-10 and DCP92-3 was 67.33 and 54.33 under alkali conditions, whereas 10.0 and 39.0 under saline condition, respectively. The 100-seed weight of RILs varied from 11.55-21.15 g and from 4.20-15.70 g under alkali and saline conditions, respectively with 50% mean reduction in test weight under saline conditions compared to alkali. ICCV-10 and DCP92-3 displayed 50% and 35% mean reduction, respectively in test weight under saline compared to alkali conditions.

The RIL yield [yield plant^{-1} (g)] ranged from 21.44-52.9 g and 0.29-11.79 g under alkali and saline conditions, respectively with 90% mean reduction under saline conditions. ICCV-10 and DCP92-3 displayed 97% and 37% mean reduction in yield under saline conditions (Table 1). Similarly, 50 advanced breeding (AB) lines were also evaluated for seed yield and other yield contributing traits under saline (EC_{IW} 6 dS m^{-1}) and alkali (pH 9.0) stresses at Karnal. Analysis was performed for each environment and for the combined data set from both the locations. The plant height of the AB lines ranged from 18.33-61.17 cm under alkali and 21.0-44.5 cm under salinity treatments, respectively with 30% mean reduction in height under saline conditions. The mean number of branches of AB lines ranged from 2.0-8.17 and 2.0-6.0 under alkali and saline conditions, respectively with 50% mean reduction under saline conditions. The number of filled pods of AB lines ranged from 15.0-116.67 and 4.0-31.0 under alkali and salinity conditions, respectively. The 100-seed weight of AB lines varied from 12.85-49.80 g and from 3.40-28.30 g under alkali and saline conditions, respectively with 48% mean reduction in test weight under saline conditions compared to alkali. The yield plant^{-1} of AB lines ranged from 5.98-37.55 g and from 0.84-9.14 g under alkali and saline conditions, respectively with 40% mean reduction under saline conditions.

Ascertaining the relative importance of various traits that are known to contribute to salinity tolerance in chickpea

A total of 283 chickpea lines including 233 RILs

Phenotyping of 233 Recombinant Inbred Lines (RILs) along with their parents ICCV-10 and DCP92-3 and 50 Advanced breeding lines

along with their parents (DCP 92-3 x ICCV 10) and 50 advanced breeding lines were characterized for morpho-physiological traits at 6.0 dS m^{-1} EC_{IW} salinity in pots and alkalinity (pH 9.0) in field with two replications during 2015-16 cropping season. Mean percent germination was 59.96% under salinity stress while it was 56.26% in alkali treatment. In advanced lines, mean percent germination was 88% and 77.29% at salinity and alkali treatments, respectively. Per cent germination varied from 42.86-100% among the lines in saline pots with 26 lines showing 100% germination at EC_{IW} 6 dS m^{-1}. At pH 9.0, as low as 28.57% germination was recorded. However, 8 lines showed 100% germination.

At 6 dS m^{-1} salinity, 21 RILs had root length equal to or more than tolerant parent while 106 RILs had root length more than the mean value. Similarly, 11 RILs had shoot length equal to or more than the tolerant parent, while 65 RILs had lower shoot length than the susceptible parent and the rest had shoot length between the parental values. At pH 9.0, root length ranged from 6.30-21.5 cm with mean of 13.3 cm. Similarly, shoot length varied from 10.2-35 cm with a mean value of 22.35 cm. The advanced breeding lines had lower root and shoot lengths in saline pots ranging from 5.06-17.2 cm with mean value of 9.37 cm. Similarly in alkaline plots, root length varied from 7.1-15.9 with mean value of 11.98. The root length of RILs ranged from 6.3-21.5 cm with mean value of 13.26 cm under alkali stress, and from 5.6-17.2 cm with a mean value of 10.03 under salinity stress.

At pH 9.0, chlorophyll content was equal to or more than the tolerant parent in 74 RILs. By comparison, 88 RILs had equal to or less chlorophyll than the susceptible parent and the rest RILs showed chlorophyll values in between the parental mean. Out of 233 RILs, 149 RILs showed chlorophyll content equal to or more than the tolerant parent at 6 dS m^{-1} salinity while 9 RILs had chlorophyll values lower than susceptible parent. Rest of the RILs had chlorophyll content in between tolerant and susceptible parents at 6 dS m^{-1}. The chlorophyll content showed a similar range in the advanced breeding lines under both stress condition. The range of chlorophyll content in ABL was 1.57-2.14 mg g^{-1} FW in 50 chickpea advanced breeding lines at pH 9.0 and from 1.54-2.25 mg g^{-1} FW at 6 dS m^{-1} salinity. Twenty lines had chlorophyll content more than the mean values under both stresses. Among these, the common lines were S-1, S-16, S-20, S-25, PB-19, PB-94, PB-127, PB-132 and PB-181.

Proline content in RIL population ranged from 2331.13-0.687 µg g^{-1} FW with mean value of 806.26 at EC_{IW} 6 dS m^{-1} salinity in pots. While 25 RILs outperformed the tolerant check and accumulated more proline at 6 dS m^{-1} salinity, 76 RILs had proline content less than the susceptible check. At pH 9.0, proline content ranged from 2074.03-13.87 µg g^{-1} FW with mean of 617.58. Sixteen RILs outperformed the tolerant parent while 51 RILs had proline content lower than the susceptible parent. Rest 164 RILs had proline content in between the parental range. Proline content in Advanced Breeding Lines ranged from 280.8-2512.14 µg g^{-1} FW with mean value of 1134.20 at 6 dS m^{-1} salinity. At pH 9.0, proline content ranged from 238.02-1286.23 µg g^{-1} FW with a mean value of 660.0. More proline accumulated under salinity than under alkali stress. The lines accumulating more proline than mean under both the stresses were S-11, S-23, S-24, S-26, S-27, PB-8, PB-29 and PB-34. At vegetative stage (45 DAS), the effect of high pH was non-significant. Root Na^+ content in chickpea RILs at vegetative stage ranged from 0.9-6.9% with a mean of 3.5%. Shoot Na^+ ranged from

Table 58: Mean and range for Na^+ and K^+ in chickpea at vegetative stage at 6 dS m^{-1} salinity stress in pots

	RILs				Advanced breeding lines			
	Root		Shoot		Root		Shoot	
	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+
	%	%	%	%	%	%	%	%
Mean	1.72	3.18	0.82	2.95	2.59	2.54	2.49	11.71
Max	3.56	5.62	2.06	4.80	5.4	4.16	4.68	15.75
Min	0.80	1.68	0.27	1.30	0.88	1.23	1.50	7.65

Table 59: Mean and range for Na and K in chickpea at harvesting stage at EC 6 dS m^{-1} salinity stress in pots

	RILs				Advanced breeding lines			
	Root		Shoot		Root		Shoot	
	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+
	%	%	%	%	%	%	%	%
Mean	11.10	4.74	5.76	9.09	17.47	5.93	7.27	11.68
Max	23.89	14.37	14.24	16.44	23.61	10.91	11.89	16.91
Min	2.44	1.43	1.17	4.45	8.08	2.07	1.34	2.85

0.164-2.17% with the mean value for 0.954. Na^+/K^+ ratio was 0.547 in roots and 0.086 in shoots of RILs. Similarly, root and shoot Na^+/K^+ ratio was 0.72 and 0.099, respectively, in advanced breeding lines. Less Na^+ accumulated in shoots than in roots probably due to restricted Na^+ translocation from the roots to shoots. At saline stress of EC 6 dS m^{-1}, K^+ concentration was more than Na^+ in both roots and shoots of RILs. However, Na^+/K^+ ratio was same (0.54) as noted at high pH stress. In advanced breeding lines, Na^+/K^+ ratio was more or less equal to one in roots while K^+ was more in shoots than in roots (Table 58). For harvesting stage, ionic data is presented in Table 59.

Molecular mapping of gene(s)/QTLs controlling salinity tolerance

Activity: *Development of mapping populations for salinity tolerance*

Following crosses have been developed involving the most contrasting salt tolerant and sensitive genotypes to develop the mapping population:

1. Pusa BG 1103 x Haryana Chana-5 (F_1)
2. Haryana Chana-5 x Karnal Chana-1 (F_1)
3. S-7 x Karnal Chana-1 (CSG 8962) (F_1)
4. Haryana Chana-5 x S-7 (F_1)

Ascertaining the relative importance of various traits that to contribute to salinity tolerance in chickpea

Genetic enhancement of tomato (*Solanum lycopersicum*) and okra (*Abelmoschus esculentus* L.) for salt tolerance (S. K. Sanwal, P. C. Sharma, Anita Mann, Raj Kumar, A. K. Rai)

Characterization of cultivated and wild species of tomato under salinity stress

A total of 98 lines collected from ICAR-Indian Institute of Vegetable Research, Varanasi were transplanted in microplots on 28th December, 2015 under 4 salinity levels (EC_e <4, 4-6, 6-8 and >8 dS m^{-1}) in Randomized Complete Block Design in two replications. Initially, two irrigations were given with the best available water. Afterwards, alternate irrigation was done with saline water according to treatments. Package of practices was same for all the treatments. Soil samples were taken at monthly intervals for monitoring of salinity. Plant height reduced with increase in salinity and the percent reductions were 25.98, 41.27 and 46.93 at salinities of 4-6, 6-8 and >8, respectively, than control. The flowering was delayed at the higher salinity. Number of fruits and fruit weight also reduced at higher salinity. The percent reductions in yield were 46.65, 60.19 and 71.42 at 4-6, 6-8 and >8 dS m^{-1} salinity levels, respectively. Total soluble solids increased at the medium salinity but decreased at high salinity (Table 60).

Top 5 performing genotypes from each treatment were selected. The genotype EC-501583 showed the highest fruit yield (9587.75 g) in control treatment but performed poorly at higher salinity levels. Line C-11-2 was the best performer up to 8 dS m^{-1}. Other lines which were found promising under saline conditions were DT-10, EC-2791, EC-13904 and EC-501576.

Blossom end rot: a physiological disorder

Blossom end rot (BER) is a physiological condition that results in a brown or yellow water-soaked spot which appears on the end of the fruit. As the tomato fruits grow, this spot darkens eventually becoming leathery and black, and may even cover half the fruit's bottom. It is caused due to calcium deficiency. The fruits of the genotypes CLN-2366 and EC-538405 were affected by this disorder. By soil analysis it was found that the calcium content of the plot where these lines were planted was comparable to other plots. So, these two lines were found most susceptible to calcium deficiency.

Characterization of okra genotypes at different sodicity levels

Twenty four okra lines were sown in microplots on 27th June, 2016 in Randomized Complete Block Design with two replications under sodic soil for evaluating yield and the yield contributing traits. The levels of sodicity in sowing plots were pH-8.0±0.2 (control), pH-8.5±0.2 (T_1), pH-9.0±0.2 (T_2) and pH-9.5±0.2(T_3). Germination rate and speed of germination was not affected in any of the treatment. Plant height reduced with the increase in sodicity and the reduction was 19.25-58.60% at flowering stage (45 DAS) and 24.44-70.35 at maturity stage (95 DAS). Flowering was 2-3 days earlier under stress conditions than normal soil in all the genotypes. Lines VRO-102, and VRO-111 performed better than other varieties in control environment. However, under sodic conditions, genotypes Kashi Kranti, VRO-112 and AE-70 performed better than other genotypes (Fig 32). With further increase in sodicity, percent yield decreased and it ranged from 44.03 (AE-70) to 92.05

Table 60: Mean and per cent reduction in important traits of tomato under salt stress

Traits	Mean	% Reduction					
	T1	T2	T3	T4	T2	T3	T4
Plant height (cm)	90.47	66.97	53.13	48.01	25.98	41.27	46.93
Days to 50% flowering	52.34	54.52	54.62	53.61	-4.20	-4.35	-2.43
Fruits plant^{-1}	150.55	100.29	78.90	60.86	33.38	47.59	59.57
Average fruit weight	20.11	16.10	15.27	14.22	19.94	24.07	29.29
Yield plant^{-1} (g)	3028.25	1615.35	1205.36	865.57	46.65	60.19	71.42
TSS (°Brix)	4.53	5.18	5.05	4.36	-14.35	-11.48	3.75

Note: T1- ECe <4 dS m^{-1}, T2- ECe 4-6 dS m^{-1}, T3- ECe 6-8 dS m^{-1} and T4- ECe >8 dS m^{-1}

Fruiting in line 'DT-10' (EC_e >8 dS m^{-1})

Fruiting in line 'EC-13904' (EC_e >8 dS m^{-1}

Blossom end rot

CLN-2366, susceptible line

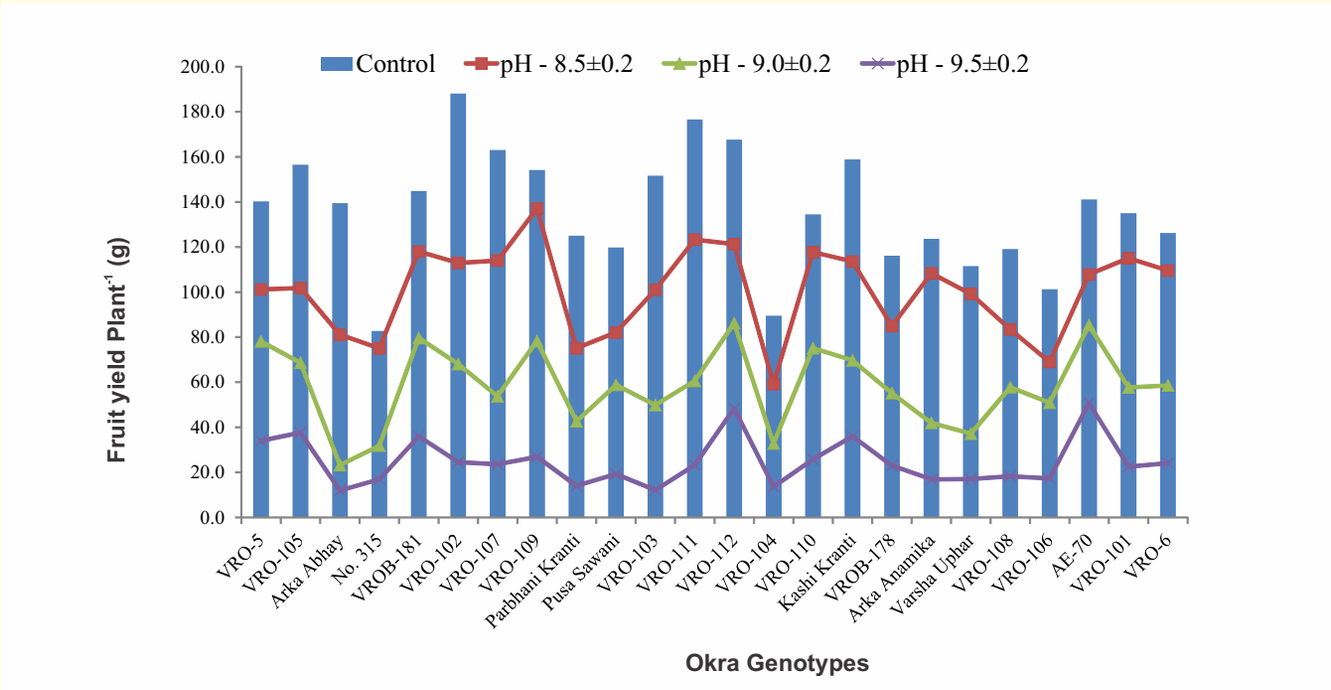


Fig. 32. Performance of different genotypes of okra under sodic conditions.

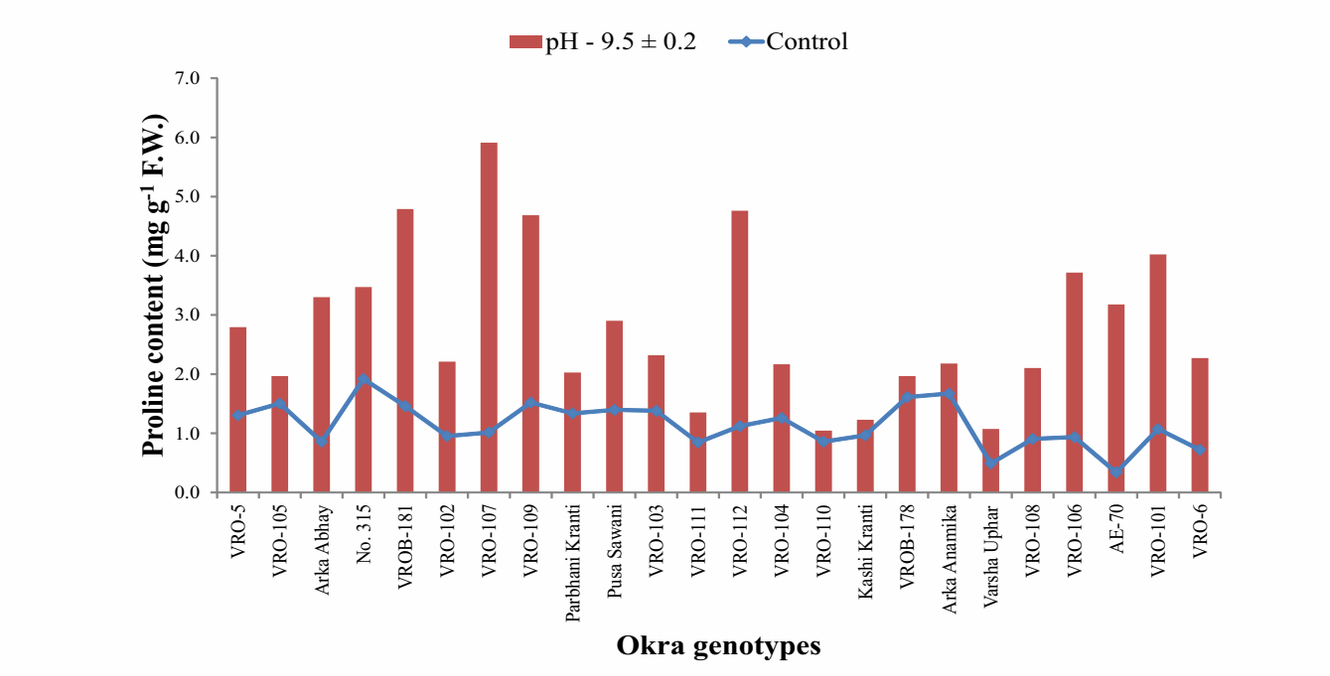


Fig. 33. Proline content of different genotypes in control and sodic conditions.

(VRO-103). Number of fruits plant^{-1}, fruit weight and fruit length also significantly reduced at high sodicity (pH-9.5±0.2).

The chlorophyll content decreased with increase in sodicity but this reduction was the minimum in varieties Parbhani Kranti and Pusa Sawani. Proline content increased with increase in sodicity and the maximum proline content at higher sodicity was recorded in VRO-107, VROB-181, VRO-112 and VRO-109 (Fig.33). Na^+ content was more in roots than shoots in control plants while higher in shoots than roots in sodic soils. K^+ concentrations decreased with the increasing sodicity but this decrease was more in shoots than roots.

Improvement of salt tolerance in chickpea through physiological and breeding approaches.

(Anita Mann, P.C. Sharma and Jogendra Singh)

In addition to the chickpea germplasm collected during previous year from different repository institutes; six chickpea genotypes were collected from Junagadh Agriculture University (JAU), Junagadh, Gujarat. The whole experiment was grouped into three experiments. Karnal Chana-1 (CSG 8962) was used as check in all the experiments. Twenty seeds from each of chickpea lines were used for seed multiplication. The initial screening for the effect of saline irrigation on early seedling stage in chickpea was performed in germination trays at EC 0, 3, 6, 9 and 12 dSm^{-1} in one experiment while the other experiment was maintained at control, EC 6 and 9 dSm^{-1} in the microplots. Salinity was maintained by irrigation with Nain water (EC 16.3 dSm^{-1}).

To study the effect of saline irrigation on chlorophyll content, third top leaves were extracted in 80 % acetone and total chlorophyll content was measured. Mean value of total chlorophyll at early seedling stage in germination trays, at vegetative and at flowering stage in microplots is shown in table 61.

At early seedling stage, total chlorophyll content decreased with increasing salt concentration. On the other hand the total chlorophyll content was more at vegetative stage than the other plant growth stages.

Relative water content: At vegetative stage, the relative water content was maintained upto 80%, which decreased with increasing levels of salinity at EC 6 dSm^{-1} and EC 9 dSm^{-1}.

Proline content: Total proline extracted at early seedling stage at 25-30 DAS, a significant accumulation was observed. Mean total proline was 972.3, 1114, 1174, 1295 and 1406 ug/gFW at control, EC 3 dSm^{-1}, EC 6 dSm^{-1}, EC 9 dSm^{-1} and EC

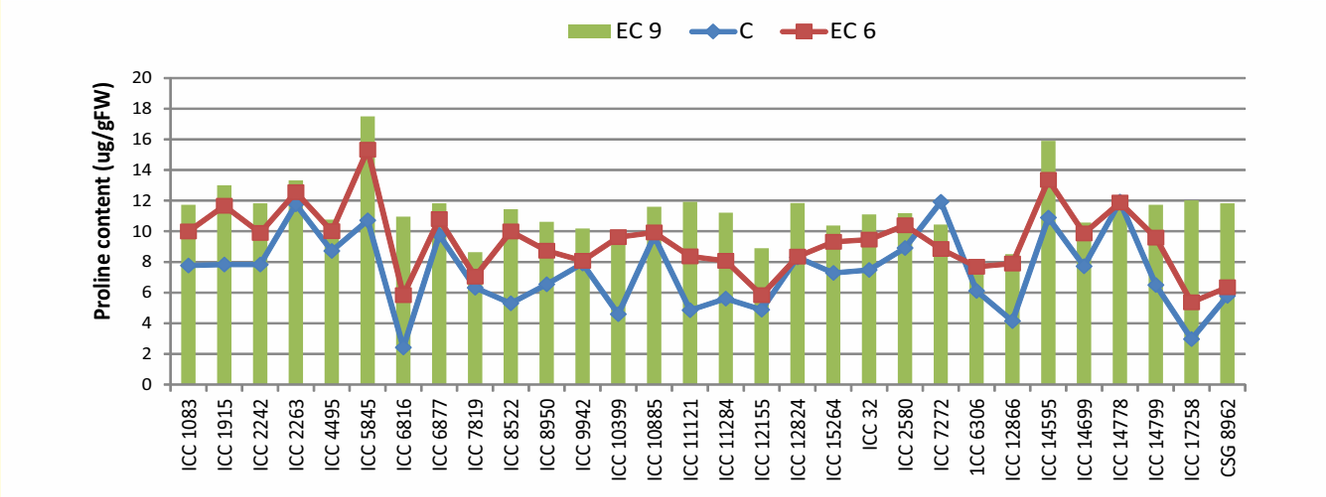


Fig. 34. Chickpea germplasm at reproductive stage

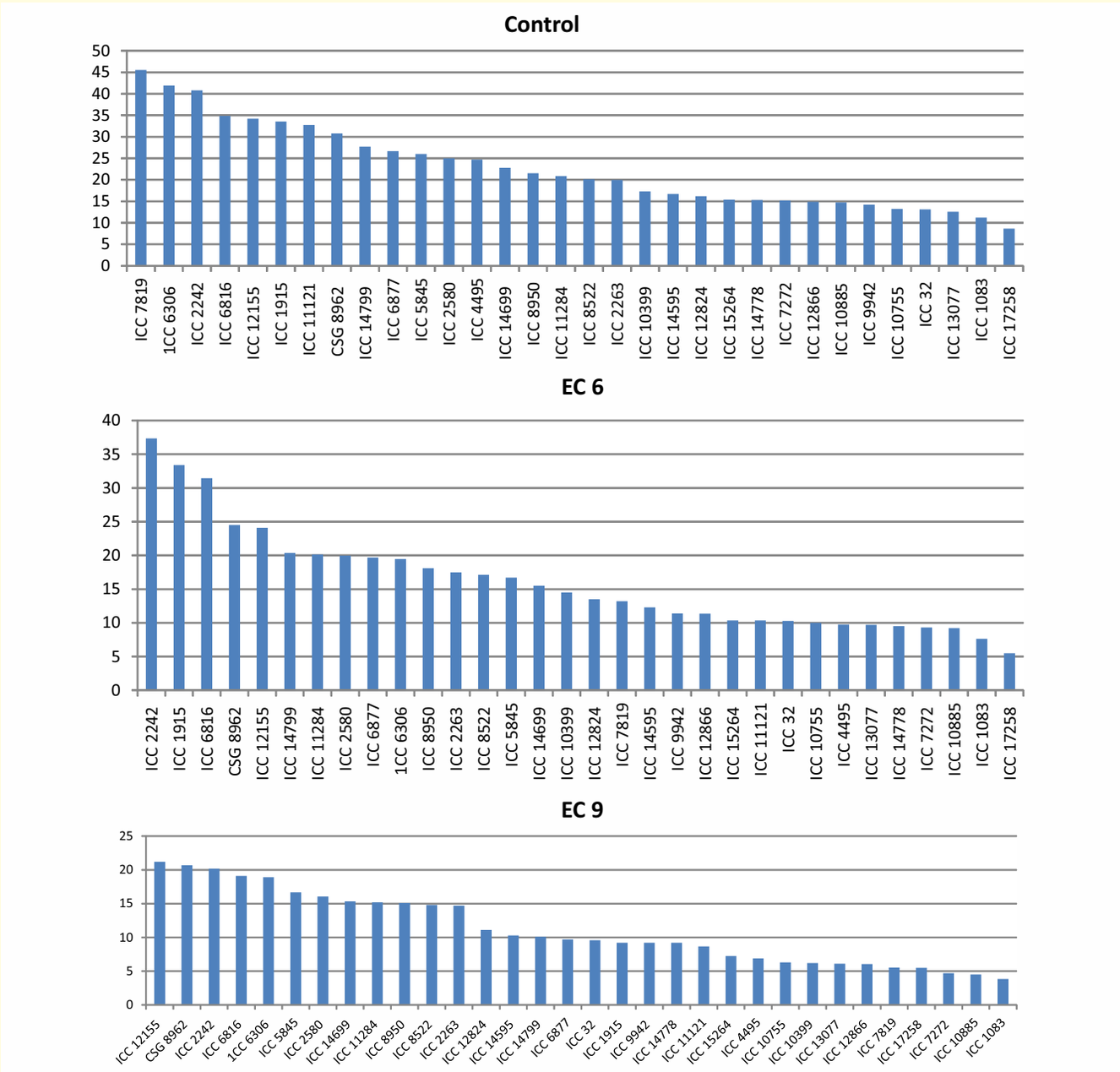


Fig. 35. Yield reduction in chickpea at different levels of salinity

Table 61 : Effect of saline irrigation on total chlorophyll content at different growth stages

	Total Chlorophyll (µg/gFW)		
	Early seedling stage	Vegetative Stage	Flowering stage
Mean	0.4839	1.26	1.238
Max	0.8341	1.43	1.354
Min	0.2863	0.93	0.954

Table 62 : Mean values of different factors studied under saline conditions

Mean values	RWC%	Proline Veg (mg/gFW)	Proline Rep (mg/gFW)	RL (cm)	SL (cm)	RFW g	RDW g	Na/K Root	Yield (g plant^{-1})
Control	79.18	3.98	7.41	18.35	66.76	8.94	2.18	1.30	22.70
EC 6 dSm-1	66.85	4.82	9.33	14.89	58.18	9.08	2.23	1.89	16.04
EC 9 dSm-1	58.72	6.13	11.35	11.96	51.18	8.78	1.95	2.68	10.88

RWC-Relative water content, RL-root length, SL-shoot length, RFW-root fresh weight, RDW-root dry weight

12 dSm^{-1} respectively. Maximum increase in proline content at vegetative stage was found in ICC-1083 followed by ICC-10885 and ICC-12866. Total proline accumulation was more at reproductive stage than vegetative stage with maximum accumulation in ICC 5845 and ICC 14595. In few lines namely, ICC 5845, ICC 6816, ICC 7819 and ICC 8950, the proline accumulation was not much than other lines at vegetative stage although ICC 8950 has been reported as drought tolerant as well. Fig.35 shows the accumulation of proline flowering stage.

Root fresh weight initially increased with application of saline water of EC 6 dSm^{-1} which decreased further with saline water of EC 9 dSm^{-1} and simultaneously the root dry weight. Root and shoot length decreased with increasing salinity level. Mean value of different parameters studied under saline condition is depicted in table 62.

Maximum yield reduction of 6.4-38.9 % was observed at EC 6 dSm^{-1} while a reduction of 25-73% was obtained at EC 9 dSm^{-1}. Thus, few chickpea germplasm lines have been identified based on different physio-biochemical parameters which will be included in the breeding programme.

Physiological and biochemical basis of salinity and drought stress tolerance in rice and wheat cropping system (Ashwani Kumar, Arvind Kumar and S. L. Krishnamurthy)

Wheat Crop

Wheat varieties exposed to different stress

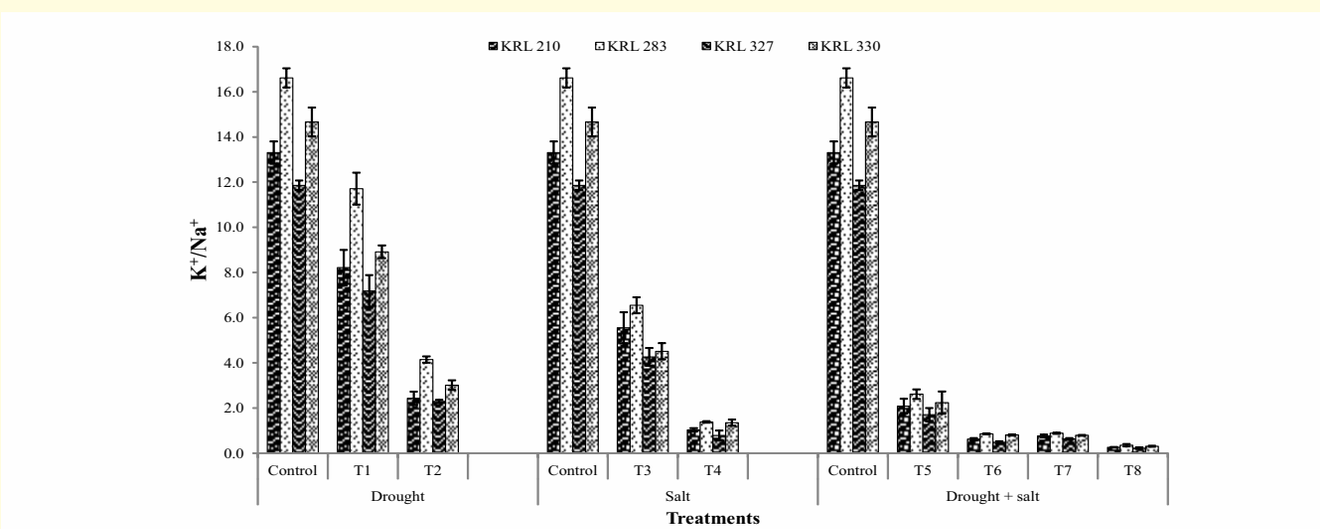


Fig. 36. Effect of salinity and drought stresses on K^+/Na^+ in wheat varieties differing in their tolerance

condition of salt and drought exhibited a significant decline in photosynthetic rate (P_N), stomatal conductance (g_S), transpiration rate (E), K^+/Na^+ ratio; drastically in HD 2009 and marginally in Kh 65 and KRL 210. All the varieties showed increased accumulation of proline with increasing salinity which helped in the osmotic adjustment. At 50% WD + 100 mM NaCl stress, K^+/Na^+ ratio decreased in the following order: Kh 65 (0.34) > KRL 210 (0.26) > HD 2851 (0.23) > HD 2009 (0.18) (Fig. 36). In addition to these four varieties, physiological responses of KRL 283, KRL 327 and KRL 330 were also evaluated in comparison to salt tolerant variety KRL 210. K^+/Na^+ ratio decreased in the following order: KRL 283 (0.35) > KRL 330 (0.31) > KRL 210 (0.26) > KRL 283 (0.22) at 50 % WD + 100 mM NaCl stress. Out of seven wheat varieties, 5 varieties showed less than 25 % reduction in grain weight (g plant^{-1}) under individual stress (either drought or salinity). In the combined stress treatment (50 % WD + 100 mM NaCl), variety Kh-65 showed significantly less (28.64 %) reductions in grain weight plant^{-1} followed by KRL 330 (36.56%), KRL 283 (39.03%), KRL 327 (39.23%), KRL 210 (45.58%), HD 2851 (57.54 %) and HD 2851 (73.64 %) (Table 63).

Rice Crop

Salinity and drought stresses caused the reduction in photosynthetic rate. Under combined stress conditions, different rice varieties maintained photosynthetic rate only up to 50 mM NaCl + 25% WD. Thereafter, severe reductions were observed for IR 29>PR 114> Pusa 44. Proline concentration increased both in roots and shoots in all the rice varieties, but accumulation was lower in roots. Under combined stresses, the highest Na^+/K^+ ratio in shoots was recorded in Pusa 44 (2.76) and the lowest in CSR 46 (1.28) whereas in roots, the highest Na^+/K^+ ratio was noted in PR 114 (3.36) and the lowest in CSR 36 (2.07). Mean yield decreased by 23.87, 24.69 and 25.39% under drought, salinity and drought + salinity stresses in comparison to BAW (14.98 g plant^{-1}). Rice variety CSR 10 and CSR 36 showed only 7.0% and 11.7% reductions in grain yield under individual stresses and 24.7% and 33.9% reductions under combined stresses of drought and salinity, respectively.

Table 63: Effect of salinity and drought stresses on grain weight (g plant^{-1}) in wheat varieties differing in their tolerance

Variety/Treatment	Grain weight (g plant^{-1})									
	C	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
Kh-65	8.03	7.63 (4.98)	6.07 (24.41)	7.91 (1.49)	6.82 (15.07)	7.06 (12.08)	6.39 (20.42)	5.88 (26.77)	5.73 (28.64)	6.83
KRL 210	8.25	7.19 (12.85)	5.92 (28.24)	7.35 (10.91)	6.49 (21.33)	6.08 (26.3)	5.07 (38.55)	5.01 (39.27)	4.49 (45.58)	6.20
HD 2851	7.89	5.74 (27.25)	4.43 (43.85)	6.14 (22.18)	4.34 (44.99)	5.51 (30.16)	4.34 (44.99)	3.97 (49.64)	3.35 (57.54)	5.07
HD 2009	8.08	6.71 (16.96)	4.97 (38.49)	5.64 (30.2)	4.33 (46.41)	5.75 (28.84)	3.04 (62.38)	2.37 (70.67)	2.13 (73.64)	4.78
KRL 283	8.48	7.65 (9.79)	6.79 (19.93)	8.11 (6.01)	7.03 (17.1)	6.94 (18.16)	6.33 (25.35)	5.78 (31.84)	5.17 (39.03)	6.90
KRL 327	8.54	7.89 (7.61)	6.83 (20.02)	8.03 (5.97)	6.97 (18.38)	6.81 (20.26)	6.29 (26.35)	5.67 (33.61)	5.19 (39.23)	6.91
KRL 330	8.37	7.69 (8.12)	6.67 (20.31)	7.93 (6.45)	6.94 (17.08)	7.03 (16.01)	6.33 (24.37)	5.78 (30.94)	5.31 (36.56)	6.88

T_1: 25 % Water Deficit; T_2: 50 % Water Deficit; T_3: 50 mM NaCl; T_4: 100 mM NaCl; T_5: 25 % Water Deficit + 50 mM NaCl; T_6: 25 % Water Deficit + 100 mM NaCl; T_7: 50 % Water Deficit + 50 mM NaCl; T_8: 50 % Water Deficit + 100 mM NaCl

AGROFORESTRY IN SALT AFFECTED SOILS

Growth and physiology of guava (*Psidium guajava* L. cv. Allahabad Safeda) and bael (*Aegle marmelos* Correa cv. NB-5) under salinity stress (Anshuman Singh, R. K. Yadav, Ashwani Kumar and Ashim Dutta)

Evidence is mounting that use of salt tolerant cultivars capable of enduring high salt levels could be one of the best strategies to achieve stable yields from salt affected soils. Although majority (~75%) of the cultivated fruit species are sensitive to salt stress, appreciable genotypic differences have been noted for salt tolerance in many fruit crops. Both guava (*Psidium guajava* L.) and bael (*Aegle marmelos* Correa) crops perform well in (semi) arid regions characterized by constraints such as poor soils, fresh water scarcity and salinity. However, little evidence exists regarding their reaction to shallow saline water table conditions. As guava and bael cultivation offers significant economic opportunities to the growers, an experiment was conducted to assess the effects of salinity on growth, physiological activities and fruiting in guava cv. Allahabad Safeda and bael cv. NB-5 at Nain Experimental Farm, Panipat, India. The farm site has barren saline lands having thick salt crust. The surface soil is mostly highly saline and also underlain with saline groundwater. Besides high salinity, impeded drainage and poor horizon development are other characteristic features of the soil. In this experiment, three different types of saline water were used. Based on the physico-chemical properties, waters applied were designated as the best available water (BAW), marginally saline water (MSW) and saline water (SW). There were five salinity treatments: BAW (EC_{iw} 2.8 dS m^{-1}), C_M- MSW (4 dS m^{-1}) and BAW in cyclic mode, R_M- regular irrigation with MSW, C_S- SW (6 dS m^{-1}) and BAW in cyclic mode and R_S- regular irrigation with SW.

Saline irrigations were withheld subsequent to the appearance of salt injury symptoms and data were recorded for plant growth, ionic composition and physiological activities in the salt treated plants. Data presented in Table 64 revealed that salinity adversely affected plant growth in guava cultivar Allahabad Safeda. While cyclic irrigation with MSW and BAW did not significantly affect the growth, regular application of MSW caused

Table 64: Effect of salinity on plant growth in guava cv. Allahabad Safeda and bael cultivar NB-5

Treatments	Survival (%)	Plant height (cm)	Stem girth (cm)	Plant spread		Branches Plant^{-1}
				N-S(cm)	E-W(cm)	
		Guava cv. Allahabad Safeda				
BAW (Control)	100.0^{a}	102.33^{ab}	4.40^{a}	148.83^{a}	143.03^{a}	9.33^{a}
CM	075.0^{b}	110.90^{a}	4.37^{a}	134.47^{b}	116.93^{b}	8.67^{a}
RM	050.0^{cd}	093.60b^{c}	4.00^{a}	114.13^{c}	098.83^{c}	6.67^{b}
CS	025.0^{e}	092.77^{bc}	3.40^{b}	093.60^{d}	085.93^{d}	5.33^{b}
RS	NPS	083.67^{c}	3.03^{b}	081.67^{e}	064.57^{e}	3.33^{c}
		Bael cv. NB-5				
BAW (Control)	100.0^{a}	152.97^{a}	3.63^{a}	126.87^{a}	143.27^{a}	5.33^{a}
CM	100.0^{a}	143.17^{a}	3.57^{a}	129.53^{a}	131.10^{a}	4.33^{b}
RM	075.0^{b}	128.97^{b}	3.20^{b}	101.40^{b}	116.30^{b}	4.00^{bc}
CS	050.0^{cd}	107.07^{c}	2.80^{c}	094.43^{b}	104.27^{b}	3.33^{cd}
RS	050.0^{cd}	086.20^{d}	2.53^{c}	080.93^{c}	084.27^{c}	3.00^{d}

Description: BAW- best available water (EC_{iw} 2.8 dS m^{-1}), C_M- marginally saline water (4 dS m^{-1}) and BAW in cyclic mode, R_M- regular irrigation with MSW, C_S- saline water (6 dS m^{-1}) and BAW in cyclic mode and R_S- regular irrigation with SW. Means (n=4) with at least one letter common are not statistically significant using Duncan's Multiple Range Test at 5% level of significance. * NPS- No plants survived.

Plant growth in saline irrigated guava and bael. a and c: Best available water (EC_{iw} 2.8 dS m^{-1}) irrigation; b and d: Regular application of saline water (EC_{iw} 6.0 dS m^{-1})

marginal to significant reductions in plant height, canopy spread and branching. Regular saline irrigation led to severe decrease in plant growth and guava plants receiving 6 dS m^{-1} water were severely affected. A more or less similar trend was also observed in case of bael cv. NB-5. Although there was little adverse impact of regular MSW irrigation, watering with SW (6 dS m^{-1}), either in cyclic or regular modes, caused severe reductions in plant growth. In both the crops, plant height and stem girth were relatively less affected but branch emergence and leaf production significantly decreased with increasing salinity giving the salinized plants an upright and sparse look. In contrast, plants irrigated with BAW tended to be compact and bushy in growth (Fig. 38).

Leaf ionic composition indicated that Na^+ concentration marginally increased while K^+ levels declined up to 4 dS m^{-1} salinity in both the crops. Leaf Na^+ increased by 225% in guava and by 144% in bael when SW and BAW were applied in cyclic mode compared to control resulting in excessive leaf Na^+/K^+ ratio unfavourable to plant growth. Regular application of SW further increased Na^+ accumulation in leaves with concurrent decrease in K^+ levels resulting in heavy leaf abscission and wilting in both the crops.

Salinity induced changes in different gas exchange parameters (Table 65) revealed that leaf chlorophyll, net photosynthesis, stomatal conductance, transpiration, chlorophyll fluorescence (Fv/Fm) and photon quantum yield consistently declined in both guava and bael with increasing salinity. Nonetheless, the decreases were only symbolic when MSW was applied in alternation with BAW. Regular use of MSW and SW, either in cyclic or regular modes, led to appreciable to severe reductions in total chlorophyll and gas exchange

Table 65: Salinity induced changes in gas exchange attributes and osmo-regulators in guava cv. Allahabad Safeda and bael cv. NB-5

Treatments	TC	P_N	gS	E	CF	PQY	P	TSS
	Guava cv. Allahabad Safeda							
BAW (Control)	1.45[a]	6.61[a]	0.41[a]	8.01[a]	0.71[a]	0.59[a]	3.68[e]	8.11[a]
C_M	1.35[b]	6.01[b]	0.37[b]	7.56[b]	0.69[b]	0.56[b]	5.24[d]	7.39[b]
R_M	1.29[c]	5.56[c]	0.29[c]	6.36[c]	0.67[c]	0.52[c]	7.44[c]	6.42[c]
C_S	1.11[d]	4.84[d]	0.27[d]	5.70[d]	0.65[d]	0.52[c]	9.67[b]	6.07[cd]
R_S	1.03[e]	4.11[e]	0.23[e]	5.14[e]	0.63[e]	0.50[d]	15.18[a]	5.70[d]
	Bael cv. NB-5							
BAW (Control)	0.94[a]	6.53[a]	0.37[a]	7.04[a]	0.76a	0.67[a]	7.73[e]	4.13[a]
C_M	0.63[b]	5.86[b]	0.31[b]	6.31[b]	0.72[b]	0.63[b]	9.07[d]	3.84[b]
R_M	0.55[d]	5.40[c]	0.28[c]	5.49[c]	0.68[c]	0.56[c]	10.66[c]	3.63[c]
C_S	0.58[c]	4.78[d]	0.19[d]	5.07[d]	0.65[d]	0.52[d]	15.50[b]	3.51[c]
R_S	0.44[e]	3.53[e]	0.17[e]	4.50[e]	0.60[e]	0.51[d]	21.61[a]	2.98[d]

Description: As in Table 2. **Note:** TC- Total chlorophyll (mg g^{-1} FW), P_N- net photosynthesis (µmol m^{-2} sec^{-1}), gS- stomatal conductance (mmol m^{-2} sec^{-1}), *E*- transpiration rate (mmol m^{-2} sec^{-1}), CF- chlorophyll fluorescence (Fv/Fm), PQY-Photon Quantum Yield (Y[II]), P- proline content (mg g^{-1} FW), TSS- total soluble sugars (mg g^{-1} FW)

characteristics. For example, net photosynthesis dropped by 26 and 37% in guava, and by 26 and 45% in bael when SW was used either in cyclic or regular modes, respectively, compared to control. While leaf proline levels increased total soluble sugars decreased with increasing salinity in both the crops.

Based on these observations, it appeared that irrigation with marginally saline water (EC_{iw} ~4 dS m^{-1}) is feasible in guava cv. Allahabad Safeda and bael cv. NB-5. Lower stomatal conductance and transpiration rate, as well as increased accumulation of proline appeared to alleviate salt stress in both the crops.

Identification of salt tolerant ber (*Zizyphus mauritiana* Lam.) rootstocks in a farmer participatory mode. (Anshuman Singh, Ashwani Kumar, Parvender Sheoran, R. K. Singh, D. K. Sharma, Rajkumar and R. K. Yadav)

Considering the importance of ber cultivation in Haryana and other salt-affected regions of the country, a project was intiated with the following objectives: 1. Screening of selected *Zizyphus* lines under *ex situ* salt stress conditions to identify the salt tolerant rootstock(s), and 2. Identification of constraints in ber cultivation and capacity building of growers to address the gaps in profitable production.

A survey was conducted in different ber growing areas of Haryana in years 2015 and 2016 to understand the current status of ber cultivation and the constraints faced by growers. A total of twenty orchards were sampled; 2 in Sonepat, 7 in Hisar, 3 in Jhajjar, 6 in Rewari and 2 in Mahendergarh districts, to record the basic orchard information and growers' perceptions about ber cultivation. Central State Farms, Durjanpur, Hisar was also visited where different ber cultivars are being maintained in the germplasm repository. In addition to basic data, soil, water and fruit samples were also collected for the research purpose. Although area of ber orchards ranged from as low as 0.2 ha to as high as 2.8 ha, majority of them were small in size. Out of total, 50% of the orchards were ≤ 0.5 ha in area, 25% were 0.6-1.0 ha in area and the remaining 25% ranged from 1.6 to 2.8 ha in size. Orchard age varied from ~10 to over 100 years indicating, on one hand, continuity in the establishment of new orchards, and on the other, conservation of the old orchards. While about 60% of the orchards had trees of only one or two cultivars, remainder were multi-varietal plantations consisting of three or more cultivars of different maturity groups likely

Table 66. Ranking of constraints impacting commercial ber cultivation in Haryana.

Constraint	Response (%)	Rank
Absence/erratic supply of canal water	74	1
Problems in marketing	72	2
Heavy incidence of powdery mildew	65	3
Saline groundwater	50	4
Damage caused by birds/ blue bulls	28	5
High conveyance charges for fresh water	22	6
Heavy lac infestation (every 3rd year)	12	7

to be more resilient to the market and climate shocks. Young orchards (≤ 25 years) mostly had either single or mixed stands of Gola (early), Kaithali (mid-season) and Umran (late) cultivars. In contrast, landraces such as Lakhal, Najuk, Katha, Reshmi, Illaichi, Bagu, Bhoora Gola and Kala Gola were also found in the old orchards of Rewari (Bawal area) and Mahendergarh districts.

A total of 7 major constraints adversely impacting commercial ber production were (in decreasing order): limited availability of canal water for irrigation, problems in sale of fruits, losses caused by powdery mildew disease, occurrence of saline groundwater, damages caused by birds and blue bulls, high conveyance charges for fresh water and heavy lac infestation every 3rd year (Table 66). Analysis of irrigation water samples indicated that salinity was a limitation in 12 locations. Irrigation water was marginally saline (EC_{iw}~3 dS m^{-1}) at four locations, moderately saline (4-5 dS m^{-1}) at three,

Table 67. Irrigation water quality at different locations

Location	pH	EC_{iw} (dS m^{-1})	Na^+ (meq L^{-1})	K^+ (meq L^{-1})	Ca+Mg (meq L^{-1})	Cl^- (meq L^{-1})	HCO^-_3 (meq L^{-1})	SAR
Hisar								
Sulkhani	7.8^{m}	9.6^{a}	89.8^{a}	5.2^{b}	35.0^{d}	58.0^{a}	6.0^{f}	21.5^{a}
Dobhi	8.2^{e}	4.3^{f}	44.7^{e}	2.9^{f}	16.0^{k}	18.0^{i}	7.0^{b}	15.8^{b}
Arya Nagar	8.3^{d}	2.3^{m}	8.2^{p}	1.4^{j}	19.0^{h}	14.0^{k}	3.0^{l}	2.7^{m}
Chautha Meel	7.5^{p}	4.0^{h}	24.5^{h}	1.7^{h}	29.0^{f}	26.0^{f}	1.0^{r}	6.4^{g}
Neoli Kalan	8.2^{e}	7.5^{b}	46.2^{b}	2.7^{g}	47.0^{a}	56.0^{b}	5.0^{g}	9.5^{e}
Kali Ravan	8.0^{hi}	1.4^{p}	8.2^{q}	1.3^{k}	8.0p	8.0^{q}	3.0^{k}	4.1^{kl}
Motsara	7.6^{o}	6.2^{d}	45.7^{d}	5.2^{a}	34.0^{e}	30.0^{d}	2.0^{q}	11.1^{d}
Jhajjar								
Ghuda	7.3^{r}	6.4^{c}	45.9^{c}	3.9^{d}	35.5^{c}	44.0^{c}	6.0^{e}	10.9^{d}
Jhajjar-1	7.9^{j}	2.9^{i}	17.9^{j}	3.9^{c}	19.0^{i}	12.0^{l}	3.0^{i}	5.8^{h}
Jhajjar-2	8.4^{c}	2.6^{l}	15.7^{l}	3.7^{e}	18.5^{j}	9.0^{p}	2.5^{n}	5.2^{i}
Rewari								
Bawal	8.2^{e}	2.8^{j}	19.7^{i}	0.7^{q}	4.0^{r}	16.0^{j}	7.0^{a}	13.9^{c}
Astal	7.8l	1.4^{o}	13.0^{m}	0.6^{r}	16.0^{l}	10.0^{o}	2.5^{p}	4.6^{j}
Kheda Murar	7.3^{q}	1.2^{q}	11.5^{o}	0.6^{s}	13.5^{n}	26.0^{g}	7.0^{c}	4.4^{jk}
Nahchana	8.8^{a}	4.1^{g}	37.1^{f}	1.6^{i}	14.0^{m}	27.0^{e}	6.5^{d}	14.0^{c}
Laduwas-1	8.1^{h}	4.6^{e}	26.2^{g}	0.8^{n}	38.0^{b}	10.0^{m}	2.5^{o}	6.0^{h}
Laduwas- 2	8.5^{h}	2.8^{k}	13.0^{n}	0.8^{o}	22.0^{g}	8.0^{r}	2.5^{m}	3.9^{l}
Mahendergarh								
Subhash Nagar	8.0^{h}	1.7^{n}	7.2^{k}	1.2^{l}	8.5^{o}	20.0^{h}	3.0^{j}	8.4^{f}
Kadiyanwala	7.9^{k}	0.5^{s}	2.1^{s}	0.7^{p}	2.0^{s}	10.0^{n}	1.0^{s}	2.0^{n}

Table 68. List of genotypes screened under salt stress

Genotype/species	Source	Remarks
Z. rotundifolia	CIAH, Bikaner	Indigenous species, used as rootstock
Z. spinachristi	CIAH, Bikaner	An introduction, being maintained at CIAH
Tikadi	CIAH, Bikaner	Very small fruits, tolerant to fruit fly
Manuki	CIAH, Bikaner	An introduction, being maintained at CIAH
Illaichi	CIAH, Bikaner	Small fruits similar to cardamom
Gol	Narnaul	A locally adapted landrace in Rewari/Mahendergarh
Bagu Gola	Narnaul	A locally adapted landrace in Rewari/Mahendergarh
Najuk	Narnaul	A locally adapted landrace in Rewari/Mahendergarh
Reshmi	Bawal	A locally adapted landrace in Rewari/Mahendergarh
Gola	Jhajjar	Most important early cultivar in Haryana
Mundia Murhera	CSF, Hisar	Mid-season cultivar recommended for Haryana
Umran	CSF, Hisar	Most important late cultivar in Haryana
Sandhura Narnaul	CSF, Hisar	Early cultivar recommended for Haryana
Katha Phal	CSF, Hisar	Purplish, sweet fruits
Kaithali	CSF, Hisar	Mid-season cultivar recommended for Haryana
Seb	CSF, Hisar	An important cultivar suitable for extremely dry areas

saline (6-7.5 dS m^{-1}) at three and very saline (~9.6 dS m^{-1}) at one location. In rest of the villages, salinity problem was not observed and the groundwater was suitable for irrigation (Table 67).

The fruit yield was also recorded to see whether excess salts in soil and water had any effect on economic returns. It emerged that salinity caused considerable decreases in fruit yield as orchards similar in age and variety significantly differed from each other in fruit size. Invariably, saline irrigated trees tended to bear small fruits compared to their counterparts irrigated with good quality water. For example, 20 year old orchards of Gola variety produced 1.5 to 2 q fruits per tree when irrigated with saline water of 6.13 dS m^{-1}. However, tree yield declined to about 1 q with further increase in soil (EC_e 10.25 dS m^{-1}) or water (EC_{iw} 9.5 dS m^{-1}) salinity.

Rootstock trials

Different genotypes/species (16), collected from various centres/locations (Table 68), were screened under two sodicity (pH 8.6 and 9.2) and two salinity (EC_e 4.5 and 6 dS m^{-1}) levels. Only 11 species germinated and grew at both the sodicity levels. None of the seeds germinated in saline soils indicating high sensitivity of ber to salinity during germination and early seedling growth. Out of the tested genotypes, five best performing lines,

Capacity building programmes for ber growers.

namely, *Z. rotundifolia* (Hisar), Katha Phal (Hisar), *Z. rotundifolia* (Bikaner), *Z. spinachristi* (Bikaner) and Tikadi (Bikaner) have been planted at Nain Farm, Panipat to record their performance in natural saline soils. Similarly, two genotypes *Z. rotundifolia* (Bikaner) and *Z. spinachristi* (Bikaner) are also being tested for their tolerance to sodic irrigation water [residual sodium carbonate (RSC) levels of 0, 3, 6 and 9 meq L^{-1}].

Capacity building of ber growers

A 'Capacity Building Programme of ber growers on 'Improved Production Technologies in Horticultural Crops' was organized from 09-12 May, 2016 at ICAR-CSSRI, Karnal. It this training, ber growers from different districts of Haryana such as Karnal, Sonipat, Jind, Jhajjar, Rewari, Mahendergarh, Hisar and Bhiwani participated and benefitted from expert lectures, field and institutional visits to enhance their knowledge and skills for increasing the farm productivity. Another study tour-cum-exposure visit of ber growing farmers was organized from 02-07 January, 2017. A total of 25 farmers representing Karnal, Sonepat, Hisar, Rewari, Mahendergarh, Bhiwani and Charkhi Dadri districts participated in this programme and visited CCSHAU, Hisar; ICAR-CIAH, Bikaner; ICAR-CAZRI, Jodhpur and RARI, Durgapura, Jaipur to learn the improved production techniques in ber and other horticultural crops.

Enhancing productivity potential of saline soil through agroforestry system using saline irrigation (R. Banyal, R. K. Yadav, P. Sheoran, M. D. Meena, Bhaskar Narjary and D. K. Sharma)

As an alternative approach for the reclamation of salt affected soils, an experiment was started to rehabilitate the saline soils through development of *Eucalyptus tereticornis* and *Melia composita* based agroforestry systems at Nain Experimental Farm, Panipat. The treatments included three land use systems (LU_1-tree+crop, LU_2-sole tree and LU_3-sole crop) and five (I_1-good quality available water with EC_{IW} <1 dS m^{-1}, I_2- EC_{IW} 4 dS m^{-1}, I_3- EC_{IW} 8 dS m^{-1}, I_4- EC_{IW} 12dS m^{-1} and I_5- no irrigation; control) irrigation treatments in plantations with pearl millet and mustard as companion crops in *Rabi* and *Kharif* seasons, respectively. Pearl millet was sown in the month of July and harvested in November, 2016. Likewise, the observations on tree parameters were recorded in the month of October, 2016.

***Eucalyptus* based agroforestry system:** *Eucalyptus* showed good establishment and growth performance. The effect of different irrigation regimes was statistically non-significant on survival percentage, plant height, bole height, DBH and crown spread. The higher values of all parameters, irrespective of land use adopted, were observed in the trees irrigated with good quality water (I_1). Growth decreased as the salinity of irrigation water increased. Tree and bole height did not differ between agro-forestry with pearl millet and sole trees; however, DBH and crown spread were higher in LU_2 than LU_1. Yield of pearl

Pearlmillet crop under Eucalyptus

Pearlmillet crop under Melia

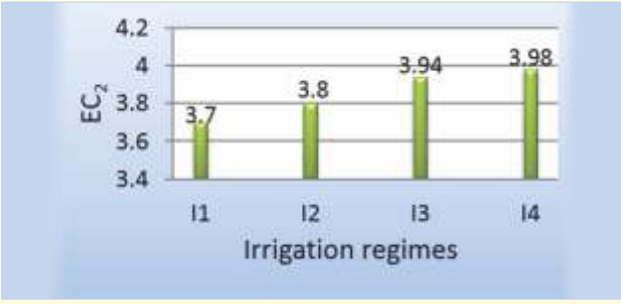


Fig. 37 (a). Effect of irrigation regimes and land uses on soil EC_2 in Melia based agroforestry system

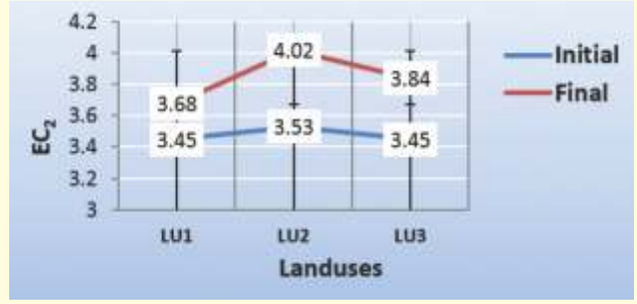


Fig. 37 (b). Effect of irrigation regimes and land uses on soil EC_2 in Melia based agroforestry system

millet was higher (0.86 t ha^{-1}) in good quality water irrigated plots and decreased with the increase in water salinity. The lowest yield (0.54 t ha^{-1}) was obtained in the plots irrigated with 12 dS m^{-1} water under *Eucalyptus* based agroforestry system. LU_1 gave higher pearl millet yield (0.64 t ha^{-1}) than LU_2 (0.48 t ha^{-1}) but the effect was statistically non-significant. Although soil salinity increased in I_2 to I_4 irrigation regimes but EC_2 and pH were lower than the initial values in the plots irrigated with good quality water (I_1). No definite trend in EC_2 and pH was observed with changing soil depths from 0-15 and 15-30 cm.

***Melia* based agroforestry system:** Irrigation regimes showed non-significant effect on survival and plant height, bole height and DBH but crown spread was significantly affected. In comparison to saline irrigated trees, those receiving good quality water had higher plant height, bole height and DBH. The lowest values of these growth parameters were observed in the trees without irrigation. Sole trees showed higher survival (95.5%) than in agro-forestry with pearl millet (90.0%). Similar trend was also noticed for plant height, bole height, DBH and crown spread. LU_2 resulted in significantly higher crown spread as compared to LU_1. Pearl millet yield was significantly influenced by different land use treatments while it was non-significant with different irrigation regimes. Higher crop yield (0.69 t ha^{-1}) was recorded under *Melia* plantations than the sole crop conditions (0.014 t ha^{-1}). The highest yield (0.79 t ha^{-1}) was observed in the plots irrigated with good quality water (ECiw <1 dS m^{-1}) and the lowest (0.54 t ha^{-1}) with the highest salinity level (I_4). The values of EC_2 and pH consistently increased from low (I_1) to higher (I_4) salinity levels (Fig. 37a). Soil salinity (EC_2) buildup over initial value was noticed in all the three land uses (Fig. 37b). LU_1 caused minimum increase (6.0%) followed by LU_3 (11.0%) and LU_2 (13.0%) during July 2016 as compared to pearl millet harvesting in November, 2016. Water table depth decreased from July to September and then slightly increased in October in both the plantations. EC_2 of ground water is higher under *Eucalyptus* than *Melia* plantations during July to October, 2016.

Evaluation of agroforestry trees in saline environment (R. Banyal, Ajay K. Bhardwaj, Parveen Kumar, R. K. Yadav and Aslam L Pathan**)**

Saline soils otherwise unsuitable for growing the field crops can be put under tree plantations to achieve steady improvements in soil properties as well as to meet the ever increasing demands of tree products as supply of wood products from the existing forest areas cannot match the current demand. In most of the previous studies, the emphasis has been given on plant survival at high salt concentrations rather than on growth performance at moderate concentrations with the intercrops. The present experiment was designed to evaluate the agroforestry trees for establishment, biometric gains including carbon sequestration and influence on soil reclamation in saline soils. A field experiment was laid out Nain Experimental Farm, Panipat; with five agroforestry tree species *viz.*, *Eucalyptus tereticornis* (clone 413), *Terminalia arjuna*, *Melia composita*, *Azadirachta indica* and *Dalbergia sissoo* planted at 4 x 2 m spacing. The soil of the experimental site is saline sodic with pH ranging from 9.03 to 10.31. The groundwater, used for irrigation, is also saline.

Eucalyptus tereticornis showed the highest survival (99%) followed by *Azadirachta indica* (98.6%), *Dalbergia sissoo* (98.5%), *Terminalia arjuna* (96.7%) and *Melia composita* (94.3%) in the first year. Increases in plant height and collar diameter were higher in the first interval (July 2015- July 2016) than July-October, 2016. The highest increase in plant height (363.5%) was noticed in *Eucalyptus tereticornis* followed by *Azadirachta indica* (176%), *Melia composita* (60.17%), *Terminalia arjuna* (53%) and *Dalbergia sissoo* (51%) over average height at the time of out-planting. *Azadirachta indica* recorded the highest increase (372%) in collar diameter than the rest of the trees tested.

Screening of 15 promising medicinal and aromatic plants, for salt stress tolerance, is also in progress under pot house conditions. Saline soil and water to be used for irrigation were brought from the Nain Experimental Farm. *Cymbopogon flexuosus*, *C. citratus*, *Glycorrhiza glabra*, *Aloe vera* and *Eclipta alba* have shown good survival. One of the best plant species in each category will be taken as companion crop in respective plantation crops in the coming rainy season.

Performance of *Eucalyptus* plantations on water logged saline ecologies (R Banyal, Ajay K. Bhardwaj, Gajender and Aslam L Pathan**)**

The present research project has been initiated to address the issues in raising bio-drainage plantations and to evaluate their potential in the reclamation of agricultural lands including the ecological sustainability of the plantations in waterlogged areas. The study is being carried out in selected locations of Jhajjar and Hisar districts of Haryana. Five sites having *Eucalyptus tereticornis* plantations in Jhajjar (three sites) and Hisar (two sites) districts were marked for studying the performance of plantations in terms of growth, effect on soil physical and chemical attributes, to generate *Eucalyptus* based agroforestry models and the socio-economic impacts. Questionnaire has been developed for taking the observations pertaining to the socio-economic aspects of bio-drainage technology. The soil EC_e and pH at

Dighal in Jhajjar

Dujyana in Jhajjar

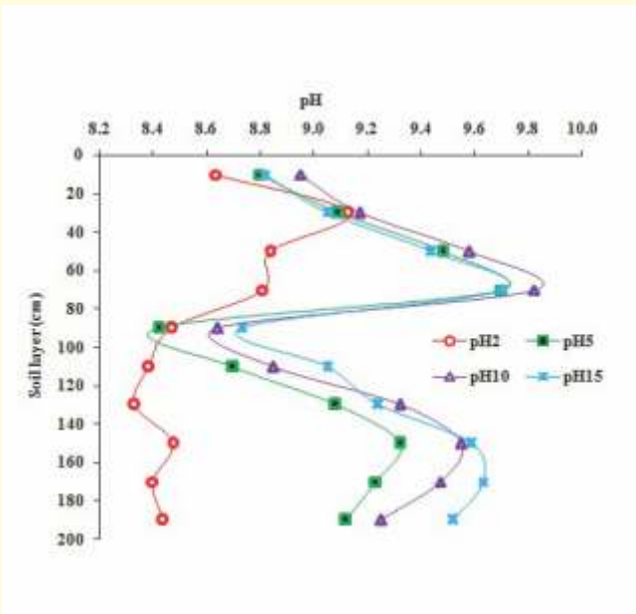
Thurana A in Hisar

Thurana B in Hisar

Dighal and Dujyana sites of Jhajjar varied from 6.87 to 45.3 dS m^{-1}, and from 7.49-8.99, respectively, across the sampling depths upto 120 cm.

Effect of land uses on salt distribution and properties of salt affected soils (Ashim Datta, Nirmalendu Basak, Anil R. Chinchmalatpure and Rakesh Banyal)

Ten land-uses namely *Eucalyptus*, Kainth, Karonda-Mustard, *Prosopis alba*-Mustard, Aonla-Mustard, Bael-Mustard, *Prosopis*-Aloevera, *Acacia nilotica*, *Tamarix articulata* and Jowar-wheat situated at Bir forest, Hisar were studied to evaluate the effect of dilution on soil pH and EC. For this purpose, soil samples were collected up to a depth of 200 cm with an interval of 20 cm. Four soil: water ratios *viz.*, 1:2, 1:5, 1:10 and 1:15 were used for estimation of pH and EC of the soil. Results showed that, irrespective of soil depth, Karonda-Mustard system recorded the highest pH and EC in all the soil: water ratios than the other land uses (Fig. 38). At 0-20 cm depth, the highest (8.95) and the lowest (8.64) pHwas observed at 1:10 and 1:2 soil: water ratios, respectively. With depth, soil pH increased irrespective of soil water ratios and the highest (9.82) was observed at 60-80 cm depth under Karonda-Mustard. Soil EC decreased with increase in dilution irrespective of soil depth and land uses. The highest salt content was observed under Karonda-Mustard land use throughout the soil profile. At 60-80 cm soil depth, the highest EC_2 (3.08 dS m^{-1}) was observed. In most of the land uses, higher EC was observed with



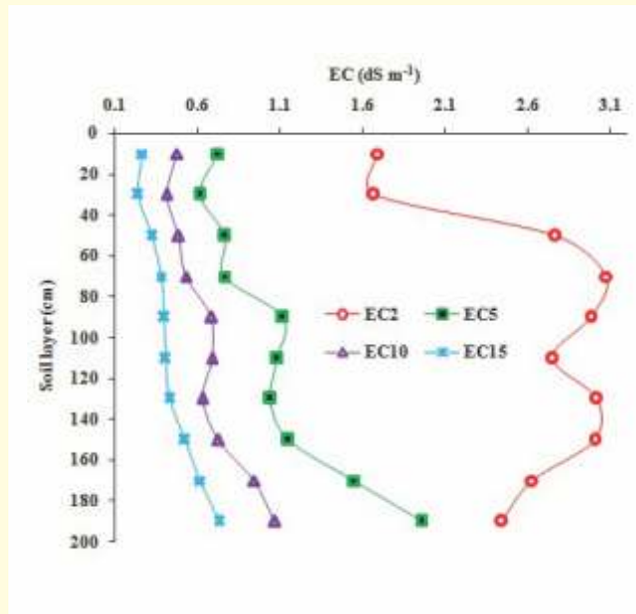


Fig. 38. Effect of dilution on changes in soil pH and EC under Karonda- Mustard system

Table 69: Litter fall under different tree plantations

*Date of collection (15 days interval)	Litchi	Guava	Mango	Jamun	Eucalyptus	Silver Oak	Kikkar	Aonla
	kg $tree^{-1}$							
1st	0.35	1.49	1.40	0.69	0.49	0.60	0.12	2.51
2nd	1.54	3.16	2.18	1.89	0.66	1.36	0.09	3.00
3rd	1.68	2.72	2.84	2.66	1.04	1.40	0.29	3.16
4th	0.77	3.00	1.64	5.56	0.17	1.03	0.17	1.14
5th	0.53	1.50	0.83	3.93	0.61	0.91	0.23	0.83
6th	0.86	2.27	0.73	3.77	0.51	2.18	0.26	1.09
7th	0.66	0.78	0.29	1.05	0.27	1.33	0.34	0.97

***Collection started from 15th September, 2016**

depth irrespective of soil: water ratios. Except *Eucalyptus* land use, the percentage increase in pH was higher from 1:2 to 1:5 soil: water ratios particularly at lower soil depths under Karonda-Mustard system. Similarly, percentage increase in pH was consistently higher from 1:5 to 1:10 soil: water ratio in all the land uses irrespective of soil depth. But soil pH at 1:15 soil: water ratio did not increase significantly and in some cases even decreased compared to 1:10 soil water ratio

Depth wise distribution of particulate organic carbon (POC) and silt + clay associated carbon (SCC) under different land uses was studied. The highest (0.92%) SCC was observed at 0-20 cm soil depth under *Tamarix* indicating higher stabilization of organic carbon in soil. With depth, both the carbon fractions significantly decreased. Under Karonda-Mustard system, POC concentration (0.48%) was higher than SCC (0.30%) at 0-20 cm soil depth. The highest POC (0.57%) was observed at 40-60 cm soil depth. Leaf litter fall production under different land uses situated at CSSRI Experimental Farm, Karnal was also studied. Litter production was higher in October and November. Jamun gave the highest leaf production value (5.56 kg tree^{-1}) whereas kikar produced only 0.17 kg tree^{-1} leaf during September-December (Table 69).

Identification of high yielding and salt tolerant genotypes of pomegranate (Rajkumar, Anita Mann, Murli Dhar Meena, Anshuman Singh, R. K. Yadav and D. K. Sharma)

Pomegranate (*Punica granatum* L.), due to its xerophytic characteristics, is a suitable fruit crop for dry and saline soils characterized by poor soil fertility and low water availability. In order to explore the possibility of commercial pomegranate cultivation in salt affected soils, an experiment was started to evaluate different pomegranate genotypes for their salt tolerance. A total of 20 genotypes (18 of unknown pedigree and two commercial cultivars) collected from the farmers' fields and research institutes of Rajasthan state, were named after the respective districts of collection. Hardwood cuttings (15-20 cm length) of these genotypes were grown in normal (EC_e~2.4 dS m^{-1}) and saline soils (EC_e ~8, 12 and 16 dS m^{-1}). Four months after planting, different growth and physiological parameters were recorded. The survival ranged from 6.67 to 100% under control conditions, in Bhagwa and Rajasmand 2, respectively. The rate of survival decreased significantly in saline soils with mean of 3% at 8 dS m^{-1}, 1.33% at 12 dS m^{-1} and only 0.67 at 16 dS m^{-1}. Genotypes Jaipur 2, Jaipur 3, Ajmer 1, Ajmer 2, Rajasmand 3, Rajasmand 4, Udaipur 1, Udaipur 2, Ganesh and Bhagwa survived up to salinity level of 8 dS m^{-1}. However, only 5 of these genotypes *i.e.*, Jaipur 2, Jaipur 3, Rajasmand 3, Udaipur 1 and Udaipur 2 tolerated salinity of 12 dS m^{-1} and only 2 (Udaipur 1 and Rajasmand 3) survived at the highest salinity (16 dS m^{-1}) level. On the basis of survival and plant growth, these genotypes are being evaluated in natural saline soils (EC_e up to 15.61 dS m^{-1}) at Nain Experimental Farm, Panipat.

Establishment of Pomegranate Mother Block

In order to create a permanent source of cuttings for the future experiments as well as to record the performance of collected genotypes, two mother blocks have been established in saline soils at Nain, Panipat and in partially reclaimed sodic soils at Karnal. Different genotypes were planted in mother block during February, 2016 at CSSRI Experimental Farm, Karnal and at Nain Experimental Farm during March, 2016. After five months of planting in the field, the maximum

Table 70: Soil properties in Progeny Block at ICAR-CSSRI Experimental Farm, Karnal

Soil depth	pH	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (me L^{-1})	Mg(me L^{-1})
0-15	7.55	0.73	141.12	36.376	213.5	2.40	2.23
15-30	7.69	0.35	130.67	29.864	211.4	1.93	2.03
30-45	8.03	0.14	128.05	29.18	210.1	1.87	1.93
45-60	8.17	0.13	120.21	27.84	204.1	1.80	1.23

plant height (105.45 cm) was observed in genotype Jaipur 2 followed by 97.85 cm in Udaipur 1 and 93.7cm in Ajmer 1. The highest average numbers of branches (16) were recorded in Ajmer 2 followed by 15 in Bhagwa and 13.67 in Udaipur 3, respectively. The maximum stem diameter (2.02 cm) was recorded in Udaipur 2 followed by Ajmer 2 (1.7 cm) and Rajasmand 4 (1.65 cm), respectively. The maximum plant spread was recorded in Ajmer 2 (90.35 cm) followed by Udaipur 1(89.53 cm), and Bhagwa (84.53 cm). Based on these observations, genotypes Jaipur 2, Udaipur 1, Ajmer 2 and Bhagwa seem to have potential for the commercial cultivation in saline soils.(Table 69) Efforts are also underway to understand the physiological and biochemical basis of salt tolerance in these genotypes.

Table 71: Vegetative growth parameters of different pomegranate genotypes grown under salt stress at Nain Experimental Farm

Genotype	Height (cm)	No. of Branches	Diameter (cm)	Spread (cm)
Jaipur 1	80.00	6.00	1.30	60.50
Jaipur 2	105.45	9.50	1.15	78.65
Jaipur 3	87.65	9.00	1.20	72.18
Ajmer 1	51.00	4.67	0.87	40.77
Ajmer 2	93.70	16.0	1.70	90.35
Ajmer 3	65.75	5.00	1.15	39.10
Udaipur 1	97.85	8.50	1.15	89.53
Udaipur 2	81.46	12.4	2.02	77.00
Rajasmand 3	85.58	12.6	1.58	73.22
Rajasmand 4	82.93	12.25	1.65	83.09
Udaipur 3	83.45	13.67	1.40	73.24
Pali 1	78.53	12.75	1.50	70.93
Jodhpur 1	78.70	8.00	1.30	65.70
Ganesh	88.95	12.5	1.50	74.75
Bhagwa	83.45	15.0	1.25	84.53

RECLAMATION AND MANAGEMENT OF ALKALI SOILS OF CENTRAL AND EASTERN GANGETIC PLAINS

Land modification based integrated farming system in waterlogged and waterlogged sodic conditions (C. L. Verma, Y. P. Singh, S. K. Jha, A. K. Singh, T. Damodaran, V. K. Mishra, D. K. Sharma and S. K. Singh)

Watertable rise due to excessive canal seepage increases the translocation of basic salts in the root zone. Uttar Pradesh state has a long network of unlined canals resulting in waterlogging and sodicity problems in the Central Indo-Gangetic plains. Due to continuous efforts, Uttar Pradesh Bhumi Sudhar Nigam has succeeded in reclaiming about 60% of the total sodic area in state (~ 1.32 M ha) using gypsum-based technology. Nonetheless, gypsum application often does not give satisfactory results in waterlogged sodic lands in canal commands (watertable < 2.0 m below the surface) which constitute about 10-15% of the total sodicity affected area of the state. Lowering the watertable below 2.0 m depth, a pre-requisite before gypsum application, is tedious. Further, repeated gypsum applications necessary to sustain the productivity of waterlogged sodic soils result in the higher reclamation costs. Although subsurface horizontal drainage is a proven technology to lower water table under such conditions, unavailability of natural gravity outlets is a major constraint in the adoption of this technology in such soils. Pumped outlet is expensive and beyond the reach of farmers. Considering such constraints, a need has long been felt to develop a sustainable technology for reclamation and management of waterlogged sodic soils.

The idea of inverting low pH deeper soil profiles upside down in a pre-specified soil column by elevating field bed would make soil surface favourable for crop production by improving the internal drainage, physical soil properties and lowering water table below a critical level. Consequently, land modification (fish ponds and raised and sunken beds) based integrated farming was hypothesized as a sustainable technology for the reclamation of waterlogged sodic soils. Both the land modification ideas were tested at Kashrawan village in Raebareli for more than five years. The fish pond model was tested over an area of 1 ha, while raised and sunken bed model over an area of 0.40 ha. Raised and sunken bed system is the most suitable technology for small land holdings with the minimum expense. In contrast, fish pond based models require comparatively large fields. As farmers of the region are resource poor with small and fragmented land holdings, the model needs to be tested for small acreage. Multilocations trials are required to investigate the necessity of alteration in pond design. Standard design equations need to be developed for deciding width of the raised bed and length and width of the elevated field beds.

Study Area

Three study sites were selected in Lalaikheda (Jitendra Singh), Patwakheda (Kalwati Devi) and Salempur Achaka (Sher Bahadur) villages of Lucknow district located along the Sharda Sahayak Canal Command within 200 m distance. These sites are nearly 40 km away from Lucknow towards Raebareli. Water table of the area fluctuates within a range of 0.00 to 1.50 m during rainy season and extreme summer, respectively. Initial soil pH of Lalaikheda, Patwakheda and Salempur Achaka fields ranged 8.96 to 9.69, 9.47 to 9.93 and 7.49 to 7.98 and the corresponding electrical conductivity ranged from 0.203 to 0.569, 0.368 to 1.1474 and 0.065 to 0.189 dS m^{-1}, respectively in a profile depth of 0 to 120 cm.

Crop Performance

Crop performance over elevated field beds during *Rabi* 2016 and *Kharif* 2016 are shown in Fig.1 Wheat (KRL 210) was sown over the raised beds in Lalaikheda and Patwakheda. Different *Rabi* vegetables were grown over raised bed in Salempur Achaka. First wheat crop in *Rabi* 2016 yielded 550 kg (2.354 t ha^{-1}) at Lalaikheda and 300 kg (3.66 t ha^{-1}) at Patwakheda sites. The corresponding B: C ratios for these sites were 2.51 and 2.67. Moong crop grown at Lalaikheda during *Zaid* 2016 yielded 80 kg (0.727 t ha^{-1}) with B: C ratio of 3.54. Rice crop (CSR 43) yields for *Kharif* 2016 at Lalaikheda and Patwakheda fields were 355 kg (4.34 t ha^{-1}) and 620 kg (2.654 t ha^{-1}), respectively

Crop performance over elevated field beds.

with corresponding B: C ratios of 1.99 and 2.37. B: C ratios were: 2.62 for potato, 4.03 for cabbage, cauliflower, brinjal and chilli; and 2.66 for carrot, dill, menthi, spinach, and coriander. Fodder crop was grown during *Kharif* 2016 over raised bed and water chestnut nursery in pond beside fish stocking at Salempur Achaka field. Fodder crop yielded 30 t ha^{-1} giving gross income Rs. 18000.00. About 3 t of water chestnut nursery was produced giving gross income of Rs. 15000.00.

Fish Stocking

Using the fingerlings supplied by NBFGR, Lucknow, fish were cultured in the ponds at Patwakheda and Salempur Achaka sites. Fish fingerlings (5-10 g size) were stocked for grow out culture in the first two ponds @ 10000 ha^{-1} with 20% catla, 30% rohu, 40% mrigal and 10% grass carp of the total. Fish grew in size and attained the weight of 325-650 g. Fish were fed with rice bran (50%) and oil cake (50%) @ rate of 3-10% of total fish biomass per day except in the winter months. Poultry farming and duck rearing were also integrated with fish stocking at Salempur Achaka site. Poultry droppings were used to fertilize the fish pond. Duck culture seemed to improve aeration in the fish pond. Spawn of *C. idella* (grass carp) @ 2 million ha^{-1} were stocked by the Lalaikheda farmer who earned gross income of Rs. 82500 by selling 275 kg of fingerlings. Farmers in Patwakheda and Salempur Achaka villages harvested 116 kg and 282 kg of fish generating gross incomes of Rs. 9280.0 and Rs. 24200.0, respectively.

Design of raised beds widths and length

1) Raised and sunken bed system

A) Steady State Conditions: Definition sketch of raised and sunken bed is shown in Fig. 39. Sunken beds on either sides of the raised bed act as ditch and water level remains below the ground surface. Depth of sunken bed is denoted by D, saturated hydraulic conductivity of filled soil by *K* and discharge rate of water from the side walls of raised bed by *q*.

For steady state conditions, rainfall or recharge (R) and seepage flow from the side walls of raised bed are equal and can be written as below.

$$Kydy = R\left(\frac{W}{2} - x\right)dx \qquad (1)$$

Equation for width of raised bed (W) was derived for the case when ground surface acts as impervious layer due to high pH.

$$W = \left[\frac{4Kh^2}{q}\right]^{\frac{1}{2}} \qquad (2)$$

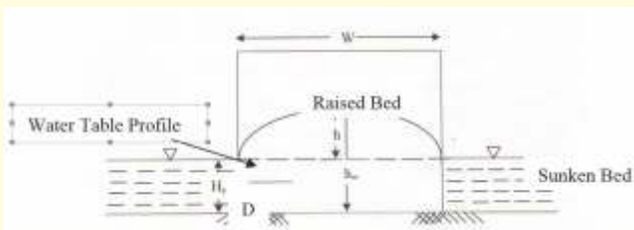


Fig. 39. Definition sketch of raised and sunken bed.

B) Transient Conditions: Raised bed width when water table height falls from ho to ht in time t can be written as below.

$$W = \sqrt{\frac{4Kh_o t}{\frac{p}{4} f\left(\frac{h_o}{h_t} - 1\right)}} \qquad (3)$$

C) Fluctuating Water Table Conditions: Following relationship was derived for transforming

transient raised width formula for predicting water table response with respect to rainfall or recharge.

$$\frac{dh}{dt} = \frac{R}{\frac{p}{4} fb} \cdot \left(1 - \frac{h_t}{h_o}\right) \quad (4)$$

Water table fluctuation in response to rainfall was derived as below

$$h_t = \frac{h_o}{1+bt} + \frac{R}{\frac{p}{4} fb} \cdot \left(\frac{b\,t}{1+b\,t}\right) \quad (5)$$

Where,

$$b = \frac{4Kh_0}{\frac{p}{4} fW^2}$$

For computing daily incremental (Δt=1) water table heights equation can be further re-written as below.

$$h_t = \frac{h_{t-1}}{1+b} + \frac{R_{Dt}}{\frac{p}{4} fb} \cdot \left(\frac{b}{1+b}\right) \quad (6)$$

2. Elevated Bed of Fish Pond: Definition figure of elevated field bed system is shown in Fig. 40.

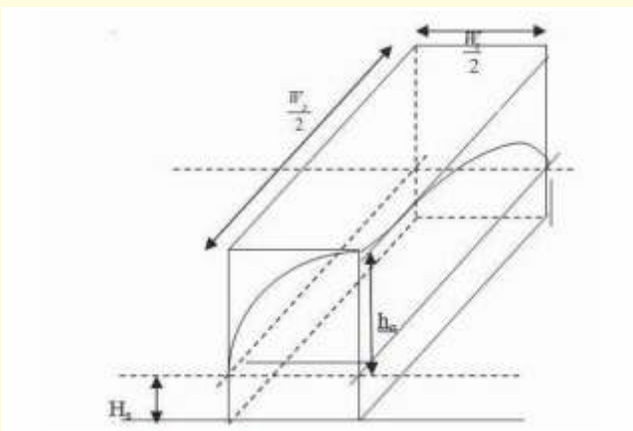


Fig. 40. Definition sketch of elevated field bed system.

A) Steady State Conditions: Raised bed width of elevated field bed having side widths as W1 and W2 can be calculated using raised bed width equation by superimposing from two side ditch systems. Calculate elevated field bed widths using following equation.

$$W_1 = \sqrt{\frac{4Kh^2}{q_{W_1}}} \quad (7)$$

Check if any of the existing widths or length of the field is less than W_1. If it is less than W_1, accept it as one side width of elevated field beds. Calculate steady state drain discharge which will be drained out of elevated fields due to this width. Now calculate left over rainfall or recharge excess or drainage coefficient (1*WTqq*-) and calculate the width of another sides of the field using the equation given below.

$$W_2 = \sqrt{\frac{4Kh^2}{q_T - q_{W_1}}} \quad (8)$$

$$q_T = q_{W_1} + q_{W_2} \quad (9)$$

Where,

q_{W1}= Steady state ditch discharge having width W1

q_T= Drainage or recharge excess or drainage coefficient of the area

B) **Transient Conditions:** Expression could be derived for predicting water table fall with time midway between the elevated field bed having length L and width W as below.

$$h_t = \left(\frac{1}{1+b_L} + \frac{1}{1+b_W}\right) h_{t-1} \quad (10)$$

Where,

$$b_L = \frac{4Kh_0}{\frac{p}{4} fL^2} \quad (11)$$

$$b_W = \frac{4Kh_0}{\frac{p}{4} fW^2} \quad (12)$$

Calculation of W1 and W2 of an elevated field bed should be done for the specific requirement of the water table drop midway between the elevated field bed to match the crop water sustaining ability. In other words, one can first establish criteria that how much water table drop is required once the water table has reached the ground surface resulting in the worst conditions for the crop.

C) Fluctuating Water Table Conditions: Expression could be further derived for predicting water table heights midway between elevated field beds in response to daily rainfall or recharge over any period of time as given below.

$$h_t = \left(\frac{1}{1+b_L} + \frac{1}{1+b_W}\right) h_{t-1} + \frac{R_{Dt}}{\frac{p}{4} f \sqrt{b_L . b_W}} \cdot \left[\left(\frac{1}{1+b_L} + \frac{1}{1+b_W}\right)\right] \quad (13)$$

Water table fluctuation data over a long period (five years) will give an insight whether designed system is appropriate or not. It may also be useful in calculating water ponding for rice fields if accordingly designed. If one is interested in rice cultivation, field bed widths and length could be optimized to retain the maximum water depth over the field during rainy season yet deep enough afterwards to minimize salt accumulation over the field beds.

Estimation of Saturated Water Conductivity: Water flow from an auger hole with spheroidal cavity at the bottom is shown in Fig. 41. Available formula assumes a flat bottom auger hole. Auger has a pointed tapering of different sizes and makes a spheroidal cavity at the bottom. The flow conditions is slightly modified.

Following governing equation was derived for water flow in auger hole.

$$2 K_s \left(h + \lambda_s \frac{r}{2}\right) = - r \frac{dh}{dt} \quad (14)$$

Where λ_s is give below.

a) For oblate spheroid

$$\lambda_{s-o} = 1 + \frac{1 - e_o^2}{e_o} \tanh^{-1} e_o \quad (15)$$

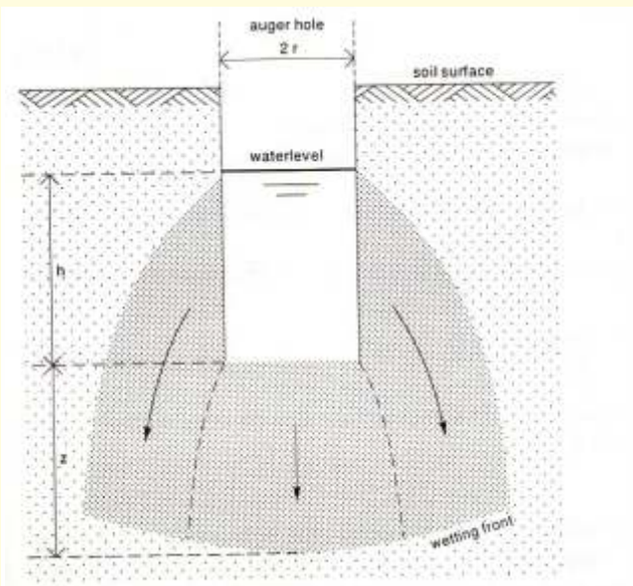


Fig. 41. Geometry of auger hole

b) For prolate spheroid

$$\lambda_{s-p} = 1 + \frac{r_{pp}}{r_{ep} e_p} \sin^{-1} e_p \quad (16)$$

Where,

$$e_o = 1 - \frac{r_{po}^2}{r_{eo}^2} \quad (17)$$

$$e_p = 1 - \frac{r_{pp}^2}{r_{ep}^2} \quad (18)$$

r_{po} = polar radius of oblate spheroid

r_{eo} = equatorial radius of oblate spheroid

r_{pp} = polar radius of prolate spheroid

r_{ep} = equatorial radius of prolate spheroid

Equation for saturated hydraulic conductivity from auger hole with spheroidal cavity at bottom in absence of was derived as below.

$$K_s = 1.15 r \frac{\log_{10}\left(h_o + \lambda_s \frac{r}{2}\right) - \log_{10}\left(h_t + \lambda_s \frac{r}{2}\right)}{(t - t_o)} \quad (19)$$

If eccentricity of oblate or prolate spheroids, e=0 the shape factor, λs=2 the above equation reduces to an auger hole with hemi-spherical cavity as below.

$$K_s = 1.15 r \frac{\log_{10}(h_o + r) - \log_{10}(h_t + r)}{(t - t_o)} \quad (20)$$

Ground water recharge for remediation of fluoride contaminated water in Unnao district of Uttar Pradesh (C. L. Verma, S. K. Jha, V. K. Mishra, S.K. Kamra and D. K. Sharma)

Excessive intake of fluoride (F^-) causes fluorosis in humans. WHO standards permit 1.5 ppm while BIS: 105001991 standards permit 1.0 ppm as the safe limit of F^- in drinking water for human consumption. In India, the area affected by F^- contamination is gradually increasing. Very high levels of F^- in drinking water (up to 24 ppm) have been reported from Rajasthan. Initially, teeth are affected and prolonged consumption of F^- laden water leads to irreversible permanent deformity in the bone skeleton and neural disorders. Children up to 12 years age are the most prone to fluorosis. Bore wells are the only source of F^- in drinking water. Common techniques for decontaminating

F^- laden water such as Nalgonda technique, ion-exchange resins, reverse osmosis and activated alumina are still beyond reach of the poor masses. Rain water and runoff water are free from F^-. Rain water is safe for drinking if stored and managed properly. Dilution of F^- concentration in ground water through recharge seems to be the easiest solution of the problem. Rural people generally use open wells, shallow and deep hand pumps and tube wells for meeting their daily water requirements. Ground water recharge through rain water harvested from roof top through hand pumps may be a possible dilution solution of the F^- problem. Consistent with these facts, a study was undertaken in Unnao district of Uttar Pradesh with the objectives: 1. Design and construction of ground water recharge structures suiting to abundant water supply from rain and canal; 2. Study of efficacy of ground water recharge in diluting fluoride concentration; 3. Design and construction of ground water skimming structures under shallow water table conditions and 4. To test their suitability, design and test roof top harvesting and storage structure for a family and to educate and train farmers/school students about fluoride dilution technology through meetings and goshthis.

Fluoride Concentration during Dry Period

Source of F^- in ground water is geogenic in nature and its concentration during dry period increases as pumping in the area continues while the water level declines. Decrease in the volume of water in aquifer and soil mass results in increased F^- concentration. Arithmetic and geometric means of F^- concentrations in ground water were observed

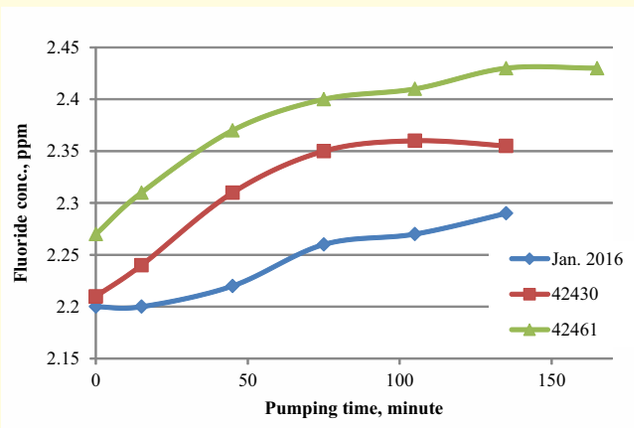


Fig. 42: Fluoride concentrations during pumping tests.

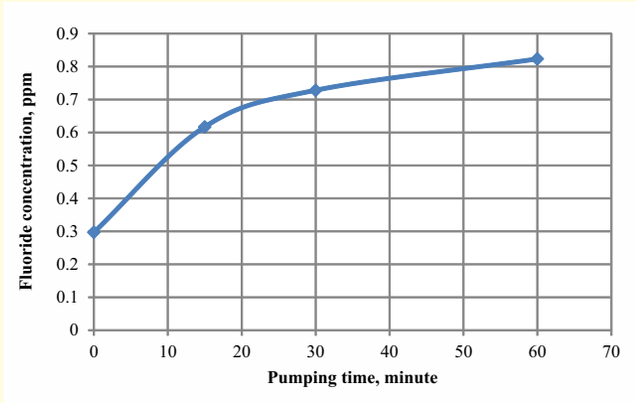


Fig. 43: Fluoride concentration variations with time after recharge

to be 2.467 and 1.946 ppm, respectively during February 2016 and 2.503 and 1.976 ppm, respectively during May-June 2016 under medium water table conditions. Similarly, arithmetic and geometric means of F^- concentrations in ground water were observed to be 2.606 and 1.478 ppm, respectively during February 2016 and 2.924 and 1.829 ppm, respectively during May-June 2016 under shallow water table conditions.

Recharge Hand Pumps and Pumping Tests

a) Before recharge

One recharge hand pump and one rain water harvesting structure from roof top were designed and installed under medium water table conditions in Sirsahakhera village of Asoha block in Unnao district. Pumping tests of hand pump were performed before and after recharge through roof top harvested water. F^- concentration during pumping test ranged from 2.0-2.25 and increased with time under medium water table conditions. It ranged from 3.14-3.30 ppm and decreased with time under shallow water table conditions. Fig. 43 shows F^- concentration with pumping time under medium water table conditions. F^- concentration increased with time similar to previous year. Concentration kept on increasing during dry months. The ranges of F^- concentrations were observed to be from 2.21-2.29, 2.21-2.36 and 2.27-2.43 ppm during January, March and April, 2016 respectively.

b) After recharge

In 2016 rainfall season, total numbers of rain days and average number of recharge days were 92 and 62, respectively. Total volume of recharge during

rainy season was 28500 l resulting in an average recharge rate of 310 l/day. Pumping tests were performed during October and F^- concentration with pumping time is shown in Fig. 43. Fluoride concentration decreased significantly after recharge. The range of F^- concentration in pumped water was only 0.297 to 0.823 ppm during October, 2016. Recharge of ground water is an effective measure to dilute F^- concentration in ground water through roof top harvested water. The technique is good for improving drinking water. Water table fluctuation of an open well indicated that water table of the village is declining due to excessive pumping for irrigation. A tube well installed within the village seems to be the main reason for steep fall in water table. Domestic water supply is facing twin problems of falling water table and F^- contaminations. Small volume of recharge through roof top harvested water may be sufficient for meeting out the domestic demand of rural people but cannot cope up with heavy pumping in the adjoining area for irrigation.

Storage of Rain Water and Dilution

Rain water is a good source of drinking water if properly harvested and stored. A conservative daily water requirement for a family having five members is 15 l considering a daily need of 3.0, l person^{-1} day^{-1}. Thus, monthly water requirement becomes 450 l and for 8 months storage duration total storage volume becomes 3.6 m^3. If daily water requirement of a person on daily basis goes as high as 5 l, total volume of storage becomes 6.0 m^3. Underground tank for storing desired volume of rain water for safe drinking could be made using the locally available bricks. For determining the quantity of rain water required for dilution of F^- laden water, the following relationship can be used.

$$\frac{W_F - 1}{W_{rain}} £ 1 \qquad (1)$$

Where,

WF= fluoride concentration in water (ppm)

Wrain= volume of rain water required for mixing (l)

Volume of rain water required for dilution of F− laden ground water to safe limits is shown in Fig. 46.

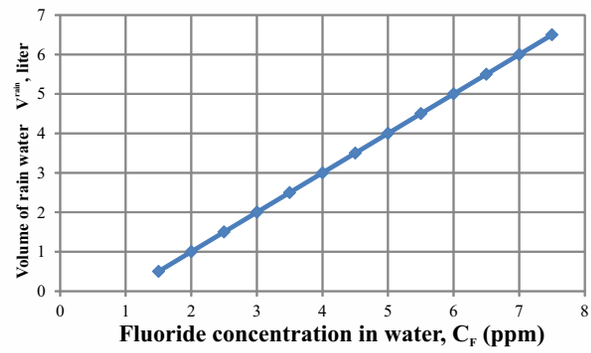


Fig. 44: Volume of rain water required for dilution of fluoride concentration.

Piloting and up-scaling an innovative underground approach for mitigating urban floods and improving rural water security in South Asia (V. K. Mishra, C. L. Verma, S. K. Jha and IWMI Team)

Prime Minister Krishi Sinchai Yojna (PMKSY) lays emphasis to achieve convergence of investments in irrigation at the field level, expand cultivable area under assured irrigation (*Har Khet Ko Pani*), improve on-farm water use efficiency, enhance the adoption of precision-irrigation and other water saving technologies (*More crop per drop*), enhance recharge of aquifers and introduce sustainable water conservation practices . Aquifer recharge is of utmost importance for achieving these goals. Groundwater depletion has become a major concerns among the researchers and planners. The problem has become so acute that the State Government of Uttar Pradesh has decided to stop free boring, deep bore wells and private tube wells in 108 over exploited blocks of 34 district.

Approach

Underground Taming of Floods for Irrigation (UTFI) is a viable solution to tackle the twin problems of floods and droughts to safeguard lives, property and livelihoods. It involves diverting high water flows from rivers or canals at times of flood risk and recharging the groundwater via village ponds modified with low cost recharge structure. In collaboration with International Water Management Institute (IWMI), village Jawai Jadid in Rampur district of Uttar Pradesh was selected after close consultation with the local people and authorities for pilot study. The site is a *Gram Panchayat* owned community pond which is located close to the road

Recharge Wells Structure in Community Pond at Jiwai Jadid (Rampur): a- Pre-implementation, b- Post implementation and c- during recharge.

and canal system (Pilakhar minor). The pond has been cleaned. The excavated soil was used to dress around the pond. To avoid the wastewater that was entering the pond, it was diverted away through a drainage channel constructed specifically for this purpose. Ten recharge wells were drilled and constructed in the pond. A PVC pipe of 150 mm diameter was installed in the centre with gravel filters placed around. The height of these structures from the bottom of the pond was 1 m and was packed with pea gravels to filter out suspended silts and ensure higher rates of groundwater recharge. Five of these recharge wells were of 3 m diameter and the rest 5 were of 1.5 m diameter .The depth of the 5 wells with 3 m diameter filter chambers was 30 m and the 5 wells with 1.5 m diameter was 24 m. The source water *i.e.*, excess rain water/ flood water is brought through a canal to pond for groundwater recharge. The pilot site is intended to serve as a demonstration of UFTI in practice as well as a scientific trial to establish the technical performance and socio-economic benefits.

The lithology of piezometers down to 24 and 30 m depth indicated that upper 3-4 m of soil is clayey in nature. The first aquifer which lies below the top soil extends from 5-8 m depth. This is the most utilized and tapped aquifer for drinking water. Second aquifer extending from 16-30 m is mainly utilized for irrigation by shallow tubewells.

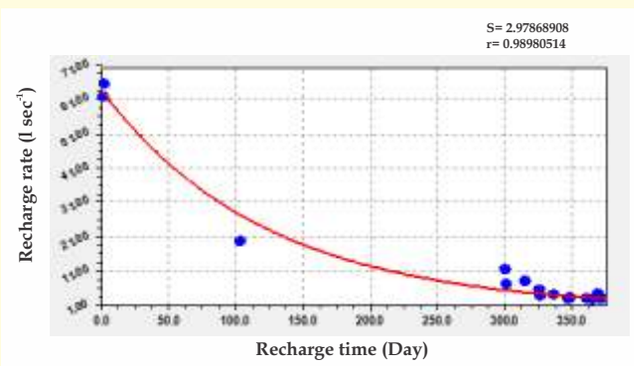


Fig 45. Recharge rate of the whole system.

Recharge Rate of the Whole System

The recharge rate measured once a week is plotted against time after combining the recharge rate data of years 2015 and 2016. Recharge rate continuously decreased with time. The best fit model describing change in recharge rate with time was exponential with r= 0.98980514 and S= 2.97868908 (Fig. 44). The recharge rate as a function of time is given below:

$$R_t = 63.144743e^{-0.007645305\ t}$$

Exponential decay explains natural processes. Above equation can be written in a standard form as below:

$$R_t = R_0 e^{-l\,t}$$

Where R_0 is the initial recharge rate at time t=0l =is the reaction factor of recharge system indicating how fast system is responding to a change

$t(t-t_o)$= time of recharge

Theoretical maximum recharge immediately after construction of recharge units which could be expected is 63.14 l/sec. There had been substantial reduction in recharge rate with time.

Quality of water

The groundwater quality depends on both natural and anthropogenic factors. The variation in the ionic composition of the groundwater may depend upon the quality of canal water by which the recharge operations were carried out, the interaction with the aquifer material, their dissolution and by anthropogenic inputs. The

Table 72: Descriptive statistics of the water quality parameters in different piezometers

Stastical Parameters	EC	pH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4
	----------Meq l^{-1}----------									
Mean	0.80	7.32	2.89	4.51	0.93	0.16	1.53	3.63	2.24	1.07
SE	0.05	0.05	0.13	0.34	0.07	0.03	0.10	0.18	0.14	0.14
Median	0.78	7.36	3.00	4.50	0.80	0.11	2.00	3.50	2.00	0.90
Mode	0.89	7.54	3.00	5.50	0.73	0.12	2.00	4.00	2.00	0.50
SD	0.27	0.31	0.78	2.05	0.43	0.17	0.60	1.10	0.81	0.84
Minimum	0.14	6.53	1.00	0.00	0.02	0.02	0.00	1.00	1.00	0.00
Maximum	1.66	7.95	4.50	10.50	1.79	0.88	2.50	6.50	5.50	4.20

major cations and anions which were analysed in the canal water, pond water, recharge wells and piezometers were Ca, Mg, Na, K and CO_3, HCO_3, Cl and SO_4. Since the effect of the recharge could be best represented by analyzing the water sample from piezometers, it was monitored periodically. It was found that pH varied between 6.53-7.95 with a mean of 7.32 and electrical conductivity (EC) varied between 0.14-1.66 dS m^{-1}. The detailed descriptive statistics of the water quality parameters are presented in Table 72. The bicarbonate which represents the major sources of alkalinity varied from 1-6.5 meq L^{-1}. Its dominance indicates the contribution from carbonate weathering. Among the alkalis, Na^+ ion is dominant while the K^+ is apparently low.

The total dissolved solid (TDS) were found maximum in the piezometers with shallow depths (P4S and P5S) and varied between 183-765 ppm with a mean of 447 ppm while the average TDS of canal water was 316 ppm only. However, at some locations, TDS exceeded the acceptable limit of 500 ppm as per Bureau of Indian Standards. Nonetheless, it meets the BIS standard with respect to permissible limits in absence of alternate sources, *i.e.*, 2000 ppm. This indicated an increase in the TDS in comparison to canal water probably due to interaction of water with the aquifer materials and various hydro-geochemical processes. The water samples were also analysed for heavy metals and fluoride. Among heavy metals, arsenic (As), Cadmium (Cd), Cobalt (Co), Chromium (Cr) and Copper (Cu) were found to be below detection limit whereas fluoride was found within the acceptable limit. The maximum acceptable limit for fluoride in drinking water as per bureau of Indian Standard (BIS, 2012) is 1.0 ppm but in absence of any alternate sources, the maximum permissible limit of fluoride is 1.5 ppm.

Harnessing productivity potential of waterlogged sodic soil through intervention of farming system module in sarda canal command for livelihood generation (V. K. Mishra, C. L. Verma, Y. P. Singh, T. Damodaran, S. K. Jha, Sajay Arora, A. K. Singh and S. K. Singh)

Sharda Sahayak Canal is one of the major canal commands which provides irrigation to 17.80 lakh ha lands in 16 districts of U.P. About 0.12-0.18 million ha sodic land suffer from shallow water table conditions in this Canal Command. Waterlogged sodic soils cannot be reclaimed sustainably through gypsum-based technology. To address these problems, pond based farming system module based on harvesting and management of canal seepage water for multipurpose use have been initiated in a farmers' participatory mode at Patawakhera (Sameshi), Lucknow. The model has been developed on 0.6 ha area.

Soil pH and electrical conductivity

Soil $pH_2$and EC_2 of raised bed and barren land were measured continuously for three years at 15 days interval. The average values are presented in Fig 46. Soil EC_2 showed an increasing trend from December to June and the maximum value (1.6 dS m^{-1}) was recorded on 15th June in the barren land. It decreased drastically during the period of July to November because of rainfall and subsequent salt leaching. The EC_2 of raised bed soil was almost similar throughout the year and its vale was considerably lower compared to the barren land.

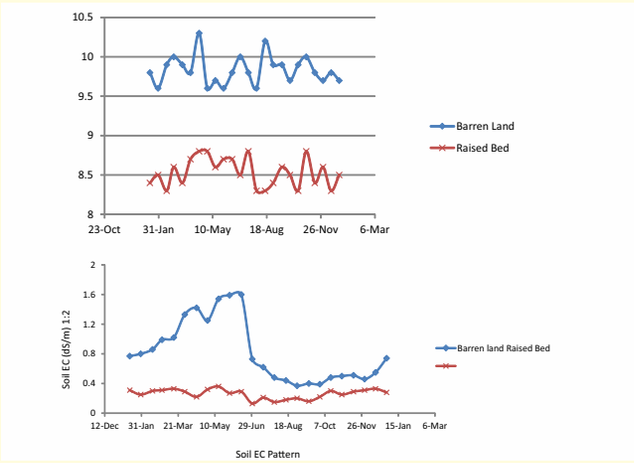


Fig 46. Temporal changes in soil pH and EC of the raised bed and barren land

Table 73: Effect of land shaping model of water and crop productivity under waterlogged sodic soil

System Productivity

	Crops	Area M2	Produ--ctivity Q ha^{-1}	Income (Rs.)	Water Produ-ctivity(Rs. /cubic m of water)	B:C ratio
System 1	Paddy	786.3	48.8	6508.8	16.2	2.1
	Wheat	786.3	49.6	7468.5	31.6	2.4
	Moong	786.3	10.8	4440.4	31.6	2.0
System 2	Mustard	889.7	19.6	6483.2	103.5	2.0
	Bottle Guard	250	116.8	4380.0	243.3	3.1
	Ridge Guard	273.9	132.2	5430.0	44.2	3.2
System 3	Ridge Guard	300	123.3	5550.0	44.0	3.1
	Tomato	155.0	785.7	18270.0	124.4	2.9
	Brinjal	155.0	322.5	5000.0	33.4	5.5
System 4	Forage crops	540.1	3795.0	41000.0	207.1	4.7
System 5	Piciculture	137.5	50.2*	157500.0	66.0	4.1
	Average		494.22	258030.9	85.94	3.2

The temporal change in pH was diminutive in raised and barren plots. However the pH < 9.0 in raised bed and > 9.5 in barren field was recorded during the whole year.

Soil Moisture Behaviour

Temporal variations in gravimetric soil moisture content in the top 15 cm soil layer of raised bed and control plot (barren land) adjoining the land shaping model was measured at the interval of 15 days. The soil moisture at field capacity and wilting point was 33.1 and 14.7 % w/w. The moisture content of barren land was above the field capacity during the period of July to October and it was below the wilting point in the month of June. The moisture content in between field capacity and wilting point was recorded during the period of November to May. In raised bed, the soil moisture content below the wilting point was observed during March to June and November to December and it was recorded above the field capacity during the period of July to August. During July to October, the moisture content was in between field capacity and wilting point. This trend was mainly due to improved drainage in the raised beds and inadequate drainage in the adjacent control areas.

Crop Production and Impact on Farmers

In land shaping model, five systems *viz.*, rice-wheat-moong, mustard-vegetables, vegetables-vegetables, fodder and pisciculture were adopted according to the need of the farmers. The productivity of rice, wheat and moong were recorded to be 4.88, 4.96 and 1.08 t ha^{-1} with B: C ratio of 2.1, 2.4 and 2.0, respectively (Table 73). The water productivity (Rs/m^3) was found to be 16.2 in rice and 31.6 in each wheat and moong. In mustard-vegetables system, the B: C ratio was higher for vegetables. Among the vegetables, the maximum B: C ratio (5.5) was noted in brinjal with water productivity of 33.4. The water productivity of bottle guard and tomato was 243.3 and 124.4, respectively. The fodder (Napier hybrid CO-4) was planted on slope of pond and raised bed. The B: C ratio for fodder system was 4.7 with water productivity of 207.1. The availability of fodder throughout the year except in extreme winter and summer had a favourable effect on animal productivity. The average milk production enhanced to about 3 l. The highest income (Rs 157500) was generated by fish production with B: C ratio of 4.1. The overall average water productivity and B: C ratio of the system were 85.9 and 3.2, respectively.

Impact of Technology

The positive impact of this technology towards productive management of waterlogged sodic lands has been recognized by Uttar Pradesh Bhumi Shudhar Nigam (UP Government).

Assessment of Municipal Solid Waste in Conjunction with Chemical Amendments for Harnessing Productivity Potential of Salt Affected Soils (Y.P. Singh, Sanjay Arora and V. K. Mishra)

Management of municipal solid wastes (MSW) is a major challenge faced by the governments. According to Central Pollution Control Board report, Uttar Pradesh is producing 5515 t of municipal solid waste per day. Various governments have developed MSW plants to

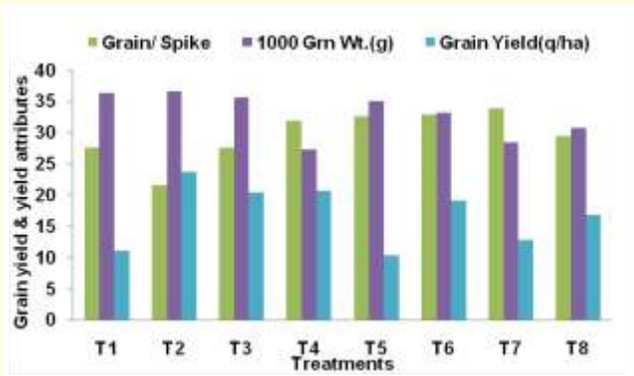


Fig. 47: Synergistic effect of organic and inorganic amendments on grain yield of wheat.

convert it into municipal solid waste compost (MSWC) but the cost of processed MSWC available in the market is very high and beyond the reach of small and marginal farmers. the municipal solid waste compost prepared through on-farm composting treatment (50% Municipal Solid Waste + 50% Agricultural Waste + Microbes + Earthworm) was high in quality. The detailed methodology for standardization of on-farm composting has been given in ICAR-CSSRI Annual Report 2014-15.

To evaluate the synergistic effect of MSWC and inorganic amendments on soil properties and productivity of rice-wheat cropping system, a field experiment was initiated at CSSRI Shivri Experimental Farm, Lucknow during *Kharif* 2015. After rice harvesting, wheat crop with the same treatments was sown on 26th November, 2015 and harvested on 4th April, 2016. Recommended dose of N, P, K and Zinc (120kg: 60kg: 40kg/ha) was applied uniformly in all the treatments. The maximum plant height (96.13 cm) was recorded with treatment T_2 (Phosphogypsum @50% GR) followed by treatment T_4 (PG@ 25% GR+ DMSW @ 10 t ha^{-1}) (86.29 cm) and minimum (58.83 cm) with treatment T_1. However, there was no significant difference between the treatments in this parameter. Number of grains per spike, spike length, and 1000 grain weight were significantly higher in treatment T_2. The highest grain yield was recorded with treatment T_2 followed by T_4 but the difference between them was not statistically significant (Fig. 47).

Higher reduction in soil pH was recorded in treatment T_3 (gypsum @ 25%GR and addition of decomposed municipal solid waste @ 10 t ha^{-1}) followed by T_2 (phosphogypsum @ 50%GR). However, the highest reduction in exchangeable sodium percentage and increase in organic carbon was recorded in T_4 (phosphogypsum @ 25% GR+ DMSWC @ 10 t ha^{-1}). A significant increase in available nitrogen was recorded in treatment T_7 (gypsum @ 25% GR + Industrial processed MSWC @10 t ha^{-1}). Significant changes in CO_3 and HCO_3 were also observed due

After harvest of rice, soil bacterial load enhanced due to application of MSWC while there was not much change in the fungal population. The maximum bacterial population was observed in T_3 (CFU=5.8 x10^7) which was 34.8 and 13.6 % higher over T_1 and T_2 where no organic amendments were added. (Table 74) After succeeding wheat crop, the bacterial and fungal population further enhanced

Table 74: Combined effect of organic and inorganic amendments on soil microbial properties after one year rice-wheat cropping system

Treatments	Initial		After rice		After Wheat	
	Bacterial	Fungal	Bacterial	Fungal	Bacterial	Fungal
T_1	1.3 x106	0.2x105	4.3 x107	0.6x105	4.4 x107	3.0 x105
T_2	1.9 x105	-	4.7 x107	-	4.4 x107	4.0 x105
T_3	1.0 x106	0.6x105	5.8 x107	1.3x105	7.8 x107	4.0 x105
T_4	0.8 x106	-	4.9 x107	-	5.5 x107	8.0 x105
T_5	1.3 x106	-	4.6 x107	0.3x105	4.8 x107	1.0 x105
T_6	2.0 x105	-	4.6 x107	-	4.6 x107	3.0 x105
T_7	1.4 x106	-	3.4 x107	-	5.2 x107	9.0 x105
T_8	2.1 x105	-	4.9 x107	0.3x105	5.3 x107	8.0 x105

over the initial values and after rice harvest. The maximum bacterial population was obtained in soil treated with gypsum @25%GR+ MSWC @10 t ha^{-1} (T_3) followed by application of phosphogypsum @25% GR+ MSWC @10t ha^{-1} (T_4) while the maximum fungal population was noted in treatment T_7 and T_4. From these results, it can be concluded that application of organic amendments improved soil bio-chemical properties and the microbial activity enhancement indicating the improvement in soil health .

Stress Tolerant Rice for Poor Farmers in Asia and South Africa (STRASA) (Y.P. Singh and V. K. Mishra)

A set of 14 genotypes *viz*., CSR 55, CSR 56, CSR57, CSR58, CSR 02013-IR-42-25, CSR-2013-IR 42-20, CSR-4013-MI-10, CSR-2013-MI-27, CSR 36 (Check), Bulk 212, CSR2711-171, CSR 2748-100, CSR 2748-140 and CSR 2748-197 was evaluated at CSSRI Shivri Experimental Farm, Lucknow and KVK Auraiya at soil pH 9.4 and 9.2, respectively. Three times replicated trials with 30-35 days old nursery were transplanted on 15th July and 27th July, 2016 at Shivri and Auraiya, respectively. Recommended dose of fertilizer (120: 60: 40 kg NPK ha^{-1}) and Zinc sulphate @2 5kg ha^{-1} was applied at both the locations. Two genotypes *viz*., CSR 56 and CSR 58 ranked 1st and 2nd under high sodicity level at Shivri. However under low sodicity, genotypes CSR2013-M1-27 and CSR2013-M1-10 produced higher yields (Fig.51).

2. Baby Trials: To scale out the high yielding salt tolerant varieties CSR 36 and CSR 43, farmers managed baby trials were conducted on 40 farmer's field in Maljha and Ulrapur villages of Unnao district. Soil pH of the selected fields ranged from 8.4-9.5. The performance of salt tolerant varieties was compared with the traditional varieties like Ganga Kaveri and Moti. On the basis of yield data collected from 40 farmers fields, CSR 36 and CSR 43 yielded 16.35 and 12.48% higher respectively over the traditional variety Ganga Kaveri. Short duration variety CSR 43 matured about 20-25 days earlier than the traditional varieties and saved the cost of two additional irrigation applied in Ganga Kaveri.

There was significant reduction in grain yield with the increasing soil pH. Variety CSR 36 produced the maximum yield at high pH levels and showed high sodicity tolerance as compared to CSR 43 and traditional varieties. However, at lower pH (up to 9.0), CSR 43 gave yield at par with that of CSR 36 and significantly higher over traditional varieties.

3. Stress Tolerant Breeding Network Trial (STBN)

An experiment consisting of 66 rice genotypes/cultures, including 6 checks, was conducted at CSSRI Shivri Experimental Farm, Lucknow in Augmented Design. The soil pH_2 and EC_2 of the experimental field were 10.3 and 0.67 dS m^{-1}, respectively. The recommended dose of fertilizers (150N: 60P: 40K) was applied in three splits. Among the genotypes evaluated, three genotypes *viz*., NDRK 11-22, CR 2838-1-S-2B-9-1, CR3879-3-1-6-1-3-1 were found promising with respect to grain yield compared to other genotypes (Fig. 48).

Performance of different rice genotypes at Shivri Experimental Farm, Lucknow

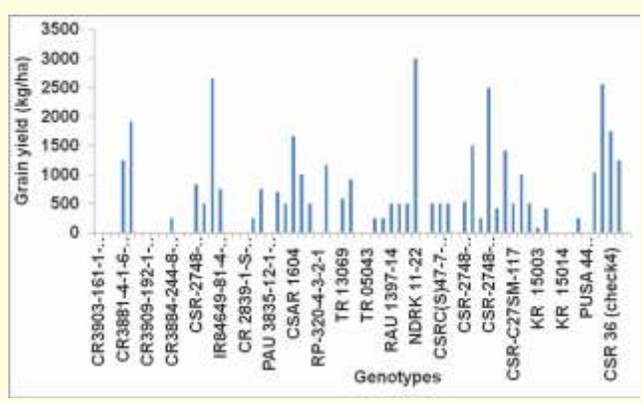


Fig.48.Grain yield of STBN entries under higher sodic conditions

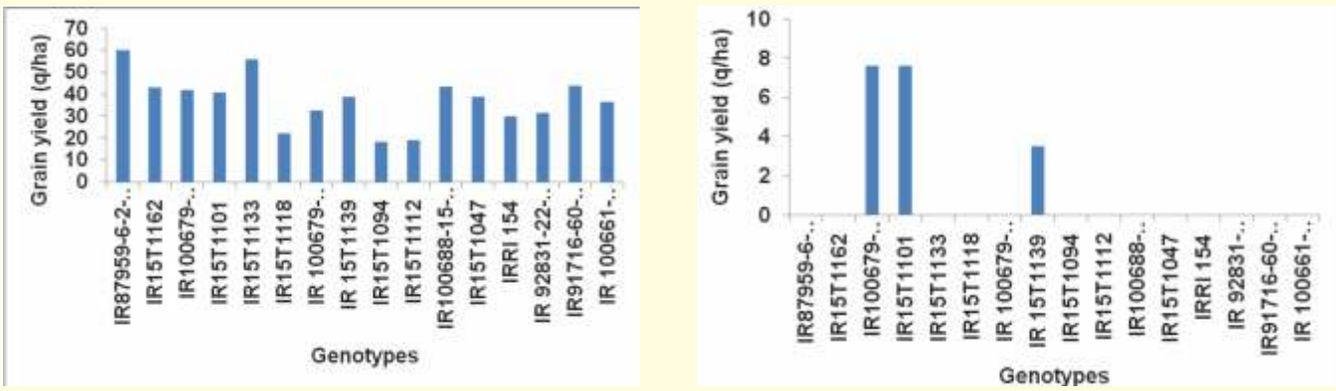


Fig. 49: Performance of rice entries (A) under normal soil and (B) Under High Sodicity Environment

4. Frontline Demonstrations

Frontline demonstrations of salt tolerant variety CSR 36 and CSR 43 were conducted on 9 farmers' fields in Kaushambi district in collaboration with KVK Kaushambi. The grain yield of salt tolerant varieties CSR 36 and CSR 43 were significantly higher over the traditional varieties at all the locations.

5. Multi Environment Trial (MET)

A multi-environmental field trial consisting of 16 rice entries was conducted under high sodicity (pH 10.2) and normal soil (pH 9.4) environments at Shivri Experimental Farm, Lucknow. Thirty days old seedlings were transplanted on 28th July, 2015. A uniform dose of fertilizer @ 150N: 60P: 40K and 25 kg zinc sulphate was applied in three splits. In normal soil, 7 entries *viz.*, IR87959-6-2-3-1-2-bay B-CMU 1, IR15T1162, IR100679-SBN B-AJY 2-CMU 2, IR15T1101, IR15T1133, IR100688-15-AJY 2-CMU 2 and IR91716-60-BAY 2-3-2 produced above 4 t ha^{-1} grain yield. However, under high sodicity only three genotypes *viz.*, IR100679-SBN B-AJY 2- CMU 2, IR15T1101 and IR 15T1139 survived and gave very low (< 1.0 t ha^{-1}) grain yield. One genotype IR 100661-SBN 11-1-AJY 1 died after 30 days of transplanting and rest of the 12 genotypes reached to panicle initiation stage but did not produce any grain (Fig.49).

Crop and resource management practices for rainfed lowland systems in Eastern India (ICAR-W3) (Y.P. Singh and V. K. Mishra)

Effect of short duration salt tolerant variety 'CSR 43' of rice on cropping intensity under different sodic environments

A field experiment consisting of four sodicity levels *i.e.*, pH 8.8, 9.0, 9.2 and 9.4 and three crop rotations *viz.*, rice-wheat, rice- cabbage -wheat and rice-beetroot-wheat was conducted at CSSRI Shivri Experimental Farm to monitor the yield optimizing level of sodicity for short duration variety; 2) increasing cropping intensity of salt affected soils with the introduction of short duration variety CSR 43 and to find out the economically viable rice based cropping system for salt affected soils. Cost economics of all three cropping systems was calculated on the basis of support price of rice, and the market price of cabbage and beet root. The maximum income was recorded with rice-cabbage-wheat cropping system as compared to both rice-wheat and rice-beetroot-wheat cropping systems. With the introduction of short duration variety 'CSR 43', it is possible to include an additional short duration crop in between traditional rice and wheat crops to fetch additional income. With the introduction of short duration variety, the cropping intensity of partially reclaimed sodic soils has increased up to 300%. Early maturity of CSR 43 help saves the cost

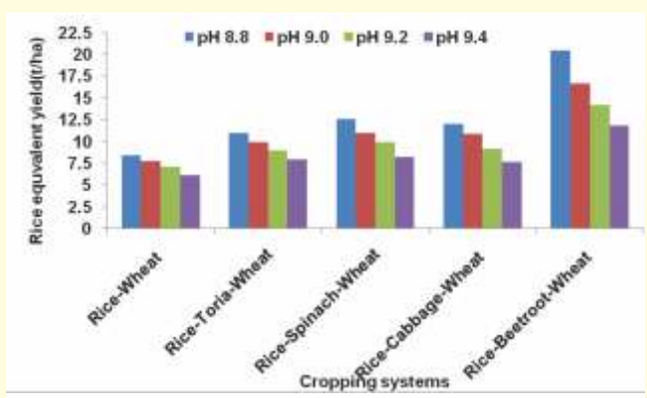


Fig. 50. Rice equivalent yield of different cropping systems with CSR 43

of two to three irrigations (~Rs. 6000 ha^{-1}). Moreover, such water saving approach could be extremely useful in conserving the depleting watertable. With the introduction of CSR 43, we identified certain other short duration crops like toria, spinach, cabbage and beetroot which can be grown successfully without significant loss in wheat yield and could provide enhanced incomes to the farmers (Fig. 50).

Screening and evaluation of wheat, mustard and rice genotypes for sodic soils (Y. P. Singh and V. K. Mishra)

All India Coordinated Wheat Improvement Trial

During *Rabi* 2015-16, All India Coordinated Wheat Improvement Trial was conducted at Shivri Experimental Farm, Lucknow. The initial soil pH of the experimental field ranged from 8.9-9.2. The trial consisted of 10 entries *viz*., AST_101, AST_102, AST_103, AST_104, AST_105, AST_106, AST_107, AST_108, AST_109 and AST_110 including 3 checks. The experiment was laid in Randomized Block design with six replications having row length of 4 m, spacing of 20 cm and a net plot size of 4 m^2. Wheat crop was sown on 20th November, 2015 and harvested on 31st March, 2016. Among the genotypes/varieties screened, genotype AST_108 produced the maximum grain yield (3.732 t ha^{-1}) followed by the genotype AST_101 (3.667 t ha^{-1}) while the minimum grain yield (2.925 t ha^{-1}) was recorded in AST_104.

All India Salinity/Alkalinity Tolerance Nursery Trial

All India Salinity/Alkalinity Tolerant Nursery Trial on Wheat consisting of 80 entries including 5 checks (Kharchia 65, HD 2009, KRL 19 and KRL 210, HD2967) with a plot size 1.6 m^2 was conducted at Shivri Experimental Farm, Lucknow. Soil pH_2 of the experimental field was >8.9. Three rows of 2 m length were sown on 21st November, 2015 and harvested on 2nd April, 2016. Among the entries evaluated, genotypes RWP 2015-17, Raj 4462,NW 7026,KRL 386 and KRL 384 produced the maximum grain yield followed by genotypes DWAP-1519, KRL 388, KRL385, KRL389 and RWP 2015-18.

All India Coordinated Trial on Rapeseed Mustard

Ten lines were evaluated in IVT under alkaline condition (pH_2 9.2) at Shivri Experimental Farm, Lucknow. The genotypes were sown on 14th October, 2015 and harvested in between 25th February and 2nd March, 2016. Each genotype was sown in 7.5 m^2 area and replicated three times. Significant differences were observed in seed yield amongst the genotypes evaluated. Seed yield ranged from 474.3 to 635.3 g $plot^{-1}$. Genotype CSCN15-4 (635.3 g/plot) followed by CSCN15-9 (581.6 g $plot^{-1}$) and CSCN15-1 (532.2 g $plot^{-1}$) produced the highest seed yield. Other AVT trial with ten genotypes was conducted at the same site. The genotypes were sown on 14th October, 2015 and harvested in between 25th February and 1st March, 2016. Each genotype was grown in a net plot area of 10.5 m^2. Significant differences were observed in seed yield amongst the genotypes evaluated. Seed yield ranged from 424-594 g $plot^{-1}$. Genotype CSCN15-16 produced the maximum grain yield (594.0 g $plot^{-1}$) followed by CSCN15-13 (570.0 g $plot^{-1}$) and CSCN15-11 (520.0 g $plot^{-1}$) whereas the minimum (424.0 g $plot^{-1}$) seed yield was noted in genotypes CSCN15-17 and CSCN15-19.

Another experiment to evaluate the performance of four promising rapeseed-mustard entries *viz*., AG-5 to AG 14 8 under different fertility levels was also conducted at Shivri Experimental Farm, Lucknow. The genotypes were sown on 13th October, 2015 and harvested on 1st March, 2016. Each genotype was sown in 15.0 m^2 area. Three times replicated experiment consisting of three N levels *viz*., 100% of RDF, 125% of RDF and 150% of RDF was laid under split plot design at pH 9.0. The maximum grain yield was recorded with genotype AG-7 at all the N levels.

Rice

Initial Variety Trial- Alkaline and Inland Saline Tolerant Variety Trial (IVT-AL& ISTVT)

To evaluate the comparative performance of promising elite cultures in alkali and inland saline environments, a field experiment consisting of 20 lines including one local check was conducted at Shivri Experimental Farm, Lucknow. The pH of experimental field was 9.5. The experiment was conducted in a Randomized Block Design with four replications. The crop was transplanted on 26th July, 2016 with twenty rows of 5 m length having gross plot size of 15.0 m^2. Among the genotypes,

2210, 2209 and 2206 were found promising in highly sodic soils. However, one genotype 2218 did not flower.

Advance Varietal Trial- *Alkaline and Inland Saline Tolerant Variety Trial (AVT-1 AL & ISTVT)*

Nineteen advance rice entries including one check (CSR 36) were evaluated under high sodicity conditions (pH 9.3) at Shivri Experimental Farm, Lucknow during *Kharif* 2016. The trial was conducted in RBD with four replications. Each genotype was planted at 15 x 15 cm spacing in 20 rows of 5 m length having gross plot size of 15 m^2. Thirty days old nursery was planted on 19th July, 2016 and recommended dose of fertilizer was applied. Genotypes 2115, 2111, 2119 and 2117 recorded the highest grain yield (>4.0 t ha^{-1}) whereas the minimum grain yield (2.23 t ha^{-1}) was in genotype 2108. Genotype 2109 did not produce any grain because there was no grain formation in the panicle.

All India Coordinated Agronomy Trial

A trial was conducted at Shivri Experimental Farm, Lucknow during *Kharif* 2016 to study the grain yield potential, nutrient response and nutrient use efficiency of promising AVT-2 cultures under high and low input management and to identify promising and stable genotypes based on the grain yield efficiency index. Treatments consisted of three nitrogen levels (N_1-50% of recommended dose, N_2-100% of recommended dose and N_3-150% of recommended does) in main plot and five rice cultures/varieties *viz.*, IET 24537, IET 24547, CSR 23, CSR 36, and Jaya in sub-plots. Three times replicated experiment was laid in split plot design with a plot size of 10.0 m^2. The soil pH of the experiment field was 9.0. Grain yield of all the entries increased with the increasing N levels. The maximum grain yield was recorded with IET 24547 at all the N levels. IET24547 produced the highest grain yield (5.99 t ha^{-1}) at 150% of recommended N level. However, there was no significant difference in grain yield between IET 24537 and IET 24547 at higher N doses (Fig. 51)

Elite rice trial

One hundred fifty elite rice lines were evaluated under high sodicity conditions (pH 10.3) at Shivri Experimental Farm, Lucknow during *Kharif* 2016.

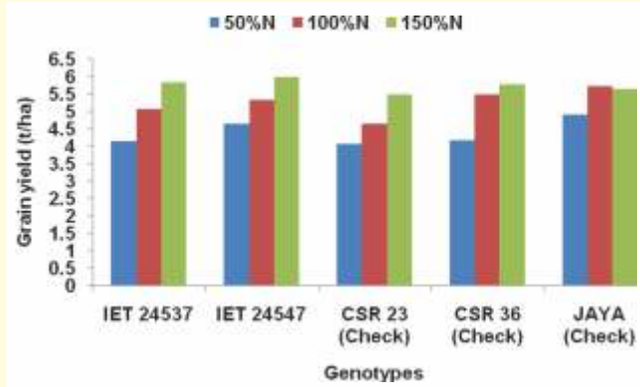


Fig.51: Grain yield of varieties/cultures under high and low N levels

Each line was planted 20 x15 cm apart in 5 rows of 4.5 m length having gross plot size of 4.5m^2. Thirty days old nursery was planted on 8th July, 2016 and the recommended dose of fertilizer was applied. Four entries *viz.*, PET 49, PET 50, PET 89, PET 77 produced > 3.0 t ha^{-1} grain yield. Five entries *viz.*, PET 84, PET 85, PET 126, PET 130 and PET 131 died after flowering. Fifteen entries did not produce panicle and 36 entries produced panicle but did not produce seed (Fig.52).

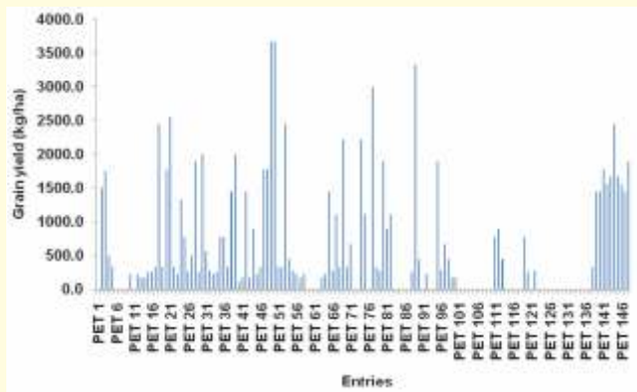


Fig.52. Grain yield of elite rice lines under highly sodic soil

Identification of salt tolerant microbes and development of dynamic substrate for cultivation of commercial crops in sodic soils (AMAAS Project) (T. Damodaran, V. K. Mishra, S. K. Jha and Y. P. Singh)

Screening of salt tolerant bacterial consortia for sodicity tolerance in tomato hybrid NS585

Effective consortia of compatible microbes C-5 (CSR-A-11 + CSR-A-16+CSR-M-16) and an untreated control were assessed for growth and yield parameters in tomato var. NS585 grown in pots filled with sodic soils at CSSRI Regional

Table 75: Effect of microbial formulation in the yield and quality of tomato hybrid NS585

Treatment	Soil pH	Nos. of fruits	Lycopene mg $100g^{-1}$
C_5T_1	9.18	15.67	12.50b
C_0T_1		8.00	9.43a
C_5T_2	9.42	6.33	10.42a
C_0T_2		0.00	-
C_5T_3	8.6	17.33	16.65c
C_0T_3		14.60	12.56b
C_5T_4	7.45	20.33	15.30b
C_0T_4		15.66	12.20b

Values are the means of three replicates. Means in the columns followed by the same subscript letter are not significantly different according to Duncan's multiple range test at P=0.05.

Research Station, Lucknow, India. The experiment was laid out in randomized block design (RBD) with three replications. A loopful of bacterium was inoculated into the CSR patent protected culture media and incubated in a rotary shaker at 150 rpm for 48 h at room temperature (28±2°C). After 48 h of incubation, the broth containing 6 x 10^8 CFU ml^{-1} was used for treating the tomato seeds @1 % for 2 h and for foliar application during flowering and fruiting stages of the crop. The culture grown in CSR patent media were inoculated in FYM @ 3 L 100 kg^{-1} of FYM $acre^{-1}$. None of the tomato plants survived in the control plots. Plant height significantly differed among the treated and untreated control. Higher plant height was noted in the treatments with C5 consortia. Significantly higher yield and lycopene content were observed in treatments involving the consortia C5 (Table 75).

Relative expression analysis of SOD gene:

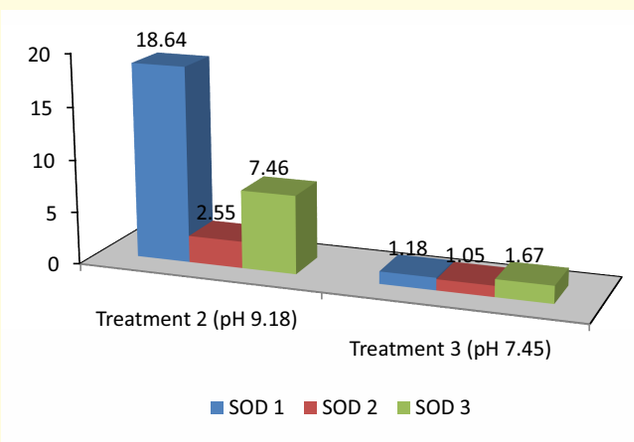


Fig.53: Relative expression analysis of SOD gene 1, 2, 3

Superoxide dismutases (SODs) are critical antioxidant enzymes that protect organisms from reactive oxygen species accumulating in plants under adverse conditions. The expression of this gene was studied using 9 SISOD primers earlier reported in tomato. The CAC gene due to its stability was used as housekeeping gene in the study. It was observed that at pH 9.18 the plants treated with C5 consortia exhibited higher expression of SISOD 1, 2 & 3 genes (Fig.53) than the treated plants growing at pH 7.65. This elucidates the role of microbial consortia in increasing the plants ability to produce the SOD genes.

In-vitro Bio-priming of tissue cultured banana plantlets for inducing salt tolerance

Five effective consortia, *viz.*, C_1 (CSR-A-11 + CSR-A-18 + CSR-M-16), C_2 (CSR-B-3 + CSR-B-2 + CSR-M-16), C_3 (CSR-A-16 + CSR-B-2 + CSR-A-18), C_4 (CSR-A-11 + CSR-A-16 + CSR-A-18) and C_5 (CSR-A-11 + CSR-A-16 + CSR-M-16) were assessed for their efficacy in growth promotion and induction of salt tolerance in plants in a three tier bio-priming protocol for *in-vitro* bio-hardening of banana. The bio-hardened plantlets were planted in the field having surface pH of 8.97 and sub-surface (15-30 cm) of 9.14. An untreated control was also planted in three replicates. There was significant difference between the treatments and the control for all assessed parameters suggesting the effectiveness of treatments irrespective of consortia. Among the bacterial treatments, C_5 resulted in significantly higher plant height (Table 76) and bunch yield (30.2 kg) while the control plants registered a bunch yield of 10.5 kg. Control plants showed very

Table 76: Effect of microbial consortia on plant growth and yield of banana

Treatments	Plant ht.(cm)	Girth (cm)	Leaf length (cm)	Days to shooting	Yield (kg plant^{-1})
C1	3.50	43.00	1.93	265	17.10
C2	3.10	40.00	1.70	278	17.90
C3	3.60	47.00	1.90	260	22.20
C4	3.50	45.00	1.99	285	17.00
C5	3.80	47.00	2.10	280	30.20
Control	2.29	40.87	1.09	260	10.50

Performance of in vitro bio-hardened banana plantlets in sodic soil

high Na^+/K^+ ratio while C_5 consortia treated plantlets showed lower Na^+/K^+.

Up-scaling of *In-vitro* mass multiplication and bio-hardening technology of banana var. Grand Naine under North Indian plains for sustainable production of quality planting material (Extramural project) (T. Damodaran, V. K. Mishra and S. K. Jha)

A project has been started to develop eco-friendly technologies for cultivation of banana and tomato in the reclaimed sodic soils (pH 8.8-9.3). The approach of acquired systemic resistance was utilized to impart tolerance to abiotic stresses with the help of endophytic inoculation. A study was conducted to develop the protocol for *in-vitro* bio-priming in tissue cultured banana plantlets of var. Grand Naine with the potential salt tolerant bacterial isolates CSR-A-16 (*Lysinibacillus sphaericus*), CSR-A-11 (*Lysinibacillus fusiformis*) and CSR-M-16 (*Bacillus licheniformis*). The technology was developed and patented for a four tier priming system. The bio-primed plants were assessed for the efficacy in the field with a complete package of application (POA) protocol where it was found that plantlets treated with the consortia five involving CSR-A-11, CSR-A-16 and CSR-M-16 had more plant height and girth with an average bunch weight of 32.0 kg. The technology of banana cultivation was commercialized with the bio-hardening technology for up-scaling the production of the banana var.G-9 in the northern plains. The salient features of bio-hardened banana plantlets are: 1. Hardening duration- 65 days from the days of transfer from laboratory; 2. Four tier hardening from laboratory to the nursery; 3. Cost incurred- Rs. 8.0/plant compared to Rs. 11.0/plant in the conventional system; and 4. Increase in tolerance to winter injury and higher productivity Table 77.

A total of 5000 plantlets were produced and were distributed to 12 farmers of four districts in

2016 and currently about 10000 plantlets are being produced for further distribution to the farmers. The scientific staff of KVK was incorporated

Table 77: Changes in shoot and root growth in in vitro bio-hardened plantlets of banana

Treatment	Root length (cm)	Shoot length (cm)	No. of leaves	Fresh wt. (g)		Dry wt. (g)	
				Root	Shoot	Root	Shoot
Bio-hardened	22	50	7	20.73	50.34	2.16	13.98
Control	14	28	5	10.80	28.60	1.20	6.75

Up-scaling of in vitro bio-hardened banana production in the northern plains.

training for dissemination of the technology among the banana growers. A brainstorming session for promotion of banana cultivation in the Northern plains was also conducted under the project where scientific staff/personnel from National Research Centre for Banana, Tissue Culture Firms, KVKs and State Horticulture department participated and charted a roadmap for the sustainable banana production.

Breeding of salt tolerant polyembryonic rootstocks of mango and assessment of bio-efficacy of microbial formulations in the control of *Fusarium* wilt of banana and guava (Inter-institutional funded**;** T. Damodaran, S. Rajan, V. K. Mishra, Maneesh Mishra, S. K. Jha and D. K. Sharma)

The study was conducted to screen the salt tolerant polyembryonic mango rootstocks in sodic plots. Six polyembryonic mango types collected from tsunami affected areas of the South Andaman Islands (ML-2, ML-3, ML-6, GPL-1, GPL-3, GPL-4) were evaluated along with the standard check '13-1'. Two accessions, ML-2 and ML-6 exhibited higher sodicity tolerance as all the plants of these accessions survived (Table 78) and endured the salt stress without any scorching symptoms during the entire period of experiment (2 years). The plant height of these two rootstocks did not significantly differ with that of '13-1'. The leaves and the meristem tips of ML-2 and ML-6 showed more uptake of K^+ over Na^+ ions resulting in higher K^+/Na^+ ratio. These accessions also accumulated 45% higher phenols and showed two fold increase in proline content than other accessions that exhibited mortality during the experimental period. Significantly higher activities of antioxidant enzymes like peroxidase and superoxide dismutase were observed in ML-2 and ML-6 as part of the defense mechanism induced to impart tolerance to sodicity.

Table 78. Effect of sodicity on the survival rate of the mango accessions (percent)

Sl. No	Accession	6 MAP*	12 MAP*	18 MAP*	24 MAP*
1	ML-2	100.00e	100.00e	100.00c	100.00b
2	ML-3	43.33b	10.00a	0.00a	0.00a
3	ML-6	100.00e	100.00e	100.00c	100.00b
4	GPL-1	63.33d	40.00d	13.33b	0.00a
5	GPL-3	36.67a	23.33b	0.00a	0.00a
6	GPL-4	46.67c	26.67c	0.00a	0.00a
7	A13-1	100.00e	100.00e	100.00c	100.00b

*MAP – Months after planting
Values are the means of three replicates. Means in the columns followed by the same subscript letter are not significantly different according to Duncan's multiple range test at P=0.05

Polyembryony accession ML-6, ML-2 & check 13-1

Feasibility of marine gypsum as an alternative source of mineral gypsum for the reclamation of sodic soils (S. K. Jha, V. K. Mishra, T. Damodaran and Y. P. Singh)

Conventionally, either calcium-rich (*e.g.*, gypsum) or sulphur containing compounds (e.g., pyrite) are used for reclaiming the sodic soils. Although widely used, mineral gypsum ($CaSO_4.2H_2O$) is increasingly becoming scarce due to continued mining and competition from the cement industry. As a result, it is not often sufficiently available for the use in reclamation. Considering the dwindling gypsum supplies and higher costs, it has become imperative to find either some other reclamation technology or to find some alternative to the mineral gypsum. In the recent past, phosphogypsum (a by-product from phosphatic fertilizer industries) have also been tried as an ameliorant for sodic soil but has not been accepted by the farmers due to the presence of fluoride and radioactive elements. The proposed amendment for the reclamation of sodic soils, *i.e.*, marine gypsum (MG), is a by-product from the manufacturing process of common salt (NaCl) whose composition is described in Table 79. In the process of salt manufacture by solar evaporation, gypsum is precipitated before the precipitation of common salt.

Table 79. Composition of marine gypsum

Constituents	Percentage
$CaSO_4.2H_2O$	89.72-92.62%
NaCl	0.48 to 2.08%
$MgCl_2$	0.57%
$MgSO_4$	3.42%
Insoluble constituents	3.48 to 7.65%

For each ton of salt production, 30-50 kg of marine gypsum is produced. So far, only small amount of this by-product is being used in the cement industry. The global salt production is about 230 million tons and India is the third largest salt producing country in the world after China and USA. The total production of marine gypsum as per the Salt Commissioner, Jaipur, was 146,028 tonnes in 2008-09 and 233,163 tonnes in 2009-10. As solar salt production is likely to exceed 15 million tons, there will also be enhanced availability of the precipitated gypsum (marine gypsum). Marine gypsum contains NaCl, $MgCl_2$ and $MgSO_4$ as impurities which may increase the ionic strength of the aqueous solution by decreasing its activity coefficient, and thus increased solubility of gypsum resulting in the enhanced reclamation efficiency compared to the mineral gypsum. In view of this fact, an initiative was conceptualized to assess the feasibility of MG for sodic soil reclamation as an alternative to mineral gypsum with various treatments : T_1- Control; T_2-50 GR gypsum; T_3- 50 GR (Eq.) MG; T_4- 25 GR Gypsum; T_5- 25 GR (Eq.) MG; and T_6- 25 GR gypsum + 25 GR (Eq.) MG. The purity of the MG was determined by following the protocol as described by Bureau of Indian Standards (IS: 1288: 1982) Indian Standard Methods of Test for Mineral Gypsum (Second Revision). The purity of marine gypsum was found to range between 92.4-94.5%.

The marine gypsum had pH_2 8.45 and EC_2 3.34 dS m^{-1}. The concentrations of heavy metals *viz.*, Cu, Zn, Mn, Fe, Cd and Cr were found to be 0.237, 0.253, 2.186, 3.52, 0 and 0.06 mg kg^{-1}, respectively which were within the permissible limits given by

WHO/FAO. The experimental field is located at Shivri Experimental Farm, Lucknow. Results of the analysis of the soil samples collected from three locations of the experimental field indicated high.

Meanwhile, an attempt was made for a formulation using marine gypsum which may act as a better amendment for sodic soil reclamation. 5 g of formulation when shaken with 100 ml of distilled water for half hour and calcium in the extract was determined. The calcium in the extract was found to be 30.5 meq L^{-1}. This was in fact comparable to the pure analytical grade $CaSO_4.2H_2O$. When 5 g of sodic soil was shaken with 100 ml of the above extract for half hr, the extract pH was 5.77 and the soil residue pH_2 was 6.53. The above results revealed that the said marine gypsum based formulation may be superior to the prevailing amendment in use and might take care of the sub-soil sodicity management.

Kinetics of gypsum and native $CaCO_3$ dissolution and nutrient transformations mediated through organic amendments and microbial inoculants for crop production in sodic soils (Sanjay Arora, A. K. Singh, V. K. Mishra, Y. P. Singh and D. K. Sharma)

GypCal Mobile App

The Hindi version of GypCal mobile application was developed on Android platform. This App in local language is user friendly and can be useful for farmers, field functionaries, researchers, line department officials desirous of chemical reclamation of sodic soil for optimizing crop production in Indo-Gangetic plains by calculating the gypsum requirement in bags (of 50 Kg), total depth of water required for leaching and the expected yields of salt tolerant as well as traditional varieties of rice-wheat after chemical reclamation. It also estimates ESP of the sodic soil. The mobile app helps in calculating the mineral gypsum requirement of sodic soils based on the mathematical equations obtained through curve fitting. The mobile application is compatible with the basic android handset mobile/tab. The application was already validated for different soils from diverse sodic areas. Further validated of GypCal on sodic soils at farmer fields.

Chemical reclamation of sodic soil

Changes in the soil properties were monitored in sodic soils treated with gypsum and phosphogypsum along with organic amendment. It was observed that soil pH reduced more in surface soil amended with phosphogypsum@50GR compared to gypsum@50GR. It was also observed that PG@25GR with organic amendment was more effective in reducing surface soil pH compared to

GypCal Mobile App

mineral gypsum @ 50GR with organic amendment. Similarly, exchangeable Na content in the pre- and post-reclamation surface soil reduced substantially when reclamation was done using PG@25GR coupled with organic amendment as compared to gypsum@25GR with organic amendment.

Sodic soil reclamation and crop production

Pot and field experiments were continued with wheat during *Rabi* 2015-16 on sodic soils amended with gypsum or phosphogypsum as chemical amendment alone and in combination with pressmud, water hyacinth as well as bio-inoculant to evaluate the effects on crop production. Crop growth and yield parameters were recorded for assessing the effects of different treatments. Wheat yield was superior by 14.7% and 18.2% over treatments where gypsum or phosphogypsum @12.5GR was applied along with pressmud indicating beneficial effect of bio-inoculation with halophilic plant growth promoting bacteria coupled with water hyacinth as organic amendment in pots. Also, changes in soil properties after harvest of crop were ascertained through different analysis that showed beneficial effect of chemical and organic amendments on soil pH and other bio-chemical properties.

The field experiment was continued on sodic soil at Shivri Experimental Farm, Lucknow to ascertain the effect of organic and inorganic amendments on rice-wheat production and effect of amendments on chemical changes in sodic soil during reclamation. The maximum grain and straw yields of wheat (*Rabi* 2015-16) obtained with the combined application of phosphogypsum @ 25% GR+ 10 t pressmud + bio-inoculant were at par with those obtained in gypsum @ 25% GR + pressmud treatment. Grain and straw yields were 42.5% and 51.2% higher in combined use of phosphogypsum @25% GR and pressmud as compared to gypsum @ 50%GR alone. After harvest of wheat, depth wise soil samples were collected and analyzed. It was noted that mean soil pH ranged from 9.31 to 10.19 in all the treated plots as compared 9.88 in unamended plots. Lowest soil pH was noted in treatment T_6 (PG_{25GR} + Pressmud) where it was 9.31. Exchangeable Na^+ content ranged from 14.77-29.24 Cmol kg^{-1} which in general was higher as compared to the values after harvest of the preceding paddy crop

Validation of GypKIT

For further validation of the Gypkit developed, large number of sodic soil samples were analysed for estimating gypsum requirement by laboratory method and values obtained through GypKit (Table 80). It is useful in calculating the accurate

Table 80. Validation of GypKIT

Location of farmers field	Soil pH_2	Schoonover method	GypKIT
Jaloun	10.12	1.95	1.75
Firojabad	9.88	1.90	1.80
Kanpur dehat	10.17	2.30	2.15
Schandi Behlampur	10.08	2.25	2.05
Metrasun	9.92	1.80	1.75
Hamirpur	9.76	1.65	1.55
Bhaisamau	9.84	1.80	1.65
Saloun	9.29	1.50	1.40
Beekamau	9.79	1.85	1.75
Bigahi	10.24	2.20	2.05
Ramnagar	9.71	1.55	1.35
Amoda	9.78	1.65	1.55
Awadhey	9.84	1.90	1.70
Bhairaich	9.97	2.15	2.05

amount of mineral gypsum required for reclamation of sodic soil under test. This kit is based on titrimetric method of quantitative sodic soil gypsum requirement to provide proper estimate at farmers' doorstep. The estimation of sodic soil gypsum requirement using laboratory method and through GypKIT was done to ascertain the accuracy of the kit. The kit was found to give valid results for different sodic soils collected from Indo-Gangetic plains of Uttar Pradesh and is being validated from large number of soil samples.

Relative Soil Quality and Production Efficiency of Sodic Soils

Relative soil quality index (RSQI) and relative production efficiency index (RPEI) for sodic and calcareous sodic soils were worked out using the soil properties and climatic variables. To see the contribution of various soil parameters towards production efficiency, influence intensity of these parameters were determined for sodic soils of Indo-Gangetic Plains as well as calcareous sodic soils of Bihar. The equations were developed and indices were evaluated and influence intensity was worked out. It was observed that soil quality wise, strongly calcareous sodic soils were not suitable for wheat (RPEI=53) but suitable for rice (RPEI=62). Relative soil quality index (RSQI) was 55 and RPEI was 59 in case of moderately calcareous sodic soils revealing that these soils were suitable for both rice and wheat crops. Values for rice were 69 and 77, respectively indicating suitability of moderately sodic soils for rice crop. In case of slightly calcareous sodic soils, both RSQI as well as RPEI values for rice and wheat were in class I making these soils suitable for rice and wheat cultivation.

SQASS : A decision support system for sodic soils

Using the generated linear equations, a desktop based software application "SQASS" was developed on Visual basic platform for soil quality assessment and yield prediction in sodic soils with user friendly and self defining menus. The model was calibrated and validated for twenty four locations representing five district of UP and two district of Bihar having sodic soils. On comparing the predicted and observed yields, a prediction variation of 0.01 to 6.1% for paddy and 3.0 to 11.61% for wheat crop was observed which is quite acceptable seeing the diversity in sodicity, climatic and other soil conditions at these locations.

Bio-augmenting crop residues degradation for nutrient cycling through efficient microbes to enhance productivity of salt affected soils (Sanjay Arora, Y.P. Singh and A.K. Singh)

A survey was conducted to collect the farm wastes and cattle shelter samples for isolating the cellulose and lignin degrading microbes. The samples collected in sterile ploybags were brought to lab for isolation. The basal salt media was used for isolation of cellulose degrading microbes while minimal salt media enriched with lignin was used for the isolation of lignin degrading microbes. The maximum population of cellulose degrading bacteria was found in partially decomposed paddy straw and FYM mixed heap samples followed by that in partially decomposed mustard straw from the field. Similarly, the maximum population of lignin decomposing bacteria was found in decomposing mustard straw followed by that in paddy straw. Morphologically, different bacterial colonies were purified and screened on specific media for cellulose and lignin decomposers. The zone size of the colonies formed by the total of 5 cellulose degrading and 10 lignin degrading isolates was measured and colony characters were recorded. Zone size of cellulose decomposers ranged from 0.8-1.5 mm and that of lignin decomposers from 0.1-0.6 mm. Both kinds of isolates were small in size, round in shape (except C-2, L-5 and L-7 which were irregular in shape),

flat in elevation, smooth surfaced and opaque (except C-3 which showed translucent opacity). While cellulose decomposers had either white (C-1, C-3 and C-4) or cream (C-2 and C-5) pigmentation, it was invariably blue in case of lignin decomposers except light blue pigmenttaion in L-3.

Biochemical characterization

Biochemical characterization of the isolates indicated that all but one were positive for ammonia production while only two cellulose decomposer and one lignin decomposer bacteria were positive for the oxidase test. HCN production was positive for 5 out of total 15 isolates while about 50% of the isolates were able to utilize citrate. Based on the phenotypic characterization, only seven of the bacterial isolates were gram-positive while 8 were gram-negative. IAA production by decomposing bacteria ranged between 8.23-52.38 $\mu g\, ml^{-1}$.

Salt and pH tolerance of decomposing bacteria

The isolated cellulose and lignin decomposing bacteria were tested for their pH and salt tolerance in the media. Cellulose and lignin degrading bacteria were inoculated onto nutrient agar medium supplemented with different concentrations of NaCl (5.0%, 7.5%, 10% and 15%). All the plates were incubated at 28°C for 5 days and bacterial growth was observed at every 24 h and recorded. All the 15 degrading bacteria showed good growth at 5.0 and 7.5% NaCl concentration while 11 (73%) isolates grew up to 10% NaCl and only three (20%) could tolerate up to 15% NaCl concentration . All the 15 isolates tolerated different pH of the media *viz*. 5, 7, 9 and 11 indicating their tolerance to sustain high alkalinity

PGP bacteria having lignocellulolytic activity

The isolates of PGP bacteria from sodic soils were tested for their lignocellulolytic activity. Out of the 54 isolates tested, 20 were found to be cellulose decomposers while 15 were able to degrade lignin. The zone size formation for cellulose decomposers on media varied from 0.6-1.8 mm while it varied from 0.1-0.7 mm for lignin decomposers. These cultures also showed pH tolerance (up to 11) in the media. Also, two fungal species having plant growth promoting properties and having cellulose and lignin degrading ability were screened and purified.

Incubation study

A laboratory incubation study was conducted in 500 ml Erlenmeyer flask where known quantity of rice and wheat straw were taken and inoculated with different cellulose and lignin bacterial and fungal isolates. The moisture was maintained and flasks were kept in dark. The CO_2 evolved during decomposition was trapped by the alkali in the sealed flask. The amount of CO_2 was determined at different periods. It was observed that initially the CO_2 evolution ranged from 17.6-25.3 mg g^{-1} of the straw and the maximum was found in the wheat straw inoculated with consortia of cellulose and lignin decomposing bacteria and fungi at all the time periods (Fig 1). However, there was gradual decline in CO_2 evolution with time. Similarly, the paddy straw chopped and treated with cellulose and lignin decomposers released CO_2 during incubation to the extent of 40.7 mg CO_2 g^{-1} during the initial phase while it ranged between 5.1-14.3 mg CO_2 g^{-1} 30 days after inoculation. The consortia of halophilic degrading bacteria resulted in cumulative CO_2 evolution of 89.1 mg CO_2 g^{-1} of the straw.

In situ paddy residue decomposition

After manual harvesting of the paddy crop, the stubbles and straw were left over the field and treated with different strains of cellulose and lignin degrading microbes by spraying the liquid culture media. The moisture was maintained and was periodically monitored for the changes. There was loss in weight of stubbles and straw left on field after harvest and the *in situ* stubble inoculated with decomposing microbes. The weight of the residue material decreased by nearly 10% in 45 days when only water was applied while reduction in weight was 32% after inoculation of cellulose and lignin degrading microbes and their consortia (Fig 54). The C: N ratio of the residue material decreased from 70: 1 to nearly 40: 1 in 45 days after inoculation. It was observed that there was maximum reduction by 44.1% with inoculation of CDM closely followed by 43.76 and 43.14% after 45

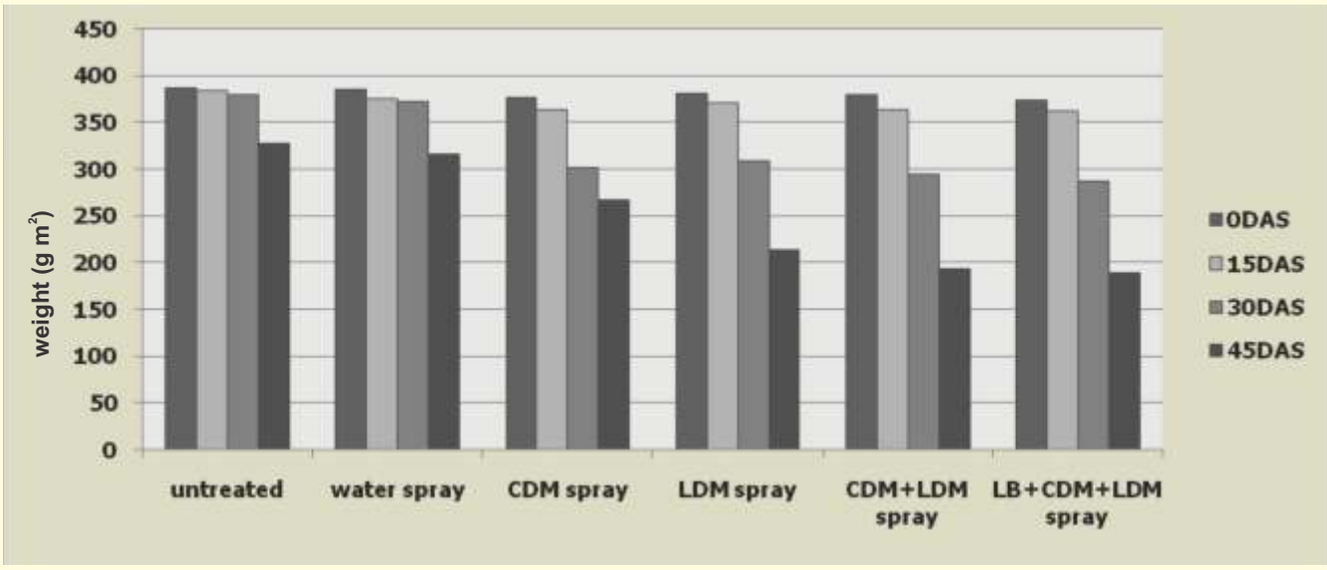


Fig. 54: Weight loss during in-situ paddy stubble decomposition

days of inoculation of residue with consortia of cellulose and lignin degrading microbes.

Ex situ decomposition

After harvesting of the paddy crop by manual or combine harvesting, the stubbles and straw left were collected for the *ex situ* decomposition. The residues were collected and treated with consortia of 6 halophilic efficient strains of cellulose and lignin degrading microbes. There was maximum reduction in weight (44.3%) of rice straw that was cut through combine and inoculated with degrading microbes followed by 42.25% reduction in weight of manually cut stubble plus straw inoculated with effective degrading microbes by 4th week (Fig 55).

Bioremediation of salt affected soils of Uttar Pradesh through halophilic microbes to promote organic farming (Sanjay Arora and Y.P. Singh)

Efficient halophilic bacterial strains were tested for their compatibility on the liquid broth media. The thermal death point of such strains was also ascertained (Table 81). Compatible *Azotobacter* and P solubilizing bacterial strains having high thermal death point were selected.

Liquid bio-formulations

To prepare the bio-formulations of these promising halophilic plant growth promoting (HPGP) strains, individually and in consortia,

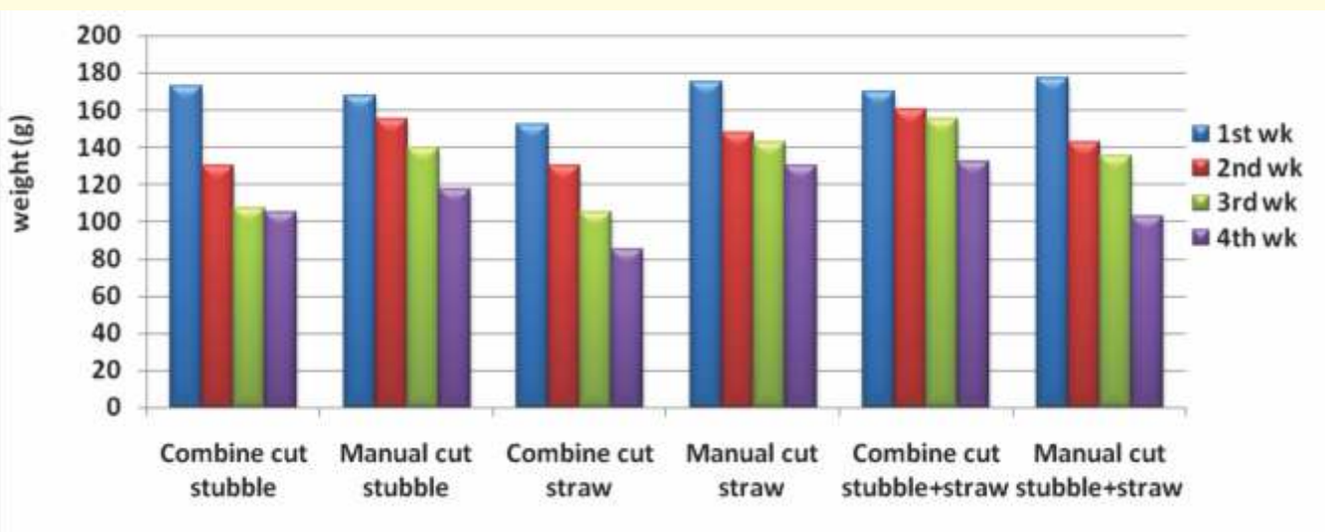


Fig. 55: Loss in weight of residue on ex situ decomposition

Table 81 : Thermal Death Point of the isolates (30 min at each temp.), No. of colonies 10^{-4}

Cultures	Temperature									
	40°C		50° C		60° C		70° C		80° C	
	PSB	Azo	PSB	Azo	PSB	Azo	PSB	Azo	PSB	Azo
PSB3xAzo	236	168	189	188	153	207	95	73	48	69
PSB2+Azo	146	98	112	91	103	87	72	41	12	3
PSB3+Azo6	218	172	192	159	136	122	131	108	115	95
PSB2+Azo2	197	85	208	71	158	36	23	21	14	0
PSB1+Azo2	128	151	108	130	94	109	3	8		
HBY+HBO	187	195	162	155	131	102	38	46	24	39

different additives were tested continuously for 330 days to standardize the media. Addition of some additives to phosphate buffer increased the stability of media with enhanced shelf life compared to other additives.

Crop Performance with Liquid Bio-formulations

Pot and field experiments were continued to test the efficacy of liquid formulations of HPGP strains in paddy and wheat crops. In a pot experiment (pH 9.4), paddy (CSR 36) grain yield increased to 11.18 g pot^{-1} in treatments where consortia of halophilic N-fixer and P-solubiliers were used compared to control (8.78 g pot^{-1}). Similarly, straw yield of paddy was also maximum (20.62 g pot^{-1}) in consortia inoculated treatments compared to minimum of 13.38 g pot^{-1} in control (Table 80). However, inoculation with sole Halo-Azsp showed better growth and yield of paddy. In another pot experiment in highly sodic soil (pH 9.7), Halo-Azsp inoculation of seedlings resulted in the maximum grain and straw yields which were statistically at par with that obtained by inoculation with consortia.

The field experiment at Shivri Experimental Farm, Lucknow was continued with paddy (CSR36) during *Kharif* 2015 and the seedlings were inoculated with the different strains of HPGP bacteria. Inoculation significantly improved growth and yield attributing characters. Grain yield was enhanced to the maximum of 5.039 t ha^{-1} in plots where seedlings were inoculated with consortia which registered an increase of 19.66% over un-inoculated controls (Table 82). Straw yield of paddy was also significantly increased by bio-formulation inoculations.

Effect of Bio-formulations on Spinach

Effect of HPGP bio-formulations on spinach growth and yield was evaluated in a sodic soil (pH 9.7). Leaf length increased by 27.9% when seeds were inoculated with the consortia. Inoculation with Halo-Azo and Halo-PSB liquid bio-formulations alone resulted in 17.5% and 19.1% higher leaf length as compared to un-inoculated control. There was significant increase in number

Table 82: Effect of bio-inoculation on paddy yield in pot experiment on sodic soil (Kharif 2015)

Treatment	Plant height (cm)	Grain yield (g pot^{-1})	Straw Yield (g pot^{-1})
Control (FYM)	69.15	8.78	13.38
FYM+Halo Azo	75.44	9.17	15.64
FYM+ Halo-Azosp	78.28	10.41	17.81
FYM+ Halo-PSB	77.61	9.84	16.65
FYM+Halo-Azo+Halo-PSB	80.07	9.96	18.72
FYM+Halo-Azosp+Halo-PSB	82.36	10.86	18.70
FYM+Consortia	82.27	11.18	20.62
CD(5%)	7.84	1.7	5.2 0

Initial soil pH= 9.4; Organic carbon= 0.21%; Plants maintained= 4

Table 83: Effect of halophilic PGP strains on paddy (*Kharif* 2015) in field experiment on sodic soil

Treatments	Plant height (cm)	No. of Tillers	Grains Panicle^{-1}	1000 Grain wt (g)	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
NPK	104.85	12.10	72.04	22.82	4.21	5.54
NPK+Halo-Azo	115.93	13.55	96.65	25.36	4.61	5.94
NPK+Halo-Azsp	128.37	14.40	104.22	27.15	4.95	6.14
NPK+Halo-PSB	122.66	12.80	89.45	24.37	4.72	6.04
NPK+Consortia	129.40	13.92	102.58	25.83	5.04	6.13
CD(5%)	12.14	1.88	12.46	2.42	0.31	0.43

of leaves plant^{-1} when halophilic strains of N-fixers and P-solublizer bacteria were used. Application of vermicompost along with seed inoculation with consortia resulted in 39% more leaves as compared to vermicompost application alone, followed by 23.1% with Halo-PSB and only 7.6% in Halo-Azo inoculation. Root length increased by 7.1, 12.2 and 27.1% with inoculation of Halo-Azo, Halo-PSB and consortia, respectively, over control. Fresh weight of spinach varied from 3.02 g plant^{-1} to 4.87 g plant^{-1} 45 days after sowing. Fresh weight increased by 13.65, 39.2 and 35.6% when seeds were inoculated with Halo-Azo, Halo-PSB and consortia, respectively, over control. Similarly, dry weight per plant increased by 10.8-39.1% with inoculation over control.

In another pot experiment in a sodic soil (pH 9.4), spinach seeds inoculated with different strains of HPGP bacteria including *Azotobacter*, *Azospirillum* and PSB alone and in consortia were used. Leaf length enhanced by 35.4, 27.3, 18.6, 11.6, 9.7 and 2.0% in seeds inoculated with consortia, Halo-Azosp + PSB, Halo-Azo + PSB, Halo-Azsp, Halo-PSB and Halo-Azo, respectively, over control. Root length was 4.25 cm in control which increased by 15.3, 29.4 and 48.9% when seeds were inoculated with Halo-Azo, Halo-PSB and Halo-Azsp, respectively. When consortia of these cultures were used, root length increased by 41.2% and 53.9% over control (Table 83). Fresh weight of spinach plants inoculated with halophilic bacteria also increased; ranging from 10.4-50.9% over control. It was the maximum when Halo-Azo, Halo-PSB and Halo-Azsp were used as consortia. Similarly, dry weight of spinach also increased subsequent to the inoculation with HPGP bacteria.

Effect of Bio-inoculation on Wheat

In a field experiment on sodic soil of Shivri Experimental Farm, Lucknow (pH 9.36), plant height varied from 79.17 cm in control to 84.75 cm in plots where seeds were inoculated with consortia of halophilic N-fixers and P-solubilizers. Increase over control was 5.7% where only Halo-Azo was used. Number of tillers ranged from 3.76-4.66 when seeds were inoculated with the consortia of HPGP bacteria were used to inoculate the wheat seeds as compared to control where it was 2.53 (Table 84). Dry biomass of wheat plants

Table 84: Effect of inoculation of halophilic bacterial strains through liquid formulations on spinach

Treatments	Plant ht (cm)	Leaves plant^{-1}	Root length (cm)	Fresh wt. (g)	Dry wt. (g)
Control	36.75	3.50	4.25	2.94	0.42
Halo Azo	37.50	4.00	4.90	3.40	0.50
Halo PSB	40.33	4.50	5.50	3.87	0.46
Halo Azosp	41.00	4.66	6.33	4.08	0.54
Halo Azo + PSB	43.60	5.33	6.00	4.34	0.72
Halo Azosp + PSB	46.80	5.50	6.33	4.70	0.82
Consortia	49.75	6.33	7.50	5.28	0.80
CD(0.05)	3.44	0.48	0.66	1.24	0.28

Table 85: Effect of halophilic PGP strains on paddy (*Kharif 2015*) in field experiment on sodic soil

Treatments	Plant height (cm)	No. of Tillers	Grains Panicle^{-1}	1000 Grain wt. (g)	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
Control (FYM)	79.17	2.57	14.29	12.50	3.72	5.64
FYM+HB1	83.72	3.76	16.17	14.67	4.11	5.82
FYM+HB2	81.39	4.66	19.02	14.37	4.28	6.21
FYM+HB3	82.15	3.81	17.76	13.44	4.24	6.07
FYM+Consortia	84.75	3.99	18.93	15.52	4.39	6.33
CD(5%)	NS	NS	1.42	NS	0.27	0.34

varied from 14.29-18.93 g. Inoculation with HB1, HB2 and HB3 strains resulted in increase of 13.1, 33.1 and 24.3% over control. By comparison, consortia inoculated plants showed 32.4% higher biomass per plant over control. Root length of wheat plant at maturity was also significantly influenced by the bacterial inoculation. Wheat root length was 7.5, 14.9 and 17.3% higher in HB3, HB2 and HB1 inoculated plants as compared to control. Seed treatment with consortia resulted in 24.2% higher root length over un-inoculated control. Also, the inoculation had significant effect on nutrient content and uptake in wheat plant parts.

In pot experiment, wheat growth and yield contributing parameters such as plant height, root length and dry matter yield also significantly improved upon seed inoculation with different bio-formulations. While 100 grain weight and total ears per plant did not significantly differ, their maximum values were observed in the consortia inoculated plants. Wheat yield increased from 5.32 to 8.17 g per pot when consortia of halophilic N-fixers and P-solubilizers were used.

Effect of bio-inoculation on soil bio-chemical properties

After paddy, spinach was taken in pots using the seeds inoculated with different bioformulations. Positive response was observed on spinach growth and yield. After spinach harvest, soil analysis indicated that use of bio-formulations enhanced soil available N and P, organic carbon build-up and enzymatic activity. After wheat harvest, soil samples were collected from respective plots and analyzed for bio-chemical properties. Organic C content increased from 0.28% in control to 0.38% in surface soil where consortia of halophilic bacteria were inoculated. Individually, inoculation of wheat seeds with HB1, HB2 and HB3 resulted in increase of soil organic carbon by 25, 17.8 and 10.7% respectively as compared to control. Soil pH reduced from 9.4 to 8.9 in consortia treated plots, to 9.1 in both HB1 and HB3 inoculated plots and 9.2 in HB2 inoculated plots. Soluble Na^+ content reduced by 16.3-38.2% in plots where halophiles were applied. Similarly, reduction in soil ESP decreased from 64 in control to 48 where consortia were used. Available N and P contents increased in surface soil after harvest of wheat to the extent of 9.7-19.8% and 5.5-44.4%, respectively with inoculation of halophilic microbial strains. Soil microbial biomass C content enhanced from 18.2 to 36.6% when seedlings of paddy were inoculated with halophilic microbial strains at transplanting compared to un-inoculation. Soil dehydrogenase activity varied from 10.2 µg TPF g^{-1} d^{-1} in control to 14.8 µg TPF g^{-1} d^{-1} in consortia inoculated plots. Similarly, use of individual inoculants HB1, HB2 and HB3 resulted in increase in DHA by 38.5, 22.1 and 31.3% over control.

Field Testing at Farmers fields to promote organic farming in sodic lands

The bio-formulations of halophilic N-fixers and phosphate solubilizers have been prepared and tested on sodic soils in experimental fields, pots as well as farmers' fields. The promising results have been obtained in paddy, wheat and other crops at farmers field in Unnao, Raebareli and Sitapur districts. Wheat yield as influenced by halophilic bioformulations along with salt tolerant as well as traditional varieties was tested at farmers' field in Sitapur district. The liquid bio-formulations namely Halo-Azo, Halo-PSB, Halo-Azsp, can be

effectively used in sodic soils for improving crop growth and yield as well as improves soil fertility and health. The other formulations like Halo-Rhizo and Halo-Mix are in testing and carrier standardization phase.

Assessment and refinement of existing irrigation practices of major crops grown under sodic environment (A. K. Singh, C. L. Verma, Y. P. Singh, Sanjay Arora)

Keeping in view the importance of efficient water management practices, this project aims to apply low depth of irrigation at varying intervals than normal soils to save irrigation water and pumping energy as well as to create favourable soil moisture regime to achieve the optimum production of rice (cv. CSR 36) in *Kharif*, and wheat (cv. KRL 210) and sugarbeet (cv. LS 6) in *Rabi* grown in the partially reclaimed sodic soils. The method of irrigation adopted was surface with different irrigation schedules. During *Kharif*, irrigation was done at two depths *i.e.*, 5 cm and 7 cm at 2 days, 3 days and 5 days after disappearance of water and when soil moisture tension reached at 7.5 kPa and 10 kPa besides one schedule as control where 7.5 cm of water was applied with the apperance of cracks in the top layer. During *Rabi* season, irrigation was applied at two depths *i.e.*, 3 cm and 5 cm at 30%, 50% and 70% depletion of soil moisture from field capacity and at IW/CPE ratio of 0.8 and 1.0. In control treatment, irrigation was applied at different crop stages of wheat.

Wheat crop (2015-16)

Water and energy (fuel) used to practice irrigation

The frequency and depth of irrigation water applied and the cost of fuel incurred were measured and analysed . In wheat, during the whole growing period a maximum number of 7 irrigations were applied when irrigation was done at 30% and 50% of SMD with 3 cm of irrigation depth. This was followed by 6 irrigations at 30% of SMD with 5 cm of irrigation depth, 5 irrigations at 70% SMD with 3 cm irrigation depth, 50% SMD with 5 cm irrigation depth and IW/CPE ratio of 1.0 (3 cm of irrigation depth), 4 irrigations at 70% of SMD with 5 cm of irrigation depth, IW/CPE ratio of 0.8 with 3.0 cm of irrigation depth, IW/CPE ratio of 1.0 with 5.0 cm of irrigation depth and under control plots with 6 cm of irrigation depth. The

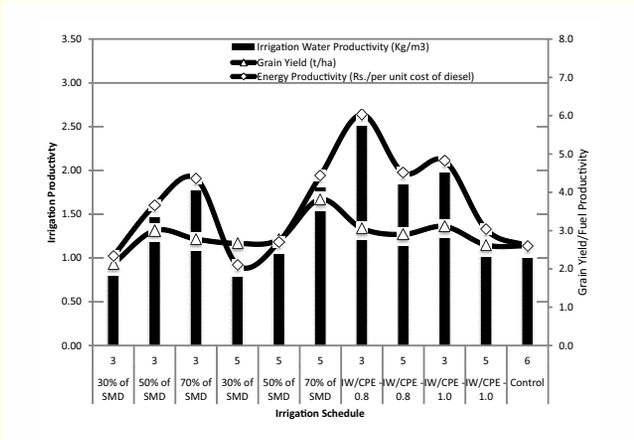


Fig.56. Water and energy productivity of wheat under varying irrigation regime

lowest number of irrigations *i.e.*, 3 were applied at IW/CPE ratio of 0.8 with 5 cm of irrigation depth and under control plot with 6 cm of irrigation depth.

Irrigation water & energy (fuel) productivity and wheat yield trends

The water and energy productivity and wheat grain yield trends under different irrigation regime are shown in Fig.56. It was observed that the highest grain yield of 3.8 t ha^{-1} was obtained when irrigation was scheduled at 70% of SMD (5 cm depth of irrigation) followed by 3.3 t ha^{-1} in case of 50% of SMD (3 cm depth of irrigation).

The highest irrigation water and energy productivity of 2.6 Kg m^{-3} and Rs. 6.0 per unit cost of diesel, respectively, was achieved when irrigation was scheduled at IW/CPE ratio of 0.8 (applying 3 cm of irrigation depth) followed by 2.1 Kg m^{-3} (irrigation water productivity) and Rs. 4.8 per unit cost of diesel (irrigation energy productivity) in case of IW/CPE ratio of 1.0 (3 cm depth of irrigation). The results reflected higher irrigation water and energy productivity when irrigation is scheduled based on IW/CPE ratios but at the cost of yield decline.

Sugarbeet crop (2015-16)

Water and energy (fuel) used for irrigation in sugarbeet

Data showed that during the whole growing period of sugarbeet crop, a maximum of 13 irrigations were applied when irrigation was practiced at 30% of SMD (3 cm depth of irrigation) followed by 12 irrigations at 30% SMD (5 cm depth

of irrigation), 9 irrigations at 50% of SMD (3cm depth of irrigation), 8 irrigations in case of 70% of SMD (3 cm depth of irrigation), 50% of SMD (5 cm depth of irrigation), IW/CPE- 1.0 (3 cm depth of irrigation) and under control plots (6 cm depth of irrigation), 7 irrigations in case of 70% of SMD (5 cm depth of irrigation), 6 irrigations each in case of IW/CPE- 0.8 (3 and 5 cm depth of irrigation) and IW/CPE- 1.0 (5 cm depth of irrigation). These irrigation events included one pre germination irrigation of 6 cm depth, which was applied to each irrigation regimes.

Irrigation water & energy (fuel) productivity and sugarbeet yield trends

Data on water and energy productivity and wheat grain yield trends under different irrigation regimes (Fig. 57) showed that highest sugarbeet root yield of 39.4 t ha^{-1} was obtained when irrigation was scheduled at 70% of SMD (5 cm depth of irrigation) followed by 36.1 t ha^{-1} under control plots (6 cm depth of irrigation), 35.1 t ha^{-1} in case of IW/CPE-1.0 (applying 3 cm depth of irrigation) and 34.3 t ha^{-1} in case of 50% of SMD (5 cm depth of irrigation), 33.4 t ha^{-1} incase of 50% of SMD (3 cm depth of irrigation), 30.7 t ha^{-1} in case of IW/CPE-0.8 (3 cm depth of irrigation), 30.6 t ha^{-1} incase of 70% of SMD (3 cm depth of irrigation), 28.9 incase of IW/CPE-0.8 (5 cm depth of irrigation), 27.2 t ha^{-1} incase of 30% of SMD (5 cm depth of irrigation), 26.5 t ha^{-1} incase of IW/CPE-1.0 (5 cm depth of irrigation) and 22.4 t ha^{-1} in case of 30% of SMD (3 cm depth of irrigation). The highest irrigation water productiovity (Kg/m^3) of 14.6 was recorded in case of IW/CPE- 0.8 (3 cm depth of irrigation) followed by 13.0 in case of IW/CPE-1.0 (3 cm depth of irrigation), 11.3 in case of 70% of SMD (3 cm depth of irrigation), 11.1 incase of 50% of SMD (3 cm depth of irrigation), 11.0 incase of 70% of SMD (5 cm depth of irrigation), 9.3 incase of IW/CPE-0.8 (5 cm depth of irrigation), 8.5 in case of IW/CPE-1.0 (5 cm depth of irrigation), 8.4 incase of 50% of SMD (5 cm depth of irrigation), 7.5 under control plots (6 cm depth of irrigation), 5.3 incase of 30% of SMD (3 cm depth of irrigation) and the lowest (4.5) in case of 30% of SMD (5 cm depth of irrigation).The energy productivity (Kg per unit cost of diesel) of these plots also followed the same trend as irrigation water productivity with the highest (206.4) energy productivity noted in case IW/CPE-0.8 (3 cm depth of irrigation) and the lowest of 62.3 incase of 30% of SMD (5 cm depth of irrigation).

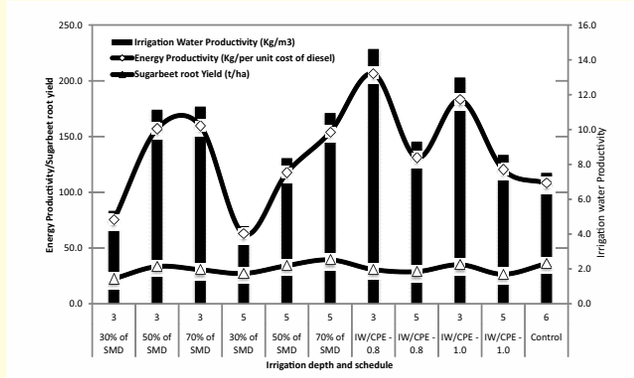


Fig.57: Water and energy productivity of Sugarbeet under varying irrigation regime

Rice crop (2016-17)

Water and energy (fuel) used for irrigation

It was observed that the maximum 13 irrigations were applied when irrigation was scheduled at 2-DAD (5.0 cm of irrigation depth) amounting to 65 cm of total depth of irrigation followed by 12 irrigation at 2 DAD (7.0 cm of irrigation depth) amounting to 84 cm of total depth of irrigation. The lowest total depth of irrigation applied was of 40 cm through 8 irrigation events when irrigation was scheduled at 5 DAD (5.0 cm of depth of irrigation). This resulted in the lowest use of energy while pumping the groundwater for irrigation when irrigation was scheduled at 5 DAD (5.0 cm of irrigation depth) over control as well as other irrigation schedules.

Irrigation water and energy productivity and rice yield trends

It was observed that the highest irrigation and energy (pumping) productivity can be achieved in rice by practicing irrigation at 5 DAD (5.0 cm of irrigation depth). The irrigation and energy productivity under this schedule was 0.84 Kg/m^3 and 1.77 Rs. per unit cost of diesel used. The corresponding rice yield was 3.4 t ha^{-1}. The highest rice yield of 3.9 t ha^{-1} was recorded when irigation was schedlued at 3 DAD (5.0 cm of irrigation depth), the corresponding irrigation water productivity was 0.78 Kg/m^3 and energy (fuel) productivity recorded was 1.64 Rs. per unit cost of diesel used (Fig.58).

The lowest irrigation water productivity of 0.46 Kg/m^3 and the energy productivity Rs. 0.96 per

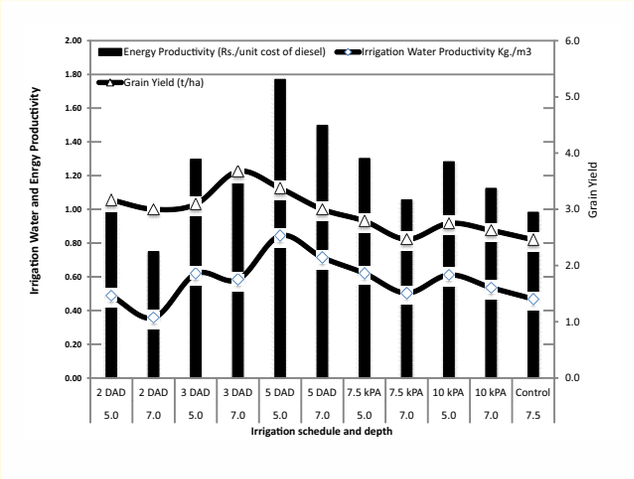


Fig. 58: Water and energy productivity of Rice under varying irrigation regime

unit cost of diesel used with rice yield of 3.8 t ha^{-1} were recorded when irrigation was scheduled at 2 DAD (7.0 cm of irrigation depth).

Impact of CSR-Bio on crop production in Uttar Pradesh (Thimmappa. K, T. Damodaran and R. Raju)

The use of plant growth promoting rhizobacteria is being considered as an alternative way to improve the productivity of sodic soils while minimizing the use of chemical amendments. The Institute has developed CSR-Bio, a bio-growth enhancer based on the integration of microbial consortia for increasing the productivity of crops grown in sodic and normal soils. Farmers are using CSR-Bio on a large scale in cereals, pulses, fruits and vegetable crops. Impact of CSR-Bio on crop production, was in Trivediganj block of Barabanki district and Gauriganj block of Amethi district in Uttar Pradesh. The average farm size of the farmers in the study area was 1.56 ha and a majority of the farmers (73%) belonged to marginal and small category. The crop production was the most important activity contributing 89% to the total household income. A few farmers (11%) also supplemented their household incomes by engaging themselves or their family members in off-farm activities.

Crop yields were higher with the use of CSR-Bio than non-adopter farms (Table 86). The yield increase was the highest in gram. The yield gain was 0.4 t ha^{-1} (22%) with the use of CSR-Bio. The yield increase was also higher in potato (17.61%), wheat (14.63%), tomato (14.29%), banana (13.64%) and gladiolus (4.12%) crops. Adopters observed that the use of CSR-Bio had improved appearance of the produce, *e.g.*, shinier fruits in banana and tomato; and increase in spike length and brightness in gladiolus flowers enabling the farmers to get higher prices for gladiolus (11%), banana (10%) and tomato (6.25%). The impact of adoption of CSR-Bio was assessed in terms of reduction in the use of chemical fertilizers and fungicides. Farmers using CSR-Bio saved 100 kg ha^{-1} Diammonium phosphate (DAP) fertilizer to be used in banana and tomato crops. They also saved 50 kg ha^{-1} DAP fertilizer (11.28%) in rice. CSR-Bio use also reduced plant protection chemical sprays from 13 to 8 in banana. Farmers saved 3 sprays in tomato and 2 sprays in gladiolus. It reduced the cost of plant protection chemicals by 31% in red gram followed by 27.16%

Table 86: Changes in crop yield and per unit price of crop produce

Crop	Yield (t ha^{-1})			Price per unit (t ha^{-1})		
	Non-adopters	Adopters	Change (%)	Non-adopters	Adopters	Change (%)
Banana	41	46	13.64	1000	1100	10.00
Tomato	70	80	14.29	800	850	6.25
Potato	28	33	17.61	900	900	0.00
Rice	60	68	13.33	1450	1450	0.00
Wheat	41	47	14.63	1450	1450	0.00
Red gram	16	20	21.88	3000	3000	0.00
Gladiolus*	230500	240000	4.120	4.5	5	11.11

Note: * Number of Gladiolus spikes

Table 87: Parameter estimates for logit model

Variables	B	S.E.	Sig.	Exp (B)
Farm Size	2.031	1.021	0.047	7.624
Education	0.251	0.979	0.797	1.286
Contact with extension agency	8.238	2.808	0.003	0.0004
Age	-0.058	0.091	0.524	0.944
Constant	-6.589	3.758	0.080	0.001

$R^2 = 0.76$

in potato, 25.48% in gladiolus, 8.81% in tomato and 8.59% in banana.

Farmers' behavior in the use of CSR Bio was studied using logit model. The results of maximum likelihood estimate of the coefficients of the logit model (Table 86) indicated that age and contact with extension agency were positive and significant. Extension agency contact influenced the rate of adoption by 0.0004 times and a unit increase in farm size tended to increase the adoption behaviour by 7.6 times. The extension person's interactions with farmers would help in rapid adoption of CSR-Bio. Small, medium and large farmers showed interest in attending training and demonstration programmes as well as adopting the technology intensively than the marginal farmers.

RECLAMATION AND MANAGEMENT OF SALT AFFECTED VERTISOLS

Breeding and evaluation of field crops for salt tolerance in saline vertisols (Monika Shukla, Anil R. Chinchmalatpure and D. K. Sharma)

Among various approaches for management of salt affected Vertisols, introduction of high-yielding salt-tolerant varieties of field crops is seen as the best management strategy because of its economic viability and cost-effectiveness. Accordingly, experiments were continued to identify salt tolerant lines of cotton (*G. herbaceum* and *G. arboreum*), wheat and maize. These studies also aimed to identify the physiological traits imparting salt tolerance in these crops and to assess their utility in breeding programmes.

Cotton

Microplot study

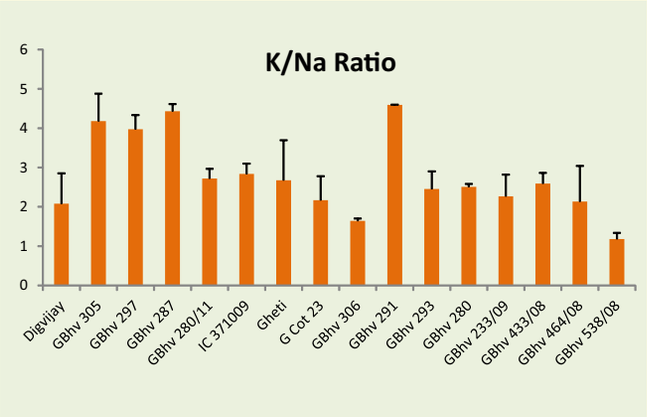
During 2015-16, sixteen genotypes of *Desi* cotton (*G. herbaceum*) were evaluated for their salinity tolerance. These genotypes were selected from previous year field experiments, based on their superior performance for yield and related attributes. Treatments were imposed by irrigating the microplots with saline water: EC_{IW} of 8 and 16 dS m^{-1}. The experiment was conducted in factorial RBD with two replications. The *in situ* salinity of the microplots ranged between 3.4-3.9 dS m^{-1} at the start of the experiment which was increased to 5.2-5.8 dS m^{-1} at the time of harvesting. Various morphological, biochemical and yield attributes were recorded during the entire crop season. Pooled analysis of data revealed that GBhv 538/08 followed by IC 371009 and Digvijay were the top three performing genotypes based on seed cotton yield per plot. These lines also had superior performance for several traits *viz.* biomass, lint yield per plot, number of bolls/plant, proline content and leaf K^+content. K^+/Na^+ ratio seemed to have insignificant role in imparting salinity tolerance in these genotypes. Genotype GBhv 433/08 was the lowest yielder (78.44 g/plot) among all the entries and could be categorized as salt susceptible. Low yield in GBhv 433/08 could be mainly attributed to less boll weight and biomass (Fig. 59).

Generation advancement of *G. herbaceum* L. and *G. arboreum* L.

Generation advancement from F_4-F_5 of 40 *herbaceum* lines, and F_2-F_3 advancement of 15 *arboreum* lines was carried out at the Samni Experimental Farm. Among the *herbaceums*, high variability was noted for all the observed agronomical and biochemical traits *viz*., plant height (147.4-227.2 cm), seed cotton yield per plant (34.5-186 g), number of bolls per plant (64.0-206.2), sodium ion content in leaf tissue (0.74-2.10 meq L^{-1}), leaf K^+ content (0.60-22.3 meq L^{-1}), Cl^- content (9.0-25.0 meq L^{-1}) and K^+/Na^+ ratio (0.88-25.83). Similarly, wide range of variabilty was recorded in *G. arboreum* populations for plant height (134.0-190.8 cm), seed cotton yield per plot (85.6-154.8 g), number of bolls/plant (66.8-131.0), leaf Na^+ content (0.9-3.0 meq L^{-1}), leaf K^+ content (149.2-283.9 meq L^{-1}), K^+/Na^+ ratio (2.64-10.72) and leaf Cl^- content (16.5-26.0 meq L^{-1}). Pedigree selection in this germplasm yielded 200 F_5 progenies of *G. herbaceum* and 60 F_3 progenies of *G. arboreum* which were planted in Kharif, 2016-17 for further selection.

Varietal trial of thirty entries

A varietal trial of 30 entries having *herbaceum*, *arboreum* and *hirsutum* accessions and Bt-hybrid as check was planted at the Samni Experimental Farm in two replications. The plot size was 5 m x 2.4 m and plant to plant spacing was 45 cm. Farm soils is categorized as saline Vertisol with sub-surface salinity. The EC_e of soils at the start of experiment was 4.5 dS m^{-1} which increased to 5.8 dS m^{-1} at the end of the experiment. Crop was provided life saving irrigation with saline water (EC_{iw} 10.8 dS m^{-1}). Analysis of variance revealed significant variation for almost all the observed parameters except for leaf Cl^- ion content. The maximum plant height was recorded in GBhv 464/08 (170.6 cm) followed by CNA 398 and GBav 124. GBav 124 was the highest yielder with 97.5 g seed cotton yield per plant followed by GBav 131 (90.0 g) and CNA 398 (89.0 g). Thus, there was close similarity between plant height and high yield which may be due to



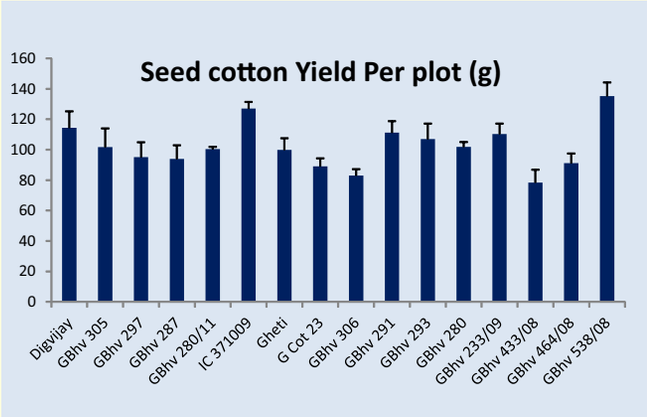


Fig. 59: Biochemical and agronomical parameters recorded in desi cotton genotypes in saline microplots.

high number of boll bearing sympodia in genotypes with tall stature. Total seed cotton yield per plot was highly correlated with seed cotton yield per plant for some superior genotypes *viz.*, CNA 398, GBav 131 and GBhv 464/08. Top yielding hybrids were also superior for contributing traits such as low Na^+ and C^{-1} content (GBhv 433/08), high sugar content in leaf (GBav 124), leaf area (G cot 23) and K^+/Na^+ ratio (GBhv 433/08). Gheti, a traditional variety showed

Table 88: Performance of twenty two wheat genotypes in saline Vertisols

S. No.	Genotype	Yield (kg plot^{-1})	Leaf Na^+ content (meq L^{-1})	Leaf K^+ content (meq L^{-1})	K^+/Na^+ Ratio
1	DBW 181	3.67	1.56	1.03	1.09
2	GW 322	3.67	1.58	0.53	0.55
3	GW 366	3.90	2.80	0.88	0.56
4	GW 496	3.37	2.88	0.66	0.42
5	HD 2009	2.65	3.66	1.33	0.63
6	HUWL 1412	4.27	2.22	0.97	0.72
7	HUWL 1413	4.46	3.26	0.71	0.39
8	HUWL 1427	4.33	2.37	1.47	1.02
9	KH-65	3.72	2.49	0.83	0.55
10	KRL 19	4.43	1.45	0.63	0.71
11	KRL 210	4.42	2.46	1.55	1.04
12	KRL 345	4.53	3.28	1.74	0.94
13	KRL 346	3.87	2.77	1.70	1.05
14	KRL 347	3.69	4.17	1.31	0.56
15	KRL 351	3.98	2.73	1.28	0.80
16	KRS 1416	3.66	3.63	1.40	0.67
17	LOK 1	3.46	3.51	1.01	0.47
18	LOK BOLD	3.22	2.33	0.98	0.70
19	NW 6096	4.79	2.38	1.42	1.00
20	RWP 2014-20	4.76	2.35	0.66	0.49
21	WH 1309	4.49	2.26	0.98	0.75
22	WH 1311	4.18	0.85	0.86	1.70
	Mean	3.98	2.59	1.09	0.76
	S.D	0.58	0.80	0.36	0.03
	C.V.	14.48	11.05	33.14	14.29
	C.D. (5%)	1.20	0.82	0.10	0.07

superior performance for most of the ionic parameters. Most of the genotypes tested were superior for yield and related attributes over *Bt*-hybrids indicating the suitability of these genotypes under saline conditions in native environment. These genotypes may be utilized as a donor for many traits in the breeding programme for development of salt tolerant and high yielding genotypes.

Wheat

A trial consisting of 22 wheat entries was planted at the Samni Experimental Farm in two replications. These lines were selected from previous year experiments of wheat trials and nursery. Few varieties released from the State Agricultural Universities in Gujarat were also included in the trial. The plot size was 4 m x 2.4 m with 20 cm row spacing. Salinity in the field at the start of experiment was 4.5 dS m^{-1} and crop was irrigated four times with saline waters (EC_{IW} 8.2-10.6 dS m^{-1}). Yield of these genotypes along with ionic content in their leaf tissues were measured (Table 88). NW 6096, RW 2014-20 and KRL 345 were top three performing entries in terms of yield. These entries also maintained higher K^+/Na^+ ratio in their leaf tissue at the time of flowering which would have imparted more tolerance in these lines and thus higher yield. Five entries performed better than salt tolerant check KRL 19 and KRL 210 while 19 entries were having yield superiority over popular variety GW 496. Even though K^+/Na^+ ratio was found higher in top performing entries, any conclusive relation of K^+/Na^+ ratio with yield potential was missing in this experiment.

Maize

Two sets of field experiment of *Rabi* maize were conducted during 2015-16, namely, varietal trial and germplasm nursery. Trial was planted with plot size of 3 m x 1.8 m with plant to plant spacing of 20 cm and row spacing of 60 cm. The experiment was conducted in saline Vertisols and salinity stress was imposed by irrigating the experimental plots with saline water (EC_{IW} 3.0-3.5 dS m^{-1}). Analysis of variance revealed significant differences among the genotypes for almost all the observed traits. Hybrid SS-7077 was the highest yielding hybrid (6.77 Kg $plot^{-1}$) followed by DKC 8101 and Challenge-1 (Table 89). DKC -8101 also

Table 89 : Performance of maize genotypes under saline water irrigation

S. No.	Genotype	Yield (kg Plot $^{-1}$)	Leaf K^+/Na^+ ratio	Biomass (kg $plot^{-1}$)
1	Kesharking 919	4.46	22.62	4.55
2	SS-6066	4.65	24.81	4.37
3	SS-7077	6.77	14.41	7.76
4	Godawari-989	4.08	18.03	3.14
5	Challenge-1	6.01	14.45	4.46
6	DKC-8101	6.15	27.25	4.21
7	900-M-Gold	5.31	16.06	7.51
8	DKC-7074	2.90	20.45	4.00
9	DKC-9117	3.79	23.47	5.49
10	Prakash	3.20	16.12	3.41
11	GM-6	2.03	22.41	3.55
12	GAYMH-1	4.00	18.09	3.83
13	GWL-8	2.91	17.22	1.30
14	GWL-15	3.63	8.49	2.56
15	GYS-705	1.89	20.87	1.82
16	DMRQPM-0903	3.69	13.31	3.01
	Mean	4.09	18.63	4.06
	SD	0.68	3.36	0.66
	CV	16.63	18.05	16.15
	CD 5%	1.13	5.61	1.09

had the highest leaf K^+/Na^+ ratio. After three years of testing, DKC-8101 emerged as the best hybrid under saline water irrigation. For biomass, SS-7077 again was the best hybrid followed by 900 M GOLD which ranked fourth in terms of yielding ability. High biomass and maintenance of better K^+/Na^+ ratio were found to be highly correlated with grain yield in the superior hybrids. Among thirty two genotypes planted in the nursery, IL 8537, Hishell, CWC 305 and GM-2 were superior in yield and related attributes.

Soil physical characteristics and nutrient dynamics in Vertisols with subsurface salinity

(Anil R. Chinchmalatpure and David Camus D.)

The present investigation was carried out to evaluate the distribution of available nutrients (N, P, K, S, Fe, Mn, Zn, Cu) in 6-irrigated and 6-rainfed pedons in *Vertisols* area of Amod (21^0 59' 39.26'' N; 72^0 52' 09.30'' E), Vagra (21^0 50' 41.84'' N; 72^0 50' 40.95'' E) and Jambusar (21^0 03' 10.78'' N; 72^0 48' 04.30'' E) talukas of Bara tract (Bharuch district). In irrigated pedons, available N, P_2O_5, K_2O, S and DTPA-Fe, Mn, Cu and Zn varied from 156.8 to 323.5 kg ha^{-1} (low to medium), 15.4 to 59.5 kg ha^{-1} (low to marginally high), 325.2 to 1315.8 kg ha^{-1} (high to very high), 3.5 to 35.1 ppm (low to high), 1.92 to 9.33 mg kg^{-1} (low to medium), 3.3 to 16.44 mg kg^{-1} (low to high), 0.57 to 2.54 mg kg^{-1} (high) and 0.07 to 0.39 mg kg^{-1} (low, except one sample with 0.61 mg kg^{-1}), respectively. In comparison, the corresponding values of these parameters in the rainfed pedons were 125.4 to 258.3 kg ha^{-1} (low), 12.1 to 50.2 kg ha^{-1} (low to medium), 205.5 to 1305.9 kg ha^{-1} (medium to very high), 2.3 to 22.3 ppm (low to high), 1.68 to 9.33 mg kg^{-1} (low to medium), 1.82 to 10.2 mg kg^{-1} (low to high), 0.31 to 1.49 mg kg^{-1} (medium to high) and 0.06 to 0.29 mg kg^{-1} (low), respectively. Slightly higher of available N, P_2O_5, K_2O, S, DTPA-Fe, Mn, Cu and Zn under irrigated pedons were due to addition of higher organic manures, better management practices and higher leaf-litter fall.

Available N

In irrigated pedons 1, 3, 5, 7, 9 and 11 (Kalak, Nadiad, Kerwada, Pahaj, Amod and Samni villages, respectively), the status of available N was low to medium and it varied from 156.8 to 323.5 kg ha^{-1} (Table 90). Available N was high in surface soils of all pedons and slightly decreased with depth showing somewhat irregular trend which might be due to churning processes of vertic clay soils (swelling shrinkage characteristics may create deep and wide cracks) except pedon-1, 5 and pedon-11. However, in rainfed pedons of 2, 4, 6, 8, 10 and 12 (Kalak, Nadiad, Kerwada, Gandhar, Amod and Samni villages, respectively), available N was low ranging from 156.8 to 258.3 kg ha^{-1}. Available N decreased with depth in pedon-4, 6 and 10, while in others trend was somewhat irregular, which might be due to variations in SOC because of churning process and its subsequent mineralization/ decomposition in the lower horizons.

Available P_2O_5

In irrigated pedons 1, 3, 5, 7, 9 and 11, available P_2O_5 was low to high (20.1 to 59.5 kg ha^{-1}, Table 90) and decreased with depth in pedon 1, 5 and 7 while in other pedons any definite trend was not observed. The reason for mean P_2O_5 variations from pedon to pedon might be due to the variation in soil pH, texture and organic matter. In case of rainfed pedons 2, 4, 6, 8, 10 and 12, available P_2O_5 was low to medium ranging from 12.1 to 50.2 kg ha^{-1}, and decreased with depth in all pedons except pedon 2 and 8. Low to medium available P status in both irrigated and rainfed soils was perhaps due to less vegetative cover, hot dry weather and soil constraints like calcareousness, alkalinity or fixation of released phosphorus by clay minerals or fixation of P as $CaPO_4$ by silt and clay sized fractions.

Available K_2O

Available K_2O status in irrigated pedons 1, 3, 5, 7, 9 and 11 was high (325.2 to 1315.8 kg ha^{-1}) and decreased with depth in all the pedons except pedon-11 (Table 90). Similarly, in rainfed pedons 2, 4, 6, 8, 10 and 12, available K_2O was generally high (205.5 to 1305.9 kg ha^{-1}) except at lower depth of pedon 2. The reason for high available K content in these soils might be the presence of high quantity of micaceous (biotite and muscovite) clay minerals, release of K by dissolution of muscovite under sodic conditions and organic residues and application of K fertilizers.

Available sulphur

Status of available S in irrigated pedons 1, 3, 5, 7, 9

Table 90: Distribution of nutrients in irrigated and rainfed situations

Profile No. (cm)	Soil depth	Macro-nutrients			S (ppm)	DTPA-extractable nutrients (mg kg^{-1})			
		N	P_2O_5	K_2O		Fe	Mn	Cu	Zn
P11		Irrigated situation(Village: Samni, Taluka: Amod)							
	0-19	313.6	59.5	1315.8	35.1	4.31	13.22	2.54	0.61
	19-45	282.2	38.6	1026.5	22.3	3.83	5.99	2.10	0.37
	45-70	267.3	47.9	950.3	30.3	3.59	5.76	2.15	0.33
	70-91	250.9	36.2	650.3	21.3	3.35	5.76	2.10	0.29
	91-110	250.9	42.5	760.5	26.5	3.11	5.37	1.80	0.28
	110-135	219.5	26.2	345.6	16.2	4.31	3.30	0.88	0.22
	Min	219.5	26.2	345.6	16.2	3.11	3.30	0.88	0.22
	Max	313.6	59.5	1315.8	35.1	4.31	13.22	2.54	0.61
	Mean	264.1	41.8	841.5	25.3	3.75	6.57	1.93	0.35
P12		Rainfed situation(Village: Samni, Taluka: Amod)							
	0-30	258.3	50.2	1215.4	12.6	3.83	10.20	2.50	0.29
	30-63	219.6	37.4	1190.6	4.6	3.35	8.86	2.15	0.19
	63-80	125.4	32.8	651.2	11.2	3.35	8.01	2.15	0.20
	80-110	225.4	41.5	712.3	12.6	3.83	7.25	1.19	0.27
	110-135	125.4	25.6	346.2	6.8	3.35	5.37	0.70	0.19
	Min	125.4	25.6	346.2	4.6	3.35	5.37	0.70	0.19
	Max	258.3	50.2	1215.4	12.6	3.83	10.20	2.32	0.29
	Mean	190.8	37.5	823.1	9.6	3.54	7.94	1.70	0.23

and 11 varied widely from low to high showing (3.0 to 35.1 ppm) and did not follow any definite trend with depth in all the pedons, except pedon-1 and 5 (Table 90). Pedon-11 (35.1 ppm) showed the highest S content. However, in rainfed pedons, available S also varied from low to high (2.3 to 22.3 ppm). The variation in available S in different horizons of both irrigated and rainfed pedons under study might be attributable to varying amounts of organic matter and clay, and differences in the degree of mineralization.

DTPA micronutrients

Results of DTPA-extractable (available) Fe, Mn, Zn and Cu (Table 7) revealed that DTPA-extractable (available) Fe in soil horizons of all irrigated and rainfed pedons was low to medium. In irrigated and rainfed pedons, DTPA-extractable Fe varied from 3.11 to 9.33 mg kg^{-1} and 1.68 to 9.33 mg kg^{-1}, respectively, *i.e.*, no appreciable differences amongst the pedons and the trend was irregular with soil depth. Surface soils of all the pedons recorded the highest value exhibiting an irregular trend with soil depth except pedon-9. The reason might be its close association with high SOC in the surface layer. From surface downwards, the magnitude started declining slightly in sub-horizons with somewhat irregular trend probably due to variation in pH and SOC. Pedon-5 (Kerwada) recorded the highest DTPA-extractable Fe in surface horizon as compared to others.

DTPA-extractable (available) Mn in different horizons of irrigated and rainfed pedons varied from low to high (Table 88). It varied from 6.45 to 16.44, 5.10 to 6.85, 4.43 to 11.75, 7.05 to 11.48, 7.05 to 11.48 and 3.30 to 13.22 mg kg^{-1}, respectively with corresponding mean values of 9.65, 6.19, 9.17, 8.91, 7.52 and 6.57 mg kg^{-1} in above irrigated pedons in chronological order with no appreciable difference amongst the pedons. DTPA-Mn content also exhibited irregular trend with soil depth except pedon-1. Like DTPA-Fe, surface soils of all the pedons showed similar trend in DTPA-Mn. In rainfed sites, the same varied from 1.82 to 8.46, 1.88 to 3.90, 5.15 to 7.78, 3.02 to 4.10, 3.24 to 7.72 and 5.37 to 10.20 mg kg^{-1}, respectively with corresponding mean values were 5.72, 2.93, 6.55, 3.83, 5.58 and 7.94 mg kg^{-1}, respectively in the above rainfed

Table 91: Distribution of nitrogen and potassium forms in irrigated and rainfed situations

Profile No.	Depth (cm)	NH^{4+} (ppm)	NO^{3-} (ppm)	TN (%)	WSK (ppm)	Exch. K (ppm)
P11	Irrigated situation (Village: Samni, Taluka: Amod)					
	0-19	70.0	84.0	0.048	21.0	415.6
	19-45	56.0	65.2	0.035	11.6	396.7
	45-70	45.5	56.6	0.025	12.9	395.8
	70-91	42.0	61.2	0.027	14.3	370.1
	91-110	31.5	45.6	0.018	10.0	301.3
	110-135	42.0	44.3	0.020	5.0	313.2
	Min	31.5	44.3	0.018	5.0	301.3
	Max	70.0	84.0	0.048	21.0	415.6
	Mean	47.8	59.5	0.029	12.5	365.4
P12	Rainfed situation (Village: Samni, Taluka: Amod)					
	0-30	56.3	77.0	0.035	18.8	375.4
	30-63	42.0	42.0	0.032	17.6	349.3
	63-80	31.5	17.5	0.025	12.3	380.9
	80-110	45.5	7.0	0.021	9.0	320.7
	110-135	21.0	7.0	0.018	8.9	266.1
	Min	21.0	7.0	0.018	8.9	266.1
	Max	56.3	77.0	0.035	18.8	380.9
	Mean	39.3	30.1	0.026	13.3	338.5

TN= Total nitrogen; WSK= Water soluble potassium, Exch.= Exchangeable

pedons chronological order. DTPA-Mn content did not follow any particular trend with depth, except pedons 2, 10 and 12 and reason might be the same as stated above.

DTPA-extractable (available) Cu was very high in different horizons of irrigated and rainfed pedons (Table 88). However, DTPA-extractable (available) Zn was low to medium in different horizon soils of irrigated and rainfed pedons. DTPA-extractable Zn varied from 0.07 to 0.26, 0.12 to 0.25, 0.28 to 0.39, 0.13 to 0.28, 0.13 to 0.22 and 0.22 to 0.61 mg kg^{-1}, respectively, with corresponding mean values of 0.14, 0.17, 0.34, 0.18, 0.17 and 0.35 mg kg^{-1}, respectively, in the above irrigated pedons in chronological order. DTPA-Zn content exhibited an irregular trend with soil depth, except pedon-7 and 11 showing surface soils of all the pedons the highest value which might be due the same reason as stated above. In case of rainfed pedons (Table 88), the same was 'low' ranging from 0.06 to 0.20, 0.11 to 0.19, 0.06 to 0.17, 0.12 to 0.24, 0.11 to 0.21 and 0.19 to 0.29 mg kg^{-1}, respectively with corresponding mean values of 0.12, 0.15, 0.12, 0.17, 0.15 and 0.23 mg kg^{-1}, respectively in the above rainfed pedons in chronological order. DTPA-Zn content showed irregular trend with depth, except pedon-2, the reason might be due to the same as stated above.

It was observed that DTPA- Fe, Mn, Zn and Cu tended to increase with the increasing SOC. Mean values of all micronutrients were invariably higher in irrigated pedons than rainfed pedons which might be due higher organic sources, plant debris or roots and crop management practices. However, the amounts of DTPA-micronutrients in both the cases generally decreased with depth with decreasing SOC, which acts as chelating agent.

Nutrient dynamics

In irrigated pedons, NH_4^+, NO_3^-, TN, water soluble K (WSK) and exchangeable K (Exch. K) varied from 10.0 to 73.2 ppm, 35.0 to 93.8 ppm, 0.014 to 0.080 per cent, 4.2 to 73.8 ppm and 122.3 to 415.6 ppm, respectively with the corresponding mean values of 38.0 ppm, 60.1 ppm, 0.035 per cent, 32.2 ppm and 249.4 ppm, respectively (Table 91). Similarly, the corresponding values for rainfed pedons were 3.5 to 66.5 ppm, 7.0 to 77.0 ppm, 0.008 to 0.049 per cent, 2.4 to 59.7 ppm and 92.7 to 380.9 ppm, respectively with the corresponding mean

Table 92: Soil properties of irrigated and rainfed soils of Bara tract

Profile No. (Village)	pH		EC_e (dS m^{-1})		ESP	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
P1& P2 (Kalak)	7.0-8.5	7.5-8.9	0.6-01.3	0.5-01.5	0.8-13.0	0.4-09.1
P3& P4 (Nadiad)	8.3-8.6	8.4-8.8	0.9-04.8	1.0-16.0	3.4-20.0	2.4-09.2
P5& P6 (Kerwada)	8.1-8.6	8.5-8.9	0.8-09.4	0.9-04.0	3.3-16.9	2.8-08.1
P7& P8 (Pahaj&Gandhar)	7.8-8.5	8.4-8.8	1.1-02.0	1.7-15.3	8.0-13.4	7.7-16.4
P9& 10 (Amod)	7.8-8.3	8.3-8.6	2.3-12.5	0.8-08.9	9.7-27.1	3.8-18.1
P11& 12 (Samni)	7.5-8.1	8.2-8.7	4.8-05.5	0.9-07.6	5.6-11.5	3.8-10.6
Overall	7.0-8.6	7.5-8.9	0.6-12.5	0.5-16.0	0.8-27.1	0.4-18.1

values of 34.4 ppm, 44.4 ppm, 0.026 per cent, 24.6 ppm and 193.7 ppm, respectively. Ammonical and nitrate contents were high in the surface soils of all pedons and the magnitude slightly decreased with depth showing somewhat irregular trend which might be due to churning processes of vertic clay soils because of swelling shrinkage characteristics may create deep and wide cracks.

Soil pH, EC and ESP from soils of all the pedons from irrigated and rainfed cotton growing areas of Bharuch district are presented in Table 92. Soil pH of all the horizons of different pedons, irrespective of irrigated and rainfed situation, widely varied from mild to strongly alkaline. The overall results revealed that pH, EC and ESP of irrigated soils varied from 7.0 to 8.6, 0.6 to 12.5 dS m^{-1} and 0.8 to 16.0, respectively, while for rainfed soils the corresponding values were 7.5 to 8.9, 0.5 to 16.0 dS m^{-1} and 0.4 to 18.1, respectively. In irrigated and rainfed pedons, sub-surface (below 75 cm) salinity was observed in all pedons, except pedon-1 and 2, which were categorized as moderately to strongly saline. In rainfed pedons in close vicinity of coast (Nadiad and Gandhar), high sub-surface salinity can be ascribed to the ingress of sea water. ESP of soils in all the irrigated pedons widely varied from upper to lower depth of pedons. ESP of soils from all irrigated-pedons was within the permissible limit of 15 at upper soil layer, but at lower layers (below 60 cm) ESP was > 15 in the Nadiad, Kerwada and Amod pedons. Similarly, rainfed pedons of Gandhar and Amod had >15 ESP in the lower layers. For heavy swelling-shrinkage black soils, critical level of ESP might lie between 6 and 10 and accordingly irrigated area encompassing all the pedons, except Kalak site depicted ESP higher than critical level and as a result might cause yield reduction in cotton crop to certain extent depending upon the soil-clay content. Higher ESP was possibly due to regular irrigation of canal/ borewell/ tubewell water etc. which ultimately induced the sodification process in surface as well as sub-surface soils.

Crop productivity:

After introduction of canal irrigation, cotton productivity increased by two to three folds than rainfed situations (Table 93). In rainfed cotton, the life-saving irrigation plays a crucial role in determining the productivity. *Bt*-cotton occupied 100% area in 2014-15, as compared to 80% of total area under *desi* cotton prior to canal command. In rainfed areas, farmers were still growing *desi* cotton.

Based on the overall results and soil-crop related constraints following suggestions are made for improving/sustaining the cotton yield and soil health in the study area:

- Low available N and DTPA-Zn status in major soils necessitate the use of more organic manures such as farm waste/compost/bio-comost/vermicompost etc. to improve their availability. In specific cases, soil application or foliar spray may be necessary to overcome Zn deficiency. In case of N-deficiency, adoption of INM/ RDF with inorganic-N in splits and

Table 93: Average productivity of different crops in the study area

Crop	Productivity (q ha^{-1})	
	Rainfed	Irrigated
Arhar (*Cajanus cajan*)	5.5-10.5	15.0-20.0
Cotton (*Gossypium spp.*)	3.2-05.5	9.2-11.6
Wheat (*Triticum aestivum*)	10.2-15.8	30.5-45.1
Green gram (*Cicer arietinum*)	3.5-05.9	10.5-15.5

Table 94: Relationship between EC_1, EC_2, EC_5 and EC_{10} with EC_e

	EC_1	EC_2	EC_5	EC_{10}
Equation	y = 0.3439x	y = 0.2719x	y = 0.1225x	y = 0.0724x
R_2	0.8098	0.8153	0.8698	00.8221
Factor	2.9100	3.6800	8.1600	13.8100

introduction of leguminous crop under suitable situation and *in situ* incorporation of decomposable crop residue would give desirable results for improving soil OC and available N status.

- Adoption of sodicity/salinity tolerant crop varieties would be highly essential in soils having high soil pH, ESP above threshold limit (9.0) and moderate to high salinity. Making of field bunds for ponding rain water and subsequent salt leaching would be most useful in saline soils.
- In the study area (semiarid climate), rainwater harvesting by making the field bunds for maximum rain water storage in profiles would be highly beneficial. As ground water is saline and unsuitable for irrigation in the entire tract, ground water must be judiciously used (as life-saving/ supplementary) by mixing with rain water/canal water or alternately with canal/ rain water to sustain crop yield while preventing the further deterioration in soil health.

To fulfil the action taken report on the IRC comment "Curve for conversion of EC_2 to EC_e should be worked out for Vertisols" about 543 soil samples from different places representing Vertisols and associated soils have been analysed for electrical conductivity with different soil: water ratios and also for saturation extract electrical conductivity and curves have plotted (Fig. 60) for

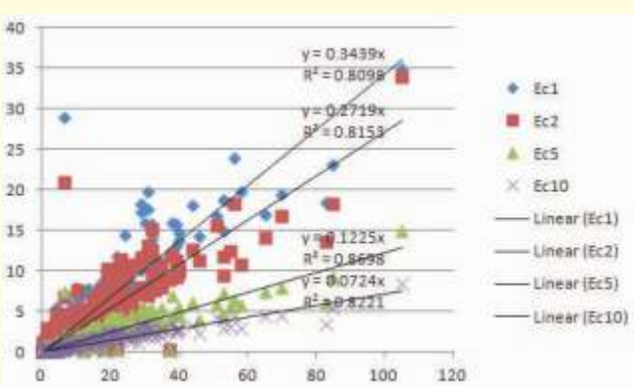


Fig.60: Linear plotting of soil EC_1, EC_2, EC_5 and EC_{10} with EC_e

EC_1, EC_2, EC_5 and EC_{10} verses EC_e and obtained a factor of 3.68 for converting EC_2 to EC_e (Table 94).

Prospects of cultivating desi cotton genotypes and salt tolerant wheat varieties in saline vertisols (Sanjay Vasant Kad, Anil R. Chinchmalatpure and Monika Shukla)

The study area, located in Bharuch and Bhavnagar districts of Gujarat, experiences hot sub tropical type of climate. Soil of the region is mix of black cotton soil and sandy soil and has sub-surface salinity. Ground water is mostly saline, and in most of the part irrigation is provided by canals. Considering the above scenario, this study was conducted to understand the trends in the adoption of *desi* cotton and salt tolerant wheat varieties in saline Vertisols and to study the constraints faced by farmers in growing these varieties. From the study area, 20 farmers cultivating *desi* cotton (cv. G Cot- 23) from Jambusar taluka of Bharuch district and 10 farmers from Valbhipur taluka of Bhavnagar district were selected. Similarly, 30 farmers cultivating salt tolerant wheat varieties (KRL 19 & KRL 210) from Amod, Vagra, Bharuch and Jambusar talukas of Bharuch district were also sampled. Data pertaining to socio-economic, biophysical aspects, cost of cultivation, perception about salt tolerant varieties and constraints faced were collected by personal interviews with the farmers. Soil samples from the selected farmers' fields were also collected to assess the salinity status.

Cotton Crop

Study was initiated with the 20 *desi* cotton growing farmers of Jambusar taluka of Bharuch district and 10 farmers of Valbhipur taluka of Bhavnagar district in 2015-16. These farmers were given seeds of salt tolerant *desi* cotton cv. G Cot-23. Data were collected regarding perception about *desi* cotton (G Cot- 23) compared to other varieties. The pH_4 soil of study area was 7.55 to 8.86 and EC_2 ranged from 0.32 to 1.57 dS m^{-1}.

Economic analysis of STV cultivation

Data related to various aspects of cost of cultivation were collected using the recall method. It was observed that cost A involving various operational costs was Rs.18290 ha^{-1} for the farmers growing *desi* cotton. As *desi* cotton is grown under rainfed conditions, irrigation costs are saved as compared to hybrid cotton varieties. Average yield of *desi* cotton (G Cot- 23) obtained at farmers field was 0.676 t ha^{-1}. Farmers could earn gross income of Rs. 28730 ha^{-1} and net income of Rs. 10440 ha^{-1}. B: C ratio for salt tolerant variety was 1.57.

Perception of the farmers about *desi* cotton

Majority of the farmers perceived benefits (Table 13) of the salt tolerant desi cotton in terms of cheaper seeds (> 90%), low cost of cultivation (90%) and suitability for rainfed and saline conditions compared to other hybrids and *Bt* cotton. About 35% of the respondents agreed that salt tolerant varieties helped in increasing the standard of living. About 65% of the farmers reported benefits in terms of less irrigation requirement. About 75% farmers perceived that STV had less boll drops in saline soils and that caused by intercultural operations. About 50% of the farmers perceived that salt tolerant *desi* cotton had high market demand in market and fetched higher prices than hybrids and *Bt* cotton.

Constraints faced by STV growing farmers

Analysis of different constraints revealed that non-availability of quality seeds and lack of knowledge (35%) were the major production constraints faced by the farmers. Among labour constraints, high cost of labour (80%) and non-availability of labour during peak demand (70%) were reported as severe constraints. Among marketing constraints, heavy yearly fluctuations in price (70%) and lack of government procurement policy (65%) were the major problems faced by the farmers.

Wheat crop

This study was conducted in Jambusar, Vagra, Amod, Hansot and Bharuch talukas of Bharuch district in 2015-16. The farmers were given seeds of salt tolerant varieties (STVs) of wheat (KRL 210 and KRL 19) as a part of technology demonstration. From the study area, 30 farmers cultivating STVs were selected. Data pertaining to socio-economic, biophysical aspects, cost of cultivation, perception about salt tolerant varieties and constraints faced were collected by personally interviewing the farmers. Soil samples were collected to assess the salinity status from the farmers' fields. Soil salinity level at surface was low and increased. In 0-30 cm layer, salinity ranged from 0.17-1.86 dS m^{-1} indicating sub-surface salinity. Same trend was observed in case of pH. At depth 0-30 cm, pH level ranged from 7.45 to 8.85.

Economic analysis of STV cultivation

Data related to various aspects of cost of cultivation were collected using the recall method. It was observed that cost A involving various operational costs was Rs. 24060 ha^{-1} for the farmers growing STVs. STVs required less number of irrigations than other varieties resulting in reduced costs of 1-2 extra irrigation. Average yield of salt tolerant wheat varieties obtained at farmers' field was 1.97 t ha^{-1}. Farmers could earn gross income of Rs. 39540 ha^{-1} and net income of Rs. 15480 ha^{-1}. B: C ratio for salt tolerant varieties was 1.64.

Perception about salt tolerant varieties of wheat

Majority of the farmers perceived benefits of STV in terms of higher grain (93%) and straw (86%) yields than other varieties. Half of the respondents agreed that STVs helped raise their standard of living. About 70% farmers reported less irrigation requirement of STVs. In crop characteristics, 90% farmers perceived that STVs showed less lodging while 60% reported less grain shattering problem. About 56.6% farmers perceived STVs to be more compatible to the changing climatic situation.

Constraints faced by STV growing farmers

Analysis of different constraints faced by the farmers indicated that non-availability of seed (60%) and lack of knowledge (60%) were the major production constraints. Among the labour related constraint, 90% of the farmers opined that high cost of labour was a very severe problem. Among economic constraints, 70% of the farmers rated high cost of fertilizer as quite severe. Among the marketing constraints, heavy yearly fluctuation in price was reported as the major problem by 54% farmers. Among general constraints, 53% farmers reported fragmentation of land holding as quite severe constraint.

Performance of guava orchards with forage intercropping and pruning intensity on saline Vertisols of Gujarat (David Camus. D., Anil R. Chinchmalatpure and Monika Shukla)

A study was undertaken at the Samni Experimental Farm to evaluate the interaction effect of pruning, irrigation and fertilizer on yield characteristics and fruit quality in 9 year old trees of guava cv. Allahabad Safeda. Orchard spacing was 5m x 5m. The treatments consisted of three pruning intensities (No pruning [P_1], 25% pruning [P_2] and 50% pruning [P_3]), three irrigation treatments (Best Available Water [I_1], EC_{iw} 4 dS m^{-1} [I_2] and EC_{iw} 8 dS m^{-1} [I_3]) and three fertilizer levels (500g: 250g: 250g NPKtree^{-1} year^{-1} + 50kg FYM tree^{-1} year^{-1} [F_1], 750g: 250g: 250g NPK tree^{-1} year^{-1} + 50kg FYM tree^{-1} year^{-1} [F_2] and 1000g: 250g: 250g NPK tree^{-1} year^{-1} + 50kg FYM tree^{-1} year^{-1} [F_3]). Observations on number of fruits per tree, yield (kg tree^{-1}), yield per unit area (t ha^{-1}) and yield increase over control (%) were recorded for each treatment. Fruits were harvested from a height of 1.5 m from the ground level and data on fruit weight (g), total soluble solids (° Brix), titratable acidity (%) and sugar acid ratio were recorded.

Data analysis showed that the maximum fruit yields of 9.47, 9.18 and 8.88 kg tree^{-1} were recorded in $I_1P_2F_2$, $I_1P_2F_1$ and $I_2P_2F_2$, respectively, as compared to control $I_1P_1F_1$ (5.93 kg tree^{-1}; Table 18). Similar trend was also recorded for yield per unit area (t ha^{-1}). Among different treatment combinations, 59.65% higher yield over control was obtained under $I_1P_2F_2$. Other treatments ($I_1P_2F_1$ and $I_2P_2F_2$) were also superior in terms of fruit yield giving 54.76 and 49.79% higher yields over control, respectively.

Pruning increased the fruit weight, total soluble solids (TSS) and sugar: acid ratio under each treatment interactions. Trees with 50% pruning had heavier fruits (150-172 g) closely followed by 25% pruned trees (125-154 g). The average TSS ranged from 13.5 to 14.3°Brix in 50% pruned trees. On the contrary, average TSS ranged from 12.5 to 13.7°Brix in 25% pruned trees and 10.9 to 11.5°Brix in control (no pruning). There was non-significant variation in titratable acidity between different treatment combinations. The sugar: acid ratio was high in 50% pruned trees (42.17-54.74) followed by 25% pruned trees (36.69-49.76) and unpruned trees (29.44-40.17). These results suggest that treatment combination of 50% pruning (P_2), application of best available water (I_1) and 50% increase in the recommended dose of nitrogen (F_2) gave the maximum fruit yield per unit area (3.787 t ha^{-1}) followed by $I_1P_2F_1$ (3.671 t ha^{-1}) and $I_2P_2F_2$ (3.553 t ha^{-1}) during winter season.

Maximization of yield and factor productivity through Integrated Nutrient Management in *Desi* Cotton-based cropping systems in saline Vertisols (Monika Shukla, Anil R. Chinchmalatpure and D. K. Sharma)

Cotton is the most important crop in Gujarat covering an area of 30.06 lakh hectares during

Variation in fruit size under different pruning treatments

2014-15 with total production of 125 lakh bales and productivity of 707 kg ha^{-1}. Gujarat contributes about one third of India's total cotton production. Decline or stagnation in cotton productivity is observed due to irregular rainfall pattern, depleting soil fertility, continuous mono-cropping and improper management of crop. For the risk coverage and maintaining the soil fertility, diversification by incorporation of another crop in the farming system is very necessary. In Bara tract area of Gujarat state, cotton is one of the main crop and farmers are practicing *Cotton-fallow* system on their fields year after year. Continued monocropping in a vast area has also decreased on-farm biodiversity and made crops more vulnerable to pest and disease infestation. Alternative cropping system and management practices such as double-cropping, crop rotation, and addition of organic amendments may prove beneficial for sustainable gains. Crop rotation including legume crops can effectively help in maintaining the soil fertility. Management of solid wastes is one of the critical issues for the urban areas of developed and developing countries. Composting is one of the traditional and common methods of processing of Municipal Solid Wastes (MSW) in most of the countries. Application of composted MSW to agricultural land has several beneficial effects similar as other organic manures. The idea of inclusion of other crops in the cotton monocropped system and integrated nutrient management plan can be used for maximization the crop yield in the Bara tract of Gujarat. Keeping this in view, an experiment was planned with three cotton-based cropping systems in two year crop rotation; C_1: Cotton monocropped, C_2: Cotton-sorghum-wheat and C_3: Cotton-pigeonpea-wheat in main plot and

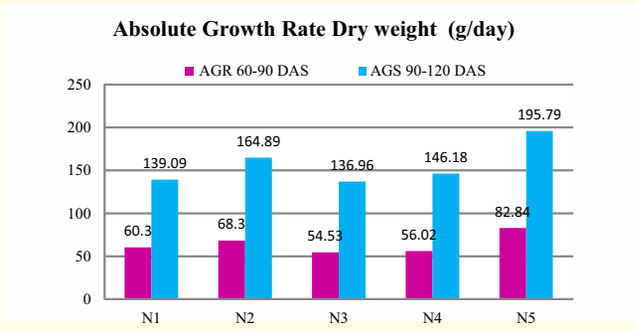


Fig. 61: Absolute Growth Rate (dry weight) of cotton under different integrated nutrient management treatments

five treatments of integrated nutrient management in sub-plot; N_1: 100% RDF; N_2: 75% RDF + 25 % through MSWC; N_3: 50% RDF + 50 % through MSWC; N_4: 50% RDF + 50 % through MSWC + *Azotobacter;* N_5: 50% RDF+ 50 % through MSWC + *Azotobacter* + Soil application of Zn. Integrated nutrient management experiment with cotton (G Cot-23) in first year was conducted at Samni Experimental farm during *Kharif* 2016. Soil pH_2 ranged from 7.5-7.9 at 0-120 cm depth. Soil EC_2 was 0.34, 0.31, 0.46 and 0.78 dS m^{-1} at 0-30, 30-60, 60-90 and 90-120 cm depths.

Plant growth in cotton

Plant height of cotton was recorded at 45, 90 and 135 days after sowing (DAS). Treatment differences were significant at 45 DAS but non-significant at 90 and 135 DAS. The maximum plant height (26.6 cm, 116.36 cm and 184.29 cm, respectively at 45, 90 and 135 DAS) was observed under treatment N_5 followed by $N_2$75% RDF + 25% through MSWC (25.3 cm, 113.3 cm and 147.40 cm, respectively at 45, 90 and 135 DAS). The minimum plant height at 45, 90 and 135 DAS was observed in treatment N_1 (100% RDF). Fresh weight and dry weight of cotton plants including root and shoot was recorded at 30, 60, 90 and 120 days after sowing. The maximum fresh weight (20.36 g) at 60 DAS was observed under the treatment N_5 (50% RDF + 50% through MSWC + *Azotobacter* + Soil application of Zn) followed 18.16 g in treatment N_4. The maximum fresh weight at 90 and 120 DAS (310.11 g and 679.06 g, respectively) was observed under the treatment N_5 which was at par with N_2 (289.50 g and 581.61 g, respectively). The results for dry weight were non-significant at 30 and 60 DAS. The maximum dry weight at 90 and 120 DAS (83.00 g and 198.56 g, respectively) were observed under the treatment N_5. The results for absolute growth rate (dry weight) were non-significant for 30 and 60 DAS. The maximum AGR (dry weight) at 60-90 and 90-120 DAS (82.84 g day^{-1} and 195.79 g day^{-1}, respectively) was observed under the treatment N_5 (Fig. 61).

Leaf area of cotton plants was also recorded at 30, 60, 90 and 120 days after sowing. The results for leaf area were non-significant at 30 and 60 DAS (Table 95). The maximum leaf area at 90 and 120 DAS (5749.8 cm^2 and 50742.81 cm^2, respectively) was observed under the treatment N_5 which was at

Table 95: Leaf area and leaf area index of cotton under different integrated nutrient management treatments

	Leaf area per plant (cm^2)				Leaf area index	
Treatment	30	60	90	120	LAI 90 DAS	LAI 120 DAS
N1	208.34	564.39	4271.220	36100.54	0.79	6.68
N2	254.13	667.29	4920.250	36925.77	0.91	6.84
N3	205.31	604.79	4698.340	37400.11	0.87	6.92
N4	222.60	569.19	4851.700	38931.26	0.90	7.21
N5	250.52	590.26	5749.810	50742.81	1.06	9.40
CD (p=0.05)	NS	NS	936.27	8554.75	0.17	1.58

par at 90 DAS with N_2 (4920.25 cm^2) but significantly higher than all other treatments at 120 DAS. Leaf area index was calculated for 90 and 120 DAS and was maximum under the treatment 50% RDF + 50% through MSWC + *Azotobacter* + Soil application of Zn (1.06 and 9.40) which was at par with 75% RDF + 25% through MSWC and 50% RDF + 50% through MSWC + *Azotobacter* (0.91 and 0.90) at 90 DAS and at 120 DAS significantly different from all other treatments which were significantly at par.

Screening experiment of pigeonpea varieties

According to the project programme, in one treatment, cotton has to be replaced next year with pigeon pea-wheat cropping system. In Gujarat, pigeon pea has been cultivated as a long duration crop in the rainy and post-rainy seasons. However, early maturing and extra short duration varieties are neither popular nor available for this region. One experiment was conducted to screen of pigeon pea for early maturity at Bharuch conditions. Five varieties of pigeon pea (GT-101, BDN-711, GT-1, GT-100, Vaishali) were acquired from Navsari Agricultural University, Navsari, Gujarat and two varieties (AL-201 and PAU-881) from Punjab Agricultural University, Ludhiana, Punjab. Among them GT-100 did not germinate.

The maximum fresh weight at 30 DAS was observed in GT-1 while at 60, 90 and 120 DAS it was observed in GT-101. Similarly, the maximum dry weight at 30 DAS was observed in GT-1; at 60 and 90 DAS in GT-101 and at 120 DAS in Vaishali varieity. The maximum plant height at 45 and 135 DAS was observed in GT-1 and at 90 DAS in GT-101. The maximum AGR (dry weight) at 30-60 DAS and 60-90 was observed in GT-101and at 90-120 DAS in Vaishali.

Two varieties acquired from PAU (AL-201, PAU-881) were harvested in 148-150 DAS at Bharuch conditions. Among them, performance of PAU-881 was the best in terms of yield and yield parameters (Table 96).

Utilization of treated effluent from Aniline-TDI Plant of GNFC Unit II in rabi Maize and its long term impact on properties of Vertisols (Anil R. Chinchmalatpure, Indivar Prasad, David Camus, Shrvan Kumar, Sagar Vibhute and P. C. Sharma)

The Aniline-TDI plant of Gujarat Narmada Valley Fertilizer and Chemicals Ltd., Bharuch (GNFC Unit-II) primarily deals with the manufacturing of Toluene diisocyanate and Aniline.It has established a well developed treatment plant which produces about 500 M^3 of treated effluent. Maize is a staple food and feed in the tribal belt of the state. In Gujarat, maize is grown on 4.8 lakh ha with production of 8.4 lakh tones and productivity of 1750 kg ha^{-1}. In order to understand the feasibility of using these effluents in maize crop

Table 96: Growth and yield parameters of early maturing pigeon pea varieties

Variety	Days to 50% flowering	No. of branches	No. of pods $plant^{-1}$	No. of seed pod^{-1}	Seed yield $plant^{-1}$ (g)	Stover yield $plant^{-1}$ (g)	Seed yield $plot^{-1}$ (kg)	Stover yield $plot^{-1}$ (kg)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Days to maturity
AL-201	76	10.80	97.0	3.6	35.00	162.55	1.05	5.214	873.03	4345.27	149
PAU-881	76	12.53	120.3	4.3	57.33	287.00	1.52	8.491	1266.66	7076.11	148

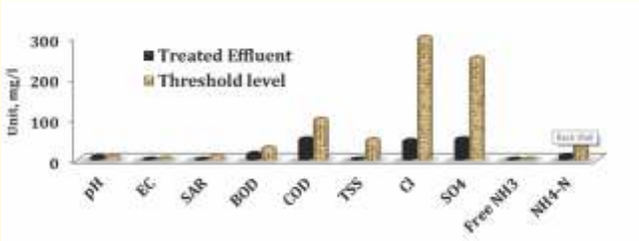


Fig. 62: Chemical composition of treated effluent

and woody species; and the likely impacts on soil properties, salinity development and produce quality in long run, field trials were initiated. The treated effluents collected from the ETP of GNFC Unit-II were analysed for different chemical parameters. The analytical report of the treated effluent indicated that the effluents produced are less toxic as their chemical constituents are within acceptable limits. Data indicated that the chemical parameters *viz*., pH, electrical conductivity, BOD, COD, total soluble solids, chloride, sulphate, SAR, free ammonia and ammoniacal nitrogen are well within the threshold values (Fig. 62) meant for irrigating the field crops.

Initial characterization of soils of the experimental field at GNFC Unit-II was also done (Table 95). Soils of the experimental site were neutral to slightly alkaline in reaction (pH 7.4-8.3) and marginally saline (0.5 to 3.2 dS m^{-1}). Salinity increased with soil depth (Table 95). Organic carbon content of these soils ranged from 3.9-5.7 g kg^{-1} and $CaCO_3$ content from 45-59.2 g kg^{-1}. Among the exchangeable cations, Ca^{2+} was dominant followed by Mg^{2+}, Na^+ and K^+ with cation exchange capacity ranging from 43-48 cmol(p+) kg^{-1} and exchangeable sodium percentage (ESP) from 1.3-5.6 which increased with depth. Bulk density ranged from 1.2-1.4 Mg m^{-3}. These soils were clayey with clay content ranging from 39.3-49.6%. Dominant clay mineral was montmorrillonite. Saturation extract analysis showed that Na^+ was the dominant cation followed by Mg^{2+}, Ca^{2+} and K^+. Among anions, Cl^- was dominant followed by SO_4^{2-} and HCO_3^-. Sodium adsorption ratio (SAR) of these soils ranged from 1.0-7.7 which increased with depth.

Studies were initiated with use of treated effluent from Aniline-TDI plant with the following objectives: (i) To study the long term effect of treated effluent application on physical and chemical properties of Vertisols under arable crops as well as woody species; (ii) to study the impact of the treated effluents on growth and productivity of *Rabi* maize; and (iii) to study the quality of maize grain and maize fodder under effluent irrigation.

Study 1: Experiment with *Rabi* maize variety SS-7077 was initiated and sowing was done on 8th December, 2016. Initial seed germination percentage was 85-90%.

Study 2: Effect of treated effluent on biomass

A) Irrigation Treatments	B) Nitrogen levels
Effluent: BAW ratio 1:0	80 kg N ha-1
Effluent: BAW ratio 1:1	100 kg N ha-1
Effluent: BAW ratio 0:1	120 kg N ha-1

woody species (*Pongamia, Terminelia arjuna* and *Eucalyptus*) in RBD design with three replications and irrigation treatments like once in 10 days, once in 20 days and once in 30 days.

Study 3: The mixed effluent from GNFC Unit-I and Unit-II (Aniline TDI plant) goes to natural stream-Garamiya Kans and it's downstream. As the farmers in nearby villages are in need of irrigation water, they have been using these waters since longtime to meet their irrigation need. For knowing the effect of long term use of effluent on soils, a soil profile study will be conducted in the

Table 97: Physico-chemical properties of soils

Hori-zon (m)	Depth (dS m^{-1})	pH (g kg^{-1})	EC_e (Mgm^{-3})	OC (gkg^{-1})	BD	CaCO3	Exchangeable cations [cmol(P+) kg^{-1}]				CEC [cmol (P+)kg^{-1}]	ESP
							Ca	Mg	Na	K		
A	0.00-0.44	7.7	0.5	5.4	1.30	47.0	21.5	20.0	0.55	0.15	43.8	1.3
A12	0.44-0.86	8.3	0.6	5.7	1.40	56.5	23.5	17.0	1.63	0.11	44.1	3.7
Bss1	0.86-1.16	8.1	1.1	4.8	1.31	58.8	24.5	19.0	2.60	0.08	46.8	5.6
Bss2	1.16-1.45	7.7	2.0	5.1	1.29	54.5	24.5	21.0	2.36	0.07	48.3	4.4
BC	1.45-1.60	7.5	2.4	4.8	1.28	45.0	25.0	18.5	2.12	0.06	45.8	4.6
C	1.60+	7.4	3.2	3.9	1.20	59.2	24.5	16.5	2.20	0.08	43.3	5.1

Germination of maize (SS 7077) under treated effluent irrigation treatment

farmers' fields along the Garamiya Nala who have been using these effluents for crop cultivation in their field since longer period.

Cost effective drainage in waterlogged saline Vertisols for improving crop productivity in Gujarat. (Anil R. Chinchmalatpure, Monika Shukla, David Camus, Sanjay Kad and M. J. Kaledhonkar)

Waterlogging and soil salinity problems are adversely affecting agricultural lands in many irrigation commands of India posing threats to the sustainability of the irrigated agriculture. Need for drainage planning is felt and now it is considered as an important component of irrigation development. Genesis of this project is in response to the action point raised in the ICAR-Regional Committee No. VI meeting held at AAU, Anand during 12-13 September, 2014 as "Cost effective and convincing model of drainage including subsurface drainage are to be developed and demonstrated at six places in one year (CSSRI-RRS, Bharuch)". Sub-surface drainage (SSD) is basically adopted for reclamation and management of soils affected by waterlogging and salinity. Similarly, to get rid of water logging situation during monsoon season in salt affected black soils, open surface drainage and mole drainage (pipe less drainage) options are also available. ICAR-CSSRI has vast experience in this field. Yet, there are several location specific problems that pose difficulties in the implementation and operation of such drainage interventions. During the period under report, SSD installation work at 2 locations (Village Ghodadara, Taluka Hansot and village Adadara, Taluka Ankleshwar in Bharuch district) was carried out. The soils in the selected fields were tested for salinity status and it was found that soil salinity ranged from 3.4-41.0 dS m^{-1} and soil pH ranged from 7.3-7.9. The soil hydraulic conductivity ranged from 0.05-0.06 m day^{-1}. The farmers are witnessing low productivity of crop from these lands due to waterlogging and salinity. The SSD was installed with different lateral spacings of 35 m one place and 40 m at another with 1.2 m depth. These sites were having gravity outlet condition and natural drainage channel was present along the boundary of one site (Ghodadara) and at second site (Adadara), drainage discharge from outlet to open drain is about 200 m from study site. The site condition is having uniform land slope and having deep black cotton soils with clay percentage ranging from 48-55%.

Impact evaluation of sub-surface drainage technology for reclamation of water logged saline soils in Maharashtra (Sanjay Vasant Kad, R. K. Singh, Raju. R and D. S. Bundela)

An impact evaluation study in Dudhgaon village of Miraj taluka, Sangali, Maharashtra indicated the

Fields affected by salinity and waterlogging

Table 98: Salient features of Dudhgaon Subsurface drainage project

Parameters	Value/feature
Proposed area under SSD project (ha)	1100
Actual Area covered under subsurface drainage (ha)	1085 (98.63%)
Total Farmers (beneficiaries) covered (No.)	1326
Type of drainage system	Pipe drainage with natural outlet
Total pipe length	238.54 km
Years of installation	2004 to 2006
Total cost of SSD Project (Rs. in Lakhs)	458.95
Approximate cost of installation (Rs./ha)	44,000/-

Field without SSD

Crop in SSD installed field

potential of SSD technology in restoring the productivity of waterlogged saline lands. The study village is located in the Krishna river command with lift irrigation system. The soil salinity and water logging problems were witnessed in Dudhgaon village severely affecting the land productivity and posing threats to livelihood security of small and marginal farmers. The main factors which are responsible for increased soil salinity are excess and faulty irrigation methods, poor drainage of Vertisols and high levels of salt in water.

Salient features of Dudhgaon Subsurface drainage project

In Dudhgaon village, the subsurface drainage project was installed under RKVY scheme where government took initiative to reclaim waterlogged saline soil in 2004-06. The total geographoical area of Dudhgaon village is 2012 ha of which 1100 ha (54.67%) area is waterlogged and saline. On 1085 ha (98.63%) land, about 238.54 km drainage length SSD system with cost of Rs.485.95 lakhs was installed benefitting about 1326 farmers (Table.98).

The average cost of SSD installation was Rs. 44000 ha^{-1} at the time of project implementation. The data were collected using personal interviews, focus group discussions and PRA techniques from 30 farmers of Dudhgaon village having SSD installed in their fields. About 50 % of the selected farmers had medium and large land holdings followed by 30% farmers in the marginal category who benefited from SSD project

Impact of subsurface drainage before and after installation

Cropping pattern

In the project area, sugarcane was the major crop which occupying about 82% area followed by cereals and pulses (9%), fruits and vegetable (7%) and oilseeds (2%). Farmers cultivated cereals such as sorghum, bajra, and wheat, fruits like banana, guava and mango, oilseeds such as soybean and groundnut and vegetables (chilli, tomato and brinjal). After SSD implementation, the cropping pattern became more diversified than earlier.

Yield of major crops

Before SSD installation, the average yield (Table 99)

Table 99: Yield of crops before and after subsurface installation

Crop	Yield (t ha^{-1})		Percentage increase in yield
	Before SSD	After SSD	
Sugar cane	46.30	108.7	234
Wheat	01.16	2.881	248
Soyabean	00.92	2.614	284

of sugarcane, wheat and soybean were 46.3 t ha^{-1}, 1.16 and 0.92 t ha^{-1}, respectively. After SSD implementation, however, average yields increased to 108.7 t ha^{-1} in sugarcane, 2.881 t ha^{-1} in wheat and 2.614 t ha^{-1} in soybean. It was also observed that yield improvements in the SSD blocks located in low lying areas were very low. The significant increase in crop yield can be attributed to the direct effect of SSD system which in turn lowered the water table and salinity from the root zone.

Average annual income

Agriculture was the main source of income of all the respondents followed by dairy business in the case of some farmers. The average agriculture income of farmers increased from 1.16 lakh to 2.72 lakh (233%) per annum after SSD installation. The increase in income was largely related to the increase in crop yield due to improvement in land productivity.

Perception of farmers after adopting SSD technology

Majority of the farmers (43.33%) strongly agreed and 56.67% farmers agreed that yields of sugarcane and other crops increased after SSD installation. All the farmers agreed that there was increase in productivity of sugarcane crop from 46.3 t ha^{-1} to 108.7 t ha^{-1} after SSD. About 83% of the farmers agreed that soil salinity considerably reduced after SSD. Similarly, 90% of the respondents perceived that land drainage significantly improved. All the farmers reported significant decrease in water table depth in the post-SSD phase. All the farmers agreed that increase in farm incomes was mainly due to high crop productivity in the SSD reclaimed lands. About 80% of the farmers agreed that the cost of SSD installation was recovered within 3 years of installation. But 90% farmers disagreed that SSD technology is economically feasible. About 83.33% of the farmers agreed that their annual income and standard of living significantly improved in the post-SSD phase. About 70% of them agreed that active participation of farmers right since the planning as well as during implementation and maintenance of SSD projects was key to the success. About 76.67% farmers perceived that land affected by salinity can be effectively ameliorated by adopting SSD.

Constraints faced by farmers

A number of constraints adversely impacting the SSD adoption were recorded. For about 70% farmers, high cost of PVC drain pipes was a major limitation. Similarly, 83.3% of them faced problems with regard to the high cost digging machine. A strong majority of the farmers (90%) agreed that high cost of farm labourers was a hindrance to SSD implementation and management. Only 46.67% of the respondents opined that lack of proper knowledge of SSD among the farmers proved a constraint. Majority of farmers (> 90%) agreed that non-availability of loan facility, unavailability of machine on time and the use of low quality material were not serious constraints while about 10% faced problems of clogging and blocking of drain pipes after some years of SSD installation especially in low lying area.

Groundwater contamination due to geogenic factors and industrial effluents and its impact on food chain (Anil R. Chinchmalatpure, David Camus and Monika Shukla)

In recent years, increasing industrialization, urbanization and developmental activities have led to the generation of large amounts of waste water from domestic, commercial, industrial and other sources. Industrial waste waters directly discharged into rivers, lakes and other water bodies cause severe pollution. Industrial pollution

Sampling locations in the study area

is noted in many areas of Surat, Vapi and Ankleshwar cities of Gujarat. The present project was taken up to evaluate the impact of industrial effluent in Ankleshwar industrial estate of Bharuch district of Gujarat, one of the heavily industrialized regions of Gujarat on ground water quality. This industrial estate has more than 1200 industries manufacturing diverse range of chemicals, pesticides, pharmaceuticals, bulk drugs, petroleum products, engineering, textiles, plastics, rubber, and packaging. Random sampling technique was adopted for collection of ground water samples. Due care was taken to avoid contamination of samples during handling. For every well, separate 1 l capacity polyethylene pre-cleaned containers were used after thoroughly rinsing with the sample water. Collected water samples were labelled properly. Operating conditions of well, GPS locations, well depths, etc. were recorded in the field. Samples from tubewells/ handpumps from 40 villages of Ankleshwar and Hansot *taluka*s of Bharuch district were also collected after pumping the well for few minutes. In all, 100 ground water samples were collected during pre- and post- monsoon season (June and December, 2016). Suction filtered (through 0.45 *u*m membrane filter paper) and acidified samples were used to determine different physico-chemical properties like pH, EC, cations (Ca, Mg, Na, K), anions (Cl, SO_4, CO_3, HCO_3, PO_4) and ion metals (Cd, Cr, Ni, Pb, As, Mn, Cu, Mn, Zn) using standard methods. Analysis of variance revealed significant differences in sampling sites with respect to different parameters *viz.*, EC, pH, Na, Ca, Mg, As, Cr, Co, Cu, Mn, Ni and Pb. Great variation was observed for almost all the recorded parameters. Results showed that electrical conductivity of ground water (Pre-monsoon) samples varied from 0.28-11.40 with average of 3.24 dS m^{-1} and standard deviation of 2.02. Similarly, in post-monsoon season, EC of ground water samples ranged from 0.3-9.3 dS m^{-1} with mean of 2.9 and SD of 1.82. Similarly, pH varied from 6.76-8.28 and from 6.78-8.12 in pre- and post-monsoon seasons, respectively, which remained within the permissible limit. However, some of the samples had higher content of almost all the heavy metals than permissible limit for irrigation/drinking. Average values for cadmium (0.03 ppm), chromium (0.06 ppm), cobalt (0.05 ppm), manganese (0.01 ppm) and nickel (0.17 ppm) were found to be more than permissible limit in the collected ground water samples (pre-monsoon). Significant and positive correlation (Table 100) was observed between chromium and lead which might be attributed to chemical nature of effluent discharged in the study area. Multivariate analytical technique revealed that maximum variability in sample data may be attributed to cobalt and chromium contents followed by chloride content. Further, spatial and temporal changes in content and distribution of these elements would be done to assess the impact of industrial effluents on long term basis. Heavy metals like cadmium, cobalt and manganese were alos categorised based on their permisible limits (Table 101).

Cluster analysis for heavy metals in groundwater samples

Cluster analysis reduces the number of variables by combining variables with similar characteristics. Cluster analysis is used for grouping the cases based on the similarity of the responses to several variables. On the basis of the connecting distances between parameters and their positions on the dendrogram, distinctive clusters of the variables were defined. Cluster analysis is a useful method for combining groundwater wells into homogenous groups according to their water quality. Cluster analysis showed that the heavy

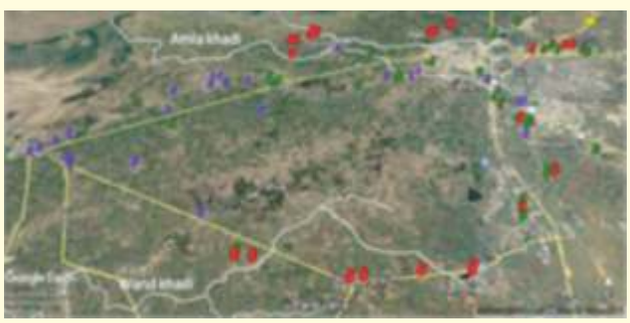
Table 100. Correlation among metal ions in ground water sample (Pre-Monsoon)

	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Cd	1	0.03	0.10	0.02	-0.05	0.02	0.12	0.10	-0.02
Co		1	0.60	0.70	0.21	0.35	0.63	0.69	0.12
Cr			1	0.65	0.24	0.26	0.33	0.97	0.00
Cu				1	0.29	0.45	0.48	0.74	0.00
Fe					1	0.37	0.09	0.23	0.22
Mn						1	0.32	0.33	0.00
Ni							1	0.37	-0.04
Pb								1	-0.01
Zn									1

Table 101. Categorization of samples based on permissible limits for heavy metals

Cadmium		Cobalt		Manganese	
Range (ppm)	No. of samples	Range (ppm)	No. of samples	Range (ppm)	No. of samples
0.00-0.01	51	0.00-0.05	57	0.00-0.10	74
0.01-0.02	36	0.05-0.10	40	0.10-0.20	7
0.02-0.03	0	0.10-0.15	3	0.20-0.40	12
0.03-0.04	12	-	-	0.40-0.80	6
>0.04	1	-	-	0.80-1.60	1

* Permissible limit of Cd, Co & Mn: 0.01, 0.05 & 0.20 ppm respectively



Clustering of different heavy metals in the study area

metals like Cd, Co, Cr, Ni and Cu were concentrated more around the effluent carrying channel and relatively less in agricultural fields and very less in inhabited area.

COASTAL SALINITY MANAGEMENT

Role of soil salinity and land uses on status and characteristics of organic matter under different landforms in coastal ecosystem (Shishir Raut, B. Maji and D. Burman)

Soil organic matter (SOM), being a storehouse of all essential plant nutrients, plays a pivotal role in crop production. For the efficient management of SOM, it is necessary to study the influence of agricultural activities, soil salinity and cropping patterns on organic matter availability. The study area covers three villages of Gosaba Block (S24PGS) namely, Rangabelia, Gosaba and Pakhiralay. The study area covering approximately 4 sq. km consists of three types of landforms *viz.*, deltaic, depressed lowland and mudflat/ mangrove. Soil samples were collected in the *Kharif* season (2016) from three different depths (0-20, 20-40, 40-60 cm) from the selected villages (Lat. 22° 09'-22°10' N; Long. 88°47'-88°48' E) coming under three different landforms namely, non-cultivated deltaic (NCD), mudflat (MUD) and depressed lowland (DL). The season for collections was June- July, 2016 (before rice cultivation). The area is mostly monocropped with rice. Soil samples were collected from three different locations (three replications) under each landform. The infiltration measurements were carried out in soil cores from the collected samples. Infiltration data was fitted to the Phillip's model (1957), which is described by the following equation: $I = St^{0.5} + At$; where I= cumulative infiltration (cm), S= soil water sorptivity, A= parameter close to saturated hydraulic conductivity, and t= time (min). The infiltration rate (I) was divided by the corresponding value of $t^{0.5}$ (min) in the entire infiltration measurement. The values obtained were then regressed against $t^{0.5}$ to obtain S as the intercept. Physicochemical characteristics like soil texture, pH, EC, organic C etc. were also studied. The humic acid and fulvic acid fractions of organic matter were separated. Relationship between sorptivity and other soil parameters were also

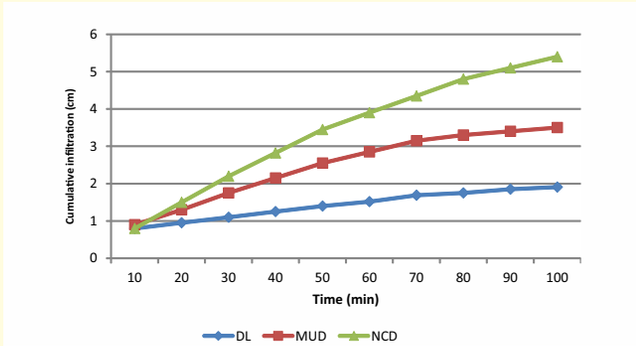


Fig. 63: Cumulative infiltration vs time relationship in three different soils

Table 102: Physicochemical characteristics of Gosaba soil (1st season)

Name of soil	Particle size (%)			Tex class	Org C	pH	EC (dSm^{-1})	θ_s-($m3m^{-3}$)
	S	Si	C					
0-20 cm								
NCD	16	55	29	Scl	1.19	5.0	3.7	0.59
MUD	26	22	52	C	1.19	6.9	9.3	0.54
DL	26	24	50	C	0.85	5.9	13.2	0.59
20-40 cm								
NCD	24	47	29	cl	1.13	5.7	3.6	0.56
MUD	26	20	54	C	0.71	6.9	6.9	0.55
DL	20	28	52	C	0.80	6.2	8.3	0.61
40-60cm								
NCD	25	45	30	cl	0.78	5.7	2.8	0.53
MUD	26	20	54	C	0.71	7.0	6.9	0.55
DL	28	20	52	C	0.80	6.0	8.0	0.60

S: sand, Si: Silt, C: Clay, l: Loam; NCD: non-cultivated deltaic, MUD: mudflat/mangrove, DL: depressed low land

determined. Correlation between clay and organic C as well as clay plus silt and organic carbon for the soils was studied.

The highest steady state cumulative infiltration was observed in NCD soil (5.5 cm) followed by MUD soil (3.5 cm) and DL soil (2.0 cm). These results can be verified from the slope of the cumulative infiltration and time curves (Fig. 66). These results can also be verified from the slope of the cumulative infiltration versus square root of time relationship curves. The slope of NCD soils in the present study was higher than the MUD and DL soils. In 50 minutes time, only 1.5 cm water infiltrated in DL soil. For the same period, 3.5 cm water infiltrated in NCD soil. Infiltration in MUD soil was medium (2.5 cm). MUD and DL soils were clayey with a clay content of 50-52 % in the surface layer (Tables 102). Clay content in NCD soil (sandy clay loam in texture) was 29 %. In the 20-40 cm and 40-60 cm soil layers, there was not much difference in clay content between MUD and DL soils (50-54 %, clayey). All three soils were medium to high in organic C content (0.71-1.19%). The surface layer and 20-40 cm layer of NCD soil contained higher (1.13-1.19 %) organic carbon. The highest porosity or saturation water content was found in DL soil (0.59-0.61 cm^3cm^{-3}) and the lowest was in MUD (0.54-0.55 cm^3cm^{-3}). The NCD and DL surface soils were slightly acidic to neutral (pH 5.0 to 6.2) in reaction. The EC values of NCD soils were low for all depths (2.8 to 3.7 dS m^{-1}); other soils had higher EC values (6.9-13.2 dS m^{-1}).

Average water content in soils before infiltration varied from 0.08-0.09 cm^3cm^{-3} in MUD and 0.09 cm^3cm^{-3} in DL soils and 0.09-0.11 cm^3cm^{-3} in NCD soils. Saturated hydraulic conductivity values for NCD soil varied from 0.018-0.02 cm min^{-1} and for DL soil from 0.005-0.012 cm min^{-1}. The highest sorptivity (3.4-3.5 $mmmin^{-1/2}$) was observed in NCD soil followed by 2.2-2.5 $mmin^{-1/2}$ in MUD soil and 0.90-1.0 $mmmin^{-1/2}$ in DL soils. Sorptivity values significantly differed for three different landforms for different depths. Clay and clay plus silt content were positively correlated with the percentage of organic carbon (r^2 = 0.79 and 0.75, respectively).

The humic acid (HA) and fulvic acid (FA) fractions of organic matter were separated by the method of Kononova (1966) (Table 103). It was noted that HA fraction was the highest (0.31%) in DL soil but FA fraction was the lowest (0.10%) in the surface layer of the same soil. In contrast, FA fraction was the highest in NCD soil (0.14%). MUD soils showed intermediate values (0.09%). In the lower soil layers, HA was higher in the DL soils (0.25 to 0.30). The HA/FA ratio decreased with depth (0.5 to 0.6 for NCD and 2.7 to 3.1 for DL soils). The relationships between sorptivity and clay, pH, E.C., porosity and humic acid were highly significant (r^2= - 0.91, - 0.85, - 0.86, - 0.87 and - 0.90, respectively), exponential and negative (Table 102).

Table 103: Humic acid and fulvic acid contents of Gosaba soil

Soils	Total organic matter (%)	H.A. (%)	F.A. (%)	H.A./F.A. ratio
		0-20 cm		
NCD	1.96	0.09	0.14	0.6
MUD	1.22	0.16	0.10	1.6
DL	1.55	0.31	0.10	3.1
		20-40 cm		
NCD	1.62	0.08	0.13	0.6
MUD	1.20	0.15	0.10	1.5
DL	1.47	0.30	0.10	3.0
		40-60 cm		
NCD	1.34	0.06	0.11	0.5
MUD	1.16	0.14	0.09	1.5
DL	1.22	0.25	0.09	2.7

NCD: non-cultivated deltaic, MUD: mudflat/mangrove, DL: depressed low land

Table 104: Relation between sorptivity (S) and other parameters (X) of soil

Soil parameter	Correlation coefficient (r)	Regression equation
% Clay	-0.91*	S= 06.25 e -0.02x
pH	-0.85**	S= 06.70 e -0.17x
EC (dSm^{-1})	-0.86*	S= 03.93 e -0.06x
Porosity (%)	-0.87*	S= 81.20 e -6.29x
H.A. (%)	-0.90*	S= 04.10 e -2.37x
F.A. (%)	+0.95*	S= 00.97 e 9.10x

**Significant at 5% probability level, *significant at 1% probability level; S is sorptivity (mmmin $^{-1/2}$)

Percentage fulvic acid was positively correlated (r^2= 0.95, significant at 1% level) with sorptivity.

Impact of saline water on solar powered drip irrigated *Rabi* crops in coastal soils of West Bengal (K. K. Mahanta, S. K. Sarangi, U. K. Mandal, D. Burman and B. Maji)

An experiment was carried out at Canning Town Experimental Farm during the *Rabi/summer* season of 2015-16 to evaluate the performance of different vegetable crops for different qualities of water under drip irrigation. The designed dripper discharge rate was 2.4 lph at 1 kg cm^{-2} pressure. The uniformity coefficient and the irrigation efficiency of this irrigation system were evaluated to be 92.5 and 87.2%, respectively. Water of different salinities were prepared by mixing the saline groundwater with fresh water for the four treatments: T_1: 2 dS m^{-1}, T_2:6 dS m^{-1}, T_3: 10 dS m^{-1} and T_4: 14 dS m^{-1}. Only one quality of water was applied through the drip irrigation at a time. Okra cv. Avantika was taken as the test crop. The treatments were imposed after 1 month of fresh water irrigation to establish the crop. The temporal variations of NDVI values for different treatments were also recorded. The amount of irrigation water was 40 cm for each treatment. The highest yield of 3.37 t ha^{-1} was obtained in the treatment T_1. Yield was about 56 % less in T_4 than T1.

Experiment was conducted with solar power drip irrigation system in the *Rabi* season in cabbage, cauliflower, knol-khol, beet, and tomato crops using rain water harvested in the pond. The highest yield was obtained for cabbage crop (34.21 t ha^{-1}) at irrigation of 100% CPE (Table 105). There was about 35% reduction in tomato yield than the previous year as the crop was affected by virus. There was no operational problem in the solar pump for four consecutive years and the drip irrigation system functioned smoothly. The water requirement of the vegetable crops ranged from 30 cm to 60 cm, the highest being for tomato (31 irrigations) and the lowest for cauliflower (21 irrigations). The operational cost of cultivation of *Rabi* vegetables was reduced due to introduction of solar drip irrigation system as there was 60% saving of labour with 40~50% saving of irrigation water. Drip irrigated vegetables gave 20-30% higher yield in comparison to the conventional irrigation method.

Table 105: Yield of Rabi vegetables under solar drip irrigation

Sl. No.	Crop	Variety	No of irrigations	Yield (t ha^{-1}) with IW/CPE ratio (%)			
				50	65	80	100
1	Cauliflower	Madhuri	21	26.37	28.45	32.62	30.34
2	Cabbage	Maharani	24	22.57	28.41	31.3	34.21
3	Knol-khol	Rakhuse	24	15.36	17.62	20.5	18.78
4	Tomato	Rocky	31	15.52	18.74	20.8	22.46
5	Red Beet	Red globe	26	15.74	18.35	20.46	23.74

Long term impact of land shaping techniques on soil and water quality and productivity of coastal degraded land (D. Burman, U. K. Mandal, S. K. Sarangi, K.K. Mahanta, S. Mandal, S. Raut and B. Maji)

This study was carried out to study the long term impact of land shaping techniques and rain water harvesting on soil and water quality and to determining economics of land shaping techniques in the coastal region. The effect of different land shaping techniques *viz*., farm pond, deep furrow & high ridge and paddy-cum-fish practiced from <5 years to >15 years on soil and water quality; and farm economics were studied. Soil salinity and nutrient status of different land situations (high land, medium land and original low land) and water harvesting structure were determined. Soil salinity under different land shaped situations was less in comparison to control (without land shaping). Soil salinity and nutrient status under farm pond land shaping technique are given in Table 106. Organic carbon and available N & P under different land situations created under farm pond land shaping technique implemented since <5 years and > 15 years were higher compared to control. However, organic C and available N & P contents were higher under old land shaped plots compared to the newly created plots. Similar trend was also observed for other land shaping techniques like deep furrow & high ridge and paddy-cum-fish. Available K content was less in land shaping compared to control. However, higher average K was observed in the soil at the bottom of pond.

Deep furrow & high ridge land shaping technique at farmers' field during rabi season

The higher B: C ratio was recorded for farm pond technique followed by the deep furrow & high ridge and paddy-cum-fish land shaping techniques (Table 107). The duration of implementation of land shaping techniques did not affect the economics of land shaping techniques.

Table 106: Soil salinity and nutrient status under farm pond land shaping technique

Land situations	Duration of implementation	EC_e (dS m^{-1})	OC(%)	Av. N (Kg ha^{-1})	Av. K (Kg ha^{-1})	Av. P (Kg ha^{-1})
High land	>15	3.09	0.91	279.8	313.2	18.4
	<5	3.82	0.56	264.3	325.6	20.2
Medium land	>15	4.53	0.89	270.5	290.6	17.4
	<5	4.61	0.47	232.9	324.1	18.2
Low land	>15	7.84	0.48	218.5	348.7	15.2
	<5	7.56	0.47	225.1	352.1	16.1
Pond	>15	1.76	1.23	345.2	402.6	42.2
	<5	1.89	1.24	338.1	380.2	35.0
Control	-	12.4	0.53	179.3	390.5	13.7

Table 107: Economics (B:C ratio) of land shaping techniques

Duration of implementation	LS technologies (B:C ratio)		
	Farm pond	Deep furrow & high ridge	Paddy-cum-fish
>15 years	2.56-3.82	-	2.12-2.36
< 5years	2.61-3.75	2.41-2.77	2.11-2.45

Impact of Land Shaping Techniques

The impact study of land shaping techniques demonstrated in the farmers' field was carried out at different villages of the Sundarbans region. As the interventions were made around four years back (2012) and all the support (input or financial) from the implementing agencies (ICAR-CSSRI or RAKVK) was withdrawn, presently land shaped sites are being completely managed by the farmers themselves. Although such sites were being successfully managed by the farmers at different locations, the extent of benefits varied from farmer to farmer. The reasons of differential benefit accrual depended on factors such as farmers' financial capacity to manage the system and the remoteness of the land shaping sites. It was also noted that sometimes the extent of adoption also depended on non-agricultural factors (*e.g.*, backwardness) rather than technologies *per se*. For example, at Mokanberia village of Basanti Block, Sh. Panchanan Sahoo was highly successful in managing the land shaped areas round-the-year through intensive vegetable cultivation. His net annual income was Rs.2,30,600 from 0.93 ha land where he had implemented the farm pond and deep furrow & high ridge land shaping techniques. His location is well connected with the nearest city. By comparison, in Achintanagar village of Patharpratima Block, Sh. Durga Shankar Manna who has adopted farm pond land shaping in his 0.53 ha farm land was managing his land through cash crop based cropping system. As this area is not well connected with the cities, farmers prefer to grow remunerative cash crop like betel vine in place of vegetables. The area has good marketing network for betel leaves but not for vegetables. Land shaping techniques in this area has created additional water resources for irrigation and many farmers are taking up betel vine cultivation. This labour intensive cash crop can provide Rs. 7000-8000 monthly net income throughout the year. In Mokanberia village, more than 50 farmers have adopted land shaping techniques without any external support (induced investment).

Assessing carbon sequestration potential of conservation tillage practices under rice based cropping system in coastal saline soils (U.K. Mandal, D. Burman, S.K. Sarangi and T. D. Lama)

Enhancing soil organic carbon (SOC) pool through judicious land use and soil management options improves several ecosystem services through improvement of soil quality including mitigation of climate change. Soil carbon sequestration is a major challenge in soils of tropical coastal India where climate is harsh and resource poor farmers cannot afford the use of organic manures and crop residues. This project was initiated to study the soil carbon dynamics under conservation tillage practices in coastal region of West Bengal. The design of experiment was split-split plot with cropping system (rice-rice and rice-cotton) (*Kharif-Rabi*) as main plot treatments and tillage type such as zero tillage (ZT), reduced tillage (RT), and conventional tillage (CT) as sub plot treatments. The residue (R) and no residue (NR) were the sub-sub plot treatments. Depth-wise soil properties indicated that at surface depth there was reduction in bulk density and increase in SOC in ZT than other treatments. SOC stock was determined up to 45 cm soil depth and it was highest in RT with residue (29.6 Mg ha^{-1}) followed by CT with residue (28.9 Mg ha^{-1}), ZT with residue (27.4 Mg ha^{-1}), RT

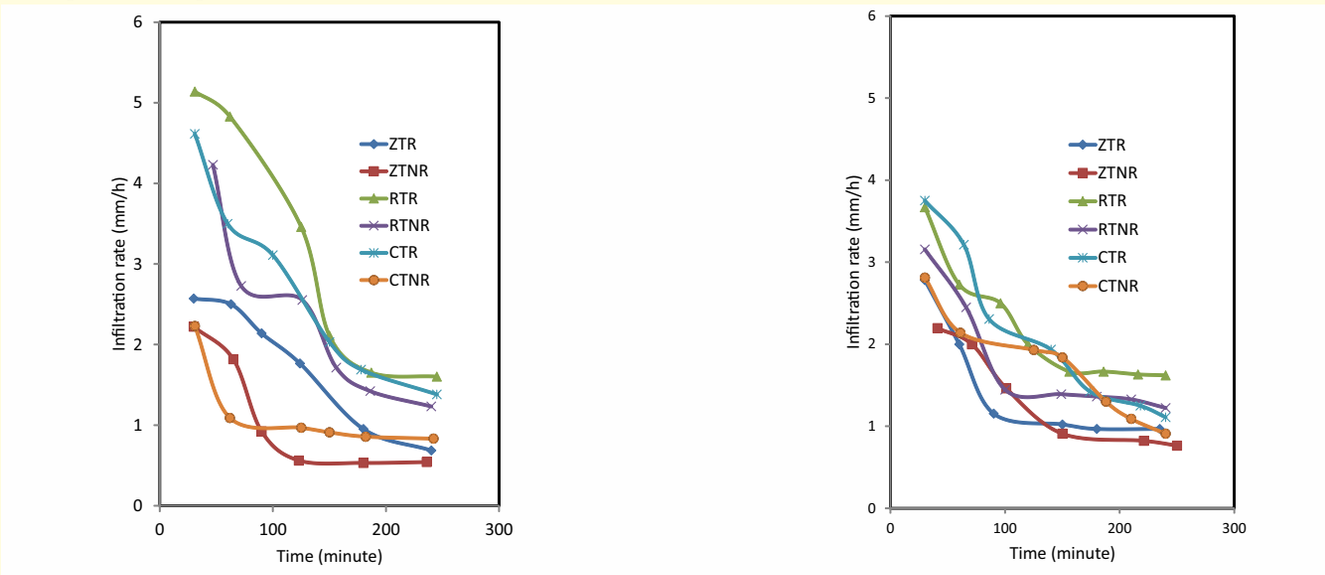
Table 108: Treatment wise different fraction of biomass (t ha^{-1}) added to soil and total C input (t ha^{-1}) in rice-rice system during 5 years (cumulative) of experiment

Treatment	Stubble	Roots	Rhizodeposition Estimated	Aquatic growth	Total C input
ZTNR	5.60	8.21	5.47	8.90	9.48
ZTR	34.00	8.43	5.62	9.50	18.70
RTNR	8.66	8.52	5.68	6.05	9.72
RTR	45.51	8.63	5.75	8.20	22.00
CTNR	8.58	8.36	5.57	4.02	8.94
CTR	39.21	7.91	1.94	4.20	17.13

Table 109: Treatment wise different fraction of biomass (t ha^{-1}) added to soil and total C input (t ha^{-1}) in rice-cotton system during 5 years (cumulative) of experiment

	Rice (*Kharif*)			Cotton (*Rabi*)				
Treatment	Stubble	Roots	Rhizo-deposition	Aquatic growth	Leaf	Dried boll exocarp	Rhizo-deposition	Total C input (estimated)
ZTNR	4.78	4.61	3.07	4.50	0.00	0.00	2.99	6.67
ZTR	19.07	4.72	3.15	4.65	7.33	4.49	3.92	15.46
RTNR	4.92	4.59	3.06	3.52	0.00	0.00	3.72	6.63
RTR	22.79	4.72	3.15	3.82	10.23	4.85	4.13	17.50
CTNR	4.53	4.62	3.08	2.80	0.00	0.00	3.67	6.27
CTR	20.06	4.68	3.12	2.90	9.74	4.70	3.78	16.00

Description: As in previous table.



Rice-rice system *Rice-cotton system*

Fig. 64: Infiltration rate under different conservation tillage treatments

without residue (27.3 Mg ha^{-1}), CT without residue (27.2 Mg ha^{-1}) and the lowest in ZT without residue (26.2 Mg ha^{-1}). Organic C stock was more in rice-rice system than rice-cotton system. The treatment ZT without residue under rice-cotton system showed decline in SOC stock than initial levels in the year 2012. Total biomass and C input in each treatment under rice-rice and rice-cotton system were also assessed. Rhizodeposition C was estimated as two thirds of root biomass C. During five years of experiment, total C inputs was 8.9 to 22 t ha^{-1} in rice-rice system whereas it was 6.3 to 17.5 t ha^{-1} in rice-cotton systems (Table 108 and 109). Carbon sequestration rate was 0.45, 0.9 and 0.76 t ha^{-1}yr^{-1} under ZT, RT and CT, respectively with addition of 3.4-4.4 t C ha^{-1} in rice-rice system whereas it was 0.09, 0.52 and 0.37 t ha^{-1}yr^{-1}, respectively with the addition of 3-3.5 t C ha^{-1} under rice-cotton system. The soil infiltration rate was also studied in each treatment. Final infiltration rate was higher in rice-cotton system than rice-rice system (Fig. 64).

Conservation agriculture for rice-maize cropping system in coastal saline region (S. K. Sarangi, B. Maji, U. K. Mandal, K. K. Mahanta and T. D. Lama)

In the coastal salt-affected areas, mostly mono-cropping of rice is practiced during *Kharif* season and most of the land remains fallow in the subsequent *Rabi* season due to salinity stress and irrigation water scarcity. Some farmers grow *Rabi*/summer rice (*boro*) with the utilization of scarce irrigation water. However, with the

Table 110: Effect establishment methods and residue on yield components and yield of rice (var. Amal-Mana) during kharif 2016

Treatment	Panicles/ m^2	Grains/ panicle	Chaffs/ panicle	1000 grain wt (g)	Grain Yield (t ha^{-1})	Straw yield (t ha^{-1})
DSR – R	236	96	14	31.33	3.28	8.89
DSR + R	370	104	14	31.67	3.71	9.75
PT – R	311	94	20	31.00	3.66	7.18
PT + R	340	94	20	31.67	3.91	7.26
LSD (P=0.05)	ns	ns	Ns	Ns	ns	Ns

ZTNR, zero tillage with no residue; ZTR, zero tillage with residue; RTNR, reduced tillage with no residue; RTR, reduced tillage with residue; CTNR, conventional tillage with no residue; CTR, conventional tillage with residue

adoption of improved technology, there is possibility of maize (*Zea mays* L.) cultivation during *Rabi* season in rotation after the traditional *Kharif* rice crop with less irrigation water. For a sustainable rice-maize cropping system, this project was initiated during 2016 with four *Kharif* rice treatments (1) conventional puddled transplanted rice (PT) with residue removed (PT-R); (2) PT with 30-40% residue retained (PT+R); (3) dry direct seeded rice (DSR) with residue removed (DSR-R); and (4) DSR with 30-40% residue retained (DSR+R) in main-plot and four nitrogen applications to hybrid maize: (1) Control (0% N), (2) 80 kg ha^{-1} (50%), (3) 120 kg ha^{-1} (75%) and (4) 160 kg ha^{-1} (100%) in sub-plot. The experiment was conducted in split-plot design with three replications. The objectives were (1) Increasing cropping intensity in the salt affected coastal region through improved crop management practices; (2) Studying the effect of crop residue retention on the soil properties and crop productivity; and (3) Optimizing nitrogen dose for hybrid maize under different residue and previous crop management practices. Root growth, plant height, biomass, yield components and yield (Table 108) of *Kharif* rice were studied. It was observed that though the root length and plant height were higher in the DSR+R, but the there was no significant difference in yields between the treatments during the first year. The mean grain yields of rice were 3.28, 3.71, 3.66 and 3.91 t ha^{-1} under DSR-R, DSR+R, PT-R and PT+R respectively. The mean straw yields of rice were 8.89, 9.75, 7.18 and 7.03 t ha^{-1} under DSR-R, DSR+R, PT-R and PT+R respectively.

During *Rabi* season, maize was grown on the same layout of *Kharif* season with 4 nitrogen doses (0, 80, 120 and 160 kg N ha^{-1}). Phosphorus and potassium was applied uniformly to all the plots before sowing as basal @ 80 kg P_2O_5 and 40 kg K_2O ha^{-1}. Nitrogen was applied in 5 splits. Soil salinity and soil moisture was observed in different treatments at periodic intervals. Soil salinity in the first week of February, 2017 varied from 4.37 dS m^{-1} in DSR + residue to 6.72 dS m^{-1} in PT-residue treatment.

Coastal Saline Tolerant Variety Trial (CSTVT)

(S. K. Sarangi)

During the *Kharif* season of 2016, three trials were conducted under CSTVT: (1) IVT –CSTVT; (2) AVT 1-CSTVT and (3) AVT 2-CSTVT. Soil salinity of these trials are given in Table 109. Out of 34 entries under IVT, the highest grain yield was obtained from entry no. 2421 (6.28 t ha^{-1}) followed by entry no. 2401 (5.82 t ha^{-1}) and entry no. 2414 & 2418 (5.78 t ha^{-1}) in comparison to the local check (CSR 4) which produced grain yield of 5.16 t ha^{-1}. Out of the 34 entries; 2401, 2404, 2409, 2414, 2416, 2418, 2419, 2421, 2422, 2425 and 2430 were found to be highly tolerant to salinity. Local check (CSR 4) flowered in 76 days, entries flowering with local check were 2417, 2423, 2425 and 2426. None of the entries flowered before local check. Other entries flowered after the local check. Plant height varied from 70 cm in entry no. 2423 to 122 cm in entry no. 2412. Number of panicles per hill was the highest (12) in entry no. 2416, 2423, 2428, 2430 and lowest (7) in entry no. 2432 & 2402.

Out of 32 entries evaluated under AVT, the highest grain yields were obtained from entry no. 2312 (6.99 t ha^{-1}) and entry no. 2327 (6.46 t ha^{-1}) as

Table 111: Monitoring of soil salinity and pH in CSTVT trials at Canning Town during Kharif 2016

Date	CSTVT	EC_e (dS m^{-1})	pH
30.07.2016	AVT -1 (32)	4.08	6.93
	AVT -2 (10)	6.25	6.78
	IVT (34)	4.98	6.65
25.08.2016	AVT -1 (32)	4.07	6.46
	AVT -2 (10)	4.96	6.20
	IVT (34)	4.05	6.07
08.11.2016	AVT -1 (32)	3.84	6.76
	AVT -2 (10)	4.51	6.54
	IVT (34)	4.21	6.62

CSTVT trial during kharif 2016 at Canning Town

compared to the local check (CSR 1) which produced grain yield of 5.93 t ha^{-1}. Days to flowering varied from 77-115 days. Entries 2326 and 2332 flowered in 77 days, whereas entries 2304 and 2324 flowered in 115 days. Local check variety CSR 1 flowered in 90 days. Plant height was the lowest (83.5 cm) in entry no. 2326 and the highest (147.2 cm) in entry no. 2316. Average number of panicles per hill varied from 8-13.

Out of 10 entries (including 4 checks) evaluated under AVT 2-CSTVT, the highest grain yields were obtained from Improved White Ponny (4.36 t ha^{-1}) followed by IET 24425 (4.16 t ha^{-1}), IET 24434 (4.17 t ha^{-1}). The local check variety Canning 7 produced grain yield of 3.87 t ha^{-1}. Days to flowering varied from 84-114 days. Improved White Ponny flowered in 101 days, IET 24425 in 90 days and IET 24434 in 84 days. Local check Canning 7 flowered in 78 days. Plant height was the lowest (94.1 cm) in Jaya and the highest (126.2 cm) in IET 25071. Canning 7 was 101.1 cm tall. These entries were evaluated under two nitrogen levels (1) 50%N (2) 100%N. Average grain yield was 18% higher under 100% N compared to 50% N.

Seed production, maintenance and evaluation of rice germplasm (S.K. Sarangi)

Breeder seeds of Amal-Mana, CSRC(D) 7-0-4 and CSRC (D) 12-8-12 were produced. TL seeds of Bhutnath, Sumati, Utpala, SR 26B, Sabita, Canning 7 and CST 7-1 were also produced. Out of eight Sub 1 introgressed varieties (Ciherang - Sub 1, CR 1009-Sub 1, IR 64 - Sub 1, BR 11- Sub 1, Samba Mahsuri-Sub 1, Swarna- Sub 1, DRR 39 and Sabita) evaluated during *Kharif* 2016, the highest grain yield was recorded in CR 1009- Sub 1 (3.67 t ha^{-1}) under stagnant flooding, which was at par with Sabita (3.50 t ha^{-1}). However, under flash flooding situation, CR 1009- Sub 1 produced 4.75 t ha^{-1}, which was significantly higher over other varieties tested.

Rice germplasm including released varieties and lines from ICAR-CSSRI, IRRI and local landraces were maintained and evaluated under different land situations and seasons during 2016. Twenty nine ICAR-CSSRI varieties (CSR 1, CSR 2, CSR 4, CSR 8, CSR 10, CSR 12, CSR 13, CSR 14, CSR 16, CSR 20, CSR 21, CSR 22, CSR 23, CSR 25, CSR 26, CSR 27, CSR 28, CSR 29, CSR 31, CSR 32, CSR 33, CSR 34, CSR 35, CSR 36, CSR 37, CSR 38, CSR 39, CSR 40 and CSR 41) were evaluated during *Kharif* 2016. Under semi-deep water situation with stagnant flooding, 25 entries (Gitanjali, Swarna-Sub 1, SR 26- B, Sabita, Patnai- 23, Dinesh, Purnendu, Ambica, Nalini, Manas swarabar, Tilak kanchari, Najani, Sada Mota, CSRC(D)5-2-2-2,

Rice seed production plots and preferential analysis during Kharif 2016

Evaluation of Sub 1 genotypes under stagnant and flash flood situations

CSRC(D)7-0-4, CSRC(D)7-12-1, CSRC(D)13-16-19, CSRC(D)12-8-12, CSRC(D)7-5-4, CSRC(D)2-0-8, CSRC(D) 2-17-5, C 300 BD-50-11, Asfal, NC 678 and Gavir saru) were evaluated. Twenty two entries (Amal-Mana, Utpala, Sumati, SR 26B, Dadsal, CST 7-1, Bhutnath, Namita-Dipti, Chamar Mani, Dudheswar, Buck Tulsi, CSR 1, CSR 2, CSR 6, Talmugur, Nona Bokra, Pankaj, Pokali, CN 1233-33-9, CN 1231-11-7, CN 1039-9 and Swarna-Sub 1) were evaluated under low land situation. During *Rabi* season, forty entries are under evaluation.

Impact of deficit irrigation on salt dynamics and crop productivity in coastal saline soil (T. D. Lama, D. Burman, B. Maji, S. K. Sarangi and K.K. Mahanta)

Shortage of good quality irrigation water and soil salinity are the major factors that adversely affect agricultural production during the post rainy season in the coastal regions. Evolving irrigation water management strategies that allow more efficient use of fresh water and saline water in irrigation with minimum salt build up in the soil remains a major challenge. The present study has been initiated to study the impact of deficit irrigation on salt dynamics and crop productivity in a heavy textured coastal saline soil. The field experiment was laid out in a split plot design with water quality (good, saline - 4 dSm^{-1} and saline - 8 dSm^{-1}) as main plot treatments and irrigation levels (125%, 100%, 75% and 50% CPE) as sub-plot treatments in maize and tomato crops during *Rabi* season. The soil of the experimental site was silty clay in texture, weakely to moderately saline, neutral in reaction, medium to high in organic carbon (OC) content, low in available N and P and medium to high in K with very slow permeability (Table 110). Among cations, Na^+ was the dominating one followed by Mg^{2+} and Ca^{2+}, while SO_4^{2-} was the predominant anion followed by Cl^-. In soil saturation extract, the order was $Na^+ > Mg^{2+} > Ca^{2+} > K^+$ among cations and $SO_4^{2-} > Cl^- > HCO_3^-$ among anions (Table 111).

Table 112: Physico-chemical properties of experimental site

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	pH_2	EC_e	OC (%)	N ($Kgha^{-1}$)	P ($Kgha^{-1}$)	K ($Kgha^{-1}$)	B.D. (Mgm^{-3})	Infil. rate ($mmhr^{-1}$)
0-15	13.6	34.8	51.6	6.9	9.2	1.3	222.3	7.8	268.0	1.45	0.75
15-30	8.3	35.2	56.6	7.7	5.5	0.6	90.7	5.8	331.4	1.53	
30-45	8.3	34.2	57.6	7.5	6.8	0.6	68.0	6.1	401.4	1.42	
45-60	6.9	36.2	56.9	7.4	6.6	0.6	49.9	8.2	451.7	1.44	
60-90	6.3	37.8	55.9	7.2	6.8	0.5	63.5	7.1	519.3	1.45	

Table 113: Ionic composition of soil saturation extract

Depth	Na^+ (me L^{-1})	K (meL^{-1})	Ca^{2+} (me L^{-1})	Mg^{2+} (me L^{-1})	Cl^- (me L^{-1})	SO_4^{2-} (me L^{-1})	HCO_3^- (me L^{-1})
0-15	46.8	1.0	5.9	8.4	38.0	60.4	4.5
15-30	51.0	0.9	4.5	7.0	17.8	47.3	2.3
30-45	81.4	1.2	4.1	5.9	21.3	57.9	1.4
45-60	73.5	1.2	4.5	7.5	26.0	61.2	1.3
60-90	67.6	1.4	3.5	6.8	26.9	62.4	1.2

With rising temperatures and changes in rainfall pattern, climate change would affect the water balance as well as water requirement of agricultural crops. Effective rainfall, crop ET and irrigation water requirement of rice, maize and tomato for the post rainy season (*Rabi*) were estimated with CROPWAT model (FAO) using the downscaled weather data (2016-75) obtained from MarkSim™ DSSAT weather file generator (http://gisweb.ciat.cgiar.org/MarkSimGCM/) for RCP 6.0 scenario and compared with that using the actual weather data for the base period (1966-2015). Significant increases in mean temperature, rainfall and effective rainfall were observed during the monsoon over the period 2016-2075. During the non monsoon period, the mean temperature would increase at the rate of 0.023^0C per year. However non-significant decreasing trends in rainfall and effective rainfall were observed during this period. The crop water balance parameters,

Table 114: Trend analysis of crop evapotranspiration, effective rainfall and irrigation requirement of maize, rice and tomato during the period 2016-2075

Parameter	Max	Min	Mean	SD	CV (%)	Kendall's tau	Sen's slope
Maize							
ET_C (mm)	403.6	368.6	395.9	4.91	1.24	0.887*	0.198
ER (mm)	78.9	72.2	76.6	2.08	2.73	-0.595*	-0.114
IR (mm)	328.8	289.1	316.7	6.44	2.03	0.850*	0.319
Rice							
ET_C (mm)	592.6	553.5	580.7	6.36	1.10	0.911*	0.311
ER (mm)	91.9	82.0	88.1	3.03	3.44	-0.708*	-0.181
IR (mm)	803.4	756.1	785.0	9.29	1.18	0.906*	0.513
Tomato							
ET_C (mm)	551.4	520.0	541.3	5.40	1.00	0.916*	0.273
ER (mm)	117.7	112.2	115.8	1.79	1.54	-0.735*	-0.106
IR (mm)	434.3	398.9	420.9	6.88	1.63	0.921*	0.377

* Significant at 5% level

Table 115: Climate change impacts on water requirement of maize, rice and tomato in different decades during 2016 – 2075 over the base period (1966 – 2015)

	Early sowing			Normal Sowing			Late Sowing		
	ET_c (mm)	Rain Eff.	IR (mm)	ET_c	Rain Eff. (mm)	IR (mm)	ETc (mm)	Rain Eff. (mm)	IR (mm)
	Maize								
Base period (1966-2015) (Actual)	332.6	73.4	259.0	384.6	99.5	281.8	441.4	181.4	274.0
2016-25	345.2 (3.8)	56.3 (-23.3)	288.7 (11.5)	392.5 (2.1)	77.3 (-22.3)	312.6 (10.9)	440.8 (-0.1)	138.1 (-23.9)	307.7 (12.3)
2026-35	345.2 (3.8)	59.0 (-19.6)	286.1 (10.5)	393.9 (2.4)	78.5 (-21.1)	312.8 (11.0)	443.0 (0.4)	137.7 (-24.1)	310.1 (13.2)
2036-45	346.2 (4.1)	59.6 (-18.8)	286.5 (10.6)	395.0 (2.7)	78.6 (-21.0)	313.8 (11.4)	445.2 (0.9)	137.2 (-24.4)	312.6 (14.1)
2046-55	348.2 (4.7)	57.5 (-21.7)	290.6 (12.2)	396.9 (3.2)	77.1 (-22.5)	317.2 (12.6)	446.8 (1.2)	136.5 (-24.6)	315.2 (15.0)
2056-65	350.8 (5.5)	54.0 (-26.4)	296.7 (14.6)	398.8 (3.7)	75.0 (-24.6)	321.2 (14.0)	448.1 (1.5)	136.2 (-25.0)	317.3 (15.8)
2066-75	354.1 (6.5)	51.0 (-30.5)	303.3 (17.1)	402.1 (4.6)	72.9 (-26.7)	326.7 (15.9)	451.5 (2.3)	136.3 (-24.9)	320.9 (17.1)
	Rice								
Base period (1966-2015) (Actual)	512.1	102.8	714.6	564.9	116.1	739.3	630.2	207.0	713.0
2016-25	526.2 (2.8)	82.1 (-20.1)	749.3 (4.9)	575.0 (1.8)	89.8 (-22.7)	777.2 (5.1)	633.0 (0.4)	159.2 (-23.1)	763.4 (7.1)
2026-35	526.4 (2.8)	85.5 (-16.8)	746.5 (4.5)	576.7 (2.1)	90.9 (-21.7)	777.9 (5.22)	635.5 (0.8)	159.5 (-23.0)	765.3 (7.3)
2036-45	528.1 (3.1)	86.4 (-16.0)	747.5 (4.6)	578.9 (2.5)	90.6 (-22.0)	780.5 (5.6)	639.1 (1.4)	159.6 (-22.9)	768.7 (7.8)
2046-55	531.4 (3.8)	84.1 (-18.2)	753.2 (5.4)	582 (3.0)	88.5 (-23.8)	785.9 (6.3)	641.3 (1.8)	159.0 (-23.2)	771.4 (8.2)
2056-65	535.0 (4.5)	80.1 (-22.1)	760.7 (6.5)	585 (3.6)	85.4 (-26.4)	792.2 (7.2)	644.0 (2.2)	158.5 (-23.4)	774.7 (8.7)
2066-75	539.6 (5.4)	76.9 (-25.2)	768.6 (7.6)	590.1 (4.5)	82.8 (-28.7)	800.1 (8.2)	649.1 (3.0)	158.2 (-23.6)	780.2 (9.4)
	Tomato								
Base period (1966-2015) (Actual)	430.0	136.9	310.3	473.4	99.2	371.9	530.0	151.6	373.1
2016-25	443.9 (3.2)	120.0 (-12.3)	340.3 (9.7)	484.8 (2.4)	76.1 (-23.3)	406.9 (9.4)	535.8 (0.9)	116.9 (-22.9)	414.4 (11.1)
2026-35	443.8 (3.2)	124.1 (-9.4)	336.6 (8.5)	485.7 (2.6)	78.4 (-21.0)	405.6 (9.1)	537.9 (1.3)	117.5 (-22.5)	415.9 (11.5)
2036-45	445.2 (3.5)	125.7 (-8.2)	336.8 (8.5)	487.2 (2.9)	78.7 (-20.7)	407.0 (9.4)	540.3 (1.8)	117.3 (-22.6)	418.4 (12.1)
2046-55	448.0 (4.2)	123.8 (-9.6)	341.7 (10.1)	489.9 (3.5)	76.4 (-23.0)	412.0 (10.8)	542.6 (2.2)	115.9 (-23.6)	422.1 (13.1)
2056-65	451.8 (5.1)	120.1 (-12.3)	348.7 (12.4)	492.8 (4.1)	72.7 (-26.7)	418.4 (12.5)	545.0 (2.7)	114.2 (-24.7)	426.2 (14.2)
2066-75	455.7 (6.0)	116.9 (-14.6)	355.6 (14.6)	497.0 (5.0)	69.7 (-29.7)	425.7 (14.5)	549.5 (3.5)	112.7 (-25.7)	432.1 (15.8)

Figures in parentheses indicate % change over base period

namely, crop evapotranspiration (ET_C) and irrigation requirement (IR) exhibited significantly increasing trends under climate change scenario during 2016-2075 for all the crops. Effective rainfall (ER) exhibited a decreasing trend during the same period (Table 112). The increase in decadal ET_C varied from -0.1 to 6.5 %, 0.4 to 5.4 % and 0.9 to 6.0 % over the base period for maize, rice and tomato, respectively in different sowing windows. On the other hand, the ER during the crop growth period reduced by 8.2 to 30.5 % over the base period (Table 113). The decadal IR for the different crops showed an increasing trend and was highest during the 2066-75 decade for maize (15.9-17.1 %) as compared to tomato (14.5-15.8%) and rice (7.6-9.4%).

Assessment and coping strategies of agricultural risk under coastal region of West Bengal and Odisha– A Socio-economic analysis (Subhasis Mandal, D. Burman, U. K. Mandal and T. D. Lama)

Contribution and performance of coastal districts in State Net State Domestic Product (NSDP)

The project on assessing farm-level agricultural risks and coping strategies has been undertaken to understand the various types, sources and impact of risk in agriculture in coastal areas of West Bengal and Odisha. Under this project, performance and contribution of coastal districts of West Bengal (North 24 Parganas,, South 24 Parganas and East Midnapore) and Odisha (Balasore, Bhadrak, Ganjam, Jagatsinghpur, Kendrapara, Khordah and Puri) have been analyzed with the secondary information available during the period 2004-05 to 2010-11. The coastal districts' contribution to the State Net State Domestic Product (NSDP) was hovering about 28-29% in case of both West Bengal and Odisha and the share was almost static during this period. The Annual Compound Growth Rates (ACGR) of the district level NSDP at current prices of 2004-05 was accounted to be 14-15% in West Bengal and 15-17% in Odisha, across the districts. The agricultural development performance in these coastal districts of West Bengal and Odisha has been analyzed by estimating ACGR of Net Cropped Area (NCA), Gross Cropped Area (GCA) and Cropping Intensities for the period of 2000-01 to 2013-14. The NCA and GCA during this period indicated decelerating trend in almost all the coastal districts. Also, the trend in cropping intensities indicated static to decelerating rates across these districts. This indicated that the cropping intensification in both the coastal districts of West Bengal and Odisha have been quite low during this period. Also, there was a dip in the cropping intensities in coastal West Bengal after 2010 due to cyclone '*Aila*' in 2009 that made large extents of cultivable area highly saline rendering them uncultivated during the subsequent years. Change in cropping pattern in coastal West Bengal indicated small shift from area under food grains towards high value fruits and vegetables during 1998-99 to 2014-15. It was observed that around 5% area under food grains crops (from 76 to 71%) was shifted to fruits and vegetables. There was also 2% increase in the area under non-food crops (like oilseeds, cotton etc.) during 1998-99 to 2014-15. Similar trend was observed in case of whole West Bengal also. In case of coastal Odisha, rice was the pre-dominant crop across the districts and the area under rice increased significantly during 1998-99 to 2014-15, mainly due to focus on rice cultivation under National Food Security Mission. In West Bengal, diversification towards high value crops has been given special thrust during the previous decades.

Sources of farm level risk and farmers' response

The operational area of farms under coastal districts of West Bengal and Odisha are dominated by marginal farmers with average farm size of 0.77 ha (West Bengal) and 1.04 ha (Odisha). The size of operational holdings is gradually declining over the period and further the lands are fragmented to different plots/parcels. The small and marginal holdings and that too fragmented to several plots reduce the risk bearing abilities of the farmers and in turn capacity to withstand risks and uncertainties. Farmers choose to operate at low investment-low return options that have less risk attached instead of preferring high-investment-high return but more risk options. Farmers prefer output with more stability rather high return as they are naturally risk-averters. The sources of various farm-level risk in coastal areas of West Bengal are

Table 116: Sources of farm level risks in coastal areas of West Bengal

Sources	Causes	Response of farmers	Extent
Salinity	Natural	Water management	Low to very high
Acid sulfate soil	Natural	Green manuring & water management	20-25 % yield loss
Damage by pest and disease	Weather	Plant protection	15-20 % yield loss
Waterlogged	Poor drainage during heavy rain	Delayed harvesting	15 to 20 days delay in sowing fetched market price (eg., tomato, cucumber, bitter gourd etc) by 10%
Flash rain	Heavy downpour in short time	Early harvest but not always possible	Sometime up to 100% crop loss (eg., potato, chilli), higher labour to harvest lodged paddy
Long dry spell	Erratic weather	Delayed sowing	Increased irrigation cost by 25%, labour 15%
Market price	Production glut, poor transport linkage	Delay in selling (future market)	Loss of income varies Govt. Policy
(Demonetisation)	Cash crunch	Selling at lower volume, buy input and sell produce in credit	Paddy prices fall (8-10%), delayed payment

salinity stress, presence of acid sulfate soils, damage caused by pest and diseases, prolonged waterlogged situation, flash rain, long dry spell, market price uncertainty and government policies (Table 116). All these risks affect the crop cultivation; limit the crop choice, reduce the yield and farm income.

Risk and uncertainties in profitability of paddy cultivation in coastal west Bengal (2015-16)

Rice is the major crop in coastal areas both in *Kharif* and *Rabi* seasons. Risk and uncertainties in profitability of rice cultivation have been analyzed through estimating output-input ratio, returns to investment (ROI), comparison between costs of cultivation with market price realization and co-efficient of variation (CV) in yield and net return

Table 117: Returns to investment (ROI), comparison between cost of cultivation with market price realization and co-efficient of variation (CV) in yield and net return

Particulars	*Kharif paddy*		*Rabi Paddy*	
Total Cost (Rs ha^{-1})	35588	(32.85)	56325	(45.23)
Total return (Rs ha^{-1})	39975	(41.42)	76538	(50.46)
Net return (Rs ha^{-1})	4388	(37.11)	20213	(48.43)
Yield (t ha^{-1})	3.83	(25.56)	4.98	(55.47)
Output-input ratio	1.12		1.36	
Return to Investment (ROI) %	12.33		35.89	
Unit cost of production (Rs kg^{-1})	9.29		11.30	
Selling price realized (Rs kg^{-1})	10.00		15.00	
Min. support Price (Rs kg^{-1})	14.70		14.70	

Note: Figures within the parentheses show coefficients of variation (CV) in percent.

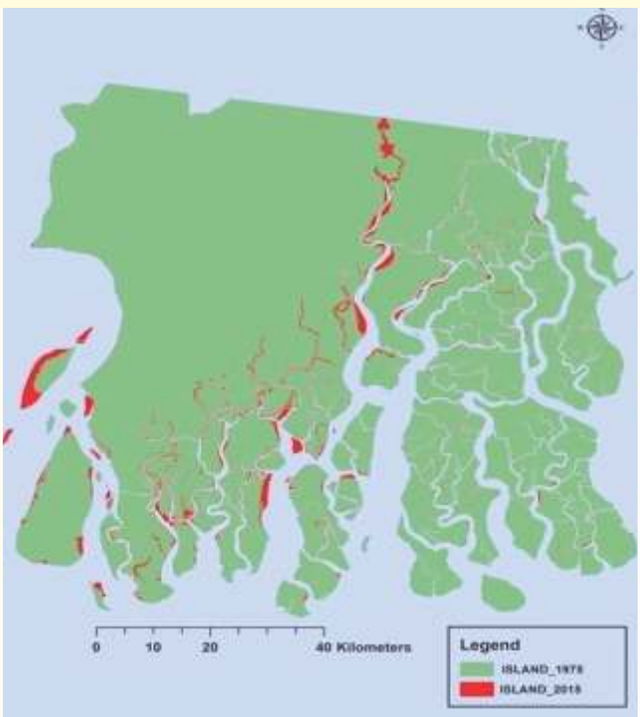
(Table 117). In terms of realizing market price, *Rabi* rice fetched higher price primarily due to better quality as compared to *Kharif* rice. Selling price of *Kharif* rice was observed to be less than the Minimum Support Price (MSP) and was just covering the cost of cultivation. *Rabi* rice provides better yield, higher net return and better return to investment as compared to *Kharif* rice. However, these gains are also attached with higher level of CV indicating that growing *Rabi* rice is more profitable but subjected to more risks. Under high uncertainty situation, the risk of investing additional amount of capital also increases risk considerably and expansion of area under particular crop becomes difficult. Therefore, farmers prefer to grow more *Kharif* rice even though it produces lower yields.

Following key observations emerged from this analysis: (1) contribution of coastal districts in terms of NSDP to states indicated almost static to marginal increase; (2) Agricultural intensification has been at low pace and decelerating in most coastal districts; (3) Cropping pattern change towards high value crops (fruits & vegetables) needs more focus to enhance farm income; (4) Agricultural risk in coastal areas is mostly inherent to soil and water resources characteristics. Farmers response to agricultural risks management is constrained by insufficient capital; and (5) Returns to Investment (RoI) on crop production across seasons indicated that *Rabi* crops provided better return but high risk. On the other hand, *Kharif* rice provides low RoI with low risk.

NICRA: Climate change mitigation and adaptation strategies for salt affected soils with the objective of management of sea water intrusion due to climate variability in coastal regions (U. K. Mandal, B. Maji, K. K. Mahanta, S. Raut; PI: A. K. Bhardwaj, CSSRI, Karnal)

Sundarbans in West Bengal of India in the Eastern coast on the Bay of Bengal falls in the most vulnerable zones to abrupt climate change. Despite the vulnerability of the coastal delta, very little data exist on the spatio-temporal dynamics of the land and the impacts of anthropogenic and natural disturbances on the Sundarbans

Accretion zone (Red) between 1975 to 2015 in Sundarbans based on LANDSAT imagery



Erosion zone (Red) between 1975 to 2015 in Sundarbans based on LANDSAT imagery

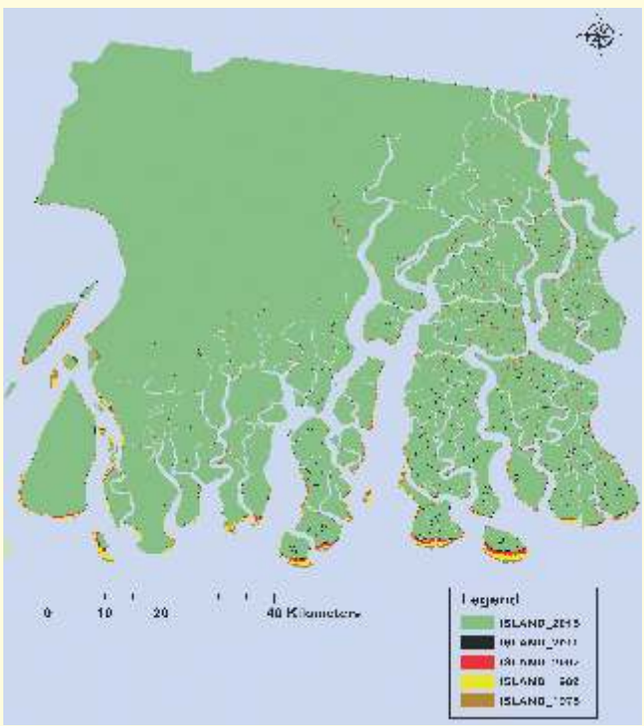


Fig. 65: Erosion and accretion zone of the Sundarbans analyzed using multi-temporal LANDSAT imagery

Table 118: Estuary water characteristics around Basanti Delta in Sundarbans

Place	Dist. from Bay of Bengal (km)	pH	EC (dSm^{-1})	Ca (me L^{-1})	Mg (me L^{-1})	Na (mg L^{-1})	K (mg L^{-1})	Cl (me L^{-1})
Jharkhali	57.2	7.61	36.51	10.80	71.80	4855.68	271.32	345.60
Joygopalpur	65.4	7.56	16.32	5.20	28.00	2142.36	118.92	143.10
Harvangi	76.3	7.42	9.02	4.80	14.60	44.39	51.23	129.60
Kathal Beria	86.8	6.67	5.98	7.80	6.20	29.57	35.90	49.50
Pond	72.0	7.73	0.78	1.80	1.40	119.52	16.34	5.40

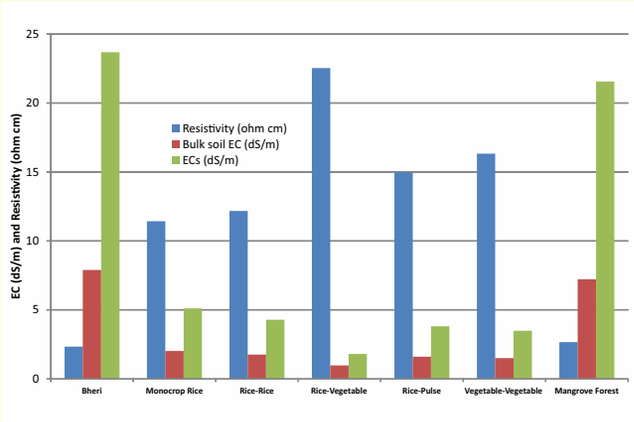


Fig. 66: Resistivity, Bulk soil EC and ECs of different land use systems in Basanti

ecosystem. Multi-temporal LANDSAT imagery was used for studying land-use/land cover dynamics and shoreline changes. Out of total 7300 km^2 study area of Indian Sundarbans total erosion and accretion was 163 km^2 and 149 km^2 during 1975 to 2015 (Fig. 65). Net change was erosion of 14 km^2. Accretion was dominant towards landlocked side while erosion occurred towards sea side. We also characterized the water and sediment of the estuary around Basanti delta in Sundarbans. Nutrient concentration and salinity in estuary water were influenced by seasonal change and distance from sea. Salinity of estuary water increased in the dry season whereas it decreased with the increase in distance from Bay of Bengal sea (Tables 116). A total of 114 soil samples from 0-15 cm depth and bulk soil EC data up to 90 cm depth were collected at Basanti delta to develop a soil salinity map of the delta. The EC-probe developed by Eijkelkamp was used to measure the bulk soil EC in this study. The EC-probe set for soil conductivity measurements consists of an EC probe and an earth resistivity meter. Electrical conductivities measured with the salinity probe in the field were compared with saturation extract of soil samples measured in the laboratory (ECs). A soil salinity map of the Basanti was developed using kriging interpolation techniques in GIS environment. The soil salinity was maximum in Bheri and mangrove system where as it was lowest in rice-vegetable systems (Fig. 66).

Stress-tolerant rice for Africa and South Asia (STRASA - Phase 3) stress tolerant rice for coastal soil (B. Maji, D. Burman, S. K. Sarangi and S. Mandal)

Salinity Tolerant Breeding Network (STBN) trial was conducted at the Canning Experimental Farm during *Kharif* 2016 under the Bill and Melinda Gates Foundation (BMGF) funded project. The soils of the experimental site have Hyperthermic temperature and Aquic moisture regimes. The soil is heavy in texture (silty clay) and normal in soil reaction. Soil salinity during dry moths is very high (EC_e 9-12 dS m^{-1}). However, it varied from 3.65 to 6.87 dS m^{-1} during *Kharif* season. Soil salinity and pH of the experimental site during *Kharif* season are given in Table 119. The experiment consisted of 66 rice genotypes including 5 check varieties

Table 119: Soil pH and salinity (EC_e, dS m^{-1}) of the experimental site at different months

Soil Parameters	Months					
	July	Aug.	Sep.	Oct.	Nov.	Dec.
pH	7.42	7.68	7.34	7.08	7.12	7.11
Salinity	6.87	6.26	6.50	3.65	3.89	4.59

Salinity Tolerant Breeding Network (STBN) trial during Kharif season

(PUSA 44, CSR 10, CSR 27, CSR 36 and CSR 7-1) and 1 local check variety (Amal-Mana).

Days to 50 % flowering of the entries in the trial ranged from 73 days (KR 15005) to 130 days (CR 3900-193-9-9-10, CR 2851-S-1-B-4-1-1-1-1, CR2860-S-B-189-1-1-1 and CR 2850-S-2B-12-1-2-1) with a mean of 98 days. Plant height of the entries varied from 68 cm (KR 15014) to 152 cm (CR2860-S-B-189-1-1-1 and CR3884-244-8-5-11-1-4) with a mean height of 102 cm. Total number of tillers per plant of the entries ranged from 8 (CR3909-192-1-7-2, TR 09027, CR3878-245-1-9-2, CR 2851-S-1-B-4-1-1-1-1, CR3903-161-1-3-2, CR3879-3-1-6-1-3-1 and RP-320-4-3-2-1) to 15 (CSR-2748-4441-193) with a mean value of 10. Number of reproductive tillers varied from 7 (CR3909-192-1-7-2, RP-320-4-3-2-1, CR3879-3-1-6-1-3-1, CR3878-245-1-9-2, CSAR 1604, TR 09027) to 15 (CSR-2748-4441-193) with a mean value of 10. Panicle length of the different entries under trial ranged from 15.3 cm (KR 15003) to 25.5 cm (CR3879-3-1-6-1-3-1) with a mean of 20.7 cm. Number of filled grains per panicle varied from 28 (CSR-2748-4441-193) to 124 (RP-320-4-3-2-1) with a mean value of 66. Number of un-filled grains per panicle varied from 5 (CSR-2748-4441-72) to 44

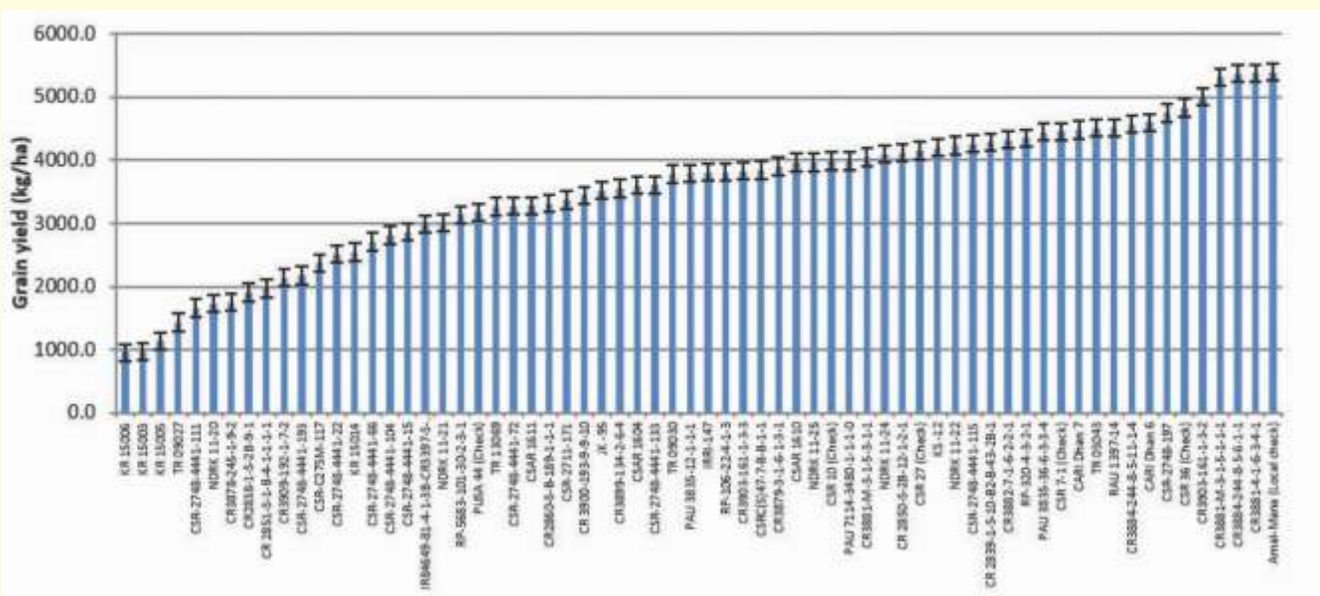


Fig. 67: Grain yield of entries under STBN trial

(CARI Dhan 7) with a mean value of 20. Spikelet fertility of the entries under trial ranged from 53.9% (NDRK 11-21) to 89.5 % (CSR-2748-4441-115) with a mean of 76.9 %. In the trial, 1000 grain weight of the entries varied from 19.2 g (KR 15003, RP-320-4-3-2-1 and KR 15006) to 30.1 g (CR2838-1-S-2B-9-1) with a mean weight of 24.1 g. At reproductive stage, stress score varied from 1 (CR3903-161-1-3-2, CR3881-4-1-6-3-4-1, CR3909-192-1-7-2, CR2838-1-S-2B-9-1, CR2860-S-B-189-1-1-1, CR3884-244-8-5-11-1-4, TR 05043, NDRK 11-24, CSR-2748-4441-193, CSR-2748-4441-104, KR 15014, CSR 7-1 (Check) and Amal-Mana (Local check)) to 5 (CR3878-245-1-9-2, CSR-2748-4441-133, PAU 3835-12-1-1-1, RP-320-4-3-2-1, RAU 1397-14 and CARI Dhan 6) with a mean value of 3. Grain yield of the entries varied from 0.956 to 5.389 t ha^{-1} with mean yield of 3.524 t ha^{-1} . Out of all the entries, higher grain yield was recorded in CSR-2748-197 (4.748 t ha^{-1}), CSR 36 (Check) (4.831 t ha^{-1}), CR3903-161-1-3-2 (5.009 t ha^{-1}), CR3881-M-3-1-5-1-1-1 (5.320 t ha^{-1}), CR3884-244-8-5-6-1-1 (5.373 t ha^{-1}), CR3881-4-1-6-3-4-1 (5.381 t ha^{-1}) and Amal-Mana (Local check) (5.389 t ha^{-1}).

ACIAR Project: Cropping systems intensification in the salt affected coastal zones of Bangladesh and West Bengal, India (B. Maji, D. Burman, U. K. Mandal, S. K. Sarangi, S. Mandal and K. K. Mahanta)

Under the externally funded project on 'Cropping systems intensification in the salt affected coastal zones of Bangladesh and West Bengal, India' funded by Australian Centre for International Agricultural Research (ACIAR), research experiments were conducted both during wet (*Kharif*) and dry (*boro*) seasons at Canning Experimental Farm (on-station) as well as at the farmers' fields (on-farm). The project aims to sustainably increase cropping intensity and productivity in the coastal zones of West Bengal particularly in the dry (*Rabi*) season through integrated soil, water and crop management. The objectives to meet this aim, and the general approach to address each objective, are to:

1. Develop a sub-regional scale understanding of the surface water and groundwater resources, groundwater recharge/discharge mechanisms, and their trends in study area: *Addressed by review of literature and secondary data on soil, surface water and groundwater conditions, and a polder level water balance analysis.*
2. Develop a detailed understanding of the salt and water dynamics of the case study island and model pre-monsoon and post-monsoon groundwater abstraction regimes that improve groundwater quality and availability during the dry season: *Addressed by understanding island infrastructure and water management and modelling salt and water dynamics for different polder water management options.*
3. Develop detailed understanding of crop production responses to various improved crop water management strategies, including early sowing: *Addressed by APSIM modelling of crop and water management options.*
4. Identify superior cropping options, water and salt management strategies (developed in 2 and 3) through field evaluation and co-learning with farmers: *Addressed by on-farm field crop trials of options for crops (species/varieties) and management strategies.*

Project Site of CSSRI, RRS, Canning Town: Village: Sonagaon, GP: Gosaba, Block: Gosaba, District: South 24 Parganas

Field experiments

Two types of field experiments were conducted at eight farmers' fields during *Kharif* 2016. First experiment was on three crop establishment methods (puddle transplanting, unpuddled

ACIAR Project site at Gosaba Island, Sundarbans

Table 120: Effect of crop establishment methods and varieties on grain and straw yield of rice at Sonagaon, Gosaba during kharif 2016

Treatments	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
Puddled transplanting	4.09	6.66
Unpuddled transplanting	3.81	6.61
Drum seeding	3.09	6.15
CD (P=0.05)	0.30	0.11
Amal-Mana	4.19	8.12
CR 1009	3.86	6.89
Swarna-Sub 1	2.93	4.41
CD (P=0.05)	0.18	0.19

Table 121: Plant height, root length and biomass of maize (Indo-hybrid) at 75 days after sowing under different acid soil management treatments during rabi 2016-17 at Sonagaon, Gosaba

Treatments	Plant height (cm)	Root Length (cm)	Biomass (t ha^{-1})
Control	112.2	17.8	5.39
Lime @ 1.5 ha^{-1}	146.1	19.1	6.16
RP @ 0.25 ha^{-1}	126.8	21.2	5.99
Lime @ 1.5 ha^{-1}+ RP @ 0.25 ha^{-1}	139.3	24.3	6.77

RP: Rock Phosphate

transplanting and drum seeding) in main-plot and three varieties (Amal-Mana, CR 1009 and Swarna-Sub 1) in sub-plot. The grain and straw yields of this experiment are given in Table 120. The second experiment was on management of acid saline soils. In this experiment rice variety Amal-Mana was grown in acidic soils (pH 4.6-4.8) with and without green manuring. During the first year, there was no significant difference between green manuring and control plots. The mean grain yield varied from 2.69-3.45 t ha^{-1} under lower and higher soil pH levels, respectively. During *Rabi* season, maize crop was grown on these acid saline soils with four treatments *viz*., control (no amendment), lime, rock phosphate and lime + rock phosphate. The growth performance of maize at 75 days after sowing is given in Table 121.

Apart from maize, other *Rabi* season crops like potato, onion, green gram and grass pea were also evaluated in the on-farm trials. Potato variety Pokhraj was grown under conventional tillage (ridge and furrow method of cultivation) and zero tillage (direct sowing of potato tubers to the wet soil) just after harvesting of *Kharif* rice. Early sowing was achieved by zero tillage and the crop also needed significantly less irrigation water. The tubers were covered with dry compost and then 30-45 cm layer of paddy straw. The residual soil moisture helped in very good germination of tubers. In addition, there was no weed infestation and the tubers were not damaged by sudden heavy rain as compared to conventional practice. Tuber yield varied from 7.5-26.9 t ha^{-1} in conventional tillage and 12.4-32.1 t ha^{-1} in ZT cultivation. Tuber quality in zero tillage was better and due to early harvest, it was possible to take other *Rabi* crops like maize or green gram or onion in the same plot. Therefore, cropping intensity can be increased to 300% in rainfed low lands of Sundarbans.

Grass pea (*Lathyrus*) was cultivated as *paira* crop with *Kharif* rice. This system of cultivation helped in utilization of residual soil moisture in the low land paddy fields. Green gram was grown with and without *Rhizobium* culture treatments. Seed treatment was done with *Rhizobium* culture 30 g + 70 mL water + sugarcane molasses 5 g + rice starch 30 mL for 1 kg seed. Onion variety Sukhsagar was grown with soil moisture conservation treatments (with and without paddy straw mulching) and liming.

Apart from on-farm experiments, one on-station experiment is continuing at the Canning Experimental Farm with six dates of sowing (1st October, 15th October, 1st November, 15th November, 1st December and 15th December) and three varieties (IET 4786, WGL 20471 and Bidhan 2) of *Rabi* season rice. The data of this experiment has been planned to be used in APSIM model. Observations show that the rice variety IET 4786 is susceptible to salinity. However, with the first two dates of sowing the mortality of IET 4786 after transplanting in the main field is less and it increased from third date of sowing. Other two varieties are not affected by increasing salinity.

Ground and surface water study in the ACIAR Project site

Five piezometers were installed 20 feet below ground level at the project site in January, 2017. Periodic monitoring of water table depth, salinity and pH of ground water are being recorded. Data collected for February and March months of 2017 are given in Table 120. The quality parameters like salinity, pH, sodium and potassium levels of water samples collected from different sources before start of *kharif* 2016 experiments is given in Table 123.

Socio-economic study

Socio-economic status of the farmers was recorded by conducting the baseline survey in the project area primarily focusing on the collaborative farmers under the cropping system intensification project. Majority (92%) of the farmers in the region belonged to the marginal category (< 1 ha land). Almost all the farming activities were taken care of by the aged farmers (average age 62 years) indicating that young generation in the villages was looking for other livelihood options. Cropping intensity in the study area hovered around 118% as mono-cropping of *Kharif* rice was predominant. Intensively utilized homestead lands significantly contributed towards household food and nutrition security and had some kind of market linkages. Since mono-cropping provided

Table 122: Depth and quality of ground water as observed in different piezometers

Date of observation	Depth of Water table below ground level (m)					Groundwater EC (dS m^{-1})					Groundwater pH				
	Pz 1	Pz 2	Pz 3	Pz 4	Pz 5	Pz 1	Pz 2	Pz 3	Pz 4	Pz 5	Pz 1	Pz 2	Pz 3	Pz 4	Pz 5
15.02.2017	0.66	0.73	0.82	0.92	0.68	29.16	2.18	3.97	1.89	1.61	6.5	7.3	7.1	6.9	7.2
03.03.2017	0.75	0.95	0.90	0.86	0.85	28.84	2.40	4.55	2.38	1.95	7.0	7.6	6.7	6.6	6.7
22.03.2017	0.81	1.10	1.02	0.71	0.72	26.63	2.33	3.98	1.94	1.65	6.9	7.2	7.2	6.9	7.2

Table 123: Surface water quality in the study site at Sonagaon, Gosaba

Sampling points	Latitude (N)	Longitude (E)	pH	EC (dS m^{-1})	K (me L^{-1})	Na (me L^{-1})
Gosaba River	22°09.971′	88°47.845′	6.67	19.07	2.25	117.22
Gumor River	22°07.843′	88°48.160′	5.79	18.54	2.11	111.25
Durga-duani River	22°07.344′	88°47.038′	7.42	20.02	2.11	118.33
Sluice Gate No 6 (River side)	22°06.931′	88°47.333′	5.97	19.50	1.97	99.36
Sluice Gate No 6 (Canal side) Field Water	22°06.950′	88°47.348′	4.97	1.06	0.13	4.95
(Ram Hari Mandal) Pond Water	22°07.002′	88°47.343′	7.35	0.34	0.05	1.49
(Nitai Mandal)	22°07.976′	88°47.956′	6.72	0.29	0.24	0.89
Tube Well Supply Water	22°07.315′	88°47.079′	7.77	2.97	0.09	18.57
(Drinking)	22°07.042′	88°47.298′	7.23	3.14	0.08	20.10

insufficient income to the farm families, most of the farmers depended on off-farm income sources like wage labour or migration to the nearby cities or even long distances to other states. Outcome/ options of cropping intensification project are likely to be compared with this income to make adoption decision by the farmers. During *Kharif* experiments, five rice varieties *viz*., Amal-Mana (Sonagaon village), CR 1009 (Sonagaon village), Swarna Sub-1 (Sonagaon and Jatirampur village), CR 1017, (Jatirampur village) were taken into consideration in two study villages. After *Kharif* season, focussed group discussions and personal interactions were conducted with the farmers to identify the preferences of rice varieties undertaken in experiments. Based on the discussion with the farmers and preference analysis, it was observed that farmers in Sonagaon site preferred rice variety CR 1009 over Amal-Mana and Swarna Sub-1. In contrast, in Jatirampur village, farmers preferred Swarna Sub-1 over CR 1017. Farmers' choice of a particular rice variety was influenced by several attributes like tolerance to salinity, waterlogging, lodging, pests and diseases, grain and straw quality, and crop duration.

Visit of ACIAR Team to Project site at Sonagaon

Project team consisting of scientists headed by Dr. Mohammed Mainuddin, Project Leader, CSIRO, Australia and Indian partners from CSSRI, BCKV and TSRD visited the ACIAR project sites at Sonagaon, Rangabelia, Gosaba as well as on-station trial at Canning Town during 24-25 October, 2016 and 22-24 February, 2017. During the visit, instruments like DUALEM, soil moisture sensors were demonstrated and used in the project experimental plots.

Study on the effect of salinity stress on jute (*C. capsularis & C. olitorius*) (M. Ramesh Naik, Dhananjay Barman, Maruthi R.T. and U. K. Mandal)

In order to find out suitable jute varieties which can produce higher yields in saline coastal soils, a project was initiated under inter-institutional collaboration with CRIJAF, Barrackpore. Eight varieties of both *Olitorius* (JRO 128, JRO 524, JRO 204, JRO 632) and *Capsularis* (JRC 321, JRC 698, JRC 532, JBC 5) were sown during second week of March, 2016 at the Canning Experimental Farm (Fig. 68). The biomass and fibre yield varied from 70-87 t ha^{-1} and 2.9-4.2 t ha^{-1} for *Olitorious* where as it was 43-72 t ha^{-1} and 1.3-2.48 t ha^{-1} for *Capsularis* variety. *Olitorious* cv. JRO 204 and *Capsularis* cvs. JRC 532 and JBC 5 performed well in the coastal region. Initial establishment of jute during April-May under high salinity conditions is often poor. Postponement of sowing date to the first fortnight of March has good scope for increasing the yield level and salt tolerance in jute in the coastal regions of West Bengal.

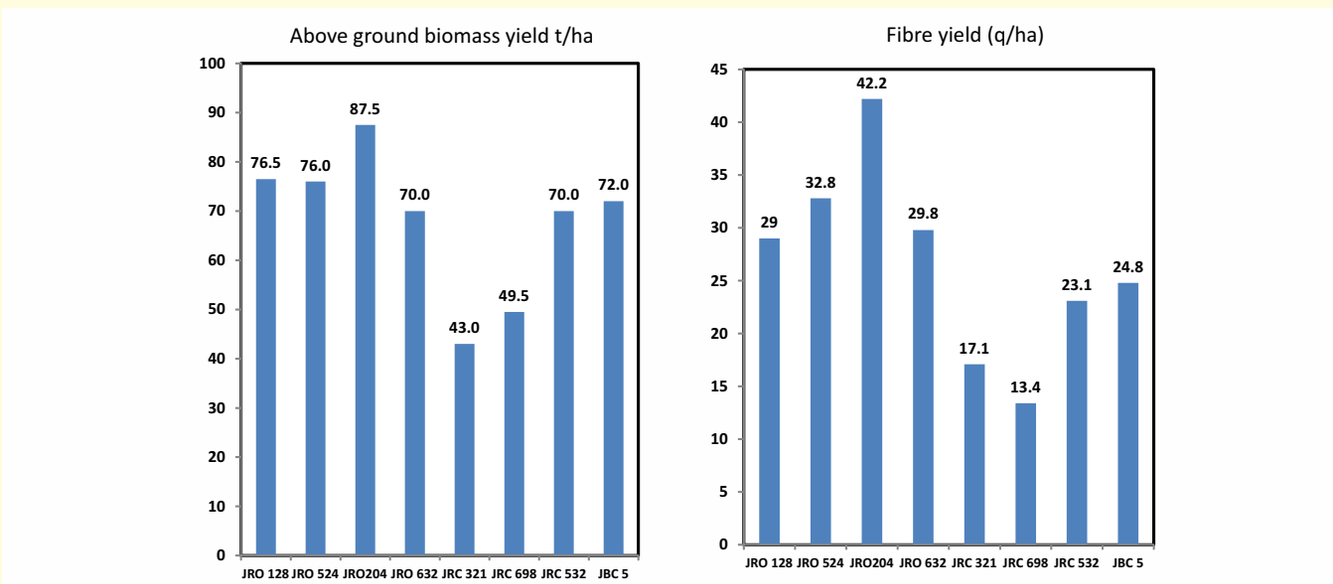


Fig.68: Total above ground biomass and fibre yield of jute

Land use options for enhancing productivity and improving livelihood in Bali Island of Sundarbans - *Collaborative research project (TSP funded)* (K. D. Sah, K. Das, S. K. Reza, A. K. Sahoo, D. C. Nayak, Subhasis Mandal, D. Burman and P.P. Chakraborty)

With fund support from TSP, a collaborative (NBSS&LUP, CSSRI and CIFA) project has been undertaken in the extremely disadvantaged areas of coastal Sundarbans with the objectives of (1) Augmenting farm productivity through sustainable management of land & water resources and integrated farming system under coastal salt affected areas in Sundarbans and (2) Enhancing farm income and better livelihoods for disadvantaged farming communities in coastal areas. Major interventions that have been undertaken are (1) Land shaping techniques (Farm pond, deep furrow & high ridge, shallow furrow and medium ridge and paddy-cum-fish cultivation); (2) Improved and salt tolerant rice varieties; (3) Multiple cropping/crop diversification (low water requiring crops, vegetables etc); (4) Improving homestead production system; and (5) Vermicomposting unit.

Initially, in 2014, only 7 beneficiary farmers were selected. In 2015, farmers numbers increased to 32. During 2016, 23 additional tribal farm families have been included. Currently, project activities have been extended over 60 farm households. Inputs for soil management, growing vegetables and fish have been provided. Information on soil and water management, performance of the technologies and socioeconomic status has been carried out. Success stories have been documented. Farmers are growing a number of crops throughout the year. A marginal farmer Mr. Suresh Dolui is currently growing vegetables and paddy. He earned Rs. 28000-32000 from tomato and chillies with an expenditure of Rs. 3500 for 0.5 bigha of land. During *Kharif* season, he grew cucumber and bitter gourd and earned Rs.12000/- with expenditures of Rs. 1500. Mr. Biswajit Mondal, another marginal farmer in Bali-II village Panchayat of Gosaba block, South 24 Parganas, could double his income in two years by adopting improved agricultural practices. After cyclone '*Aila*' in 2009 his land was inundated by saline water threatening his livelihood security. He was forced to mortgage his land (0.40 ha) for Rs. 90000/-. He left agriculture and worked as daily paid labourer in nearby cities without any secured livelihood. Now after this intervention, he has returned to the village, paid the borrowed money and got back 90% of his mortgaged land. He now raises crops, fish and animals throughout the year and earns around Rs. 8000 per month. Farming operations in the area experienced some constraints like heavy rains in the first week of November that delayed *Rabi* crops sowing by around one month. Due to this delay, cabbage, cauliflower, tomato, chillies and brinjal fetched lower market prices *i.e.*, 40-50% lower than normal. Replication of success stories depends on farmers socio-economic characteristics, resource availability, risk preferences, capacity to capital investment and willingness. Also, cash crunch due to demonetization drive affected the paddy selling during the November-December.

AICRP ON MANAGEMENT OF SALT AFFECTED SOILS AND USE OF SALINE WATER IN AGRICULTURE

Evaluation of commercial vegetable crops under protected cultivation structure in saline environments (R. L. Meena, B. L. Meena, Anshuman Singh, M. J. Kaledhonkar and S. K. Sanwal)

Cultivation of vegetable crops is seen as a low gestation and high income agricultural activity. Many vegetables are now grown under protected cultivation, especially in the off-season to fetch remunerative prices. However, precise information regarding the likely impacts of prolonged saline water use on commercial vegetable crops under protected conditions is limited. Hence, an experiment was started with three vegetable crops *viz*., capsicum (cv. Indra), hot chilli (cv. Kranti) and tomato (cv. Cibelia) in 2015 under a naturally ventilated protected structure with saline water irrigation to study the improvements in crop productivity and profitability along with feasibility of such structures in ensuring livelihood security of the resource poor farmers. There were six saline irrigation treatments with irrigation water salinity (EC_{IW}) ranging from 0.8-10 dS m^{-1}. Best Available Water (BAW) with EC_{IW} 0.8 dS m^{-1} was taken as control. Capsicum and chilli seedlings were transplanted on 4th August, 2015 and tomato seedlings were transplanted on 26th August, 2015. After initial establishment period of 15 days with BAW, saline water treatments were initiated. The vegetables were grown on raised beds of 15 cm height at spacing of 45 cm x 30 cm. Drip system operated under gravity flow was used for saline irrigation. Recommended doses of fertilizers were mixed with the irrigation water. Capsicum and chilli vegetables were harvested by the end of April, 2016 and tomato was harvested by end of May, 2016. Results of 1st year of experimentation are promising despite the continued irrigation with saline water. The highest fruit yield of 63 t ha^{-1} of capsicum was obtained with BAW followed by 62.2 t ha^{-1} with EC_{IW} of 6 dS m^{-1} and 58.2 t h^{-1} with EC_{IW} of 8 dS m^{-1}. Similarly, the highest fruit yield of chilli (48.5 t ha^{-1}) was obtained with EC_{IW} 6 dS m^{-1} followed by 45.7 t ha^{-1} with EC_{IW} 10 dS m^{-1} and 45.2 t ha^{-1} with EC_{IW} 4 dS m^{-1}. In case of tomato, the highest fruit yield of 116.2 t ha^{-1} was obtained with EC_{IW} 6 dS m^{-1} followed by 111.0 t ha^{-1} with EC_{IW} 10 dS m^{-1} and EC_{IW} 4 dS m^{-1} each. Tested vegetables were harvested at regular intervals and there were a total of 15, 13 and 28 pickings for capsicum, chilli and tomato, respectively. Preliminary results of one year experimentation are encouraging and it appears that vegetable cultivation with saline irrigation water under naturally ventilated protected structures may ensure livelihood security of the resource poor farmers.

Optimizing zinc and iron requirement of pearl millet-mustard cropping system on a salt affected soil (B. L. Meena, Parveen Kumar, Ashwani Kumar, R. L. Meena and M. J. Kaledhonkar)

Low productivity of pearlmillet and mustard crops in salt-affected soils is often due to the poor availability of micronutrients; especially Zn and Fe. Hence, a field experiment was carried out at the Nain Experimental Farm, Panipat to optimize the Zn and Fe requirements in pearlmillet-mustard crop rotation. There were 12 treatments replicated 3 times in RBD. Zinc and iron were applied through soil in the form of $ZnSO_4.7H_2O$ and $FeSO_4.7H_2O$, respectively, at the time of sowing. Foliar sprays of respective nutrients were also applied using the same fertilizers as in soil application at 30 and 45 days after sowing. Among 12 different treatments, only one treatment was with FYM besides application of 5 kg Zn +10 kg Fe. It was implemented for pearlmillet crop only. In case of mustard, same treatment without FYM was implemented. The soil had initial EC_e of 10.55 dS m^{-1} and pH_s of 8.45 in the 0-15 cm soil depth.

The experimental results indicated that mustard seed yield (2.27 t ha^{-1}) and pearlmillet grain yield (3.5 t ha^{-1}) were 41.9% and 45.2% higher over control with the combined application of 5 kg Zn +10 kg Fe +10 t FYM. However, yield

Table 124: Effect on zinc and iron applications methods on yield of pearl millet and mustard

Treatment	Mustard Seed yield (t ha^{-1})	Pearl millet Stover yield (q ha^{-1})	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})
T1- Control	16.0	55.6	24.1	55.0
T2- 5 kg Zn	16.7	60.5	27.0	62.5
T3- 6.25 kg Zn	18.2	66.5	28.4	73.2
T4- 7.5 kg Zn	19.3	71.1	30.6	79.0
T5- 7.5 kg Fe	17.1	60.0	25.5	65.1
T6- 10 kg Fe	18.0	62.3	26.6	70.9
T7- 12.5 kg Fe	18.5	70.3	27.4	71.4
T8- 5 kg Zn+10 kg Fe	19.0	79.5	32.1	77.0
T9- 5 kg Zn+10 kg Fe+ 10 t FYM	22.7	85.5	35.0	90.5
T10- Foliar sprays of 0.5% ZnSO4; twice	16.6	60.3	24.6	59.5
T11- Foliar sprays of 1% FeSO4; twice	17.2	61.1	27.1	66.2
T12- Combined foliar sprays of 0.5% ZnSO4+ 1% FeSO4; twice	17.5	62.5	28.4	69.0
CD (0.05)	2.30	6.40	6.30	8.00

Performance of pearlmillet and mustard crops with the combined application of Zn, Fe and FYM

improvement was only 18.7 and 33.2 % higher over control in mustard and pearl millet, respectively, with the application of 5 kg Zn + 10 kg Fe without FYM. Results also showed that soil application of 7.5 kg Zn ha^{-1} and 12.5 kg Fe ha^{-1} alone significantly increased yields of both mustard and pearlmillet over control. Among the foliar applications, spray of 0.5 % $ZnSO_4$+1% $FeSO_4$ twice was equally effective in increasing the yields of mustard and pearlmillet similar to that obtained with the soil application of 5 kg Zn and 7.5 kg Fe ha^{-1} alone (Table 124). On the basis of experiment results, it is concluded that combined soil application of Zn and Fe with FYM was effective in increasing mustard yield, decreasing EC_e and maintaining the higher amounts of available micronutrients in salt-affected soils. Also, combined foliar application of Zn and Fe was better than foliar application/sprays of an individual nutrient.

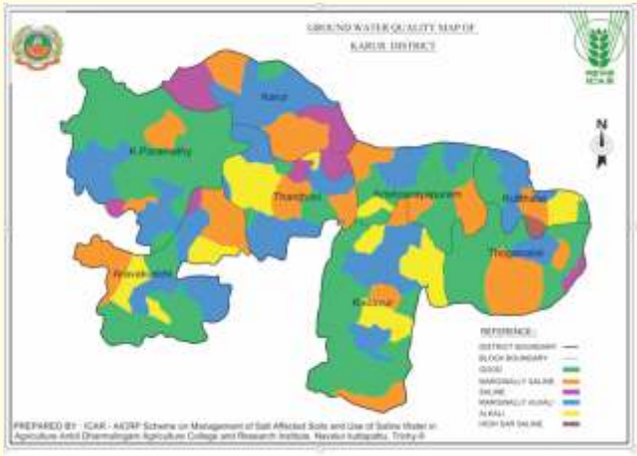
Survey and characterization of ground water of Tamil Nadu for Irrigation (AICRP Tiruchirappalli Centre)

Ground water quality survey of Nagapattinam and Karur districts were carried out. To characterize the ground water quality, 215 water samples from Nagapattinam distict and

153 water samples from Karur district were collected covering all the blocks of the districts. The water samples were analyzed for pH, EC, cations (Ca, Mg, Na and K) and anions (CO_3, HCO_3, Cl and SO_4). Quality parameters like SAR and RSC were calculated. Classification of water quality is done on the basis of EC, SAR and RSC values as suggested by CSSRI, Karnal.

The Nagapattinam district has 11 Blocks viz., Keelaiyur, Kilvelur, Kollidam, Kuttalam, Mayiladuthurai, Nagapattinam, Sembanar Koil, Sirkazhi, Thirumarugal, Talanayar and Vedaranniyam. Out of the total samples collected in Nagapattinam district, 72.6% is characterized under good quality, 12.7% is marginally saline, 7.8 % is saline, 2.9% is marginally alkaline, 2.9 % is alkaline, and 0.4% high SAR saline. More than 90 % water samples collected from Kuttalam and Mayiladuthurai blocks were good quality waters. Nagapattinam and Vedaranniyam blocks have less than 50 per cent good quality waters. Marginally saline water was observed in almost all the blocks except Kuttalam and Mayiladuthurai. The distribution of marginally saline water were 9.09% in Sembanarkoil, 9.0% in Sirkazhi, 16.7% in Kollidam , 18.2% in Thirumarumarugal, 18.5 % in Kilvelur, 25% in Keelaiyur, 38.5% in Thalanayar and 17.6 % in Vedaranniyam Blocks. The distribution of saline water was 4.54% in Sembanar Koil, 9% in Sirkazhi, 0.09% in Thirumarugal, 44.4% in Nagapattinam, 6.25% in Keelaiyur, 7.69 in Talanayar and 7.8% in Vedaranniyam Block. Small quantity of marginally alkali and alkali water was distributed in almost all the blocks. High SAR Saline water was present only in Kilvelur Block.

Karur District has 8 Blocks viz., Aravakurichi, Kadavur, Karur, Krishnarayapuram, Kulithalai, K.Paramathi, Thanthoni and Thogaimalai. Among the 8 blocks, the distribution of good quality samples were higher in Thogaimalai block (66.6 %) and K.Paramathi block (65.4 %). The occurrence of good quality water is lowest in Karur (12.5%) and Thanthoni (12.5 %) blocks. The occurrence of marginally saline water (7.7 to 37.5 %) and marginally alkali water (11.1 to



Ground water quality map of Karur District

37.6%) was prevalent in all the blocks. Saline water is prevalent in Aravakurichi (5.9%), Karur (31.3%), K.Paramathi (3.8%), Thanthoni (16.7%) and Thogaimalai (5.6%) blocks. Alkali water was found in almost all the blocks (5.9 to 17.6%) except K.Paramathi and Thogaimalai blocks. High SAR saline water was found in Kulithalai block only (6.7%). Out of the total samples collected from Karur district, 38.6% is coming under good quality, 18.3% is marginally saline, 7.8% is saline, 0.70% is high SAR Saline, 26.1 % is marginally alkali and 8.5% is alkali water categories. The spatial groundwater quality maps for Nagapattinam and Karur district were prepared and the map Karur district is shown in Fig. 72 as an example.

Assessment of ground water quality status of A & N Islands (AICRP Port Blair Centre)

The ground water survey of all three district of Andaman and Nicobar islands was carried out during post-monsoon and pre-monsoon period (during the 2015-16 & 2016-17) by collecting 248 samples from shallow wells in the coastal areas during each survey to study the seasonal variation in ground water quality. Total 496 samples were analyzed for different water quality parameters by following the standard procedures. The mean and range of EC, pH, SAR and RSC are presented in Table 125. Although water EC showed wide variation (0.1-13.7 dS m^{-1}), the mean EC value exceeded 2.0 dS m^{-1} only at Ferrargunj and Mayabunder blocks. Among the districts, the salinity level was low in Car Nicobar followed by

Table 125: Mean and range of ground water quality parameters in different blocks of A & N islands

Blocks	Year of sampling	EC (dS m^{-1})		pH (meq l^{-1})		RSC		SAR (mmol $l^{-1})^{1/2}$	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
South Andaman District									
Ferrargunj	2016	0.10-13.68	2.10	6.10-8.09	7.10	0.0-0.10	0	0.04 -3.52	0.56
Prothrapur	2016	0.02-2.69	1.36	5.29-8.05	7.35	0.0-0.0	0	0.01-5.66	0.46
Little Andaman	2015	0.20-4.62	1.80	5.52-7.86	6.82	0.0-0.20	0	0.02-4.62	0.42
North & Middle Andaman District									
Diglipur	2016	0.63-3.10	1.13	6.05-7.65	7.08	0.0-0.10	0	0.12-0.47	0.27
Mayabunder	2016	0.76-4.23	2.04	6.88-7.38	7.33	0.0-0.0	0	0.18-0.46	0.31
Rangat	2015	0.73-3.40	1.38	6.40-7.70	7.14	0.0-0.20	0	0.28-0.67	0.47
Car Nicobar district									
Car Nicobar	2015	0.23-3.65	0.93	7.23-8.31	7.78	0.0-9.20	0	0.03-3.78	0.72
Nancowry	2016	0.65-2.31	1.02	7.08-8.24	7.66	0.0-0.00	0	0.12-0.56	0.29
Campbell Bay	2015	0.40-2.15	1.10	6.90-7.70	7.80	0.0-0.00	0	0.20-0.46	0.30

N&M Andaman and the highest was observed in South Andaman district. Mean pH varied from slightly acidic to mildly alkaline in all the districts. However, the values varied from strongly acidic to moderately alkaline in different blocks. In general, the RSC and SAR were well within the permissible limits for irrigation.

Use of alkali groundwater to supplement canal water in *Toria-Chikori* crop rotation (AICRP Agra Centre)

A field experiment was initiated during *rabi* 2015-16 for assessing different modes of irrigation with canal and alkali waters (cyclic and mixing) in toria-chicori crop rotation. The alkali water having RSC 10 meq l^{-1} was used for irrigation. Crop yield data for grain, stover, biological yield and harvest index for different canal and alkali water use modes are given in Table 126.The grain and stover yield did not differ significantly amongst the different mode of canal and alkali irrigations and also found at par with the single irrigation source either canal or alkali (RSC 10 meq l^{-1}). The biological yield of toria was recorded no significant difference in all the irrigation modes. The harvest index of toria crop was no significant difference but all the treatment at par. The maximum net profit and B: C ratio was observed in canal irrigated

Table 126: Effect alkali water irrigation to supplemental canal water irrigation on seed yield, stover yield, net profit and benefit cost ratio of toria

Treatments	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)	Net profit (Rs ha^{-1})	B:C ratio
CW	0.85	1.93	2.79	30.58	17,041	1.08
1CW:1AW	0.81	1.88	2.69	30.09	15,385	0.97
2CW:2AW	0.83	1.86	2.69	30.92	16,271	1.03
2AW:2CW	0.81	1.81	2.63	30.66	15,385	0.97
Mix.(1:2)	0.80	1.80	2.62	30.68	15,115	0.96
Mix. (2:1)	0.81	1.82	2.62	30.70	15,385	0.97
AW	0.79	1.80	2.60	30.61	14,885	0.94
CD at 5%	NS	NS	NS	NS	-	-

Table 127: Effect alkali water irrigation to supplemental canal water irrigation yield, net profit and benefit cost ratio of chikori

Treatments	Diameter of chikori root (cm)	Length of chikori root (cm)	Yield of chikori root (t ha^{-1})	Net profit (Rs ha^{-1})	B:C ratio
CW	12.17	22.37	17.19	43,980	1.56
1CW:1AW	11.17	21.57	16.73	42,048	1.49
2CW:2AW	11.37	20.50	16.66	41,760	1.49
2AW:2CW	10.33	19.90	16.23	40,058	1.42
Mix.(1:2)	11.07	20.70	16.11	39,444	1.40
Mix. (2:1)	11.43	21.77	16.73	42,061	1.49
AW	09.93	18.67	15.90	36,908	1.31
CD at 5%	00.92	01.60	05.33	-	-

Table 128: Effect alkali water irrigation as supplemental to canal water irrigation on net profit and benefit cost ratio of toria and chikori

Treatments	Net profit (Rs ha^{-1})			B:C ratio		
	Toria	Chikori	Total	Toria	Chikori	Total
CW	17,041	43,980	61,021	1.08	1.56	2.64
1CW:1AW	15,385	42,048	57,433	0.97	1.49	2.46
2CW:2AW	16,271	41,360	57,631	1.03	1.47	2.50
2AW:2CW	15,385	40,058	55,443	0.97	4.42	2.39
Mix.(1:2)	15,115	39,444	54,559	0.96	1.40	2.36
Mix. (2:1)	15,385	42,061	57,446	0.97	1.49	2.46
AW	14,885	36,908	51,793	0.94	1.31	2.25

plots (Rs. 17,041) and 1.08.

After harvest of Toria crop, the Chikori crop was grown during rabi season with different alkali: canal irrigation modes. The Chikori root yield data are given in Table 127. The Chikori root yield differed significantly amongst the different mode of canal and alkali irrigations. The maximum Chikori root yield was found in canal irrigation treatment (17.18 t ha^{-1}) and lowest in alkali water irrigated treatment (15.9 t ha^{-1}) and all other treatments in between. The maximum net profit and B: C ratio was found in canal irrigated treatment (Rs.43,980) and 1.56.

The annually net profit for Toria-Chikori rotation is given in Table 126. The maximum net profit for two crops grown in one year was Rs. 61,021 with canal irrigation and minimum profit was Rs. 51,793 with alkali irrigation. The maximum benefit cost ratio for this rotation was 2.64 for canal irrigation and minimum was 2.25 for alkali water irrigation.

Soil profile wise ECe, SAR, pH and ESP were determined at sowing and harvest of Toria crop and harvest of Chikori crop for different irrigation treatments. In general the ECe, pH, SAR and ESP at sowing and harvest of toria crop was stable as number of irrigations was limited and also there was rainfall during crop period. However, these values increased slightly during Chikori crop due use of alkali water in case of alkali water treatments.

Micro (Drip) irrigation system with saline water for different vegetable crops in coastal sandy soils (AICRP Bapatla Centre)

An experiment was laid out during *Rabi* 2015-16 for different vegetables (capsicum, clusterbean and palak) with five levels of irrigation water viz. best available water (BAW) pumped from bore well (0.6 dS m^{-1}) and saline water with EC of 2, 4, 6 and 8 dS m^{-1} replicated 4 times in each plot of 62.50 m^2. The experimental soil was sandy loam in texture, neutral in reaction, non saline with medium levels of available nitrogen

Table 129: Yield details of vegetables with different EC levels of irrigation water through drip irrigation system

Different salinity levels (dS m^{-1})	Capsicum Yield (t ha^{-1})	Clusterbean Yield (t ha^{-1})	Palak Yield (t ha^{-1})
BAW(0.6)	11.02	8.49	10.24
2	8.83	6.97	08.80
4	6.54	5.76	6.16
6	4.61	3.94	4.30
8	2.70	2.16	2.32

Table 130: Mathematical models for yield under drip irrigation system with saline water

Sr. No.	Crop	Equation	R^2 Value
1.	Capsicum	Y(kg ha^{-1}) = -1103*EC (dS m^{-1}) + 11286	R^2 = 0.991
2.	Clusterbean	Y(kg ha^{-1}) = -832.8x*EC(dS m^{-1})+ 8894	R^2 = 0.995
3.	Palak	Y(kg ha^{-1})= -1080*E.C*(dS m^{-1} + 10817	R^2 = 0.996

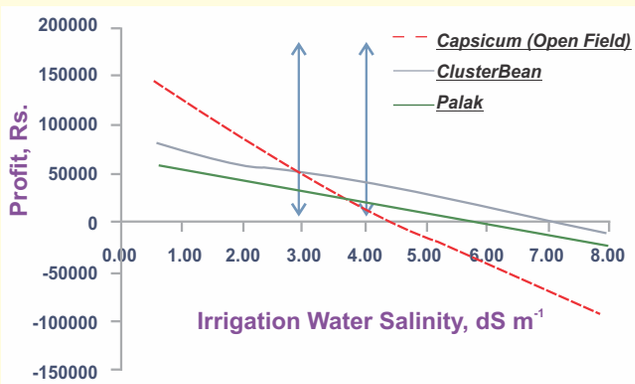


Fig. 70: Relative profit analysis for vegetable crops under saline water irrigation through drip

and phosphorous and high potassium. Yield with irrigation water salinity for three vegetables are given in Table 129.

The mean yields of Capsicum, Clusterbean and Palak followed inverse linear relation with irrigation water salinity as given in Table 130.

It was observed that 90, 75 and 50 percent yield levels for Capsicum, Cluster bean and Palak were realised at 1.2, 2.7 and 5.2 dS m^{-1}; 1.5, 3.2 and 4.5 dS m^{-1} and 1.5, 2.9 and 5.3 dS m^{-1} irrigation water salinity, respectively. The relative economics for vegetable growing with saline water using drip was also worked out and is shown in Fig. 70. Capsicum, Clusterbean and Palak are found economically viable upto 3.15, 4.25 and 4.50 dS m^{-1} irrigation water salinity, respectively, in open field cultivation.

The initial and final soil properties, as given in Table 131, at 2 and 4 dS m^{-1} irrigation water salinity indicated an increase in EC, pH and available potassium content where as the available nitrogen and phosphorous decreased.

Effect of frequency of irrigation and irrigation water salinity on carrot yield (AICRP Hisar Centre)

The purpose of the experiment, conducted during 2015-16, was to study effect of frequency

Table 131: Initial and final soil properties

Sr. No.	Parameter	2 dS m^{-1}			4 dS m^{-1}		
		Initial	Final	Change (%)	Initial	Final	Change (%)
1.	EC dS m^{-1}	0.5	0.7	40.0	0.7	1.00	48.50
2.	pH	7.4	7.7	4.0	7.6	7.80	2.60
3.	N (kg ha^{-1})	295.0	224.0	-24.1	282.5	210.0	-25.70
4.	P2O5 (kg ha^{-1})	27.0	28.0	-3.7	26.5	25.25	-4.72
5.	K2O (kg ha^{-1})	320.0	330.0	3.1	310.5	328.0	5.640

of irrigation and irrigation water salinity on carrot yield in drip irrigated soil. Main treatments were irrigation frequency levels namely i) Daily basis (F_1) and ii) Alternate day basis (F_2). Sub treatments were related to salinity levels namely a) Canal water (S_1), b) Saline water EC_{iw} = 2.5 dS m^{-1} (S_2), c) Saline water EC_{iw} = 5.0 dS m^{-1} (S_3) and d) Saline water EC_{iw} = 7.5 dS m^{-1} (S_4). The experiment was laid out in 2.0 x 2.0 m plot as per the following lay out plan (Figure 71).

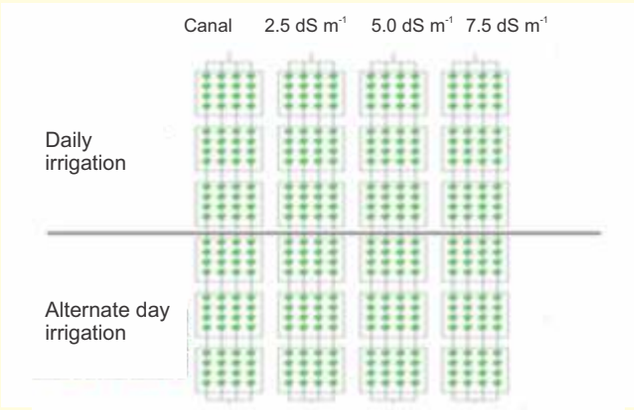


Fig. 71: Layout of the experimental field plots

In daily drip irrigation treatment, the relative yields of carrot were obtained 90.34, 78.80 and 53.08 % when irrigated with saline water of 2.5, 5.0, 7.5 dS m^{-1}, respectively, as compared to the yield recorded in canal water irrigation (Table 132). In alternate day drip irrigation treatment, the relative yields of carrot were obtained 87.29, 69.82 and 48.23 % when irrigated with saline water of 2.5, 5.0, 7.5 dS m^{-1}, respectively, as compared to the yield recorded in canal irrigation. On comparing drip irrigation frequency treatments, 2.67 and 11.57% yield was reduced in case of alternate irrigation compared to daily irrigation, in canal and saline water irrigation (7.5 dS m^{-1}), respectively. This indicates that increase in irrigation frequency may help in maintaining optimum moisture and leaching of salts from root zone. These things might have helped in higher yield in case of daily irrigation schedule of drip irrigation.

Effect of organics on plant growth and yield parameters of Brinjal (AICRP Port Blair Centre)

A field experiment was conducted at Field Crops Experimental Farm, Bloomsdale of Central Islands Agricultural Research Institute, Port Blair during January to May 2016 to study the effect of application of CIARI bioconsortia along with biogranules on the plant growth and yield parameters of brinjal (Var.VNR 218). The experiment was conducted in RBD with 4 treatments (T1: control, T2: Chemical fertilizer as per RDF), Vermicompost (100% RDF N through VC) and T4: Bioconsortia + biogranules @ 100g per plant) in 3 replications. The 45 days old seedlings were transplanted at a spacing of 60 x 60cm during January 2016 and all cultural practices were common except nutrient application. From each plot 5 plants were randomly tagged to record observations on plant height, no.of branches, no. of fruits, fruit weight per plant. The results showed that all treatments have significantly increased the plant growth and yield parameters. Among the treatments bioconsortia significantly increased number of fruits, fruit weight and total yield which was on par with 100% RDF of chemical fertilizers under normal conditions.

Table 132: Effect of salinity and irrigation frequency on the yield of carrot

Treatment	Crop yield (q ha^{-1})		Mean crop yield (q ha^{-1})
	Daily irrigation	Alternate irrigation	
Canal water	32.51	31.64	32.08
Saline water (2.5 dS m^{-1})	29.37	27.62	28.50
Saline water (5.0 dS m^{-1})	25.63	22.09	23.86
Saline water (7.5 dS m^{-1})	17.26	15.26	16.26
Mean	26.19	24.16	
CD (5%) : Irrigation frequency (F) = 1.25, Salinity (S) = 1.77, F XS = NS			

TECHNOLOGY ASSESSED AND TRANSFERRED

1. Economic Impact of Subsurface Drainage Technology in Waterlogged Saline Areas

1.1 Haryana: Three sub-surface drainage project being implemented at Jagsi (Sonipat; 430 ha area with 9 drainage blocks), Siwana Mal (Jind; 295 ha area with 7 drainage blocks) and Mokhra Kheri (Rohtak; 520 ha area with 10 drainage blocks) were studied for the performance evaluation and suitable interventions for better results. In the post-project period, large patches of soil salinity at Jagsi site shrunk by 46% and eventually disappeared from the Landsat data of May, 2014 and February, 2016. This is attributed to efforts of farmers for the timely and regular pumping of sump well during the monsoon season for effective salt leaching/flushing from the affected area. The drainage water was re-used for irrigation of both rice and wheat crops in the project area. The yields of rice and wheat obtained from Jagsi site were at par with that of rice and wheat from normal soils in Haryana. At Siwana Mal and Mokhra Kheri sites, significant improvements observed in seven blocks (JD-1, 2, 5 and 6, and RK-8, 9 and 10) due to farmers' efforts for the timely pumping. At Siwanamal site, notable increase in crop yields (35-110 % in rice and 25- 120% in wheat) in the post-project period was observed in the four selected blocks over pre-project period. The area under moderate and high salinity (ECe >8 ds m^{-1}) reduced from 56.4% in June 2012 to 28.3% in June 2016 at Siwana Mal site. Seven solar pump sets at Siwanamal site are to be shortly installed. At Mokhra Kheri site, significant increase in crop yields (35- 105 % in rice and 40- 110% in wheat) in the post-project period was observed in the three selected blocks over the pre-project period.

1.2 Maharashtra: An impact evaluation study in Dudhgaon village of Miraj taluka, Sangali, Maharashtra indicated the potential of SSD technology in restoring the productivity of waterlogged saline lands. The study village is located in the Krishna river command with lift irrigation system where soil salinity and water logging problems have posed threats to the livelihood security of small and marginal farmers. In Dudhgaon village, the subsurface drainage project was installed under RKVY scheme over an area of 1085 ha benefitting about 1326 farmers. The average cost of SSD installation was Rs. 44000 ha^{-1} at the time of project implementation. Before SSD installation, the average yields of sugarcane, wheat and soybean were 46.3 t ha^{-1}, 1.16 and 0.92 t ha^{-1}, respectively. After SSD implementation, however, average yields increased to 108.7 t ha^{-1} in sugarcane, 2.881 t ha^{-1} in wheat and 2.614 t ha^{-1} in soybean (Table 133). The significant increase in crop yield can be attributed to the direct effect of SSD system which in turn lowered the water table and salinity from the root zone. The average agriculture income of farmers increased from 1.16 lakh to 2.72 lakh (233%) per annum after SSD installation.

Karnataka: Subsurface drainage system was

Field without SSD

Sugarcane crop in SSD ameliorated field

Impact of subsurface drainage before and after installation

Table 133: Yield of crops before and after subsurface installation

Crop	Yield (t ha^{-1})		% increase in yield
	Before SSD	After SSD	
Sugar cane	4.63	108.7	234
Wheat	1.16	2.881	248
Soyabean	0.92	2.614	284

installed during 2009-10 to 2011-12 in the waterlogged saline areas of Ugar Budruk village of Belgaum District covering 925 ha area and benefitting 644 farmers. The per hectare cost of saline land reclamation through SSD installation was estimated at Rs. 52,000. Cropping intensity increased from 62.64% (pre-SSD) to 77.62% (post-SSD) in the ameliorated lands. The mean soil salinity of the project area was 6.63 dS m^{-1} during pre-SSD which reduced to 2.52 dS m^{-1} in post-SSD phase. Net returns increased by 161.81%. During pre-SSD, the B: C ratio was 0.54 which increased to 1.21 in the post-SSD phase. The increase in net income and B: C ratio was largely due to increase in crop yield in the post-SSD phase. The unit cost (on per ton basis) of sugarcane production also reduced from Rs. 4116 to Rs. 1815 showing a significant reduction of 55.91% during post-SSD. This study revealed considerable improvements in the soil properties within 2-3 years of SSD installation. As a consequence, soils became suitable for growing high value crops.

2. Alkali Soil Reclamation through Gypsum Technology for Higher Incomes

Gypsum-based technology package developed by the Institute has become very popular in different sodicity affected states of the country. After successful implementation in Punjab and Haryana states, the technology was later extended to Uttar Pradesh under World Bank aided project. Till now, about 1.95 M ha alkali land has been reclaimed adding about 16 Million tonnes of food grains to national food basket. Taking a cue from the fact that reclamation of entire alkali affected area would further add around 12 M t of food grains to the national pool, sincere attempts are being made to disseminate this technology to other areas. Presently, major thrust of alkali soil reclamation is in Uttar Pradesh and the state has reclaimed 0.73 M ha of alkali land by 2015. The reclaimed alkali lands

Bumper crop of rice in a reclaimed alkali land in Uttar Pradesh

produced 4.42 M t of additional food grains per annum in Uttar Pradesh alone and contributed around 2% to the India's total food grain production. The benefits of sodic land reclamation in Uttar Pradesh were not limited to direct benefits to the farming community but spanned across sectors benefitting the society as a whole. Alkali land reclamation programme contributed highest business transaction in food grain agri-business sector annually (Rs. 60,754 million). It generated additional employment of 116 million person-days (Rs. 14,479 million) per annum.

3. Land Modification Based Integrated Farming System in Waterlogged Sodic Soils

The practical utility of land modification based integrated farming has been successfully demonstrated to improve the productivity of waterlogged sodic lands in Central Indo-Gangetic Plains of India. Models based on 'fish pond' and 'raised and sunken bed' technologies were tested at three sites, namely, Lalaikheda, Patwakheda and Salempur Achaka villages of Lucknow district. Watertable of the area fluctuates within a range of 0.00 to 1.50 m during rainy season and extreme summer, respectively. Wheat cultivar KRL 210,

different *Rabi* vegetables and moong crop in *Zaid* season, grown over raised beds, gave considerably higher yields compared to those grown on unshaped lands in the adjacent fields. For example, wheat crop in *Rabi* 2016 yielded 2.35 t ha^{-1} at Lalaikheda and 3.66 t ha^{-1} at Patwakheda sites with corresponding B: C ratios of 2.51 and 2.67, respectively. Moong crop grown at Lalaikheda during *Zaid* 2016 yielded 0.727 t ha^{-1} with B: C ratio of 3.54. Rice crop (CSR 43) yields for *Kharif* 2016 at Lalaikheda and Patwakheda fields were 4.34 t ha^{-1} and 2.65 t ha^{-1}, respectively with corresponding B: C ratios of 1.99 and 2.37. B: C ratios were: 2.62 for potato, 4.03 for cabbage, cauliflower, brinjal and chilli; and 2.66 for carrot, dill, menthi, spinach, and coriander. Fodder crop was grown during *Kharif* 2016 over raised bed and water chestnut nursery in pond beside fish stocking at Salempur Achaka field. Fodder crop yielded 30 t ha^{-1} giving gross income Rs. 18000.00. About 3 t of water chestnut nursery was produced giving gross income of Rs. 15000.00. Using the fingerlings supplied by NBFGR, Lucknow, fish were cultured in the ponds at Patwakheda and Salempur Achaka sites. Fish grew in size and attained the weight of 325-650 g. Poultry farming and duck rearing were also integrated with fish stocking at Salempur Achaka site. Poultry droppings were used to fertilize the fish pond. Duck culture seemed to improve aeration in the fish pond. These data indicate the worth of land shaping models in enhancing the economic value of highly degraded waterlogged sodic lands in a cost-effective manner. Efforts are being made to disseminate these interventions to other similar locations of the central Uttar Pradesh.

4. Ground Water Recharge for Remediation of Fluoride Contaminated Water

High fluoride (F^-) levels in groundwater in many alkali affected parts of country have gradually emerged as a serious health and environmental concern. WHO standards permit 1.5 ppm while BIS: 105001991 standards permit 1.0 ppm as the safe limit of F^- in drinking water for human consumption. Very high levels of F^- in drinking water (up to 24 ppm) have been reported from Rajasthan. Techniques available for decontaminating F^- laden water such as Nalgonda technique, ion-exchange resins, reverse osmosis and activated alumina are still beyond reach of the poor masses. Groundwater recharge through rain water harvested from roof top through hand pumps may be a possible dilution solution of the F^- problem. A study was undertaken in Unnao district of Uttar Pradesh to demonstrate the feasibility of this approach. One recharge hand pump and one rain water harvesting structure from roof top were designed and installed under medium watertable conditions in Sirsahakhera village of Asoha block in Unnao district. Pumping tests of hand pump were performed before and after recharge. F^- concentration during pumping test ranged from 2.0-2.25 ppm and increased with time under medium watertable conditions. F^- concentration further increased during dry months. Total volume of recharge during 2016 rainy season was 28500 l resulting in an average recharge rate of 310 l day^{-1}. Fluoride concentration significantly decreased after recharge ranging from 0.29-0.82 ppm during October, 2016. Recharge of ground water is an effective measure to dilute F^- concentration in ground water through roof top harvested water.

5. Impact of Salt Tolerant Varieties in terms of additional food grain production and revenue generation

During the year 2016-17, about 17.01 t Basmati rice, 3.28 t Non-basmati rice, 30.18 t wheat and 0.72 t Indian mustard Breeder and TL seeds of salt tolerant varieties were produced and distributed to various seed multiplication agencies, farmers

FLD of CSR-30 on a farmers' field of village Mundadi, Kaithal district

and other stakeholders. The estimated area coverage was 0.51 Million ha with salt tolerant basmati rice occupying the highest area (0.37 M ha) followed by the non-basmati rice (0.13 M ha), wheat (0.01 M ha) and mustard (0.008 M ha). The value of additional production obtained due to adoption of ICAR-CSSRI salt tolerant varieties of rice, wheat and mustard during 2016-17 would be 1.15 million tonnes giving estimated revenue of Rs1676.3 Crores at the national level (Table 134).

6. Front line demonstrations of salt tolerant varieties (Parvender Sheoran and Ranjay K. Singh)

FLDs on Rice: To demonstrate the yield potential of Basmati CSR 30 in saline and sodic soils, a total of 16 farmers' participatory frontline demonstrations were conducted in different villages of Kaithal district adopted under MGMG scheme. An average yield of 2.92 t ha^{-1} was obtained with a range of 2.18-3.55 t ha^{-1} in the demonstrated plots (Table 135).

FLDs on Wheat: A total of 25 front line demonstrations covering an area of 10 ha were conducted in six villages of Panipat and Kaithal districts of Haryana. Soil pH of the demonstration fields ranged from 8.26-9.60 and EC_2 from 0.27-1.03 dS m^{-1}. The RSC of water ranged from 0.9-3.9 me L^{-1} and salinity (EC_{IW}) from 0.49-4.80 dS m^{-1}. Salt tolerant wheat variety KRL 210 was sown in these demonstrations whereas HD 2967 was sown as the local check. The results indicated that KRL 210 gave about 8% higher yield over check variety HD 2967 (Table 136).

7. Sustainable Use of Alkali Waters at Farmer's Field

A field experiment was initiated in June 2014 to evaluate the performance of salt tolerant varieties and ameliorants (gypsum and pressmud) either individually or in combination for sustaining the use of high RSC alkali water in irrigation. Two sites were selected for the experimental purpose in village Mundri, District Kaithal, having RSC_{iw}≈7.0 and 5.0 meq L^{-1}. With the increase in RSC_{iw}, Basmati CSR 30 performed relatively better than Pusa 1211 as evident from narrow yield gaps between two varieties from 16.5% at site I to 9.1% at site II. Better physiological efficiency for salt stress adaptation were recorded in CSR 30 in terms of higher relative water content (RWC) and SPAD values and lower membrane injury and Na^+/K^+ ratio in shoot and root tissues compared to Pusa 1121. Varietal intervention through inclusion of salt tolerant wheat variety KRL 210 can be an important strategy to overcome the yield reduction as well as improving the system productivity. Overall, yield superiority of 11.9% (11.0-12.8%) was recorded with salt tolerant KRL 210 in comparison to HD 2967. Neutralization of RSC water through amendments (gypsum/pressmud) either individually or in combination resulted in 11.6-17.4% (mean 14.7%) higher system (wheat) equivalent yield. Rice and wheat plants grown on amendment treated soils showed higher RWC and SPAD values, lower membrane injury and Na^+/K^+ ratio in shoot and root tissues in comparison to untreated RSC water irrigated plants. Better grain quality and economic returns were observed with neutralization treatments.

8. Impact of CSR-Bio on Crop Production in Uttar Pradesh

Institute has developed CSR-Bio, a bio-growth enhancer based on the integration of microbial consortia for increasing the productivity of crops grown in sodic and normal soils. Farmers are using CSR-Bio on a large scale in cereals, pulses, fruits and vegetable crops. Impact of CSR-Bio on crop production, was studied in Trivediganj block of Barabanki district and Gauriganj block of Amethi district in Uttar Pradesh. The average farm size of the farmers in the study area was 1.56 ha and a majority of the farmers (73%) belonged to marginal and small category. Crop yields were higher with the use of CSR-Bio than non-adopter farms (Table 137). The yield increase was the highest in gram. The yield gain was 0.4 t ha^{-1} (22%) with the use of CSR-Bio. The yield increase was also higher in potato (17.61%), wheat (14.63%), tomato (14.29%), banana (13.64%) and gladiolus (4.12%) crops. Adopters observed that the use of CSR-Bio had improved appearance of the produce, *e.g.*, shinier fruits in banana and tomato; and increase in spike length and brightness in gladiolus flowers enabling the farmers to get higher prices for gladiolus (11%), banana (10%) and tomato (6.25%).

Table 134. Estimated impact of the salt tolerant varieties of rice, wheat and mustard during the year 2016-17

Crop/Variety	Multiplication Ratio	Production year	DAC Indent of Breeder Seed (q)	Certified Seed (q)#	Seed already sold (q) as certified/ TL seed	Total Seed (q) [E+F]	Estimated area coverage (ha) $	Estimated Produce (t) [Based on average productivity of crops in tones] @	MSPs (Rs./q)**	Estimated Value of Produce (Crore Rs.)
A	B	C	D	E	F	G	H	I	J	K
Rice										
Basmati CSR 30	**1:80**	2016	17.28	110592	152.80	110744.8	365457.8	730915.7	1450	1059.80
Non-basmati (CSR 10, CSR 13, CSR 23, CSR 27, CSR 36, CSR 43)		2016	6.00	38400	26.75	38426.8	126808.3	380424.8	1410	536.40
Wheat										
KRL 19, KRL 1-4, KRL 210, KRL 213	**1:20**	2015-16	25.80	10320	276.00	10596	10596	31788.0	1625	51.66
Mustard										
CS 52, CS 54, CS 56	**1:100**	2015-16	00.05	500	6.70	506.70	8463.6	8463.6	3350	28.40
Total			**49.13**	**159812**	**462.25**	**160274.3**	**511325.7**	**1151592.1**		**1676.26**

***http://cacp.dacnet.nic.in/ViewContents.aspx?Input=1&PageId=36&KeyId=0*
#Multiplication of seed from breeder to foundation and foundation to certified seed
$Total seed (q) is multiplied with factor (area covered by one quintal seed); Rice=3.3, Wheat=1, Mustard=16.7
@ Average productivity of Rice= 2t ha-1; Wheat= 3t ha-1, Mustard= 1t ha-1

Table 135 : Soil and water quality and the yield potential of Basmati CSR 30 at different locations in frontline demonstrations during Kharif 2016

District	Village	No. of FLDs	Average yield (t ha^{-1})	Soil		Water		
				EC_2	pH_2	EC	pH	RSC
Kaithal	Mundri	3	3.08 (2.84-3.25)	0.32-1.29	7.28-9.02	0.38-1.96	7.36-8.63	2.9-6.4
	Sampli Kheri	3	2.98 (2.66-3.45)	0.34-0.86	7.56-8.94	0.82-1.62	7.63-7.94	2.6-5.9
	Geong	4	2.87 (2.45-3.21)	0.43-1.06	7.62-9.13	0.43-1.71	7.96-8.56	3.6-6.6
	Kathwar	6	2.18-3.55 (2.86)	0.26-0.96	7.82-8.80	0.26-1.52	7.46-8.32	2.4-7.1
	Total/Mean	16	2.92 (2.18-3.55)					

Table 136: Performance of wheat crop under FLDs in Panipat and Kaithal districts

District	Village	No. of FLDs	Av. yield(t ha^{-1})		Soil		Water	
			KRL 210	HD 2967	EC_2	pH_2	EC	RSC
Panipat	Kaith/Nain	3	4.57	4.27	-	-	3.60-4.80	-
Kaithal	Mundri	8	3.89	3.59	0.27-0.98	8.32-9.10	1.12-1.89	2.2-7.1
	Geong	5	4.80	4.53	0.33-0.57	8.57-8.80	0.49-1.78	1.6-5.3
	Kathawar	4	4.43	4.13	0.56-0.99	8.26-8.85	1.35-2.15	4.3-5.2
	Sampli kheri	4	4.68	4.13	0.27-0.50	8.42-8.62	0.73-1.36	0.9-5.3
	Bhaini Majra	1	4.00	3.80	1.03	9.60	1.40	3.90
	Mean	25	4.40	3.39	-	-	-	-

The impact of adoption of CSR-Bio was assessed in terms of reduction in the use of chemical fertilizers and fungicides. Farmers using CSR-Bio saved 100 kg ha^{-1} DAP fertilizer to be used in banana and tomato crops. They also saved 50 kg ha^{-1} DAP fertilizer (11.28%) in rice. CSR-Bio use also reduced plant protection chemical sprays from 13 to 8 in banana. Farmers saved 3 sprays in tomato and 2 sprays in gladiolus. It reduced the cost of plant protection chemicals by 31% in red gram followed by 27.16% in potato, 25.48% in gladiolus, 8.81% in tomato and 8.59% in banana.

Table 137 : Changes in crop yield and per unit price of crop produce

Crop	Yield (t ha^{-1})			Price per unit (Rs. t^{-1})		
	Non-adopters	Adopters	Change (%)	Non-adopters	Adopters	Change (%)
Banana	41	46	13.64	1000	1100	10.00
Tomato	70	80	14.29	800	850	6.25
Potato	28	33	17.61	900	900	0.00
Rice	60	68	13.33	1450	1450	0.00
Wheat	41	47	14.63	1450	1450	0.00
Red gram	16	20	21.88	3000	3000	0.00
Gladiolus*	230500	240000	4.12	4.5	5	11.11

*Note: * Number of Gladiolus spikes*

Miscellaneous

केन्द्रीय मृदा लवणता अनुसंधान संस्थान

1969

CSSRI

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TRAININGS IN INDIA AND ABROAD

Sr. No.	Name and Designation	Subject	Duration	Place
1	Dr. Raju, R, Scientist	Intellectual property rights and related aspects in the area of agriculture and livestock sector	13.7.2016-15.7.2016	ICAR-NBAGR, Karnal
2	M. V. S. Rajeshwar Rao ACTO	Computer application for Technical Persons of ICAR	18.07.2016-23.07.2016	ICAR- IASRI, New Delhi
3	Dr. Raju, R. Scientist	Designing impact evaluation for agricultural technologies	01.08.2016 - 10.08.2016	ICAR-NRRI, Cuttack
4	Dr. Indivar Prasad & Dr. Jogendra Singh Scientists	Innovative breeding techniques for development of climate smart crops	23.08.2016-12.09.2016	PAU, Ludhiana
5	Dr. Raju, R Scientist	Massive open online training courses on competency enhancement for effective teaching	18.11.2016 - 22.12. 2016	ICAR- NAARM, Hyderabad
6	Dr. Indivar Prasad Scientist	NIAS-DST course on Science, technology and Society: Multi disciplinary perspectives	05.12.2016-16.12.2016	NIAS, Bengaluru
7	Dr. Thimmappa K Senior Scientist	Advances in statistical modeling and forecasting in agriculture	23.12.2016-12.1.2017	ICAR-IASRI, New Delhi
8	Dr. A. K. Bhardwaj Senior Scientist	Workshop cum training program on 'Simulation modelling for climate impact assessment' under NICRA'	14.02.2017-18.02. 2017	IISS, Bhopal
9	Dr. Anita Mann Senior Scientist	DST sponsored training programme on "Science for progress in India: focus on sustainability"	27.02.2017 03.03. 2017	NIAS, Bangaluru
10	Dr. Ashwani Kumar Scientist	Advanced omics-techniques and tools for crop improvement	08.03.2017-28.03.2017	ICAR-IARI, New Delhi.

DEPUTATION OF SCIENTISTS ABROAD

Sr. No.	Name and designation	Subject	Period of deputation	Country
1.	Dr. Ranjay K. Singh, Principal Scientist	Autonomous adaptation to climate change (LBS-ICAR Visiting Fellowship)	01.05.2016-30.06.2016	United Kingdom
2.	Dr. B. Maji, Principal Scientist Dr. U. K. Mandal, Principal Scientist Dr. S. K. Sarangi, Principal Scientist Dr. K. K. Mahanta, Principal Scientist Dr. S. Mandal, Principal Scientist	Inception workshop and impact pathways analysis training under the ACIAR project "Cropping system intensification in the salt affected coastal zones of Bangladesh and West Bengal, India"	02.05.2016-08.05.2016	Bangladesh
3.	Dr. S. K. Sarangi, Principal Scientist	15th Review, Planning and Steering Committee Meeting of the "Consortium for unfavourable rice environments"	24.05.2016-26.05.2016	Philippines
4.	Dr. V.K. Mishra, Head, RRS Lucknow	IWMI- ICAR Steering Committee Meeting at IWMI, Colombo, Sri Lanka	07.07.2016-08.07.2016	Sri Lanka
5.	Dr. A.K. Bhardwaj, Sr. Scientist	TWAS-UNESCO Associateship	04.11.2016-28.12.2016	Argentina
6.	Dr Parvender Sheoran, Senior Scientist Dr. Anshuman Singh, Scientist Dr. Bhaskar Narjary, Scientist	Australian Awards Fellowship	05.02.2017-25.02.2017	Australia

AWARDS AND RECOGNITIONS

- Dr. A. K. Bhardwaj received 'Lal Bahadur Shastri Outstanding Young Scientist Award 2015' of ICAR, New Delhi.
- Dr. S. Mandal received 'ICAR Lal Bahadur Shastri Outstanding Young Scientist Award 2015' of ICAR, New Delhi under the Social Sciences group.
- Dr. Ranjay K.Singh, Principal Scientist (Agril. Extension) received 'Lal Bahadur Shastri Award Visiting Fellowship' to University of Leeds, United Kingdom.
- Dr. D.K. Sharma was bestowed with the 'Gold Medal' of the Indian Society of Agronomy, New Delhi.
- Dr. R.K. Yadav and Dr. Parveen Kumar were elected the 'Fellow' of the Indian Society of Agronomy, New Delhi.
- Dr. R.K. Yadav was elected the 'Fellow' of the Indian Society of Soil Salinity and Water Quality, Karnal.
- Dr. Pavender Sheoran, Dr. Anshuman Singh and Dr. Bhaskar Narjary received the 'Australia Awards Fellowship' of the Government of Australia to attend the international training programme entitled 'Enhancing private sector capability in on-farm irrigation for food security (Indo-Gangetic Plains)' held in Australia from 5-25 February, 2017.
- Dr. Rajkumar was awarded the 'Young Scientist Award 2017' in the '1st National Conference on Advances in Global Research in Agriculture & Technology (AGRAT-2017)' organized by the Society of Human Resource and Innovation Agra, India during 19-20 March, 2017.
- Dr. R. Raju, Scientist (Agril. Economics) received the 'Best Young Scientist Award-2016' in the '3rd International Conference on Agriculture, Horticulture, and Plant Sciences' organized by International Journal of Tropical Agriculture (IJTA) and Serials Publications Pvt. Ltd. New Delhi, India during 25-26 June, 2016.
- Dr. R. Raju, Scientist (Agril. Economics) adjudged as the 'Best Trainee' during ICAR-sponsored 10-days short course on 'Designing impact evaluation for agricultural technologies' organized at ICAR-NRRI, Cuttack during 1-10 August, 2016.
- Dr. R. Raju, Scientist (Agril. Economics) was awarded for Best Paper Presentation (Male) in the memory of Shri. Bhau Punaji Hile Memorial Award in the '2nd International Conference of Agricultural Economics-2017' of Maharashtra Society of Agricultural Economics held at MPKV, Rahuri during 10-11 February, 2017.
- Dr. Arijit Barman received the 'Best Poster Award' in the 'International Conference on Integrated Land Use Planning for Smart Agriculture- An Agenda for Sustainable Land Management' held at ICAR-NBSS & LUP Campus, Nagpur during 10-13 November, 2016.
- Dr. S. K. Sarangi received the 'Best Poster Award' in the '5th National Seminar on Climate Resilient Saline Agriculture: Sustaining Livelihood Security' held at Swami Keshwanand Rajastahan Agricultural University, Bikaner during 21-23 January, 2017.
- Dr. Madhu Chaudhary received the 'Best Poster Award' in the '5th National Seminar on Climate Resilient Saline Agriculture: Sustaining Livelihood Security' held at Swami Keshwanand Rajastahan Agricultural University, Bikaner during 21-23 January, 2017.
- Dr. A. K. Bhardwaj bestowed with the 'Best Poster Award' in the 'XIII Agricultural Science Congress held during 21-24 February, 2017 at UAS, Bengaluru.
- Dr. R. K. Yadav was identified as the 'Resource Person' by AARDO, New Delhi and FICCI-DST, New Delhi.
- Dr. A. K. Bhardwaj was appointed the 'Editorial Board Member' of Ecological Processes (Springer-Nature) for the period of 2016-2020 and Journal of Environmental and Social Sciences.

LINKAGES AND COLLABORATIONS

Collaborative Programmes at Main Institute, Karnal

International Collaboration

- Stress Tolerant Rice for Poor Farmers of Africa and South Asia (IRRI-BMGF)
- Climate Change, Agriculture and Food Security (CCAFS, CIMMYT, Mexico)
- Novel Genetics Stocks: Multi-parent advanced generation inter-crosses (MAGIC) among diverse genotypes to facilitate gene discovery for various traits in rice (IRRI).
- Research Institute of Theoretical & Applied Physical Chemistry (INIFTA), La Plata, Argentina (UNESCO-TWAS-CONICETS).

National Collaborations

- Transgenics in crops-salinity tolerance in rice: functional genomics component (ICAR)
- Establishment of National Database on rice. (DBT, New Delhi)
- Intellectual property management and transfer/commercialization of agricultural technology system (ICAR)
- Network project on improvement of salt tolerance in wheat using molecular approach (IIWBR-CSSRI)
- Wheat improvement for water logging, salinity and element toxicities in India (IIWBR, Karnal)
- Molecular genetic analysis of resistance/ tolerance in rice, wheat, chickpea and mustard including sheath blight complex genomics (ICAR)
- Monitoring and evaluation of large-scale subsurface drainage projects in the state of Haryana (Haryana Operational Pilot Project, DOA, Haryana)
- Farmers' participatory diagnostic survey using modern techniques and demonstrating technological interventions for sustainable use of poor quality waters to enhance agricultural productivity in Haryana– (RKVY)
- Identification of salt tolerant ber (*Zizyphus mauritiana* Lam.) rootstocks in a farmer participatory mode. - (RKVY)
- AMAAS-Application of micro-organism in agriculture and allied sectors (ICAR)
- Developing the alternate strategies for reclamation of sodic (Reliance Industries Ltd.)
- Mineral nutrient diagnostic and site specific nutrient management demonstrations to improve agricultural productivity of salt affected soils in Haryana. (RKVY)
- Empowering farmers through selective interventions in salt affected agroecosystems of Ghaghar Plains.(ICAR)
- An inter-institutional collaborative project on Evaluation of Salinity Tolerance of Coriander, Fennel and Fenugreek Seed Spices (NRC on Seed Spices, Ajmer, Rajasthan).

Regional Research Station, Canning Town (W.B.)

International Collaborations

- IRRI: Development of crop and nutrient management practices in rice
- IRRI-STRASA Project on stress tolerant rice for poor farmers in Africa and South Asia
- CSIRO, Murdoch University, Australia - Cropping system intensification in the salt affected coastal zones of Bangladesh and West Bengal, India
- Bangladesh Agricultural Research Institute, Bangladesh Rice Research Institute, Khulna University - Cropping system intensification in the salt affected coastal zones of Bangladesh and West Bengal, India

National Collaborations

- Coastal salinity tolerant varietal trial (CSTVT) and national salinity and alkalinity screening nursery (NSASN) with IIRR, Hyderabad
- Strategies for sustainable management of degraded coastal land and water for enhancing livelihood security of farming communities with RAKVK, West Bengal, CIBA, Chennai, CARI, Port Blair and BCKV, West Bengal
- Coastal salinity tolerant variety trial (CSTVT)

with IIRS, Hyderabad

- ICAR-Indian Institute of Wheat and Barley Research (IIWBR), Karnal, Haryana.
- Bidhan Chandra Krishi Viswavidyalaya (BCKV), West Bengal
- Tagore Society for Rural Development (TSRD), West Bengal
- ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Kolkata Centre
- ICAR-Central Institute of Freshwater Aquaculture, Rahara, Kolkata
- ICAR-Central Research Institute for Jute and Allied Fibres (CRIJAF), Barrackpore
- Department of Agriculture, Government of West Bengal
- Department of Soil Conservation, Government of West Bengal

Regional Research Station, Lucknow (U.P.)

International Collaborations

- Stress tolerant rice for poor farmers in Africa and South Asia (IRRI)
- Piloting and up-scaling an innovative underground approach for mitigating urban floods and improving rural water security in South Asia (IWMI)

National Collaborations

- Bio-remediation of Salt Affected Soils of UP through Halophilic microbes to promote organic farming (UPCAR)
- Land Modification based integrated farming system under waterlogged and waterlogged sodic conditions (UPCAR)
- Assessment and refinement of existing irrigation practices of major crops grown under sodic environment (UPCAR)
- Identification of salt tolerant microbes and development of dynamic substrate for cultivation of commercial crops in sodic soils (AMAAS)
- An inter-institutional collaborative project on Impact assessment of pesticides on environment using EIQ tool under rice cropping system (NCIPM, Pusa, New Delhi)
- An inter-institutional collaborative project on Development of bioformulation(s) for low input organic farming (NBAIM, Mau)

Regional Research Station, Bharuch (Gujarat)

National Collaboration

- Navsari Agricultural University, Navsari
- Anand Agricultural University, Anand
- Junagadh Agricultural University, Junagadh
- ICAR-Central Institute of Cotton Research, Nagpur
- ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur
- ICAR-Indian Institute of Water Management, Bhubaneshwar
- ICAR Indian Institute of Wheat and Barley Research, Karnal
- Gujarat Narmada Valley Fertilizer Company Ltd., Bharuch
- College of Agriculture, Bharuch
- Cotton Research Station, Surat.
- Cotton Research Station, Bharuch
- VIKAS-NGO, Ahmedabad.
- ATAPI Seva Foundation, NGO Jambusar
- Bidhan Chandra Krishi Visva Vidyalaya, Kalyani (West Bengal)
- Water Technology Centre, TNAU, Coimbatore (TN)
- Krishi Vikas Kendra, Surat, Gujarat
- Krishi Vikas Kendra, Dediapada, Dist. Narmada
- Krishi Vikas Kendra, Chaswad, Dist. Bharuch
- Subham Seeds, Hyderabad (Maize)
- All India Coordinated Cotton Improvement project , Coimbatore
- Monsanto India Limited
- Maharashtra Hybrid Seeds Co Pvt Ltd. (MAHYCO)

NEW LINKAGES WITH NATIONAL AND INTERNATIONAL AGENCIES

- Cropping Systems Modeling to Promote Food Security and the Sustainable Use of Water Resources in South Asia with SAARC Agriculture Centre (SAC) and CSIRO, Australia
- Recent Space Technologies and Image Interpretations for Mapping and Characterizing Salinity Affected Areas with Higher Accuracies with National Remote Sensing Centre (NRSC), Hyderabad, State Remote Sensing Application Centres (RSAC) and ICAR-NBSS&LUP, Nagpur
- Academic linkages with Institute of Environmental Studies, Kurukshetra University, Kurukshetra, Haryana; Department of Biotechnology, Maharishi Markandeshwer University, Mullana, Haryana; and ICAR-NDRI, Karnal, Haryana for Post Graduate teaching and research
- For collaborative research on seed spices with ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan
- Sardar Vallahbhai Patel University of Agriculture & Technology, Meerut (UP)
- CCSHAU, Hisar, Haryana for collaborative research
- Punjabi University, Patiala, Punjab
- Research Institute of Theoretical & Applied Physical Chemistry (INIFTA), La Plata, Argentina (funding from UNESCO-TWAS-CONICETS) for collaborative research.
- Development of efficient and cost effective materials for remediation of salt-affected soils with Centre for Environmental Science and Engineering (CESE), Indian Institute of Technology, Kanpur, India,
- International Rice Research Institute, Philipines
- CIMMYT,Mexico
- ACIAR, Australia
- ICAR-NRCPB, New Delhi, ICAR-IARI, New Delhi, ICAR-NRRI, Cuttack, ICAR-IIPR, Hyderabad, ICAR-IIWBR, Karnal, ICAR-DRMR, Bharatpur

LIST OF PUBLICATIONS

Journal Papers

Angchuk, D., Singh, R.K., Chorol, S., Tamchos, T. and Katyar, A. 2016. Local institutions for sustainable management of common property resources: Learning from Nubra valley of Leh district, India. *Indian Journal of Traditional Knowledge*, 15: 395-402.

Arora, Sanjay, Singh, Y.P., Vanza, M. and Sahni, D. 2016. Bioremediation of saline and sodic soils through halophilic bacteria to enhance agricultural production. *Journal of Soil and Water Conservation, India*, 15: 302-305.

Arora Sanjay, Singh Y. P., Singh A. K., Mishra V. K., and Sharma D. K. 2016. Effect of organic and inorganic amendments in combination with halophilic bacteria on productivity of rice-wheat in sodic soils. *Bhartiya Krishi Anusandhan Patrika,* 31: 165-170.

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Bhattacharyya, R., Ghosh, B.N., Dogra, P., Mishra, P.K., Santra, P., Kumar, S., Fullen, M. A., Mandal, U.K., Anil, K. S., Lalitha, M., Sarkar, D., Mukhopadhyay, D., Das, K., Pal, M., Yadav, R., Chaudhary, V. P. and Parmar, B. 2016. Soil conservation issues in India. *Sustainability*, 8:1-37.

Bundela, D. S., Kaledhonkar, M. J., Gupta, S. K., Lal, M., Kamra, S. K., Sharma, D. K., Sharma, P. C. and Chaudhari, S. K. 2016. Cost estimation of sub surface drainage systems for reclamation of waterlogged saline lands. *Journal of Soil Salinity and Water Quality,* 8:131-143.

Chaudhary, D. P., Kumar, A., Kumar, R., Singode, A., Mukri, G., Sah, R.P., Tiwana, U. S. and Kumar, B. 2016. Evaluation of normal and speciality corn for fodder yield and quality traits. *Range Management and Agroforestry,* 37: 79-83.

Choudhary, A.D., Haritha, G., Sunita, T., Krishanmurthy, S.L., Divya, B., Padmavathi, G., Ram, T. and Sarla, N. 2016. Haplotyping of rice genotypes using SSRs associated with salt tolerance. *Rice Science*, 23: 317–325.

Choudhary, M., Sharma, P. C., Jat, H. S., Nehra, V., McDonald A. J. and Garg, N. 2016. Crop residue degradation by fungi isolated from conservation agriculture fields under rice-

wheat system of North-West India. *International Journal of Recycling of Organic Waste in Agriculture*, 5: 349-360.

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PARTICIPATION IN CONFERENCE/SEMINAR/SYMPOSIUM/WORKSHOP

Name	Title	Period
Dr. Krishnamurthy, S. L. Dr. P.C. Sharma Dr. B. Maji Dr. Y.P. Singh Dr. D. Burman Dr. Krishnamurthy	51st All India Annual Rice Group Meeting held at Raipur	02.04.2016 - 05.04.2016
Dr. S. K. Sarangi Dr. M. J. Kaledhonkar Dr. R. L. Meena	Annual review and planning workshop of "Stress Tolerant Rice for Africa and South Asia" (STRASA) held at Bhubaneswar	25.04.2016- 28.04. 2016
Dr. B. L. Meena	Annual Review Meeting of AICRP on Management of salt affected Soils and Use of Saline Water in Agriculture, ICAR-CSSRI, Karnal	06.05.2016- 07.05. 2016
Dr. S. K. Sanwal	XXXIV AICRP-VC Group Meeting held at ICAR-IARI, New Delhi	10.05.2016-13.05. 2016
Dr. R. Raju Dr. S. K. Sarangi	IJTA 3rd International Conference on Agriculture, Horticulture, and Plant Sciences held at New Delhi	25.06.2016-26.06. 2016
Dr. K. K. Mahanta	All India Seminar on Post Harvest Management of Fruits And Vegetables held at Kolkata, West Bengal	01.06.2016-02.06. 2016
Dr. P.C. Sharma Dr. Arvind Kumar	55th All India Wheat and Barley Workshop Meet held at CCSHAU, Hisar, Haryana	21.07.2016- 24.07.2016
Dr. P.C. Sharma Dr. Jogendra Singh	23rd Annual AICRP (Rapeseed & Mustard) group meeting held at DUVASU, Mathura (U.P.)	05.08.2016- 07.08.2016
Dr. Ashim Datta	SAARC Regional Training on Climate Change Impact on Soil Carbon Storage and Turnover under Different Land Use Systems held at ICAR-IISS, Bhopal	16.08.2016 -23.08.2016
Dr. Krishnamurthy, S. L. Dr.Arijit Barman	International Conference on Agricultural Science and Food Technologies for Sustainable Productivity and National Security	25.08.2016 - 27 .08.2016
Dr. Madhurama Sethi Dr. D.K. Sharma Dr. R.K. Yadav Dr. D.S. Bundela Dr. Anita Mann	International Conference on Integrated Land Use Planning for Smart Agriculture- An Agenda for Sustainable Land Management held at Nagpur, India	10.09.2016-13.09.2016

Dr. B. L. Meena	81st Annual Convention of Indian Society of Soil Science held at Gwalior	20.10.2016- 23.10.2016
Dr. Thimmappa K	Workshop on Right to Information Act at NASC, New Delhi	21.10.2016
Er. A. L. Pathan	Review Meeting of the CRP on Conservation Agriculture held at New Delhi	25.10.2016
Dr. B. L. Meena	1st International Agro-biodiversity Congress	06.11.2016-09.11.2016
Dr. Ashwani Kumar	International Conference on Climate Change and its Implication on Crop Production and Food Security, 2016 held at Varanasi	12.11.2016- 13.11 2016
Dr. M. J. Kaledhonkar	Confederation of Indian Industry (CII) Conference on Making Indian Agriculture Sustainable Focus on Natural Resource Management, Climate Smart Agriculture and Renewable, Energy held at Chandigarh	21.11.2016
Dr. P.C. Sharma Dr. D.K. Sharma Dr. R. K. Yadav Dr. B. Maji Dr. S. K. Sarangi Dr. R. L. Meena Dr.Thimmappa K Dr.P. Sheoran Dr. Madhu Choudhary Dr. Bhaskar Narjary	4th International Agronomy Congress on Agronomy for Sustainable Management of Natural Resources, Environment, Energy and Livelihood Security to Achieve Zero Hunger Challenge held at ICAR-IARI, New Delhi	22.11.2016-26.11.2016
Dr. D. S. Bundela	National Workshop on Challenges in Irrigation Management for Food Security held at IIT, Roorkee	26.11. 2016- 27.11.2016
Dr. R. K. Banyal	National Symposium on Agroforestry for Environmental Challenges, Sustainable Land Use, Biodiversity Conservation and Rural Livelihood Options held at Jhansi.	03.12.2016- 05.12.2016
Dr. D.S. Bundela Dr.Satyendra Kumar Dr.Narjary Bhaskar Dr. U. K. Mandal	Annual review workshop of National innovations on Climate Resilient Agriculture, held at NASC Complex, New Delhi	09.12.2016-10 .12. 2016

Dr. P.C. Sharma Dr. R.K. Yadav Dr. Anil R. Chinchmalatpure Dr. M.J. Kaledhonkar Dr. D.S. Bundela Dr. R.K. Singh Dr. S.K. Sanwal Dr. R.L. Meena	Biennial Workshop of AICRP on Management of Salt-Affected Soils & Use of Saline Water in Agriculture held at SKRAU, Bikaner	19.01.2017-20.01.2017
Dr. P.C. Sharma Dr. D.K. Sharma Dr. R.K. Yadav Dr. M.J. Kaledhonkar Dr. D.S. Bundela Dr. R.K. Singh Dr. S.K. Sanwal Dr. R.L. Meena & other scientists	5th National Seminar of Indian Society of Soil Salinity & Water Quality on 'Climate Resilient Saline Agriculture Sustaining Livelihood Security' held at Bikaner, Rajasthan	21.01.2017- 23.01.2017
Dr. Anil R. Chinchmalatpure	Review Meeting of Agri-CRP on Water Platform Project entitled Ground Water Contamination due to Geogenic Factors and Industrial Effluents and its Impact on Food Chain held at TNAU, Coimbatore	30 .01. 2017
Er. A. L. Pathan Er. R.S.Tolia	National Drainage Stakeholders Meeting held at ICAR-CSSRI, Karnal	06.02.2017
Dr. R. Raju	2nd International Conference of Agricultural Economics-2017 of MSAE held at MPKV, Rahuri, Maharashtra	10.02.2017-11. 02. 2017
Dr. A.K. Bhardwaj	Workshop cum training program on 'Simulation Modelling for Climate Impact Assessment' under NICRA at Indian Institute of Soil Science, Bhopal	14-18 Feb, 2017
Dr. R. K. Banyal	National workshop on Agroforestry-Present Status, Opportunities and Challenges held at Yamunanagar.	15.02.2017-16.02.2017
Dr. Jogendra Singh	3rd National Brassica Conference (NBC-2017) on Enhancing Oilseed Brassica production through Climate-Smart Technologies held at the ICAR-IARI, New Delhi	16.02.2017-18.02. 2017
Dr. M. J. Kaledhonkar Dr. Satyendra Kumar Dr. A. L. Pathan	51st Annual Convention of ISAE & National Symposium on Agricultural Engineering for Sustainable and Climate Smart Agriculture held at CCSHAU, Hisar	16.02.2017- 18.02. 2017

Dr. Anita Mann Dr. U. K. Mandal	Swarna Jayanti National Conference on Biodiversity & Sustainable Utilization of Plant Resources held at Kurukshetra University, Kurukshetra	17.02.2017- 18.02.2017
Dr. A. K. Bhardwaj	XIII Agricultural Science Congress-2017 on Climate Smart Agriculture held at Bengaluru	21.02.2017- 24.02.2017
Dr. Jogendra Singh Dr. D.S. Bundela Dr. Satyendra Kumar	International Seminar on Oilseed Brassica-2017 held at SIAM, Jaipur	23.02.2017-27.02.2017
Dr. Anita Mann	Two days Workshop on Molecular Characterization of Genetic Variability in Medicinal Plant held at UIET, Kurukshetra	09.03.2017-10.03.2017
Dr. D. Burman & Scientists	Regional Seminar and Farmers' Interaction on Coastal Ecosystem of India: Recent Developments and Future Strategies held at ICAR-NIRJAFT, Kolkata, West Bengal	18.03. 2017
Dr. Ashim Datta Dr. M.J. Kaledhonkar	Training-cum-workshop on Potential Application of Quantitative Analysis Tools In Farming Systems Using Farm Design held at ICAR-IIFSR, Modipuram	17.03.2017- 18.03.2017
Dr. R.L. Meena	World Water Day 2017 celebration at ICAR-IARI, New Delhi	27 03.2017

LIST OF ON GOING PROJECTS

Institute Funded

Priority area - Data Base on Salt Affected Soils & Poor Quality Waters

1 P1-2011/DBR3.1-ISR-F24./F20 Mapping and characterization of salt affected soils in Central Haryana using remote sensing and GIS (A. K. Mandal, Ranbir Singh and P. K. Joshi)

2 NRMACSSRISIL201400400862.Assessment and mapping of salt affected soils using remote sensing and GIS in Rewari and Mahendragarh districts of Haryana State (Madhurama Sethi, Anil R. Chinchmalatpure, Nirmalendu Basak Ashim Datta, Anil Yadav (KVK Rewari) and M. L. Khurana, Soil Testing Lab. Karnal)

Priority Area - Reclamation and Management of Alkali Soils

3 P1-2011/ASM5.1-ISR-F25/F27/0150/0180. Nutrient management strategies for sustainable rice and wheat production in reclaimed alkali Soils. (A. K. Bhardwaj, Nirmalendu Basak, Parveen Kumar and D. K. Sharma)

4 NRMACSSRISIL201300700852. Optimizing zinc and iron requirement of pearl millet-mustard cropping system on a salt affected soil. (B. L. Meena, Parveen Kumar, Ashwani Kumar, R. L. Meena and M. J. Kaledhonkar)

5 NRMACSSRISIL201400100859. Effect of land uses on salt distribution and properties of salt affected soils. (Ashim Datta, Nirmalendu Basak, Anil R. Chinchmalatpure and Rakesh Banyal)

6 NRMACSSRISIL201400600864. Nutrient and residue management of ZT-DSR basmati rice-ZT wheat cropping system under partially reclaimed sodic soils. (Parveen Kumar, D. K. Sharma, R. K. Yadav, A. K. Rai and Ashwani Kumar)

7 NRMACSSRISIL201500100877. Impact assessment of CSR-BIO on livelihood security of farmers in salt affected regions. (Thimmappa K., T. Damodaran and Raju R.)

8 NRMACSSRISIL201501300889. Impact of secondary salinization and other stressors on agricultural systems: constraints analysis in South-Western Punjab. (R. K. Singh, Satyendra Kumar, Anshuman Singh, Nirmalendu Basak, Randhir Singh and D. K. Sharma)

9 NRMACSSRISIL201600400902. Farmer participatory enterprise mix diversification on reclaimed sodic land (Gajender, R. Raju, A.K. Rai, R. K. Yadav, Madhu Choudhary, Raj Kumar, K. S. Kadian and D. K. Sharma)

10 NRMACSSRISIL201600100899. Characterization and application of sewage sludge and municipal solid waste compost for reclamation of sodic soils. (Parul Sundha, A. K. Rai, Gajender Yadav and Nirmalendu Basak)

Priority Area - Drainage Investigations and Performance Studies

11 NRMACSSRISIL2014001000868. Impact assessment of subsurface drainage technology in canal command areas of Karnataka. (R. Raju, Thimmappa K., Pathan and Aslam Latif]

12 NRMACSSRISIL201501400890. Performance evaluation of subsurface drainage systems in Haryana and to implement interventions for improving operational performance and impact. (D. S. Bundela, Bhaskar Narjary, Pathan Aslam Latif, R. Raju, Parvender Sheoran, R. K Singh, S. K. Kamra and D. K. Sharma)

Priority Area - Management of Marginal Quality Waters

13 NRMACSSRISIL201300200847. Hydro-physical evaluation of a rain water harvesting system under saline soil and groundwater environment. (Bhaskar Narjary, Satyendra Kumar, M. D. Meena, S. K. Kamra and D. K. Sharma)

14 NRMACSSRISIL201400300861. Improving farm productivity through sustainable use of alkali waters at farmer's field in rice-wheat production system. (Parvender Sheoran, R. K. Yadav, Nirmalendu Basak, Satyendra Kumar, K. Thimmappa and R. K. Singh)

15 NRMACSSRISIL201400700865. Conjunctive water use strategies with conservation tillage

and mulching for improving productivity of salt affected soils under limited fresh water irrigation.(Arvind Kumar Rai, R. K. Yadav, Anil Chinchmalatpure, Nirmalendu Basak, Satyendra Kumar, Bhaskar Narjary, Gajender Yadav, A. K. Bhardwaj, Madhu Choudhary and D. K. Sharma)

16 NRMACSSRISIL201500300879. Evaluation of commercial vegetable crops under protected cultivation structures in saline environment (R. L. Meena, B. L. Meena, Anshuman Singh, S. K. Sanwal and M. J. Kaledhonkar)

17 NRMACSSRISIL201501500891. Assessing use of press mud/press mud compost in gypsum beds for neutralization of RSC in irrigation water. (R. K. Yadav, M. D. Meena, Satyendra Kumar, Parul Sundha, Madhu Choudhary and D. K. Sharma)

18 NRMACSSRISIL201502100897. Isolation, identification and evaluation of plant growth promoting bacteria for mitigating salinity stress in crops. (Madhu Choudhary, P. K. Joshi, Vineeth T.V., Gajendra and M. D. Meena)

Priority Area - Crop Improvement for Salinity, Alkalinity and Waterlogging Stresses

19 P1-2011/CIS4.7-ISR-F30/0338. Development of Indian mustard (*Brassica juncea*) genotypes with improved salinity tolerance and higher seed yield. (Jogendra Singh, Vineeth T. V. and P. C. Sharma)

20 NRMACSSRISIL201200100842. Genetic enhancement of wheat with respect to salt and waterlogging tolerance. (Arvind Kumar P. C. Sharma, Y. P. Singh and Indivar Parsad)

21 NRMACSSRISIL201300600851. Physiological and biochemical basis of salinity and draught stresses tolerance in rice and wheat cropping system. (Ashwani Kumar, Krishnamurthy S. L. and Arvind Kumar)

22 NRMACSSRISIL201400900867. Growth and physiology of guava (*Psidium guajava* L. cv. Allahabad Safeda) and bael (*Aegle marmelos* Correa cv. Narendra Bael-5) under salinity stress. (Anshuman Singh, R. K. Yadav, Ashwani Kumar and Ashim Datta)

23 NRMACSSRISIL201500800884. Identification of high yielding and salt tolerant genotypes in pomegranate. (Raj Kumar, R. K. Yadav, Anita Mann, M. D. Meena, Anshuman Singh and D. K. Sharma)

24 NRMACSSRISIL201500900885. Genetic enhancement of tomato (*Solanum lycopersicum*) and okra (*Abelmoschus esculentus* L) to salt tolerance. (S. K. Sanwal, P. C. Sharma, Anita Mann, Rajkumar and A. K. Rai)

25 NRMACSSRISIL201501000886. Improvement of salt tolerance in chickpea through physiological and breeding approaches. (Anita Mann, Jogendra Singh and P. C. Sharma)

26 NRMACSSRISIL201501100887. Development of rice genotypes for salt tolerance in rice: Conventional and Molecular approaches. (Krishnamurthy, S. L., P. C. Sharma, Ravi Kiran K. T., Vineeth T. V., Y. P. Singh, S. K. Sarangi)

Priority Area - Agroforestry in Salt Affected Soils

27 NRMACSSRISIL201400800866. Enhancing productivity potential of saline soil through agroforestry system using saline irrigation.(Rakesh Banyal, R. K. Yadav, Bhaskar Narjary, Parvender Sheoran, M. D. Meena and D. K. Sharma)

28 NRMACSSRISIL201600200900. Performance of *Eucalyptus* plantations on water logged saline ecologies. (R. Banyal, A. K. Bhardwaj, Gajender and Ashlam Pathan)

29 NRMACSSRISIL201600300901. Evaluation of agroforestry trees in saline environment. (R. Banyal, A. K. Bhardwaj, Parveen Kumar, R. K. Yadav, Aslam L. Pathan)

Priority Area - Reclamation and Management of Coastal Saline Soils

30 NRMACSSRISIL201300500850. Impact of saline water on solar powered drip irrigated rabi crops in coastal soils of West Bengal. (K. K. Mahanta, S. K. Sarangi, U. K. Mandal, D. Burman and B. Maji)

31 NRMACSSRISIL201401100869. Long term impact of land shaping techniques on soil and water quality and productivity of coastal degraded land. (D. Burman, U. K. Mandal, S. K.

Sarangi, S. Mandal, K. K. Mahanta, S. Raut and B. Maji)

32 NRMACSSRISIL201600500903. Conservation agriculture for rice-maize cropping system in coastal saline region. (S. K. Sarangi, B. Maji, U. K. Mandal, K. K. Mahanta and T. D. Lama)

33 NRMACSSRISIL201600600904. Study of soil salinity in relation to land use and land cover in coastal areas of West Bengal using remote sensing and GIS.(S. Raut, B. Maji and D. Burman)

34 NRMACSSRISIL201600700905. Assessment and coping strategies of agricultural risk under coastal region of West Bengal – a social-economic analysis. (S. Mandal, D. Burman, U. K. Mandal and T. D. Lama)

35 NRMACSSRISIL201600800906. Assessing carbon sequestration potential of conservation tillage practices under rice based cropping systems in coastal saline soils. (U. K. Mandal, D. Burman, S. K. Sarangi and T. D. Lama)

36 NRMACSSRISIL201600900907. Impact of deficit irrigation on salt dynamics and crop productivity in coastal saline soils.(T. D. Lama, D. Burman, B. Maji, S. K. Sarangi and K. K. Mahanta)

Priority Area - Reclamation and Management of Salt Affected Vertisols

37 NRMACSSRISIL201200400845. Breeding and evaluation of field crops for salt tolerance in saline Vertisols (Monika Shukla, Anil R. Chinchmalatpure and D. K. Sharma)

38 NRMACSSRISIL201300100846. Soil physical characteristics and nutrient dynamics in Vertisols with subsurface salinity (Anil R. Chinchmalatpure and David Camus D.)

39 NRMACSSRISIL201400200860. Prospects of cultivating desi cotton genotypes and salt tolerant wheat varieties on saline vertisols (Sanjay Kad, Monika Shukla and Anil R. Chinchmalatpure)

40 NRMACSSRISIL201500200878. Performance of guava orchards with forage intercropping and pruning intensity on saline vertisols of Gujarat (David Camus. D., Anil R. Chinchmalatpure and Monika Shukla)

41 NRMACSSRISIL201501200888. Impact evaluation of sub-surface drainage technology for reclamation of water logged saline soils in Maharashtra. (Sanjay Kad, R. K. Singh, R. Raju and D. S. Bundela)

42 NRMACSSRISIL201601000908. Cost effective drainage in waterlogged saline Vertisols for improving crop productivity in Gujarat. (Anil R. Chinchmalatpure, Monika Shukla, David Camus, Sanjay Kad and M. J. Kaledhonkar)

43 NRMACSSRISIL201601100909. Maximization of yield and factor productivity through integrated nutrient management in desi cotton based cropping systems in saline vertisols. (Monika Shukla, Anil R. Chinchmalatpure, Sanjay Kad, David Camus and D. K. Sharma)

Priority Area - Reclamation and Management of Alkali Soils of Central and Eastern Gangetic Plains

44 NRMACSSRICIL201301000855. Harnessing productivity potential of waterlogged sodic soil through intervention of farming system modules in Sarda canal command for livelihood generation. [V. K. Mishra, C. L. Verma, Y. P. Singh, T. Damodaran, S. K. Jha, A. K. Singh, Sanjay Arora, S. K. Singh (NBFGR) and D. K. Sharma]

45 NRMACSSRISIL201500700883. Ground water recharge for remediation of fluoride contaminated water in Unnao district of U.P. (C. L. Verma, S. K. Jha, V. K. Mishra, S. K. Kamra and D. K. Sharma)

46 NRMACSSRISIL201601200910. Screening of salt tolerant polyembryony mango rootstocks and assessment of bio-efficacy of the microbial formulations in control of *Fusarium* wilt of banana and guava. [T. Damodaran, V.K. Mishra, S.K. Jha D.K. Sharma (ICAR-CSSRI), R. M. Khan, S. Rajan (ICAR-CISH) Dr. Bhagwan (YSR University)]

47 NRMACSSRISIL201601300911. Bio-augmenting crop residues degradation for nutrient cycling through efficient microbes to enhance productivity of salt affected soils. (Sanjay Arora, Y. P. Singh and A. K. Singh)

48 NRMACSSRISIL201601400912. Feasibility of marine gypsum an alternative source of mineral gypsum for the reclamation of sodic soils. (S. K. Jha, V. K. Mishra, T. Damodaran, Y. P. Singh and D. K. Sharma).

Externally Funded Research Projects

1. Intellectual property management transfer/ commercialization of agricultural technologies. (Parveen Kumar, D. S. Bundela, R. K. Singh, Jogendra Singh and Anshuman Singh)- ICAR, New Delhi.
2. C2-2006/CIS3.6-ISR-F30/F26/0150. National project on transgenics in Crops. (Functional Genomics component) salinity tolerance in rice. (S.L. Krishnamurthy, P. C. Sharma and Ravi Kiran K.T.) - NRCPB, New Delhi
3. Improvement of wheat for salt tolerance using molecular approach. (P. C. Sharma and Arvind Kumar) – IIWBR, Karnal
4. Establishment of National Database on rice. (S.L. Krishnamurthy and Jogendra Singh) - DBT, New Delhi
5. Stress tolerant rice for poor farmers in Africa and South Asia (STRASA Phase 3). (D. K. Sharma, Krishnamurthy S. L, P. C. Sharma, Ravi Kiran K.T., B. Maji, D. Burman, S. K. Sarangi, S. Mandal, V. K. Mishra and Y. P. Singh)- BMGF
6. Groundwater resource management to mitigate the impact of climate change in Punjab and Haryana. (Satyendra Kumar, S. K. Kamra, Bhaskar Narjary and R. K. Yadav)- NICRA, ICAR, New Delhi
7. NRMACSSRISOL201401200870. Development of effective salt tolerant microbes to mitigate salt stress for higher crop production in salt affected soils. (Madhu Choudhary)- AMAAS
8. NRMACSSRISOL201401300871. Assessment of municipal solid waste in conjunction with chemical amendments of harnessing productivity potential of salt affected soils. (Y. P. Singh, Sanjay Arora and V. K. Mishra)- UPCAR
9. NRMACSSRISOL201401400872. Bio-remediation of Salt Affected Soils of UP through Halophilic microbes to promote organic farming. (Sanjay Arora and Y. P. Singh) -UPCAR
10. NRMACSSRISOL201401500873. Land modification based integrated farming system under waterlogged and waterlogged sodic conditions. (C. L. Verma, Y. P. Singh, T. Damodaran, A. K. Singh, S. K. Jha, V. K. Mishra and D. K. Sharma) -UPCAR
11. NRMACSSRISOL201401600874. Assessment and refinement of existing irrigation practices of major crops grown under sodic environment. (A. K. Singh, Y. P. Singh, C. L. Verma and Sanjay Arora)- UPCAR
12. NRMACSSRISOL201401700875. Identification of salt tolerant microbes and development of dynamic substrate for cultivation of commercial crops in sodic soils. (T. Damodaran, S. K. Jha, V. K. Mishra, D. K. Sharma and Y. P. Singh)- AMAAS
13. NRMACSSRICOP201500400880. Climate change mitigation and adaptation strategies for salt affected soils. (A. K. Bhardwaj, Ranbir Singh, R. K. Singh, Parul Sundha, D. K. Sharma, Rakesh Banyal, U. K. Mandal, Shishir Raut, K. K. Mahanta, B. Maji and V. K. Mishra)-NICRA, ICAR
14. NRMACSSRICOP201500500881. Development of efficient and cost effective alternatives to gypsum using nanotechnology for sodic soils reclamation. [Ajay K. Bhardwaj and Nitish Verma (IIT, Kanpur)]-CPRI, Shimla
15. NRMACSSRICOP201500600882. Wheat improvement for water logging, salinity and element toxicities in India (P.C. Sharma, Arvind Kumar and Nirmalendu Basak)- IIWBR, Karnal
16. NRMACSSRISOL201501600892. Molecular genetic analysis of resistance/tolerance in rice, wheat, chickpea and mustard including sheath blight complex genomics. [(Rice: component 1): Krishnamurthy, S. L., P. C. Sharma and Ravi Kiran K.T.) (Wheat: component 2): P. C. Sharma, Arvind Kumar and Ashwani Kumar) (Chickpea: component 3): P. C. Sharma, Anita Mann and Jogendra Singh) (Mustard:

component 4): P. C. Sharma, Jogendra Singh and Vineeth T. V.)]- ICAR, New Delhi

17. NRMACSSRISOL201501700893. Novel Genetics Stocks: Multi-parent advanced generation inter-crosses (MAGIC) among diverse genotypes to facilitate gene discovery for various traits in rice. (Krishnamurthy, S.L. and P.C. Sharma)- IRRI-ICAR
18. NRMACSSRISOL201501800894. CRP on Agro-Biodiversity-Evaluation of rice germplasm for salinity/sodicity. (Krshnamurthy S. L., P. C. Sharma and Ravi Kiran K. T.)
19. NRMACSSRISOL201501900895. Identification of salt tolerant ber (*Zizyphus mauritiana* Lam.) rootstocks in a farmer participatory mode. (Anshuman Singh, Ashwani Kumar, Parvender Sheoran, R. K. Singh, Raj Kumar, R. K. Yadav and D. K. Sharma)- RKVY
20. NRMACSSRISOL201502000896. Farmers' participatory diagnostic survey using modern techniques and demonstrating technological interventions for sustainable use of poor quality waters to enhance agricultural productivity in Haryana. (Parvender Sheoran, R. K. Yadav, D. S. Bundela, B. L. Meena and A. K. Mandal, R. K. Singh, Randhir Singh and D. K. Sharma)- RKVY
21. NRMACSSRISOL201502200898. CRP on Conservation Agriculture: Productive utilization of salt affected soils through conservation agriculture. (Ranbir Singh, Arvind Kumar Rai, Parvender Sheoran, Pathan Aslam Latif and D.K. Sharma)- ICAR
22. NRMACSSRISOL201601500913. Strategic Research Platform on Climate Smart Agriculture: Developing and defining climate smart agricultural practices portfolios in South Asia [P.C. Sharma (PI), Ashim Datta and Madhu Chaudhary) ICAR-CIMMYT
23. NRMACSSRISOL201601600914. Perceived climatic variability & agricultural adaptations by material resource-poor farmers in salt affected agroecosystems: Implications for food & livelihood security. [Ranjay K. Singh, Anshuman Singh, Satyendra Kumar, P.Sheoran, Thimmappa K, D. K. Sharma and Dheeraj Singh, KVK, Pali (CAZRI)]- ICAR
24. NRMACSSRISOL201601700915. Spatio-temporal monitoring of secondary salinization in the Indira Gandhi Canal Command using geoinformatics (D. S. Bundela, Bhaskar Narjary, R. L. Meena, A. K. Mandal, Madhurama Sethi and D. K. Sharma)
25. NRMACSSRISOL201601800916. Efficient groundwater management for enhancing adaptive capacity to climate change in sugarcane based farming system [(S.K. Kamra) (CCPI) Satyendra Kumar, Aslam Latif Pathan and D.K. Sharma]- ICAR
26. NRMACSSRISOL201601900917. ICAR-Extramural project: Up-scaling of *in-vitro* mass multiplication and bio-hardening technology of banana var. Grand Naine under North Indian plains for sustainable production of quality planting material (T. Damodran, V. K. Mishra and S. K. Jha)- ICAR
27. NRMACSSRICOP201602100919. CRP on Water: Groundwater contamination due to geogenic factors and industrial effluents and its impact on food chain (Anil R. Chinchmalatpure, David Camus and Monika Shukla)-ICAR
28. NRMACSSRISOL201602000918. CRP on Water: Evaluation of irrigation system and improvement strategies for higher water productivity in canal command (C. L. Verma, A. K. Singh, Y. P. Singh, Sanjay Arora, T. Damodaran, V. K. Mishra, S. K. Jha, C. S. Singh and D. K. Sharma)
29. NRMACSSRICOP201602200920. Cropping system intensification in the salt-affected coastal zones of Bangladesh and West Bengal, India (LWR/2014/73/KGF). (Budheswar Maji, D. Burman, U. K. Mandal, S. K. Sarangi, Subhasis Mandal and K.K. Mahanta)- ACIAR.
30. NRMACSSRICOP201602300921. Piloting and up-scaling an innovative underground approach for mitigating urban floods and improving rural water security in South Asia (V. K. Mishra, C. L. Verma and S. K. Jha)- IWMI
31. Developing the alternate strategies for

reclamation of sodic soils [A. K. Rai, Nirmalendu Basak, R. L. Meena, Parul Sundha, R. K. Yadav, D. K. Sharma S.K. Jha and U.R. Khandkar, AICRP (MSUSWA), Indore]- Reliance Industries Ltd.

32. Mineral nutrient diagnostic and site specific nutrient management demonstrations to improve agricultural productivity of salt affected soils in Haryana. (Anita Mann, R. K Yadav, Parvender Sheron, Ashwani Kumar and B. L. Meena)- RKVY

33. Empowering farmers through selective interventions in salt affected agroecosystems of Ghaghar Plains. [Parvender Sheoran, R. K. Yadav, Randhir Singh, Satyendra Kumar, Arvind Kumar, R. Raju, Ashim Datta, S. K. Sanwal and K Punnusamy (NDRI)].

Collaborative Projects

1. Evaluation of seed spices for edaphic stresses. (R. K. Yadav and R. L. Meena)

   (O. P. Aishwath, R. S. Mehta, P. N. Dubey- NRCSS, Ajmer; B. K Jha- Ranchi)

2. Land use options for enhancing productivity and improving livelihood in Bali Island of Sundarbans. [S. Mandal (NBSSLUP-Kolkata, CSSRI RRS Canning Town and CIFA – Kalyani)]

3. Study the effect of salinity stress on jute (*C. capsularis & C. olitorius*). [Uttam Kumar Mandal (Co-PI) in collaboration with CRIJAF, Barrackpore, Kolkatta]

4. Development of bioformulation(s) for low input organic farming [T. Damodaran (CCPI) in collaboration with ICAR-NBAIM, Mau]

5. Characterization and mining genetic variability in sugarcane germplasm against abiotic stress (salinity/alkalinity and low temperature) under subtropical India (Karnal). [Ashwani Kumar (Co-PI) in collaboration with ICAR-SBI RRS Karnal]

Consultancy

1. Subsurface drainage for heavy soils of Maharashtra, Karnataka and Gujarat (D. K. Sharma and S. K. Kamra)

2. Evaluation of BAYER rice hybrids under salinity stress (P. C. Sharma and Krishnamurthy, S. L.)

3. Utilization of treated effluent from Aniline-TDI Plant of GNFC Unit II in *rabi* maize and its long term impact on properties of Vertisols. (Anil R. Chinchmalatpure, Indivar Prasad, David Camus, Shrvan Kumar, Sagar Vibhute and P. C. Sharma)

INSTITUTE ACTIVITIES

Institute Management Committee Meeting

41st Institute Management Committee meeting was held on 8th March, 2017 at Karnal and was attended by the following IMC Members

1.	Dr. P. C. Sharma, Director, ICAR-CSSRI, Karnal.	Chairman
2.	Dr. S. K. Dubey, Head, IISWC, Regional Station, Agra	Member
3.	Dr. N. G. Patil, Principal, Scientist NBSS&LUP, Nagpur	Member
4.	Dr. P. P. Biswas, Prin. Scientist, ICAR, New Delhi	Member
5.	Sh. Sunil Kumar, FAO, ICAR-NBAGR, Karnal	Member
6.	Sh. Abhishek Srivastava, SAO, CSSRI, Karnal.	Member Sec.

The Meeting started with the confirmation of the proceedings of the last meeting held on 11th January, 2016. Subsequently, the research achievements of different Divisions, Regional Research Stations and Project Coordinating Unit were discussed for the period of May-December, 2016. This was followed by discussion on other activities carried out during May-December. 2016. These included activities by the Institute Rajbhasha Committee, different trainings and Kisan Gosthis organized during the period, the issues related to staff position, Institute budget and expenditure, sale of farm produce, publications, linkages and collaborations. Activities related to '*Swachh Bharat Abhiyaan*' and '*Mera Gaon Mera Gaurav*' programme were also discussed.

Institute Joint Staff Council Meeting

The Institute Joint Staff Council Meeting was held at ICAR-CSSRI Karnal on 20th March, 2017 under the Chairmanship of Dr. P.C. Sharma, Director. It was attended by Dr. R.K. Yadav, Head, SCM Div., Sh. Abhishek Srivastava, SAO, Sh. Anil Sidharth, F&AO, Sh. N.K. Vaid, OIC, Estate and Sh. Tarun Kumar, Sh. Suresh Pal Rana, Sh. Dilbag Singh, Sh. Dharambir Singh, Sh. Dalip Kumar and Sh. Ramesh Kumar. The members discussed the various agenda items and other related issues for the welfare of the Institute staff at length and settled various issues systematically and amicably.

IMC, Meeting in progress

IJC meeting in progress

WORKSHOP, SEMINAR, TRAINING, FOUNDATION DAY AND KISAN MELA ORGANISED

Annual Review Meeting of AICRP on SAS and Poor Quality Water

The Annual Review Meeting of All India Coordinated Research Project on "Management of Salt Affected Soils and Use of Saline Water in Agriculture" was organized during 06-07 May, 2016 at ICAR-CSSRI, Karnal. Dr. P.C. Sharma, Director (A) welcomed the Chief Guest Dr. S.K. Chaudhari, ADG (SWM), ICAR and apprised him about the achievements of 12 centres of the scheme operational in different agro-climatic zones of the country. He emphasized that research being conducted at these centres aims to reduce the cost of cultivation and double the farmers' income by 2022. Dr. Chaudhari appreciated the progress of the scheme and expressed happiness that farmers have benefitted through technologies developed by these centres. He stressed the need to develop location specific technologies for different agro-climatic conditions as well as to address the limitations being posed by the climate change. Dr. D. K. Sharma, Ex. Director, ICAR-CSSRI said that there is a need to promote integrated farming and crop diversification to ensure more income per unit of land and water. Dr. M. J. Kaledhonkar, Project Coordinator discussed the future action plan to improve the overall research output of the scheme.

Discussion during Annual Review Meeting

Brainstorming Session on "Coastal saline soils- problems, solutions, and future research strategies"

A brainstorming session entitled "Coastal saline soils- problems, solutions, and future research strategies" was organised by AICRP on SAS&PQW, Panvel, Maharashtra (Volunteer Centre) and Dapoli Chapter of ISCAR, Canning Town, West Bengal on 13th June 2016 at Khar Land Research Station, Panvel. Dr. Tapas Bhattacharya, VC, Dr. BSKKV, Dapoli inaugurated the session which was attended by many noted researchers and officers engaged in coastal salinity management. The ingress of sea water and reclamation measures, crop production issues, nutrient management, salt tolerant rice varieties and other alternative crops, management of farm ponds, etc. were thoroughly discussed on this occasion.

Brainstorming Session in progress

Swachh Bharat Abhiyan

A number of programmes were organized on Swachh Bharat Abhiyan in different villages viz; Bhudmor (Patiala), Sampli Kheri (Kaithal), Zarifa Viran (Karnal), Sikander Kheri (Kaithal) and at the Main Campus of the Institute during the period under report. Under these programmes, villagers, farmers and school children were sensitized about pressing environmental issues like crop residue burning, importance of cleanliness, advantages of composting of the farm and domestic waste, climate change adaptation, etc. They were motivated for maintaining cleanliness in homes, surroundings, community lands, village roads and farm premises for health and environmental

Glimpesses of swachh bharat abhiyan

benefits. During these events, a few competitions among school children on environmental issues such as soil and water health, agro-biodiversity conservation, local cultural traditions and livelihoods were also organised. Children and farmers were briefed about the value of rice residue incorporation/retention for enhancing the soil organic matter and micriobial activity as well as for reducing the environmental impact of burning. In this series, a seminar on 'Swachhta, Samgatishilta and Paryawaran' was also organized at ICAR-CSSRI, Karnal on 28th October, 2016 during which about 100 farmers, scientists and other employees of the Institute were present. Sh. Aditya Dahiya, Commissioner, Municipal Coorporation, Karnal was the Chief Guest. Safe disposal of solid waste, prevention of crop residue burning, methodology for compost preparation using the farm waste, kitchen gardening using home grown organic inputs and use of solar power in homes and offices were the major issues discussed during this seminar. A few progressive farmers also shared their experience about the adavnages accruing from crop residue management and vermi-composting.

Kisan Gosthis and other activites under *"Mera Gaon Mera Gaurav* (MGMG)" programme

'Mera Gaon Mera Gaurav' (MGMG) policy of the Indian Council of Agricultural Research, New Delhi is being implemented by ICAR-CSSRI, Karnal and its Regional Research Stations located at Lucknow, Bharuch and Canning Town since May, 2015. A total of 13 pre-rabi and 12 Pre-kharif *Gosthis* were organized under MGMG during the period under report in which 2670 farmers participated and benefitted by interacting with the scientists and officials of the state development departments, KVKs, etc. In all *goshthies*, recommended package of practices for growing the major crops in respective regions were thoroughly discussed. In addition, farmers were also sensitized about the benefits of soil test based nutrient use, adoption of water use efficient irrigation techniques, use of organic composts, proper care of dairy animals and different initiatives of Central/State governments to improve farm incomes and sustainability. Specifically, the farmers were encouraged to use the improved seeds of salt tolerant varieties in crops such as rice, wheat and mustard developed by ICAR-CSSRI, Karnal to obtain high productivity in saline, sodic and partially reclaimed soils. During these *goshthies*, individual farmers also raised varied problems related to crops/livestock and were suggested appropriate remedial measures by the experts in the concerned fields. Soil and water samples were also collected from the farmers for free of cost testing and issue of soil/water test reports. Different MGMG teams also conducted 164 visits to the adopted villages and personally contacted 3167 farmers for resolving their agricultural problems through appropriate technological interventions and suggestions. The scientists of the institute provided 267 mobile advisory services benefitting 616 farmers of the

Scientists and Farmers interaction

Some Glimpesses of kisan gosthies

adopted villages. Similarly, literature on different technologies developed was also distributed among 2726 farmers. A total of 256 front line demonstrations on salt tolerant crop varieties were also conducted in different villages.

Kisan Gosthis under LBS Award Project

A *Kisan Gosthi* was organized in Sikander Kheri village of Kaithal district at farmers' field on 12th August, 2016 with aim to enhance the farmers' knowledge and creativity for sustainable crop production under climate change. Farmers of nearby villages interacted with Sh. Rajesh Kumar, a progressive farmer who has pioneered organic vegetable cultivaton in partially reclaimed sodic soils using vermi-compost and organic pesticides. In addition to vegetables, he also grows guar, cotton, wheat and mustard crops. Two *Kisan Gosthis* were organized in sodicity affected Chakwa and Hasanpur villages of Jaunpur district on 24th September, 2016 during which scientists and local KVK experts interacted with about 160 farmers and suggested solutions to their problems. Similarly, two *Kisan Gosthis* were organized in the salinity affected Chidaud and Bhatol Jatan villages of Hisar district during 08-09 November, 2016. The main objective of these *gosthis* was to understand the compounded impacts of salinity, climate change and socio-economic changes on livelihood security of the farmers. Previously, soil and water samples were collected from these villages and analysis report in the form of Soil Health Card was handed over to the farmers to enable them for balanced fertilizer management in crops. Considering the fact that salinity in soil and water is a major problem, efforts have been made to provide the selected farmers in these villages the seeds of salt tolerant rice (Basmati CSR 30, CSR 43), wheat (KRL 210) and mustard crops (CS 54 and CS 56) capable of giving stable yields under saline conditions. During these goshthis, farmers were made aware of climate resilient agronomic practices, efficient irrigation techniques, different government schemes such as 'Kisan Credit Card' and 'Crop Insurance'. Dr. Ranjay K. Singh coordinated these farmer-scientist goshthis.

Hindi week

The Institute celebrated the Hindi Week during September 14-29, 2016. Dr. A.K Srivastava, Director ICAR-NDRI, Karnal inaugurated the function on 14th September, 2016. On this occasion, he urged the

Dr. A.K Srivastava, Director ICAR-NDRI, addressing the gathering during Hindi Pakhwara

staff to use Hindi in day to day work. During this week, different competitions such as *Tatkal Bhashan, Tippan Aalekhan, Aavedan Patra, Computer mein hindi typing, Tippani evam masauda lekhan, Prashanotri Pratiyogita* and *Takniki Poster Pradarshani* were organized.

On the concluding function, Dr. P.C. Sharma, Director, advised the scientists of the institute to make use of Hindi language in brining out the scientific and technical literature it is beneficiary for farmers. Dr. P.C. Sharma told the institute staff to do more and more work in Hindi.

CSSRI RRS Bharuch celebrated the Hindi Saptah during 14-20 September 2016, events like quiz, letter, essay and precise writing and elocution were organized. The prizes for different events were distributed to the winners by the Chief Guest.

24th meeting of the ICAR-Regional Committee V

The XXIV meeting of the ICAR-Regional Committee V was organized at Indian Agricultural Research Institute, New Delhi during 03-04 October, 2016 under the Chairmanship of Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR, New Delhi to discuss the constraints hampering sustainable agricultural production in the food basket states of Punjab, Haryana and Delhi. The Regional Committee meeting provided a platform to discuss the region specific issues related to agriculture, horticulture, animal husbandry and fisheries and to strengthen agricultural research, extension and education through policy decisions. A total of 103 delegates including senior officials from DARE, members of ICAR Governing Body, Senior Officers of Punjab, Haryana and Delhi Governments, Vice Chancellors of State Agricultural Universities, Deputy Director Generals of ICAR and Directors of ICAR Institutes participated in the meeting. In the inaugural session, Dr. H. Rahman, Deputy Director General (AS), ICAR and Nodal Officer, Regional Committee V. He expressed serious concern about the secondary salinization and natural resource degradation threatening agriculture in the south-western parts of Punjab and Haryana states. He also stressed other major issues such as land fragmentation, slow rate of farm diversification, constraints in

Regional Committee in progress

Commercial dairying and food processing, scarcity of animal fodder, animal diseases and growing labour shortages that need greater attention. Sh. Chhabilendra Roul, Additional Secretary, DARE and Secretary, ICAR advocated that developing countries like India will have to be self-reliant to solve their agricultural problems as protectionist policies and reduced funding by the developed countries have adversely impacted the scope of collaborative international R & D. Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR in his inaugural address appreciated significant contribution of Punjab and Haryana states to the food grain production making the country self-sufficient in foodgrain availability. He mentioned the serious challenges faced by the region such as relentless land degradation, climate variability, salinization and water depletion that have created formidable stumbling blocks to the sustainable agricultural development in the region. He urged the researchers and policy makers to give immediate attention to the issues related to climate change, excessive use of the nitrogenous fertilizers, secondary salinity, deterioration in soil health, micronutrient deficiencies, groundwater decline, rice straw burning, erosion of crop and animal genetic resources and insecticide resistance. The session ended with a vote of thanks proposed by Dr. P.C. Sharma, Member Secretary, ICAR Regional Committee V and Director, ICAR-CSSRI, Karnal.

Kharif Kisan Mela

A *Kharif Kisan Mela* was organized on 7th October, 2016 in village Budhmor of Patiala district (Punjab).

Chief Guest Dr. Gandhi addressing the farmers

Kisan Mela was inaugurated by the Chief Guest Dr. R. S. Gandhi, ADG (AS), ICAR, New Delhi while Dr. P.C. Sharma, Director, ICAR-CSSRI, Karnal presided over the function. In his address, Dr. Gandhi appreciated the efforts being made by the ICAR-CSSRI in the transfer of salinity management technologies immensely benefitting the farmers in the salinity affected areas. He advised the farmers to have a close contact with the scientist so that they could adopt the technologies developed by the various organizations located in the area. He also stressed that the farmers should adopt those technologies which give more profit with less investments. He also urged the farmers to include high income giving components such as animal husbandry, fishery, poultry, fruits and vegetables in the farming system. Dr. P.C. Sharma emphasized that farmers should adopt salt tolerant varieties of wheat and mustard developed by ICAR-CSSRI. He also advised the farmers to stop crop residue burning and more organic inputs such as FYM and green manures to crops for sustaining the soil health. A 'Farmer-Scientist Interaction Workshop' was also organized during the *Kisan Mela* in which Subject Matter Specialists suggested solutions of the problems raised by the farmers. A total of 100 soil and water samples brought by the farmers were also tested free of cost and the test reports were simultaneously issued. Seeds of salt tolerant wheat (KRL 210 and KRL 213) and mustard (CS 52, CS 54 and CS 56) were also sold. Different government and private organizations as well as Self Help Groups dealing with improved seeds, fertilizers, pesticides and agricultural implements also organized their stalls during the *Mela*. About 500 farmers, farm women and extension workers were present. Dr. Ranjay K. Singh acted as the Nodal Officer of the Mela.

Kisan Diwas

A Kisan Diwas was celebrated on 26th October, 2016 at ICAR-CSSRI RRS Bharuch in which about 100 farmers from Jambusar, Amod, Vagra and Hansot

A glimpse of Kisan Divas organized at RRS Bharuch

Dr. P.C.Sharma, Director, CSSRI with school children

Visit of school children to CSSRI Museum

talukas of Bharuch district and officials from local agriculture department, Agricultural College Bharuch, NABARD, NGO and KVK participated and discussed different aspects of cultivation of salt tolerant wheat varieties (KRL210 and KRL 19). Seeds of KRL 210 and KRL 19 were distributed among 40 farmers for on-farm trials in Rabi season 2016.

Agricultural Education Day

The 132nd birth anniversary of late Dr. Rajender Prasad, the First President of India was celebrated as 'Agricultural Education Day' on 3rd December, 2016. On this occasion, 64 students and teachers of the Government Senior Secondry School, Dabri (Karnal) and ICAR-CSSRI staff were present. At the outset, Dr. P. C. Sharma, Director welcomed the students and explained the importance of Agricultural Education Day. He appraised the students about the challenges and employment apportunities in the field of agriculture. He also informed the gathering about the past achievements and current efforts to enhance the standard of living of the resource poor farmers by technology-led improvements in crop productivity in several salt-affected areas of the country. On this occasion, a 'Scientist-Student Interaction Meeting' was also organized and scientists replied to the students' queries related to soil and water management. An exposure visit of school children to different research experiments, Herbal Garden and the Institute Museum was also organized.

43rd Foundation Day of Agricultural Scientists Recruitment Board

Agricultural Scientists Recruitment Board, New Delhi organized its 43rd Foundation Day at ICAR-CSSRI, Karnal on 3rd November 2016. Prof. Ramesh Chand, Member, NITI Ayog was the Chief Guest on this occasion. At the outset, Dr. Gurbachan Singh, Chairman, ASRB welcomed the Chief Guest and the dignitaries followed by the presentation of the ASRB Report. He highlighted some of the significant achievements and the new initiatives.

Prof. Ramesh Chand, Member NITI Ayog and Chief Guest of the function appreciated the glorious achievements of ASRB. He said that besides conventional responsibilities of recruitment and selection, the role of ASRB has significantly expanded in the last few years as it now also

A glimpse of ASRB Foundation Day

recruits administrative and technical staff for ICAR. He added that despite these credible achievements, there is always a scope for further improvements so as to address the emerging issues in the field of agricultural research and education. Dr. T. Mohapatra, Secretary, DARE and DG, ICAR complimented ASRB for its achievements and illustrious journey of 42 years. Considering the recommendations of different committees to further improve the transparency and working efficiency of ASRB, he advocated for joint deliberations among different stakeholders to identify the points of action for future reforms. Dr. M. Mahadevappa, Former Chairman, ASRB expressed concern over the mushrooming of private collages/universities offering agricultural degrees without appropriate quality checks which are likely to deteriorate the quality of agricultural education in the country. Prof. R. B. Singh, Former Chairman, ASRB noted that consistent reforms are the key to the lasting relevance of an organization and urged the ASRB to be always receptive to the reforms.

World Soil Health Day

'World Soil Health Day' was organized in Mundri village of Kaithal district on 5th December, 2016. Dr. V.P. Chahal, ADG (KVK), ICAR, New Delhi was the Chief Guest while Dr. P. C. Sharma, Director, ICAR-CSSRI, Karnal presided over the function. About 200 farmers, extension personnel and IFFCO officers participated in this important function. Dr. Chahal requested the farmers for maintaining soil health for better crop productivity. Dr. Sharma highlighted the importance of soil health and the approaches, inter alia, residue incorporation, integrated nutrient management and efficient water management to sustain it. Twenty five soil health cards and 50 IFFCO Green SIM cards were distributed to the farmers.

Model Training Course (MTCs) on Quality Seed Production

A 8-days model training course on 'Quality Seed Production, Processing and Certification of Selected Field and Vegetable Crops in Salt Affected Area" was organized during 15th-22nd December, 2016 at ICAR-CSSRI, Karnal. A total of 29 participants from line department, KVKs and ICAR institutes representing 4 states attended the training . Dr. P.C. Sharma, Director, along with trainees programme. Some of the key topics covered during this training were diagnosis and management of salt-affected soils, status of quality seed availability, requirement and gap in seed demand in the major field and vegetable crops, seed quality assessment, standards of seed certification and the prospects of farmer participatory seed production in India. Quality seed production techniques of rice, wheat, mustard, chickpea and maize were discussed in details. Chief Guest of the valedictory function Dr. G.P. Singh, Director, ICAR-IIWBR, Karnal emphasized the importace of the use of quality seed and increase in the seed replacement ratio. He also discussed on IPR issues, farmers rights and importance of Seed Act 2006 in the changing scenario. Dr. P.C. Sharma, Director, ICAR-CSSRI, Karnal highlighted the different technologies developed by the ICAR-CSSRI and requested the participants to provide quality seeds to the farmers for higher farm profits.

Dr. P.C. Sharma, Director addressing the farmers

Dr. P.C. Sharma, Director, along with trainees

Training on Dairy Management for Livelihood Security

A 3-days training programme on 'Dairy Management for Livelihood Security' was organized under Farmers FIRST Project during 27-29 December, 2016. Thirty farmers of Mundri, Kathwar, Geong, Sampli Kheri and Bhaini Majra villages of Kaithal district participated in this training programme. Chief Guest Dr. Gurbachan Singh, Chaiman, ASRB, New Delhi advised the farmers to adopt multi-enterprise agriculture model for livelihood security. In this model, the farmers could opt a combination of more than one components including dairying, poultry, fishery, horticulture, mushroom etc. to get regular incomes. He advised the farmers to use crop residues as animal fodder and for composting. Dr. P.C. Sharma, Director, ICAR-CSSRI, Karnal briefed about institute's achievements and shared his ideas about how integration of salt tolerant varieties of rice, wheat and mustard can minimize the risks of crop failures in sodic agroecosystems. Dr. Parvender Sheoran coordinated this training programme.

Dr. Gurbachan Singh, Chaiman, ASRB, addressing the farmers

Dr. Randhir Singh, ADG, addressing the trainnes

Training on Agriculture Management in Sodic Environment

A 3-days training programme on 'Agriculture Management in Sodic Environment: Challenges and Remedies' was organized under Farmers FIRST Project during 11-13 January, 2017. Thirty three farmers of Mundri, Kathwar, Geong, Sampli Kheri and Bhaini Majra villages of Kaithal district attended this training programme. Chief Guest Dr. Randhir Singh, ADG, ICAR, New Delhi said that training is an effective method for enhancing the farmers' knowledge and to provide timely solutions to the problems faced by them. He informed that the Govt. of India has initiated the 'ARYA' Project in 25 states in which Krishi Vigyan Kendras and Scientists of ICAR Institutes will work together to train the rural youth in agriculture. He requested the farmers to ensure periodical soil health testing, and to get their Soil Health Cards ready linked with the Aadhar card. He requested the farmer trainees to apply the knowledge gained during this training in their fields. Dr. P.C. Sharma, Director, ICAR-CSSRI, Karnal informed that many parts of Kaithal district suffer from high sodicity in soil and irrigation water necessitating the combined use of soil ameliorants such as gypsum and salt tolerant crop varieties to get sustainable yields. Dr. Pavender Sheoran, training coordinator, informed different activities carried out under Farmers FIRST Project in Kaithal district.

25th Biennial Workshop of AICRP on SAS&USW

The 25th Biennial Workshop of All India Coordinated Research Project on Management of Soils and Use of Saline Water in Agriculture was organized during 19-20 January, 2017 at Swami

Dr. P. C. Sharma, Director, ICAR-CSSRI addressing the gathering

Keshwanand Rajasthan Agricultural University (SKRAU), Bikaner. Dr. V. N. Sharda, Member, ASRB, New Delhi and Chief Guest of function inaugurated Biennial Workshop on 19th January, 2017. During two days deliberations, OICs/ Nodal officers presented progress reports for 2014-16 and proposed new research projects which were discussed thoroughly and comprehensively. Dr. M. J. Kaledhonkar, Project Coordinator thanked ICAR and different stakeholders for the guidance and support for research projects coordinated by the AICRP.

5th National Seminar on Climate Resilient Saline Agriculture

Indian Society of Soil Salinity and Water Quality (ISSSWQ) organized the 5th National Seminar on "Climate Resilient Saline Agriculture: Sustaining Livelihood Security" in collaboration with SKRAU, Bikaner and ICAR-CSSRI, Karnal during 21-23 January 2017 at SKRAU, Bikaner. Dr. Gurbachan Singh, Chairman, ASRB, New Delhi inaugurated the seminar and Dr. B.R. Chhipa, Vice Chancellor, SK RAU, Bikaner presided over the function. Dr. Gurbachan Singh, in his inaugural address, lauded ICAR-CSSRI, Karnal for the systematic researches culminating into technology packages for the reclamation and management of salt affected soils and poor quality waters. Taking a note of the emerging constraints, he stressed the need to employ frontier techniques for sustained gains from the soil reclamation efforts. Dr. B.R. Chhipa advised the farmers' to follow scientific recommendations for the judicious use of precious soil and water resources in crop and livestock production. Dr. G. L. Keshwa, Vice Chancellor, Agriculture University, Kota suggested that only collective and concerted efforts can tackle the problem of salinity/alkalinity under a climate change scenario. Dr. A. K. Gahlot, Vice Chancellor, Rajasthan University of Veterinary and Animal

Dr Gurbachan Singh, Chairman, ASRB, New Delhi delivering Inaugural Address at Bikaner

Sciences, Bikaner echoed the sentiments for developing synergy between SAU's and CSSRI, Karnal for expediting the reclamation of saline soils and poor quality groundwater. Dr. S.K. Chaudhari, ADG (SWM), ICAR, New Delhi called upon the scientific community for absolute dedication to transform saline India into Green India. Dr. P.C. Sharma, Director, ICAR-CSSRI, Karnal and President, ISSSWQ, drew the attention for the rapid and precise delineation and regular updating of database on salt affected soils and saline groundwater to achieve the goal of sustainable management of salt affected soils.

National Productivity Week

'National Productivity Week' was celeberted during 13-18 February, 2017 in which 35 students, 45 farmers and about 80 scientists and officials of CSSRI participated. During the entire programme, different interaction and competition events like painting competition on agricultural waste management and role of biogas in sustainable agriculture was organized among the participating school students. An essay competition on the subject sustainable management of kitchen wastes was also held among the women participants. During this occasion, a total of 35 farmers also visited the Institute Experimental Farm to aquint themselves with the ongoing research projects. Final event on sustainable management of rice residues and the productive use of compost was organized with the participation of about 60 farmers, children and scientists.

School students and CSSRI staff on the occasion of National Productivity Week

Foundation Day

ICAR-CSSRI, Karnal celebrated its 48th Foundation Day on 1st March 2017 by organizing a Foundation Day lecture delivered by Dr. K. Alagusundaram, DDG (AE), ICAR, New Delhi. Dr. Alagusundaram addressed the gathering on the subject 'Approaches for harnessing higher productivity from degraded salt affected lands'. He said that Indian agriculture supports 18% of world population with only 9% of world's arable land. Nearly one-third of the country's population lives below poverty line, and about 80% of our land is highly vulnerable to drought, floods and cyclones. Demand projections for food grains reveal that we may need at least 345 million tonnes in 2030, requiring almost the same rate of increase per annum but from shrinking land and water resources and aberrations in climate. Efforts made over the last four decades at ICAR-CSSRI have demonstrated that development of salt tolerant varieties is the key to enhancing the economic value of the degradaed lands. He

Dr. K. Alagusundaram, delivering the Foundation Day Lecture

appealed to the scientific community to address land degradation issues and come out with appropriate solutions for the salt-affected and waterlogged saline regions of India. On the occasion, Dr. P.C. Sharma, Director gave a brief glimpse of Institute's achievements.

Rabi Kisan Mela

ICAR-Central Soil Salinity Research Institute, Karnal has organized the Rabi Kisan Mela on 8th March, 2017. Prof. Vijay Paul Sharma, Chairman, Commission on Agricultural Costs and Prices, Ministry of Agriculture and Farmers Welfare, Govt. of India, was the Chief Guest. About 1500 farmers, school students, extension workers and NGOs attended the Kisan Mela and benefitted by visiting different ongoing research experiments on CSSRI campus.

As the Mela coincided with the World Women's Day, special efforts were made to ensure the presence of women farmers. Over 100 women farmers enthusiastically participated in the Mela and shared their farming success stories with the scientists. Free analysis of soil and water samples, exhibition of improved agricultural technologies developed by ICAR institutes, government agencies and private companies, sale of improved salt tolerant seeds in rice and other crops, and an interactive dialogue between scientists and farmers were the main attractions. Chief Guest Prof. Sharma addressed the farmers and requested them to remain in regular contact of the scientists for enhancing the farm profits. He urged the farmers of the region to adopt sustainable intensification farm practices to enhance their incomes while protecting the precious natural resources. He said that present government has initiated many schemes such as Mera Gaon Mera gaurav, Paramparagat Krishi Vikas Yojana, Pradhan Mantri Fasal Bima Yojana and Pradhan Mantri Krishi Sinchayee Yojana for the sustainable agricultural development in the country. He remarked that farmers of the region should gradually switch over to water and fertilizer use efficient crops including pulses and oilseeds to overcome the sustainability concerns related to rice-wheat cropping system. He added that continual technological improvements, reduction in post-harvest losses, infrastructure development, climate change adaptation and strengthening of rural financial institutions are some of the key areas which need immediate attention for transforming agriculture into a remunerative business. About 21 innovative farm women and farmers were felicitated on this occasion for their progressive agricultural practices. Dr. P.C. Sharma, Director highlighted the achievements and recent initiatives by ICAR-CSSRI to augment the farm profitability in salt affected regions of the country. Dr. Ranjay K. Singh was the Nodal Officer of this Kisan Mela.

Prof. Vijay Paul Sharma, Chairman, CACP Addressing the Farmers

LIST OF SCIENTIFIC, TECHNICAL AND ADMINISTRATIVE PERSONNEL

Dr. D.K. Sharma, Ph.D., Director (03.05.2016)[a]
Dr. Parbodh Chander Sharma, Ph.D., Director (A) (03.05.2016)[b]
Dr. Parbodh Chander Sharma, Ph.D., Director (10.10.2016)[b]

Division of Soil and Crop Management

D.K. Sharma,Ph.D., (31.01.2017)[c]
R.K. Yadav, Ph.D., Head
P.K. Joshi, Ph.D. (31.10.2016)[c]
Madhurma Sethi, Ph.D. (30.11.2016)[c]
A.K. Mandal, Ph.D.
Ranbir Singh, Ph.D.
Parveen Kumar, Ph.D
A.K. Rai, Ph.D
A.K. Bhardwaj, Ph.D.
Rakesh Banyal, Ph.D.
Gajender Yadav, Ph.D.
Madhu Chaudhary, Ph. D.
Anshuman Singh, Ph.D.
Murli Dhar Meena, Ph.D.
Nirmalendu Basak, Ph.D.
Ashim Dutta, Ph.D
Parul Sundha, Ph.D.
Raj Kumar, Ph.D.
Arijit Burman, M.Sc. (01.04.2016)[b]
Awtar Singh, M.Sc. (07.04.2016)[b]
Priyanka Chandra, Ph.D. (08.03.2017)[b]
Manish Kumar, M.Sc (29.03.2017)[b]

Technical Officers

Naresh Kumar, Ph. D.
Raj Kumar
Sukhdev Parshad (31.08.2016)[c]
Dilbag Singh

Division of Crop Improvement

Parbodh Chander Sharma, Ph.D., Head, (10.10.2016)[a]
S.K. Sanwal, Ph.D. Head, (A) (10.10.2016)[b]
Anita Mann, Ph.D.
S.L.Krishna Murthy, Ph.D
Jogender Singh, Ph.D.
Ashwani Kumar, Ph.D
Arvind Kumar, Ph.D.
Vineeth TV, M.Sc.
Ravi Kiran, M.Sc.
Vijayata Singh, Ph.D.

Technical Officers

G.C. Purty
Roshan Lal (31.03.2017)[c]

Division of Irrigation and Drainage Engineering

D.S. Bundela, Ph.D., Head
S.K. Kamra, Ph.D. (31.12.2016)[c]
Satyender Kumar, Ph.D.
Bhaskar Nurjury,Ph.D.
Aslam Latif Pathan, M.Tech.
R.S. Tolia, Ph.D.,(11.04.2016)[b]

Technical Officers

Rajiv Kumar, M.Sc.
S.K. Srivastava, Diploma
Jai Parkash, M.Sc.
S.K. Dahiya
Mohinder Pal
Sat Pal

Division of Technology Evaluation and Transfer

Randhir Singh, Ph.D., Head, (10.08.2016)[a]
R.K. Singh, Ph.D.Head (A), (11.08.2016)[b]
Parvender Sheoran, Ph. D.
K. Thimmappa, Ph.D.,(18.03.2017)[a]
M. Raju, Ph.D
Kailash Prajapat, Ph.D.,(15.03.2017)[b]

AICRP (Saline Water)

M.J. Kaledhonkar, Ph.D., P.C.
R.L. Meena, Ph.D.
Babu Lal Meena, Ph.D.
R.K. Fagodiya, Ph.D. (16-11-2016)[b]

Technical Officers

Anil Kumar Sharma, M.A.

Regional Research Station, Canning Town

D. Burman, Ph. D., Head,(A)
B. Maji, Ph.D.
S.K. Sarangi, Ph. D.
Subhasis Mandal, Ph. D.
U.K. Mandal, Ph.D.
Shishir Raut, Ph. D.
K.K. Mahanta, Ph. D.
T.D. Lama, Ph.D.

Technical officers

D. Pal, Ph. D.
N.B. Mondal, Diploma
Sivaji Roy, M.Sc

P.K. Dhar, B. Sc. (31.01.2017)[c]
S. Mandal, B.Sc.
A.K. Pramanik
L.K. Nayak,
D. Mukherjee
D. Banerjee

PS to the Head

A.K. Nandi, B. Sc.

Regional Research Station, Bharuch

Anil R. Chinchmalatpure, Ph.D., Head
Sarwan Kumar, Ph.D.
Indivar Parshad, Ph.D.
Kad Sanjay Vasant, M.Sc.
Monika Shukla, M.Sc.
David Cames D., M.Sc.
Vibuti Sagar, M.Sc.(11.04.2016) [b]

Technical Officer

M.V.S. Rajeshwar Rao, M.Sc.
Akshay Kumar

Regional Research Station, Lucknow

V.K. Mishra, Ph.D. Head (A)
Y.P. Singh, Ph.D.
Chhedi Lal Verma, Ph.D.
T. Damodaran, Ph.D.
Atul Kumar Singh, Ph.D.
Sanjay Arora, Ph.D.
S.K. Jha, Ph.D.

Technical Officers

C. S. Singh, Ph.D.
Hari Mohan Verma, M.Tech.

Administrative and Supporting Section

Administration

Abhishek Srivastava, Sr. Admn. Officer
Anil Sidharth, Finance and Accounts Officer
Ishwar Dayal, AO (17.10.2016) [b]
Randhir Singh, Jr. Accounts Officer
A.K. Mishra, Asstt. Admn. Officer
Tarun Kumar, Asstt. Admn. Officer
Ranjeet Singh, Asstt. Admn. Officer

RTI Cell

K. Thimmappa, Ph.D., CPIO (18.03.2017)[b]
Parvender Sheoran, Ph.D., CPIO (19.03.2017)[b]
S.K. Srivastava, Diploma
Vinod Kumar, M.A.

Transparency Officer and Vigilance Officer

Dr. A.K. Rai

Priortizing, Monitoring and Evaluation (PME) and Institute Technology Management Unit (ITMU)

Parveen Kumar, Ph.D

Technical Officer

Vinod Kumar, M.A. (Economic)

Publication and Supporting Services Unit

Parveen Kumar, Ph.D. CO
Anshuman Singh, Ph. D., OIC

Technical Officers

Madan Singh, M.A. (Geography & Diploma)

Hindi Cell

A.K. Srivastava, Sr.Admn. Officer,OIC

Technical Officers

S.K. Tyagi, Ph.D

Director Cell

Santra Devi, PS

Public Relation Officer

Anil Kumar Sharma, M.A. (English)

PS to Heads

Dinesh Gugnani
Sunita Malhotra
Rita Ahuja
Shashi Pal

Farm Section

H.S. Tomar, M.A., Farm Manager
Chander Gupt
Seth Pal
Jaswant Singh

Library

Meena Luthra, M.A., M. Lib. Sci., OIC,

Medical Unit

Dr. R.K. Yadav, Ph.D., CO
Dr. (Mrs.) Mahathi Parkash, M.B.B.S.,OIC
Sunita Dhingra
Chanchal Rani
Geeta Rani

Estate Section

Satyender Kumar, Ph.D. CO
N.K. Vaid, M.Tech. OIC (Estate Civil)
S.K. Dahiya, OIC, Security
Ashwani Kumar, Diploma
Kulbir Singh, Diploma

* Superscripts a, b and c refer to date of relieving, joining and superannuation, respectively.

CSSRI STAFF POSITION

Statement showing the total number of employees and the number of Scheduled Castes (SC)/Scheduled Tribes (ST) as on 31.3.2017

Group/class	Number of employees			Scheduled Castes		Scheduled Tribes	
	Temporary	Permanent	Total	No.	% of total	No.	% of total
Class-1 permanent other than lowest rung of Class-1	-	32	32	02	6.25	1	3.13
Lowest rung of Class-1	-	53	53	05	11.32	4	7.54
Class-II	-	36	36	10	27.77	4	11.00
Class-III	-	72	72	19	26.00	9	12.50
Class-IV (excluding sweepers)	-	45	45	14	31.00	4	8.88
Class-IV (only sweepers)	-	05	05	05	100	-	-
Total	**-**	**243**	**243**	**40**			

Statement of Scheduled Castes (SC) and Scheduled Tribes (ST)

Statement showing the number of reserved vacancies filled by Scheduled Castes (SC)/Scheduled Tribes (ST) as on 31.3.2017.

Classified posts	Total vacancies		Scheduled Castes		Scheduled Tribes	
	Notified	Filled	Notified	Filled	Notified	Filled
Direct Recruitment						
Class-I Class-II						
Class-III			Nil			
Class-IV						
Promotions						
Class-I Class-II			Nil			
Class-III Class-IV						

WEATHER REPORT 2016

Main Institute, Karnal

During the year 2016, total rainfall of 627.5 mm was recorded at Agro-met Observatory at Karnal as compared to the mean annual rainfall of 736.2 mm (for the last 45 years). Year 2016 was a normal rainfall year (85% of the long-term mean annual rainfall) whereas the year 2015 was also a normal rainfall year (91% of the long-term mean annual rainfall). The maximum monthly rainfall of 283.7 mm was recorded in August. During the monsoon season, the highest rainfall of 84.0 mm was recorded on 8thAugust and the second highest of 59.8 on 2nd July. The winter rainfall (January and February) was zero as compared to the last year winter rainfall (43.5). No winter rainfall resulted in increased irrigation demands for different *Rabi* crops during January and February which were met either from canal or ground water or both, particularly for wheat crop. During March, there was a good amount of rainfall of 46.2 mm which substantially met the irrigation demand of *Rabi* crops leading to bumper *Rabi* crop production. There were 41 rainy days as compared to 48 during the last year.

The minimum and maximum air temperatures of 2.2° and 44.0 °C, respectively, were recorded on 22nd January and 3rd May, respectively. The lowest air relative humidity was 6% on 25th April, 26th April, 27th April and 2nd May while the highest (100%) was recorded on several occasions during the year. The highest soil temperatures at 5, 10 and 20 cm depths were 43.0, 41.0 and 40.0 °C on 2ndMay, respectively. The lowest values at same depths were recorded as 8.0, 9.0 and 10.0 °C on 2ndJanuary (5 cm, 10 cm). The total open pan evaporation during the year was 1419.1 mm, which is twofold higher than the annual rainfall. The lowest evaporation of 0.4 mm was recorded on 25th December and the highest of 14.0 mm was on 18th May and 8th June. The average sunshine hours per day were 6.5. The highest and lowest vapour pressure values were 28.5 mm on 8th July and 6.5 mm on 22nd January, respectively. The average wind speed was 3.5 km per hour. The monthly weather parameters recorded at Agro-meteorological Observatory, ICAR-CSSRI, Karnal for the year 2016 are presented in Table 1.

Regional Research Station, Bharuach

Agro-meteorological observations (Table I) recorded at Cotton Research Station, Bharuch (latitude 22°N, longitude 73.5^{O}E, and altitude 16.50 m) during 2016 revealed that this region received normal rainfall of 481 mm spread over 53 days. Season's highest rainfall (149.5 mm) was received during July followed by 114.6 mm, 105.2 mm and 90.2 mm during October, September and August 2016, respectively. The maximum air temperature ranged from 39.5 °C (May) to 30.8 °C (January) and the minimum air temperature varied from 13.3 °C (Dec) to 28.1 °C (June). Pan evaporation varied from 4.4 mm day^{-1} during August to 11.0 mm day^{-1} during May. The average bright sunshine hours varied from 1.7 during July to 9.0 hr per day during April. Mean relative humidity varied from 45% during March to 81% in August. The average wind speed varied from 0.4 kmph during November to 12.8 kmph during May 2016.

Regional Research Station, Canning Town

Total annual rainfall of 2020.2 mm was recorded during 2016. The maximum rainfall of 619.0 mm was recorded in the month of August, but the maximum rainy days (22) were recorded in the month of July. There were total 86 rainy days in this year. The average daily sunshine hour was moderate. The minimum temperature reached its lowest (total mean monthly average 13.6 C) in the month of January. The average mean monthly temperature of 19.5 C in January increased very rapidly to 31.7^{0} C in the month of April and the maximum temperature of 41.8^{0}C was recorded on 12th April, 2016. The relative humidity remained quite high throughout the year causing high infestation of weeds, pest and diseases. The highest wind velocity of 30.1 km h^{-1} was recorded in May. The mean monthly weather parameters recorded at RRS, Canning, are presented in Table III

Table 1: Mean monthly weather parameters for the year 2016 recorded at the Agro-meteorological Observatory, ICAR-CSSRI, Karnal

Latitude: 29° 43' N
Longitude: 76° 58' E
Altitude : 245 m above the Mean Sea Level
I Time : 0722/0830 hours IST
II Time : 1422 hours IST

Month	Temperature, °C							Vapour pressure (mm of Hg)		Relative humidity (%)		Max. Temp, °C		Min. Temp, °C	
	Max.	Min.	Grass Min.	Dry bulb		Wet bulb						High/ date	Low/ date	High/ date	Low/ date
				I	II	I	II	I	II	I	II				
Jan.	18.3	7.1	3.3	8.6	17.7	8.4	13.7	8.3	9.5	97	63	24.0/31	9.5/26	12.2/31	2.2/22
Feb.	23.2	7.9	3.1	10.0	22.9	9.4	16.4	10.8	10.2	92	49	28.5/29	18.0/2	16.0/20	3.6/02
Mar.	28.3	13.1	6.2	16.3	27.9	15.0	19.9	12.1	12.7	87	45	34.0/31	24.0/13	17.0/26	10.0/02
Apr.	37.6	18.6	8.2	23.7	37.2	17.6	20.1	11.5	07.3	54	15	41.5/28	35.0/01	22.5/22	13.0/08
May	38.4	23.6	9.3	27.5	37.1	21.9	24.1	16.4	14.7	60	33	44.0/03	31.0/31	29.4/20	19.5/01
Jun.	37.7	26.6	11.4	29.3	36.5	25.6	27.0	22.4	20.7	73	46	42.0/04	32.6/29	29.0/25	23.2/01
Jul.	33.3	26.4	14.9	27.8	54.2	26.6	27.9	25.1	25.4	88	72	39.4/01	26.5/03	29.0/07	23.0/03
Aug.	32.4	25.5	13.7	27.1	30.9	25.9	27.3	24.5	24.9	90	75	35.2/06	28.8/07	27.0/05	23.4/31
Sept.	33.2	24.1	11.6	25.9	32.5	24.6	27.0	22.3	22.9	89	63	35.2/22	29.0/01	25.4/21	21.0/04
Oct.	33.1	17.8	8.6	20.6	32.0	19.3	22.6	16.3	15.0	88	42	35.0/03	28.0/31	26.6/04	13.4/28
Nov.	28.7	11.1	6.0	13.4	27.9	12.3	18.0	10.1	9.4	88	36	32.0/04	25.2/30	14.2/26	8.2/19
Dec.	22.0	8.3	4.3	9.7	21.1	9.4	16.0	8.8	10.8	97	58	27.0/02	17.5/30	12.0/01	5.2/23
Total:	--	--	--	--	--	--	--	--	--	--	--				
Average:	8.4	17.5	08.4	20.0	31.5	18.0	21.7	15.7	15.3	83.7	49.8				

Month	Soil temperature, °C (Depth-wise)						Rainfall*			Evaporation		Sunshine (hr/day)	Wind speed (km/hr)
	5 cm		10 cm		20 cm								
	I	II	I	II	I	II	Monthly (mm)	No of rainy days	Heavy/ date	mm/ day	mm/ month		
Jan.	11.5	17.1	12.4	16.0	13.2	15.0	0.0	00	0.0	1.2	35.9	3.1	2.2
Feb.	12.7	21.7	13.8	19.9	14.5	18.2	0.0	00	0.0	2.0	59.3	6.8	2.8
Mar.	17.8	27.3	18.6	25.4	19.3	24.0	46.2	05	30.0/13	3.1	94.9	7.6	3.6
Apr.	24.9	36.9	25.9	35.5	26.9	34.3	0.0	00	0.0	6.1	182.7	8.2	3.7
May	27.4	38.1	28.4	36.8	29.6	35.9	48.6	04	20.0/11	8.7	270.0	8.7	6.0
Jun.	30.3	38.6	31.3	36.8	32.3	34.5	42.4	06	14.5/11	7.8	234	7.8	7.0
Jul.	28.5	32.8	29.1	31.9	29.8	31.1	185.0	11	59.8/30	4.6	141	4.7	4.5
Aug.	26.6	31.6	27.0	30.7	27.8	29.9	283.7	12	84.0/08	3.3	96.4	5.4	3.2
Sept.	26.4	35.0	27.2	33.6	28.0	31.7	21.6	03	18.0/01	3.4	100.7	7.6	1.4
Oct.	22.4	32.0	23.7	30.4	25.2	29.0	0.0	00	0.0	2.9	89.4	6.3	out of order
Nov.	16.3	24.8	17.8	22.9	19.4	21.7	0.0	00	0.0	2.6	78.3	6.7	1.7
Dec.	11.8	20.2	13.3	18.3	15.1	17.2	0.0	00	0.0	1.2	35.9	4.8	2.2
Total:	--	--	--	--	--	--	**627.5**	**41**	--	--	**1419.1**	--	--
Average:	**21.4**	**29.7**	**22.4**	**28.2**	**23.4**	**26.9**	--	--	--	**3.9**	**118.3**	**6.5**	**3.5**

** Rainfall < 2 mm is drizzle or trace.*

Table I. Monthly average agro-meteorological parameters at Bharuch during 2016

Month	Air Temperature (^{0}C)		Rainfall (mm)	Total rainy days	Avg. Relative humidity (M+E) (%)	Vapour pressure (mm)		Wind speed (km/hr)	Sunshine (hr/day)	EPan (mmpd)
	Max	Min				M	E			
January	30.8	14.4	0.0	0	47	9.8	8.5	3.1	8.7	5.1
February	32.5	16.9	0.0	0	47	11.1	10.0	4.7	8.4	5.9
March	37.9	21.4	0.0	0	45	15.5	11.1	4.4	8.1	7.5
April	39.0	24.6	0.0	0	47	17.8	14.6	5.8	9.0	8.9
May	39.5	27.7	0.0	0	56	24.6	18.6	12.8	8.8	11
June	37.4	28.1	21.2	5	62	24.2	21.4	12.4	7.0	9.4
July	31.8	26.1	149.5	23	80	24.1	23.9	8.4	1.7	6.3
August	30.7	25.6	90.2	12	81	23.8	23.3	9.4	2.3	4.4
September	31.6	24.9	105.2	8	75	23.1	22.2	5.0	5.3	6.3
October	32.5	21.8	114.6	5	66	19.7	18.0	1.3	6.8	6.6
November	32.0	14.3	0.0	0	49	12.3	10.6	0.4	8.6	6.9
December	31.4	13.3	0.0	0	50	10.9	10.7	1.0	8.8	7.0
Total			**481**	**53**						

Table III : Mean monthly weather parameters at Canning Town (latitude: 22^{0}15' N, longitude: 88^{0}40'E, altitude (AMSL): 3.0 m) during the year - 2015

Month	TEMPERATURE (^{0}C)			MIN. RH (%)	Rainfall (mm)	Rainy Days	AV. WIND (km h^{-1})	MAX. WIND (km h^{-1})	SOLAR Radiation (MJ m^{-2} day^{-1})	BSSH (day^{-1})
	MAX.	MIN.	MEAN							
Jan	25.4	13.6	19.5	43.8	8.6	1	2.5	15.2	10.0	4.5
Feb	29.9	20.0	24.9	49.8	96.6	3	3.7	17.2	11.3	4.8
Mar	33.2	23.3	28.2	40.9	3.0	1	4.7	20.1	15.2	6.1
Apr	36.8	26.7	31.7	41.8	4.4	1	9.1	28.4	16.6	7.0
May	35.1	26.0	30.9	47.6	248.6	8	5.6	30.1	13.9	7.0
Jun	33.9	26.9	30.4	60.9	217.9	13	4.1	27.7	13.7	6.7
Jul	31.5	26.4	28.9	73.0	502.4	22	2.8	26.8	9.9	2.4
Aug	31.8	26.6	29.3	73.0	619.0	17	2.6	25.4	12.3	4.5
Sep	32.2	26.6	29.4	68.1	244.0	14	0.6	20.1	12.7	5.2
Oct	31.9	24.8	28.3	61.0	27.5	3	0.3	15.4	14.0	5.8
Nov	29.2	18.6	23.9	47.3	48.2	3	0.2	11.6	12.4	6.6
Dec	26.3	14.6	20.5	50.1	0.0	0	0.3	11.9	11.1	5.9
Total	**377.0**	**274.2**	**326.0**	**657.3**	**2020.2**	**86**	**36.5**	**249.9**	**153.0**	66.3
Avg.	**31.4**	**22.8**	**27.2**	**54.8**			**3.0**	**20.8**	**12.8**	5.5

Max temperature: 41.8^{0}C on 12/04/16
Minimum temp.: 9.4^{0}C on 25/01/16
Maximum rainfall: 129.8 mm on 02/08/16
Maximum wind velocity: 53.1 km h^{-1} on 18/08/16

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