भाकृअनुप
ICAR

1969-2019

वार्षिक प्रतिवेदन
ANNUAL REPORT 2017-18

ICAR - Central Soil Salinity Research Institute
Karnal, Haryana- 132 001

वार्षिक प्रतिवेदन

Annual Report
2017-18

ICAR-CENTRAL SOIL SALINITY RESEARCH INSTITUTE

KARNAL - 132001 (HARYANA)

Citation

Annual Report, 2017-18, ICAR-Central Soil Salinity Research Institute, Karnal-132001, Haryana, India

Edited by

P. C. Sharma and Anshuman Singh

Compiled by

Madan Singh

Photography

D.B. Thapa

Cover Photo

Swarna Jayanti *Rabi* Kisan Mela

Published by

Director, ICAR-Central Soil Salinity Research Institute , Karnal-132001, India
Telephone : + 91-184-2290501; Fax +91-184-2290480,2292489
Email: director.cssri@icar.gov.in; Website: www.cssri.org

Printing

Aaron Media
UG-17, First Floor, Super Mall,
Sector-12, Karnal | +91-98964-33225
Email : aaronmedia1@gmail.com

Contents

Mandate

1. Developing technologies for reclamation and management of salt affected soils and use of poor quality irrigation waters in different agro-ecological regions of India

2. Evaluate and recommend strategies that promote adoption of preventive/ameliorative technology

3. Coordinate/support the network of research for generating and testing location specific technologies

4. Centre for training in salinity researches in the country

Preface

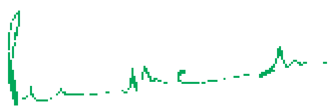
In 1969, in recognition of the pressing need to reclaiming and managing the salt affected soils, Government of India established ICAR-CSSRI for spearheading salinity research in the country. Thanks to the wisdom of our predecessors and the collective efforts of different stakeholders, determined attempts shortly culminated into a basket of doable technologies ushering in yield revolution in areas otherwise considered to be non-reclaimable. While the 'fight against salinity' continues with zeal, Golden Jubilee celebrations (1969-2018) are an apt time to introspect our strengths and weaknesses to devise a robust action plan compatible with the changing needs. Present situation is strikingly different from the preceding decades in that fresh water- key to the success of soil reclamation projects- has not only increasingly became scarce but the problem of poor quality waters has grown by leaps and bounds. At a time when climate change impacts have become the new normal, greater preparedness than before is absolutely essential to infuse resilience into farmlands reeling under the compounded impacts of multiple stresses. A paradigm shift in the way of doing business with focus on 'adaptive management practices' instead of exclusive reliance on 'reactive reclamation measures' is the need of the hour. In changing circumstances, mere improvements in crop yields will not serve the purpose. A holistic approach capable of delivering multiple benefits, *inter alia*, sustainable land use, quantum jump in farm incomes and stable improvements in environmental quality is desirable. The fact that salinity management technologies developed by ICAR-CSSRI result in manifold improvements in farmers' incomes is undeniable. Yet, slower than expected spread of many of these technologies remains a significant concern. This highlights the need for continual refinements in existing technologies to make more appealing to the farmers. Empowering the farmers and removing the barriers stalling technology adoption are equally important to ensure sustainable management of salt affected soils in different agro-climatic zones of the country.

The Annual Report for the period 2017-18 compiles the new developments in the areas of research, technology development and transfer. Major research outcomes during the period under report are: Soil salinity characterization using hyper-spectral remote sensing data, release of salt tolerant wheat variety 'KRL 283' and Indian mustard variety 'CS 60', development of halophilic plant growth promoters to improve crop yields in sodic soils, identification of high yielding salt tolerant cotton genotypes, impact evaluation of sub-surface drainage technology in Maharashtra, assessment of financial viability of land shaping models in coastal saline soils and optimization of crop zinc and iron requirements in salt affected soils. During the year, Institute produced 15.5 tonnes of breeder seeds of rice, wheat, mustard and chick pea for distribution among various agencies.

A series of skill development and awareness programmes were organized to empower the farmers and farm women for increased adoption of improved technologies. A '*Mahila Kisan Mela*' was organized in Sikander Kheri village of Kaithal district of Haryana on 15th October, 2017 during which about 500 farm women, farmers, extension workers benefitted by interacting with experts and visiting the technology exhibition stalls. A total of 4 pre-Kharif and 5 pre-Rabi Kisan Goshthis were also organized under '*Mera Gaon Mera Gaurav*' programme to fast track technology dissemination in salt affected areas of Haryana, Uttar Pradesh, West Bengal and Gujarat states. A total of 27 front line demonstrations on salt tolerant crop varieties were conducted during 2017-18. 'World Soil Day' and 'Agricultural Education Day' were celebrated on 5th December, 2017 at Karnal. '*Swarna Jayanti Rabi Kisan Mela*' was organized on 10th March, 2018. Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers Welfare, addressed the farmers on this occasion. During 2017-18, a total of 8 exhibitions were organized at different research institutions and developmental agencies to portray the improved salinity management technologies.

'*Swachh Bharat Abhiyan*' was organized at regular intervals on the Main Campus and Regional Research Stations throughout year. 'Hindi Pakhwara' was celebrated during 14-28 September, 2017. First meeting of 'Technical Committee for Haryana Operational Pilot Project on Sub Surface Drainage' was held on 12th July, 2017 at Karnal. Mid Term Review Meeting of ICAR Regional Committee Zone-V was held on 12th December, 2017. An international training programme on 'Use of Poor Quality Water in Agriculture' sponsored by African-Asia Rural Development Organization was organized during 10-24 November, 2017. Another international training on 'Advance and Innovative Technologies for Sustainable Management of Salt Affected Soils' was organized under Indo-African Forum during 15-26 March, 2018.

I express my gratitude to Dr. Trilochan Mohapatra, Hon'ble 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 guidance and support. Sincere efforts of Dr. Anshuman Singh and Shri Madan Singh in the compilation, editing and timely printing of the Annual Report are appreciated. I firmly believe that information furnished in this report will broaden the understanding of researchers, policy makers and general readers about research efforts and constraints in salinity management in agriculture. Relevant suggestions and inputs from the readers will help us further improve the quality of the Annual Report in the future.



(Parbodh Chander Sharma)

सारांश

वर्ष 1969 में करनाल (हरियाणा) में स्थापित केन्द्रीय मृदा लवणता अनुसंधान संस्थान एक प्रमुख अनुसंधान संगठन है। यह देश के विभिन्न कृषि पारिस्थितिकी 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 एक अखिल भारतीय समन्वित परियोजना लवणग्रस्त भूमियों के प्रबंधन और खारे पानी के कृषि में प्रयोग हेतु विभिन्न पारिस्थितिकी क्षेत्रों–आगरा, कानपुर, हिसार, इंदौर, बीकानेर, बापटला, गंगावटी और त्रिचुरापल्ली बीठंडा (पंजाब), पैनवलै (महाराष्ट्र), पोर्टब्लेयर (अण्डेमान एवं निकोबार आईलैण्ड) एवं वाईटिल्ला (केरल) में कार्यरत है। संदर्भित अवधि के लिए विभिन्न महत्वपूर्ण क्षेत्रों में संस्थान की कुछ प्रमुख अनुसंधान उपलब्धियाँ निम्नलिखित हैं।

दूर–संवेदी हाईपर वर्णक्रमीय डेटा के आधार पर मृदा लवणता चिन्हीकरण

लवणता प्रक्रियाओं की जटिलता, इसकी स्थानिक एवं सामयिक भिन्नता आदि के कारण मृदा लवणता का मानचित्र तैयार करना अत्यन्त कठिन कार्य है। अत्यधिक लवणग्रस्त मृदा लवणपरत से उच्चपरावर्तन होने के कारण आसानी से पहचानी जाती है लेकिन मध्यम एवं निम्न लवणग्रस्त मृदाओं को लवण, मृदा जल एवं वनस्पति के निश्चित प्रभाव के कारण पहचानना सरल नहीं है। ऐसी लवणग्रस्त मृदाओं को अतिवर्णक्रमीय (हाइपर–स्पैक्ट्रल) दूरसंवेदी डेटा के उपयोग द्वारा चिन्हित करने का एक प्रयास केन्द्रीय मृदा लवणता अनुसंधान संस्थान करनाल में किया गया है। इसके लिये अतिवर्णक्रमीय डेटा को सीमित वास्तविक स्थानिक जांच के साथ समेकित कर सांख्यिकी मॉडल द्वारा लवणग्रस्त मृदाओं के विस्तार की मात्रा जानने संबंधी कार्यप्रणाली विकसित की गई है। मृदाओं की लवणता एवं क्षारीयता संबंधित मापदंडों जैसे विद्युत चालकता, सोडियम, क्लोराइड, कार्बोनेट व बाइकार्बोनेट आदि की परिवर्तनशीलता का अति वर्णक्रमीय परवर्तन डेटा से मात्रात्मक सह–संबंध स्थापित किया गया है। परावर्तन के शिखर 1400, 1900 व 2200 नैनो मीटर वर्णक्रमीय क्षेत्रों पर मिट्टी की लवणता के कारण अतिवर्ण क्रमीय परवर्तन के 1900 नैनोमीटर क्षेत्र पर शिखर मिट्टी में नमक की मात्रा के साथ क्रान्तिक रूप से सह–संबंधित रहती है। अतिवर्णक्रमीय परावर्तन डेटा आधारित विकसित इस पद्धति द्वारा अंतरिक्ष से ही लवणग्रस्त मृदाओं को चिन्हित करना कारगर हो सकता है।

गेहूँ की नई लवण सहिष्णु प्रजाति 'केआरएल 283'

गेहूँ की एक नई लवण सहिष्णु प्रजाति 'केआरएल 283' उत्तर प्रदेश की लवण प्रभावित मृदाओं हेतु 'फसल मानकों तथा अधिसूचनाओं के आधार पर किस्मों को जारी करने वाली केन्द्रीय उपसमिति' की 20 जनवरी, 2018 को आयोजित 79वीं बैठक में जारी अनुशंसित की गई। तीन वर्षों की औसत उपज के आधार पर 'केआरएल 283' ने लवण सहिष्णु चेक किस्मों के 8334,

एनडब्ल्यू 1067 एवं केआरएल 17 की तुलना में अधिक लवण सहिष्णुता एवं दाना उपज (क्रमश : 15.02 प्रतिशत, 13.68 प्रतिशत एवं 5.24 प्रतिशत) प्रदर्शित की। सामान्य दशाओं में यह 5.8–6.2 टन / हे. की दाना उपज जबकि क्षारीय मृदाओं (पीएच 9.0–9.3) में 4.5–4.8 टन / हे. उपज देती हैं। यह 128–133 दिनों में पककर तैयार हो जाती है और 6.7 डेसीसीमन / मी. तक लवण तनाव व पीएच 9.3 तक क्षारीय तनाव सहन करती है। यह विभिन्न रोग और कीटों जैसे पीला भूरा तना, रतुआ, करनाल बण्ट, एफिड एवं तना मक्खी के प्रति भी सहिष्णु है।

सरसों की नई लवण सहिष्णु किस्म सीएस 60 विकसित

सरसों की एक नई लवण सहिष्णु किस्म सीएस 60 को अगस्त, 2017 में आयोजित रेपसीड–सरसों की अखिल भारतीय समन्वित अनुसंधान परियोजना की 24वीं वार्षिक समूह बैठक के दौरान पहचान किया गया था तथा जनवरी 2018 में फसल मानक अधिसूचना एवं विमोचन की केंद्रीय उप–समिति (सीवीआरसी) द्वारा आयोजित 79वीं मीटिंग में उच्च तेल और बीज उपज के लिए हरियाणा, उत्तर प्रदेश, पंजाब, दिल्ली और राजस्थान (उत्तर पश्चिमी समतल जोन) में लवण ग्रस्त मृदा और समय पर बिजाई की अवस्थाओं के तहत रिलीज किया गया है। इस किस्म ने लवणता (मृदा लवणता ईसीई 10–11 डेसी साइमन / मीटर, सिंचाई जल लवणता ईसीआईडब्लू 10–12 डेसी साइमन / मीटर), क्षारीयता (पीएच 9–9.4)के तहत राष्ट्रीय चैक सीएस 54 और उच्च पैदावार वाली किस्मों क्रांति और गिरिराज की तुलना में 25% अधिक बीज उपज और 27% उच्च तेल उपज का उत्पादन दिया। यह किस्म लगभग 134 दिनों में परिपक्व हो जाती है और पुष्पन अवस्था के लिए 58 दिन लगते हैं। इसके पौधों की लंबाई 187 सेमी प्राथमिक शाखाएं (6), माध्यमिक शाखाएं (9), मुख्य तने की लंबाई (77 सेमी) और 1000 दानों का वजन 5 ग्राम है। लवण प्रभावित मृदा में उपज 1.8–2.1 टन / हेक्टेयर और सामान्य परिस्थितियों में 2.4–2.9 टन / हेक्टेयर है। इसमें लगभग 41 प्रतिशत तेल की मात्रा है। यह किस्म प्राकृतिक परिस्थितियों में अल्टरनेरिया ब्लाइट, सफेद रतुआ, पाउडरी और डाउनी मिलडिउ (फफूंदी), स्टैग हेड एवं स्क्लेरोटिनिया तना गलन के लिए प्रतिरोधी है तथा इसमें तैला (एफिड) का प्रकोप भी कम होता है।

क्षारीय मृदाओं में फसल उपज बढ़ाने के लिए हैलोफिलिक पादप वृद्धि सूक्ष्मजीव

तरल जैव पदार्थों 'हैलो–एजो' एवं 'हैलो–पीएसबी' का फसलों की वृद्धि, उपज एवं क्षारीय मृदाओं (पीएच 9.4) के गुणों पर प्रभाव का अध्ययन करने के लिए गमलों में और प्रक्षेत्र प्रयोग संचालित किए गए। गेहूँ में हैलोफिलिक नाइट्रोजन फिक्सर्स एवं फास्फोरस साल्यूबलाईजर्स (हैलो–एजो, हैला पीएसबी एवं हैलो–एजास्प) द्वारा बीजोपचार करने पर पौध ऊंचाई में लगभग 21 प्रतिशत एवं जड़ लम्बाई में लगभग 17–25 प्रतिशत की वृद्धि हुई। इसी प्रकार नियंत्रण उपचार की तुलना में हैलो–एजो, हैलो–पीएसबी एवं हैलो–एजास्प से उपचार करने पर दाना उपज में क्रमशः 14.2 प्रतिशत, 10.9 प्रतिशत एवं 17.9 प्रतिशत की वृद्धि हुई। हालांकि इनके संयुक्त प्रयोग से बीजोपचार करने पर दाना उपज में नियंत्रण उपचार की तुलना में 21.8 प्रतिशत की वृद्धि हुई। इसी प्रकार धान में इन पादप वृद्धि सूक्ष्मजीवों के संयुक्त प्रयोग से नियंत्रण उपचार की तुलना में दाना एवं भूसा उपज में क्रमशः 18.6 प्रतिशत एवं 24.9 प्रतिशत की वृद्धि हुई। तीन वर्षों के प्रक्षेत्र आंकड़ों के औसत के आधार पर यह निष्कर्ष निकाला गया कि इन हैलोफिलिक सूक्ष्मजीवियों के संयुक्त प्रयोग से क्षारीय मृदाओं में गेहूँ एवं धान की उपज में अनुपचारित नियंत्रण की तुलना में क्रमशः 18 प्रतिशत एवं 19.7 प्रतिशत की वृद्धि हुई।

लवणीय वर्टिसोल मृदाओं हेतु कपास जननद्रव्य का प्रजनन एवं मूल्यांकन

देशी कपास (*गासीपियम आर्बोरियम* एवं *गासीपियम हर्बेसियम*) की पृथक्करित समस्टियों की कुल 400 लाइनों का भरूच, गुजरात स्थित सामनी परीक्षण प्रक्षेत्र पर रोपाई की गई। लवणीय

वर्टिसोल मृदाओं में विभिन्न पृथक्करित समष्टियों का पीढ़ी विकास भी किया गया। देशी कपास के प्रजनन कार्यक्रम में आठ विभिन्न संयोजनों द्वारा *गासीपियम हर्शेसियम* के 70 एफ$_6$ जीनोटाइप विकसित किए गए। खरीफ 2017–18 के दौरान इन जीनोटाइप का 'प्राथमिक उपज परीक्षण' में मूल्यांकन किया गया। संतति वरण द्वारा *गासीपियम आर्बोरियम* की 76 एफ$_5$ संततियों का चिन्हीकरण का उन्हें पुनःवरण के लिए खरीफ 2017–18 में लगाया गया। पूरी फसल अवधि के दौरान विभिन्न उपज एवं जैव–रासायनिक लक्षणों के आधार पर इन लाइनों का चयन एवं विकास किया गया। इस परियोजना में चिन्हित सहिष्णु पैतृकों के प्रयोग द्वारा *गासीपियम हर्बोसियम* में नई प्रजनन समष्टियों का विकास किया गया।

महाराष्ट्र में उप–सतही जलनिकास तकनीक के प्रभाव का मूल्यांकन

महाराष्ट्र के अहमदनगर, सतारा, सांगली एवं कोल्हापुर जिलों में लगभग 0.18 मिलियन हेक्टेयर क्षेत्र जलभराव एवं मृदा लवणता की समस्याओं से प्रभावित है। भारतीय कृषि अनुसंधान परिषद–केन्द्रीय मृदा लवणता अनुसंधान संस्थान, करनाल द्वारा डिजाइन अनुमोदन के पश्चात राज्य सरकार द्वारा सांगली जिले के दुधगांव (1085 हे.) एवं कस्बे डिगराज (523 हे.) गांवों मे उपसतही जलनिकास प्रणाली की स्थापना की गई है। एक प्रभाव मूल्यांकन अध्ययन ने एसएसडी क्षेत्र में काफी विविधता देखने को मिली। कुछ हिस्सों में परिणाम अच्छे हैं जबकि कुछ दूसरे हिस्से अच्छी दशा में नहीं है। खराब एसएसडी प्रदर्शन के मुख्य कारणों में जलनिकास पाइपों का बंद होना, किसानों द्वारा प्रणाली की सही देखभाल न करना एवं गन्ने की जड़ों द्वारा अवरोध उत्पन्न करना सम्मिलित थे। कुछ स्थानों पर खुली नालियों में अत्यधिक वानस्पतिक वृद्धि के कारण जलनिकास बाधित हुआ। किसानों के साथ हुई चर्चा से ज्ञात हुआ कि एसएसडी प्रणाली लगाते समय एवं बाद में देखभाल में हुई गलतियों के कारण वांछित परिणाम नहीं मिल रहे हैं। संबंधित फर्म द्वारा निम्न गुणवत्ता की पाइपों की आपूर्ति, अकुशल श्रमिकों की अवहेलना एवं पार्श्व अंतरण एवं निकास गहराई में बदलाव जैसे कारणों ने एसएसडी प्रणाली की दक्षता पर प्रतिकूल प्रभाव डाला है। किसानों ने कहा कि एसएसडी प्रणाली स्थापना के समय उनकी राय जरूर ली जानी चाहिए। उनका मानना था कि वृहद क्षेत्र में प्रणाली लगाने के बजाय व्यक्तिगत किसान या किसान समूहों को सब्सिडी के माध्यम से एसएसडी प्रणाली लगाने के लिए उत्साहित कर अच्छे परिणाम प्राप्त किए जा सकते हैं। चूंकि गन्ने की जड़ें 6 फीट गहराई तक जाती है इसलिए इस क्षेत्र में जलनिकास गहराई 6 फीट से अधिक होनी चाहिए। तीस मीटर का पार्श्व अंतरण प्रभावी नहीं है और इसे घटावे की आवश्यकता है।

तटीय लवणीय मृदाओं में भू–आकार माडल्स की आर्थिक व्यवहार्यता

पश्चिम बंगाल के सुंदरवन के तटीय लवणीय क्षेत्रों में भू–आकार देने वाली तकनीकियों जैसे प्रक्षेत्र तालाब, धान–मछली सहपालन एवं गहरी कूंड–उभरी टीला किसानों के खेतों पर मृदा लवणता घटाने, जल उपलब्धता बढ़ाने, कृषि आय बढ़ाने व रोजगार सृजन में कारगर सिद्ध हुई हैं। हालांकि इन तकनीकियों के क्रियान्वयन में शुरू में मिट्टी की खुदाई में लागत अधिक आती है। बनकर तैयार हो जाने के बाद ऐसे माडल एक लम्बी अवधि तक केवल सामान्य परिचालन खर्च से अच्छा लाभ दे सकते हैं। इस तथ्य के दृष्टिगत प्रति इकाई होने वाले खर्च और लाभ का आर्थिक विश्लेषण किया गया। बढ़ती हुई लागत और बढ़ते हुए शुद्ध लाभ के आधार पर यह पाया गया कि प्रक्षेत्र तालाब, धान–मछली सहपालन और गहरी कूंड–उभरा टीला–इकाईयों का आंतरिक प्रतिफल दर क्रमशः 46, 42 एवं 36 प्रतिशत था। इसी प्रकार शुद्ध वर्तमान मूल्य क्रमशः रूपये 285059, 232450 एवं 96817 एवं ऋण वापसी की अवधि क्रमशः 1.41, 1.78 एवं 2.13 वर्ष थे। इन आंकड़ों से सिद्ध हुआ कि ऐसी भू–आकार तकनीकियों में आर्थिक निवेश व्यवहार्य हैं। वर्तमान में पश्चिम बंगाल सरकार राष्ट्रीय कृषि विकास योजना एवं अन्य कार्यक्रमों के माध्यम से तटीय लवणीय क्षेत्रों में इन तकनीकियों को बढ़ावा दे रही है।

लवण प्रभावित मृदाओं में फसलों की जस्ता और लोहा आवश्यकता का अनुकूलन

उत्तर–पश्चिमी भारत की लवण प्रभावित मृदाओं में जस्ते और लोहे की कम उपलब्धता फसलोत्पादन के लिए एक बाधा है। नैन परीक्षण प्रक्षेत्र, पानीपत की लवणीय मृदाओं में बाजरा–सरसों फसल चक्र में विभिन्न विधियों और मात्राओं में प्रयुक्त जस्ते और लोहे का मृदाओं में व्यवहार, विभिन्न अंशों में उपलब्धता और पौधों द्वारा अवशोषण का अध्ययन किया गया। बाजरे और सरसों की बुआई के समय जिंक सल्फेट एवं फेरस सल्फेट मिट्टी में मिलाए गए। इन पोषक तत्वों का बुआई के 30 और 45 दिन बाद पर्णीय छिड़काव भी किया गया। परिणामों से ज्ञात हुआ कि 5 किग्रा. जिंक, 10 किग्रा. लोहा और 10 टन गोबर की खाद के संयुक्त प्रयोग से जिंक (0.55 मिग्रा/किग्रा) एवं लोहे (1.85 मिग्रा/किग्रा) के जल घुलनशील एवं विनिमेय अंशों में सार्थक वृद्धि हुई जो कि सरसों की कटाई के उपरांत 0–15 सेमी. मृदा में नियंत्रण उपचार की तुलना में क्रमशः 52.8 एवं 33.1 प्रतिशत अधिक थे। चार वर्षों के जमा आंकड़ों ने इंगित किया कि इस उपचार से बाजरे की दाना उपज (3.66 टन/हे.) और सरसों की बीज उपज (2.27 टन/हे.) में नियंत्रण उपचार की तुलना में क्रमशः 57.1 एवं 42.8 प्रतिशत की वृद्धि हुई। यह निष्कर्ष निकाला गया कि जस्ता, लोहा एवं गोबर की खाद के संयुक्त प्रयोग से लवण प्रभावित मृदाओं की भौतिक–रासायनिक दशाओं में सुधार होता है जिससे इन तत्वों के कार्बनिक और विनिमेय अंशों व पौधों को उपलब्धता में वृद्धि होती है।

पुरस्कार एवं मान्यताएं

- प्राकृतिक संसाधन प्रबंधन एवं कृषि अभियांत्रिकी में वर्ष 2014–15 का हरिओम आश्रम ट्रस्ट पुरस्कार परिषद द्वारा डा. एस. के. कामरा, डा. सत्येन्द्र कुमार एवं डा. भास्कर नर्जरी को प्रदान किया गया।

- डा. प्रवीन कुमार, प्रधान वैज्ञानिक को वर्ष 2014–15 का भाकृअनुप, नई दिल्ली द्वारा फसल एवं बागवानी विज्ञान के लिए 16 जुलाई 2017 को हरिओम आश्रम ट्रस्ट पुरस्कार भाकृअनुप द्वारा प्राप्त हुआ।

- आबरडीन विश्वविद्यालय, यूनाइटेड किंगडम में अनुसंधान कार्य के लिए डा. असीम दत्ता को भारत–यूनाइटेड किंगडम फैलोशिप प्राप्त हुई।

- पीएच डी. (मृदा विज्ञान एवं कृषि रसायन) में सर्वाधिक सम्पूर्ण ग्रेड औसत प्राप्त करने हेतु डा. श्रवण कुमार को नवसारी कृषि विश्वविद्यालय का वर्ष 2016–17 का कुलाधिपति स्वर्ण पदक प्रदान किया गया।

- मृदा विज्ञान में उत्कृष्ट योगदान के लिए डा. संजय अरोड़ा ने भारतीय मृदा विज्ञान समिति, नई दिल्ली का वर्ष 2017 का 'डा. जे. एस. पी. यादव मेमोरियल पुरस्कार' प्राप्त किया।

- सूक्ष्म जीवी तकनीकियों द्वारा लवण प्रभावित मृदाओं के सुधार और प्रबंधन हेतु डा. संजय अरोड़ा को 'जे. एस. बाली पुरस्कार 2016' से सम्मानित किया गया।

- अंतर्राष्ट्रीय सम्मेलन 'दक्ष मृदा एवं फसल प्रबंधन के लिए पोटाशियम अनुसंधान में प्रगति' (28–29 अगस्त, 2017) के दौरान डा. असीम दत्ता ने 'पश्चिमी सिंधु–गंगा मैदानों में सतत सघनीकरण आधारित संरक्षण खेती में पोटाशियम उपलब्धता' विषय पर सर्वोत्तम पोस्टर पुरस्कार (द्वितीय) प्राप्त किया।

- भारतीय मृदा संरक्षण समिति, नई दिल्ली के 26वें सम्मेलन के दौरान डा. संजय अरोड़ा ने सर्वोत्तम अनुसंधान पत्र पुरस्कार 2017 प्राप्त किया।

- भारतीय मृदा संरक्षण समिति, नई दिल्ली द्वारा आयोजित 26वें राष्ट्रीय सम्मेलन 'जलवायु अनुकूल सतत कृषि के लिए प्राकृतिक संसाधन प्रबंधन' (11–13 सितम्बर, 2016) के दौरान डा. अजय भारद्वाज ने सर्वोत्तम पोस्टर पुरस्कार प्राप्त किया।

कार्यशाला

- महाराष्ट्र के अहमदनगर जिले के 15 किसानों के लिए 5–8 जून, 2017 के मध्य 'लवण प्रभावित मृदाओं एवं निम्न गुणवत्ता जल में सतत फसलोत्पादन' विषय पर एक चार दिवसीय प्रशिक्षण कार्यक्रम आयोजित किया गया।

- भारतीय कृषि अनुसंधान परिषद–केन्द्रीय मृदा लवणता अनुसंधान संस्थान, करनाल और हरियाणा कृषि एवं किसान कल्याण विभाग द्वारा संयुक्त रूप से 'उपसतही जलनिकास हरियाणा आपरेशनल पायलट प्रोजेक्ट' की तकनीकी समिति की पहली बैठक 12 जुलाई, 2017 को करनाल में आयोजित की गई।

- 'महिला खरीफ किसान मेला' कैथल जिले के सिंकदर खेड़ी गांव में 15 अक्तूबर, 2017 को आयोजित किया गया।

- अफ्रीका–एशिया ग्रामीण विकास संगठन द्वारा प्रायोजित अंतर्राष्ट्रीय प्रशिक्षण कार्यक्रम 'कृषि में निम्न गुणवत्ता जल का प्रयोग' 10–24 नवम्बर, 2017 के मध्य आयोजित किया गया।

- 'विश्व मृदा दिवस' एवं 'कृषि शिक्षा दिवस' 5 दिसम्बर, 2017 को आयोजित किए गए।

- भारतीय कृषि अनुसंधान परिषद क्षेत्रीय समिति पांच (पंजाब, हरियाणा एवं दिल्ली) की मध्यावधि समीक्षा बैठक 12 दिसम्बर, 2017 को आयोजित की गई। इस दौराना 24वीं बैठक में की गई अनुशंसाओं एवं प्रगतियों की समीक्षा की गई।

- भारतीय कृषि अनुसंधान परिषद–केन्द्रीय मृदा लवणता अनुसंधान संस्थान, करनाल की 50वीं वर्षगांठ के उपलक्ष्य में 'स्वर्ण जयंती रबी किसान मेला' 10 मार्च, 2018 को आयोजित किया गया जिसके मुख्य अतिथि केन्द्रीय कृषि एवं किसान कल्याण मंत्री माननीय श्री राधामोहन सिंह थे।

- भारत–अफ्रीका फोरम द्वारा प्रायोजित 'लवण प्रभावित मृदाओं के सतत प्रबंधन के लिए उन्नत एवं नवोन्मुखी तकनीकियों' विषय पर अंतर्राष्ट्रीय प्रशिक्षण कार्यक्रम 15–26 मार्च, 2018 के मध्य आयोजित किया गया।

क्षेत्र प्रदर्शनी व भ्रमण

- वर्ष 2017–18 के दौरान कृषि में लवणग्रस्त मृदा के सुधार और प्रबंधन व निम्न कोटि जल के उपयोग पर विभिन्न अनुसंधान संस्थानों और विकास अभिकरणों में 8 प्रदर्शनियां लगाई गई। 265 समूहों में आये 2141 हितधारकों ने संस्थान के सूचना प्रौद्योगिकी केन्द्र व प्रायोगिक फार्म का दौरा किया। 1678 हितधारकों में 24 समूहों में आये 263 किसान, 9 समूहों में आए 139 प्रसारकर्मी और वस्तु विषय विशेषज्ञ, 28 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 ने 18001801014 नम्बर पर निःशुल्क फोन सेवा शुरू की है।

वर्ष 2017–18 के दौरान देश के विभिन्न क्षेत्रों से कृषि संबंधित समस्याओं संबंधित 528 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 चावल (आईआरआरआई व वीएमजीएफ द्वारा प्रायोजित)।
- बांग्लादेश एवं पश्चिम बंगाल, भारत के लवण प्रभावित तटीय क्षेत्रों में फसल प्रणाली सघनीकरण (सीएसआईआरओ एवं मुडोर्क विश्वविद्यालय, आस्ट्रेलिया द्वारा वित्त पोषित)
- पूर्वी भारत में बरानी निचली भूमियों में धान प्रणालियाँ (धान में फसल एवं पोषक तत्व प्रबंधन तकनीकियों का विकास) (आइसीएआर डब्ल्यू 3) (आईआरआरआई द्वारा विमोचित)
- जलवायु परिवर्तन, कृषि एवं खाद्य सुरक्षा (सीसीएएफएस) (सीआईएमवाईटी, मैक्सिको)
- दक्षिण एशिया में शहरी बाढ़ को कम करने तथा ग्रामीण क्षेत्रों में पानी की सुरक्षा में सुधार के लिये भूगत नवप्रवर्तनकारी परीक्षणात्मक को बढ़ावा देना (आईडब्ल्यूएमआई)।
- भारत के जल संवेदनशील क्षेत्रों में सतत संसाधन प्रबंधन प्रणालियों का विकास (जिरकास, जापान)।

प्रकाशन

- संस्थान द्वारा प्रमुख जरनलों में 75 अनुसंधान आलेख, 14 पुस्तक अध्याय, 40 पुस्तक/मैनुअल, 3 बुलेटिन/फोल्डर, 14 प्रचलित आलेख, तकनीकी प्रतिवेदन छपवाये गये और 25 आलेख सेमीनार/सिमपोसिया और कानफ्रेन्सों में प्रस्तुत किये गये।

वैज्ञानिकों का विदेश भ्रमण कार्यग्रहण व सेवानिवृत्ति

- ज्ञान व कुशलता को बढ़ाने हेतु संस्थान के 8 वैज्ञानिकों ने विभिन्न देशों जैसे वियतनाम, फिलीपीन्स, आस्ट्रेलिया, युनाईटेड किंगडम, जापान, और बांग्लादेश, का दौरा किया। इस अवधि में 3 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. To pursue specific research needs of different agro-climatic regions, 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 8 regular research centres at Agra (Uttar Pradesh), Baptala (Andhra Pradesh), Bikaner (Rajasthan), Gangawati (Karnataka), Hisar (Haryana), Indore (Madhya Pradesh), Kanpur (Uttar Pradesh), Tiruchirapalli (Tamil Nadu) along with 4 voluntary centres at 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:

Soil salinity characterization using hyper-spectral remote sensing data

Severely salt affected soils can be easily detected due to high reflectance from salt crust on soil surface. In contrast, detection of low and medium salinity affected lands is difficult due to intricate association of salt, soil, water and vegetation. A methodology was developed by integrating hyper-spectral (HRS) data with limited ground truth and further quantification through a statistical model. Study area (10.8 ha of CSSRI Experimental Farm, Nain, Distt. Panipat) was divided in regular grid (30 × 30 m) to collect surface soil samples (0-30 cm) during the post monsoon season for analyzing physico-chemical properties. Hyper-spectral data were collected from a spectroradiometer in different wavelength regions and standardized using a statistical model to find prominent absorption region between 1420 to 2020 nm. Salinity model was developed by integrating hyper-spectral data with soil physico-chemical properties by multivariate statistical analysis and subsequent validation using the band math techniques. A spectral library was thus developed for further mapping of salt affected soils with limited ground truth data. Variability of salinity and sodicity attributes such as EC_e, Na^+, Cl^-, CO_3^{2-} and HCO_3^- (me L^{-1}) of the saturated soil extract were related quantitatively (r^2=>90%) to hyper-spectral data. The spectral regions of 1400, 1900 and 2200 nm showed prominent peak due to the changes in soil salinity. At 1900 nm prominent shifting facilitated in establishing a significant correlation with salt concentration.

KRL 283: new salt tolerant wheat variety released

A new salt tolerant wheat variety KRL 283 has been recommended for notification in 79th meeting of Central Sub-Committee on Crop Standards, Notification and Release of Varieties, for Agricultural Crops on 20th January, 2018 for salt affected soils of Uttar Pradesh. KRL 283 has shown good yielding ability and salt tolerance with superiority in grain yield on three year's mean (15.02%, 13.68% and 5.24%) over salt tolerant checks, K 8334, NW 1067 and KRL 19, respectively. Under normal conditions, its yield potential is 5.8-6.2 t ha^{-1} while in sodic soils (pH 9.0-9.3) it gives 4.5-4.8 t ha^{-1} yield. It takes 128-133 days for maturity and can tolerate salinity up to 6.7 dS m^{-1} and sodicity up to pH 9.3. It is also tolerant to stripe rust/ brown rust/ stem rust/Karnal bunt/aphid/ shoot fly.

CS 60: new salt tolerant variety of Indian mustard released

This variety has been identified and recommended by the 24th Annual Group Meeting of All India Coordinated Research Project on Rapeseed-Mustard during 2017 and released & notified by Central Sub-Committee on Crop Standards, Notification & Release of Varieties (CVRC) during 79th meeting held on 20th Jan., 2018, for salinity affected areas of the mustard growing regions of the country Zone–II comprising the states of Haryana Punjab, Uttar Pradesh and Rajasthan. This variety gave 25% higher seed yield and 27% higher oil yield per hectare over the national check CS 54 and high yielding varieties Kranti and Giriraj under soil salinity EC_e 10-11 dS m^{-1}, irrigation water salinity: EC_{iw} 10-12 dS m^{-1} and alkalinity pH 9-9.3. It matures, on an average, in 134 days and takes 58 days to flower. The productivity of this variety under normal soils is 2.4-2.9 t ha^{-1}, while under salt affected soil is 1.8-2.1 t ha^{-1} with 41% oil content. CS60 showed resistance to *Alternaria* blight, White rust, Powdery Mildew, Downy Mildew, Stag head, *Sclerotinia* stem rot and mustard aphid under field conditions also.

Halophilic plant growth promoters to improve crop yields in sodic soils

Pot and field experiments were conducted to study the effects of liquid bioformulations 'Halo-Azo' and 'Halo-PSB' on growth and yield of crops and properties of sodic soils (pH 9.4). In wheat, seed inoculation with halophilic nitrogen fixers and P solubilizers (Halo-Azo, Halo-PSB and Halo-Azsp) resulted in ~21.0% increase in plant height and ~17.0-25.0% increase in root length over control. Grain yield increased by 14.2, 10.9 and 17.9% in Halo-Azo, Halo-PSB and Halo-Azsp treatments, respectively, over control. However, consortia of halophilic strains resulted in an increase of 21.8% in grain yield over control. Grain and straw yields of rice increased by 18.6 and 24.9% in consortia treated pots over control. Field experiments data of three years also showed that combined application of these halophilic strains enhanced wheat and rice yields by 18.0 and 19.7%, respectively, over un-inoculated control under sodic field conditions. Halophilic strains of N-fixers were found to be superior over P-solubilizer in enhancing yield of both the crops.

Breeding and evaluation of cotton germplasm for saline Vertisols

A total of 400 lines of segregating populations of *desi* cotton (*G. arboreum* and *G. herbaceum*) were planted at Samni Experimental Farm, Bharuch, Gujarat. Generation advancement of the segregating populations in saline Vertisols was also done. Breeding programme of *desi* cotton yielded 70 F_6 genotypes (*G. herbaceum*) of eight diverse crosses. These lines were tested in Preliminary Yield trial (PYT) during *kharif* 2017-18. Pedigree selection yielded 76 F_5 progenies of *G. arboreum* which were planted in *kharif* 2017-18 for further selection. These lines were selected and advanced on basis of yield and biochemical parameters recorded during the entire crop duration. New breeding populations were developed in *G. herbaceum* with tolerant parents identified in this project.

Impact evaluation of sub-surface drainage technology in Maharashtra

About 0.18 M ha area in Ahmednagar, Satara, Sangli and Kolhapur districts of Maharashtra suffers from waterlogging and soil salinity. Subsurface drainage (SSD) systems have been established by the State government in Dudhgaon (1085 ha) and Kasbe Digraj (523 ha) villages of Sangli district after design approval from ICAR-CSSRI. An impact evaluation study revealed large variations in the SSD area with some parts giving good results while others being in bad condition. Poor SSD performance in some blocks was attributed to the choking of drain pipes, poor upkeep by the farmers and blockage caused by the sugarcane roots. At some places, open drains were heavily infested with vegetation creating problems in the disposal of drainage water. Detailed discussion with the farmers revealed that discrepancies in installation and upkeep have reduced the efficiency of SSD systems. These include poor quality of pipes supplied by the responsible firm, installation work done by the unskilled workers, neglect of approved design during installation and alterations in the lateral spacing and drain depth. Farmers' opined that their opinions must be considered while installing the SSD systems. Instead of large scale installation, SSD on the fields of individual farmers or a group of farmers with subsidy support from the government will give better results. Because sugarcane roots can grow up to the depth of 6 feet, drain depth should be >6 feet in sugarcane growing areas. Lateral spacing of 30 m is not effective and it should be reduced.

Financial viability of the land shaping models in coastal saline soils

On-farm demonstrations of the land shaping techniques *viz*., farm pond (FP), paddy-cum-fish (PCF) and deep-furrow & high ridge (DFHR) models in farmers' field in Sunderbans have been successful in terms of reducing salinity, improving water availability, increasing farm income and providing gainful employment to the farmers. However, land shaping techniques involve high initial investments particularly to meet the soil excavation cost. Once the land shaping techniques are constructed, the operational costs incurred and benefits accrued during the project period and these cost-benefit streams were likely to continue over the economic life of the techniques. Financial analyses of these land shaping techniques was done to find out whether the investment will yield a reasonable rate of return to all resources engaged for an average unit. Based on the incremental cost incurred and incremental net return realized from each land shaping techniques, IRR were estimated to be 46%, 42%, and 36% under FP, PCF and DFHR systems, respectively.

Similarly, NPV were Rs. 285059, Rs. 232450, and Rs. 96817; BCR were estimated to be 1.58, 1.55, and 1.20 and payback period was calculated to be 1.41, 1.78 and 2.13 years, respectively under FP, PCF and DFHR type of land shaping techniques. Financial analysis indicated that investment on such interventions were financially viable for the coastal region in Sunderbans of West Bengal. Government of West Bengal is now implementing these land shaping techniques under PMKSY and RKVY in the different salt affected coastal districts in West Bengal.

Optimizing crop zinc and iron requirements in salt affected soils

Decreased activities of micronutrients, especially Zn and Fe, in salt-affected soils of north-western India result in their low availabilities. It is a major constraint for crop production. Hence, a field experiment was conducted at Nain Experimental Farm to understand the mechanism of distribution of Zn and Fe in different fractions as result of Zn and Fe application methods and different doses for pearl millet-mustard crop rotation to know their retention in soils and release to plants. 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 of pearl millet as well as mustard. Foliar sprays of respective nutrients were also applied with same chemicals as in soil application at 30 and 45 days after sowing. Results indicated that combined application of 5 kg Zn+10 kg Fe +10 t FYM significantly increased the water + exchangeable fraction of Zn (0.55 mg kg^{-1}) and Fe (1.85 mg kg^{-1}) that were 52.8% and 33.1% higher over control in soil (0-15cm) at harvest of mustard crop. Four years pooled data also indicated that combined soil application of 5 kg Zn+10 kg Fe +10 t FYM significantly increased the pearl millet grain yield (36.6 q ha^{-1}) and mustard seed yield (22.7 q ha^{-1}) by 57.1% and 42.8% higher over control. It is concluded that combined soil application of Zn and Fe with FYM was effective in increasing the available Fe and Zn in soils by enhancing the pools of exchangeable and organic matter fractions of Zn and Fe through altering the physical and chemical characteristics of salt affected soils.

Awards and Recognitions

- ICAR, New Delhi conferred 'Hari Om Ashram Trust Award' in Natural Resources Management and Agricultural Engineering to Dr. S.K. Kamra, Dr. Satyendra Kumar and Dr. Bhaskar Narjary for the Year 2014-15
- Dr. Parveen Kumar, Principal Scientist received Hari Om Ashram Trust Award of ICAR, New Delhi for Biennium 2014-15 for Crop and Horticultural Sciences on 16 July 2017
- Dr. Asim Datta was selected for NEWS (Newton Bhabha Virtual Centre on Nitrogen Efficiency of Whole Cropping Systems) India-UK fellowship (3 months) for conducting research on 'Whole farm modelling of carbon sequestration and organic resource use at case study sites in India' at University of Aberdeen, Unite Kingdom
- Dr. Shrvan Kumar, Scientist was awarded the Chancellor's Gold Medal of NAU, Navsari, Gujarat for securing the Highest Overall Grade Point Average and presenting quality research work for Ph. D. degree (Soil Sci. & Agril. Chem.) in the year 2016-17
- Dr. Sanjay Arora received 'Dr. J.S.P. Yadav Memorial Award' of Indian Society of Soil Science, New Delhi for Excellence in Soil Science during 2017
- Dr. Sanjay Arora received 'J.S. Bali Award 2016' of SCSI, New Delhi for contribution in reclamation and management of saline and sodic soils through microbial techniques for sustaining agricultural productivity and soil health management

- Dr. Ashim Datta received Best Poster Award (Second) for paper entitled 'Potassium availability under conservation agriculture with sustainable intensification in Western IGP' during the International conference on 'Advances in Potassium Research for Efficient Soil and Crop Management' held at NASC complex, New Delhi during 28-29, August 2017
- Dr. Sanjay Arora received Best Paper Award 2017 of SCSI at 26th National Conference held at CAU, Barapani
- Dr. Ajay Bhardwaj received Best Poster Award in the 26th National Conference on 'Natural Resource Management for Climate Smart Sustainable Agriculture (NRMCSSA-2017)' held at Barapani, Meghalaya, India during during 11-13 September, 2017

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

- A four days training programme on 'Sustainable management of crop productivity in salt affected soils and poor quality waters' was organized for 15 farmers of Ahmednagar district of Maharashtra State from 5-8 June, 2017
- ICAR-CSSRI and Department of Agriculture & Farmers' Welfare, Govt. of Haryana jointly organized the 'First Meeting of Technical Committee for Haryana Operational Pilot Project (HOPP) on Sub Surface Drainage (SSD)' on 12th July, 2017 at ICAR-CSSRI Karnal.
- *Mahila Kharif Kisan Mela* was organized at Sikandar Kheri village of Kaithal district of Haryana on 15th October, 2017.
- An international training programme on 'Use of Poor Quality Water in Agriculture' sponsored by African-Asia Rural Development Organization was organized during 10-24 November, 2017.
- 'World Soil Day' and 'Agricultural Education Day' were celebrated on 5th December 2017 at Karnal.
- ICAR- Mid Term Review Meeting of Regional Committee Zone-V (Punjab, Haryana & Delhi) was held on 12th December, 2017 at ICAR-CSSRI, Karnal. Action Taken Report and recommendations made in 24th ICAR Regional Committee Zone–V meeting held at ICAR-IARI, New Delhi during 3-4 October, 2016 were reviewed and discussed.
- '*Swarna Jayanti Rabi Kisan Mela*' was organized on 10th March, 2018 to mark the Golden Jubilee Year of ICAR-CSSRI. The Mela was inaugurated by Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers Welfare, Government of India.
- An International Training on "Advance and innovative technologies for sustainable management of salt affected soils" was organized under Indo-African Forum during 15-26 March, 2018.

Field Exhibition and Visit

During 2017-18, a total of 8 exhibitions were organized at different research institutions and developmental agencies to portray the improved technologies for the reclamation and management of salt-affected soils and poor quality waters. Out of 2141 stakeholders, 263 farmers in 9 groups, 1678 students in 24 groups, 172 extension workers in 30 groups and 28 scientists in 12 groups from India and abroad visited Institute Technology Information Centre and experimental farms to learn about the technologies commercialized and being developed.

Farmers' Advisory Services

During 2017-18, a total of 528 advisories on soil testing, salinity and alkalinity management, salt tolerant crop varieties, crop management practices, animal husbandry, horticultural crops, and nutrient management were provided to the farmers through TOLL Free Number 1800 180 1014.

International Collaboration

- Stress Tolerant Rice for Poor Farmers of Africa and South Asia (funding IRRI-BMGF)
- CSIRO, Murdoch University, Australia- Cropping system intensification in the salt affected coastal zones of Bangladesh and West Bengal, India
- Future Rainfed Lowland Rice Systems in Eastern India (Development of Crop and Nutrient Management Practices in Rice) (ICAR-W3) (IRRI funded).
- Climate Change, Agriculture and Food Security (CCAFS) (Funding CIMMYT)
- Developing of Sustainable Resources Management System in the Water-Vulnerable Area in India(Funding JIRCAS)
- Piloting and Up-scaling an Innovative Underground Approach for Mitigating Urban Floods and Improving Rural Water Security in South Asia (Funding IWMI)

Publications

The Institute published 75 research papers in peer reviewed journals, 14 Books/Training Manuals, 40 Book/Manual Chapter, 3 Technical Bulletins/Folder, 14 popular articles. Besides, 25 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, 8 scientists of the institute visited different countries *viz*. Vietnam, Philippines, Australia, Japan, U.K. and Bangladesh. Four 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. Government of India constituted an Indo-American team to assist the Indian Council of Agricultural Research in developing 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 soils 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 having surface drainage congestion and high water table conditions, another Regional Research 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). In 2014, four new voluntary 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, vegetables 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 by 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 chickpea 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 identifies the constraints hampering adoption of land reclamation technologies and their impact on rural development.

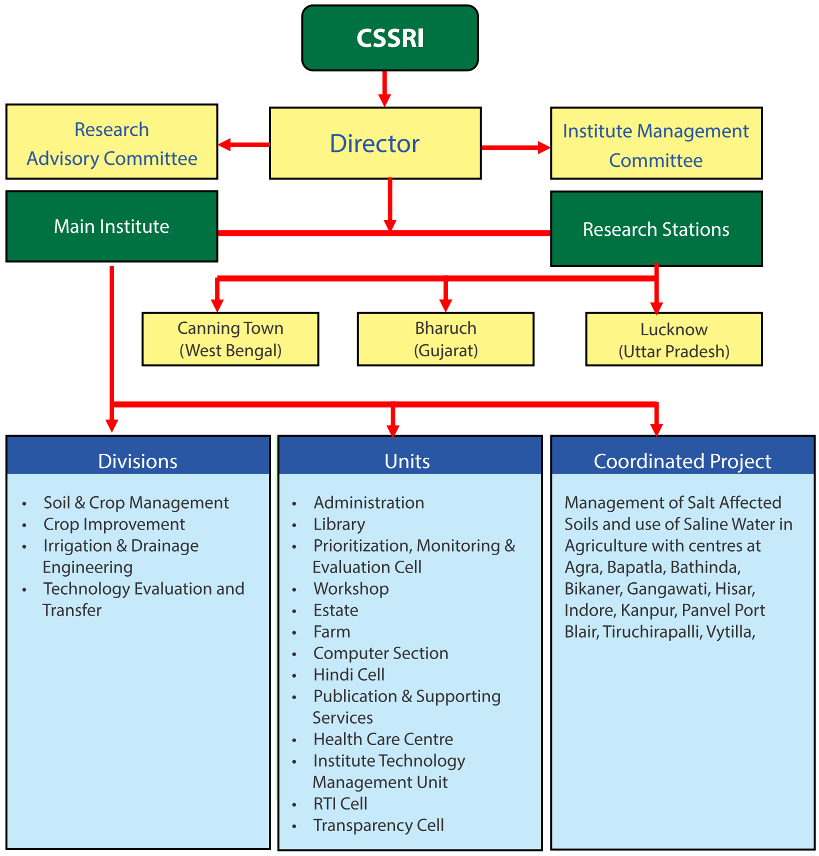
The Institute has developed technologies for the chemical amendment based reclamation of alkali soils, reclamation of saline soils through subsurface drainage, development and release of salt tolerant crop varieties of rice, wheat, mustard and chickpea and the biological reclamation of salt affected soils through salt tolerant multipurpose trees. A microbial consortia CSR BIO as a plant growth enhancer has been developed and commercialized. 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 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 faculty also serve as guest teachers and advisors for the Post Graduate education and research programmes of State Agricultural Universities (SAUs), other Universities and Institutes. 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 taming 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 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 generations. A transgenic green house facility has also been created. A central laboratory with modern equipments has been established.

Organogram

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



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 21.60 ha area, while general crops are grown in 16.6 ha, which also includes the 10 ha area under seed production mainly of salt tolerant varieties of rice and wheat. During the period under report, the farm unit generated revenue of Rs. 92 lakh. To reduce the emission of green

Productivity of crops at CSSRI farm

Crop	Variety	Average yield (t ha^{-1})
***Rabi* 2016 - 17**		
Wheat	KRL 210	5.10
	KRL 213	4.15
Mustard	CS 52	2.00
	CS54	2.45
	CS56	2.65
	CS 58	2.84
Chickpea	Karnal chana 1	2.25
***Kharif* 2017**		
Paddy	CSR 30	3.60
	CSR 36	5.00
	CSR 43	5.35
	Pusa 44	5.60

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 6.2 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 1.20 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.

Nain Experimental Farm, Panipat

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 km from Karnal. This farm covers an area of 10.8 ha. Initially, the site had *Prosopis juliflora* and other 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 HCO_3^-. 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 and agroforestry/fruit crops for salinity tolerance. In addition, institutes like Regional Research Stations of IARI and SBI, Karnal also use this facility for screening of the germplasm.

Finances

Summary of allocation and expenditure during the year 2017-18 under Plan and Non-Plan budget is presented below:

(Rs. in lakhs)

Head	Progressive Expenditure (other than NEH & TSP expenditure)	Progressive Expenditure (TSP)	Progressive Expenditure (NEH)	Grand Progressive Expenditure
Capital (Grant for creation of capital assets)	115.00	-	-	115.00
Establishment Expenses (grant in aid-salaries)	2832.41	-	-	2832.41
Grant in aid general	715.05	-	-	715.05
Grand Total	3662.46	-	-	3662.46
Loan and advance	13.98	-	-	13.98

Staff

The total staff strength of the institute is 351. The category wise details are:

Category of post	Sanctioned	In position	Vacant	% Vacant
Scientific	81	65	16	19.75
Technical	117	72	45	38.46
Administrative	58	33	25	43.10
Skilled Supporting Staff	95	38	57	60.00
Total	351	208	143	40.74

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 to meet their teaching and research needs. Library has always been striving hard to meet the expectations of its users. ICAR-CSSRI library is well furnished, fully air-conditioned and equipped with four computers, one server and two UPS. The Institute library has rare and large collection of Technical, Scientific books, Journals, Reports and other publications. 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 15570 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. 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 for easier to search 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, Tech. 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 03 priced publications also which are supplied on cash payment or D.D.in advance.

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), HPLC,GLC 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 an 'Information Technology Centre' for displaying salient research findings and the technologies commercialized. This centre is periodically upgraded with new additions and state of art display infrastructure/material. An international guesthouse and scientists hostel with boarding facilities cater to the need of scientists and other visitors. A dispensary with physiotherapy unit is also available. 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

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)

IRS LISS III data of March, June and October 2010 were used to detect salt affected soils in Ambala district of central Haryana (Fig. 1). Spatial distribution of soils indicated common occurrence in the Markanda and Ghaggar plains. March data showed surface water stagnation in partially cropped areas suggesting temporary waterlogging and apparent alkali soils formation. At places, white incrustation indicated soil salinization in irrigated areas along the Bhakra canal command. Red to dark red tones indicated scattered, discontinuous and mottled crop covers in the salt affected areas. High reflectance from sand with no vegetative cover indicated the presence of riverine sands as wastelands along the river beds. High energy absorption from surface water restricted delineation of soil salinity using IRS data, inputs from ground truth studies are vital for such areas. The ground water depth and quality data indicated deep and marginal quality in general.

Ground truth studies indicated the presence of sodic soil and calcium carbonates concretion layer at sub-surface depths that inhibits movement of water. Saline soil was also found along the irrigated areas of Bhakra canal. Significant areas of wastelands were found in the hummocky plain in Naraingarh block. Common source of irrigation is good quality of groundwater. Rice-wheat and oilseeds are common arable crops and forestry plantation is also practiced along the river course. Soil samples were collected from surface and sub-surface depths to assess nature, extent and degrees of soil salinity/ sodicity. Representative soil profiles were analyzed for physico-chemical properties such as pH_s, EC_e, ESP, CEC, ionic (cation and anion) composition, OM, $CaCO_3$ (<2 mm size) contents.

Pedon P1 and P2 were collected from Dangri river plain and P3 and P4 were located in the Markanda plain. The ranges of pH_s (7.9 to 9.4 in P1, 8.5 to 9.6 in P2, 9.1 to 9.5 in P3 and 9.3 to

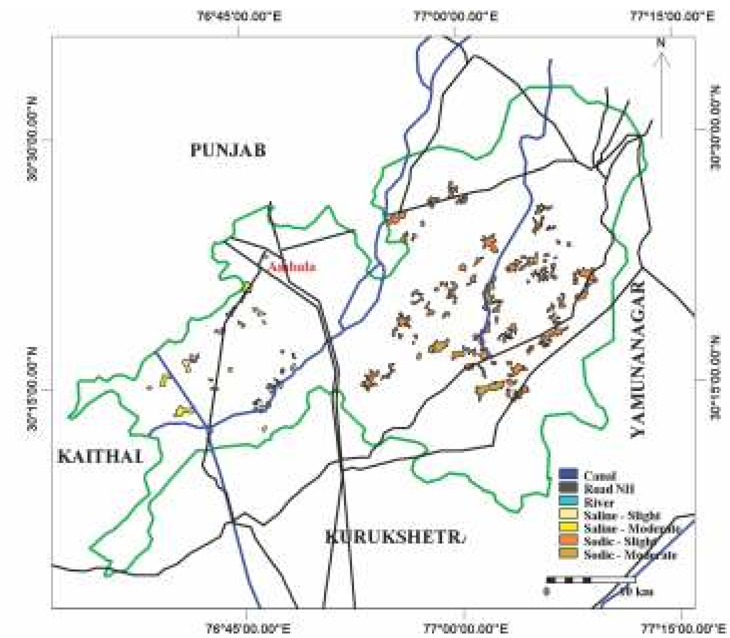


Fig. 1. Distribution of salt affected soils and waterlogged areas in Ambala district of Haryana

9.8 in P4) indicated moderate to strongly sodic soils. Low pH_s at the surface layers in P1 and P2 indicated reclamation. pH_s increased at the lower depths in P1, P2 and P3, and consistent at all depths in P4. The dominance of Na^+, Ca^{2+}, Mg^{2+}, CO_3^{2-} and HCO_3^- salts indicated the presence of alkaline parent materials. $CaCO_3$ content indicated calcareous nature at sub-surface depths and imperfect drainage. Low to moderate CEC are related to coarse to medium soil texture. Particle size analysis data showed loam in P1, loam to clay loam in P2, sandy loam in P3 and loam in P4. P1 showed increasing pHs and ESP (24 to 60) at sub-surface depths and needs careful soil and water management after gypsum application. pH_s and ESP (25 to 75) of P2 showed sodicity at sub-surface depths. The presence of calcareous layer and higher clay content (13 to 29%) apparently caused poor drainage and waterlogging. Proper soil and water management is crucial in managing such soil after careful reclamation with GR application. P3 showed higher Na^+, CO_3^{2-} and HCO_3^- contents that indicated residual sodicity and needs low dosage of gypsum application and suitable for growing salt resistant crops. P4 is a strongly sodic soil located in the Markanda plain, showing high pH_s, ESP and loamy soil texture. It needs gypsum application @ 6-8 t ha^{-1} for reclamation followed by salt leaching before putting for arable cropping. The total area affected was 5064 ha of which sodic and saline soils covered 4222 and 842 ha while slight and moderately salt affected soils covered 4040 and 1024 ha, respectively.

Salt affected soils data in Haryana- A current status (A. K., Mandal, M Sethi., Anil Chinchmalatpure, R. K. Yadav and P. C.Sharma)

The salt affected soils data for Haryana state was compiled using Geographic information System (GIS). The methodology includes integration of IRS LISS III data and the inputs from field studies of soil profiles (1.5 m depth) and laboratory analysis data for physico-chemical properties of soils. The map legends described nature, degree and extent of salinity and sodicity. Slight, moderate and strongly salt affected soils were classified as per USDA approach and were merged to two categories viz, saline and sodic respectively. Depth-wise soil samples were analyzed for physico-chemical properties such as pH_s, EC_e (dS m^{-1}) , soluble salt composition for Na^+, K^+, Ca^{2+}, Mg^{2+}, CO_3^{2-}, HCO_3-, Cl^- & SO_4^{2-} (me L^{-1}), O.M.(%) , $CaCO_3$ (%), CEC, ESP (%) and sand, silt and clay (%) contents. The water samples collected from tube wells were also analyzed for quality appraisal. These were mapped using the Survey of India topographical sheets on 1:50, 000 scale.

Salt affected soils were distributed in eighteen districts that covered 315617 ha. Saline and sodic soils covered 145054 ha and 170563 ha respectively. Significant areas were distributed in Sonepat (35077 ha), Jhajjar (41546 ha), Rohtak (32633 ha) and Jind (11805 ha) districts, confined at the low-lying flats/ depressions in Central Haryana. Soil salinity was distributed in sandy arid and semiarid plains western Haryana districts viz., Hisar (34245 ha), Sirsa (30311 ha) and Bhiwani (15958 ha). Thick calcareous layers in these areas caused secondary soil salinization and waterlogging as a result of irrigation from canal and tube well. The use of sodic ground water in Kaithal (9812 ha) district and sodium carbonate and bicarbonate containing parent materials in Ghaggar plains in Kurukshetra (15873 ha) district caused sodicity development in these areas. Karnal (19183 ha) and Panipat (7514 ha) districts showed the sporadic occurrence of soil sodicity at the post-reclamation stage. The salinity and sodicity in Faridabad (8637 ha), Gurgaon (9314 ha), Palwal (10033 ha) and Mewat (8834 ha) districts were influenced largely by the Aravalli hills.

Spectral characterization of saline soil located at Nain experimental farm of ICAR-CSSRI in Panipat district of Haryana (Arijit Barman, Rajeev Srivastava, A.K. Mandal, Jogendra Singh and R. K. Yadav)

Degraded salt-affected soils (SAS) lead to reduction of food grain production in alluvial soils of Indo-Gangetic plains (IGP) of north-western arid and semi-arid regions of India. Timely identification of SAS and their monitoring are essential for arresting further degradation. Remote sensing (RS) based characterization provides non-destructive high temporal resolution and fast categorizing technique. Previous results indicated that the spectral regions of 1400, 1900 and 2200 nm were highly sensitive to changes in salinity. Present study aims to develop soil reflectance spectral models for rapid and cost-effective assessment of cations like Na^+, K^+, Mg^{2+}, Ca^{2+} and anions such as CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} in SAS of CSSRI experimental farm Nain (Village Nain, District Panipat, Haryana). The farm area (12 ha) extends from 29°19'7.09" to 29°19'10.0"N latitude and 76°47'30.0" to 76°48'0.0" E longitude and is located at an elevation of 230 to 231 m above MSL. The soil of the site is classified as Haplustepts. These are highly variable and complex saline and sodic in nature with poor drainage condition. Surface and subsurface soil samples with core based on 30 m × 30 m grids was collected during September 2017. The farm area was also scanned with EM 38 instrument for EC_e prediction. A wide range of measured soil salinity (3 to 81 dS m^{-1}) and sodicity (7.24 to 8.75) was found at surface soil samples (Fig. 2). Surface soils with moderate (EC_e 8-30 dS m^{-1}) and strong (EC_e>30 dS m^{-1}) salinity covered 64.9% and 33.6% area and the extent of soil salinity increased by 8.3% and 15.8% (Table 1) after 6 years, respectively. Surface soil reaction in saturated paste covered 57.9% and 24.3% area (Table 1), and the extent of pH_s increased by 28.9% and 20.3% after 6 years, with the pH_s ranging from 8.2 – 8.5 and >8.5, respectively. The value of soil EC_e can be significantly predicted (R^2 = 0.65; $p<0.05$) by EM_h value of EM38 (Fig. 3). Mustard leaf samples were also collected from the same grid points during January 2018. Leaf greenness (R^2 = 0.33; $p<0.05$) and RWC (R^2 = 0.38; $p<0.05$) value of mustard leaf significantly linearly regressed by EC_e value.

$$SPAD = 121.25 + 0.29 \times EC_e\,(dS\,m^{-1}) - 8.92 \times pH_s$$

$$RWC\,(\%) = 95.23 + 0.47 \times EC_e\,(dS\,m^{-1}) - 3.56 \times pH_s$$

Leaf greenness can be significantly predicted by binomial (R^2 = 0.49; $p<0.05$) than linear

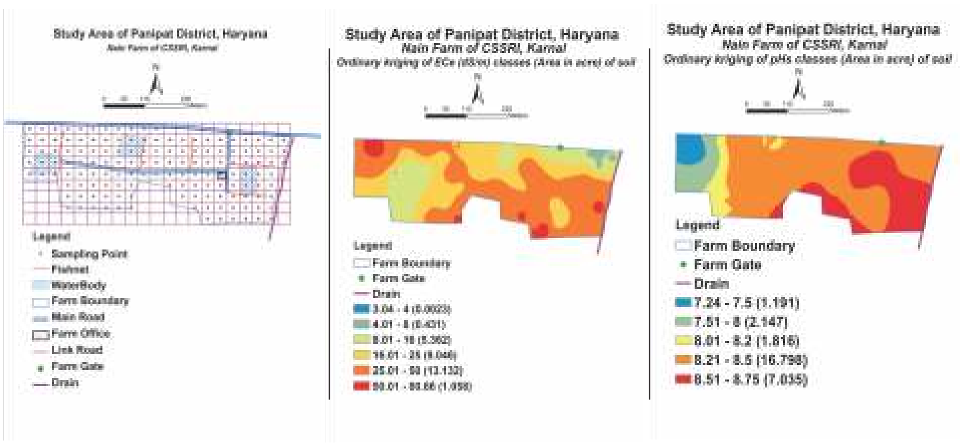


Fig.2. Creation of (a) fishnet and Variation of (b) soil salinity (EC_e) and (c) soil reaction (pH_s) in Nain Farm experiment of CSSRI

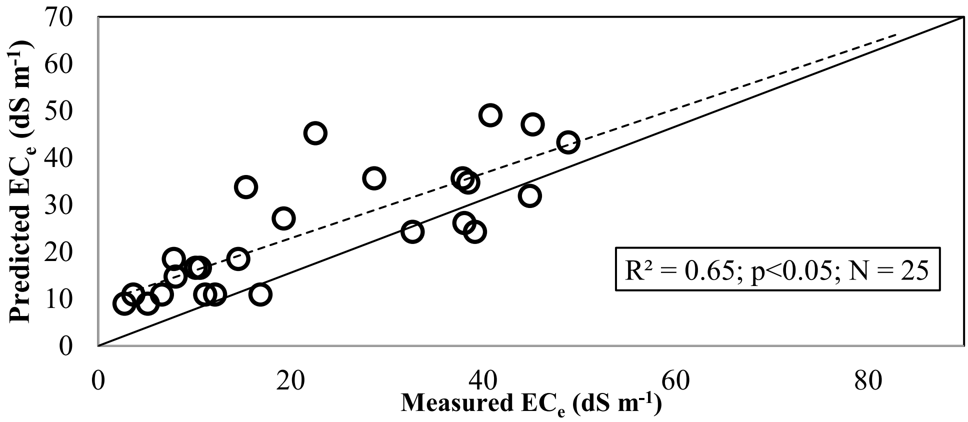


Fig. 3. Scatter plot of measured and predicted values of EC_e by EMh value of EM 38.

Table 1: Changes of soil salinity and sodicity over years

Soil Properties	Range in property	Percent of the total area (2011-12*)	Percent of the total area (2017-18)	Δ_6% area
pH_s	<8.2	67.0	17.80	49.2
	8.2–8.5	29.0	57.90	(+) 28.9
	>8.5	4.0	24.30	(+) 20.3
EC_e (dS m^{-1})	<4	8.7	0.01	8.7
	4 to 8	16.9	1.49	15.4
	8 to 15	25.4	15.40	10.0
	15–30	31.2	49.50	(+) 18.3
	>30	17.8	33.60	(+) 15.8

*Mandal *et al.*, 2013

function with respect to EC_e. Relative water content of mustard leaf is significantly correlated with SPAD (r = 0.54; p<0.05) and percent membrane injury (r = 0.56; p<0.01). The measured SAS and leaf stress parameters will be predicted by hyperspectral and NIR spectra. Developed ground based salt affected and crop stress index will be validated by satellite imagery. Recorded spectral signature will aid in building a spectral library for SAS 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.

Reclamation and Management of Alkali Soils

Productive utilization of reclaimed sodic soils through conservation agriculture under rice –wheat cropping system (Ranbir Singh, A.K. Rai, Parvender Sheoran, Pathan A. Latif)

Indo-Gangetic plains (IGP) comprising of Punjab, Haryana and Uttar Pradesh states; plays a prime role in food security of the country. However, in the recent past, the productivity of the dominant rice-wheat cropping system (RWCS) in this region is either stagnating or decreasing due to associated problems of declining water table and organic matter in the soil, nutrient imbalances, emerging deficiencies of secondary and micronutrients and extensive tillage and residue burning. Problems multiply several folds in the areas with salt affected soils. Improved management practices such as residue retention and zero tillage increase soil organic carbon (SOC) and improve soil fertility with agricultural sustainability. Improved SOC is associated with higher biomass of microbes and root growth, nutrient and water supply, soil aggregation, and better pH and temperature regulation. This calls for upgrading of water, nutrients and energy use efficiency through better management of land and water resources to sustain agriculture in this food bowl of the country. Targeting different resource conserving technologies offer newer opportunities for sustained yields, better livelihood for the resource poor, small and marginal farmers of the region. Keeping these constraints in view, a field experiment has been continuing from 2011 to evaluate the effect of resource conservation strategies viz., tillage, residue and irrigation methods for enhancing crop productivity and sustaining health in semi-reclaimed sodic soils. Conventional practice (Cv) *vis-à-vis* eight resource conservation techniques were imposed. High yielding variety of rice (Ariz-6129) and wheat (H.D 2967) were used as test crops. Weed infestation has been found in DSR. Preponderance of *Cyperous rotundus* (motha), *Echinochloa crusgali* (Barta), *Echinochloa colonum* (Sanmak), *Dactyetenium aegyptium* (Makra) and Kallar grass, etc. caused significant yield reduction under zero tillage and reduced tillage techniques. The results indicated that Cv rice with wheat residue incorporation produced the highest grain yield (7.42 t ha^{-1}) followed by transplanting (7.01 t ha^{-1}) without crop residue. DSR with crop residue produced 6.2% higher grain yield (6.90 t ha^{-1}) than DSR without crop residue (Fig. 4). ZT wheat in anchored rice residue recorded marginally higher wheat grain yield (5.99 t ha^{-1})

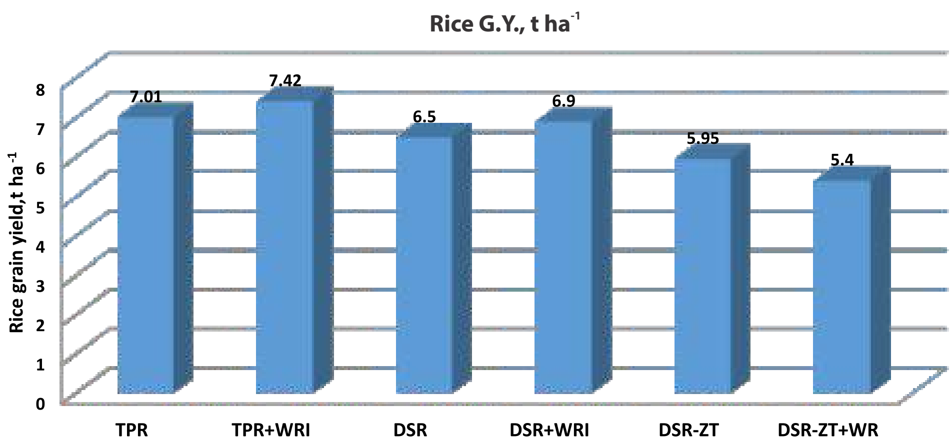


Fig.4.Rice grain yield with different tillage and residue management

Note: TPR= Transplanted rice; WRI= wheat residue incorporation; DSR= direct seeded rice; ZT=zero tillage; WR= Wheat residue retention/anchored; RGY= Relative grain yield; GY=Grain yield compared to Cv (5.24 tha^{-1}) and in ZT without residue (5.77 t ha^{-1}; Fig. 5). Wheat in 50% tillage with crop residue incorporation yielded 13.74% higher grain yield in comparison to CV without crop residue.

Mini-sprinkler (12960 l ha^{-1} acre^{-1} discharge rate at 2 kg cm^{-2} pressure with 90 % uniformity) and drip system (discharge rate 14824 l ha^{-1}) were being evaluated. Sprinkler fertigation saved 31, 5 and 58% water, electricity and nitrogen with 5.77 t ha^{-1} grain yield and the highest NUE 91 kg grain kg^{-1} N in wheat sown in 100% rice residue during rabi 2016-17. Mini sprinkler fertigation in DSR, under 50% reduce tillage with wheat residue, produced 6.66 t grain yield ha^{-1} and saved 64.2, 42.7 and 27% irrigation water, electricity and nitrogen, respectively compared to conventional rice. Also, it recorded the maximum NUE of 60.6 kg grain kg^{-1} N (Table 2).

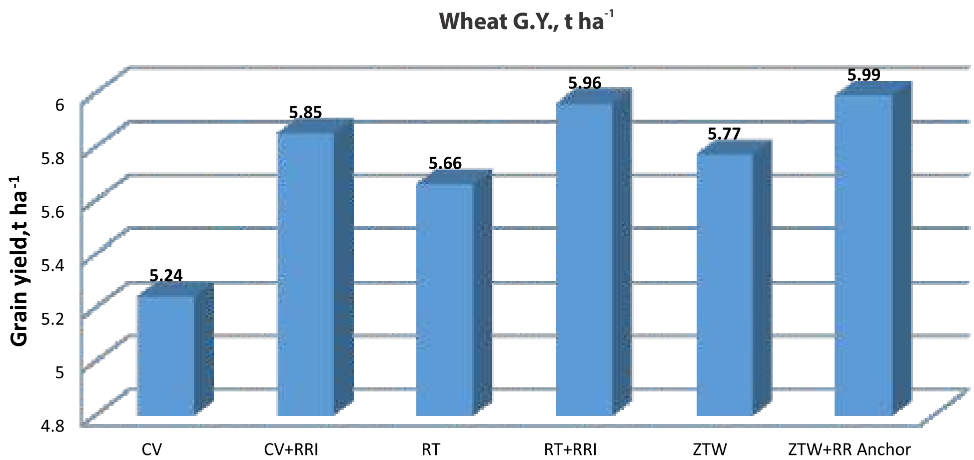


Fig. 5. Effect of tillage and residue management on grain yield of wheat.

Note: CV= Conventional tillage; RRI= Rice residue incorporation; RT= Reduced tillage; ZTW= Wheat in zero tillage; RR=Rice residue; RGY= Relative grain yield; GY= Grain yield

Table 2: Effect of irrigation methods on wheat (Cv.HD 2967) yield, irrigation water requirement, water productivity, saving of water, electricity and nitrogen use efficiency

RCTs	Conventional wheat sowing	ZT+100% RR/DSR	ZT+100% RR/DSR	ZT+100% RM/DSR	ZT+100% RM/DSR
Mode of irrigation	Surface T_1	Drip irrigation T_7	Surface T_8	Mini –Sprinkler T_9	Mini –Sprinkler T_{10}
Irrigation criteria	Growth stages	(7 days CPEx CFx0.8)	Growth stages	(7 days CPExCF)	(7 days CPEXCF)
Grain yields (tha^{-1})	5.24	5.24	5.43	5.58	5.77
Total crop productivity (t ha^{-1})	12.48	11.57	14.16	14.08	14.56
Total irrigation water (ha-cm)	21.65	11.33	17.49	14.85	14.85
Total irrigation water (m^{3}ha^{-1})	21.65	1133.30	1748.90	1485.30	1485.30
Crop water productivity (kg m^{-3})	5.76	10.21	8.09	9.48	7.11
Grain water productivity (kg m^{-3})	2.42	4.62	3.10	3.76	3.88
Irrigation water saving (%)	-	47.65	19.22	31.39	31.39
Electricity saving (%)	-	27.35	19.23	4.78	4.78
NUE (kg kg^{-1} nitrogen) 50% N saving	34.79	71.39	52.11	88.43	91.44

During Nov. 2015 to March 2016, rainfall received and pan evaporation were 201 and 113 mm, respectively. Sprinkler irrigations were scheduled at 7 days interval based on cumulative pan evaporation and crop coefficient (CPExCFx0.8) CD grain (0.05) = 0.29

Table 3: Effect of irrigation methods on hybrid rice yield (Arize 6129), irrigation water requirement, water productivity, saving of water and electricity and nitrogen use efficiency

RCTs	TPR	DSR+RT	DSR+RT	DSR+RT	DSR +WR incorporation
Mode of irrigation	Surface T_1	Surface T_8	Drip T_7	Mini –Sprinkler T_9	Mini –Sprinkler T_{10}
Irrigation criteria	1DADPW	Small soil cracks with surface dryness	(previous 3days CPE) Alternate day	(previous 2days CPE) Alternate day	(previous 2 days CPE) Alternate day
Grain yields(t ha^{-1})	7.01	6.53	6.30	6.56	6.66
Total crop productivity (t ha^{-1})	12.46	12.17	13.42	14.68	14.69
Total irrigation water (ha-cm)	104.93	72.45	30.52	37.58	37.58
Total irrigation water (m^3 ha^{-1})	104.93	7245.40	3052.0	3758.00	3758.00
Crop water productivity (k gm^{-3})	1.19	1.68	4.38	3.91	3.91
Grain water productivity (k gm^{-3})	0.67	0.90	2.06	1.75	1.77
Irrigation water saving (%) Electricity saving (%)	-	30.95	70.91	64.18	64.18
NUE(kg kg^{-1} nitrogen) 40 kg N saving	46.70	43.53	42.0	59.64	60.55

Rainfall received and pan evaporation during June to September 2017 were 714 and 553 mm, respectively. CPE= cumulative pan evaporation criteria used for irrigation through mini sprinkler system. CD (p=0.05) for grain yield = 0.35

Drip fertigation of wheat turbo seeded in 100% rice residue produced 5.24 t ha^{-1} grain yield and saved 47.7, 27.4 and 51% irrigation water, electricity and nitrogen (186.6 kg urea ha^{-1}) with the highest NUE of 71.4 gg grain kg^{-1} N. However, drip fertigation of drill seeded DSR in 50% reduce tillage produced 6.30 t ha^{-1} grain yield and saved 70.9 and 27% irrigation water with 2.06 kg grain m^{-3} irrigation water and electricity, respectively. It recorded NUE of 42.0 kg grain kg^{-1} N with saving of 162 kg urea. Drip irrigation saved >15.8 and 47% water than sprinkler and surface irrigation, respectively (Table 3).

Sustainable nutrient management strategies for partially reclaimed salt affected soils (Ajay Kumar Bhardwaj, Bhaskar Narjary and Priyanka Chandra*)*

Integrated nutrient management experiments were started with ten treatments replicated four times in randomized block design. 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 was kept untouched and incorporated into the soil by power tiller before wheat (DBW-17) sowing only in T_8 treatment. Before rice transplanting, greengram 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 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).

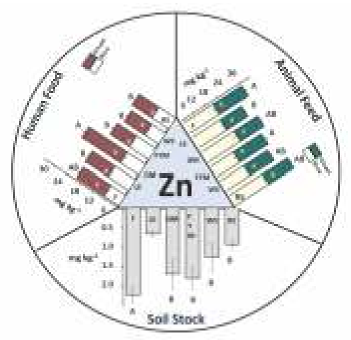


Fig. 6. Distribution of zinc in soil and plants (grain and straw)

Soil samples were taken at the time of harvesting of both rice and wheat crops. Available micronutrients were determined in the soil and plant parts (grain, straw). Ion exchange resin (IER) membranes (cation, anion) were used as plant root simulators. The membranes are implanted in soil for 10-15 days intervals, throughout 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 micronutrients-Zn, Fe, Cu, Mn over the full growing season.

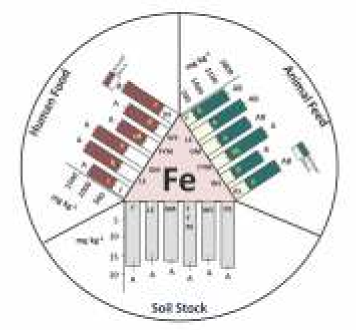


Fig. 7. Distribution of iron in soil and plant (grain and straw).

Distribution of four micronutrients namely Zn, Fe, Cu, and Mn was studied in soil and plant-shoot and grains of rice and wheat. Fertilizer treatment had the maximum stock of Zn in soil followed by FYM and GM treatments. The FYM treatment maintained the maximum (80.93%) and LE maintained least (29.86%) soil Zn stock compared to F. Zn in rice and wheat grain was in the range of 6.52-9.84 and 9.28-13.03 mg kg^{-1}, respectively. Wheat grain showed significantly higher concentration of Zn and found the maximum in treatment GM followed by F (Fig. 6). In rice grain, no significant difference was observed in any treatments; however, LE showed the maximum Zn concentration of 9.84 mg kg^{-1}. In case of straw, RS showed highest Zn concentration 16.85 mg kg^{-1} in rice straw, followed by F and LE, respectively; whereas, in wheat, Zn was found the maximum in FYM treatment (14.42 mg kg^{-1}) followed by the F treatment.

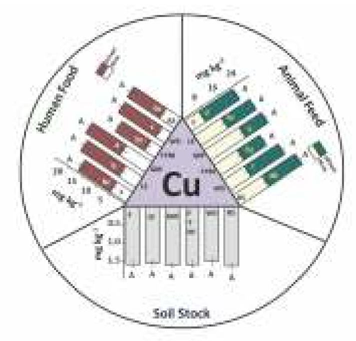


Fig. 8. Distribution of Cu in soil and plants (grain and straw)

Soil iron stock did not show any significant difference among all treatments Fe was 2.63% more in RS than in F. Overall, Fe content in wheat grain was 56% more than that of the rice grain. GM recorded the maximum Fe to the tune of 696.8 mg kg^{-1} but as such RS recorded the highest i.e. 1312.62 mg kg^{-1} Fe in wheat grain. In case of straw, the average concentration of Fe in wheat was 58.8% more than the rice straw. In rice straw, LE showed the highest accumulation of Fe 856.62 mg kg^{-1}, whereas, FYM added the highest Fe (1902.61 mg kg^{-1}) in wheat straw (Fig. 7).

Soil Cu (DTPA-extractable) ranged from 1.50 to 1.64 mg kg^{-1}; however the differences were non-significant. Although concentration of Cu was nearly same in all treatments, it was little higher in RS treated plots (1.64 mg kg^{-1}). In human food, contribution of wheat grain was more than the rice grain in terms of availability of Cu in the diet. Cu concentration was the highest in GM (9.08 mg kg^{-1}), whereas, Cu in wheat grain was found the maximum in LE 13.88 mg kg^{-1}. In case of rice straw, GM translocated more Cu as compared to WS (reduced by 33.77 %) (Fig. 8).

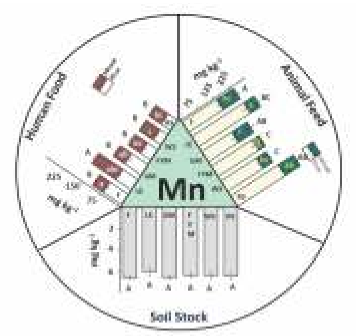


Fig. 9. Distribution of manganese in soil and plants (grain and straw).

Availability of DTPA-Mn in soil under all the treatments was similar; however, in F and GM recorded the maximum Mn content (6.62 and 6.57 mg kg^{-1}, respectively). On the other hand, grain and straw for both crops showed significant availability of Mn. Moreover, total available Mn in wheat grain was 16.57% (average) higher than that of the rice grain. In rice grain, F treatment showed the highest concentration of Mn, 69.67 mg kg^{-1}, whereas in wheat, the maximum Mn availability of 100.94 mg kg^{-1} was observed in LE. Overall, average Mn concentration was 184.45 mg kg^{-1} in rice straw, which was 67.96% higher than wheat straw (Fig. 9).

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

Direct seeding of rice is eco-friendly practice with higher resource use efficiency than conventional transplanted rice. However, certain agronomic issues especially management of weed, nutrient, residue and water; need to be standardized before its promotion on large scale. In this background, a field experiment was conducted with

Table 4: Effect of nutrient and residue management on yield and yield attributes ZT-DSR (CSR 30 basmati)

Treatment Nutrient Management	Effective tillers /m.r.l.	Panicle length (cm)	Grains/panicle	1000-GW (g)	Grain yield (t ha^{-1})	Lodging (%)
T1: RDF*	88.47	21.83	85.07	21.46	2.45	53
T2: RDF+10% N	88.10	21.90	87.97	21.69	2.51	41
T3: RDF+20% N	90.53	22.17	90.87	21.51	2.47	43
T4: RDF+20% N+ Cut	91.80	21.63	85.80	20.70	2.73	10
T5: RDF+25 kg ZnSO4	89.60	22.30	91.97	21.15	2.51	53
T6: RDF+ 3% FeSO4 (40, 60 d)	91.17	21.13	88.10	21.06	2.40	61
T7: RDF+CSR-BIO	88.97	21.40	88.60	22.33	2.80	21
T8: RDF+CSR-BIO+ Cut	89.17	22.03	84.87	22.65	2.95	6
LSD0.05	NS	1.11	6.61	0.97	0.30	-
Residue management						
Rice mulch (5 t ha^{-1})	89.08	21.84	87.23	21.47	2.60	39
Control	90.38	21.76	88.58	21.67	2.60	33
LSD0.05	NS	NS	NS	NS	NS	-
NM × RM	NS	NS	NS	NS	NS	-
Transplanted rice	81.00	25.20	85.00	26.00	3.60	60

*RDF 60 kg N+30 kg P_2O_5+30 kg K_2O+25 kg $ZnSO_4$/ha + 5q/ha FYM (30 d) : T_1: *RDF (60 kg N+30 kg P_2O_5+30 kg K_2O+25 kg $ZnSO_4$/ha) + 5q/ha FYM (30 d); T_2: RDF+10% higher N; T_3: RDF+20% higher N: T_4: RDF+20% higher N with top cutting; T_5: RDF+25 kg/ha $ZnSO_4$; T_6: RDF+foliar spray of $FeSO_4$ @ 3% (40 and 60 DAS); T_7: RDF + CSR-BIO (Seed treatment with 3% liquid formulation + soil application @ 25 kg/ha with FYM @ 5 q/ha at 30 DAS); T_8: RDF + CSR-BIO with top cutting

eight nutrient management treatments (Table 4) under 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 attributes and yield of wheat KRL 210. After three years, available N, K and Zn in soil improved with addition of rice mulch @ 5t ha^{-1} than without mulch. Direct seeding of salt tolerant basmati rice (CSR 30) was done on 14 June 2017. Nutrient and residue management did not affect plant height and tillers/m.r.l. of ZT-rice. In DSR, physiological traits *viz.,* photosynthetic rate, transpiration rate, stomatal conductance, chlorophyll content, chlorophyll fluorescence, relative water content and SPAD readings; were higher in RDF + CSR BIO (with or without top cutting) and RDF + 20% N + cut with mulching and without mulching treatments, (Fig. 10). While yield traits i.e., panicle length and 1000-grain weight and grain yield were significantly higher under transplanting conditions (3.60 t ha^{-1}). Among ZT-DS basmati grain yield was highest in RDF+CSR-BIO with top cutting (2.95 t ha^{-1}) at par with RDF+CSR-BIO (2.80 t ha^{-1}) and RDF+20% higher N with top cutting (2.73 t ha^{-1}). Reduction in ZT-DSR was by 18% in best treatment than transplanted rice. Additional Zn application and foliar Fe sprays did not increase grain yield over RDF. Top cutting reduced the lodging significantly in ZT-DSR which was also positively correlated with the grain yield.

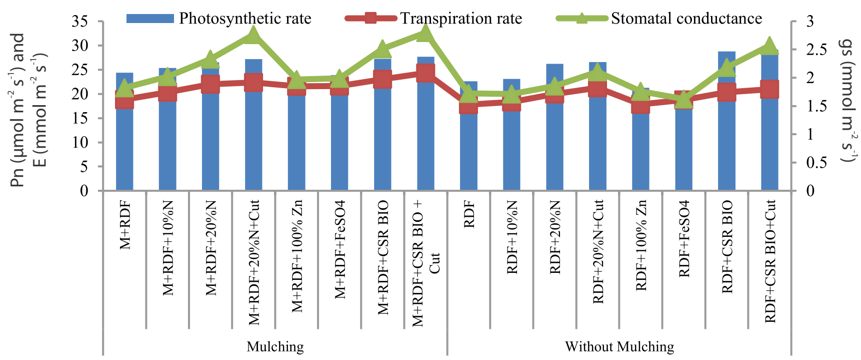


Fig. 10. Effect of nutrient and residue management on physiological efficiency of ZT-DSR (CSR 30 Basmati)

Developing the alternate strategies for reclamation of sodic soils (Arvind Kumar Rai, Nirmalendu Basak, Rameshwar Lal 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, JV Narasimham, Hemant Katti)

Sodic soils cover >50% (3.77 Mha) of the total salt-affected area (6.74 M ha) of India. As per the projections, extent of sodic and associated problems area is likely to increase in the cultivated irrigation commands of the country by 2030. There has been an increasing interest in using elemental S for calcareous-sodic soil reclamation. A memorandum of understanding was signed between ICAR-CSSRI, Karnal and Reliance Industries Limited (RIL) for improving the efficacy of the elemental sulphur in sodic soil reclamation. Field and lysimeter experiments have been initiated under this project. The initial observations in different lysimeter and field experiments showed reduction in soil pH after application of Reliance Formulation Sulphur (RFS) alone or in combination with gypsum (Fig. 11). Average reduction in soil pH, of variable sodicity and texture soils, in response to different combination of RFS + gypsum was statistically at par with 50% gypsum requirement (50GR) treatment. Days of application of the amendment prior to rice transplanting showed significant effect on lowering of soil pH_2. RFS applied 21 days prior to rice transplanting recorded significantly less soil pH compared to other days of application. Alternate wetting and drying and continuous flooding condition had similar effect on transformation of RFS. Also substrate application, water management and particle size of RFS had no significant difference on lowering of soil pH_2. However, it needs further evaluation under upland conditions. Visual differences in different treatments are being observed in field. Different treatments showed 0.2-0.7 unit decline in soil pH_2 after application of amendments, however, on equivalent basis the values are at par with gypsum application.

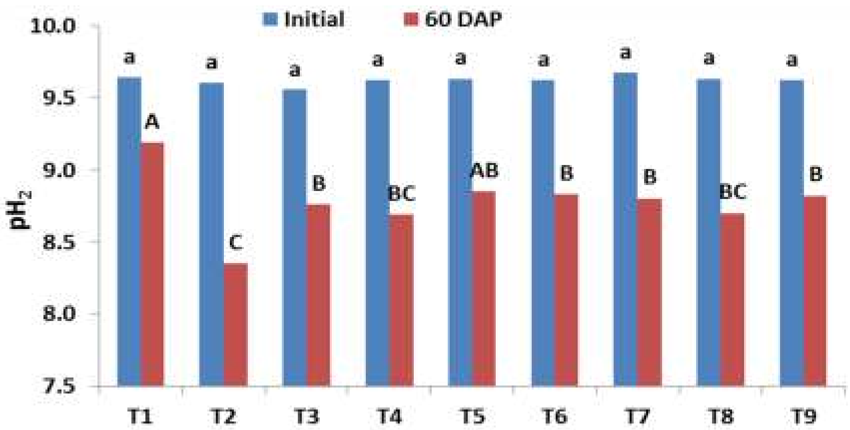


Fig. 11. Efficacy of the RFS in reclamation of sodic soils of different sodicity in conjunction with gypsum

Lysimeter experiment for evaluation RFS for sodic soil reclamation

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

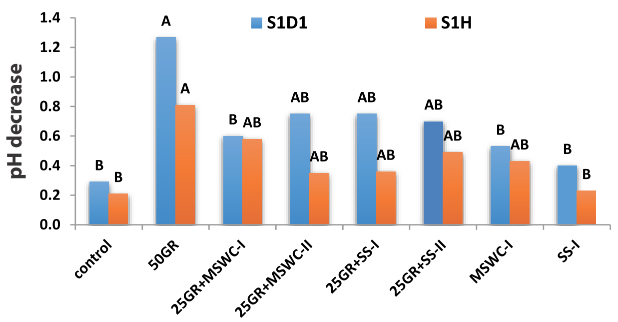
Application of urban waste such as sewage sludge and municipal solid waste compost in conjunction with gypsum can be an option for reducing soil sodicity. In addition, these organic amendments provide essential nutrients (N, P, K and others secondary and micronutrients); improve soil physical and chemical properties and enhance microbial populations and activities. Sodic soil reclamation experiment was carried out, on different texture and pH (Table 5) sodic soils collected from Haibatpur, Karnal and Saraswati range, Kaithal of Haryana; in lysimeter at CSSRI campus. The experiment was carried out in lysimeter in Factorial RBD under rice –wheat cropping system in triplicate with following treatments, viz., No Gypsum (0 GR); 50% GR; 25% GR + MSW Compost I (10 t ha^{-1}); 25% GR + MSW Compost II (10 t ha^{-1}); 25% GR + Sewage sludge I (10 t ha^{-1}); 25% GR + Sewage sludge II (10 tha^{-1}); MSWC sole (10 t ha^{-1}); Sewage sludge sole (10 t ha^{-1}). Sewage sludge samples were collected from identified sites in Haryana state *viz.* Karnal, Panipat and municipal solid waste compost was collected from Karnal and Delhi. Characterization of the MSW Compost and STP (sewage treatment plant) sludge from different industrial and non-industrial cities was done before application. The microbial count and pathogen test of urban waste was carried out to test the presence of pathogenic microbes in compost.

Table 5: Chemical properties of different sodic soils

Soils	pH_2	EC_2 (dS m^{-1})	ESP (%)	CEC (cmol(P+) kg^{-1})	Clay (%)	$CaCO_3$ (t ha^{-1})	GR
Haibatpur (S1)	10.11	0.7	95.8	10.9	17.9	1.9	16.7
Saraswati (S2)	9.59	0.6	41.5	8.1	11.9	2.6	7.5

(pH_2 and EC_2 - in soil : water ratio 1:2; ESP - exchangeable sodium per cent; CEC - cation exchange capacity; GR - gypsum requirement)

Salt-tolerant rice variety (CSR-30) was transplanted in the lysimeters after incorporating the amendments. Soil sampling was done on regular intervals. Application of 25 GR+ MSWC/SS decreased soil pH_2 in both types of sodic soils. The decrease in pH_2 ranged from 0.2-1.3 units in Haibatpur soil and 0.06 to 1.1 units in Saraswati soil (Fig. 12).



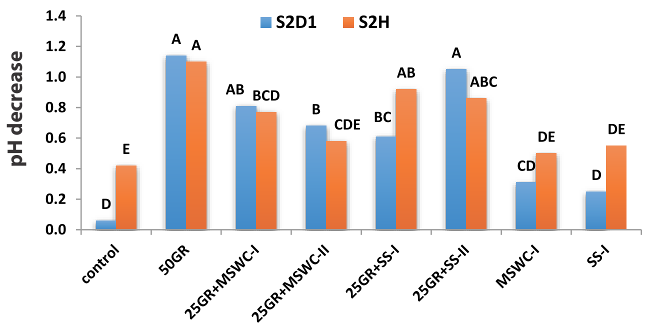
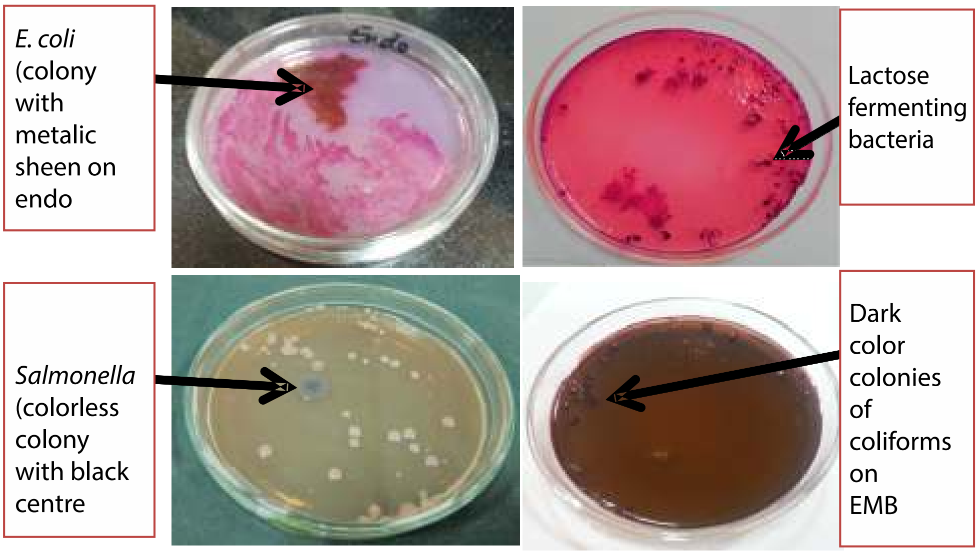


Fig.12. Effect of amendments on change in pH_2 after transplantation and harvest of rice crop

Note: S1D1= Haibatpur soil (after transplantation); S1H= Haibatpur soil (after harvest); S2D1= Saraswati soil (after transplantation); S2H = Saraswati soil (after harvest)



Microbial count in sewage and municipal solid waste compost

There was an increase in the yield and dry biomass in 25GR+organics compared to control. The maximum grain yield was recorded in 25GR+ MSWCI/SSII (~16 q ha^{-1}) over GR50 (~10 q ha^{-1}) in Haibatpur soil and 25GR+SSII (~13 q ha^{-1}) over 50GR (~11.6q ha^{-1}) in Saraswati. The maximum straw yield was recorded in 25GR+SSI (~460 g m^{-2}) over GR50 (~160 g m^{-2}) in Haibatpur and 25GR+SSII (~1009 g m^{-2}) over 50GR (~102 g m^{-2}) in Saraswati. The micronutrients i.e., Fe, Mn, Zn and Cu were more in organic amended plots compared to control. Concentrations of heavy metals (Cd, Cr, Pb and Ni) in soil and leachate samples were below the permissible limits. Pathogen tests revealed safer application of compost and sewage sludge in sodic soil reclamation.

Performance of rice in sewage sludge and compost amended sodic soils

Dynamics of Nitrogen and Organic matter fractions in Soils under Long-Term Conservation Agriculture in reclaimed sodic soil (Ashim Datta, Madhu Chaudhary, P.C. Sharma)

Different organic nitrogen fractions were studied under four crop management scenarios namely conventional rice-wheat system (TPR-CTW) (Sc1), partial CA based rice-wheat-mungbean system (TPR-ZTW-ZTMb) (Sc2), full CA-based rice-wheat-mungbean system (ZTDSR-ZTW-ZTMb) (Sc3) and maize-wheat-mungbean system (ZTM-ZTW-ZTMb) (Sc4). Significant variation has been observed among the conventional and CA based treatments. The highest total hydrolysable organic N was observed in Sc4 (2759 kg ha^{-1}) followed by Sc3 (2663 kg ha^{-1}), Sc2 (2234 kg ha^{-1}) and Sc1 (1797 kg ha^{-1}) at 0-15 cm soil depth (Fig. 13).

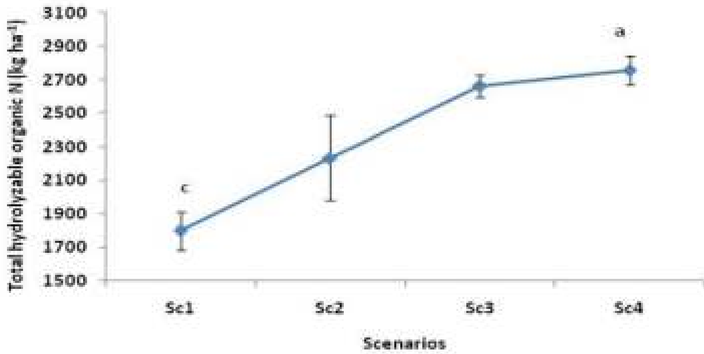


Fig. 13. Total hydrolysable organic N under different scenarios at 0-15 cm soil depth.

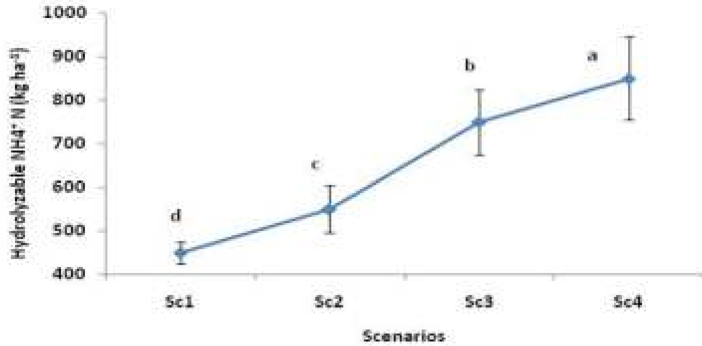


Fig. 14.Hydrolysable NH_4 N under different scenarios at 0-15 cm soil depth.

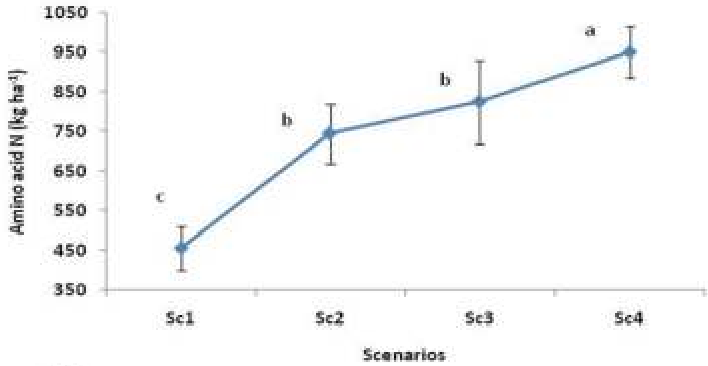


Fig. 15.Amino Acid N under different scenarios at 0-15 cm soil depth.

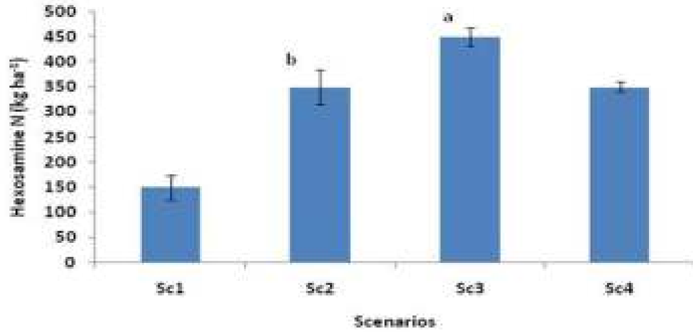


Fig. 16.Hexosamine N under different scenarios at 0-15 cm soil depth.

Hydrolyzable NH_4^+ N ranged from 450 to 850 kg ha^{-1}, with the highest and lowest being associated with Sc1 (450 kg ha^{-1}) and Sc4 (850 kg ha^{-1}), respectively (Fig. 14). Sc4 showed the highest amino acid N (950 kg ha^{-1}) followed by Sc3 (825 kg ha^{-1}), Sc2 (745 kg ha^{-1}) and Sc1 (455 kg ha^{-1}), respectively (Fig. 15). Hexosamine and serine+threonine N concentration were much lower as compared to other fractions of organic N. Hexosamine N concentration varied from 150 to 450 kg ha^{-1}, soils under Sc3 showed the highest (450 kg ha^{-1}) than other scenarios (Fig. 16).

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 Latif Pathan and R. Raju)

Twelve subsurface drainage (SSD) projects out of 15 projects installed in Haryana covering 8,178 ha waterlogged saline lands and 5,918 beneficiary farmers in eight districts were selected for operational performance study. In order to assess the project operational performance, site surveys of twelve projects in Sonipat, Jind, Rohtak, Charkhi Dadri, Bhiwani, Fatehabad, Sirsa and Palwal districts were carried out to assess the conditions of pump sets, pump houses, manholes, and sump wells and link/open drains. The inputs from beneficiary farmers and project authority on pump operating hours of SSD systems and functioning of farmers' drainage societies (FDS) were collected. A project operational index of SSD projects can be worked out to assess project operational readiness status by considering key implementation process tasks (variables) and their timeliness of completion (weightage). These implementation variables can be a set of tasks such as registration of a farmers' drainage society, laying of lateral and collector pipes, installation of manholes and sump well, delivery of 6 hp diesel pump set and diesel fuel for 200 pumping hours for first year reclamative pumping, construction of pump house, transfer of drainage blocks to registered FDS, annual operation & maintenance, adequate farmers training, etc.

The implementation data of 12 SSD projects were collected from HOPP project authority and beneficiary farmers. Weightage of each variable was decided on the basis of its importance in implementation process and making project functional. Pump set and its fuel was given the highest weightage due to their significant roles in reclamative leaching. Pump house was given the second highest weightage and then registered FDS, transfer of drainage blocks to FDS, farmers' training and so on. Project operational index was computed using Equation (1) from 12 project data (Table 6) and varies from 0.3 to 1.0. Operational ranking of 12 projects was done on the basis of value of operational index and the rank-1 to a project was assigned to the highest value of operational index and so on. Sonipat SSD project (Jagsi) got the first rank (highest) while Charkhi Dadri project got the lowest (12th) rank (Table 7). The operational ranking helps to indicate what was lacking in the project and to suggest interventions for improving operational performance including transfer of drainage blocks to registered societies.

$$\text{Project operational index} = \Sigma\,(Var_i * Wt_i) \qquad \ldots \text{Eq. (1)}$$

Where, Var_i = Operational variable, i=1 to n, and

Wt_i = Weightage of the variables (Pump set, diesel fuel, pump house, registration of society (FDS), transfer of blocks to society, and farmers' training)

From analysis of 12 SSD project data (Table 6), it was found that on an average, only 47% pump houses out of 185 were constructed, 90% diesel pump sets were delivered to beneficiary farmers, 75% diesel fuels were distributed to farmers, and 48% drainage blocks were handed over to the registered societies. In Sonipat SSD project, 100% implementation tasks were achieved whereas in Charkhi Dadri project, zero percent achievement on delivery of pump sets, diesel fuel and handover to drainage blocks to societies was made. Farmers' drainage societies which were registered at the time of implementation could sustain till end of the project period and became non-functional during post-project period.

Table 6: Operational data on implementation process of 12 SSD projects in Haryana

S No	Name of project	Drainage block ID	Blocks installed	Pumphouse constructed	Society registered	Handed over		
						Pump sets	Diesel fuel	Blocks
1	Jhajjar-I	J-1 to 6 & J-12 to 19	14	11	14	14	14	14
2	Charkhi Dadri	Cd-1 to 16	16	16	16	0	0	0
3	Sonipat	S-7 to 19 & S-25 to 34	23	23	23	23	23	23
4	Sirsa	R-1 to 7, R-8, 9, 11, 12 & 13	12	8	12	11	11	0
5	Fatehabad	F-1 to 10	10	7	10	6	6	0
6	Jhajjar-II	Jh-1 to 9, Jh-11 & 15 to 21	23	17	23	17	6	17
7	Palwal	P-1 to 7, 12, 13 & 14	10	5	5	5	5	0
8	Rohtak	RK-1 to 19 (except 8)	18	0	18	18	18	18
9	Jind	JD-1 to 10 & JD-11 to 17	17	0	10	9	9	0
10	Sonipat-II	SG-1 to 9 & B-11, K19-21	13	0	13	13	13	0
11	Rohtak-II	Rk-II-1 to 12	11	0	11	11	11	11
12	Sonipat-III	Kt-1, 3 to 19	18	0	12	12	12	6
Total			185	87	167	139	128	89
Average (%)				47	90	75	69	48

Table 7: Operational performance and ranking of 12 SSD projects in Haryana

S No	Name of project	Name of sites/ villages	Area (ha)	Beneficiary farmers	Operational index value	Project Ranking
1	Jhajjar-I	Beri, Dopana, Gochhi, BeriKhas, Dhandlan,	805	873	0.96	2
2	Charkhi Dadri	Rawaldhi, Khatiwas, Lohawara, Jhinja	904	963	0.30	12
3	Sonipat	Dhanana, Jagsi	1137	836	1.00	1
4	Sirsa	Surtia, Darba-alan, Manak-Dhiwan	479	180	0.78	5
5	Fatehabad	Banmandori, Gorakhpur, Kumaria	277	152	0.60	8
6	Jhajjar-II	Wazirpur, Baghpur, Beri	1034	798	0.65	7
7	Palwal	Khatli-Jeeta, Kanoli, Madina	351	253	0.45	10
8	Rohtak	Mokhrakheri, Mokhrarojh	980	546	0.80	4
9	Jind	Siwanamal, Gangana, Bambewa	315	294	0.38	11
10	Sonipat-II	Gharwal, Banwasa, Kohla	640	365	0.70	6
11	Rohtak-II	Madina, Kharkara & Basana	526	364	0.80	3
12	Sonipat-III	Katwara, Kathura & Ahulana	730	294	0.50	9
Total	8,178	5,918	--	--		

Based on project operational ranking, three SSD projects with the first, fourth and eleventh ranks at Jagsi (Sonipat), Mokhra Kheri (Rohtak-I) and Siwana Mal (Jind) were intensively studied for improvement in soil salinity and crop performance and suitable interventions for further improving project impact. Jagsi site with 10 drainage blocks in 430 ha, Siwana Mal site with 7 blocks in 295 ha, and Mokhra Kheri site with 13 blocks in 600 ha implemented in May 2009, June 2012 and June 2012 were monitored for improvement of soil salinity and crop performance from multi-date Landsat ETM+ and OLI imageries including pre and post-project periods for assessing operational performance. From pre-project Landsat imagery of 12 February 2007, 63-80% area in 10 drainage blocks at Jagsi site was affected by moderate soil salinity (EC_e >8 dS m^{-1}). In post-project period, soil salinity was reduced to 26% of the area on 4 April, 2011 imagery and disappeared completely from Landsat imagery of 28 May 2014 and 22 February 2016. This is mainly attributed due to adequate pumping of SSD systems by progressive farmers for achieving full reclamative leaching. Drainage water was also reused for irrigation of both rice and wheat crops in the project area. The yields of rice and wheat ranged from 3.50-4.20 and 4.90-5.64 t ha^{-1}, respectively, from Jagsi site during *Kharif* 2017 and *Rabi* 2016-17. In Siwana Mal and Mokhra Kheri sites, small patches of soil salinity were still found from the satellite data during post-project period due to late distribution of diesel pump sets and diesel fuel and sporadic response of farmers on pumping operation. The significant improvements in four blocks each in both project sites (JD-1, 2, 5 and 6, and RK-8, 9 10 and 11) were observed from field surveys. The yields of rice and wheat from improved blocks of Siwana Mal site ranged from 2.15-3.50 and 3.55-4.54 t ha^{-1}, respectively, during 2017-18 whereas the yields of rice and wheat from improved blocks of Mokhra Kheri site ranged from 2.10-3.10 and 3.15-4.40 t ha^{-1}, respectively.

Technical Guidance and Monitoring and Evaluation of Large Scale SSD Projects in Haryana (D.S. Bundela, Satyendra Kumar, R.L. Meena, Bhaskar Narjary, R. Raju, Aslam Pathan, Rahul Singh Tolia, Arijt Barman, Kailash Prajapat, and P.C. Sharma)

Evaluation of design and layout of SSD systems

The feasibility for new SSD projects in 1,601 ha waterlogged saline area under Phase-1 (340 ha at Kohla under Sonipat-II, 515 ha at Kathura and Ahulana under Sonipat-III, and 746 ha at Gangana, Bhambhewa, Ludana under Jind), and 4,000 ha under Phase-2 (700 ha at Kahni, Rithal and Sanghi under Rohtak-III, 1,300 ha at Baniyani under Rohtak-IV and 2,000 ha at Jahajgarh and Beri under Jhajjar-III) was recommended by the ICAR-CSSRI. Further, designs and layouts of SSD systems for 18 blocks of three projects under RKVY *viz*., two blocks of Kathura site (Kt-20 & 21) and four blocks of Ahulana site (Ah22 to 25) under Sonipat-III, six blocks of Gangana site (JD-18 to 23) under Jind, and six blocks of Kanhi site (Kh-1 to 6) under Rohtak-III covering total area of 555 ha were technically evaluated for flow directions, lateral and collector slope, discharge capacities and permissible length of lateral pipes and drainable area of collector pipes and were found satisfactory. Therefore, designs and layouts of eighteen drainage blocks were approved and recommended for implementation during 2018-19.

Identification of new sites

Eight new sites *viz*., Nizampur (Sonipat), Kharenti, Chand and Sanghi (Rohtak), Dighal (Jhajjar), Sikrona (Faridabad), and 10 sites/villages in Sirsa district (Gudiya Kheda, Shankar Mandori, Nahrana, Khand Nathusari Chopta, Surtiya, Dadba Kalan, Manak Diwan, Lohgarh, Dubwali and Rupana Khurd) were jointly identified for further survey works and designing of SSD systems. These new sites were characterized by shallow groundwater (water table depth < 1.5 m) and moderate to high soil salinity (EC_e > 8 dS m^{-1}) and groundwater salinity (EC_{gw} > 2 dS m^{-1}) and availability of a surface drain for discharge of drainage water. At these sites, field surveys and drainage investigations will be conducted and detailed SSD designs are to be proposed by HOPP for approval of CSSRI for funding and execution.

Monitoring and evaluation of SSD projects

Monitoring and evaluation of five SSD projects at Gharwal, Katwara, Siwana Mal, Mokhra Kheri and Kharkara sites under Sonipat-II & III, Jind, and Rohtak-I and II were initiated for 2017-18 as per the MOU of HOPP signed in March 2017 for the next five year term. These five projects with 67 installed drainage blocks covering reclaimed area of 2,443 ha and 1,863 beneficiary farmers are distributed in three districts (Table 8). The average crop yields increased by 45-95 and 165-190% for paddy and cotton crops, respectively, where adequate pumping was done by farmers for achieving full reclamative leaching and by 15-35 and 85-120% for paddy and cotton crops, respectively, in case of partial pumping. The SSD system has reduced the soil salinity (EC_e) from 15-32 to 4-7 dS m^{-1} in 1-2 years. Further, four non-woven polypropylene filters from HOPP project authority/drainage industries tested at 'Drainage Engineering Lab' for thickness, mass per unit area and characteristic opening size ($>O_{90}$) failed on O_{90} criterion except one filter sample and three samples were not recommended for use in SSD projects in Haryana whereas woven nylon socks for 160, 200, 250 & 294 mm collector pipes tested for thickness, mass per unit area and pore size (60 mesh) have met all three criteria and were recommended for use in SSD projects. It can be concluded that SSD projects have resulted in nearly doubling crop yield and farmers' income provided adequate pumping for achieving reclamative salt leaching was done by farmers.

Table 8: Detailed information of five SSD Projects under monitoring and evaluation (M&E)

Name of project	Villages covered	Total Blocks	SSD blocks Completed	Total Area sanctioned (ha)	Area reclaimed (ha)	Beneficiary farmers (No)
Rohtak-I	Mokhra Kheri & Mokhra Rojh	RK-1 to 13 & RK-14 to 19	18	1,000	980	546
Rohtak-II	Madina Kharkara & Basana	RK-II-1 to 2 RK-II-3 to 8 & RK-II-10 to 12	11	1,000	526	364
Jind	Siwana Mal, Gangana, Bambewa & Ludana	JD-1 to 7, JD-8 to 10 & JD-11 to 17	10	600	295	294
Sonepat-II	Gharwal, Banwasa & Kohla	SG-1 to 9, S-II-B-11 & K-19, 20 & 21	13	1,000	415	365
Sonepat-III	Katwara, Kathura & Ahulana	S-III Kt-1 & 3 to 19, Kh1-2 & Ah 1-4	15	1,000	227	294
	Total	77	67	5,600	2,443	1,863

Identification of a new site with shallow water table (Kharenti), installation of SSD system and bumper paddy crop during post SSD project

Consultancy on Sub Surface Drainage in Heavy Soils in Maharashtra, Karnataka Gujarat, Andhra Pradesh and Telangana (P.C. Sharma, D.S. Bundela, Anil Cinchmalatpure, Aslam Latif Pathan, Sagar Vibhute and Rahul Singh Tolia)

Consultancy services on drainage project investigations, design, evaluation and monitoring, and capacity building trainings of field engineers/drainage contractors and farmers of Maharashtra and Karnataka were provided to M/s Polyextrusion Pvt Ltd, Sangli during 2017-18. Poor irrigation management practices in heavy soils (Vertisols) of Maharashtra and Karnataka are mainly responsible for twin problems of waterlogging and soil salinization which result in drastic reductions in yields of major crops like sugarcane, turmeric, cotton, wheat, etc.

Maharashtra

A new SSD project with total area of 480 ha in three phases (149, 136 and 195 ha) at Shedshal (Shirol Taluka, Kolhapur district) in the sugar factory command area has been proposed for implementation. The project is fully funded by farmers and financed through Jaysingpur Udgaon Sahakari Bank, Dattanagar, Shirol, Kolhapur. The design of SSD systems for three phases were evaluated for flow directions, lateral and collector pipe slopes, discharge capacities and permissible length of lateral pipes and were found satisfactory and recommended for the implementation (Fig. 17).

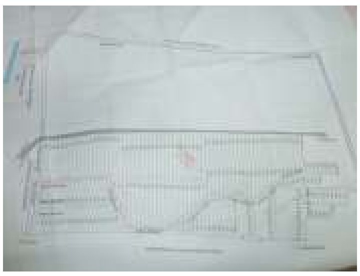


Fig.17. Layout map of SSD project at Shedshal (Kolhapur district)

Two SSD projects at Karandwadi and Urun Islampur (Sangli district) installed in 297 ha out of 495 ha area and 190 ha out of 362 ha, respectively, were monitored for impact evaluation. The impact of these projects was very good as sugarcane and others major crops were grown successfully from the first year itself. Overall, there was a significant increase in yield of sugarcane and other major crops (80-150%). All beneficiary farmers were fully satisfied with the impact of SSD technology. These SSD projects were funded by Central government, State government and the beneficiary farmers in the ratio of 60:20:20, and were executed by Small Scale Irrigation (SSI) Division under Water Conservation Department, Govt. of Maharashtra through our consultancy firm. The problems of lateral pipe clogging by sugarcane roots reported by farmers were also investigated and it was found that water leakage at lateral and collector junction was responsible.

Realizing the quick returns of SSD technology by farmers in terms of water table control, reduction of soil salinity and enhancement of crop yields and farm income, a large number of farmers individually or in groups have come forward to adopt SSD technology with their own investment. During the last year, subsurface drainage installations have picked up in heavy/ black cotton soils of Maharashtra and Karnataka in a very impressive way. Once installed, the operating cost of SSD system is virtually nil with gravity outlet condition. During 2017-18, SSD installation works were affected badly in both Maharashtra and Karnataka states due to non-revision of cost norms for SSD work under *Sub-scheme of Reclamation of problem soils (RPS) under RKVY*.

CSSRI consultancy team interacted in April 2017 with Er. Sunil Kushire, Superintending Engineer, Small Scale Irrigation (Water Conservation) Department; Sh. D.B. Bote, Joint Director of Agriculture (Soil Conservation and Watershed Management), Agriculture Department; and Er. P.B. Gokhale, Director, Directorate of Irrigation Research & Development (DIRD), Water Resource Department and discussed the problem of slow pace of implementation of SSD projects in Maharashtra. Major constraints affecting slow pace of implementation of SSD technology was its unit cost norms approved under RKVY which need to be revised/enhanced to make it affordable in Maharashtra for fast implementation of SSD projects.

Karnataka

Three SSD projects at Kusnal, Ugar, and Ainapur sites in Belgaum district were evaluated. The impact of these projects was very good as farmers started growing sugarcane and others crops. Total 190 ha area out of 362 ha in Kusnal was completed and 25-30 farmers were satisfied with the impact of SSD technology. We also traversed to head-end fields where sugarcane and pulse crops were grown. The project at Kusnal was funded with 60:40% cost sharing basis (Centre: Farmers) and without any state government fund support and was implemented by Rex's contractors. This technology has also been implemented successfully through PPP (Public-private partnership) mode in two states (Maharashtra, and Karnataka) of the country realizing its significant improvements on soil health, crop yield and farmers' income.

A SSD project at Ugar Budruk in Belgaum district (Karnataka) was implemented for reclamation of about 925 ha of waterlogged saline Vertisols benefitting over 600 farmers. The project was monitored for impact assessment study. The sugarcane yield in new planted and ratoon crops increased to 119.0 and 82.0 t ha^{-1}, respectively, in the post-reclamation phase as compared to 42.0 and 26.0 t ha^{-1} respectively, in the pre-SSD phase. Overall, sugarcane yield increased by up to 300%. The SSD projects in Maharashtra and

Implementation of SSD projects using small trenchers in Maharashtra and Karnataka and their monitoring

Karnataka have been evaluated and found that the technology has a benefit-cost ratio ranging from 1.5-3.2 and internal rate of return (IRR) of 20-58% and payback period of 2-3 years.

Farmer's response to land drainage

For successful cultivation of cash crops such as sugarcane, turmeric and cotton crops in waterlogged saline Vertisols in Maharashtra and Karnataka, farmers themselves have come forward and paid the cost of SSD installation for reclamation of their farms realizing the economic benefits and impact of SSD technology on crop yield and farm income. A large number of farmers in both states are opting for SSD as a land reclamation measure for their waterlogged and salt-affected Vertisols. More than 100 farmers have installed SSD on their fields with area ranging from 0.5-20 ha. It has been made possible because of the gravity outlets available in the lift irrigation command area under the Krishna river basin. As such, farmers don't wait for the response of state department/even farmers groups and straightway go for the SSD installation on their fields.

Efficient groundwater management for enhancing adaptive capacity to climate change in sugarcane based farming system in Muzaffarnagar district (Satyendra Kumar and Aslam Latif Pathan)

Two cavity type groundwater recharge structures were installed at Nirmana and Kutba villages of Muzaffarnagar to meet the objective of "evaluation of technological interventions on a pilot basis for sustainable use of groundwater for enhancing adaptive capacity to climate change". During this period, total 11 observation wells were installed at different locations in the study area to monitor the fluctuation in groundwater table beneath and vicinity of adopted interventions. Seven observation wells were installed in the vicinity of recharge structures at Nirmana and Kutba, while 4 were installed near to check dam in Harsuali for studying groundwater fluctuation. Out of 7 observation wells, 4 were installed at Kutba village recharge site and remaining 3 were at Nirmana village recharge site. Observation wells are located at varying distance from the structure to observe spatial variation in groundwater depth. Similarly, depth of each observation well was kept variable, based on geology of that area, so as to differentiate the contribution of pond seepage from recharge structure.

The rate of recharge was estimated for the installed recharge structure at Kutba site through water balance of pond supplying water to the structure. Recharge rate was estimated for consecutive two periods, while the structure was under operation for the last two months spaning from December, 2017. The rate of recharge varied with time and the maximum was found in the start of recharging cycle (Fig. 18). The recharge rate varied

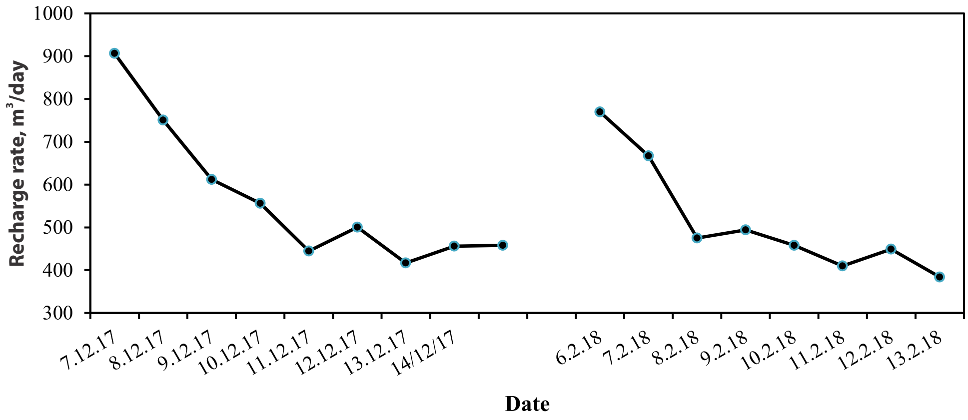


Fig. 18. Estimated rate of recharge for structure installed at at Kutba

from 906-417 m^3 day^{-1} and 780- 384 m^3 day^{-1} for two test cycles. Considering conservative rate of recharge (mean of the lowest 6 values) and operation of 50 days in the last two months, it was estimated that about 21,775 m^3 water had recharged through the structure during December 2017-January 2018.

Groundwater table depth and quality was monitored periodically from the structures as well as by using the installed observation wells. Apart from water samples collected from the observation wells, water samples were also taken from hand pump and tubewell running in nearby area. Samples collected from hand pump and tubewell situated near the recharge struture in Nirmana village were also analysed for microbial load. The temporal change in groundwater fluctuation in Nirmana and Kutba recharge sites is presented in Fig. 19. The data presented in Fig. 19 shows that water table declined during summer months of May and June. But at the end of the December, 2017, rise in watertable depth was recorded probably due to natural recharges during rainy season. A similar trend was found in Nirmana and Kutba sites. However, groundwater table rise at Nirmana structure was more as compared to Kutba structure as water for recharging through structure was available at Nirmana only during this period. The groundwater table declined during summer months, probably due the fact that there was no water was available for recharge and at the same time water pumping was also going on for irrigation.

Comparison of watertable fluctuation of different observation wells installed at Nirmana site, indicates variable values (Fig. 20). During the period of Sepetmber 2017- February

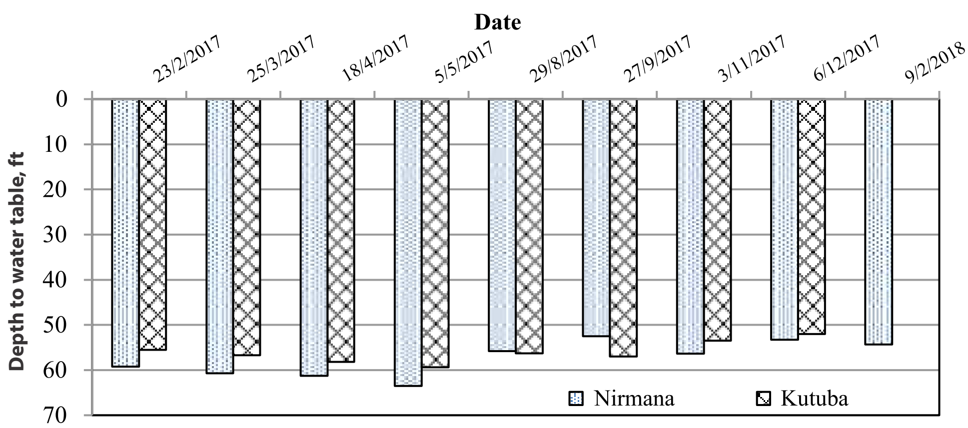


Fig. 19. Temporal change in groundwater table depth at Nirmana and Kutba study sites

2018, water table rise of 98.3 cm was recorded in N-P-1 (observation well installed near to recharge structure), while the observation well located away from the waterbody (N-P-3) and representing normal groundwater level, displayed 78.6 cm rise in groundwater level. Additional water level of 19.7 cm indicates the effect of recharge structure on groundwater resource. However, groundwater table fluctuation in different observation wells was almost similar at Harsoli site suggesting that check dam did not influence groundwater table during the period of September 2017- February 2018 (Fig. 21), because there is no water in drain for recharging. The data on chemical analysis indicates slightly higher pH of pond water of Nirmana site during summer, but it came down during the rainy season probably because of dilution effect by rain water. Overall, grountwater quality in the study area was found to be of good quality. The microbial analysis of water samples collected from the hand pump and tube well were also found to be in safe category (Table 9). It is clear that water samples collected from the pond directly had slightly higher microbial load than threshold limit. Observation well (P-1) installed near the structure at Nirmana showed no microbial load in December, 2017 water sample. Similarly, water samples collected from different drinking sources like hand pump, submersible pump, situated around the pond and structure, did not reveal any microbial load. However, further monitoring and supervision for more time is needed to reach affirmative conclusion about the use of fish pond water on groundwater resources.

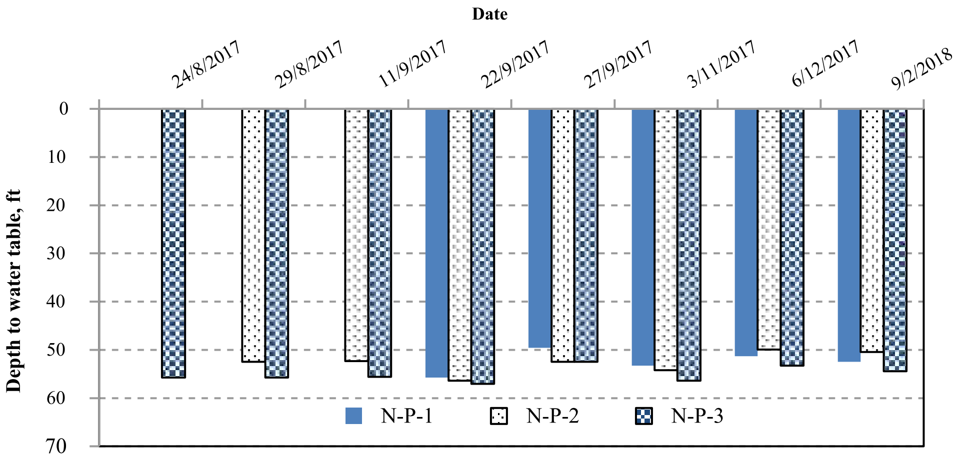


Fig. 20. Temporal change in water level of different observation wells at Nirmana study site

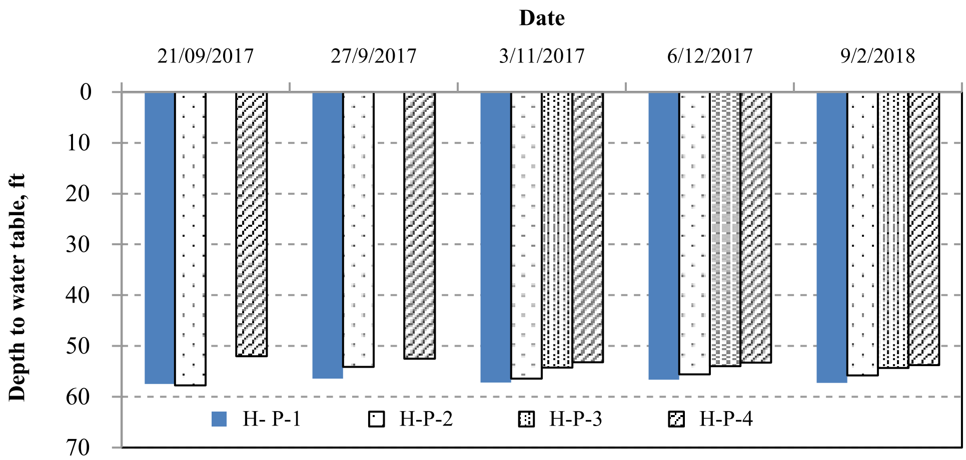


Fig. 21. Temporal change in water level of different observation wells at Harsuali study site

Table 9: Microbial load (coliform count, MPN/100 ml) in water sample collected from different

Location	Date of sampling				
	2/6/2017	15/6/2017	24/8/2017	27/9/2017	6/12/2017
Nirmana (P-1)	-	-	<1300 x 10^2	50x 10^2	0
Nirmana village (HP)	-	-	0	0	0
Nirmana s-1 (pond)	700x 10^2	500 x 10^2	33 x 10^2	6.1 x 10^2	<1600 x 10^2
Nirmana (P-3)	-	-	<1600 x 10^2	350 x 10^2	540 x 10^2
Nirmana school (HP)	-	-	2 x 10^2	0	0
Power house (SP)	-	-	2 x 10^2	0	0
Nirmana (P-2)	-	-		<1600 x 10^2	6.8 x 10^2
N-S-2 (Pond)		1700 x 10^2			<1600 x 10^2

(Threshold 100×10^2)

Note- P – observation well, HP- hand pump and SP- Submersible pump


Installation of observation well


Cleaning of recharge well at Nirmana site

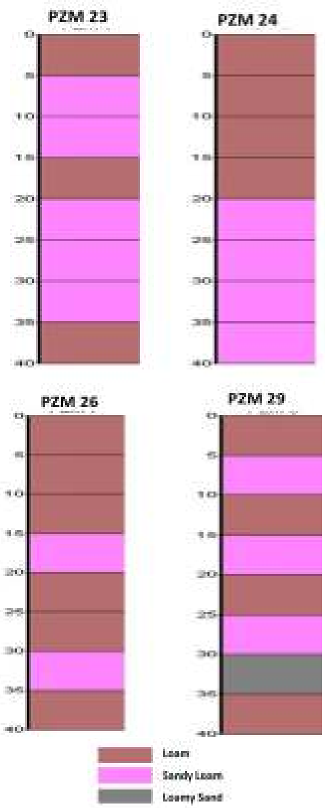


Fig.22. Lithology of observation wells installed at surroundings of Nain farm, Panipat, Haryana

Hydro-physical evaluation of a rainwater harvesting system under saline soil and groundwater environment (Bhaskar Narjary and Satyendra Kumar)

In order to study spatio-temporal variation in groundwater depth and salinity in shallow groundwater table area, a field study was carried out at Nain Experimental Farm situated in a depressional area having shallow and saline groundwater conditions. Apart from 27 already installed observation wells, 10 additional observation wells were installed in 2017 outside the farm boundary/along the farm boundaries for studying groundwater balance of the farm. From the lithology of the installed observation wells, it was noticed that soil texture was uniform throughout the study site. In upper 20 ft, soil profile is loam in texture and in lower part (25-40 ft) sandy loam in texture (Fig. 22).

For modelling of groundwater behaviour under shallow saline groundwater environment, the Modflow model was calibrated on the basis of the observed data of water table depth. There was a good agreement between the observed and simulated head of groundwater table as indicated by the smaller *RMSE* and higher R^2 values. For calibration periods, the model accounted *RMSE* of 0.2 m and R^2 of 0.96 during the monsoon period. Net groundwater flow (Inflow-outflow) was positive during the monsoon season. In the monsoon season 0.18, 0.33, 0.43, 0.52 and 0.57 m^3 net groundwater recharge occurred in June, July, August, September and October months, respectively. Spatiotemporal groundwater behaviour in the monsoon season (June-Oct.) indicated that hydraulic head was more in southwest corner of the farm i.e., along the drain side of the farm (Fig. 23). During the commencement of the monsoon season (June –July), average hydraulic head of the farm ranged between 208.84 to 210.78 m. During the monsoon season (July-Sep) groundwater recharge took place from drain side and nearby farmers' field. At the end of the monsoon season, there was little spatial variation in groundwater hydraulic head

(212.34-2.12.40 m) exist in the farm (Fig. 24). Main groundwater inflow occurred from drain water and nearby paddy field area during the monsoon season.

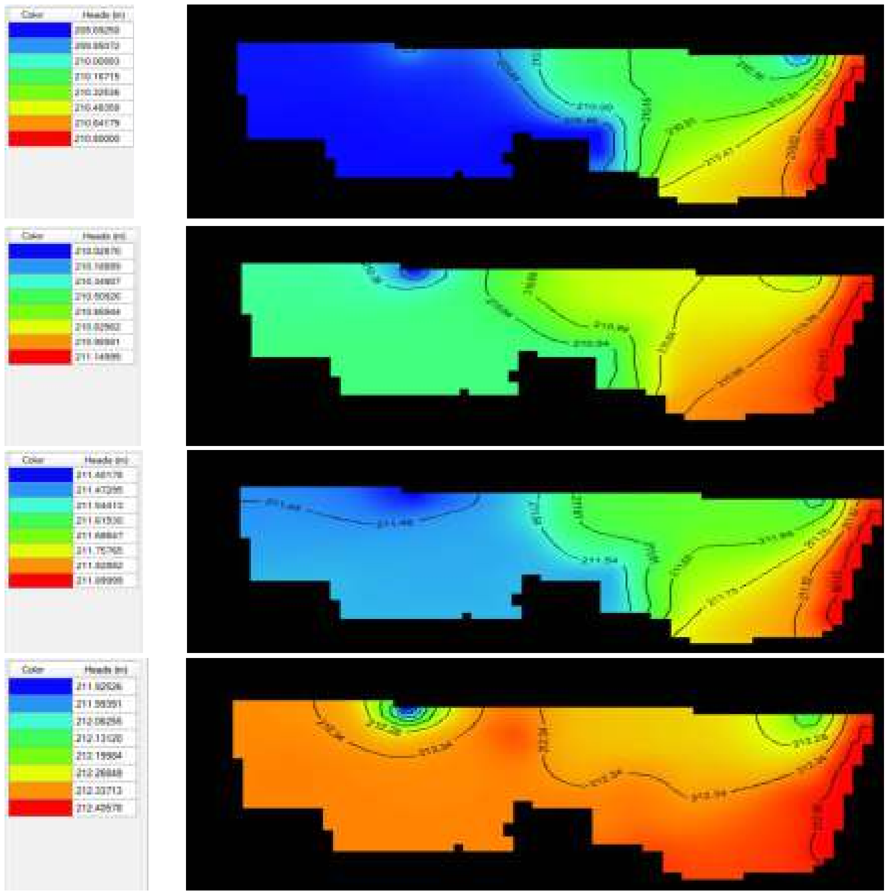


Fig. 23. Groundwater behaviour of Nain farm, Haryana in the Monsoon season

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)

The south-western part of Punjab is exposed to secondary salinization coupled with a number of other factors which make agroecosystems vulnerable. The depressional location (study areas Abohar and Fazilka) coupled with the lack of proper drainage system, and constant seepage from Rajasthan and Sirhind feeder canals lead to waterlogging in about 2.0 Lacs hectare of fertile land. Further, major shifts in cropping pattern and poor water management practices have led to decline of cotton-wheat and kinnow based cropping systems. Collapse of natural drains, some policy issues (mismanagement of SSD; imbalance supply of canal water at head tail points), climate variability and use of poor quality groundwater for irrigation are major sources of hazards to the agroecosystems leading to increased soil and water stressors. Such stressors together with impact of salinity induced stressors put 0.2 m farmers at risk for their primary income source. Looking to this issue, this study was carried out with a group of farmers following rice-wheat, cotton-wheat and kinnow based cropping systems. This study includes (i) profiling of soil and water elated stressors in different cropping systems, (ii) knowledge status of farmers on soil and water salinity, (iii) farmers perception about multiple stressors including salinity, (iv) farmers adaptation strategies, and performance of salt tolerant crops' varieties conducted in sodic-saline environments.

A total of 5 villages from three different blocks were sampled randomly. On average, 15 farmers (with different land holdings), thus a total of 74, were selected for study from 5 sampled villages. A questionnaire for personal interview was developed with open-ended and closed types of questions, tested well in pilot studies. We recorded observations on farmers' perception about the salinity induced stressors, other compounding factors, soil and water salinity induced stressors, and adaptation strategies being followed by the farmers. Data were collected using personal interview, FGD (Focus Group Discussions), transect walk, soil and water sampling and some secondary sources. Depth-wise (0-20, 20-40, 40-60 and 60-80 cm) soils were collected from rice-wheat (n=4), cotton-wheat (n=5) and kinnow (n=11) based systems. Soil pH_s, EC_e, cations and anions in soil saturation paste extract were determined. Data were analysed with descriptive statistics and thematic categorization techniques.

Soil salinity and sodicity: It is evident from Fig. 24a that soil pH_s was nearly unaffected but EC_e were greater in soil with cotton-wheat system compared to kinnow and rice-wheat system (Fig. 24b). It is obvious from Fig 25a that there is good agreement between $pH_{1:2}$ and pHs (R^2=0.56, data not shown) and R^2 of EC_e and EC_2(R^2=0.90, n=80). SAR (sodium adsorption ratio of saturation extract) varied along soil depth. Overall, soil data depicted that soil sodicity (SAR) was greater in soil under cotton-wheat system (2.9-28.0) compared to kinnow (0.2-16.2) and rice-wheat (0.5-18.2) systems.

Irrigation water salinity: Results indicated that farmers use water from diverse resources which have different ranges of EC and RSC (Table 10). Minimum EC of tube-well water being used for irrigation was 0.76 while maximum of 5.26 with mean value 2.59. Sometimes farmers in compulsion also use water from SSD drain which carries saline water, and this had EC 2.57 to 3.98 with mean value 3.49. These together increases the salt load in soil, however, in between farmers use canal water for irrigation that helps to minimize the salinity impact. Although, canal water was not easily available to some of the farmers. Overall, the salinity of water (*Choa*) of land having increased watertable varied from EC 3.77 to 3.85 with mean value 3.8.

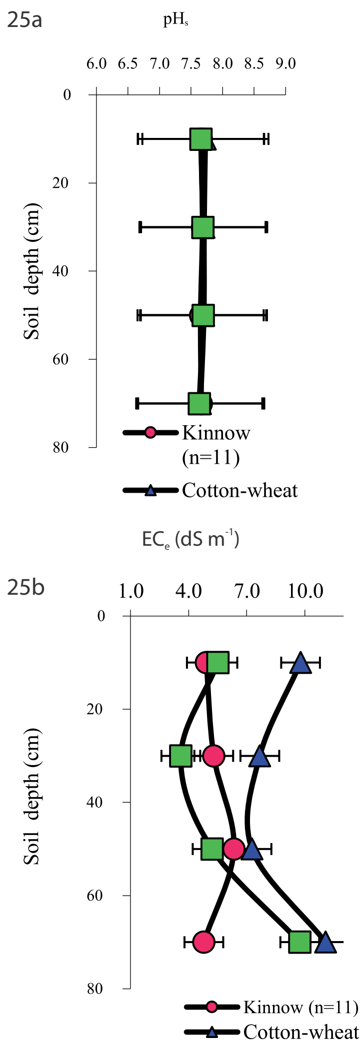


Fig. 24a and b. Depth-wise change in pH_s and EC_e (dS m^{-1}) in different soil depths under cropping.

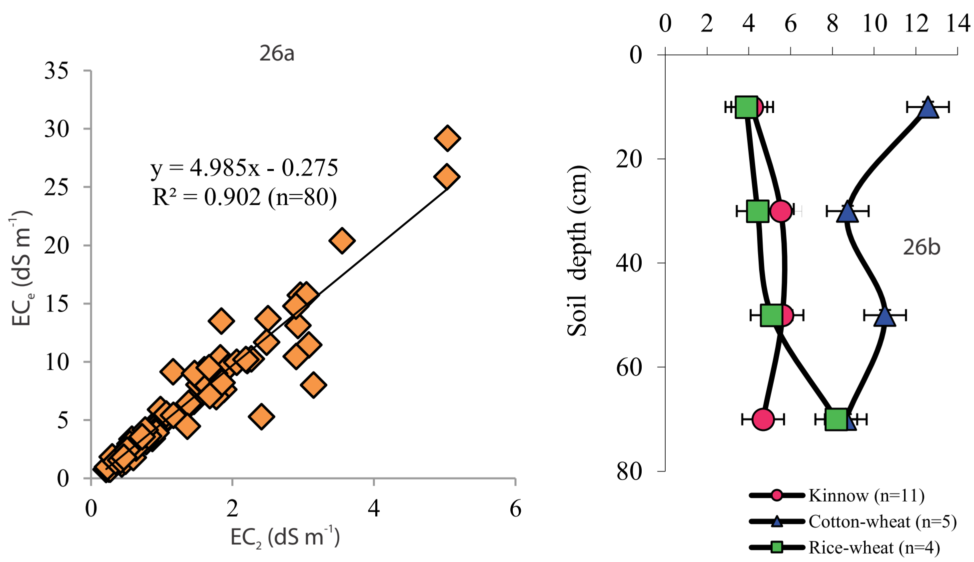


Fig. 25a&b. EC_2 Vs EC_e (r^2=0.90) in soils irrespective of cropping systems and depth-wise soil sodicity (SAR) under different cropping systems

Table 10: EC and RSC of water resources in study areas

Water resources	Minimum	Maximum		Mean		
	EC_{iw}	RSC	EC_{iw}	RSC	EC_{iw}	RSC
Tube well (n=6)	0.76	0.46	5.26	28.06	2.59	11.94
SSD drainage Nala (biggest exposure during intense rains) (n=3)	2.57	3.22	3.98	5.06	3.49	4.14
Water logged soils (Choa water) (n=6)	3.77	23	3.85	25.3	3.81	24.15
Pond water (used for pisciculture) (n=2)	2.68	7.1	3.24	8.4	2.96	7.75

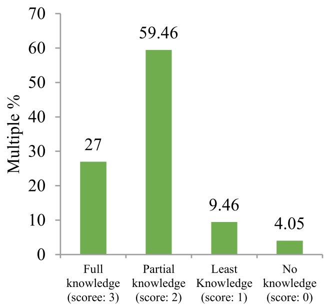


Fig. 26. Knowledge status of farmers (n=74) about soil and water salinity

Knowledge status of farmers about soil salinity hazards: Farmers were asked to narrate how they understand about soil and water salinity so that their ways of management can be explored. It was found that majority over 59.0 farmers had partial knowledge about the understanding of soil and water salinity (Fig. 26). Farmers define such lands based the soil, plant and crop indicators, however, about 27.0% farmers had full knowledge. Remaining had either least (9.46%) or no knowledge (4.05%) about soil and water salinity.

Perceived multiple stressors: Results presented in Fig. 27 indicated that ecological stressors (salinity) were found to be highly perceived with mean score 38.6% and CV 8.0%. This was further compounded by climate variability (mean score 34.48) stressor. Policy and institutional (means score 27.19 with CV 14.0%), and socio-cultural stressors (mean score 25.85 with CV 9.0%) further compounded the salinity risks. Economic and labour related stressors were also observed as aggravating factors as perceived by farmers impacting their crop production systems.

Adaptation strategies: It is evident from Table 11 that most of the farmers (32.43%) have switched over autonomously from kninnow and cotton-wheat to rice-wheat system, exclusively in low lying areas to moderate landscape by replacing. This was more prevalent among medium and small farmers. About 19.0 per cent farmers started integrated adaptations with rice-wheat (low lying areas) and cotton-wheat (upper

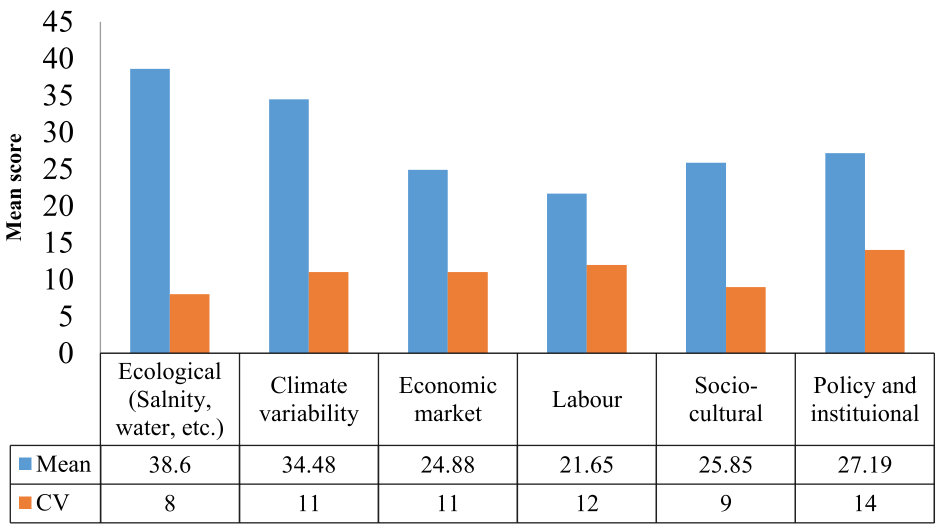


Fig. 27. Perception of farmers (n=74) about multiple stressors

Table 11: Adaptation strategies among the farmers (n= 74)

Planned adaptations with autonomous decision	Percentage	Remarks on salinity and social-ecological systems
Cotton-wheat	13.51	Upper landscape in the replaced kinnow fields, where salinity is less and market is an opportunity for cotton (more among medium and large farmers)
Varietal diversity (hybrid in cotton and rice, and improved varieties such as Pusa 1121, Pusa 1509, and somewhere CSR-30, etc.)	14.86	Low lying areas where salinity is high (more among medium and small farmers)
Rice-wheat, and kinnow	6.75	Rice-wheat low lying areas, kinnow at upper landscape where water table is below 5 feets (more among large farmers)
Rice-wheat, and fish culture	5.40	In low lying areas where water logging is a problem and salinity is high (more among large and medium farmers)
Rice-wheat/cotton-wheat (BT & Deshi to avoid climate and salinity risks)	18.91	Low lying and upper landscape (more among small and medium farmers)
Rice-wheat	32.43	Exclusively at low lying areas to moderate landscape by replacing kinnow and cotton (more among small and medium farmers)
Rice, and Kinnow-cotton at far places	8.10	In low lying areas, and upper landscape for initial 2-3 years (more among large farmers)

landscape, BT & Deshi cotton) to marginalize the risks of salinity and climate induced stressors. This was again more prevalent among small and medium farmers. Diversification of varieties (hybrid in cotton and rice, and improved varieties in coarse grain rice, and Pusa 1121, Pusa 1509, and somewhere CSR-30, etc.) was another set of autonomous adaptation strategies hybridized with formal knowledge among more than 14.0 per cent farmers, particularly in the landscapes where salinity vary from marginal to higher level.

Other than CSR-30, farmers face larger yield penalty (30-50%) in particularly Basmati group of rice varieties. Although, area under CSR-30 was observed very less. About 13.0% farmers have started adapting cotton-wheat by replacing kinnow orchards where surface water table is less than 4.0 feets and salinity is in marginal range (0.5 to 3.27) .

FLD in wheat and rice: Under institute funded research project for Punjab, a total of 35 FLDs (5 on CSR-43 rice, 9 on CSR-36 rice, 9 on CSR-30 Basmati rice and 12 on KRL-210 wheat varieties) were conducted as an intervention to motivate farmers about making adaptations of such varieties against ecological stressors (salinity). The mean pH of soils where FLDs of salt tolerant rice varieties were conducted was found to be 9.22 with EC value 1.69. Results indicated that the yield of CSR-43 varied between 5.0 to 7.4 t ha^{-1}, whereas the yield of CSR-36 in same soil and water environments varied between 5.5 to 7.2 t ha^{-1}. The yield performance of CSR-30 was recorded between 2.0 2.9 t ha^{-1}.

The FLDs of salt tolerant wheat KRL-210 was conducted/networked with farmers to adapt saline-sodic environments of Malot areas. These farmers after adopting KRL-210 reported the performance of this variety on 15 parameters. The variety was assessed well on its salinity tolerance, climate resilience, tolerance to waterlogging, lodging behavior and pod shattering attributes (Fig. 28). The yield of KRL-210 was found to be 5.7 t ha^{-1} at the soil salinity level of 4.03 dS m^{-1} as compared to local variety which provided 4.5 to 4.8 t ha^{-1}.

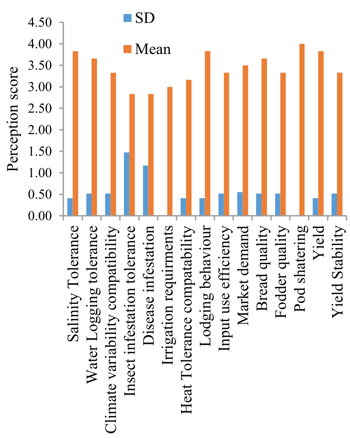


Fig. 28. Perception of farmers (n=35) about attributes of salt tolerant wheat variety.

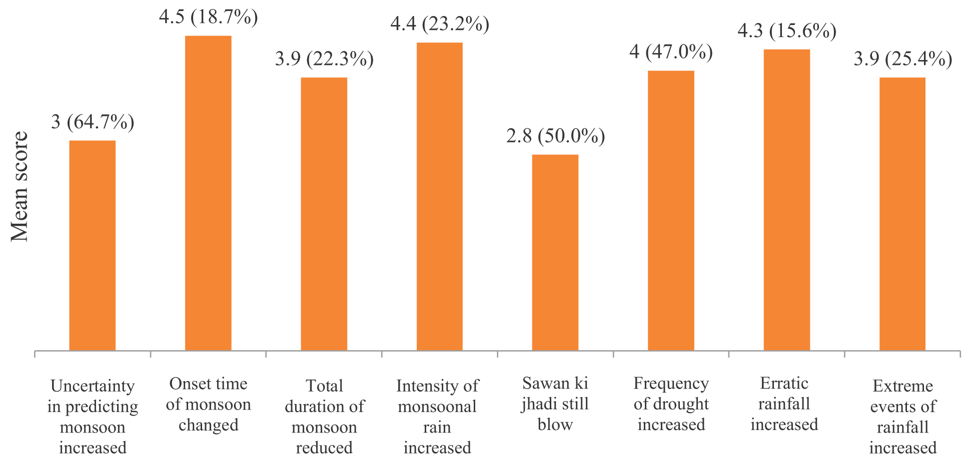
Perceived Climate Variability and Agricultural Adaptations by Material Resource-Poor Farmers in Salt Affected Agro-ecosystems-Implications for Food and Livelihood Security (Ranjay K. Singh, Anshuman Singh, Satyendra Kumar, Parvender Sheoran and Dheeraj Singh)

It is well recognized that climate change would adversely impact agroecosystems, health, agricultural productivity and livelihoods in India. Although vulnerability due to extreme weather events and variable climate is a historical phenomenon in India (e.g. severe droughts in 1918, 1972, 1987, 2002, 2009 and 2012) and in the recent past frequency of such events has increased manifold. Sensitivity of resource-poor farmers to various levels and types of environmental risks has compelled them to develop location specific adaptive practices to sustain their livelihoods under risk-prone conditions. The vulnerability caused by climate, ecological and socioeconomic stressors is being identified as factors causing compounded impact on agricultural adaptation among small and marginal farmers of India. Out of 20 major agroecological regions of India, 16 are identified as rainfed, and the remaining of the country is semi-arid (67% per cent of total area and 40 % of total food production system). The farmers living in these ecologically stressed areas with low agricultural productivity and high level of vulnerability have been the major victims of loss of food and livelihood security in the past 20 years due to significant climate variability. Looking to the climate variability as a challenge, this project was implemented in Hisar (Haryana), Pali (Rajasthan) and Jaunpur districts Uttar Pradesh) in December 2015. The activities included during 2017 include: (i) studying farmers' perceptions about monsoonal weather in Pali district, (ii) knowledge among farmers of Plai on local indicators in predicting rains and use of formal and informal knowledge in reducing rain related uncertainty, (iii) making interventions of salt tolerant and other improved crop varieties in Pali, Hisar and Jaunpur, (iv) capacity building of farmers in Pali and Hisar through goshthis, soil and water testing based agroadvisories, and (v) mainstreaming of grassroots knowledge (landraces) in relation to soil salinity.

Data for the listed activities were collected in Pali from a total of 122 farmers selected randomly from a list of 12 villages sampled randomly from four blocks of Pali and Jodhpur (2 from each). Interview schedule with open-ended questions, well tested trough pilot study was developed to record observations on farmers perception about monsoonal patter and knowledge on local indicators. The soil and water samples were taken along with GPS information to test the salinity stressors into these samples and provide the soil heath cards along with the agroadvisories to the farmers of Pali. Interventions of salt tolerant and other improved varieties were made into the selected villages of Pali, Hisar and Jaunpur district (three states). Soil and water samples were tested into institute lab, while other information were entered into excel sheet and analyzed using descriptive statistics to draw the valid inference from the study

Perception on monsoonal variability: Results indicated that 18.7% farmers perceive changes in time of monsoon onset (mean score 4.5) with increase in intensity of rains (mean score 4.4; 23.2%) over past 5 years (Fig. 30). Secondary data indicated that average rainfall which uses to be around 300-350 mm is increased upto 500-600 mm/annum. Farmers' perception is built most often with more recent phenomenon of climate, while some memories get fixed with extreme vents whether nit is current or even of past. Farmers in past 5 years are experiencing less *Kall* duration (modest drought) with increase in extreme event of rainfall (mean score 3.9; 25.4%) which use to happen in every 3 years followed by *Mahakal* (extreme drought) in 7 years. The frequency of *Mahakal*

Fig. 29. Agreement/disagreement (Data in parenthesis indicates percentage)



(extreme drought) is now reduced and converted into *Mahakal-Badh*. Further, total duration of rainfall is perceived (22.3%) to be reduced (mean score 3.9) and uncertainty in prediction of rainfall is also increased as perceived by 64.0% farmers with mean score 3.0 (Fig. 29).

Table 12: Knowledge on monsoon among farmers (n=122)

Winds typology	%	Clouds typology	%	Plant species phenology	%	Animals behavior %
4	10.0	3type	20.0	3	80.0	3 type 10.0
3	60.0	2 type	70.0	2	20.0	2 type 10.0
2	30.0	1 types	10.0	1	0.00	1 type 80.0

Knowledge on monsoon among farmers: While interacting with farmers during FGD, it was learned that farmers are still more dependent on the local indicators for predicting rainfall and monsoonal weather (Table 12). The observation with large sample of farmers (n= 122) taken through personal interview indicated that majority of farmers (60.0%) have knowledge on three types of winds behavior which bring rains followed by knowledge on two types of winds (30.0%). Further, 70.0 per cent of farmers had knowledge on two types of cloud related behaviors those bring rain. Knowledge on plant indicators in predicting monsoonal weather was popular among farmers, and 80.0 per cent of them were aware about three plant species (phenology related to good rains or drought) used in guessing the monsoonal weather. Contrary to this, 80.0% per cent farmers were knowing only one animal species followed by 2 to 3 (10.0% each) being applied in predicting monsoonal weather. It was found that plant species related indicators were applied to predict long term weather while, animal, cloud and winds for the short term weather. Multiple percentage analysis revealed that use of modern media such as print was popular among 90.0% educated farmers followed by TV among 80.0% relatively less educated farmers. Farmers receiving SMS on weather related news on phone was found among young age farmers, but was scanty. Triangulation analysis revealed that farmers also integrate their local indicators with formal ways of monsoon prediction (34.5%) to take decision on cropping calendar.

Capacity building: In capacity building, interventions of salt tolerant and other improved varieties, agroadvisories and farmers' gosththis were undertaken as major activities in Pali, Hisar and Jaunpur districts. The details are as:

Table 13: Performance of muskmelon variety Kajari

Hemawas village	Min.	Max.
Soil pH	8.05	8.4
Soil EC	0.69	7.4
Irrigation water EC	4.12	9.1

Interventions of salt tolerant and other improved varieties in Pali

Muskmelon (*Kajari* variety)

A total of 20 demonstrations on Kajari variety of muskmelon were conducted with a objective to intensify the farmers' cropping systems. These demonstrations were conducted in the soil with pH 8.05 to 8.4 having EC 0.69 to 7.4 dS m^{-1}. The water EC was between 4.12 to 9.1 dS m^{-1}(Table 13).

Results indicated that yield of *Kajari* variety of 20 farmers ranged from 425.0 to 525.0 quintal per ha. Farmers have open-well into the Hemawas dam from where good quality rainwater was harvested by farmers in their open-wells (managed collectively) and used to irrigate muskmelon crop. The muskmelon is grown in the residual moisture of soil of dam catchment areas rich in clay and organic matter deposited from upper landscapes. The income generated by farmers from muskmelon intensification (net income average Rs. 15000/ha with cost of Rs. 5000/ha) was used by them to marginalize risks and uncertainty involved in rainfed and saline lands where they have more areas of cropping.

Moong (GM-4)

A total of 20 demonstrations were conducted in selected three villages of Pali district. The soil pH varied from as low as 7.03 in Kharda to as high as 9.33 in Rampura village (Table 14). The soil EC was lowest 0.36 in Kharda while highest 7.4 in Hemawas village in the fields where demonstration of moong GM-4 was conducted. The EC of irrigation water varied from 0.88 to 13.2.

Table 14: Soil and EC parameters of farmers field where demonstration of GM-4 was conducted

Water resources	Minimum	Maximum		Mean		
	EC_{iw}	RSC	EC_{iw}	RSC	EC_{iw}	RSC
Tube well (n=6)	0.76	0.46	5.26	28.06	2.59	11.94
SSD drainage Nala (biggest exposure during intense rains) (n=3)	2.57	3.22	3.98	5.06	3.49	4.14
Water logged soils (Choa water) (n=6)	3.77	23	3.85	25.3	3.81	24.15
Pond water (used for pisciculture) (n=2)	2.68	7.1	3.24	8.4	2.96	7.75

Result revealed that under such stresses of sodicity and salinity, the performance of GM-4 moong ranged from 5 to -7.5 q ha^{-1} on 20 fields of farmers.Although, some of the fields suffered intense rains (60% more rain) during 2017.

KRL-210 (wheat)

A total of 41 demonstration on KRL-210 were conducted on a total of 15 ha land of farmers in the salinity range as indicated in the Table 15. Results revealed that yield increase in KRL-210 was 35.4% with a maximum yield of 39.2 q ha^{-1} in comparison to local variety. The minimum yield of KRL-21o recorded was 25.4 q ha^{-1}. The net return obtained by farmers in KRL-210 was Rs. 27,600 ha^{-1}a as compared to local variety with Rs. 19,500 (Table 15). The B:C ratio of KRL-210 was found 2.7 as compared to1.9 in local variety.

Table 15: Performance of KRL-210

Yield (q ha^{-1})		Gross Return (Rs. ha^{-1})		Net Return (Rs. ha^{-1})		B : C Ratio	
KRL-210	Local	KRL-210	Local	KRL-210	Local	KRL-210	Local
32.5	24.0	43,400	33,500	27,600	19,500	2.7	1.9

CS-54 (mustard)

A total of 25 demonstrations were conducted on 10 ha of lands with CS-54 variety in saline-sodic environments (Table 16). Results indicated that percentage of increase in CS-54 was upto 26.7% as compared to local variety. The maximum yield recorded was 17.4 q ha^{-1} while minimum was 11.6 q ha^{-1}. The net return with CS-54 was Rs. 48050 ha^{-1} as compared to Rs. 19,400 ha^{-1} local variety (Table 16). The B:C ratio of CS-54 was observed to be 3.5 as compared to local variety 2.11 in local variety.

Table 16: Performance of CS-54

Yield (q ha^{-1})		Gross Return (Rs. ha^{-1})		Net Return (Rs. ha^{-1})		B:C Ratio	
CS-54	Local	CS-54	Local	CS-54	Local	CS-54	Local
1.46	1.12	67300	36700	48050	19400	3.5	2.11

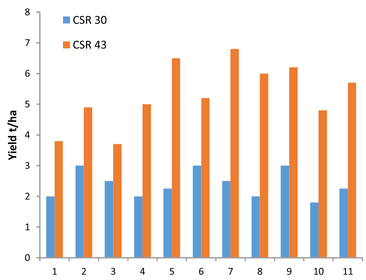


Fig. 30. Performance of CSR-43 and CSR-30 in saline environment

CSR-43 and CSR-30 (rice) in Hisar district

A total of 11 FLDs on salt tolerant rice varieties of CSR-43 and CSR-30 were conducted in the saline environments of Hisar district of Haryana. The water EC varied between 3.2 to 13.3 with mean 7.98, while soil EC varied between 0.98 to 4.5 with mean 2.88 dS m^{-1}. The pH of soil was between 7.2 to 8.5. Results indicated that yield of CSR-43 could vary between 3.7 to 6.8 t ha^{-1}. In the same environment, yield of CSR-30 was found to be between 1.8 to 3.0 t ha^{-1} (Fig. 30).

Performance of salt tolerant rice varieties CSR-30 and CSR-43 in sodic soils in Jaunpur district

A total of 11 FLDs on salt tolerant Basmati rice variety CSR-30 was conducted in sodic soils of Jaunpur district having pH_e between 8.64 to 9.48 with EC_e 0.45 to 2.9 dS m^{-1} and mean soil pH_e 9.07. A similar pattern of sodicty was observed in the soils of villages where 18 FLDs of CSR-43 were conducted. Results presented in Table 17 indicated that yield of salt tolerant rice variety CSR-30 was recorded minimum 1.1 while maximum 2.2 t ha^{-1} with CV 24.09%. The yield performance of CSR-43 under the same sodicity range of soils in adopted villages varied from 3.0 to 4.5 t ha^{-1} with CV 12.63% (Table 17).

Table 17: Performance of salt tolerant rice varieties CSR-30 and CSR-43 in sodic soils of Jaunpur district

Varieties	Yield t ha^{-1}		Mean	CV (%)
	Minimum	Maximum		
CSR-30 (n=11)	1.1	2.2	1.54	24.09
CSR-43 (n=18)	3.0	4.5	3.8	12.63

Farmers' Goshthis

Organizing farmers' goshthis in adopted villages of Lal Bahadur Shastri award project (ICAR) was one of the major capacity building activities. Other than the research team, the personnel from Krishi Vigyan Kendra and progressive farmers have participated during these goshthis to share their knowledge and experiences on climate induced stressors and adaptation strategies they are following. During the last one year, a total of 8 farmers' goshthis were conducted to enhance the capacity of farmers. During these goshthis, soil and water samples were also taken, and farmers were provided agroadvisories on the spot based on the results of EC and pH (recorded by EC and pH meter). The detailed agroadvisories on soil and water induced stressors and compounding risks by climate were provided later on. The goshthi of Chiduad (Hisar) helped farmers to get networked together for reciprocal learning and reduce the uncertainty/risks caused by ecological and climatic variables.

Mainstreaming of grassroots knowledge/landraces: One of the key activities in the project was to mainstream the grassroots knowledge and related bioresources which are observed as resilient against ecological/climatic stressors. During the course of two years of field works, we have recorded a local landrace called *Newar* radish from Jaunpur district which perform better in saline condition with record length (4-6 feet, as reporte d local media also), as reported by farmers. This grassroots knowledge tempted us to take this for testing its characters in sodic and saline environments. Seed sample was taken from a farmer (Mr. Jiya Lal Maurya) and experiment was conducted in controlled condition at CSSRI, Karnal. Simultaneously, a participatory trial with farmers at 8 locations in Kaithal and Karnal districts, and two locations in saline environment of Pali district were conducted. The objective was to record the unique attributes of *Newar* and mainstream with formal knowledge so that potential of this landrace for abiotic stress can be used in future breeding lines.

The initial results indicated that the Newar radish (the landrace) performed better in terms of morpho-physiological attributes over the high yielding checks white execl and Pusa mirdula. Result further revealed that Newar has high ability to maintain membrane integrity/injury at higher salinity (EC_{iw} dS m^{-1}) by synthesizing higher amount of proline (225.28 umol) campared to checks White Excel (96.52 umol) and Pusa Mirdula (115.27 umol), restricting translocation of Na^{+} from its roots to shoot parts reveled by the lowest root and shoot Na/K ratio (0.97, 1.16) as campare to checks White Excel (1.42, 1.93) and Pusa Mirdula (3.07, 1.83) and accumulating higher amount of potassium content in shoots which makes it more salt tolerant. It could be inferred that this landrace (Newar) can be used as potential donor for breeding radish for salt tolerance.

The study indicated that farmers are experiencing anomalies in monsoonal weather with increased rains intensity in past five years and occurrence of extreme rain events. They perceive changes in time of monsoon onset and reduction in total rainy days period. Generally, farmers had experience of normal to moderate drought at every 3 years and severe drought at every 7 years. Farmers have their own definition of normal to moderate and severe droughts in case of Pali district. Although, farmers use local indicators to predict monsoonal weather (short term and long term), the uncertainty of prediction is increased, and thus farmers are trying to explore formal knowledge. Some farmers integrate informal knowledge with formal one they received though TV and news paper. The use of weather based messages is still to be strengthened among these farmers to take proper decision in cropping. Interventions of intensifying component (muskmelon with Kajari variety), salt tolerant wheat and mustard varieties in saline environment of Pali could enhance the yield considerably and thereby farmers' capacity. Similar results with salt tolerant rice (CSR-30 and CSR-43) were found in water-logged salinity of Hisar district (adjoin to Jind district)/ the results of rice variety CSR-43 and CSR-43 in sodic soils of Jaunpur district was encouraging for the farmers. Farmers' goshthis, and soil and water based agroadvisories provided to the farmers could excel their ability to take proper decision in cropping in marginal (saline and sodic) environments. Scientific study on grassroots knowledge on *Newar* radish (explored from Mr. Jiyalal Maurya's field, Jaunpur) has provided significant result to mainstream such landrace and related knowledge for developing future lines on abiotic stressors.

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
(Arvind Kumar Rai, Nirmalendu Basak, Satyendra Kumar, Bhaskar Narjary, Gajender)

Conservation tillage, deficit irrigation and crop residue mulching approaches were employed for managing root zone salinity for increasing production, of low water requiring cropping system (sorghum–wheat), under limited water supply in arid and semi-arid region. No significant effect of tillage, irrigation and mulch was observed on sorghum yield. Wheat grain yield increased significantly in 2016-17 compared to 2015-16. It was significantly higher under CT-CT and mulched fields (Table 18). The soil pH in experimental plot did not change (>8.0), with different tillage, mulch and irrigation treatments during the study (Table 18). Interaction effect of different practices was also non-significant. The soils contained soluble salts with $EC_{1:2}$ being >1.58 dS m^{-1} during both *kharif* and *rabi* seasons. On an average salinity remained higher in surface soil during *rabi* (4.92 and 2.92 dS m^{-1}) compared to *kharif* (1.58 and 2.13 dS m^{-1}) in both the years (Table 19). Though application of different tillage, mulch and irrigation treatments did not affect salinity in any of *rabi* and *kharif*, however, it decreased from 4.92 dS m^{-1} in 2015-16 to 2.92 dS m^{-1} in 2016–17 (P< 0.05). EC relatively reduced in mulched plots in both seasons. Due to low rainfall in *kharif* 2016-17, EC_2 was higher compared to previous year. About 72 mm rainfall in January-2017 caused reduction of EC_2 in *rabi* season. In *rabi* season, EC_2 was reduced by two units. Mulching under deficit irrigation was more effective for soil moisture conservation, EC_2 reduction and improvement in soil biological activity. Dehydrogenage activity was significantly higher in mulched plots under deficit irrigation i.e., 80 and 60% application of water requirement (WR; Fig. 31). Higher soil moisture content was also recorded in mulched plots receiving 80 and 60 WR. Soil salinity was reduced significantly in 60WR+mulch compared to 60 WR, but it was at par with other irrigation and mulch combinations.

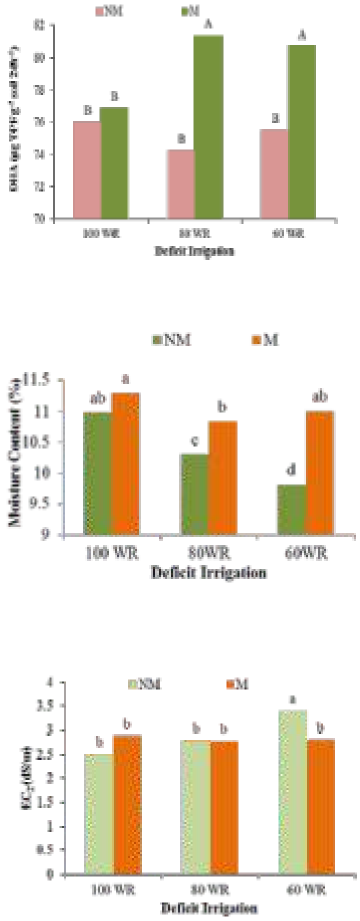


Fig. 31. Effect of irrigation x mulch interaction soil moisture, EC_2 and dehydrogenase activity of soil during sorghum-wheat cropping seasons

Table 18: Effect of tillage, mulch and deficit irrigation on the sorghum and wheat yield (t ha^{-1})

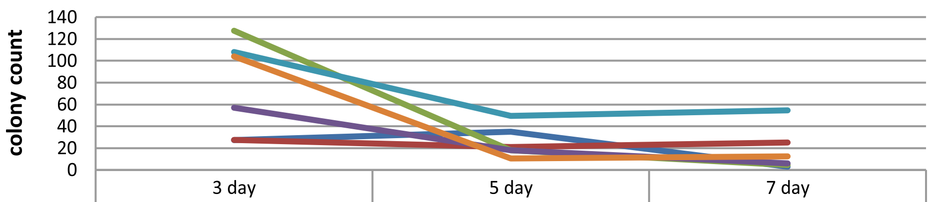
	Sorghum yield (t ha^{-1})			Wheat Yield (t ha^{-1})	
Year	GFY	DFY	DM %	Grain yield	Straw yield
2015-16	55.69	13.48	24.38	5.78B	8.62
2016-17	55.14	13.29	24.24	6.04A	8.51
Tillage					
RT-ZT	56.11	14.03	25.27	5.94AB	8.73
CT-CT	53.68	12.72	23.84	6.10A	8.95
ZT-ZT	56.46	13.40	23.81	5.70B	8.01
Irrigation					
100 WR	53.89	13.03	24.43	5.86	8.36
80 WR	54.72	13.19	24.21	5.98	8.91
60 WR	57.64	13.93	24.29	5.9	8.42
Mulch					
No Mulch	54.91	13.30	24.37	5.77B	8.54
Mulch	55.93	13.47	24.25	6.05 A	8.59

Table 19: Soil EC_2 and pH_2 with tillage, mulch and deficit irrigation after sorghum and wheat harvest

Year	Sorghum		Wheat	
	EC_2 (dS m^{-1})	pH_2	EC_2 (dS m^{-1})	pH_2
2015-16	1.58^{B}	8.33	4.92^{A}	8.29
2016-17	2.13^{A}	8.35	2.92^{B}	8.25
Tillage				
RT-ZT	2.10	8.29	4.33	8.25
CT-CT	1.61	8.42	3.51	8.29
ZT-ZT	1.86	8.31	3.92	8.28
Deficit Irrigation				
100WR	1.87	8.33	4.06	8.26
80WR	1.91	8.33	3.78	8.29
60WR	1.79	8.37	3.93	8.27
Mulch				
No Mulch	2.03	8.33	4.10	8.30
Mulch	1.68	8.36	3.74	8.24

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

Rhizospheric microbes found in salt affected soils may serve as a potent source for novel plant growth-promoting (PGP) microbial resources. These could ameliorate salt stress without harming the environment. The potential application of PGP microbes in agriculture is based on their ability to increase crop growth and yield. For the isolation of salt tolerant plant growth promoting bacteria (PGPB), rhizospheric soil samples were collected from two sites viz., i) ICAR-CSSRI experimental farm, Nain and ii) salt affected area in district Jhajjar (Haryana). EC_e and pH ranged from 10.5 to 42.4 dS m^{-1} and 7.99-8.80 in samples from Nain Farm, whereas 13.84-19.16 dS m^{-1} and 6.50-6.90 in samples from Jhajjar. All isolates from two sites (84 from Nain farm and 81 from Jhajjar) were screened for PGP activities. Total 35 isolates showed IAA production > 5 ppm. The highest activity was shown by isolate HB4A1 (15.89 ppm) followed by HB6P2 (14.01 ppm) and HB6J2 (13.65 ppm). Total 41 isolates showed ammonia production > 5ppm, with the highest shown by isolate HB6N1 (12.6 ppm) followed by HB5N1 (12.5 ppm) and HB9A1 (12.5 ppm). HCN positive results were shown by only 13 isolates. These isolates were further screened for salt tolerance and some isolates showed higher colony count at higher EC (> 4 dS m^{-1}; Fig. 32).



	3 day	5 day	7 day
DW	27.5	35	3
EC3	27.5	21	25
EC4	127.5	18	4.5
EC9	57	18	6
EC12	108	49.5	54.5
EC15	104	10.5	12.5

Fig. 32. Growth of isolate HB8P1 in growth media having different EC

Isolates which showed PGP traits and also growth at higher EC were screened. Out of these, best five (HB6J2, HB8P1, HB6P2, HB4A1, HB4N3) and five from previous study (STB32, STB1, 10STB3c (1), 5STB19, 15STB2C) were selected for pot experiment

Effect of isolates was observed more in salt sensitive variety than salt tolerant. Root length was significantly higher in salt sensitive HD 2009 treated with HB4N3 and 15 STB2C than control and other treatments. But such effect was not observed in salt tolerant KRL 210. Similarly shoot length was also significantly higher in the same treatments as compared to control and other treatments. Control treatment was inoculated with the same medium used to inoculate other treatments but in the control, medium was without any culture.

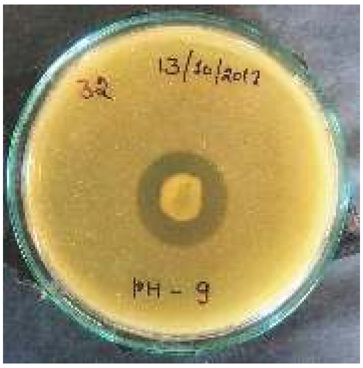
In shoot of variety HD 2009, Na^+/K^+ ratio was comparatively lower at 14, 21 and 28 days after sowing in almost all treatments than control but such type of trend was not observed in variety KRL 210. In the root Na^+/K^+ ratio, it was higher in both the varieties than control with many exceptions (Table 20). It may be because of salt accumulation is higher in root than shoot.

Table 20: Na^+/K^+ in roots of salt sensitive (HD 2009) and tolerant (KRL 210) variety

Isolate	HD 2009			KR L210		
	14DAS	21DAS	28DAS	14DAS	21DAS	28DAS
HB6J2	0.381	0.732	0.855	0.948	0.721	0.619
HB8P1	0.769	0.703	0.790	0.645	1.090	0.832
HB6P2	0.580	0.734	1.111	0.828	1.013	0.902
HB4A1	0.849	0.622	1.056	0.400	0.946	1.361
HB4N3	0.727	0.488	1.217	0.600	0.954	1.125
STB32	0.517	0.433	0.950	0.886	0.942	0.917
STB1	0.853	0.950	0.914	0.579	1.143	1.000
10STB3C(1)	0.960	0.854	0.899	1.174	0.856	0.986
5STB19	1.027	0.597	0.927	0.832	0.861	1.062
15STB2C	0.853	0.980	1.137	0.747	0.709	0.786
Control	0.846	0.904	1.377	0.655	0.989	0.666

Isolation, identification and assessment of salt tolerant zinc solubilising bacteria for enhancing availability and use efficiency of zinc in salt affected soils (Awtar Singh, R.K. Yadav, A.K. Rai and Madhu Choudhary)

Zinc deficiency is very common and worldwide problem which drastically reduces crop growth, yield and nutritional quality. This problem is more common in areas under cereal production. Almost half of the soils, on which cereals are grown, have low zinc availability. Availability of zinc reduces with increase in pH of the soil owing to increased zinc adsorbtion, formation of zinc hydroxide, co-precipitation of zinc in oxides of iron and chemisorption on calcium carbonate. Zinc deficiency is mostly pH-dependent, and concentration of zinc in soil solution decreases 100-fold for each unit increase in pH value of the soil. More than 95% of soil zinc present in mineral fraction contributes very less for plant uptake. Remaining 5% of soil zinc presents in water soluble and exchangeable (WSEX) and complexed fractions contributes the maximum for plant uptake. It suggests that soil contains enormous reserves of unavailable zinc. Therefore, the present study was initiated in 2017 for enhancing availability and use efficiency of zinc in salt affected soils, utilizing zinc solubilizing bacteria. So far, rhizospheric soil samples were collected from different locations (Salt affected soils as well as zinc mine) for isolation of salt tolerant zinc solubilising bacteria. Bacterial isolation was carried out from these



Clear halo produced by zinc solubilising bacteria on modified pikovskaya agar medium

Fungi showing positive phosphorus solubilizing activity

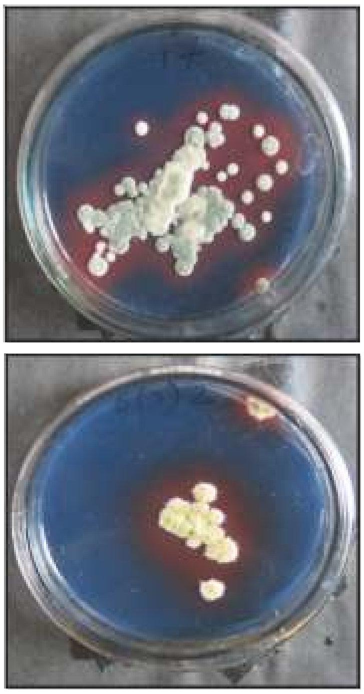
rhizospheric soils using modified pikovskaya medium (maintained pH 9.0 before autoclaving) supplemented with insoluble zinc oxide. Initially, 27 zinc solubilising isolates were selected on the basis of halo formation around colonies.

Development of endo-rhizospheric fungal consortia to increase salt tolerance in crops (Priyanka Chandra, Awtar Singh and Kailash Prajapat)

Salinity and alkalinity are among the major environmental stresses affecting crop production, particularly in arid and semi-arid areas. Soil salinity affects mainly due to the excessive accumulation of toxic ions (Na^+, Cl^-, and SO_4^{2-}), whereas alkaline soils are generally characterized by poor physical conditions due to high concentrations of bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) as well as high exchangeable Na^+.

Microbial biostimulants such as PGPR, and beneficial fungi (*Arbuscular- Mycorrhizal* Fungi (AMF) and *Trichoderma spp. etc.*) are considered as promising tools to overcome the limitations of salinity and alkalinity on crop growth and productivity. Many PGPRs, AMF and fungi like *Trichoderma spp.* strains can enhance crop tolerance to abiotic stresses including salt stress by increasing nutrient uptake through greater effective root area (for AMF) and better solubilization of nutrients and by production of metabolites such as indole-3-acetic acid or auxin analogs.

Hence, rhizospheric and non-rhizospheric soil samples were collected for isolation of salt tolerant fungi from different salt affected areas. The sodic soil samples, with pH range 8.18 – 10.11, were collected from four sites of rice and sorghum fields in district Patiala (Punjab) and CSAFS experimental site at ICAR-CSSRI, Karnal. Some non rhizophereic soil samples were also collected from villages Sitamai, Dharamgarh, Haibatpur, Geong and Saraswati farm. While saline soil samples were collected from the rhizosphere of sorghum, pearl millet and mustard crops grown at the institute experimental farm Nain (Panipat). Collected soil was serially diluted for the isolation of the fungi. Salt tolerant fungi isolation, from saline soil, was done using medium supplemented with 5% NaCl; while from sodic soil, by maintaining pH of the medium at 10. The number of salt tolerant fungi varied in different sites. The isolated fungi were subjected to screening for their nutrient acquisition activities, mainly phosphate solubilization. Fungi were inoculated on the medium supplemented with calcium triphosphate. Twelve fungi were found to solubilize phosphorus at pH 10, while fifteen at 5% NaCl in a range of 2-6 mm zone of solubilisation. Other nutrient acquisition activities, like zinc solubilization and siderophore production potential were also observed. Ten fungi isolated from sodic soils showed both the activitities. While 9 and 11 fungi isolated from saline soil demonstrated zinc solubilising and siderophore production potential, respectively. Ammonia and indole acetic acid production, of the selected fungal isolates, was also tested to check their antagonistic and plant growth promoting activity while results were found positive in some of the fungi.



Fungi showing positive results for siderophore production

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, Satyender Kumar, K. Thimmappa and R.K. Singh)

The 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 gypsum and pressmud used either individually or in combination for sustained use of sodic waters in the concerned ecologies. A total of 4 treatments as RSC neutralizing ameliorants viz., available RSC water/untreated control (T_1); T_1 + gypsum @ 7.5 t ha^{-1} (T_2); T_1 + pressmud @ 10 t ha^{-1} (T_3) and T_1 + gypsum @ 3.75 t ha^{-1} + pressmud @ 5 t ha^{-1} (T_4) were taken in main

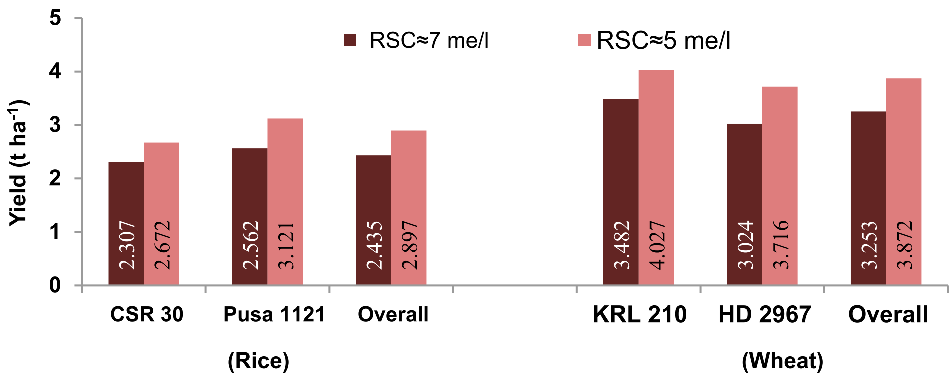


Fig. 33. Yield (t ha^{-1}) performance of rice and wheat varieties irrigated with different RSC waters (mean of 3 years)

plots while two varieties one each as salt tolerant (CSR 30 Basmati in rice and KRL 210 in wheat) and most adopted ones (Pusa 1121 in rice and HD 2967 in wheat) in respective growing seasons were superimposed to the neutralization treatments at both locations. All other cultural practices including fertilization and plant protection measures were adopted as per the state recommendation 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}.

The 3 year mean yield data indicated that with the increase in residual alkalinity in irrigation waters, yield reduction of 16% was observed in both rice and wheat crops with the increase in RSC_{iw} from 5 (site I) to 7 me L^{-1} (site II). Among rice varieties, salt tolerant CSR 30 basmati performed relatively better compared to Pusa 1211 with yield reduction of 13.7% as against the 17.9% in case of Pusa 1121. Cultivation of salt tolerant wheat variety KRL 210 revealed lesser yield reduction (13.5%) and better physiological efficiency for adaptations to stress environment (Table 21) compared to HD 2967 (Fig. 34).

Table 21: Physiological adaptation of wheat varieties to stress conditions

Varieties	Photosynthetic rate (µmol CO_2/m^2/sec)	Stomatal Conductance (mmol water/m^2/sec)	Transpiration Rate (mmol water/m^2/sec)	Chlorophyll Fluorescence	Proline content (mg/g FW)	Chlorophyll content (mg/g FW)
KRL 210	17.87	1.41	2.63	0.61	3.06	1.22
HD 2967	17.00	1.17	2.39	0.58	3.46	1.31

Irrespective of the neutralization amendment, the yield superiority of Pusa 1121 recorded at 15.5% at site II (RSC~5 me L^{-1}) reduced to 8.6% at site I (RSC~7 me L^{-1}) in comparison to CSR 30 Basmati (Table 22). In contrast, the yield superiority of KRL 210 further enhanced from 10.8% (Site II) to 14.7% (Site I) with the increase in increase in residual alkalinity in irrigation waters. Varietal intervention through inclusion of salt tolerant varieties KRL 210 and CSR 30 basmati can be an important strategy to counter yield reduction under stress conditions (Fig. 35).

The data presented in Table 22 revealed that neutralization of RSC water through amendments (gypsum/pressmud) either individually or in combination resulted in 12.7-19.2% (mean 16.3%) higher system productivity (WEY). The overall yield increment due to neutralization treatments (irrespective of kind of amendment used) in comparison to irrigated waters used as such without any neutralization treatment was higher (16.0%) at site I (RSC~7 me L^{-1}) compared to 14.7% at site II (RSC~5 me L^{-1}), indicating relatively better performance of neutralization ameliorants under stress environments.

Table 22: Interactive effect of RSC_{iw} neutralization treatments and crop varieties on system productivity in RWCS (mean data of 2 locations and 3 years crop rotation)

Cropping sequence	System productivity (Wheat equivalent yield in kg ha^{-1})				
		RSC water	Gypsum	Press mud	Gypsum + Press mud
CSR 30 basmati	HD 2967	7775	8785	9095	9237
	KRL 210	8093 (+4.0%)	9178	9593	9731
Pusa 1121	HD 2967	7456	8360	8604	8817
	KRL 210	7840 (+5.1%)	8815	9137	9339
Mean	7791	8784(+12.7%)	9107(+16.8%)	9288 (+19.2%)	

System productivity (3 yrs mean) calculated on the actual price received by the farmer

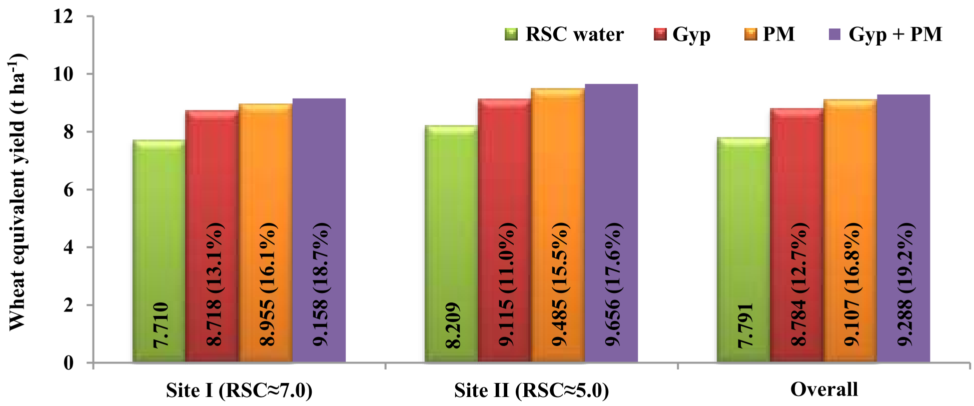


Fig. 34. Effect of RSC_{iw} neutralization treatments on the system productivity (wheat equivalent yield) in RWCS

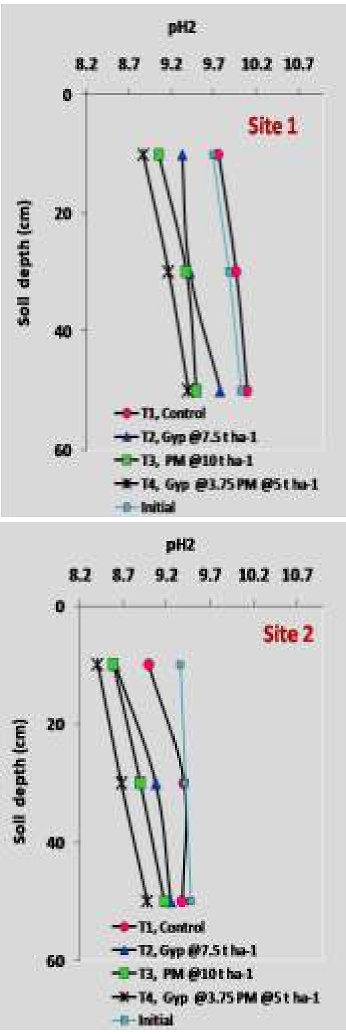


Fig. 35. Change in soil pH due to neutralization treatments

Decrease in soil pH was recorded with the application of different neutralization treatments at both the sites. Reduction in soil pH was more pronounced in surface layer compared to sub-surface layers.

Farmers' participatory diagnostic survey using modern techniques and demonstrating technological interventions for sustainable use of poor quality waters to enhance agricultural productivity in Panipat, Haryana (Parvender Sheoran, B.L. Meena, R.K. Yadav, D.S. Bundela, R.K. Singh and A.K. Mandal)

A total of 1106 samples have been collected from on grid basis (1 km x 1 km) for quantification and characterization of water quality to prepare geo-referenced digital stratified thematic maps delineating poor quality groundwater problematic areas in Panipat district of Haryana state.

About 38.4% of the collected water samples were having RSC>2.5 me l^{-1}, needs neutralization ameliorants for sustainable use of such waters for irrigation purpose. About 11.1% samples were confirmed with SAR>10. Highest salinity problems were observed in Israna block followed by Matlauda and Samalkha blocks of Panipat district. Residual alkalinity in irrigation water (RSC >2.5 meq l^{-1}) was highest in Matlauda (47.3%) and Samalkha (43.8%) block. RSC problem was observed to be more pronounced at low salinity compared to high salinity of waters.

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

ICAR-CSSRI, Karnal and NRCSS, Ajmer has been working on a collaborative research project on "*evaluation of salinity tolerance of seed spices*". During 2018, three (one pot and two lysimeter) experiments were conducted to assess overall and stage dependent

Stage dependent saline irrigation in anise, ajwain and dil under variable salinity irrigation.

tolerance of seed spice crops to salinity and RSC levels in irrigation water. Anise (*Pimpinella anisum*), ajwain (*Trachyspermum ammi*) and dil (*Anethum sowa*) were being evaluated for overall tolerance to irrigation water salinity (3.0, 6.0 and 9.0 dS m^{-1}). Earlier, fennel, coriander, celery and fenugreek were also evaluated for salinity tolerance. These crops were also assessed for their stage dependent salinity tolerance by imposing treatments viz., continuous fresh water, saline irrigations using 6.5 dS m^{-1} saline water during 0-30, 31-60, 61-90, 91-120 DAS and continuous saline water. Anise and ajwain were also assessed for tolerance to RSC levels (0, 2.5, 5.0 and 5.0 meq/l + gypsum to neutralize to 2.5) in irrigation water. Irrigations were scheduled at 1.2 ID/CPE ratio in all the three experiments. Growth, development, yield parameters and yield of all the crops were recorded periodically and compared with normal (~0.6 dS m^{-1} EC and nil RSC) water applied as per treatment in respective experiments.

Direct seeding of anise, ajwain and dil produced higher biomass and seed yields of 0.40, 0.37 and 0.89 t ha^{-1} as compared to 0.36, 033 and 0.78 t ha^{-1}, respectively with transplanting method. Ajwain, anise and dil germination reduced by 25-29 and 12-14% with irrigations using saline water of 9 and 6 and 3.0 dS m^{-1}, respectively over control. Irrigation water salinity > 6.5 dS m^{-1} had significant negative effect on seed yield of all the three crops. While the early stage (0 – 30 DAS) osmotic stress delayed germination of dil, anise and ajwain by 2, 3 and 4 days, respectively. Continuous saline irrigation decreased seed yield of anise, ajwain and dil by 32, 24 and 15, respectively over continuous fresh water irrigation. Osmotic stress during initial 0-30 DAS and reproductive (> 90 DAS) period of these seed spice crops were more sensitive to salinity. Overall, irrigation water salinity thresh hold limits for fennel, coriander, fenugreek, celery, anise, ajwain and dil were 6.4, 6.1, 4.7, 6.2, 6.1, 5.9 and 7.2 dS m^{-1}, respectively.

Fennel and coriander were observed to be sensitive to RSC in irrigation water. Germination and seed yield reduced by 29-41, 26-34 and 30–35% under RSC of 2.5 and 5.0 me L^{-1}, 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. Seed yield of fennel and coriander reduced by 20 and 39%, respectively under RSC of 5 me L^{-1}.

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

A research project on "*assessment of press mud in gypsum beds for neutralization of RSC in irrigation water*" was continued with the objective to overcome the difficulty in passage of water through gypsum beds. Optimizing ratio of gypsum and press mud for maximization of RSC neutralization in irrigation water was the major objective for the period under report. Column studies comprised of triplicate set of variable mixing ratios of gypsum and press mud (gypsum alone; 5:1; 4:1; 3:1; 2:1 and press mud alone) used for passage of different RSC (2.0, 4.0 and 6.0 me L^{-1}) concentration water . Analysis was done (2 hourly intervals) of bed material and outlet (leachate) water for RSC neutralization was.

High RSC (6, 4 and 2 me L^{-1} and nil) water was passed @8, 10 and 12 l sec^{-1} discharge rate through a set of columns and leachate was collected after 2 hr. and analyzed for neutralization of RSC. Mixing press mud, in gypsum beds, in increasing proportion increased the passage of water through beds by 1.40 to 2.50 times over gypsum alone with ~5.6 to 7.2% less neutralization of RSC. The temporal changes in RSC neutralization has been depicted follwing fig. 36.

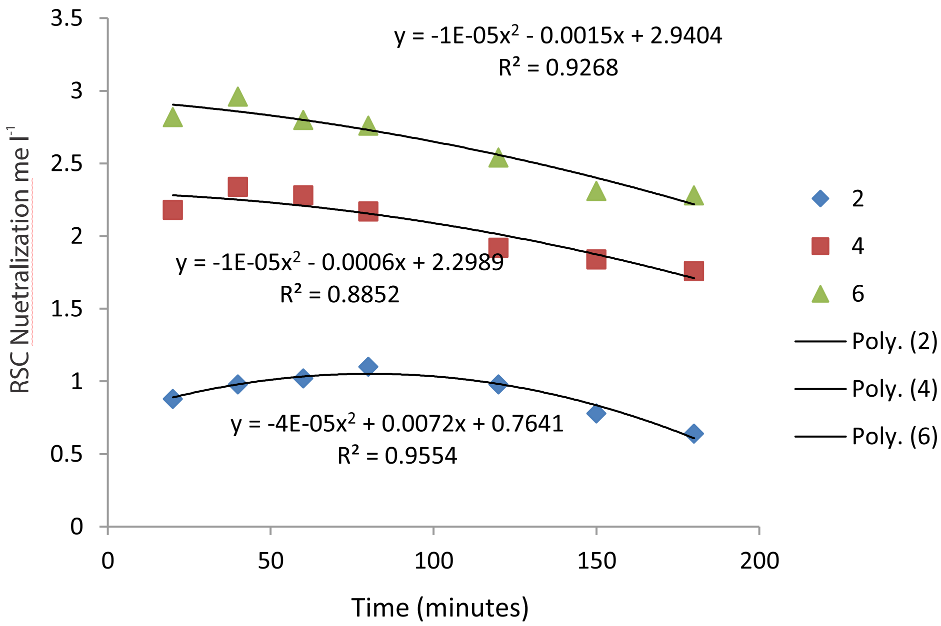


Fig. 36. Temporal change in RSC neutralization under gypsum mix press mud

Crop Improvement for Salinity, Alkalinity and Waterlogging Stresses

Development of salt tolerant genotypes in rice – Conventional and molecular breeding approaches (S. L. Krishnamurthy, P. C. Sharma, 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* 2017.

A. National trials:

a) IVT-Alkaline and Inland Saline Tolerant Variety Trial-2017

The IVT-Alkaline and Inland Saline Tolerant Variety Trial (IVT-AL&ISTVT) comprised of 44 entries including check variety (CSR 36, CSR 23 and yield check Jaya) which were evaluated across four salt stress locations (Table 23) in Random Block Design with three replications.

Table 23: Soil status at different locations under IVT-AL&ISTVT Trial-2017

S.N	Locations	Local check Name	Net Plot size	Date of Sowing	Date of Planting	pH	ECe (dS m^{-1})
E1	Salinity microplot Karnal	CSR 23	0.39 m^2	23.06.2017	20.07.2017	7.5	8.0
E2	Sodic microplot Karnal	CSR 36	0.39 m^2	23.06.2017	20.07.2017	9.6	0.4
E3	GB Nagar UP	CSR 23	5.0 m^2	23.06.2017	20.07.2017	9.6	0.4
E4	Lucknow, UP	CSR 36	8.0 m^2	16.06.2017	14.07.2017	9.8	0.1

Under salinity stress at Karnal, ten entries outperformed the national salinity check CSR 23. The entry 5023 showed the highest grain yield (3322 kg ha^{-1}) followed by 5034 (3256 kg ha^{-1}), and local check (2644 kg ha^{-1}). Under sodic stress at Karnal, eighteen entries performed better than the local check CSR 36. The entry 5019 showed the highest grain yield (3990 kg ha^{-1}) followed by 5003 (3982 kg ha^{-1}), and local check (3267 kg ha^{-1}). At Gautam Buddh Nagar (U.P.), eleven entries performed better than the local check CSR 36. The entry 5044 showed the highest grain yield (3969 kg ha^{-1}) followed by 5034 (3736 kg ha^{-1}), and local check (3183 kg ha^{-1}).

b) AVT-Alkaline and Inland Saline Tolerant Variety Trial-2017

The AVT-Alkaline and Inland Saline Tolerant Variety Trial (AVT-AL&ISTVT) comprising of fifteen entries including check variety (CSR 36, CSR 23 and yield check Jaya) were tested across four salt stress locations (Table 24) in Random Block Design with three replications.Under salinity stress at Karnal, six entries outperformed the local check CSR 23. The entry 4901 showed the highest grain yield (3585 kg ha^{-1}) followed by 4915 (3207 kg ha^{-1}), and local check (2589 kg ha^{-1}). Under sodic stress at Karnal, five entries performed

Table 24: Soil status at different locations under AVT-AL&ISTVT Trial-2017

S.N	Locations	Local check Name	Net Plot size	Date of Sowing	Date of Planting	pH	ECe (dS m^{-1})
E1	Salinity microplot Karnal	CSR 23	0.39 m^2	23.06.2017	20.07.2017	7.5	8.0
E2	Sodic microplot Karnal	CSR 36	0.39 m^2	23.06.2017	20.07.2017	9.6	0.4
E3	GB Nagar, UP	CSR 23	5.0 m^2	23.06.2017	20.07.2017	9.6	0.4
E4	Lucknow, UP	CSR 36	8.0 m^2	16.06.2017	14.07.2017	9.6	0.1

better than the local check CSR 36. The entry 4915 showed the highest grain yield (4103 kg ha^{-1}) followed by 4910 (4033 kg ha^{-1}), and local check (3300 kg ha^{-1}). At Gautam Buddh Nagar (U.P.), five entries performed better than the local check CSR 36. The entry 4901 showed the highest grain yield (3945 kg ha^{-1}) followed by 4910 (3941 kg ha^{-1}), and local check (3438 kg ha^{-1}).

Analysis of genotype by environment (GxE) interaction for IVT-Alkaline and Inland Saline Tolerant Variety Trial-2017

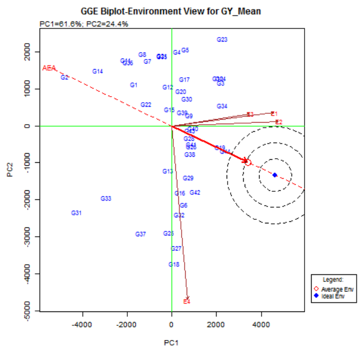
The GGE analysis was carried out using 44 IVT rice genotypes for yield across the 4 salt stress locations (Fig. 37a,b,c):

- E4 (Lucknow) is highly discriminating but least representative location.
- E2 (Karnal Sodic MP) is ideal location with high representativeness and appreciable discriminating ability.
- G44 is the ideal genotype with highest mean yield and stability followed by G19.
- Three mega environments were identified namely, E1 and E3 with winning genotypes of G23, E2 with winning genotypes of G44 and E4 with winning genotypes of G18.

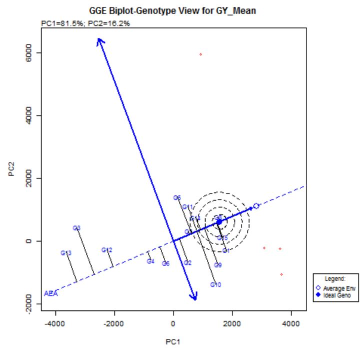
Analysis of genotype by environment interaction for AVT-Alkaline and Inland Saline Tolerant Variety Trial-2017

The GGE analysis was carried out using 15 AVT rice genotypes for yield across the 4 salt stress locations (Fig 37. a,b,c)

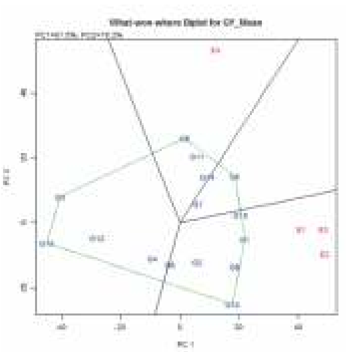
- E7 (Lucknow) is highly discriminating, but least representative location
- E1 (Karnal Saline MP) is ideal location with high representativeness and appreciable discriminating ability
- G8 (2115) is the ideal genotype with highest mean yield and stability followed by G15
- Two mega environments were identified namely E1, E2 and E3 with winning genotypes of G1 and G10 and E4 with winning genotypes of G5



(a)



(b)



(c)

Fig. 37. (a) Environment, (b) genotype, (c) and "which-won-where" of GGE biplots constructed using AVT genotypes tested across salt stress locations during 2017

B. Station Trials

Monitoring, maintenance and development of breeding materials

Many salt tolerant lines were used in hybridization with high yield varieties to enhance the genetic variation and to transfer the salt tolerance in high yielding varieties. Several segregating populations were screened under high salinity (EC_{iw} ~ 12 dS m^{-1}) in micro plot, sodic microlplot and stress field. The top performing progenies were selected from each segregating population for further screening/evaluation in the next cropping season.

Advancement and screening breeding materials for salt tolerance during 2017

Different combination of crosses made during *Kharif* 2017 to combine the yield and salt tolerance in rice were multiplied during *Kharif 2017* and same were advanced for next generation. Simultaneously, these breeding materials were also screened across salt affected situations. The top 50 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.

Table 25: Summary performance of promising entry IET 24537 during 2014 - 2016 in AL & ISTVT.

State / Year	Proposed variety (CSR 36) IET 24537	Qualifying Variety-1 (IET 24547)	Qualifying Variety-2 (IET 23782)	Qualifying Variety-3 (IET 23784)	National check	Local check	Yield check (Jaya)
2014	3451	3199	3209	3268	3139	2519	2228
2015	3460	2637	3165	3034	2533	2988	2304
2016	3135	3150	–	–	2783	2910	1877
Mean	3349	2995	3187	3151	2818	2806	2136
% Increase over checks		11.80	5.07	6.27	18.82	19.35	56.75

Field view of Back cross Inbred Lines (BILs) of Basmati CSR30x FL478

Development of back cross inbred lines in the back ground of Basmati CSR 30

The main aim was to develop or improve the Basmati CSR 30. Hence, we developed the BC_1F_5 by crossing the Basmati CSR30 with FL 478. We have identified some lines with basmati back ground and salt tolerance in different duration.

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 Uttar Pradesh. It showed yield superiority of 18.82%, 19.35% and 56.75%, higher yield than CSR 36, Local Check and Jaya, respectively (Table 25) across alkaline locations of Uttar Pradesh.

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 (1.0 Q), CSR 13 (1.0 Q), CSR 23 (1.0 Q), CSR 27 (1.0 Q), CSR 30 (17.0 Q) CSR36 (10.0 Q), CSR 43 (10.0 Q) and CSR 46 (10.0 Q) was produced to meet the demand of seed producing agencies as per DAC (Department of Agriculture and Cooperation) during 2017.

Rice entries nominated to AICRP 2017

AL&ISTVT- CSR2748-4441-193, CSR2748-4441-195, CSR16-18-12, CSRRIL-01 –IR165 and CSRRIL-01 –IR75

CSTVT- CSR TPB-156, CSR2748-49, CSR TPB-127 and CSR16-18-12

Basmati trials - CSR TPB-99 and CSR TPB-31

National project on Transgenic in crops-salinity tolerance in rice: Functional genomics component (ICAR funded) (S.L. Krishnamurthy and P.C. Sharma)

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 NRCPB, 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 augmented 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}) micro plots} during *Kharif* 2017. The range, mean and per cent reduction in different traits for RIL population were

Table 26: 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 stress.

S. No.	Normal		Moderate Saline (EC_{iw} ~ 6.0 dS m^{-1})		High Saline (EC_{iw} ~ 12.0 dS m^{-1})	
1	RIL 210	92.39	RIL 135	81.82	RIL 53	77.50
2	RIL 183	91.30	RIL 92	75.78	RIL 54	77.31
3	RIL 137	90.94	RIL 204	74.70	RIL 197	61.90
4	RIL 150	89.92	RIL 192	73.38	RIL 134	58.89
5	RIL 205	89.51	RIL 205	72.97	RIL 92	58.82
6	RIL 138	89.49	RIL 113	71.29	RIL 83	58.72
7	RIL 139	87.91	RIL 186	68.82	RIL 85	58.59
8	RIL 105	87.85	RIL 128	68.65	RIL 141	58.21
9	RIL 30	87.46	RIL 207	68.38	RIL 91	57.92
10	RIL 178	87.34	RIL 199	67.01	RIL 147	57.34

Table 27: Top 10 genotypes with high grain yield per plant under normal, moderate and high salinity stress.

S. No.	Normal		Moderate Saline (EC_{iw} ~ 6.0 dS m^{-1})		High Saline (EC_{iw} ~ 12.0 dS m^{-1})	
1	RIL 31	29.60	RIL 189	6.0	RIL 76	4.60
2	RIL 15	29.40	RIL 41	6.0	RIL 91	4.60
3	RIL 120	29.20	RIL 44	5.8	RIL 121	4.20
4	RIL 16	28.40	RIL 91	5.6	RIL 105	3.80
5	RIL 157	27.60	RIL 115	5.4	RIL 138	3.80
6	RIL 90	26.00	RIL 106	5.2	RIL 81	3.43
7	RIL 46	25.80	RIL 201	5.2	RIL 80	3.30
8	RIL 60	24.00	RIL 122	5.0	RIL 212	3.11
9	RIL 61	22.80	RIL 136	5.0	RIL 31	3.00
10	RIL 121	22.60	RIL 187	4.8	RIL 143	2.92

Table 28: Top 10 RILs showing less % reduction for grain yield under moderate (ECiw ~ 6 dS m^{-1}) and high (ECiw ~ 12 dS m^{-1}) salinity stress.

S. No.	Moderate Saline (EC_{iw} ~ 6.0 dS m^{-1})		High Saline (EC_{iw} ~ 12.0 dS m^{-1})	
	Genotypes	%reduction	Genotypes	%reduction
1	RIL 189	6.25	RIL 132	28.57
2	RIL 115	12.90	RIL 112	38.89
3	RIL 39	20	RIL 143	39.2275
4	RIL 33	21.43	RIL 81	44.67
5	RIL 22	22.22	RIL 118	49.81
6	RIL 26	25	RIL 98	50
7	RIL 187	27.27	RIL 80	51.5
8	RIL 112	27.78	RIL 97	53.8
9	RIL 201	29.73	RIL 96	54.5
10	RIL 109	34.62	RIL 115	54.8

recorded during 2017. The grain yield (g plant^{-1}) ranged from 2.2 (RIL 81) to 29.60 (RIL 31), 0.20 (RIL 1) to 6 (RIL 41) and 0.017 (RIL 164) to 4.6 (RIL 76) under normal, moderate salinity and high salinity, respectively. The spikelet fertility was ranged from 38.60 (RIL 71) to 92.39 (RIL210), 0.51 (RIL 164) to 81.82 (RIL 135) and 0.37 (RIL 178) to 77.5 (RIL 53) under normal, moderate salinity and high salinity, respectively. The RIL 178 had registered the lowest spikelet fertility of 0.37% in high salinity stress. Top 10 RILs with high spikelet fertility (%) under normal, moderate salinity and high salinity stress are presented in Table 26. The top 10 lines based on grain yield under normal, moderate salinity and high salinity stress are presented in Table 27. The top 10 lines showing less per cent reduction for grain yield under moderate and high salinity stress are presented in Table 28.

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 and P.C. Sharma)

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

The salient findings of the systematic phenotyping of 215 recombinant inbred lines (RILs) derived from Trichy x Pusa Basmati 1 cross are presented. A total of 225 genotypes including 215 RILs along with parents were evaluated in replicated Simple Lattice Design in 3 environments {normal, moderate sodic (pH_2 ~ 9.5) and high sodic (pH_2 ~ 9.9 soil conditions} during *Kharif* 2017. The range, mean and per cent reduction of different traits for RIL population were recorded during 2017 (Table 29). High mean grain yield and other related traits performance was noticed under normal soil as compared to moderate sodic and high sodic stresses. The grain yield was the most sensitive traits and reduced by 53.23% followed by productive tiller, total tillers per plant, spikelet fertility, plant height and panicle length under moderate sodicity stress. The grain yield was reduced by 93.28% under high sodicity stress followed by productive tillers per plant, spikelet fertility, plant height, total tillers per plant, and panicle length. The grain yield

Table 29: 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	
	Normal	Mod. Sodic	High Sodic	Normal	Mod. Sodic	High Sodic	Mod. Sodic	High Sodic
Plant Height (cm)	135.25	104.68	66.06	89 (RIL59)-161.30 (RIL 92)	87.30 (RIL59)-123.80 (RIL137)	21.20 (RIL 22)-84.4 (RIL 118)	22.59	51.15
Panicle length (cm)	29.32	25.96	18.42	24.22(TRICHY) -35.10(RIL 125)	21.80 (TRICHY)-30.10 (RIL143)	7.9(RIL 21)-23.43 (RIL 118)	11.46	37.18
Total tillers plant^{-1}	9.46	6.32	5.39	5.80 (RIL 42)-24.70 (RIL 215)	4.00 (RIL 1)-10.10 (RIL 215)	2.20(RIL 6)-11.00 (RIL 87)	33.19	43.09
Productive tillers plant^{-1}	8.40	5.32	3.3	4.80 (RIL42)-18.60 (RIL 31)	3.00 (RIL155)-9.10 (RIL 215)	0.50(RIL 88)-6.80 (RIL 96)	36.85	60.73
Spikelet fertility (%)	73.41	53.4	32.6	38.79 (RIL 164)-93.21(RIL 91)	6.11(RIL 169)-85.66 (RIL 142)	0.67(RIL109)-78.15 (RIL 141)	27.25	55.58
Grain yield plant^{-1} (g)	11.95	5.59	0.8	1.84 (RIL 197)-23.99 (RIL 79)	0.50 (RIL 135)-13.65 (RIL 86)	0.06 (RIL 22)-4.42 (RIL 95)	53.23	93.28

ranged from 1.84 (RIL197) to 23.99 (RIL79), 0.50 (RIL135) to 13.65 (RIL86) and 0.06 (RIL 22) to 4.42 (RIL 95) under normal, moderate sodic and high sodicity, respectively. The spikelet fertility ranged from 38.79 (RIL 164) to 93.21(RIL 91), 6.11(RIL 169) to 85.66 (RIL142) and 0.67 (RIL 109) to 78.15 (RIL141) under normal, moderate and high sodicity, respectively. The top 10 lines based on grain yield under normal, moderate and high sodicity stress are presented in Table 30. The top 10 lines showing less per cent reduction for grain yield under moderate and high sodicity stress are presented in Table 31.

Table 30: Top 10 RILs with high grain yield per plant under normal, moderate and high sodicity stress

S.N0	Normal		Moderate Sodic		High Sodic	
1	RIL 79	23.99	RIL 86	13.65	RIL 95	4.42
2	RIL 15	23.81	RIL 129	13.62	RIL 110	2.83
3	RIL 129	22.81	RIL 145	11.86	RIL 99	2.76
4	RIL 61	22.66	RIL 58	11.74	TRICHY	2.69
5	RIL 158	22.58	RIL 29	11.31	RIL 205	2.60
6	RIL 86	22.39	RIL 130	11.24	RIL 42	2.60
7	RIL 16	22.20	RIL 148	10.9	RIL 145	2.50
8	RIL 188	21.90	RIL 101	10.88	RIL 6	1.92
9	RIL 87	21.87	RIL 87	10.28	RIL 16	1.91
10	RIL 127	21.81	RIL 76	10.12	RIL 202	1.90

Table 31: Top 10 RILs showing less % reduction for grain yield under moderate (pH_2~ 9.5) and high (pH_2~ 9.5) sodicity stress.

S. No.	Moderate Sodicity (pH_2 9.5)		High Sodicity (pH_2 9.9)	
	Genotypes	% reduction	Genotypes	%reduction
1	RIL 8	21.77	RIL 205	63.59
2	RIL 211	26.74	RIL 6	64.80
3	RIL 191	27.87	RIL 195	67.72
4	RIL 77	30.35	RIL 178	69.39
5	RIL 147	31.00	RIL 42	71.55
6	RIL 39	31.56	RIL 95	76.16
7	RIL 210	31.59	RIL 80	77.90
8	RIL 4	31.82	RIL 99	81.54
9	RIL 142	32.11	RIL 110	81.67
10	RIL 113	32.30	RIL 166	83.07

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)

Phenotyping of Chickpea genotypes: Yield and yield contributing traits

A total of 232 Recombinant Inbred Lines (ICCV-10 x DCP92-3) along with their parents were evaluated for seed yield and other yield contributing traits in control, 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. Analysis was performed for each environment and for the combined data set from all the locations. The plant height of the parental lines ranged from 53.33 to 64.67, 29.00 to 35.67 and 48.56 to 60.33 cm, respectively under control, saline and alkali condition. There was reduction in plant height in the parents under salinity and alkali condition compared to control condition. However this reduction was higher under saline condition. The plant height of RILs ranged from 22.33

to 88.33 cm under control, 40.33 to 76.00 cm alkali and 20.67 to 49.67 cm under salinity respectively (Table 31).

The number of branches of the parental lines ranged from 7.0 to7.33, 2.0 to 4.33 and 5.67 to 6.33, respectively, under control, saline and alkali condition. There was reduction in number of branches in the parents under salinity and alkali condition compared to control condition, whereas this reduction was higher under saline condition. The number of branches of RILs ranged from 3.67 to 31.67 cm under control, 8.33 to 16.00 alkali and 1.67 to 6.67 under salinity, respectively (Table 32). The number of pods of parental lines ranged from 228.67 to 484.00, 18.33 to 27.33 and 169.00 to 225.33, respectively under control, saline and alkali condition. There was reduction in number of pods in the parents under salinity and alkali condition compared to control condition, whereas, this reduction was greater under saline condition. The number of pods of RILs ranged from 70.00 to 824.33, 4.00 to 56.67 and 92.67 to 278.33, respectively under control, saline and alkali condition (Table 33).

The 100 seed weight of parental lines ranged from 11.35 to 13.73, 6.80 to 8.84 and 11.27 to 13.10g, respectively under control, saline and alkali condition. There was reduction in 100 seed weight in the parents under salinity and alkali condition compared to control condition, whereas, this reduction was very high under saline condition. The 100 seed weight of RILs ranged from 10.15 to 26.60, 2.80 to 12.20 and 11.91 to 20.10g, respectively under control, saline and alkali condition. The Yield/plant of parental lines ranged from 51.00 to 78.33, 1.09 to 1.46 and 2.00 to 2.98g, respectively under control, saline and alkali condition. There was reduction in Yield/plant in the parents under salinity and alkali

Table 32: Phenotyping of 232 RILs along with their and 50 advanced breeding lines under control, salinity (EC_{iw} 6.0 dS m^{-1}) and alkali (pH 9.0) conditions

RILs	Plant Height (cm)			No. of Branches			No. of pods			100 Seed Weight (g)			Yield Plant^{-1} (g)		
	Control	Saline	Alkali	Control	Saline	Alkali	Control	Saline	Alkali	Control	Saline	Alkali	Control	Saline	Alkali
RILs (DCP 92 -3 × ICCV-10)	47.04	31.65	60.27	9.70	3.07	11.77	253.92	21.59	178.38	21.69	6.37	15.75	57.97	1.29	5.67
P1	64.67	29.67	60.33	7.33	4.33	6.33	484.00	20.67	178.33	13.73	8.84	13.10	78.33	1.46	2.98
P2	53.33	35.67	48.56	7.00	2.00	5.67	228.67	27.33	225.33	12.95	7.15	11.27	57.33	1.19	2.00
P3	58.67	29.00	50.62	7.33	2.33	6.33	280.00	18.33	169.00	11.35	6.80	12.22	51.00	1.09	2.10
RILs Mean	55.93	31.50	54.95	7.84	2.93	7.53	311.65	21.98	187.76	14.93	7.29	13.08	61.16	1.26	3.19
Range (RILs)	22.33 (R178)	20.67 (R34)	40.33 (R81)	3.67 (R62)	1.67 (R59,69, 78,136, 140174, 210,224)	8.33 117, 214, 227)	4.00 (R137)	92.67 R69)	10.15 (R11)	2.80 (R191)	11.91 (R174)	13.00 (R166)	0.18 (R136)	1.90 (R23)	(R209)
	88.33 (R78)	49.67 (R199)	76.00 (R66)	31.67 (R129)	6.67 (R27)	16 (R167)	824.33 (R115)	56.67 (R26)	278.33 (R167)	26.60 (R22)	12.20 (R73)	20.10 (R104)	133.33 R104)	7.80 (R43)	21.60 (R14)

Table 33: Phenotyping of 50 advanced breeding lines under control and salinity (EC_{iw} 6.0 dS m^{-1})

Genotype	Plant Height (cm)		No. of Branches		No. of Pods		100 Seed Weight (g)		Yield Plant^{-1} (g)	
	Control	Saline	Control	Saline	Control	Saline	Control	Saline	Control	Saline
Mean values of Advanced Breeding Lines	59.93	45.94	6.66	3.49	221.47	17.24	22.19	6.84	65.79	1.64
Range	43.33 (AS39)	34.00 (AS50)	3.33 (AS47)	2.00 (AS24)	48.00 (AS45)	4.50 (AS27)	10.00 (AS25)	2.80 (AS38)	11.00 (AS47)	0.48 (AS31)
	85.00 (AS48)	61.50 (AS32)	10.00 (AS13)	6.00 (AS13)	495.33 (AS13)	42.33 (AS13)	51.00 (AS44)	20.12 (AS7)	125 (AS16)	8.50 (AS1)

Phenotyping of Chickpea advanced breeding lines at EC 6 dS m^{-1} salt stress in pots.

condition compared to control condition, whereas, this reduction was very high under saline condition. The Yield/plant of RILs ranged from 13.00 to 133.33, 0.18 to 7.80 and 1.90 to 21.60g, respectively under control, saline and alkali condition (Table 32).

Similarly, 50 advanced breeding (AB) lines were also evaluated for seed yield and other yield contributing traits in control and saline (EC_{iw} 6 dS m^{-1}) conditions at Karnal. Analysis was performed for each environment and for the combined data set from both conditions. All the parameters were greatly reduced under saline condition followed by alkali as compared to control (Table 33).

Phenotyping of Chickpea genotypes: Physiological traits

At vegetative stage (45 DAS), the effect of alkalinity of pH 9.0 was not significant. The mean value for Na content in chickpea RILs in roots at vegetative stage was 3.5% with maximum of 6.9% and minimum of 0.9 % while in shoots percent Na content is less than roots, with mean value of 0.954 ranging from a minimum of 0.164 to maximum of 2.17. Na/K ratio in roots was 0.547 while in shoot it was 0.086 in RILs and 0.72 in roots and 0.099 in shoots in advanced breeding lines. This may be due to the fact that roots restrict the entry of Na into shoot and thus upward flow of toxic Na ions. K is more in shoots with a mean value of 6.43 in roots and 11.05 in shoots at vegetative stage. At saline stress of EC 6 ds m^{-1}, in RILs K was more in roots and shoots than Na, although the Na/K ratio was same (0.54) at higher 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.

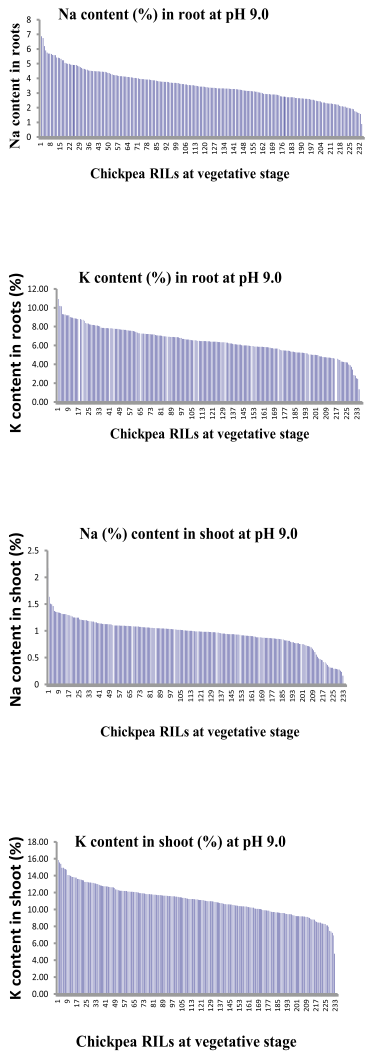


Fig. 38. Na and K content in roots and shoots of chickpea RILs at pH 9.0.

At pH 9.0 about 45 RILs have more Na content than the parent DCP-92-3 while 59 RILs have Na content less than the parent ICCV-10 (Fig. 38). In one of parent DCP-92-3, Na/K ratio is 1 while in.00000 another parent ICCV-10, Na/K ratio is 0.306. Na content was more in roots than shoot while K was more in shoot than roots. In advanced breeding lines, Na/K was almost equal to 1 although K was more in shoot than roots and Na was more in root than shoot. The performance of advanced breeding lines was better than the RILs at saline stress at vegetative stage. In twenty three lines, Na/K ratio was more than one while in rest the ratio was less than one. K content was more than Na in roots and shoot.

Na and K contents at harvesting stage: In chickpea RILs at harvesting stage, mean Na content was 2.71% with 2.68% K content in roots while mean Na content in shoots was 2.95 % with 3.82% K. In advanced breeding lines, mean Na was more than in RILs, *i.e.*, 2.95% with 3.82% K in roots while a lower Na content of 0.83% in shoot with 6.73% K. On the other hand, at a saline stress of 6 dS m^{-1}, Na content was more in roots than K while K was more in shoots in both RILs as well as advanced breeding lines. The range of Na content was 2.44-23.89 % in RILs roots while in advanced breeding lines it was 8.08-23.61%. Thirteen RILs had more Na than parent DCP-92-3 (3.72%) in roots while 95 lines had less Na than parent ICCV-10; rest had Na content in between the range of both parents. K was more in shoots than roots. Sixty eight lines had more K than parent DCP-92-3 while 140 lines had less K than parent ICCV-10. Na/K ratio was less than one in roots while more K was observed in shoots at pH 9.0 in advanced breeding lines. High accumulation of Na was observed in roots in chickpea RILs at saline stress whereas the Na/K ratio was almost equal to one in shoot (Fig. 39). High accumulation of Na was observed in roots whereas in shoot, accumulation of K was observed in advanced breeding lines at saline stress of EC 6 dSm^{-1}. More Na was observed in roots than shoot and leaves in chickpea advanced breeding lines.

Glycine betaine of chickpea RILs alongwith parents and 50 advanced breeding lines was done. At vegetative stage (45 DAS), in field conditions at pH 9.0, glycine betaine content range was 1.51-12.36 mg g^{-1} DW in RILs. At maturity stage, glycine betaine content was 5.28 mg g^{-1} DW in parent DCP-92-3 while 4.56 mg g^{-1} in ICCV-10, but in RILs the range was 0.70 to 10.92. At EC 6 dS m^{-1}, glycine betaine at vegetative stage was in range of 0.70-12.12 mg g^{-1} DW while that of parents was 4.19 and 3.19 in DCP-92-3 and ICCV-10, respectively. At EC 6 dS m^{-1}, glycine betaine at maturity stage was in range of 0.70-11.51 mg g^{-1} while that of parents was 9.11 and 6.80 in DCP-92-3 and ICCV-10, respectively. No significant differences were observed in glycine betaine at either of stress conditions, pH 9.0 or EC 6 dS m^{-1}. In chickpea advanced breeding lines, glycine betaine was in range of 4.25 to 10.33 mg g^{-1} at vegetative stage while at maturity stage the range was 1.92-10.63 mg g^{-1} at EC 6 dS m^{-1}.

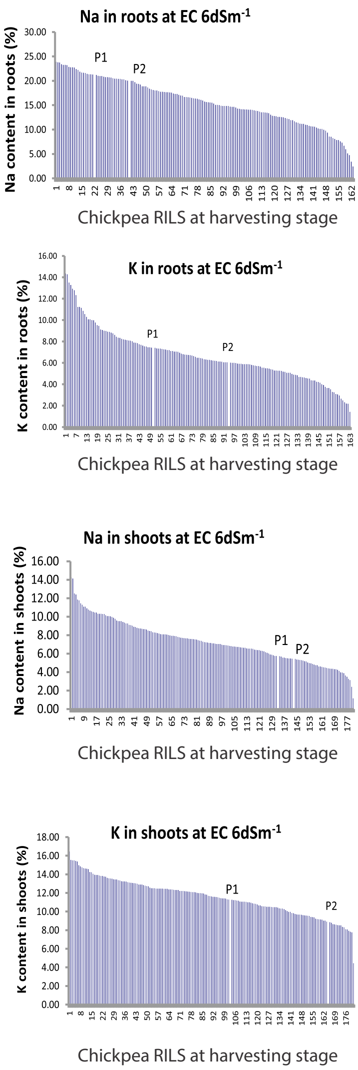


Fig. 39. Na and K content in roots and shoots of chickpea RILs at harvesting stage at EC 6 dS m^{-1}.

Total chlorophyll was measured from the top third leaf using 80 % Acetone method. Total proline was measured using ninhydrin. Total chlorophyll content was more in advanced breeding lines than RILs. Under saline stress, total chlorophyll content decreased in both RILs as well as ABL. Twenty RILs outperformed all the three parents while 35 RILs have total chlorophyll less than all the parents. Different plant growth parameters measured at flowering stage like root-shoot length and fresh weight. A significant decrease in all the parameters was recorded with saline stress.

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)

Phenotyping of RILs under control (Normal) conditions

Plant growth: Plant height of the parental lines CS 56 and CS 614-1-1-100-13 was 176.67 cm and 160.0 cm, respectively, under normal conditions. Plant height of RILs ranged from 151.33 to 215.0 cm with mean of 184.91 cm. The highest plant height under normal condition was recorded with RIL153 (215.0 cm). The number of primary branches of both the parental lines CS 56 and CS 614-1-1-100-13 was 4.67 under normal conditions. Primary branches of RILs ranged from 4.0 to 8.0 with mean of 5.58. The highest primary branches under normal condition were recorded with RIL5 (8.00). The number of secondary branches of both the parental lines CS 56 and CS 614-1-1-100-13 was 10.67 under normal conditions. Secondary branches of RILs ranged from 3.67 to 19.0 with mean 11.11 and under normal condition. The highest secondary branches under normal condition were recorded with RIL5 (19.0). The main shoot length of parental lines CS 56 and CS 614-1-1-100-13 was 78.33 and 69.0 cm, respectively, under normal conditions. Main shoot length of RILs ranged from 48.67 to 101.33 cm with Mean 76.26 cm under normal condition. The highest main shoot length under normal condition was recorded with RIL184 (101.33 cm).

Yield and yield contributing traits: Number of siliqua on main shoot of parental lines CS 56 and CS 614-1-1-100-13 was 49.67 and 41.0, respectively, under normal conditions. Siliqua on main shoot of RILs ranged from 33.0 to 139.33 with mean of 47.87 under normal condition. The highest number of Siliqua on main shoot under normal condition was recorded with RIL119 (139.33) . The test weight of parental lines CS 56 and CS 614-1-1-100-13 was 4.86 and 4.23 g, respectively, under normal conditions. Test weight of RILs ranged from 3.04 to 6.53 g with mean of 4.83 g under normal condition. The highest test weight under normal condition was recorded with RIL170 (6.53 g). The yield $plant^{-1}$ of parental lines CS 56 and CS 614-1-1-100-13 was 25.67 and 19.33 g, respectively, under normal conditions. Yield $plant^{-1}$ of RILs ranged from 6.67 to 40.0 g with mean of 20.17 g under normal condition. The highest seed yield plant^{-1} under normal condition was recorded with RIL153 (40.0 g).

Na and K contents in roots and shoots: Root Na content of parental lines CS 56 and CS 614-1-1-100-13 was 9.52 and 11.64 mg g^{-1} dry weight, respectively, under normal conditions. Root Na content of the RILs ranged from 8.72 to 15.58 mg g^{-1} dry weight (mean 9.69 mg g^{-1}). RIL 40 (8.72 mg g^{-1}) showed lowest root Na content under normal condition. Root K content of parental lines CS 56 and CS 614-1-1-100-13 was 20.07 and 17.87 mg g^{-1}, respectively, under normal conditions. Root K content of the RILs ranged from 18.00 to 68.99 mg g^{-1} (mean 21.24 mg g^{-1}). RIL74 (68.99 mg g^{-1}) showed highest root K content under normal condition. Shoot Na content of parental lines CS 56 and CS 614-1-1-100-13 was 15.90 and 30.17 mg g^{-1}, respectively, under normal conditions. Shoot Na content of the RILs ranged from 8.70 to 29.25 mg g^{-1} (mean 10.46 mg g^{-1}). RIL 52 (29.25 mg g^{-1}) showed lowest Shoot Na content under normal condition. Shoot K content of parental lines CS 56 and CS 614-1-1-100-13 was 34.95 and 33.98 mg g^{-1}, respectively, under normal conditions. Shoot K content of the RILs ranged from 5.31 to 52.34 mg g^{-1} (mean 29.62 mg g^{-1}). RIL6 (52.34 mg g^{-1}) showed highest shoot K content under normal condition.

Phenotyping of RILs under salinity (EC_{iw} 12 dS m^{-1})

Plant growth: The plant height of the parental lines CS 56 and CS 614-1-1-100-13 was 120.00 cm and 90.00 cm, respectively, under saline conditions. Plant height of RILs ranged from 100.00 to 170.00 cm with Mean 122.32 cm. The highest plant height under salinity condition was recorded with RIL54 (170.00 cm). The number of primary branches of the parental lines CS 56 and CS 614-1-1-100-13 was 9.00 and 4.00, respectively, under salinity conditions. Primary branches of RILs ranged from 4.00 to 11.00 with Mean 6.56. The highest primary branches under stress condition were recorded with RIL154 (11.00). The number of secondary branches of the parental lines CS 56 and CS 614-1-1-100-13 was 12.00 and 6.00, respectively, under salinity conditions. Secondary branches of RILs ranged from 3.00 to 19.00 with Mean 9.71 and under normal condition. The highest sec. branches under saline condition were recorded with RIL2 (19.00). The main shoot length of parental lines CS 56 and CS 614-1-1-100-13 was 40.00 and 32.00 cm, respectively, under saline conditions. Main shoot length of RILs ranged from 27.00 to 48.00 cm with Mean 38.44 cm under normal condition. The highest main shoot length under stress condition was recorded with RIL218 (48.00 cm).

Yield and yield contributing traits: The test weight of parental lines CS 56 and CS 614-1-1-100-13 was 4.93 and 3.54 g, respectively, under salt stress conditions. Test wt. of RILs ranged from 2.11 to 7.57 g with Mean 5.17 g under saline condition. The highest test weight under salinity condition was recorded with RIL197 (7.57 g). The Yield/plant of parental lines CS 56 and CS 614-1-1-100-13 was 11.52 and 6.24 g, respectively, under salinity conditions. Yield plant^{-1} of RILs ranged from 2.21 to 12.16 g with Mean 6.89 g under saline condition. The highest seed yield/plant under stress condition was recorded with RIL79 (12.16.00 g).

Na and K contents in roots and shoots: Root Na content of the RILs ranged from 8.57 to 34.50 mg g^{-1} dry weight (mean 22.25 mg g^{-1}). Thirty two lines gave significantly lower root Na content over the sensitive parent CS614-4-1-4-100-13 (17.94 mg g^{-1}) with RIL 147 (8.57 mg g^{-1}) followed by RIL 190 (12.63 mg g^{-1}) recording lowest root Na content under stress. Root K content of the RILs ranged from 4.26 to 36.19 mg g^{-1} (mean 24.13 mg g^{-1}). 70 lines gave significantly higher root K content over the better parent CS 56 (26.10 mg g^{-1}) with

RIL 70 (36.19 mg g^{-1}) followed by RIL 54 (33.95 mg g^{-1}) recording highest root K content under stress. Shoot Na content of the RILs ranged from 14.59 to 69.77 mg g^{-1} (mean 26.92 mg g^{-1}). Four lines gave significantly lower shoot Na content over the better parent CS 56 (17.31 mg g^{-1}) with RIL 195 (14.59 mg g^{-1}) followed by RIL 213 (14.80 mg g^{-1}) recording lowest shoot Na content under stress. Shoot K content of the RILs ranged from 29.64 to 56.90 mg g^{-1} (mean 45.86 mg g^{-1}). 132 lines gave significantly higher shoot K content over the better parent CS 56 (45.51 mg g^{-1}) with RIL 198 (56.90 mg g^{-1}) followed by RIL1143 (56.72 mg g^{-1}) recording highest shoot K content under stress (Table 34).

Stress Tolerant Rice for Poor Farmers of Africa and South Asia (STRASA phase 3) (S. L. Krishnamurthy and P. C. Sharma)

Table 34: Phenotyping of RILs under saline (EC_{iw} 12 dS m^{-1}) conditions

RIL's	Plant Height (cm)	Prim Branch	Sec. Branch	Main Shoot Length (cm)	1000 seed wt (gm)	Yield/ plant (gm)	Na Root (mg g^{-1} DW)	K Root (mg g^{-1} DW)	Na shoot (mg g^{-1} DW)	K shoot (mg g^{-1} DW)
RILs CS614-4-1 -4-100-13 X CS56	122.32	6.56	9.71	38.46	5.17	6.89	22.25	24.13	26.92	45.86
CS56	120.00	9.00	12.00	40.00	4.93	11.52	18.93	26.1	17.31	45.51
CS614-4-1 -4-100-13	90.00	4.00	6.00	32.00	3.54	6.24	17.94	19.65	25.79	31.78
Range (RILs)	100.00 (R69,91, 107,116) to 170.00 (R54)	4.00 (R24,44, 47,76,139, 195,208, 224) to 11.00 (R154)	3.00 (R104, 109,130, 209) to 19.00 (R2)	27.00 (R58) to 48.00 (R218)	2.11 (R250) to 7.57 (R197)	2.21 (R65) to 12.16 (R79)	8.57 (R147) to 34.50 (R245)	4.26 (R147) to 36.19 (R70)	14.59 (R195) to 69.77 (R147)	29.64 (R249) to 56.90 (R198)

The experimental material comprised of 102 rice genotypes which were collected from various national and international institutes to assess their performance under saline and sodic stress conditions. The genotypes were evaluated in augmented block design with fifteen entries per block during *Kharif* 2017 under three environments *viz.*, high salinity stress (EC_{iw} ~ 10 dS m^{-1}) and high sodicity (pH_2 ~ 9.9) in micro plots and (pH_2 ~ 9.6) in sodic field at Central Soil Salinity Research Institute, Karnal, Haryana, India. Seven checks were repeated across three blocks. The 35-day old seedlings from wet bed

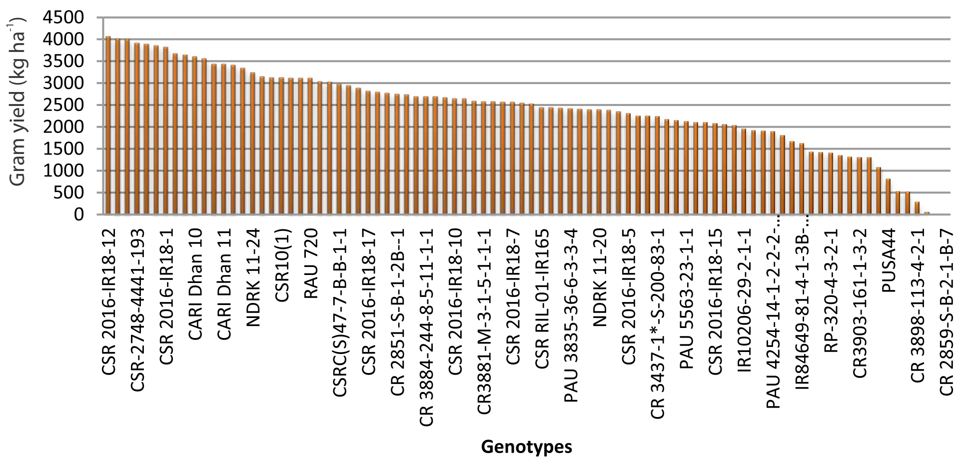


Fig. 40. Performance of STBN entries in sodic field (pH ~ 9.6)

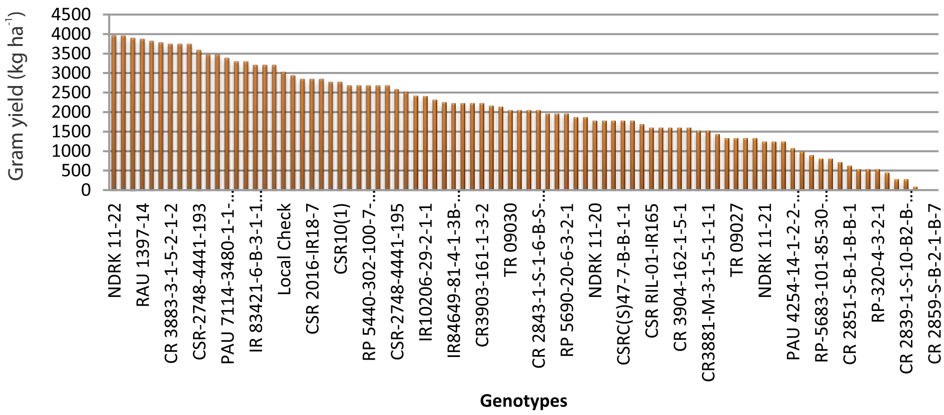


Fig. 41. Performance of STBN entries in high sodicity (pH ~ 9.9)

nurseries were transplanted 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 the traits – days to 50% flowering, plant height (cm), total tillers plant^{-1}, productive tillers/plant, panicle length (cm), stress score at reproductive stage and grain yield (kg ha^{-1}).

Under sodic stress in sodic field (pH ~ 9.6), days to 50% flowering ranged from 94 (KR 15006) to 142 (CR 3898-113-4-2-1) with a mean of 115.78, plant height (cm) varied from 58(CSR10) to 112(CR 2851-S-B-1-B-B-1) with a mean of 85.34, panicle length (cm) ranged from 17.2 (TR 09027) to 62 (CSAR1620) with a mean of 22.18, total tillers varied from 4.2 (CR 3883-3-1-5-2-1-2) to 12.2 (CSR 2016-IR18-12) with a mean of 7.04, productive tillers ranged between 3 (PUSA 44) to 10 (CST7-1) with a mean of 6.0 and the grain yield (kg ha^{-1}) varied between 58 (CR 2851-S-1-6-B-B-4) to 4063 (CSR 2016-IR18-12) with a mean of 2461.17. The best five genotypes in terms of yield advantage under sodic stress are CSR 2016-IR18-12, TR 09030, KS -12, CSR-2748-4441-193 and CSR 2016-IR18-6 (Fig. 40). Two genotypes did not reach flowering stage and grain yield was not obtained.

Under sodic stress in micro plot pH ~ 9.9), days to 50% flowering ranged from 74 (KR 15006) to 145 (CR 3898-113-4-2-1) with a mean of 108.43, plant height (cm) varied from 59.4 (KR 15016)-112 (CSRC(S)47-7-B-B-1-1) with a mean of 87.10, panicle length (cm) ranged from 14.4 ((RP-5683-101-85-30-2-3-1) to 62 (CSAR1620) with a mean of 22.18,

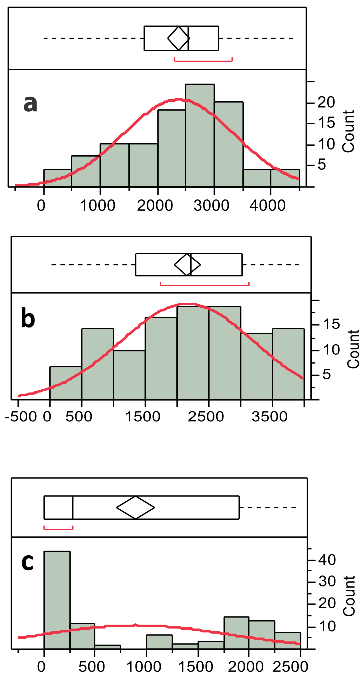


Fig.43. Frequency distribution of grain yield under (a) Sodic field (pH ~ 9.6), (b) High sodic (pH ~ 9.9) , (c) High sodic (pH ~ 9.9)

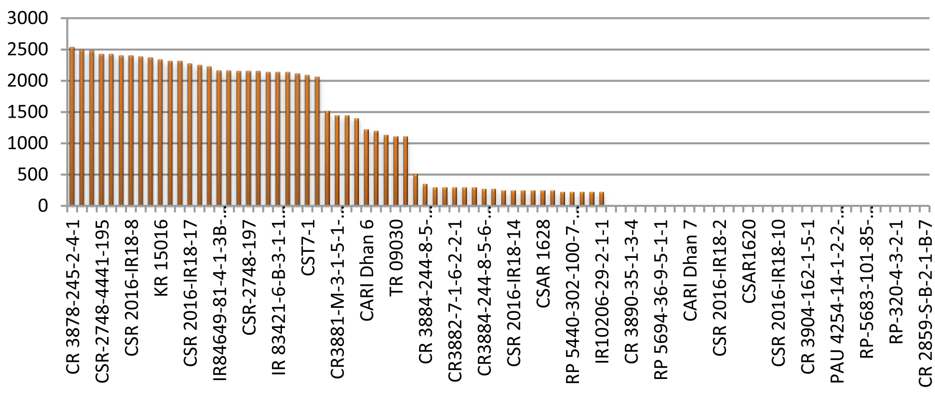


Fig. 42. Performance of STBN entries in high salinity (EC ~ 10.0 dS m^{-1})

total tillers varied from 4.2 (CR 3883-3-1-5-2-1-2) to25.2 (CSR 2016-IR18-2) with a mean of 5.57, productive tillers ranged between 2 (CARI Dhan 10)-8.6 (PAU 7114-3480-1-1-1-0)with a mean of 4.52 and the grain yield (kg ha^{-1}) varied between 89 (KR 15010)-3951(NDRK 11-22) with a mean of 2090.30. The best five genotypes in terms of yield advantage under sodic stress are NDRK 11-22, CSR 2016-IR18-5, NDRK 11-24, RAU 1397-14 and KS -12 (Fig. 41). Two genotypes did not reach flowering stage and grain yield was not obtained.

Under saline stress, days to 50% flowering ranged from 87(Sambha Sub1) to 128 (CST7-1) with a mean of 107.16, plant height (cm) varied from 46.80 (PAU 7114-3480-1-1-1-0) to 119 (Sambha Sub1)with a mean of 73.87, panicle length (cm) ranged from 10 (CR3884-244-8-5-6-1-1)-22.8 (IR52280-117-1-1-3) with a mean of 16.80, total tillers varied from 4.60 (CSR27)-9.00 (CSR10) with a mean of 6.23, productive tillers ranged between 2.00 (CR 2843-1-S-1-6-B-S-B-1)-7.20 (CSR 10) with a mean of 4.78 and the grain yield (kg ha^{-1}) varied 222 (CSR 2016-IR18-18)-2533(CR 3878-245-2-4-1) between with a mean of 1002.20. The best five genotypes under saline stress in terms of yield advantage are CR 3878-245-2-4-1, CSR RIL-01-IR165, KR15006, CSR-2748-4441-195 and CSR RIL-01-IR75 (Fig. 42). Thirty three genotypes did not reach flowering. The frequency distribution of 102 rice genotypes in moderate sodic field, high sodicity and high salinity indicates normal, normal and platy distribution, respectively (Fig. 43 a,b, c).

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

A total of 1000 genotypes including two checks (IR 29- sensitive check and FL478-tolerant check) received from NBPGR, New Delhi, were phenotyped for seedling stage salinity tolerance in 2017. Out of these 1000, twenty six genotypes did not germinate. Screening for salt tolerance at seedling stage was performed in hydroponics using Yoshida culture solution under controlled conditions in glasshouse with 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 root were measured on 28st day after sowing. The mean, maximum and minimum values of the recorded traits during 2017 are presented in Table 35.

Table 35: Summary statistics for root length and shoot length recorded on 1000 rice genotypes

Parameter	Vigour score	Root length	Shoot length
Mean	8.4	14.15	34.50
Maxiumum	9.0	40.17	52.30
Minimum	3.0	4.50	13.70

Shoot length and root length were reduced in saline condition. Vigour score (SES) ranged from 3 to 9 under saline conditions. Nearly, 27 genotypes were found tolerant (score-3), 115 genotypes were moderately tolerant (score-5), 301 were moderately sensitive (score-7) and 551 genotypes were highly sensitive (score-9) (Fig. 45). Shot length ranged from 13.70 to 52.30 cm with a mean of 34.50 cm. The range of root length is from 4.50 to 40.17 cm with a mean of 14.15.

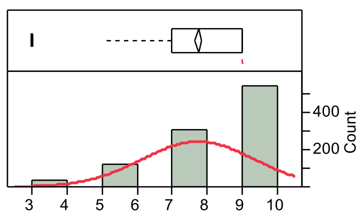


Fig. 44. Frequency distribution of 1000 rice genotypes for vigour score.

Evaluation of BAYER rice hybrids under salinity stress (Consultancy project) phase 2(P.C. Sharma and S.L. Krishnamurthy)

Two hybrids, ARIZE 6444GOLD and INH 16001 received from Bayer Crop Sciences, Hyderabad were tested under fives stress levels, normal, moderate saline, high saline, moderate sodic and high sodic conditions (Table 36) in the microplot at ICAR-CSSRI, Karnal during *Kharif*, 2017. Under normal soil, the entry INH 16001 showed the highest grain yield; while under moderate and high salinity conditions, the entry CSR 27 topped among all the genotypes with a grain yield of 2934 kg ha^{-1} and 1345 kg ha^{-1}, respectively. Under moderate and high sodic conditions, CSR 36 performed best with mean grain yield of 3420 kg ha^{-1} and 2418 kg ha^{-1}, respectively. VSR 156 was the most sensitive under all stress levels and showed highest yield reduction as compared to normal. The Bayer hybrids could give at par yield to with the check only under moderate stress levels. But under higher stress levels, their performance was significantly lower than the respective checks. Among the hybrids, INH 16001 was found promising under moderate salt stress situations compared to other hybrid.

The grain yield under normal (non salt stress) condition ranged from 3227-6629 kg ha^{-1}

Table 36: Soil status and other experiment details of the different locations

S.N	Locations	Gross Plot Size	Net Plot size	Date of Sowing	Date of Planting	pH_2	EC ($dS\ m^{-1}$)
1	Normal field	1.5 m^2	1.35 m^2	26-05-2017	13-07-2017	7.5	1.0
2	Moderate Sodicity	1.5 m^2	1.35 m^2	26-05-2017	13-07-2017	9.5	1.0
3	High Sodicity	1.5 m^2	1.35 m^2	26-05-2017	13-07-2017	9.9	1.0
4	Moderate salinity	1.5 m^2	1.35 m^2	26-05-2017	13-07-2017	7.5	6.0
5	High salinity	1.5 m^2	1.35 m^2	26-05-2017	13-07-2017	7.5	12.0

with a mean of 5776 kg ha^{-1}. The entry INH 16001 showed the highest grain yield (6629 kg ha^{-1}) followed by ARIZE 6444GOLD (6453 kg ha^{-1}). However, the grain yields of all the genotypes, except VSR 156, are at par. Plant height ranged from 127-166 cm with a mean of 137 cm. The total and productive tiller per plant ranged from 10.0 -14.80 and 9.0-13.8 respectively. The grain yield under moderate salinity (EC ~ 6 dS m^{-1}) ranged from 250-2934 kg ha^{-1} with a mean of 2182 kg ha^{-1}. The entry CSR 27 showed the highest grain yield (2934 kg ha^{-1}) followed by CSR 36 (2750 kg ha^{-1}). The days 50 % flowering and plant height ranged from 114-119 days and 88-96 cm, respectively. The spikelet fertility ranged from 41-78 % with mean of 60%. The grain yield under high salinity (EC ~10 dS m^{-1}) ranged from 734-1345 kg ha^{-1} with mean of 1005 kg ha^{-1}. The entry CSR 27 showed the highest grain yield (1345 kg ha^{-1}) followed by CSR 36 (1120 kg ha^{-1}). The genotype VSR 156 is almost dead. The days 50 % flowering and plant height ranged from 108-122 days and 76-83 cm, respectively.

The grain yield ranged from 1109-3420 kg ha^{-1} with a mean of 2857 kg ha^{-1}. The entry CSR 36 showed the highest grain yield (3420 kg ha^{-1}) followed by CSR 27 (3356 kg ha^{-1}), ARIZE 6444GOLD (3212 kg ha^{-1}), INH 16001 (3190 kg ha^{-1}), and VSR 156 (1109 kg ha^{-1}). ARIZE 6444GOLD yielded at par with CSR 36. The days 50 % flowering and plant height ranged from 99-117 days and 108-137cm respectively. The spikelet fertility ranged from 52-92% with mean of 73 %. The grain yield ranged from 1589-2418 kg ha^{-1} with a mean of 1942 kg ha^{-1}. The entry CSR 36 showed the highest grain yield (2418 kg ha^{-1}) followed by CSR 27 (2090 kg ha^{-1}), INH 16001 (1670 kg ha^{-1}) and ARIZE 6444GOLD (1589 kg ha^{-1}). The genotype VSR 156 is almost dead. The days 50 % flowering and plant height ranged from 114-145 days and 69-82 cm, respectively.

There was significant yield reduction among the genotypes particularly under high sodic conditions. Under high sodic conditions, Genotype VSR 156 showed the maximum yield reduction of about 100% followed by ARIZE 6444GOLD (75.38%), INH 16001 (74.81%), CSR 27 (67.38 %), and CSR 36 (60.78%) as compared to normal.

Genetic enhancement of wheat with respect to salt and waterlogging tolerance

(Arvind Kumar, P.C. Sharma, Y.P. Singh and Indivar Parsad)

KRL 283: a new multiple stress tolerant wheat variety released and notified by CVRC

A new salt tolerant wheat variety KRL 283 has been recommended for notification in 79th meeting of Central Sub-Committee on Crop Standards, Notification and Release of Varieties, for Agricultural Crops on 20th January, 2018 for salt affected soils of Uttar

KRL 283 in waterlogged soils

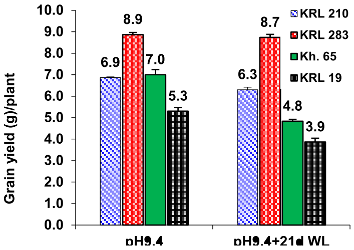


Fig. 45. Grain yield of KRL 283 under sodic and sodic conditions

Pradesh. KRL 283 has shown good yielding ability and salt tolerance with superiority in grain yield on three year's mean (15.02%, 13.68% and 5.24%) over salt tolerant checks, K-8334, NW 1067 and KRL 19, respectively. Under normal conditions, its yield potential is 5.8-6.2 t ha^{-1} while in sodic soils (pH 9.0-9.3) it gives 4.5-4.8 t ha^{-1}. In future, it could be proved as climate resilient variety because of inherent multiple stresses tolerance. It takes 128-133 days for maturity and can tolerate salinity up to 6.7 dS m^{-1} and sodicity up to pH 9.3. It is also tolerant to stripe rust/ brown rust/ stem rust/Karnal bunt/aphid/ shoot fly. (Fig. 45)

Special Trial- Alkalinity/Salinity Tolerance (Irrigated-Timely Sown) 2016-17

During Rabi 2016-2017, the special trial on salinity/alkalinity comprising seven entries (KRL 370, KRL 377, KRL 384, KRL 386, DBW 246, DBW 247, DBW 248 and WH 1316) and three checks (KRL 19, KRL 210 and Kharchia 65) was proposed at 16 locations and conducted at 14 locations (HAU Hisar, CSSRI Karnal, CSSRI Panipat, CSSRI Lucknow, CSSRI Bharuch, Muktsar, Dalipnagar, Faizabad, Vanasthali, CAZRI Bhuj, CAZRI Pali, KVK Chaswad, KVK Kaushambi and KVK Pratapgarh). The yield data of four centres were not included due to late sowing and unrealistic yield. The mean location yield of the 10 conducting sites ranged from 36.2 q ha^{-1} (CSSRI Nain) to 24.7 q ha^{-1} (CAZRI Pali). KRL370 (34.7 q ha^{-1}) was the highest yielding genotype and it alone formed the first non-significant group. Entries KRL370 (34.7 q ha^{-1}), KRL386 (32.8 q ha^{-1}) and KRL377 (32.5 q ha^{-1}) significantly out-yielded the best check KRL210 (31.0 q ha^{-1}) (Table 37). Brown rust (30S) in KRL377 was observed at Daleep Nagar. Leaf blight was also reported in the zone in all entries with highest score of 68 in Kharchia 65.

Table 37: SPL-AST-IR-TS-TAS-All Zones, 2016-17 State and Zonal Mean Yield (q ha^{-1})

SN	Variety	Haryana		Punjab		Uttar Pradesh		Rajasthan		Gujarat		Zonal	
		Yield	Rk	Yield	Rk	Yield	Rk	Yield	Rk	Yield	Rk	Yield	Rk
1.	KRL370	36.5	3	37.5	3	35.9	2	22.7	10	35.4	1	34.7	1
2	KRL377	29.7	9	27.8	6	38.8	1	22.2	11	33.1	2	32.5	3
3	KRL384	33.6	8	27.3	8	31.8	5	24.2	7	26.9	11	29.5	9
4	KRL386	40.2	1	35.2	4	32.9	4	25.6	3	29.5	6	32.8	2
5	DBW246	35.6	4	37.5	2	31.3	6	25.4	5	28.6	7	31.4	4
6	DBW247	34.7	5	27.4	7	29.1	10	25.4	4	32.9	3	30.8	6
7	DBW248	34.2	7	26.1	9	30.8	9	27.5	2	30.1	5	30.4	7
8	WH1316	38.3	2	35.1	5	27.3	11	24.3	6	27.7	9	30.1	8
9	KRL210(C)	34.3	6	41.6	1	30.9	8	23.4	9	28.1	8	31.0	5
10	Kh.65(C)	19.5	11	19.9	11	30.9	7	23.7	8	27.2	10	25.7	11
11	KRL19(C)	26.3	10	21.6	10	33.3	3	27.6	1	31	4	29.5	10
	G.M.	33		30.6		32.1		24.7		30		30.8	
	S.E.(M)	1.432		1.337		0.905		1.433		0.622		0.479	
	C.D. (10%)	3.5		3.2		2.2		3.4		1.5		1.1	

ACI score of stem rust was higher than acceptable standard (15.0) in all the entries and ACI score of stripe rust was also higher than the acceptable score in KRL 377. Therefore these entries could not be promoted in second year testing of SPL-AST-IR-TS-TAS-All Zones.

Salinity/Alkalinity Tolerance Screening Nursery (SATSN) trial 2016-17

28 test entries obtained from different wheat breeding centres were evaluated along with four checks (Kharchia 65, KRL19, KRL 210 and HD 2009) one national check (HD 2967) and one sensitive check (HD 2009) in an Randomized Block Design having 2

replications with plots of 2 m length having 3 rows spaced 20 cm apart. This trial was conducted at 11 locations (CSSRI Karnal, CSSRI Nain, Panipat, CSSRI Lucknow, CSSRI Bharuch, HAU Hisar, Muktsar, Faizabad, Dalipnagar, CAZRI Pali, CAZRI Bhuj and Kaushambi). The data of Lucknow, Hisar Pali, Bhuj, Karnal and Nain were considered for pooling. The promising entries along with rust reactions from IPPSN 2016-17. On the basis of pooled analysis KRL 399 was the highest yielding entry followed by KRL 396, and WS 1602 (Table 38). Unfortunately, ACI score of rusts in promising entries was more the 15.0 (standard). Therefore, none of the entries promoted for testing under salinity/alkalinity tolerance varietal trial 2017-18

Table 38: Promising entries in SAL/ALK screening nursery (SATSN) 2016-17

SN	Entry	Yield (g plot^{-1})	RK	Stem Rust		Leaf Rust (S)		Leaf Rust (N)		Strip Rust	
				HS	ACI	HS	ACI	HS	ACI	HS	ACI
1	KRL 399	392.1	1	80S	39.3	30S	16	40S	18.7	10S	10
2	KRL 396	381.9	2	20S	10.3	60S	18.4	20S	6.7	80S	57.5
3	WS 1602	375.1	3	30S	13.4	20S	6.5	10S	3.3	40S	30.1
C1	KRL 210	372.6	4								
C2	HD 2009	281.7	28								
C3	KRL 19	264.6	30								
C4	Kharchia 65	259.4	32								

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) made primarily for improving yield and adaptation to marginal lands (salt affected, waterlogged and elemental toxicities) and resistance to rusts. About 5-6 spikes were attempted for each combination. During this season, F_1 generations are to be grown and advanced.

Breeder and nucleus seed production

Breeder seed of CSSRI varieties KRL 210 (3.18 t) and KRL 213 (2.42 t) was produced at CSSRI Karnal farm for distribution to various public and private seed producing agencies. Nucleus seed of 10 promising advance lines and of five released varieties KRL 1-4, KRL19, KRL 210, KRL 213 and KRL 283 was produced at CSSRI experimental farm for use in the next season.

Evaluation of advance generation bulks and selections in CSSRI station Trial 2016-17

During the crop year 2016-17, 65 advance generation bulks were tested in Increased Block Design (Augmented Randomized Block Design) with check KRL 210, with the plot size of 3 rows of 2m under normal ($\sim pH_2$:<8.2), and two salt stress environments: namely, saline (5.1- 16.2 dS m^{-1}) at Nain Farm, and sodic (pH_2:>9.4) with waterlogged treatment in field condition. 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 during waterlogging periods. Out of 63 advance bulks, 20 genotypes performed better than checks. On the basis of yield performance and other desirable traits, 10 bulks were selected for further evaluation in the Salinity/Alkalinity Tolerance Screening Nursery (SATSN) and Initial Plant Pathological Screening Nursery (IPPSN) (Table 39).

Table 39: List of CSSRI entries with their pedigrees for testing under SATSN 2017-18

S. No.	Entry Name	Pedigrees
1.	KRL 410	ATTILA*2/PBW65*2//W485/HD2932
2.	KRL 411	KRL 99/PBW 525
3.	KRL 412	FRET-2/2*PASTOR-2
4.	KRL 413	KRL 3-4/ HD 2851
5.	KRL 414	W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1/5/SOKOLL/3/PASTOR//HXL7573/2*BAU
6.	KRL 415	BECARD/PFUNYE #1
7.	KRL 416	HGO94.7.1.12/2*QUAIU #1//WAXBI/5/WBLL1*2/4/BABAX/LR42//BABAX/3/BABAX/LR42//BABAX
8.	KRL 417	DANPHE #1*2/3/T.DICOCCON PI94625/AE.SQUARROSA (372)//SHA4/CHIL/4/WBLL1*2/ KURUKU// HEILO/5/ WBLL1*2/ KURUKU//HEILO
9.	KRL 418	DANPHE #1*2/3/T.DICOCCON PI94625/AE.SQUARROSA (372)//SHA4/CHIL/4/WBLL1*2/KURUKU//HEILO/5/WBLL1*2/ KURUKU//HEILO
10.	KRL 419	CPAN 3004/KHARCHIA 65//PBW-343

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 waterlogged, 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 water logged 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 tolerant genotypes whereas KRL 119, KRL 213, HD 2967 and KRL 351 were found moderately tolerant. However DW 1, DW 3, HD 2009, Brookton, Ducula 4, HD 2851 and HD 4530 were the sensitive genotypes.

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

CS 60 (CS2800-1-2-3-5-1): A new variety of salt tolerant Indian mustard released and notified by CVRC

This variety has been identified and recommended by the 24th Annual Group Meeting of All India Coordinated Research Project on Rapeseed-Mustard during 2017 and released

Indian Mustard Germplasm CS 15000-1-2-2-2-1 (INGR17051) registered as national genetic stock for salt tolerance under NBPGR

& notified by Central Sub-Committee on Crop Standards, Notification & Release of Varieties (CVRC) during 79th meeting held on 20th Jan., 2018, for salinity affected areas of the mustard growing regions of the country Zone–II comprising the states of Haryana Punjab, Uttar Pradesh and Rajasthan. This variety gave 25% higher seed yield and 27% higher oil yield per hectare over the national check CS 54 and high yielding varieties Kranti and Giriraj under soil salinity EC_e 10-11 dS m^{-1}, irrigation water salinity: EC_{iw} 10-12 dS m^{-1} and alkalinity pH 9-9.3. It matures, on an average, in 134 days and takes 58 days to flower. The height of CS 60 is 187 cm and produces a high number of primary branches (6), secondary branches (9), main shoot length (77cm) and 1000 seed weight (5.0g). The productivity of this variety under normal soils is 2.4-2.9 t ha^{-1}, while under salt affected soil is 1.8-2.1 t ha^{-1} with 41% oil content. CS60 showed resistance to *Alternaria* blight, White rust, Powdery Mildew, Downy Mildew, Stag head, *Sclerotinia* stem rot and mustard aphid under field conditions also.

CS 15000-1-2-2-2-1: Indian mustard germplasm/ national genetic stocks Registered of for salt tolerance

This genotype of Indian mustard has been registered in NBPGR (IC0624502 and INGR 17051) as National Genetic Stock for unique traits; salinity tolerant up to EC_e 12 dS m^{-1}, irrigation water salinity up to EC_{iw} 15 dS m^{-1} and alkalinity tolerant up to pH 9.4. Further, it also showed lower reduction in seedling length (21%) and dry weight/10 seedlings (16.3%) under saline condition over the control as compare to already registered genetic stock CS1100-1-2-2-3.

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

Forty one breeding lines including three checks (CS 52, CS 54 and Kranti) were evaluated in IVT for seed yield in screening trial in reclaimed alkali soils (pH 8.1 to 9.5) at Karnal. Seed yield ranged from 1.21 to 2.37 t ha^{-1} (mean 1.64 t ha^{-1}). Fifteen lines gave significantly higher yield over the best check CS 54 (1.74 t ha^{-1}) with CS 2005-196 (2.37 t ha^{-1}) followed by CS 2009-1-2-2-1-3 (2.27 t ha^{-1}) recording the maximum seed yield. Further, forty seven breeding lines including four checks (CS 54, Varuna, Kranti and CS 56) were evaluated in AVT for seed yield in screening trial in reclaimed alkali soils (pH 8.1 to 9.5) at Karnal. Seed yield ranged from 1.35 to 2.46 t ha^{-1} (mean 1.76 t ha^{-1}). Twenty five lines gave significantly higher yield over the best check Kranti (1.71 t ha^{-1}) with CS 2005-136 (2.46 t ha^{-1}) followed by CS 2009-135 & CS 2009-313 (2.30 t ha^{-1}) recording maximum seed yield.

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

Forty one breeding lines including three checks (CS 52, CS 54 and Kranti) were evaluated in IVT for seed yield in screening trial in saline soils (EC_e 9.2-15.4 dS m^{-1}) at Nain Farm, Panipat. Seed yield ranged from 0.01 to 2.24 t ha^{-1} (mean 0.99 t ha^{-1}). Seven lines gave significantly higher yield over the best check CS 52 (1.15 t ha^{-1}) with CS 2002-195 (2.24 t ha^{-1}) followed by CS 2009-261 (1.69 t ha^{-1}) recording the maximum seed yield. Further, in AVT, forty seven breeding lines including four checks (CS 54, Varuna Kranti and CS 56) were evaluated for seed yield in screening trial in saline soils (EC_e 9.2-15.4 dS m^{-1}) at Nain Farm, Panipat. Seed yield ranged from 1.18 to 3.44 t ha^{-1} (Mean 2.13 t ha^{-1}). Twenty four lines gave significantly higher seed yield over best check CS 54 (2.05 t ha^{-1}) with CS 2002-87 (3.44 t ha^{-1}) followed by CS2009-216 (3.34 t ha^{-1}) (Table 40).

Table 40: Development andevaluation of advanced breeding lines (AVT)-2016-17

Mustard AVT: 48 lines with 4 checks (CS 54, Kranti, CS 56 and Varuna)				
Sr. No.	Top 5 Genotype	Yield (t ha^{-1}) (pH_2 8.2-9.3) **	Top 5 Genotype	(EC_e 9.3-16.0 dS m^{-1}) **
1	CS 2002-87	3.44	CS 2005-136	2.46
2	CS 2009-216	3.34	CS 2009-135	2.30
3	CS 2009-401	3.00	CS 2009-313	2.30
4	CS 2009-335	2.87	CS 2009-437	2.27
5	CS 2002-62	2.85	CS 2005-137	2.25
Mean (t ha^{-1})		2.13		1.76
CD (0.05%)		0.80		0.26
Range (t ha^{-1})		1.18-3.44		0.35-2.46
Best check		CS 54 (2.05)*		Kranti (1.71)*
No. of Superior lines over				
best check		24		25

Development and evaluation of segregating material (F_8 and F_{10}) of Mustard in semi – reclaimed alkali soils

Fifty four breeding lines including eight checks (Pusa Bold, Pusa Jaggnath, CS 2007-25, CS 2007-6, Varuna, CS 54, Kranti and CS 56) were evaluated in F_8 generation for seed yield in reclaimed alkali soils (pH 8.1 to 9.5) at Karnal. Seed yield ranged from 0.92 to 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}). Sixty two breeding lines including five checks (Krishna, Kranti, CS 54 and CS 56) were evaluated in F_{10} generation for seed yield in reclaimed alkali soils (pH 8.1 to 9.5) at Karnal. Seed yield ranged from 1.15 to 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}).

Development and evaluation of segregating material (F_8 and F_{10}) of mustard in saline soils

Fifty four breeding lines including eight checks (Pusa Bold, Pusa Jaggnath, CS 2007-25, CS 2007-6, Varuna, CS 54, Kranti and CS 56) were evaluated in F_8 generation for seed yield in saline soils (EC_e 9.2-15.4 dS m^{-1}) at Nain Farm, Panipat. Seed yield ranged from 0.32 to 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}). Further, Sixty two breeding lines including five checks (Krishna, Kranti, CS 54 and CS 56) were evaluated in F_{10} generation for seed yield in saline soils (EC_e 9.2-15.4 dS m^{-1}) at Nain Farm, Panipat. Seed yield ranged from 0.41 to 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}).

Monitoring and Evaluation of promising salt tolerant strains of Indian Mustard (*Brassica juncea*) in AICRP on Rapeseed Mustard Salinity/Alkalinity Trial -2016-17

Twelve genotypes were evaluated in IVT under saline condition (PNP; EC_e 11.0 dS m^{-1}) at Nain Experimental Farm, Panipat and alkali condition (KAR; pH 9.3) at Karnal. Significant differences were observed in seed yield amongst the genotypes evaluated, both under salinity and alkalinity stresses. Under salinity stress, seed yield ranged from 1.71 to 2.41 t ha^{-1} (Mean 1.94 t ha^{-1}) at Nain and 1.73 to 2.43 t ha^{-1} (Mean 1.95 t ha^{-1}) under high alkaline conditions (pH 9.3) at Karnal. Genotypes CSCN-16-10 (2.39 t ha^{-1}) followed by CSCN-16-2 (2.37 t ha^{-1}) showed highest seed yield across the salt stress.

Table 41: Performance of mustard strains in AVT (saline/alkaline conditions)-2016-17

S. No.	Code	Strain	Seed yield (t ha^{-1})			1000-Seed wt. (g)		Oil Content (%)	
			PNP	KAR	Mean	PNP	KAR	PNP	KAR
1	CSCN-16-11	CS 700-2-1-4	2.47	2.42	2.44*	5.0	5.1	40.01	40.05
2	CSCN-16-12	CS- 54 (Check)	1.91	1.91	1.91	5.1	4.9	38.66	38.69
3	CSCN-16-13	RH 406	1.71	1.79	1.75	5.2	5.0	38.45	38.39
4	CSCN-16-14	Giriraj (LR)	1.72	1.75	1.73	5.4	4.9	38.23	38.61
5	CSCN-16-15	Kranti (NC)	1.72	1.75	1.73	5.2	5.0	38.53	38.62
6	CSCN-16-16	CS 2800-1-2-3-5-1#	2.44	2.29	2.36	5.2	4.9	39.54	39.68
7	CSCN-16-17	CS 900-1-2-2-1-3	2.35	2.31	2.33*	4.1	3.9	38.95	38.85
8	CSCN-16-18	RH 0725	1.72	1.78	1.75	4.8	4.9	38.56	38.41
9	CSCN-16-19	CS 508-1 P2	2.47	2.46	2.47*	4.2	5.0	39.99	40.02
		GM	2.06	2.05	2.05				
		CD (5%)	0.37	0.37					
		DOS	19/10/2016	08/10/2016					
		C.V.	12.01	12.03					
		ECe (dS m-1) /pH	11.00	9.30					

* Strain out yielding the best check by margin of >10 % seed yield

Similarly, nine genotypes were evaluated in AVT-I+II under saline condition (EC_e 11.0 dS m^{-1}) at Nain Experimental Farm, Panipat) and alkali condition (pH 9.3) at Karnal. Significant differences were observed in seed yield amongst the genotypes evaluated, both under salinity and alkalinity stresses. Under salinity stress, seed yield ranged from 1.71 to 2.47 t ha^{-1} (Mean 2.06 t ha^{-1}) at Nain and 1.75 to 2.46 t ha^{-1} (Mean 2.05 t ha^{-1}) under high alkaline conditions (pH 9.3) at Karnal. Genotypes CSCN-16-19 (2.47 t ha^{-1}) followed by CSCN-16-11 (2.44 t ha^{-1}) showed highest seed yield over the saline/ alkali conditions (Table 41).

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-2016-17

Four genotypes were evaluated in Agronomy trial alkaline conditions (*p*H 9.3) at Karnal with three nitrogen levels; 100%, 125% and 150% of recommended dose. Significant differences were observed in seed yield amongst the genotypes evaluated. CS 2800-1-2-3-5-1 responded favourably to the additional doses of fertilizer (NPK). Further, 100% RDF was found suitable for this genotype (Table 42). Production of nucleus and breeder seeds of three salt tolerant varieties developed at CSSRI Karnal and released by CVRC

During the year 2016-17, breeder seed (graded) of Indian mustard varieties CS 52 (0.095 t), CS 54 (0.620 t), CS 56 (0.435 t) and CS 58 (0.660 t) was produced for distribution to central and state govt. agencies.

Table 42: Influence of different fertility level at different locations on promising entries in salinity/ alkalinity conditions-2016-17

Entries	Genotype	Fertility Levels			
		100% of Recommended	125% of Recommended	150% of Recommended	Mean Yield (t ha^{-1})
AG-17	CS 54	1.77	1.95	2.08	1.93
AG-18	RH 749	1.92	2.08	2.16	2.05
AG-19	CS 2800-1-2-3-5-1	2.33	2.46	2.57	2.45
AG-20	Kranti	1.78	2.01	2.17	1.99
	Mean	1.95	2.12	2.25	
	CD (P=0.05)	Entries (E)=0.11	Fertility (F)=0.05	F at same level of E=N.S. E at same level of F=N.S.	

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

This project was initiated with the aims to characteric cultivated and wild species of tomato and okra under salt stress and to identify tolerant genotypes as well as rootstocks in tomato. To achieve the objectives, following trials were conducted during 2016-17.

Characterization of cultivated and wild species of tomato at different salinity level

Seventy lines were transplanted in microplots on 2nd January, 2018 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 best available water and after that alternate irrigation was given with saline water according to treatments. All other package of practices was same for all the treatments. Soil samples were taken at monthly intervals for monitoring of salinity. The flowering was late at higher salinity. Number of fruits plant^{-1} was reduced with increase in salinity and it was 31.95, 47.61 and 63.51 % at EC_e 4-6, 6-8 and >8 dS m^{-1}, respectively (Table 43). The percent yield reduction was 31.27, 49.47 and 63.97 at EC_e 4-6, 6-8 and >8 dS m^{-1}, respectively. The total soluble solids (TSS) increased at medium salinity and after that it reduced with increase in salinity.

Table 43: Mean and % reduction over normal of important traits

Traits	Mean				Percent reduction		
	EC_e<4 dS m^{-1}	EC_e 4-6 dS m^{-1}	EC_e 6-8 dS m^{-1}	EC_e >8 dS m^{-1}	EC_e 4-6 dS m^{-1}	EC_e 6-8 dS m^{-1}	EC_e >8 dS m^{-1}
Plant height (cm)	87.32	64.48	52.10	46.20	26.16	40.33	47.09
Days to 50% flowering	53.14	54.87	54.26	53.44	-3.26	-2.11	-0.56
Fruits/plant	159.20	108.34	83.40	58.10	31.95	47.61	63.51
Avg. fruit wt.	24.36	19.42	17.32	16.15	20.28	28.90	33.70
Yield plant^{-1} (g)	2665.55	1832.10	1346.80	960.42	31.27	49.47	63.97
TSS (°Brix)	4.34	4.96	4.62	4.28	-14.29	-6.45	1.38

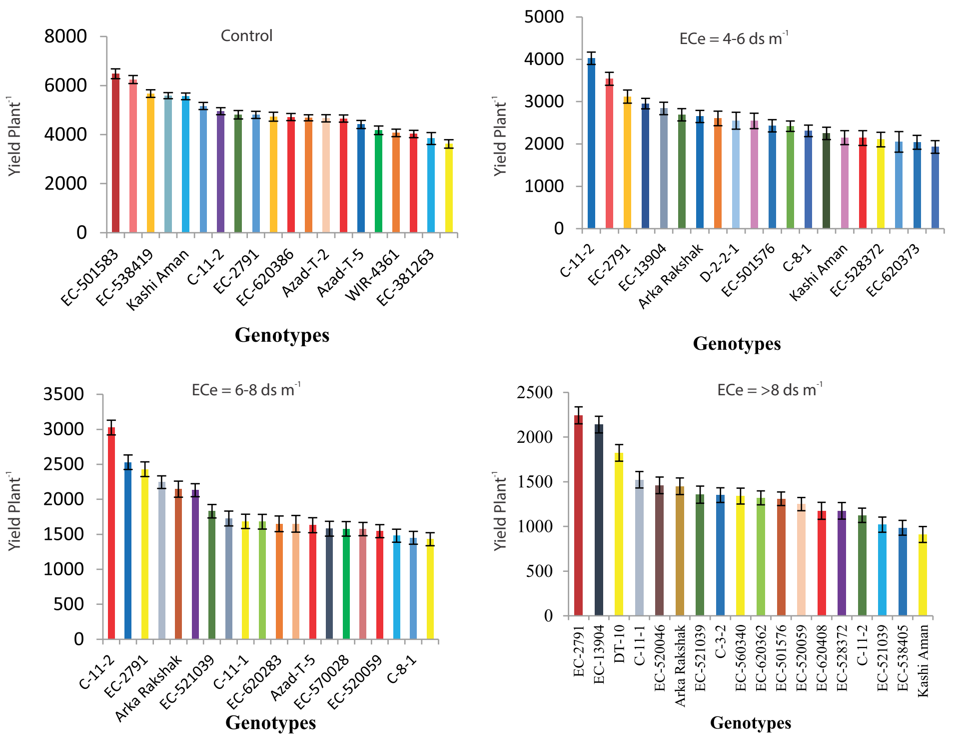


Fig. 46. Best performing 20 genotypes under different salinity levels

Top 20 performing genotypes from each treatment were selected on the basis of yield. The genotype EC-501583 showed the highest fruit yield (6480 g) in control (EC_e <4 dS m^{-1}) but at higher salinity its performance was very poor. The line C-11-2 was best performer up to EC_e 8 dS m^{-1}. But at EC_e 8 dS m^{-1}, the line EC-2791 performed better followed by EC-13904, DT-10, C-11-1and EC-520046 (Fig.46).

Ionic analysis was done in shoot and root parts. Sodium ion content was more in roots than shoots in control environment while at higher sodic conditions shoots had higher content than roots. Potassium ion decreased with higher sodicity but this decrease was more in shoots than roots. On the basis of low Na/K ratio of root and shoot, best five genotypes were selected. A positive correlation was observed between yield and low Na/K ratio in some of the genotypes.

Characterization of okra genotypes at different sodicity levels

Twenty four okra lines were sown in microplots on 20th July, 2017 in Randomized Complete Block Design with two replication in sodic soil for evaluating yield and 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-9.6±0.2(T_3). The plant height was reduced with the increase in sodicity and the flowering was 2-3 days early under stress conditions than normal in all the genotypes. The lines IIVR-11, SB-6, IC-117027, IC-45831 and VRO-4 performed better than other varieties in control environment but at sodic conditions, genotypes IIVR-11 and VRO-4 performed better than other genotypes (Fig 47).

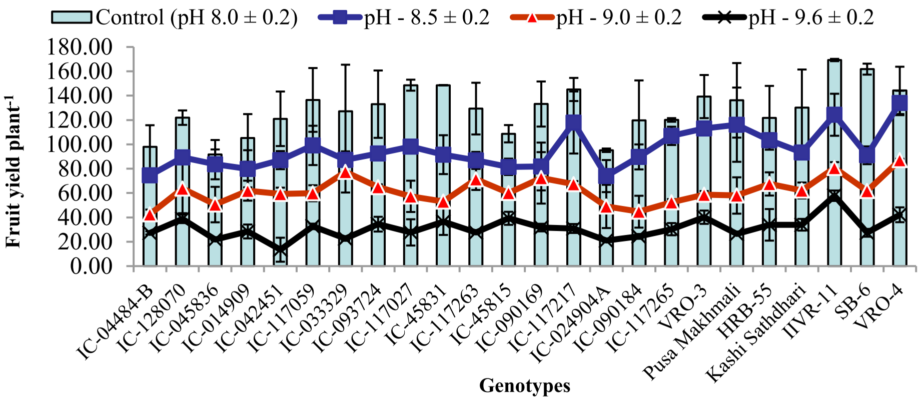


Fig. 47. Performance of different genotypes of okra under sodic conditions.

Number of fruits/plant, fruit weight and fruit length was reduced significantly at high sodicity pH-9.6±0.2. Ionic analysis was done in shoot and root. Sodium ion content was more in roots than shoots in control environment while at higher sodic conditions shoots had higher content than roots. Potassium ion decreased with higher sodicity but this decrease was more in shoots than roots. At higher sodicity the genotypes IC-014909, IIVR-1, VRO-4 and IC-45831 have low root Na/K ratio while the genotypes VRO-4, IC-042451and IC-014909 have low shoot Na/K.

Improvement of salt tolerance in chickpea through physiological and breeding approaches (Anita Mann, P.C. Sharma and Jogendra Singh)

Forty three chickpea genotypes were screened for salt tolerance in the microplots with Karnal Chana-1 (CSG 8962) as tolerant check during the cropping season of 2017-18. Twenty seeds from each of chickpea lines were used for seed multiplication. The screening for the effect of saline irrigation in chickpea was done at control, EC 6 and 9 dS

m^{-1} in the microplots. Salinity was maintained by irrigation with saline water (EC 16.3 dS m^{-1}). One saline irrigation was applied before germination. There was no germination in five lines (ICC 1915, ICC 6306, ICC 14595, ICC 14778, ICC 17258). No germination was seen in three lines (ICC 1083, ICC 6877, ICC 146699) at EC 6 & 9 dS m^{-1} and three lines (ICC 6816, ICC 12866, ICC 14799) did not germinate at EC 9 dS m^{-1}. The chickpea germplasm was screened for salt tolerance for various physiological and biochemical parameters as described below:

At flowering stage, the relative water content was measured. With increasing saline level, a significant reduction was observed in RWC only in two lines, ICC 11121 and HK-1. In Karnal Chana-1, maximum reduction in RWC was observed at EC 9 dS m^{-1} than at EC 6. In rest of the lines, there was no significant reduction in RWC at flowering stage. 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 44. Total chlorophyll content decreased with increasing salt concentration at both the plant growth stages. Also, the total chlorophyll content was more at flowering stage than at maturity. A significant accumulation of proline was observed at maturity stage than at flowering stage. Mean total proline was 3.85, 4.70 and

Table 44: Effect of saline irrigation on total chlorophyll content at different growth stages

	Flowering stage			Maturity stage		
	Control	EC 6 dS m^{-1}	EC 9 dS m^{-1}	Control	EC6 dS m^{-1}	EC 9 dS m^{-1}
Mean	1.280	0.879	0.626	0.880	0.584	0.357
Max	1.365	1.188	0.951	1.056	0.944	0.797
Min	0.802	0.597	0.411	0.475	0.266	0.195

5.63 ug g^{-1} FW at control, 6 dS m^{-1} and 9 dS m^{-1}, respectively, at flowering stage. Maximum increase in proline content at flowering stage was found in ICC-2242 followed by ICC-5845, ICC 9942 and ICC-12824. Maximum accumulation of proline was observed in ICC 2263, ICC 5845, ICC 8522and H-08-18 at maturity stage. Fig. 48 shows the accumulation of proline at flowering and maturity stage respectively. Root and shoot fresh weight decreased with application of saline water of EC 6 dS m^{-1} which decreased further with saline water of EC 9 dS $m^{-1}$and simultaneously the root and shoot dry weight. Root and shoot length also decreased significantly with increasing salinity level. The mean values of different parameters studied in chickpea under saline stress are given in Table 45.

Table 45: Mean values of different factors studied under saline conditions in chickpea

Mean values	Proline Flowering (µg g^{-1} FW)	Proline Maturity (µg g^{-1} FW)	RL (cm)	RFW (gm)	RDW (gm)	SL (cm)	SFW (gm)	SDW (gm)	Na/K Root	Yield (g $plant^{-1}$)
Control	3.85	7.24	14.80	6.53	1.57	51.17	180.03	28.23	1.32	17.5
EC 6 dSm^{-1}	4.70	9.29	11.86	2.75	0.52	24.04	125.90	13.95	1.89	13.5
EC 9 dSm^{-1}	5.63	11.24	10.93	2.46	0.50	21.45	120.76	13.04	2.59	10.0

RL-root length, RFW-root fresh weight, RDW-root dry weight, SL-shoot length, SFW-shoot fresh weight, SDW-shoot dry weight

The kabuli chickpea lines, *e.g.* HK-1, HK-2 and HK-4 have the highest Na/K ratio along with other desi germplasm lines, ICC 8522, ICC 12824, H-08-75 and hence show susceptibility towards saline stress. The range of yield reduction at EC 6 $dSm^{-1}$was observed as 5.15-52.3 % was observed while a reduction of 11.5-78.1% was obtained at EC 9 dS m^{-1}. Thus, few chickpea germplasm lines have been identified based on different physio-biochemical parameters which are being included in the breeding programme.

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 Sheoran, Ashwani Kumar and Babu Lal Meena)

A survey of salt affected soils of Haryana was done and based on that, four sites have been selected from Panipat, Sonepat and Kaithal. Approximately 500 samples of soil and water were collected from four villages: Nain (Panipat), Jagsi (Sonepat), Sanch (Kaithal) and Mundri (Kaithal). The grid map of respective village was prepared based on soil and water sampling. The major and micronutrients were estimated in soil and water samples. Based on the mineral nutrient analysis, field demonstrations have been conducted during 2017-18 at these sites. The experiment is still in progress. Final data will be analyzed after harvesting of wheat crop.

Potential gene mining from salt tolerant grasses for improvement of salt tolerance in crops (Anita Mann, Ashwani Kumar, Arvind Kumar and Babu Lal Meena).

The grasses *Urochondra setulosa* and *Dichanthium annuatum* were transplanted from field/microplots to the lysimeters at Karnal during August 2017. After proper growth of the plants, salt treatments were given to maintain the desired salinity levels of 30, 40 and 50 dS m^{-1}. Four pots for each treatment were kept for the experiment. One pot from each treatment was kept as control. Similarly, Rice was planted during June-July at NRRI, Cuttack. Three rice varieties namely CSR 10 (tolerant), Pokkali (tolerant at vegetative stage and IR29 (susceptible) were initially screened for salinity tolerance. The standardized IRRI protocol for salinity stress was followed for the experiment. Salinity stress of 18 dS m^{-1} was imposed on these rice varieties during booting and panicle emergence stages. The analysis showed CSR 10 had least reduction in shoot fresh weight after stress treatment followed by Pokkali and IR 29. There was no varietal difference between the genotypes for flag leaf width and most reduction in panicle weight was observed in Pokkali genotype. For grasses, to generate the transcripts, prior knowledge of genome size is required which is not completely available in these two grasses and hence, the samples have been sent for the same for analysis through outsourcing. Similarly to know the chromosome number of these two grass species, process is being standardized. Additionally, the markers for known functional markers of salt tolerance have been designed and their expression analysis is being done.

Development of Soybean [*Glycine max* (L.) Merrillis] genotypes for higher yield under salt stress (Vijayata Singh and S. K. Sanwal)

The main aim of this project is to characterize soybean germplasm for salt tolerance and identification of donors for salt tolerance and introgression of salt tolerance into high yielding varieties.

Collection of soybean germplasm

A total of 191 diverse soybean germplasm accessions were collected from different institutes: 40 accessions from ICAR-NBPGR, New Delhi; 52 accessions from Punjab Agricultural University, Ludhiana; 87 accessions from ICAR-IISR, Indore; 7 accessions from MPKV-Agricultural Research Station, Rahuri and 5 accessions from ICAR-IIVR, Varanasi.

Screening of soybean germplasm under saline irrigation water conditions

Initially, five seeds of each of 191 accessions were sown at depth of 1 cm in 20 kg capacity ceramic pots filled with sand inside the net house facility. The bottom of each pot was delved for drainage of extra water. The pots were irrigated by normal tap water (control), saline water (EC_{iw} 5.0 and 8.0 dS m^{-1}) and maintained at field capacity. Here, we selected above salinity levels because EC_{iw} 5 dS m^{-1} is the threshold limit for soybean crop. The saline water for irrigation was prepared in Hoagland nutrient solution by adding NaCl, Na_2SO_4 and $CaCl_2$, keeping Na:Ca and $Cl:SO_4$ ratios of 4:1 which reflect the major ion compositions of naturally occurring saline waters/soils. The pots were arranged in a factorial experiment based on completely randomized block design (CRBD) with 2 replications. The pots were irrigated daily to maintain the respective salinity level in the root zone throughout the life cycle of the crop. Saline irrigation was continued until the harvest of the crop for recording yield. Plant sampling for ionic study was done at the harvesting stage. At maturity, three plants per pot were harvested and air dried prior to recording their grain yield. Seed yield of all the genotypes under different salinity regimes was also recorded. Out of 191 lines, only 108 survived till maturity under saline condition. The higher salinity significantly reduced seed yield and 100 seed weight. Whereas, Na/K ratio in root and shoot was significantly increased with increasing salinity levels as compared to control (Table 46). The mean seed yield plant^{-1} over the salinity stress was 9.81 g. Highest yield plant^{-1} over the environment was recorded in IC392551 (13.4 g) followed by IC392618 (10.7 g) and IC391431 (9.72 g).

Table 46: Effect of salinity on morpho-physiological traits of Soybean accessions

Trait	Mean			Range			Mean over env.	CD (p=0.05)
	Control	EC_{iw} 5	EC_{iw} 8	Control	EC_{iw} 5	EC_{iw} 8		
No. of primary branches	3.00	3.00	3.00	1-14	1-12	1-12	3.00	1.63
Pods plant^{-1}	28.00	27.00	26.00	7-134	6-124	5-98	27.00	7.38
Seed yield plant^{-1} (g)	12.71	9.86	6.86	0.15-19.60	0.30-13.05	0.30-11.00	9.81	0.63
100-Seed weight (g)	12.01	9.65	4.65	9.5-13.01	5.55-8.86	4.56-6.86	8.76	0.22
Shoot Na/K at harvesting stage	0.53	0.60	0.66	0.02-2.59	0.07-3.18	0.01-5.65	0.60	0.08
Root Na/K at harvesting stage	0.98	1.04	1.16	0.05-6.25	0.04-10.98	0.04-11.86	1.06	0.56
Days to 50% flowering	55.00	54.00	53.00	38-117	53-124	53-116	54.00	2.30
Days to maturity	72.00	68.00	67.00	71-135	73-133	69-132	69.00	3.54

Screening of soybean germplasm under sodicity conditions

All 191 accessions were also evaluated under the sodic conditions (control, pH 9.0 and pH 9.3) during *Kharif* 2017. Out of 191, only 108 survived till maturity. Impact of sodicity was more pronounced on pods plant^{-1} and seed yield plant^{-1} which significantly reduced these traits. The mean seed yield plant^{-1} over the sodicity stress was 10.42 g. Highest yield plant^{-1} over the sodicity was recorded in JS335 (61.54 g) followed by JS9752 (46.39 g) and IC393172 (40.04 g). Na/K ratio in root and shoot was significantly increased with increasing sodicity levels as compared to control (Table 47). The sodicity stress also induced early flowering and maturity as compared to control.

AMMI Bi-plot analysis for identification of potential genotypes

All the genotypes respond differentially for different traits at stress level (salinity as well as in sodicity). Hence, reaching on a consensus to identify an ideal accession under stress AMMI Bi-plot analysis was performed. It indicates multiplicative portion of GE interaction into specific pattern of response of genotypes and the environments. Principal components PC1 and PC2 explained the 100% (90.1+9.9%) of interaction effects. The

Table 47: Effect of sodicity on morpho-physiological traits of Soybean accessions

Trait	Mean			Range			Mean over env.	CD (p=0.05)
	Control	EC_{iw} 5	EC_{iw} 8	Control	EC_{iw} 5	EC_{iw} 8		
No. of Primary Branches	4.00	4.00	3.00	1.5-10	1-10	1.5-8.5	4.00	2.00
Pods plant^{-1}	60.00	50.00	49.00	13-306	7-295	4-244	53.00	12.00
Seed yield plant^{-1} (g)	11.43	9.85	9.96	0.96-83.15	1.0-70.34	0.99-69.87	10.42	1.07
100 Seed weight (g)	0.63	0.65	0.64	11.23-18.28	8.05-13.05	4.05-7.85	6.40	0.40
Shoot Na/K at harvesting stage	0.20	0.22	0.25	0.01-1.80	0.01-2.10	0.01-3.21	0.22	0.05
Root Na/K at harvesting stage	1.32	1.85	3.13	0.01-7.45	0.04-9.34	0.02-12.90	2.10	0.84
Days to 50% flowering	58.00	57.00	48.00	61-104	60-101	59-98	54.00	7.00
Days to maturity	70.00	69.00	58.00	58-122	65-113	57-113	65	5.00

accession G24 (PS 1225), G44 (JS 2029) and G49 (AGS 7513) were considered as stable being falls on base line. G80 (SL 1243) and G83 (SL 1254) are specifically adapted for salinity stress that occur close to particular environments (E2 and E3; EC_{iw} 5 and 8 dS m^{-1}, respectively) on the PCA2 vs. PCA1 bi-plot (Fig. 48). Because, PCA cover more than 70% variation in salt stress, hence it needed to analyze GGE Bi-plot. Firstly, environment main effects are removed; secondly, genotype and genotype by environment interaction are retained and combined. GGE Bi-plot analysis showed that G24 (PS 1225) is the most ideal genotype as it was located almost on the AEC abscissa and had a near zero projection onto the AEC ordinate. This indicates that its rank was highly consistent across saline environments.

AMMI Bi-plot and GGE Bi-plot analysis for sodicity

Principal components PC1 and PC2 explained the 100% (85.1+14.9%) of interaction effects. The accession G57 (SL 1205) and G75 (SL 1234) were considered as stable being falls on base line. G51 (SL 1113), G60 (SL 1210), G68 (SL 1226) and G81 (SL 1258) are specifically adapted for sodicity stress that occur close to particular environments (E2 and E3; pH 9 and 9.3, respectively) on the PCA2 vs. PCA1 bi-plot. GGE Bi-plot analysis showed that no genotype was ideal as none of them was located on the AEC abscissa and had zero projection onto the AEC ordinate.

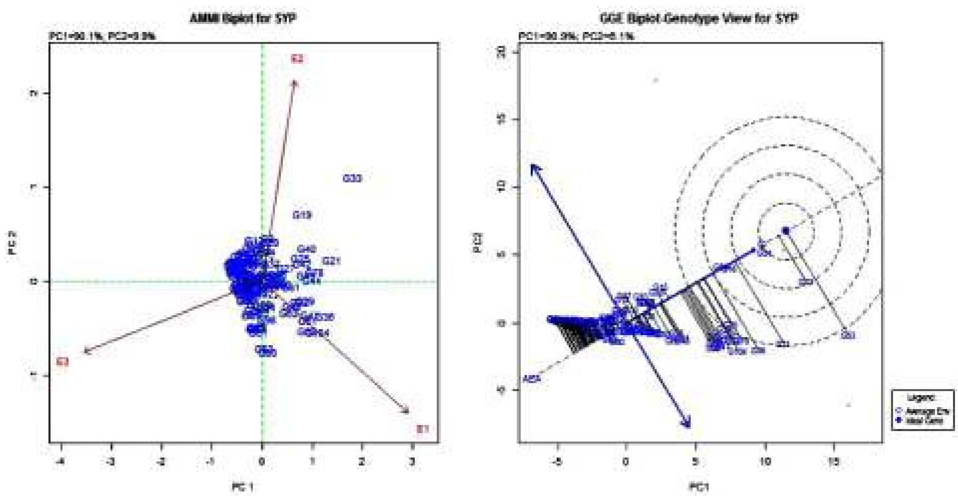


Fig. 48. AMMI Bi-plot and GGE Bi-plot analysis for identification of Ideal accession for salinity condition

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

Wheat Crop

Last year as per comments of field IRC, drought tolerant genotypes were also included in the research programme. Out of 8 genotypes viz. KRL 210 (Salt tolerant), KRL 283 (newly promoted salt tolerant variety), KRL 330 (newly promoted salt tolerant variety), KRL 370 (newly promoted genotype in AVT trails), KRL 433 (salinity and drought tolerant genotype), HD 2888 (drought tolerant), WH 1080 (drought tolerant) and C 306 (drought tolerant) selected for the study under individual and interactive salinity and drought stresses, WH 1080 maintained higher photosynthetic efficiency under individual stress of 50 % Water deficit (drought) and 100 mM NaCl (salt) whereas under interactive stresses KRL 370 and KRL 283 were the best genotypes.

Under combined stresses, the highest value of Na^+/K^+ ratio in shoots was recorded for WH 1080 (1.167) and lowest in KRL 283 (0.612). All the varieties showed increased proline accumulation with inclined stress and maximum accumulation was observed in KRL 330 (3.17 mg g^{-1} FW) and minimum accumulation in KRL 283 (2.8 mg g^{-1} FW). Significantly higher reductions (52.5 %) were observed in HD 2888 and C-306 for grain weight plant^{-1} at 100 mM NaCl + 50 % WD stress treatment whereas minimum reduction of 39.18 % was recorded in KRL 370 in comparison to control treatment. The trend of per cent reduction in grain weight/plant under different stress condition was as followed (Table 48):

Table 48: Pooled analysis of grain yield under individual and interactive stresses

Varieties	Grain Yield (Control)	Grain Yield (Drought)	Grain Yield (Salinity)	Grain Yield (Drought + Salinity)
KRL 370	9.00	7.28bc	7.42a	6.48a
KRL 433	9.34	6.53de	6.76c	6.35ab
HD 2888	8.46	6.47e	5.51e	4.91d
KRL 283	8.94	7.04bc	7.34ab	6.17ab
WH 1080	8.33	7.36b	6.75c	5.24cd
C 306	9.54	8.02a	6.20d	5.37c
KRL 330	8.78	7.34b	7.51a	5.97b
KRL 210	8.41	6.91cd	6.88bc	5.52c
General Mean	8.85	7.12	6.80	5.75
CV(%)	6.50	4.09	5.29	4.50

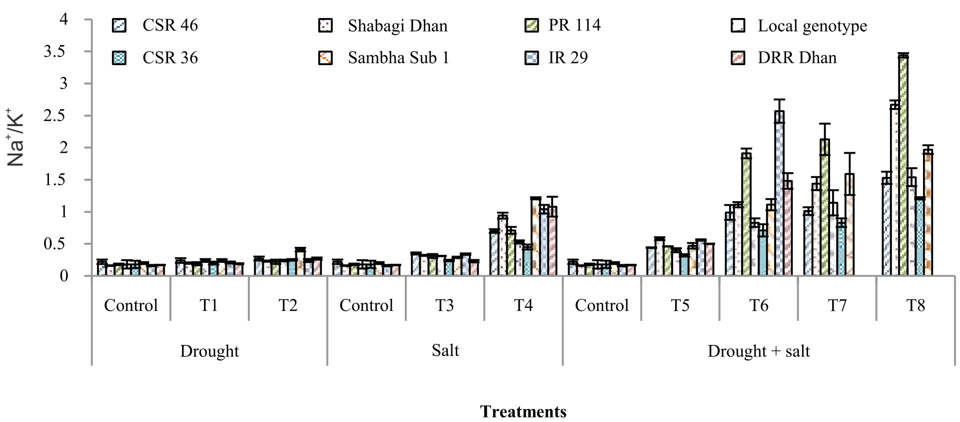


Fig.49. Effect of salinity and drought stresses on Na^+/K^+ in Rice varieties differing in their tolerance.

Drought stress - C 306 > WH 1080 = KRL 330 = KRL370 = KRL 283 > KRL 210> KRL 433 > HD 2888

Salt stress - KRL 330 = KRL 370 = KRL 283 > KRL 210 > KRL 433 = WH 1080 > C 306 > HD 2888

Salt + Drought stress - KRL 370 = KRL 433 = KRL 283 > KRL 330 > KRL 210 = C 306 > WH 1080 > HD 2888

Rice Crop

Nine genotypes i.e. DRR Dhan 42 (drought tolerant), Vandhana (drought tolerant), Shabagi dhan (drought tolerant), Sambha sub1 (drought sensitive), CSR 36 (Salt tolerant), CSR 46 (salt tolerant), IR 29 (salt sensitive), PR 114 (salt sensitive), Local genotype (selected from highly sodic waterlogged fields of Jodhpur village of Patiala district) were selected for the study. Under combined stress of 100 mM NaCl + 50 % WD, the highest value of Na^+/K^+ ratio in shoots was recorded for PR 114 (3.44) and lowest in CSR 36 (1.21).

The rice varieties CSR 36, CSR 46 and Local landrace performed well under individual as well as combined stresses in comparison to other varieties, respectively. Higher proline accumulation was observed in Sambha Sub1 (5.19 mg g^{-1} FW) with increasing stress conditions whereas CSR 46 showed the minimum accumulation (3.77 mg g^{-1} FW). Under combined stress of 100 mM NaCl + 50 % WD, the trend of per cent reduction in grain yield is as followed: Landrace > CSR 36 > CSR 46 > Shabagi dhan > Sambha Sub1 > IR 29 > PR 114 > DRR Dhan in comparison to BAW. The trend of per cent reduction in grain weight/plant under different stress condition was as followed:

Drought stress – Landrace > CSR 36 > CSR 46 > PR 114 > Sambha Sub1 > DRR Dhan > IR 29 > Shabagi dhan

Salt stress – Landrace > CSR 36 > CSR 46 > PR 114 > Shabagi dhan > DRR Dhan > Sambha Sub1 > IR 29

Salt + Drought stress - Landrace > CSR 36 > CSR 46 > Shabagi dhan > Sambha Sub1 > IR 29 > PR 114 > DRR Dhan

Agroforestry in Salt Affected Soils

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

Ber or Indian jujube (*Zizyphus mauritiana* L.) is a hardy fruit crop adapted to adverse agro-climatic conditions such as high temperature, water stress and salinity. Due to better adaptability to such adverse conditions and low input needs, it is commercially grown in arid and semi-arid areas. In India, scion cultivars of Indian jujube are commonly budded on *Z. rotundifolia* seedlings. In some other countries, a wild species *Z. spina-christi* is also used as rootstock. Although several studies suggest moderate salt tolerance in both *Z. rotundifolia* and *Z. spina-christi*, little is known about their response to irrigation with sodic waters containing high residual sodium carbonate (RSC). Similarly, virtually nothing is known about the reaction of different *Zizyphus* rootstock species under shallow saline watertable conditions. In light of these facts, two different experiments were conducted with objectives: i) to evaluate the response of *Z. rotundifolia* and *Z. spina-christi* seedlings to irrigation with high RSC water, and ii) to assess different rootstocks for *in situ* orchard establishment under saline field conditions.

Sodic water experiment

In this experiment, six month old seedlings of *Z. rotundifolia* (ZR) and *Z. spina-christi* (ZS) were irrigated with normal and sodic waters having RSC levels of 3, 6 and 9 meq L^{-1}. After transfer to ceramic pots containing approximately 16 kg normal soil (pH_e ~8.3), the plants were pruned to a uniform height. Irrigation treatments were withheld at the onset of injury symptoms and data were recorded. In both the species, stem length only marginally declined up to RSC_{iw} level of 6 meq L^{-1}. Even at the highest RSC_{iw} level (9 meq L^{-1}), stems were only about 15% and 20% shorter in ZS and ZR, respectively, compared to control. Root length did not significantly decline with increasing RSC in irrigation water in both the species. Fresh and dry weights of shoots and roots also declined with increasing RSC_{iw} level in both ZS and ZR.

Chlorophyll content in leaves, expressed as SPAD value, decreased by ~13, 22 and 25% in ZS at RSC_{iw} levels of 3, 6 and 9 me L^{-1}, respectively as compared to control. The corresponding reductions in SPAD values in ZR were ~11, 18 and 22%, respectively. Chlorophyll fluorescence (CF) in leaves also significantly decreased with increase in the sodicity of irrigation water. At RSC_{iw} level of 9 me L^{-1}, CF was nearly 19 and 8% less than control in ZS and ZR, respectively. Leaf proline levels consistently increased with the successive increase in RSC_{iw} indicating that proline plays a major role in osmoregulation in salt stressed ZS and ZR seedlings. While leaf proline content remained unchanged up to RSC_{iw} level of 3 me L^{-1}, both the species showed nearly two times higher proline content at 9 me L^{-1} RSC_{iw} compared to control. In contrast, total soluble proteins (TSP) decreased in leaves with increase in RSC_{iw}. At RSC_{iw} level of 9 meq L^{-1}, for example, ZS and ZR displayed ~76% and 45% less TSP compared to the respective control.

Na^+ content significantly increased in different vegetative parts with increase in RSC_{iw} in both the rootstocks, albeit in different ways. Increase in leaf Na^+ (% DW) was relatively greater in ZS than in ZR at a given RSC_{iw} indicating different mechanisms for Na^+ exclusion from leaves. Although stem Na^+ was invariably higher in ZR than in ZS regardless of RSC_{iw}, ZS plants showed considerable increases in Na^+ accumulation in stem

Table 49: Na^+ and K^+ (%DW) partitioning in ber rootstocks under varying RSC_{iw} levels.

Treatment (RSC; meq L^{-1})	Leaf			Stem			Root		
	Na^+	K^+	Na: K ratio	Na^+	K^+	Na: K ratio	Na^+	K^+	Na: K ratio
				Z. spina-christi					
Control	0.33d	2.1a	0.16d	0.11d	1.7a	0.06d	0.29d	2.6a	0.11d
3.0	0.39c	1.9b	0.21c	0.15c	1.4b	0.11c	0.44c	1.4b	0.31c
6.0	0.46b	1.2c	0.37b	0.29b	0.9c	0.31b	0.54b	0.9c	0.57b
9.0	0.56a	1.2c	0.47a	0.34a	0.8d	0.44a	0.94a	0.9c	1.10a
LSD at 5%	0.01	0.15	0.03	0.02	0.09	0.03	0.04	0.12	0.04
				Z. rotundifolia					
Control	0.24d	2.0a	0.12d	0.31d	1.9a	0.17c	0.38c	1.8a	0.22c
3.0	0.26c	1.6b	0.16c	0.37c	1.6b	0.24c	0.40bc	1.4b	0.28c
6.0	0.32b	1.6b	0.20b	0.43b	1.3c	0.34b	0.45b	1.2c	0.38b
9.0	0.39a	1.3c	0.30a	0.47a	0.8d	0.58a	0.70a	0.9d	0.75a
LSD at 5%	0.01	0.21	0.03	0.02	0.19	0.08	0.06	0.16	0.09

Means (n=3) with at least one letter common are not statistically significant using Fisher's Least Significant Difference.

tissues with increasing sodicity compared to control. A similar trend was noted for root Na^+ which increased by about 52, 86 and 224% in ZS, and by about 5, 18 and 84% in ZR than control at RSC_{iw} levels of 3, 6 and 9 meq L^{-1}, respectively. Although leaf K^+ declined in both the rootstocks with increasing RSC_{iw}, reductions were relatively lesser in ZR than in ZS. For example, leaf K^+ decreased by ~43% in ZS and by ~35% in ZR at the highest RSC_{iw} level of 9 meq L^{-1}. A similar trend was noted for stem and root K^+ contents as ZR showed much lower decreases in K^+ than ZS at different RSC_{iw} levels. Owing to higher Na^+ levels and the consequent K^+ depletion, ZS plants showed considerable increase in Na: K ratio in different plant parts at a given RSC_{iw} level. In leaves, stems and roots, Na: K ratio was nearly three-, seven- and tenfold higher in ZS while the corresponding increases were only about threefold higher in ZR (Table 49).

Overall, plant growth in *Z. spinachristi* and *Z. rotundifolia* only marginally declined up to RSC level of 6.0 meq L^{-1}. Leaf proline levels consistently increased with increasing RSC_{iw}, albeit to a greater extent in *Z. spinachristi*, indicating its role as a major osmolyte under salt stress. Na^+: K^+ ratio was higher at a given RSC_{iw} in stems of *Z. spinachristi* and in both stems and roots of *Z. rotundifolia* than in leaves.

Rootstock trial and *in situ* orchard establishment under saline conditions

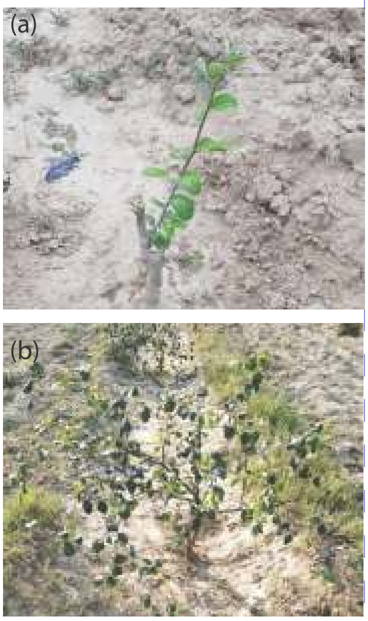
Consistent with the experimental objectives, seedlings of four different species, *viz.*, *Z. rotundifolia* (Hisar; ZRH), *Z. rotundifolia* (Bikaner; ZRB), *Z. spina-christi* (ZS) and *Z. mauritiana* cv Tikadi (ZMT) were planted under saline field conditions at Nain Experimental Farm, Panipat, India. Planting was done during September, 2016 using six-month old seedlings. Soil EC_e of the experimental field was ~5 dS m^{-1} at surface (0-15 cm) and increased with the depth, *i. e.*, 6.3, 6.8 and 5.6 dS m^{-1} at 15-30 cm, 30-60 cm and 60-100 cm depths, respectively. Saline irrigation treatments [3 dS m^{-1} (control) and 6 dS m^{-1}] were continued after October, 2016. Growth and mineral ion composition in rootstock plants were recorded in April, 2017 followed by their pruning to a uniform height. *In situ* budding using Gola scion was done during July, 2017.

Irrigation with saline water (6 dS m^{-1}) caused significant decrease in stem length in all the rootstocks. The highest reduction in stem length (~36%) compared to control was noted

Table 50: Effect of salinity on plant growth in ber rootstocks.

Rootstock	EC_{iw} ($dS\ m^{-1}$)	Stem length (cm)	Stem girth (cm)	Plant spread (cm)		Pruning fresh weight (g)	Pruning dry weight (g)
				N-S	E-W		
Z. otundifolia (Hisar)	3.0	163.7cd	3.3b	68.0de	73.0d	377.7de	159.3d
	6.0	105.3f	2.1e	60.3f	63.7e	253.0f	114.0f
Z. rotundifolia (Bikaner)	3.0	174.3bc	3.1b	70.3cd	63.3e	417.0c	182.0c
	6.0	141.0e	2.8cd	62.3ef	60.7e	398.0cd	150.3de
Z. spina-christi	3.0	190.0a	3.7a	130.7a	152.3a	903.3a	343.0a
	6.0	151.7de	2.8c	99.3b	105.0b	697.0b	305.3b
Z. mauritiana cv. Tikadi	3.0	183.0ab	2.7cd	93.0b	98.3b	370.0e	146.7e
	6.0	146.7e	2.6d	76.0c	84.3b	234.7f	102.7g

Means (n=3) with at least one letter common are not statistically significant at 5% level of significance.



Initial growth after in situ budding (a) and well developed shoot system of Gola scion budded on *Z. spina-christi* rootstock (b).

in ZRH whereas it was ~20% in others. Similarly, stem girth declined by ~35, 10, 24 and 5% in ZRH, ZRB, ZS and ZMT, respectively with increase in EC_{iw} from 3 to 6 $dS\ m^{-1}$. Canopy spread in different rootstocks was also adversely affected by the increase in salinity. Dry weight of pruned shoots decreased by ~28%, 17%, 11% and 30% in ZRH, ZRB, ZS and ZMT, respectively, at EC_{iw} level of 6 $dS\ m^{-1}$ compared to control (Table 50). Reductions in plant growth were presumably caused by higher Na^+ and reduced K^+ contents in the leaves of salinized plants. While leaf Na^+ increased by ~71%, 38%, 40% and 58%, leaf K^+ declined by ~24%, 21%, 12% and 22% in ZRH, ZRB, ZS and ZMT plants respectively, at EC_{iw} 6 $dS\ m^{-1}$ compared to control. Leaf proline was invariably higher in plants receiving 6 $dS\ m^{-1}$ water. The highest increase (~33%) in leaf proline compared to control was noted in ZRH while the lowest increase (~7%) was observed in ZRB.

After pruning to a uniform height in April, 2017, *in situ* budding was carried out using healthy scion buds of Gola variety in July, 2017. Budding success was ~53, 93, 87 and 80% on ZRH, ZRB, ZS and ZMT rootstocks, respectively. Initial observations on plant growth and leaf mineral composition suggest the feasibility of *in situ* budding using different rootstocks under saline field conditions. It is also clear that *Z. spina-christi* and *Z. mauritiana* cv. Tikadi can also be used as rootstocks in place of conventionally used *Z. rotundifolia*.

Enhancing productivity potential of saline soil through agro-forestry interventions (R. Banyal, Ajay K. Bhardwaj, Parveen Kumar, Raj Kumar and Rahul Tolia)

Rehabilitation of saline agro-ecosystems with perennial plant species through agroforestry approaches is effective way to increase farm income. An experiment was started at institute experimental farm, Nain, Panipat. The treatments include three land use systems (LU_1-tree+crop, LU_2-sole tree and LU_3-sole crop) and five irrigation regimes (I_1-good quality available water EC_{iw}<1dS m^{-1}, I_2- EC_{iw} 4dS m^{-1}, I_3- EC_{iw} 8dS m^{-1}, I_4- EC_{iw} 12dS m^{-1} and I_5-no irrigation-control) in plantations and four i.e. I_1 EC_{iw} <1 dSm^{-1}, I_2- EC_{iw} 4 dSm^{-1}, I_3- EC_{iw} 8 $dS\ m^{-1}$ and I_4- EC_{iw} 12 $dS\ m^{-1}$ in companion crops (Pearl-millet in *rabi* and Mustard in *kharif* seasons). In another experiment, five agroforestry tree species were planted in saline soils and irrigated with saline water to develop predictive allometric models for biomass and carbon estimation in such ecosystems. The effect of agro-forestry systems and tree plantations with different treatments are being monitored on soil, ground water fluctuations and its quality.

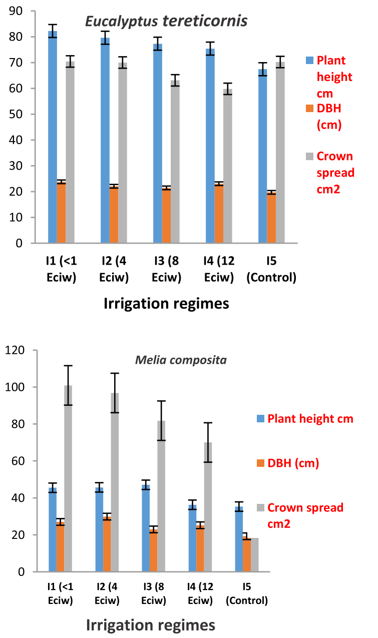


Fig. 50 and 51. Growth of Eucalyptus and Melia plantations under varying saline irrigation regimes

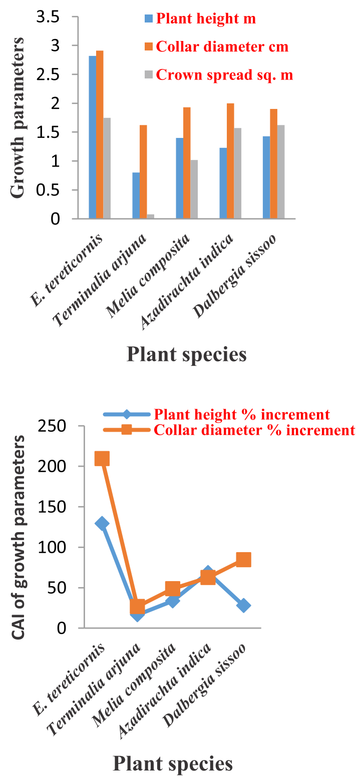


Fig. 52&53. Growth and CAI of agroforestry trees in saline soils

Irrespective of irrigation regimes, average tree growth parameters i.e. plant height, DBH and crown spread in three year old *Eucalyptus* and *Melia* plantations were 7.44 & 4.24 m, 22.01 & 24.85 cm and 6.74 & 7.82 m^2, respectively (Fig. 50 & 51). Lowest values of all the growth parameters were recorded in control (no irrigation) followed by high saline water irrigation (EC_{iw} 12 dS m^{-1}). The highest growth was observed in best available water. The highest yield (0.813 t ha^{-1}) of mustard was recorded in best available water irrigation and lowest 0.527 t ha^{-1} with 12 dS m^{-1} saline water irrigation. About 11 & 25% reduction was observed in mustard yield under *Melia* and *Eucalyptus* plantations, respectively than the sole/open crop land use. Similar trend was observed in pearl-millet. There was 3.25 & 8.62% decrease in pearl-millet yield under *Melia* and *Eucalyptus*p, respectively than the sole crop . The soil EC increased with the increase in salinity level in irrigation regimes. The EC values were higher in sub-surface (15-30 cm depth) than surface soils in both the systems. *Eucalyptus* based land use recorded high EC as compared to *Melia* and sole crop, however, soil pH did not change.

After two years of plantation, *Azadirachta indica* showed superior etablishment among all the five agro-forestry trees (*Eucalyptus tereticornis*, *Terminalia arjuna*, *Melia composita*, *Azadirachta indica* and *Dalbergia sissoo*) on saline soils and saline water irrigation. The maximum current annual increment (CAI) was observed in *Eucalyptus* (209.6%) and minimum in Arjun (26.56%) (Fig. 52 & 53). *Azadirachta indica*, *Melia composita* and *Dalbergia sissoo* recorded similar growth. Soil EC decreased from its initial level at the time of out-planting in 2015 to the current level in 2017 in all the tree species. The soil EC was low at surface and found to increase with increase in depth upto 120 cm. The soil pH did not show any specific trend of increase and/or decrease with the varying soil depths.

Eucalyptus tereticornis

Dalbergia sissoo

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

Bio-drainage could be a viable option to counter the bottlenecks of conventional engineering based approaches. There is lack of basic and applied information of the tree species exacting water from shallow saline water tables except *Eucalyptus*. In spite of severity and extent of the problem, the practice of bio-drainage has not become popular with the farmers. Impact assessment data of bio-drainage technology on socio-economic aspects is equally important for holistic implementation of the technology. Therefore the work has been initiated to address the issues of raising bio-drainage plantations and to evaluate their impact on reclamation of saline waterlogged areas.

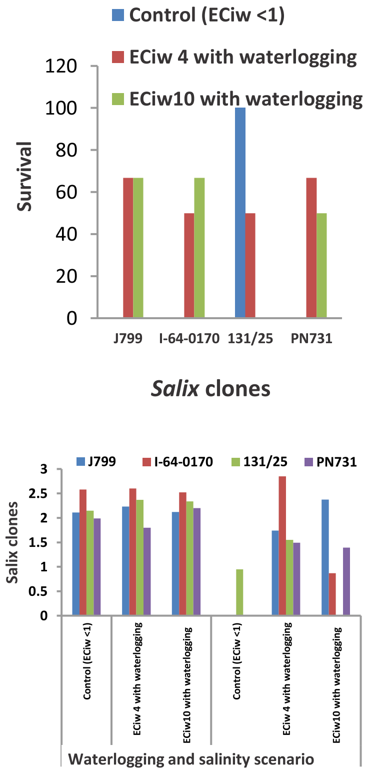


Fig. 54&55.Performance of Salix clones in lysimeters

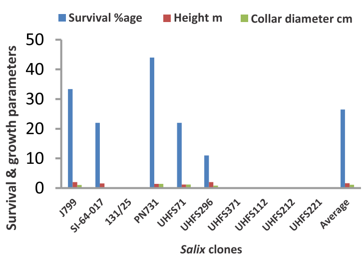


Fig. 56. Performance of Salix clones in field conditions

Salix spp. and *Acacia ampliceps* were selected to work out the possibility of alternatives to *Eucalyptus* on saline waterlogged soils. The experiment was initiated by creating three scenarios of waterlogging with low and high salinity including normal situation. The out-planting of saplings was done in closed lysimeters during May 2017 after procuring from Dr YS Parmar UHF, Nauni, Solan Himachal Pradesh. All the planted clones gave average 43% survival with order being 131/25 >J799 >PN731 =I-64-0170. Clone PN731 and I-64-0170 gave almost equal survival (Fig. 54 & 55). *Acacia ampliceps* gave 100% survival in all the three scenarios. Collar diameter increment was observed in all *Salix* clones and *A. ampliceps* saplings. Field evaluation of 10 *Salix* clones has been initiated at farmers' field but initial survival was very low. Clones J799 and PN 731 performed better than others in terms of establishment and growth parameters (Fig. 56). Soil EC at plantation site ranged from 2.60 to 9.80 dS m^{-1} across the varying depths of 0-120 cm. Likewise, soil pH ranged from 7.86 to 9.66. The ground water table is around 4 feet thus giving the waterlogged conditions to the site.

Development of *Prosopis* germplasm bank

Eight species of *Prosopis* were collected from RRS, Lucknow, CIAH, Bikaner, CAZRI, Jodhpur and locally from Karnal and Bir Forest Hisar and planted in the field in August, 2017. Only three species namely *P. cinreria, P. juliflora* and *P. pallida* were already available in institute. Process of raising nursery stock of other collections is in progress and the same will be out-planted in the coming rainy season of 2018.

Identification of high yielding and salt tolerant genotypes of pomegranate

(Rajkumar, Anita Mann, Anshuman Singh and R. K. Yadav)

To evaluate the genotypes of pomegranate, under saline conditions different genotypes were collected from Rajasthan. The collected cuttings were named *w.r.t* respective districts of collection *i.e.* Jaipur 1, Jaipur 2, Jaipur 3, Ajmer 1, Ajmer 2, Ajmer 3, Ajmer 4, Ajmer 5, Rajasmand 1, Rajasmand 2, Rajasmand 3, Rajasmand 4,Udaipur 1, Udaipur 2, Udaipur 3, Pali 1, Jodhpur 1, Nagaur, Ganesh and Bhagwa. After conducting a nursery experiment on the survival at different salinity levels, these genotypes were planted for further evaluation under natural saline soils (EC_e upto 15.61 dS m^{-1}) at ICAR-CSSRI Experimental Fram Nain, Panipat (Haryana).

Performance of pomegranate genotypes at Nain Experimental Farm after 18 months of planting

Table 51: Chemical properties soil in progeny block at ICAR-CSSRI Experimental Farm

Depths	pH	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Calcium (me L^{-1})	Magnesium (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	29.180	210.1	1.87	1.93
45-60	8.17	0.13	120.21	27.840	204.1	1.80	1.23

Pomegranate genotypes at Nain Experimental Farm, Panipat

Tolerant genotypes of pomegranate, screened at different salinity levels under nursery conditions, have been planted at Nain Experimental Farm in March, 2016. After eighteen months of planting in the field, different parameters of vegetative growth were recorded as shown in Table 51. The maximum plant height (207 cm) was observed in genotype Jaipur 1 followed by 203 cm in Ajmer 2 and 196 cm in Jaipur 2. The highest average diameter of the plants was recorded in Udaipur 2 (5.3 cm), followed by Udaipur 3 (5 cm) and Jaipur 1(4.9 cm), respectively. The maximum plant spread NS (185.8 cm) was recorded in Rajasmand 3, followed by Jaipur 2 (162.9 cm) and Jaipur 4 (160.7 cm), respectively. The maximum plant spread (188.43cm) EW was recorded in Jaipur 1, followed by in Rajasmand 3 (180.1 cm) and Udaipur 3 (175.8 cm), respectively. On the basis of vegetative growth, genotypes Jaipur 1, Jaipur 2, Udaipur 3 and Rajasmand 3 showed significantly more vegetative growth under saline soils.

Porline content in the leaves significantly differed between various genotypes; the maximum proline content was recorded in the leaves of Ajmer 1 (1110.7 µg g^{-1} FW) followed by Udaipur 1 (1088.4 µg g^{-1} FW) and Ganesh (1019.0 µg g^{-1} FW). Although other bio- & physico-chemical parameters like RWC (%), chlorophyll (mg g^{-1}FW), Na^+(%), K^+(%), Ca^{+2} (ppm) and Na^+/K^+(%) in leaves were found non-significant. Data related to fruit quality parameters was recorded during two seasons *i.e.* Ambe bahar and Mrig bahar. Date in showed that during *ambe bahar* crop, the maximum fruit length was recorded in Udaipur 2 (7.6 cm), followed by Jodhpur 1 (7.2 cm) and Jaipur 2 (7.1 cm), respectively. Similarly, Fruit breadth in Udaipur 2 was 7.5 cm, followed by Rajasmand 4 (7.5 cm) and Jaipur 2 (7.3 cm), respectively. TSS (°B) showed no significant difference among different genotypes. The maximum fruit weight was found in Udaipur 2 (234.00 g), followed by Rajasmand 4 (206.67 g) and Jaipur 2 (206.00 g), respectively. Similarly, the maximum fruit volume was (221.67 cm^3) in Udaipur 2, followed by Rajasmand 4 (190.09 cm^3) and Jodhpur 1 (190.00 cm^3). As far as number of grains per fruit are concerned, the maximum found (679.33) in Jaipur 2, followed by Udaipur 2 (667) and Rajamand 4 (614.33) (Table 52). The highest weight of grains per fruit was (154.99 g) in Udaipur 2, followed by Rajasmand 4 (139.49) and Jodhpur 1 (139.28 g); however, the maximum weight of 100 grains was recorded in Rajasmand 4 (24.02 g), followed by Udaipur 3 (23.90 g) and Rajasmand 3 (23.16 g); while the thickness of rind varies non-significantly from 0.20 to 0.37 cm in different genotypes.

As per the data recorded for the *mrig bahar* crop the maximum fruit length (6.60 cm) was recorded in Jaipur 2, followed by Jaipur 1 (6.27 cm) and Rajasmand 4 (5.93 cm), respectively. Similarly, the fruit breadth was found the maximum (5.60 cm) in Jaipur 1, followed by Jaipur 2 (5.50 cm) and Ganesh (5.47 cm), respectively. The total soluble solids were found the maximum (14.97 °B) in Jaipur 1, followed by Bhagwa (14.64 °B) and Pali & Jodhpur (14.63 °B), respectively. The maximum fruit weight was 154.67 g in

Table 52: Fruit quality parameters in pomegranate genotypes *ambe bahar* crop

Genotype	Fruit length (cm)	Fruit breadth (cm)	TSS (^{0}B)	Fruit wt (g)	Fruit volume (cm^3)
Jaipur 1	5.97^{DE}	5.00^{E}	14.30	109.33^{H}	93.33^{G}
Jaipur 2	7.07^{ABC}	7.27^{AB}	14.03	206.00^{AB}	189.67^{AB}
Ajmer 1	5.77^{E}	5.83^{DE}	14.63	141.33^{EFGH}	117.67^{DEFG}
Ajmer 3	6.43^{BCDE}	6.50^{BCD}	14.23	155.00^{DEFG}	134.67^{CDEFG}
Rajasmand 1	6.13^{CDE}	6.33^{CD}	14.97	131.00^{FGH}	114.00^{EFG}
Udaipur 1	6.30^{BCDE}	6.43^{BCD}	14.47	158.33^{CDEFG}	137.67^{CDEFG}
Udaipur 2	7.63^{A}	7.50^{A}	14.13	234.00^{A}	221.67^{A}
Rajasmand 3	6.87^{ABCD}	6.67^{ABCD}	13.77	181.67^{BCDE}	157.33^{BCDE}
Rajasmand 4	6.93^{ABCD}	7.47^{A}	14.40	206.67^{AB}	190.09^{AB}
Udaipur 3	6.93^{ABCD}	7.10^{ABC}	14.20	202.00^{ABC}	177.33^{ABC}
Pali 1	6.50^{BCDE}	6.60^{ABCD}	14.63	156.33^{DEFG}	150.00^{BCDEF}
Jodhpur 1	7.17^{AB}	7.07^{ABC}	14.27	193.00^{ABCD}	190.00^{AB}
Ganesh	6.47^{BCDE}	6.73^{ABCD}	14.61	173.00^{BCDEF}	163.33^{BCD}
Bhagwa	5.57^{E}	5.27^{E}	14.50	128.00^{GH}	106.00^{FG}
CV(%)	8.97	8.36	02.97	15.62	18.65
LSD at 5%	0.9863	0.9194	NS	44.475	47.91

Table 53: Fruit quality parameters in pomegranate genotypes *Mrig Bahar* crop

Genotype	Fruit length (cm)	Fruit breadth (cm)	TSS (^{0}B)	Fruit wt (g)	Fruit volume (cm^3)
Jaipur 1	6.27^{AB}	5.60^{A}	14.97^{A}	136.33^{AB}	136.67^{A}
Jaipur 2	6.60^{A}	5.50^{A}	14.17^{BCD}	154.67^{A}	133.33^{AB}
Jaipur 3	4.53^{CD}	3.90^{D}	14.47^{AB}	69.00^{EF}	60.00^{DE}
Ajmer 1	5.13^{BCD}	5.13^{ABC}	14.13^{BCD}	98.33^{CDEF}	80.02^{CD}
Ajmer 3	5.77^{ABC}	5.27^{AB}	14.40^{AB}	110.67^{BC}	101.67^{ABC}
Rajasmand 1	3.87^{D}	4.23^{BCD}	14.27BC	67.00^{F}	38.33^{E}
Udaipur 2	4.60^{CD}	4.93^{ABCD}	14.50^{AB}	101.00^{BCDEF}	96.67^{BCD}
Rajasmand 3	5.23^{ABCD}	5.00^{ABC}	13.60^{D}	104.33^{BCDE}	88.33CD
Rajasmand 4	5.93^{ABC}	5.23^{ABC}	13.63^{CD}	108.00^{BCD}	88.33^{CD}
Udaipur 3	4.70^{CD}	4.20^{CD}	14.20^{BCD}	72.67^{DEF}	73.33^{CDE}
Pali 1	5.30^{ABCD}	5.50^{A}	14.63^{AB}	100.00^{BCDEF}	93.00^{CD}
Jodhpur 1	4.87^{BCD}	4.57^{ABCD}	14.63^{AB}	100.67^{BCDEF}	91.67^{CD}
Ganesh	5.77^{ABC}	5.47^{A}	14.58^{AB}	101.00^{BCDEF}	98.33^{ABCD}
Bhagwa	5.83^{ABC}	5.23^{ABC}	14.64^{AB}	114.33^{BC}	91.67^{CD}
CV(%)	16.31	12.47	2.66	21.53	25.65
LSD at 5%	1.4544	1.0429	0.6408	37.107	39.099

Jaipur 2, followed by Jaipur 1 (136.33 g) and Bhagwa (114.33 g), respectively. Whereas the highest fruit volume was recorded in Jaipur 1 (136.67 cm^3) followed by Jaipur 2 (133.33 cm^3) and Ajmer 3 (101.67), respectively.

The data for fruit quality in *mrig bahar* crop (Table 53) showed that the highest weight (101.36 g) of grains per fruit was observed in Jaipur 2, follwoed by Jaipur 1 (82.97 g) and Ajmer 3 (165.16 g), respectively. However, the thickness of rind, the weight of 100 grains and number of grains per fruit showed non-significant difference between various pomegranate genotypes.

On the basis of seed mellowness, genotypes Jaipur1, Ajmer1, Ajmer 3, Udaipur 2, Rajasmand 3, Rajasmand 4, Jodhpur 1, Ganesh and Bhagwa have been categoriesed as soft seeded. The perncent juice content varied from 27.94 to 42.79 % in *ambe bahar* crop and 33.17 to 42.79 % in *mrig bahar* crop, respectively.

On the basis of qualitative fruit parameters during *Ambe & Mrig Bahar*, genotypes Ajmer 3, Rajasmand 4, Jodhpur 1 and Ganesh showed considerable superiority over other genotypes under natural saline soils. On the basis of vegetative growth parameters, genotypes Jaipur 1 & 2, Ajmer 2, Rajasmand 3 showed considerable possibility for use as rootstock in saline soils. Efforts are underway to study the effects of salinity to arrive on conclusive evidence regarding the suitability of these genotypes for commercial cultivation in saline tracts.

Evaluation of potential Olive germplasm for salt affected soils (Manish Kumar and Rakesh Banyal)

Considering the importance of commercial value of olive (*Olea europea* L.) oil, and its potential cultivation on salt affected soils as a tree borne oilseed crop due to its resistance to drought, lime and salinity, a project was initiated with the objectives: to evaluate and identify olive cultivars collected from different area/sources suitable for salt affected soils, and to work out threshold salt tolerance through physiological and biochemical traits. Olive cultivation in India is still in its infancy stage and introduced to a few pockets in the states of Jammu & Kashmir, Himachal Pradesh, Uttrakhand, Odisha and Rajasthan. Different sources of olive cultivation and nursery growers were contacted for its basic orchard information and its cultivation potential in India. A total of 8 olive cultivars have been selected for evaluation against variable salinity and sodicity levels in nursery conditions. Four olive cultivars *viz*. Coratina, Frantoio, Leccino, Picholine were collected from Department of Horticulture, Ramban, J & K, while other four cultivars *viz*. Arbequina, Barnea, Koroneiki, Picual were procured from ROCL, Jaipur. Sixty four seedlings of each cultivar were collected and kept in nursery for further growth and survival assessment to find out tolerance level of salinity and sodicity.

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, V.K. Mishra, S.K. Jha, A.K. Singh, S.K. Singh and T. Damodaran)

Gypsum based sodic land reclamation technology is ineffective under shallow water table conditions (<2.0 m below ground surface). Subsurface horizontal drainage is a proven and well adaptable technology to lower water table under such conditions but the availability of natural gravity outlet is a major constraint in the adoption of the drainage technology in such area. Pumped outlet is further expensive go out of the reach of farmers. Salt accumulation is prominent on soil surface whereas continuous and excessive seepage in the deeper soil profile keeps salts moving along the seepage water in seepage prone area lowering the soil Ph at deeper depth. A need was felt long back to develop a sustainable technology for reclamation and management of waterlogged sodic soils. The idea of inverting low pH soil of deeper soil profiles upside down in a pre-specified soil column by elevating field bed resulted in a land modification technique for reclaiming waterlogged sodic soil.

Land modification based integrated farming with fish ponds and raised and sunken beds were considered as sustainable technology for reclamation and management of waterlogged sodic soils based on more than five year studies at Kashrawan village in Raebareli district of U.P. The fish pond model was initially tested over an area of 1 ha and raised and sunken bed model over an area of 0.40 ha. Raised and sunken bed system is most suitable technology for small land holding with minimum expense. Fish pond based integrated farming system model needs comparatively larger fields whereas the farmers of the regions have small fragmented landholding with poor resource base hence the model needed to be tested on small acreage. Standard design equations and guidelines need to be developed for calculating width of raised bed and length and width of elevated field beds. Development and standardization of location-specific integrated farming system for different farm holding sizes need to be studied with multilocation trials to investigate the necessity of alterations in pond design. A study on land modification based integrated farming system model under waterlogged and waterlogged sodic conditions was taken up in Sharda Sahayak Canal Command with the objectives: 1. To develop design criteria for fish pond and raised and sunken bed systems; 2. To study crop performance and land, water and crop productivity of different sizes of Integrated Farming System (IFS) models; 3. To study salt and water balance of integrated farming models and 4. To educate farmers and state functionaries through field exposure visits.

Study Sites and Distance from the Canal

Three study sites were selected in three villages namely Lalaikheda (Jitendra Singh), Patwakheda (Kalwati Devi) and Salempur Achaka (Sher Bahadur) of Lucknow district located at 80 m, 100 m and 90 m away from the canal, respectively. The experimental sites are about 50 km away from Lucknow towards Raebareli. Water table of the area fluctuated within a range of 0.00 to 1.50 m during rainy to extreme summer. Initial soil pH of the of Jitendra Singh, Kalawati and Sher Singh's fields ranged 8.96 to 9.69, 9.47 to 9.93 and 7.49 to 7.98 and corresponding EC ranged 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. The field of Sher Bahadur located at Salempur Achaka village is waterlogged only.

Construction of Integrated Farming System Models

Two Integrated Farming System (IFS) Models were constructed under waterlogged sodic conditions and one under waterlogged conditions by hiring JCB and hydraulic tractor trolley during the month of June 2015. The width of elevated/raised beds were kept minimum fitting with field shape and boundaries to keep salt movement minimum. Leveling of elevated field beds, raised beds and embankment were done using a tractor mounted leveling blade. The respective ponds area with Jitendra Singh, Kalawati and Sher Bahadur were 2356, 817 and 1225 m^2 and elevated/raised field beds were 2336, 1307 and 2041 m^2, respectively. Corresponding total area of IFS models were 4692, 2114 and 3266 m^2. Average soil pH of elevated beds immediately after construction up to 1.20 soil depths ranged 9.01 to 9.30, 9.20 to 9.85 and 8.00 to 8.27 with corresponding EC range of 0.188 to 0.562, 0.326 to 0.737 and 0.194 to 0.485 dS m^{-1}, at Jitendra Singh, Kalawati and Sher Singh's fields, respectively (Table 54).

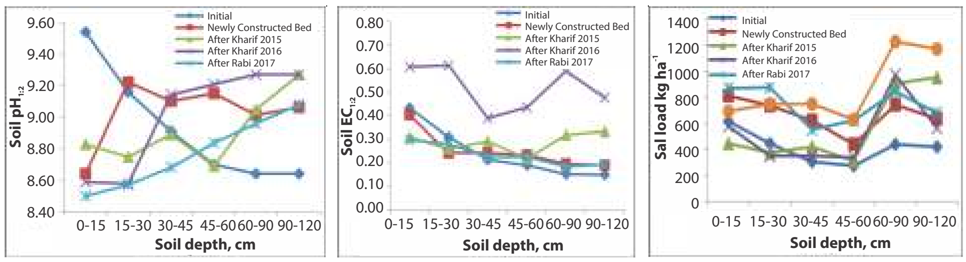
Table 54: Economic analysis of integrated farming system models at farmers' fields.

Name of Farmer	Crop	Area (m^2)	Yield (kg)	Input cost (Rs.)	Gross return (Rs.)	B:C
Jitender Singh	Pea	1122	230	1690	5750	3.40
	Moong	1122	80	1100	2995	2.72
	Okra	1122	600	4620	9000	1.95
	Sponge gourd	50	300	220	3000	13.64
	Pigeon pea	100	35	760	1908	2.51
	Fish	2353	6530	378020	587700	1.55
Kalawati	Wheat KRL 210	818	350	3666	8300	2.26
	Rice	1200	320	3122	4960	1.59
	Fish	817	80	2677	7200	2.69
Ser Bhadur	Mentha	900	7.0 (liter)	3456	11200	3.24
	Fish	1225	400	8520	42000	4.93

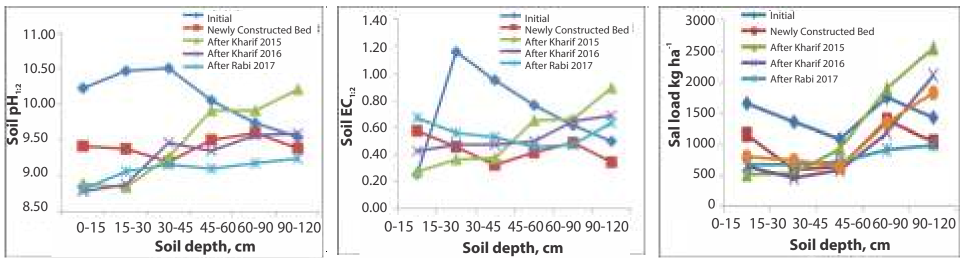
Crop performance and aquaculture in IFS Models

Soil pH, EC and salt load

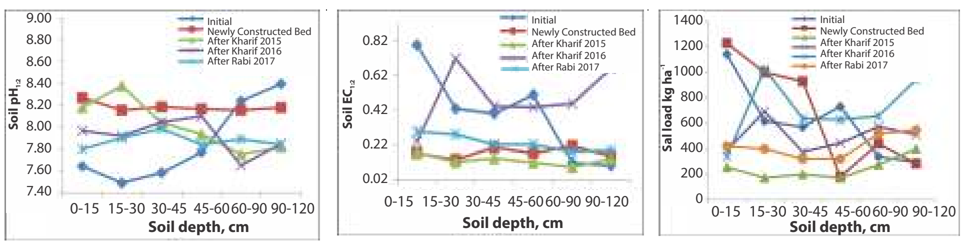
Variations in soil pH and EC with depth and time for Lalaikheda, Patwakheda and Salempur Achaka are shown in Fig. 58. Initial soil pH at Lalaikheda was 9.54, 9.16, 8.91, 8.70, 8.64 and 8.64 and that of newly constructed elevated field bed 8.64, 9.22, 9.10, 9.15, 9.01 and 9.06 at soil depths of 0-15, 15-30, 30-45, 45-60, 60-90 and 90-120 cm, respectively. The values of soil pH kept on reducing with time at respective soil depths and were observed to be only 8.50, 8.57, 8.68, 8.84, 8.96 and 9.08, respectively after the *Rabi* 2017. Initial soil pH at Patwakheda were 10.23, 10.47, 10.51, 10.05, 9.74 and 9.54 and that of newly constructed elevated field bed were 9.42, 9.38, 9.20, 9.50, 9.60 and 9.39 at soil depths of 0-15, 15-30, 30-45, 45-60, 60-90 and 90-120 cm, respectively. The values of soil pH at Patwakheda also followed the suit and kept on reducing with time for respective soil depths and were observed to be only 8.81, 9.06, 9.16, 9.10, 9.18 and 9.20, respectively after *Rabi* 2017. Sub-soil sodicity is still higher at deeper depths at Patwakheda. Soil at Salempur Achaka site was not sodic and ranged 7.64 to 8.40, 8.18 to 8.27 and 7.80 to 7.89 in a soil profile of 0-120 cm initially, after construction of elevated field bed and after Rabi 2016. EC never crossed the value of 2.0 dS m^{-1}. Total salt load in newly constructed raised bed were 4000, 6960 and 4093 kg and 5232, 6356 and 2547 kg after Rabi 2017 at Lalaikheda, Patwakheda and Salempur Achaka, respectively. There had been reduction in average salt loads at all the sites.



A) Lalaikheda (Jitendra Singh)



B) Patwakheda (Kalawati)



C) Salempur Achaka

Fig. 57. Variation of soil pH, EC and salt load in soil profile

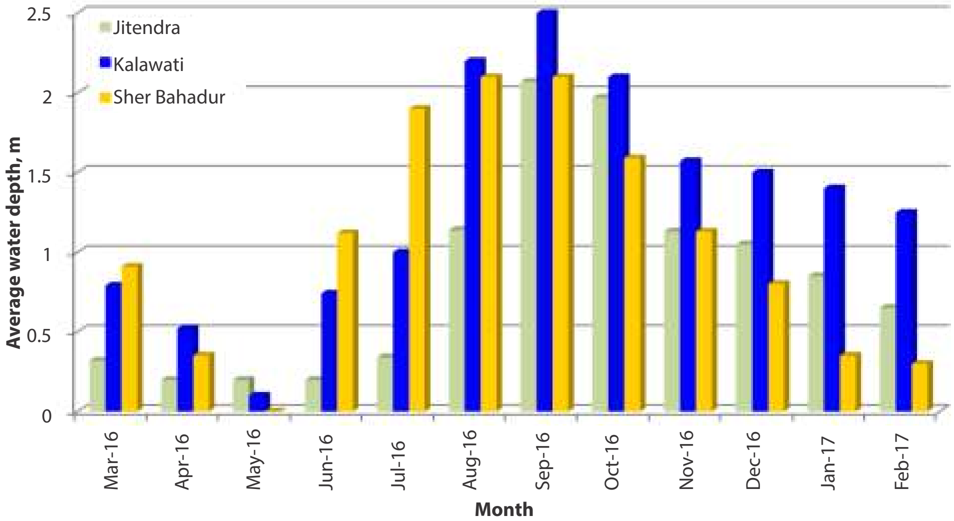


Fig. 58. Monthly average water volume in ponds

Water Depth Fluctuations in Pond

It may be seen from Fig. 58 that on an average, water depths in all pond remained above one meter depths only for four months (August to November). Water depths ranged 0.20 to 2.07 m, 0.10 to 2.20 m and 0.00 to 2.10 m at Lalaikheda, Patwakheda and Salempur Achaka sites, respectively. Corresponding water volumes in pond ranged 471.20 to 4876.92 m^3, 81.70 to 2042.50 m^3 and 0.00 to 2572.50 m^3. Rate of loss of water from Sher Bahadur pond has been observed to be the highest due to light texture of soil. Except for Kalawati pond, other two ponds need to be refilled in case of canal closures for a period of two months during summer season. One must plan fish stocking accordingly. Canal roaster may be very useful for preparing water filling plan in pond, if any.

Water Quality of Pond

EC and pH of pond water are the important quality parameters for fish production. EC and pH variations with time are shown in Fig. 59. EC of all three ponds never exceeded 0.9 dS m^{-1} and pH never exceeded 8.2. Thus water EC and pH have been always favourable for fish production in ponds.

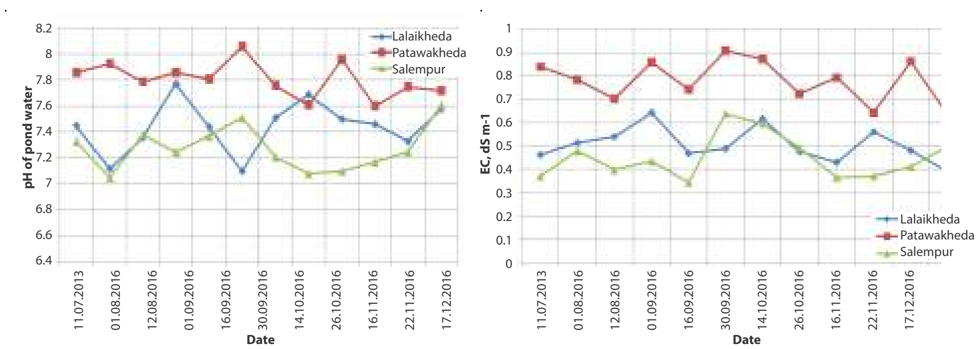


Fig. 59. Variation in pH and EC of pond water

Ground water recharge for remediation of fluoride contaminated water in Unnao district of U.P. (Chhedi Lal Verma, S.K. Jha and V. K. Mishra)

Excessive intake of fluoride causes a disease known as fluorosis in humans. BIS: 105001991 and WHO standards permit 1.5 ppm as a safe limit of fluoride in drinking water for human consumption. Rural people in several districts of Rajasthan are forced to consume water with fluoride concentrations of up to 24 ppm. The most common cause of fluorosis in India is fluoride-laden water derived from wells for drinking purpose. It has affected 17 states of India. There are number of techniques available for decontaminating water from fluoride such as Nalgonda Technique, use of bone char, use of ion-exchange resin, reverse osmosis and use of activated alumina. These techniques are still away from the reach of resource poor farmers. Ground water recharge has great potential to dilute fluoride concentration in ground water. Roof top harvesting, storage and its use for dilution of fluoride concentration can be also considered as a solution. The present study was conducted for remediation of fluoride contaminated water in Unnao district of U.P. with the following objectives: 1. To design and construct ground water recharge structures suiting to abundant water supply from rain and canal; 2. Study the efficacy of ground water recharge in diluting fluoride concentration; 3. To design and construct ground water skimming structures under shallow water table conditions and testing their suitability; 4. To design and test roof top harvesting and storage structure for a family and 5. Educating and training farmers/school students about fluoride dilution technology through meetings and goshthi.

Variations in fluoride content: Fluoride variations under medium and shallow water table conditions are shown in Fig. 60 and 61, respectively. After rainy season fluoride concentration in ground water decreases due to natural recharge and increases with increased ground water pumping during dry period. Mean fluoride concentrations during February 2016 and June 2016 were 2.467 and 2.503 ppm which reduced to 1.530 ppm during October 2016 at Sirsahakhera village. Similarly, mean fluoride concentration was 2.606 ppm and 2.924 ppm during February 2016 and June 2016 which reduced to 2.302 ppm during October 2017 due to natural recharge at Marksnagar village in Unnao.

Installation and Testing of Recharge Hand Pumps

One hand pump was installed under medium water table conditions in Sirsahakheda village located in Asoha block and the another one under shallow water table conditions

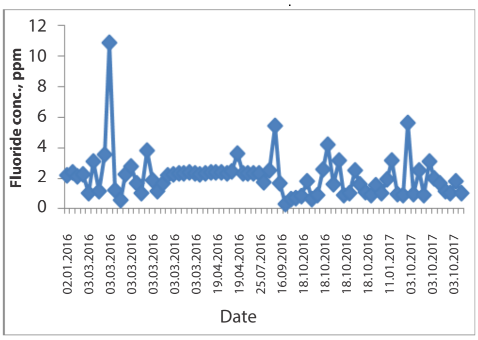


Fig. 60. Fluoride variations at Sirsahakhera. (Medium turned deep water table)

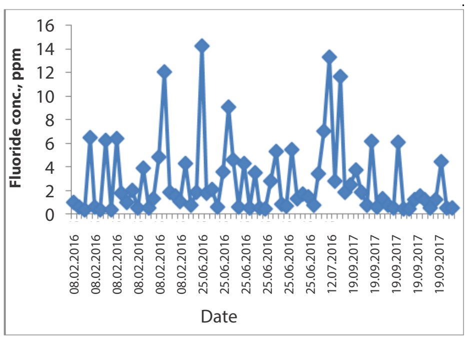


Fig. 61. Fluoride variations at Marksnagar. (Shallow water table)

in Marksnagar village in Nawabganj block of Unnao district. Pumping test of hand pumps were performed under medium and shallow water table conditions and it was observed that fluoride concentration increased in pumped water with time under medium water table condition and decreased with time under shallow water table condition. The range of fluoride concentration was 3.14 to 3.30 ppm under medium water table condition and 2.0 to 2.25 ppm under shallow water table conditions during pump testing. Fluoride concentrations under medium water table conditions without recharge remained always higher than 2.0 ppm during July 2015 to March 2016 (Fig. 62). The highest fluoride concentration was observed during the March 2016 (dry period) and minimum during October 2015 (after rainy season).

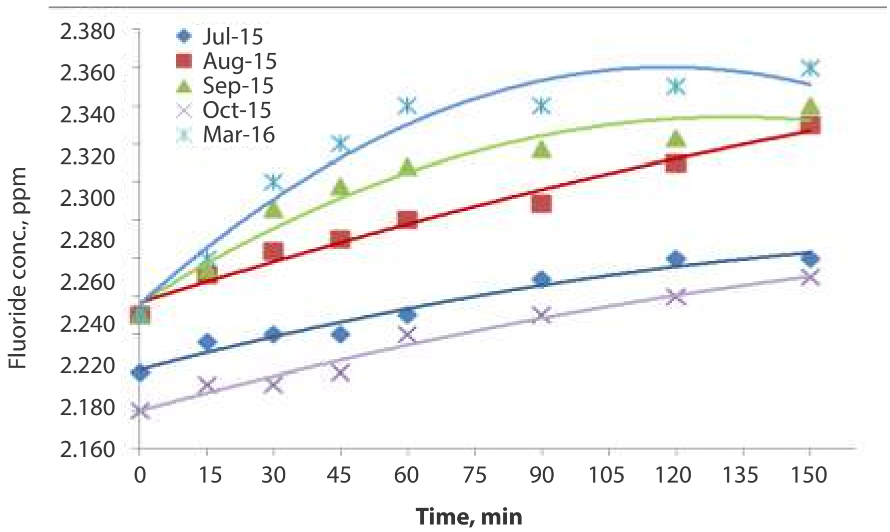


Fig. 62. Variation in fluoride concentration during pump test.

Integration of Roof Top Harvesting Structure

A roof top harvesting structure was installed during August 2016 in Sirsahakhera village. A plastic water tank of 200 liter storage capacity was fixed before the hand pump for temporary storage of rain water besides removing dirt and dust particle carried away along with harvested water. It facilitated the measurement of recharge water. Ground water recharge started during rainy season of 2016. Total recharge volume during rainy season was 28500 liter resulting in an average recharge rate of 310 liter per day. Total rainy days during year 2017 were only 122 days with a total recharge volume of 23636 liter resulting to average daily recharge rate of 194 liter per day. Pumping tests prior to recharge and after recharge. It can be seen from Fig. 62 that the fluoride concentration during 135 minutes pumping tests ranged 2.20-2.36, 2.21-2.36, 2.27-2.41 and 0.30-0.84 ppm on 02.01.2016, 03.03.2016, 19.04.2016 and 18.10.2016, respectively. Water table of Sirsahakhera has gone below 10 m hence shallow hand pumps failed completely hence pump test could not be performed during 2016. After ground water recharge the fluoride concentration reduced drastically making ground water safe for human consumption.

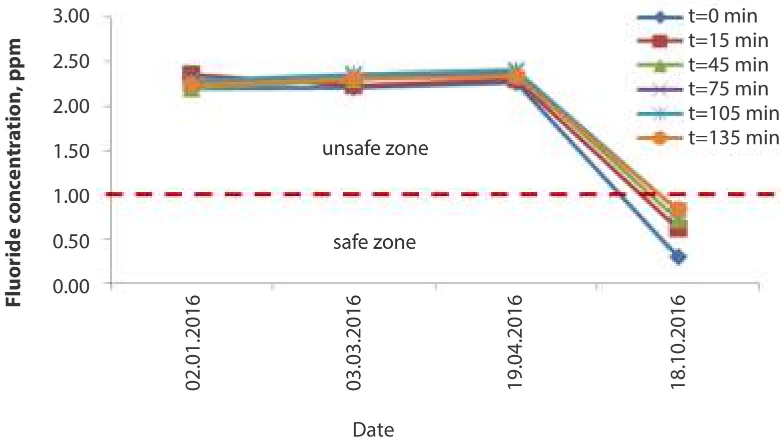


Fig. 63. Variation of fluoride concentration before and after recharge at Sirsahakhera.

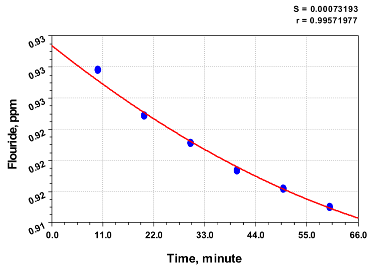


Fig. 64a. Testing of recharge cum skimming hand pump at Sirsahakhera

Testing of Recharge cum Skimming Hand Pump

A recharge cum skimming hand pump was tested under medium water table conditions located beside a pond of Sirsahakhera (Fig. 63) during December 2017. It was observed that the fluoride concentration in pumped water decreased continuously from 0.931 to 0.914 ppm with average value of 0.921 ppm best fitting to logistic model as below.

$$F_{cT} = \frac{0.90387535}{1+0.30102401e^{-0.016206575T}}$$

The fluoride concentration increased with pumping time for the hand pump located in the near vicinity of the canal under shallow water table conditions of Marksnagar (Fig. 64a&b). The fluoride concentration during pumping ranged from 0.435 to 0.477 ppm with an average value of 0.462 ppm. The variation was well explained by the MMF model given below.

$$F_{cT} = \frac{0.43500878x138.7491+0.84837536T^{1.649171}}{138.7491+T^{1.649171}}$$

Where,

F_{cT}= fluoride concentration in pumped water at time, T

Fluoride concentrations in both the recharge cum skimming hand pumps are much less than the limit prescribed by BIS or WHO.

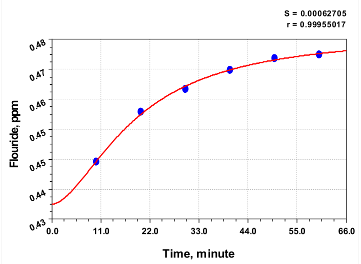


Fig. 64b. Testing of recharge cum skimming hand pump at Marksnagar.

Annual Water Withdrawal from Recharge cum Skimming Hand Pumps

Annual water withdrawal from recharge cum skimming hand pumps under medium turned deep and shallow water table conditions are presented in Table 55.

Skimming Zone Curve

Fig. 66 and 67 show the skimming zone curve for medium turned deep water table conditions and shallow water table conditions.

Table 55: Annual water withdrawal from Recharge cum Skimming Hand Pump under medium turning to deep water table conditions.

S. N.	Particulars	Water table conditions	
		Medium	Shallow
A) Human Need			
1.	Number of family getting out water from pump	50	5
2.	Average number of members in a family	5	5
3.	Total number of members getting out water from pump	250	25
4.	Average water requirement for a person (litre person^{-1} day^{-1})	3	3
5.	Total water pumped on daily basis (liter day^{-1})	750	75
6.	Monthly Pumping (liter)	22500	2250
7.	Annual pumping (liter)	273750	27375
B) Animal Need			
8.	Number of family using pump water for animal	10	5
9.	Average numbers of animals family^{-1}	2	2
10.	Total number of animals	20	10
11.	Water requirement of animal (liter animal^{-1} day^{-1})	30	30
12.	Total water requirement for animals (liter day^{-1})	600	300
13.	Monthly water requirement (liter day^{-1})	18000	9000
14.	Annual water requirements for animals	216000	108000
C) Shop Need			
15.	Number of shops using pump water for customers	-	5
16.	Water requirement of shop (liter shop^{-1} day^{-1})	-	40
17.	Total water requirement for shops (liter day^{-1})	-	200
18.	Monthly water requirement (liter day^{-1})	-	6000
19.	Annual water requirements for animals	-	72000
20.	Daily water pumping (liter)	1350	575
21.	Monthly water pumping (liter)	40500	37500
22.	Annual water pumping for human and animals (liter)	489750	207375

Roof Top Harvesting of Rain Water and Use

For harvesting, storage and use of rain water from roof tops, two farmers were given a 500 liter capacity plastic tank under medium turned deep and two farmers under shallow water table conditions. Farmers were educated to clean the roof top before collecting the rain water. They were further advised to leave two to three good rain spells for thorough roof top cleaning. The kachcha roof top was lined with plastic film to avoid contamination.

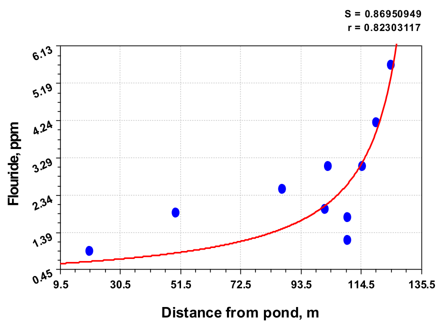


Fig. 65. Skimming zone curve under medium turned deep water table conditions.

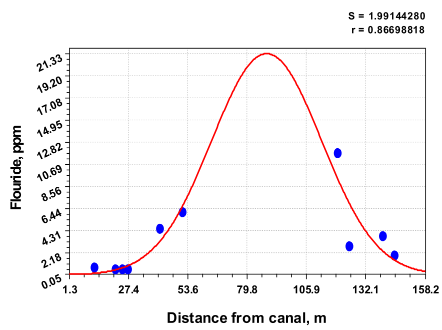


Fig. 66. Skimming zone curve under shallow deep water table conditions.

Table 56:Ground water recharge rate of the whole system

Sl. No.	Date	Recharge rate ($m^3 day^{-1}$)
1	22- Sep-15	5787.94
2	23-Jul-16	996.60
3	8-Aug-16	714.39
4	19-Aug-16	496.03
5	30-Aug-16	379.65
6	14-Sep-16	328.32
7	18-Sep-16	322.27
8	23-Sep-16	273.89
9	17-Jul-17	2499.00
10	27-Jul-17	2070.00
11	1-Aug-17	1449.3

Piloting and Up-scaling an Innovative Approach for Mitigating Urban Floods and Improving Rural Water Security in South Asia (V. K. Mishra, C. L. Verma and S. K. Jha)

Underground Taming of Floods for Irrigation (UTFI) is viable solutions to tackle the twin problem of floods and droughts to protect and safeguard lives, property and livelihoods. It involves diverting high water flows from rivers or canals at times this poses a flood risk and recharging the groundwater via village ponds modified with low cost recharge structure. In collaboration with IWMI, for pilot study, village Jawai Jadid in Rampur district, Uttar Pradesh was selected after close consultation with the local people and authorities. The site is a community pond (*Gram Panchayat* owned) which is located close to the road and canal system (Pilakhar minor). The pond has been cleaned. Ten recharge wells were drilled and constructed in the pond. A PVC pipe of 150 mm in diameter is installed in the center with gravel filters around them. 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 five other recharge wells 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 chamber was 24 m. The source water *i.e.*, excess rain water/ flood water is brought through a canal to pond for ground water recharge. Total 9 piezometers are installed at site to monitor the water level periodically.

Ground water recharge rate of whole system

The initial recharge rate was 996.60 $m^3 day^{-1}$ which reduced to 273.89 $m^3 day^{-1}$ at the end of recharge season 2016 due to continuous clogging (Table 56). In 2017, the recharge rate increased 9.15 times over the recharge rate of 2016 (273.89 m^3 day^{-1}) because of the cleaning of recharge wells and filter box. Comparing the initial recharge rate of the 2016 and 2017, recharge rate was enhanced by 2.51 fold compared to the recharge rate observed at the beginning of the recharge season 2016 (996.6 m^3 day^{-1}). Though the cleaning of recharge wells and filter boxes enhanced the recharge rate yet it was much less (2.31 fold) than the initial recharge rate (5787.94 m^3 day^{-1} in 2015) of the system immediately after the construction. Regular cleaning is inevitable for retaining high recharge rates of the system.

Piezometers Water level

Piezometers and recharge wells water level were measured at every 7- and 15-days interval during the recharge operation and non-recharge season, respectively. Water level was lowest in all piezometers on 15th June 2016 and 24th June, 2017 (Fig. 67). Hence, it was treated as reference value for water table build up. The rise in groundwater levels due to recharge is on an average 2.33 m. Water level in the piezometers dropped by 2 m after 110 days of stopping recharge in year 2016 In 2017 rise in groundwater table due to recharge is on average of 2.84 m and water level in the piezometers dropped by 1.84 m after 53 days of stopping recharge. Water table build up during the year 2017 was much higher compared to the water table build up during year 2016.

Total volume of water recharged

In 2017 the total recharge from the entire system was determined to be 72426.51 m^3 or on average 1207.14 $m^3 day^{-1}$ over 78 days of operation. Rates of recharge started at 2499

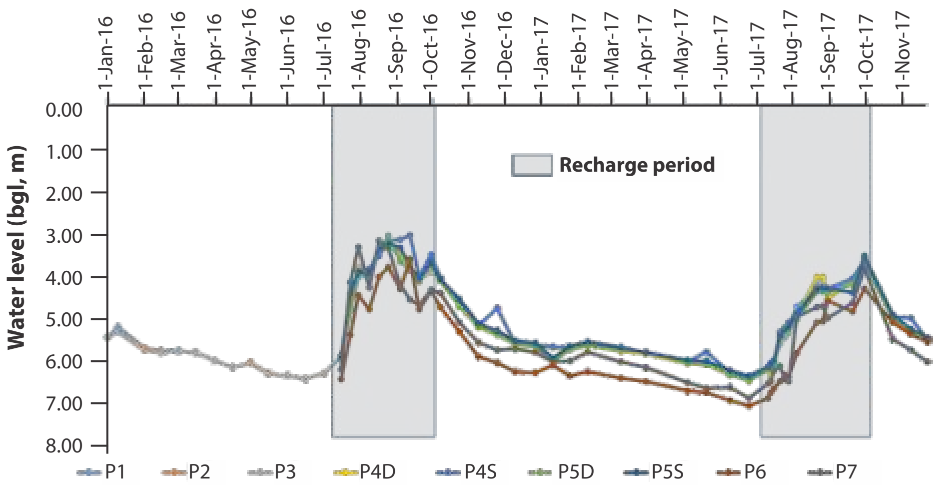


Fig. 67. Ground water level in piezometers

m^3 day^{-1} and gradually declined to 289.44 $m^3 day^{-1}$ before the water level in the pond declined below the intake level for the recharge wells. These changes in recharge are typical of the anticipated patterns of recharge rate over the course of the system as a result of siltation due to the introduction of the recharge of turbid water. The pilot system could provide 250 mm of supplementary irrigation water in the dry season to irrigate 29 ha of crop land.

Water quality parameters

The variation in the water quality characteristics depend upon the interaction with the aquifer material, their dissolution and anthropogenic sources of contaminations. The major cations and anions Ca, Mg, Na, K and CO_3, HCO_3, Cl and SO_4, were analysed in the canal water, pond water, recharge wells and piezometers during pre-recharge period (April), recharge period (August-September), and after recharge period (November). The order of dominance of cations was $Mg^{2+} > Ca^{2+}.> Na^{+} > K^{+}$ whereas among the anions the order was $HCO_3^{-} > Cl^{-} > SO_4^{2-} > CO_3^{2-}$. The total dissolved solid (TDS) were found maximum in the piezometers with shallow depths (P4S and P5S) and varied between 389 ppm to 630 ppm during pre-recharge period while the TDS of canal water was found to be 468 ppm only in this period. During recharge period, 2017 the TDS was low due to dilution factor. The TDS exceeded the desirable limit of 500 ppm as per Bureau of Indian Standards (BIS, 2012) in most of the samples during pre-recharge period while it was acceptable during recharge and post recharge periods.

Periodically, the water samples were analysed for fluoride (F), nitrate (NO_3^{-}), phosphate (PO_4^{3-}), heavy metals such as iron (Fe), nickel (Ni), zinc (Zn), manganese (Mn), arsenic (As), lead (Pb), chromium (Cr), cobalt (Co) and mercury (Hg) besides faecal coliform. In all the water samples, F was within the permissible limits as stipulated by Bureau of Indian Standards. The analysis of ammonical N (NH_4-N) revealed that in during pre-recharge (PRP) and after recharge period (ARP) NH_4-N was maximum particularly in shallow depth piezometers. On the other hand, the nitrate level in the water sources was found to be within the permissible limit of BIS which was 45 ppm. The phosphate was also almost within the permissible limit of 0.1 ppm. Maximum phosphate content was noticed to be

0.15 ppm in shallow depth piezometers only. Fe was also within the permissible limit during 2017 but during 2016, it exceeded the limit of 300 ppb in four sampling points which may be due the anthropogenic contamination. The permissible limit of Ni is 20 ppb only but 53.3% of the water samples exceeded the limit of BIS. The heavy metals such as Zn and Mn were found to be within permissible limits. As and Cr were within the maximum permissible limits of 50 ppb but As exceeded the acceptable limit of 10 ppb in all the water samples which may be due to the presence of this heavy metal coming from upstream in the canal water. In order to decipher the sources of arsenic contamination, water samples from nearby tube wells from up-stream and down streams were also collected and analyzed. In the water samples of tube wells too, the arsenic was present above 10 ppb. The BIS has prescribed 10 ppb to be the maximum permissible limit for Pb in drinking water which was found to be within the limit in pizometers but in the farmers' tube wells, it exceeded the limit. Cobalt in different water samples varied between 0.1 ppb to 2.07 ppb. The mercury was found to be higher than the permissible limit of 1 ppb in almost all the water samples including canal water. The presence of mercury in the canal water indicates contamination from industrial units in the upstream only which was 0.92 in the year 2016 and 3.82 in the year 2017. Even, in the nearby farmers' tube wells, the mercury content varied between 1.99 to 3.2 ppb which was above the prescribed limit of 1 ppb.

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)

Salt tolerant cellulose (5) and lignin (10) decomposing bacterial isolates were subjected to bio-chemical characterization and tested for plant growth promoting traits. IAA production by decomposing bacteria ranged between 8.23 and 52.38 μg ml^{-1}. Among cellulose decomposers, the IAA production ranged from 10.89 to 23.73 μg ml^{-1} while the lignin decomposers have the indole production in the range 8.23 to 52.38 μg ml^{-1}.

Cellulose degradation efficiency

Apart from the 5 cellulose degrading isolates, the plant growth promoting isolates preserved from previous studies were tested for their ability to degrade cellulose and

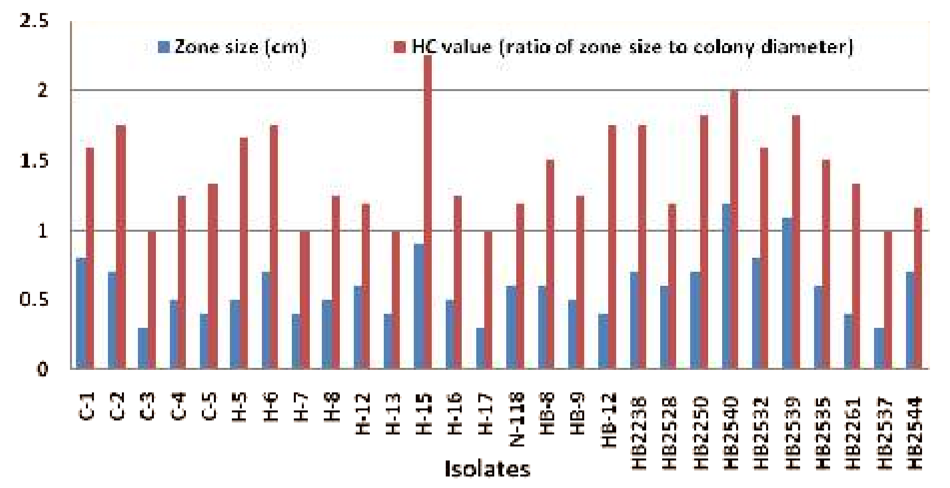
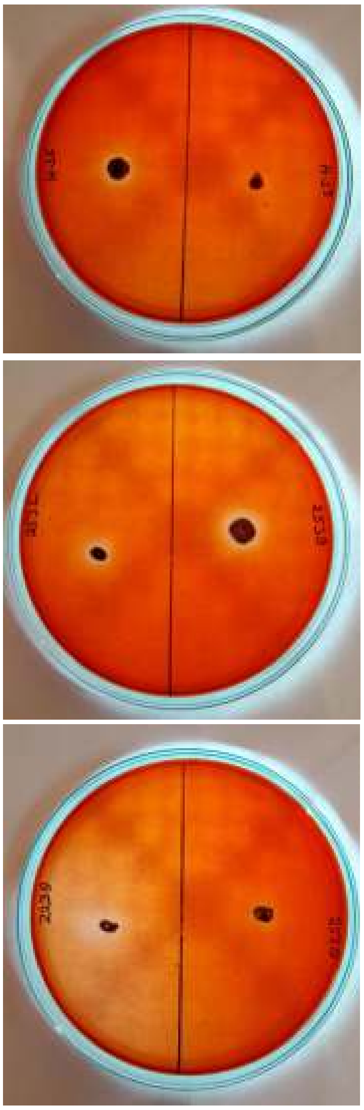


Fig. 68. Hydrolysis of cellulose in media by different isolates



Formation of a zone of cellulose hydrolysis

hemi-cellulose. Maximum hydrolysis capacity was observed in halophilic isolate H-15 followed by HB2540, HB2250 and HB2539 (Fig. 68).

Cellulose yield and Cellulase activity

The effect of temperature on cellulose yield was ascertained by incubating the isolate on cellulose media at temperature of 25 and 42°C for five days. It was noted that with increase in temperature, there was slight increase in cellulose yield and maximum yield of 2.54 and 2.46 g L^{-1} was observed from isolate H-15 and HB-2250, respectively. It was observed that with respect to time it increased in all the isolates ranging from minimum of 8 mg RS kg^{-1} h^{-1} to 124 mg RS kg^{-1} h^{-1}.

CMCase activity

It was observed that at 72 h, maximum CMCase activity of 96.7 iu mL^{-1} min^{-1} was observed in C1 isolate while H15 showed maximum CMCase activity of 98.4 and 97.6 at 72 and 96 h, respectively (Fig 69). On the basis of CMCase activity and HC, three efficient salt tolerant strains were screened for testing straw decomposition in laboratory. Incubation study was conducted with these three isolates.

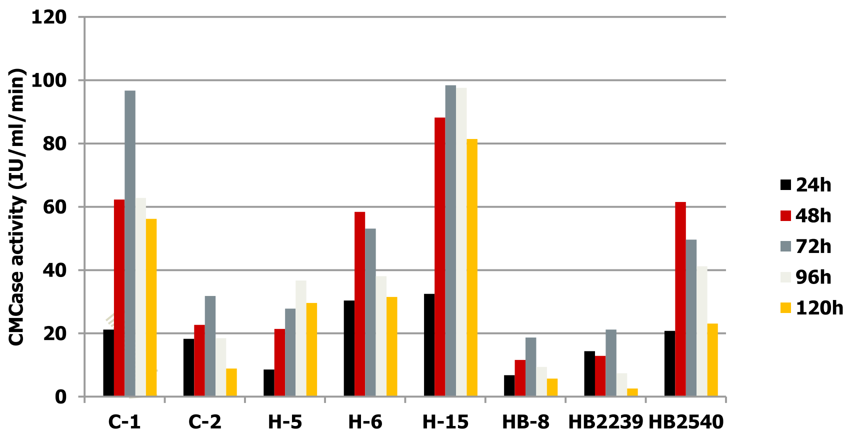


Fig. 69. CMCase activity for different isolates at different time of incubation

Incubation study for residue decomposition

A laboratory incubation study was conducted in 500 ml Erlenmeyer flask where two types of sodic soil were taken *viz.*, Shivri soil (pH 10.1) and Samesi soil (pH 9.7) and known quantity of rice straw, wheat straw and sugarcane leaf trash were mixed and inoculated with different cellulose and lignin degrading bacterial and fungal isolates. The moisture was maintained and flasks were kept in dark. It was observed that initially the CO_2 evolution ranged from 34.4 to 50.6 mg 2 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. However, there was gradual decline in CO_2 evolution with time. It was observed that during early stages of incubation, the highest CO_2 evolution was from wheat straw treated with consortia of bacterial and fungal strains (50.6 mg 2 g^{-1} straw in 100 g soil) followed by that from manual cut rice straw treated with bacterial strains (46.2 mg 2 g^{-1} straw in 100 g soil). After 40 days of incubation, maximum CO_2 evolution was observed in sugar cane leaf trash inoculated with bacterial culture followed by that in combine cut rice straw with efficient bacterial culture of lingo-cellulolytic strains.

After the completion of incubation experiment, the soils from each flask were processed and analysed for different properties. It was observed that soil pH reduced from initial value of 10.1 to 10.03 in control followed by 10.01 in combine cut rice straw and 10.0 in sugar cane leaf trash treated soil where no inoculation was done. However, soil pH reduced to 9.76, 9.77 and 9.78 in soil amended with and manual cut rice straw, sugarcane leaf trash inoculated with consortia of bacterial and fungal culture and wheat straw inoculated with only bacterial strains for faster decomposition. Sodium in ammonium acetate extract was reduced to minimum level of 7.6 g kg^{-1} in wheat straw amended soil with degrading bacterial culture. Build up of exchangeable potassium, calcium and magnesium was observed in the respective treatments indicting recycling of the ions due to decomposition of the crop residues in soil.

Soil organic C content increased with incorporation of residue of wheat, rice or sugarcane. It was observed that inoculation with degrading bacteria or fungi cultures, resulted in higher enrichment of soil organic C. It was found to be maximum of 2.8 g kg^{-1} in soil with manual cut rice straw inoculated with bacterial and fungal cultures of potential degrading strains. Total C content of soil also increased from 15.6 g kg^{-1} in control to maximum of 32.28 g kg^{-1} in soil with sugarcane leaf trash inoculated with both bacterial and fungal cultures (Table 3). Available N and P content of soil increased to a maximum of 47.89 and 7.44 mg kg^{-1}, respectively.

Compatibility test

To assess the compatibility of different bacterial strains, plate assay was conducted and 10 strains were tested. Isolate H-5, H-17, HB-12 and HB-13 were not compatible with H-12 while strains N-118 and HB2540 were not compatible with H-5 and H-6.

Media standardization for bio-formulations of cellulose and lignin degrading microbes

To prepare the liquid bio-formulations using carrier media of these promising halophilic strains of degrading bacterial isolates enabling use of these cultures in fields, different additives were tested in order to standardize the media (Fig. 70). It was observed that

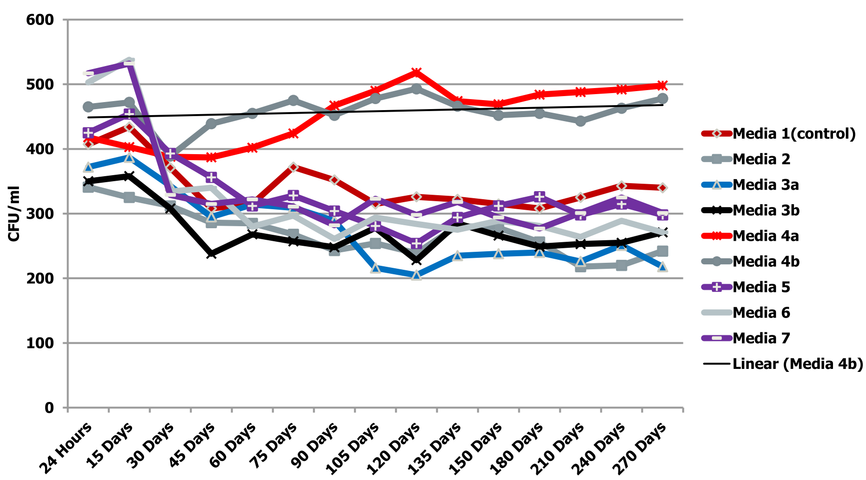


Fig. 70.Cell count in different liquid media for standardization

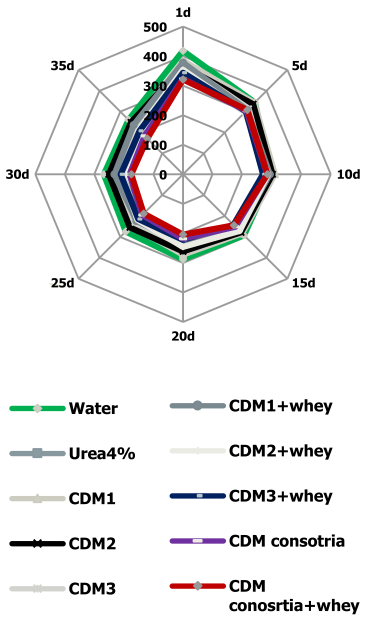


Fig. 71. Effect of degrading microbes on weight (gm^{2-}) of rice stubbles

addition of buffer and additives to stabilize media with suitable C source enhanced shelf life compared to other additives. The shelf life in terms of cell count was monitored at different intervals at room temperature. Also change in media pH and EC was recorded. Media composition 4a and 4b were found to be stabilized for 270 days with cfu ml^{-1} in desirable range and not much fluctuation in pH of the media throughout the period (Fig 4). Monitoring is being continued for some more time. Liquid media standardized during previous studies on plant growth promoters were also compared.

In situ paddy residue decomposition

The paddy and wheat stubbles and partial quantity of straw left after manual and combine harvester was retained on the field and the different efficient strains of cellulose and lignin degrading microbes by spraying the liquid culture media as was done after paddy harvest. The moisture was maintained and monitored for changes periodically. There was loss in weight of stubbles and straw left on field after harvest and the in-situ stubble inoculated with decomposing microbes.

Effect of degrading microbes on rice stubbles

In pots, the left over stubbles of paddy were retained and were sprayed with two efficient strains individually and in combination with whey to compare their performance on degradation of the stubbles with respect to time. It was observed that the dry weight of stubbles reduced from 14.26 to 8.14 g stubble^{-1} sprayed with urea @ 5% solution. The microbial cultures CDM1 and CDM2 reduced the stubble weight by 14.4 and 23.0 per cent after 3rd week while 42.9 and 37.3 per cent after 5 weeks. Inoculums of CDM1 and CDM2 with whey resulted in decrease in stubble weight by 42.9 and 39.2 per cent compared to the initial weight of stubble.

Combination of degrading strains CDM1 and CDM2 sprayed with whey resulted in maximum decomposition of stubble in 3, 4 and 5 weeks which was 36.4, 44.7 and 49.2 per cent compared to initial weight. Compared to the only urea spray, the decrease in stubble weight was additional of 6.3 per cent with CDM1+CDM2 spray along with whey after 5 weeks.

At Shivri Experimental Farm, in situ left over rice stubbles were sprayed with efficient strains of lingo-cellulolytic bacteria prepared in liquid media with and without lactobacillus through whey. It was observed that stubble weight decreased with respect to time in all the treatments due to degradation and there was maximum decrease of 46.7% over initial weight after 35 days where consortia of CDM were sprayed along with whey (Fig. 71). Decrease in stubble weight by 43 and 40.1 % was recorded after 35 days of spray of consortia of CDM without whey and CDM2 with whey, respectively compared to the initial weight of the stubble.

The C: N ratio of the residue material (stubbles and straw) decreased from 64: 1 to nearly 24: 1 in 35 days after inoculation. It was observed that there was maximum reduction with inoculation of consortia of CDM with whey was sprayed as C: N ratio decreased from 58.5: 1 to 24: 1 followed closely by CDM consortia without whey where after 35 days the C: N ratio reached 23.5:1. However, reduction in C: N ratio with only spray of water was observed to be 36.8:1 after 35 days. This indicates that inoculation of residue with consortia of degrading microbes with whey can help in faster in-situ degradation of residue (Fig. 72).

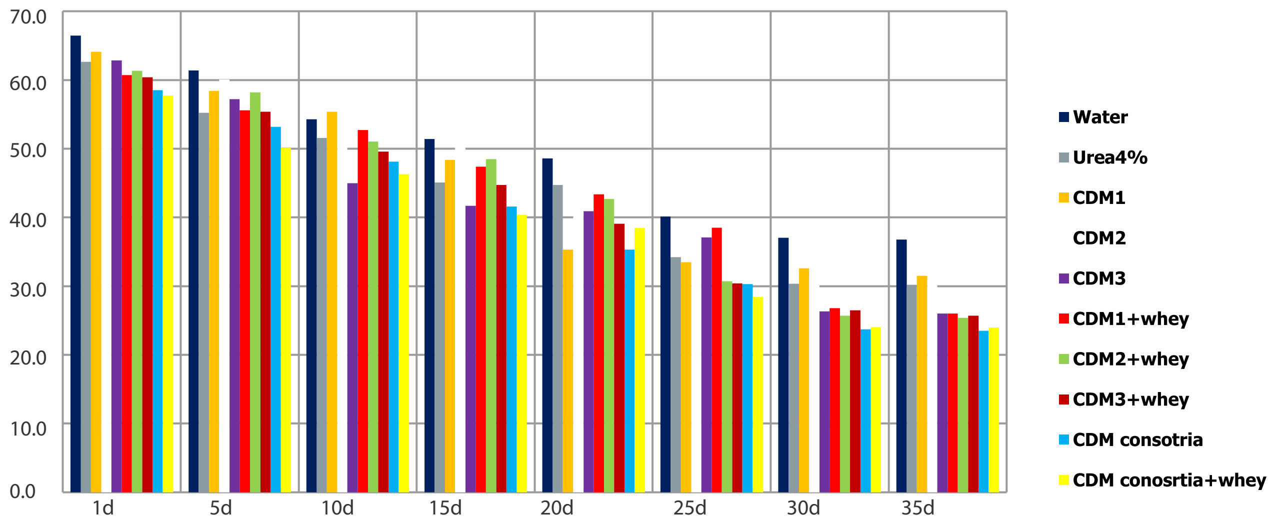


Fig. 72. Effect of degrading microbial spray on changes in C: N ratio of rice stubble

Wheat sown with retained rice residue sprayed with degrading microbial cultures

In situ residue decomposition and crop yields

After harvest of paddy (*Kharif* 2016), the leftover stubbles and straw was sprayed with culture of degrading microbes and moisture maintained to enhance in-situ decomposition. After 45 days of degradation, the wheat crop was sown through zero till and uniform fertilizer and management practices were adopted in each plot. The performance of crop in terms of growth and yield was recorded for each treatment. It was observed that incorporation of residue and its degradation resulted in maximum of 14.04 q ha^{-1} of wheat grain yield in sodic soil (average pH 9.8) from the treatment where paddy residue was degraded through consortia of CDM along with whey which was about 29.04% higher than only water treatment and 16.04 % higher over spray of 4% urea solution .

In the same plots, after wheat harvest the wheat straw and stubbles were retained in plots and tilled with power tiller after spray of respective treatments and substantial moisture was maintained for faster degradation. Paddy was transplanted and it was observed that there was maximum increase in paddy yield by 28.6% compared to no-inoculation (only water).

Residue decomposition effect on soil properties

Soil properties from each harvested plots were analysed for bio-chemical properties and it was observed that soil pH was reduced to 9.42 with incorporation of residues inoculated with consortia of degrading microbes. Soil organic C content was enriched in soil where residues were retained and inoculated with the microbial culture and maximum was in consortia. N and P content seems to be recycled through paddy residue incorporation with halophilic degrading microbes. Soil microbial biomass C content enhanced to maximum of 119 mg kg^{-1} where degrading microbe consortia was applied with whey followed by 116 and 115 mg kg^{-1} in soil where CDM2 with whey and without whey were used for spray (Table 57). Dehydrogenase enzyme activities were improved upto 23.4 µg TPF g^{-1} h^{-1} in consortia amended residues while alkaline phosphatase was maximum of 16.4 µg TPF g^{-1} h^{-1} in the same treatment.

Table 57: Effect of in-situ paddy residue microbial degradation on soil properties

Treatment	pH_2	EC_2 ($dS\ m^{-1}$)	Org. C (%)	Av. N ($kg\ ha^{-1}$)	Av. P ($kg\ ha^{-1}$)	MBC ($mg\ kg^{-1}$)	DHA (µg TPF g-1 h^{-1})	Al.PHA (µg PNP $g^{-1}\ h^{-1}$)
Water	9.89	1.27	0.16	71.89	16.4	74	11.7	8.1
Urea 4%	9.81	1.51	0.20	85.26	18.2	89	14.4	12.4
CDM1	9.70	1.31	0.22	87.81	16.5	82	12.8	12.3
CDM2	9.84	1.32	0.20	81.53	17.6	102	18.7	14.0
CDM3	9.75	1.35	0.18	94.80	15.7	94	17.1	11.3
CDM1+whey	9.73	1.27	0.24	90.30	16.2	92	16.5	12.8
CDM2+whey	9.56	0.94	0.24	102.60	18.1	115	22.1	12.7
CDM3+whey	9.51	1.06	0.24	112.89	18.4	88	18.7	14.1
CDM consortia	9.53	1.29	0.28	122.40	21.7	116	23.4	16.4
CDM consortia+whey	9.42	1.33	0.28	118.20	20.3	119	23.1	15.8
CD(5%)	0.32	NS	0.09	8.60	4.8	23.1	6.2	3.4

CDM: cellulose degrading microbe

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

Efficacy of halophilic Plant growth promoters on crop growth and yield

Pot and field experiments were continued during *rabi* 2016-17 and *kharif* 2017 to ascertain the effect of liquid bioformulations Halo-Azo and Halo-PSB on growth and yield of crops and their subsequent effect on sodic soil properties. The different liquid bio-formulations of halophilic plant growth promoting microbes were tested for their effect on growth and yield of wheat on sodic soil (pH 9.4) in green house experiment. It was observed that plant height was significantly increased by 4.91 to 12.5% with the seed inoculation of microbial formulations *viz*., Halo-Azo, Halo-PSB and Halo-Azsp. Consortia of halophilic nitrogen fixers and P solubilizers *i.e*., Halo-Azo, Halo-PSB and Halo-Azsp resulted in maximum plant height of 86.2 cm which was statistically significantly higher by 20.9% over control (un-inoculated). Similarly, root length also got influenced through seed inoculation with liquid bioformulations and showed an increase of 17.0 to 24.8% over un-inoculated control. Maximum root length was observed in Halo-PSB treatment followed by consortia application. Grain yield of wheat was influenced significantly higher in all the treatments over control. It was observed that with inoculation of Hal-Azo, Halo-PSB and Halo-Azsp, the increase was 14.2, 10.9 and 17.9% higher respectively over un-inoculated control. However, consortia of halophilic strains resulted in an increase of grain yield by 21.8% over control (no bioformulation inoculation).

Paddy seedlings were transplanted in pots after inoculation with different liquid bioformulations as per treatment in sodic soil (initial soil pH = 9.4; Org. C= 0.20%). It was observed that plant height at maturity was maximum (84.64 cm) in pots where consortia of halophilic N-fixers and P-solubilizers were inoculated which was 16.4% superior over control. Grain yield and straw yield of paddy increased respectively by 18.6 and 24.9% in consortia over un-inoculated control (Fig 74). It was further noted that Halo-Azo and Halo-PSB co-inoculation enhanced grain yield by 14.4% while Halo-Azsp and Halo-PSB co-inoculation resulted in 13.1% higher yield compared to control.

Field experiments were conducted for 3 years with rice and wheat to test the efficacy of liquid bio-formulations of halophilic PGP strains on sodic soil. It was observed from the

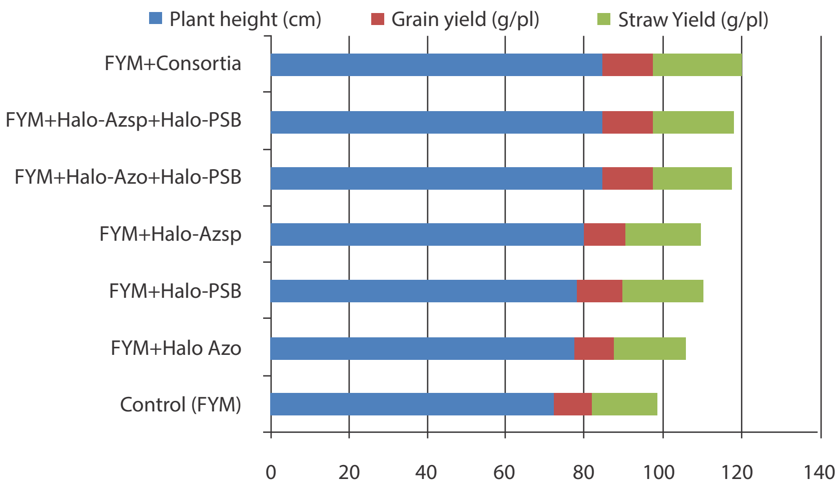


Fig. 73. Effect of bio-inoculation on paddy yield in pot experiment on sodic soil

Field experiment

mean data of three years that all the three liquid bioformulation of halophilic plant growth promoters when applied simultaneously resulted in maximum yield of wheat and rice to the tune of 18.01 and 19.66%, respectively as compared to un-inoculated control. However, halophilic strains of N-fixers were found to be superior over P-solubilizer in enhancing yield of both the crops.

Multilocation testing and validation of the bioremediation potential of liquid bioformulations were conducted during 2014-17 at Lucknow, Sitapur, Unnao, Raebareli, Barabanki, Sulktanpur, Kausambi and Hardoi to ascertain the efficacy of halophilic plant growth promoting strains of N-fixers and P-solublizers on crop growth and yield on sodic soils. It was observed on an average, there was increase in paddy yield by 11.5% with the inoculation of seedling with liquid bioformulations Halo-Azo and Halo-PSB over the un-inoculated control (Fig 73). Similarly, wheat yield was enhanced by average of 14.03% with seed inoculation by liquid formulations compared to un-inoculation (Fig 74).

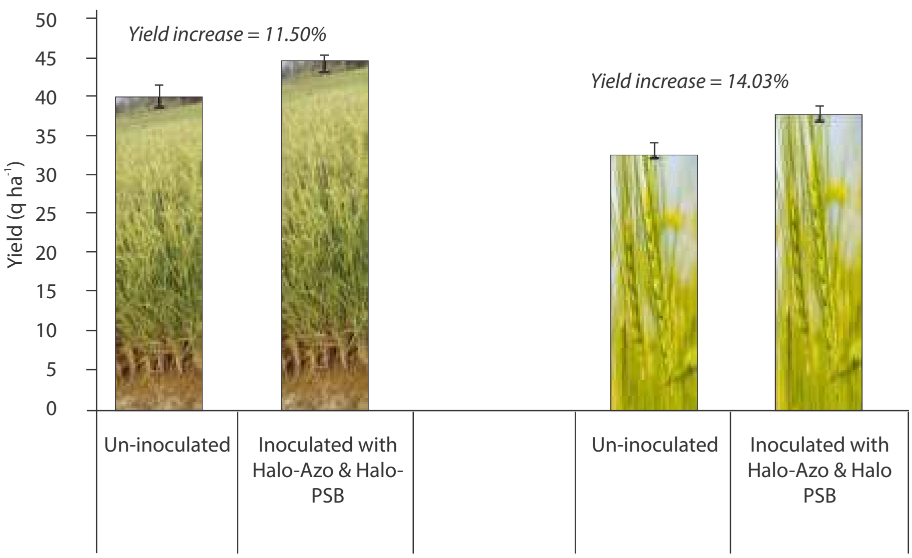


Fig. 74. Average impact of liquid bioformulations on paddy and wheat yield at multilocations

During *kharif* 2017, inoculation of bioformulations were used at farmers' field at Unnao and it was observed that liquid bioformulations improved the germination per cent from 10 to 16% as compared to control. Germination per cent, plant establishment per cent and grain yield were recorded 1.4, 1.5 and 3.6%, respectively, higher with inoculation of Halo-PSB than Halo-Azo. Co-inoculation of Halo-Azo and Halo-PSB resulted in significantly higher germination, plant establishment, grain yield and straw yield than alone inoculation of Halo-Azo and/or Halo-PSB. Increase in grain yield was 8.5, 12.5 and 18.0% with the inoculation of bioformulations, *viz*., Halo-Azo, Halo-PSB and Halo-Azo + Halo-PSB, respectively over control (no-inoculation). Inoculation of bioformulation also increased the straw yield to the tune of 11.6% as compared to control.

Chemical analysis of post harvest soil showed significant effect of bioformulation on soil fertility. Soil organic C, available N and P content increased by 20, 9.9 and 16.8%, respectively with the inoculation of halophilic bioformulations. Organic C content was significantly higher in all bioformulation inoculated treatments. Bio-formulation Halo-Azo significantly increased the N content either alone or in combination with Halo-PSB. Available P content was observed significantly higher in all PSB inoculated treatments.

The liquid bioformulations were also tested on onion on moderate sodic soil and it was observed that bulb weight and yield was improved with co-inoculation with Halo-Azo and Halo-PSB. There was increase of 5.7% in yield of onion.

Halophilic Zinc Solubilizers

The fungal and bacterial Zn solubilizing isolates were tested for their tolerance to different salt concentrations and it was observed that all the seven fungal and six bacterial strains were able to tolerate NaCl and Na_2SO_4 concentration up to 10% while only 4 fungal and 3 bacterial strains could tolerate 10% $NaHCO_3$. However all the fungal and bacterial Zn solubilizers were able to tolerate $NaHCO_3$ concentration of 7.5% in the media. Zn solubilization efficiency of the zone forming isolates were tested *in vitro* and it was observed that among six bacterial strains maximum zone size of 0.9 cm was formed by isolate H-Zn B4 and the Zn solubilization efficiency determined through ratio of zone size to colony diameter was observed to be 2.3 for both H-Zn B3 and H-Zn B4. Zn solubilizing fungal isolates formed larger zone size ranging from 2.3 to 3.9 cm with solubizing efficiency of 1.2 to 2.8. Among the seven fungal isolates, H-Zn F2 and H-Zn F3 strains showed higher efficiency of 2.6 and 2.8, respectively (Fig 75).

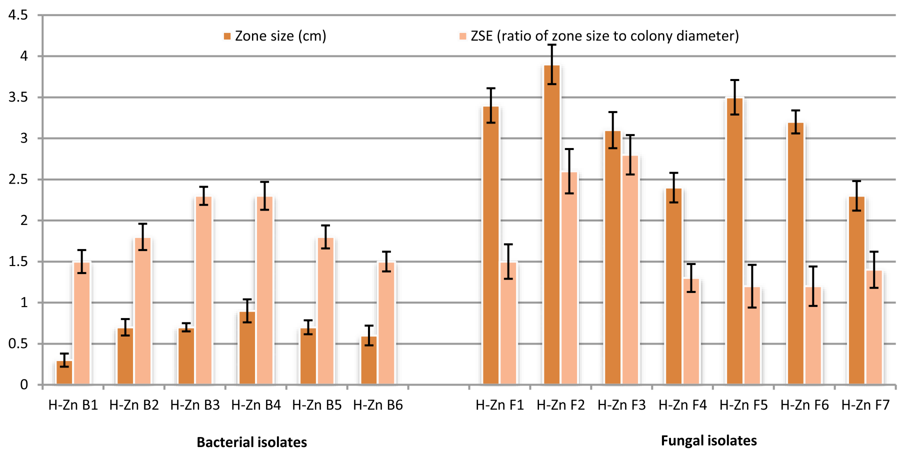


Fig. 75. Zinc solubilization efficiency of isolates

Broth assay for zinc solubilization

In broth culture assay for testing Zn solubilization of different bacterial strains with respect to time, it was observed that among six, five strains were able to solubilize maximum Zn within 20 days while H-Zn B6 was able to achieve maximum solubilization in 15 days. Maximum solubilization of ZnO throughout the time period was observed through bacterial strain H-Zn B3 followed by H-Zn B4 which was to the extent of 16.2 and 15.2 mg L^{-1}, respectively.

Liquid bioformulations developed

Liquid bioformulations for sodic soils

The liquid bioformulations of Halo-Zinc was prepared using two efficient strains of Zn solubilizers after standardizing the media and the carrier. The shelf life of the formulation was tested and found to sustain up to 310 days with cell count of 10^7 at room temperature. The changes in pH and EC was also monitored in the bioformulations and found to be stabilized. Also, we studied the compatibility of the previously tested efficient halophilic strains of N-fxers and P-solubilizers with Zn-solubilizers and standardized the media with selective additives to come out with a consortia bio-formulation 'Halo-Mix' having all these three cultures having shelf life of 240 days and still its monitoring is continued.

The mass culturing of the efficient strains of Zn-solubilizers were done and the liquid bioformulations Halo-Zinc prepared were distributed to KVKs and associated farmers for wide scale validation after thorough testing in rice, wheat, mustard, spinach, fenugreek, onion, bhindi in pots and field. It was observed that there was remarkable increase in crop growth and yield to the tune of 18.7 and 21.4% when Halo-Azo, Halo-PSB and Halo-Zinc were applied simultaneously on sodic soils over no-inoculations in rice and wheat, respectively. Additional benefit of 9.7% was observed through Halo-Zinc over Halo-Azo and Halo-PSB inoculation in rice and wheat on sodic soils (pH 9.4 to 9.6), respectively.

Efficacy of Halo-Zinc and other liquid bioformulations on crop growth and yield

Pot experiments were conducted with paddy, wheat, spinach, mentha, tulsi, fenugreek, okra and mustard to ascertain the effect of liquid bioformulations under sodic soil (pH 9.4-9.6) conditions. Results indicated the beneficial effect of all three liquid bioformulations over un-inoculated control in terms of increase in plant growth and yield. The highest effect was observed with consortia inoculation of halophilic N-fixers, P-solubilizers and Zn-solubilizers or Halo-Mix. As Zn is required during the initial development stage of plants, the liquid bioformulation Halo-Zinc containing the halophilic efficient strains of zinc solubilizers were inoculated through paddy seed treatment at the time of nursery sowing. Also, Halo-Azo and halo-PSB were inoculated to test their efficacy on nursery development. It was observed that seedling height was maximum (48.1 cm) followed by 41.2 cm in plots where seed were inoculated with Halo-Zinc and Halo-Azo, respectively at 30 DAS. However, in 40 days old seedling height was maximum (66.48 cm) with Halo-Zinc inoculation and 60.62 cm with inoculation of Halo-Mix (Halo-Azo+PSB+Zinc).

In the field experiment on sodic soil (pH 9.34), it was observed that the wheat (KRL 210) growth and yield was significantly influenced by the inoculation of different liquid bioformulations. The grain yield of wheat increased to the extent of 21.14% where consortia of halophilic N-fixer, P and Zn solubilizers (Halo-Mix) were inoculated as compared to control where the yield was 2.98 t ha^{-1}. Similarly, straw yield of wheat was also found to be maximum (7.27 t ha^{-1}) with inoculation of Halo-Mix compared to minimum of 5.45 t ha^{-1} in control (Table 58). However, inoculation with sole Halo-Zinc showed better growth and yield of wheat which was 15.77% higher over un-inoculated control. During *kharif*, paddy (CSR 36) seedlings were inoculated with different bioformulations while transplanting and uniform dose of FYM was applied in each treatment plot to provide substrate. Plant height of paddy increased to a maximum of 128.72 cm with Halo-Mix compared to 124.36 cm with Halo-PSB, 122.54 cm with Halo-Azo and 120.67 cm with Halo-Zinc while 96.44 cm in control. It was observed that grain yield of paddy increased by 19.31% where inoculation was done with Halo-Mix followed by 16.47% with Halo-Zinc over the control (only FYM).

Table 58: Efficacy of halophilic PGP strains on wheat (Rabi 2016-17) in field experiment on sodic soil (pH 9.34)

Treatment	Plant height (cm)	No. of tiller $plant^{-1}$	Dry weight (g)	Root length (cm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Control (FYM)	82.24	3.33	15.34	13.41	2.98	5.45
FYM+Halo-Azo	87.52	4.25	17.22	14.85	3.44	6.58
FYM+Halo-PSB	85.36	4.33	18.82	15.13	3.42	7.14
FYM+Halo-Zinc	86.38	4.75	19.55	14.52	3.45	6.82
FYM+Halo-Mix	88.34	4.75	20.08	16.28	3.61	7.27
CD(5%)	4.62	NS	1.74	2.08	0.36	0.42

In field experiment at KVK Sitapur II, efficacy of liquid bio-formulations was tested and it was observed that growth and yield parameters of paddy was influenced significantly with the inoculation of different bioformulations as compared to un-inoculated control. There was maximum influence of Halo-Mix followed by Halo-PSB, Halo-Azo and Halo-Zinc in terms of compared to control. The yield increased to the tune of 14.9% with consortia Halo-Mix inoculation and 7.9% with Halo-PSB over control. Liquid bioformulations were used in different crops on farmers' field at Hasanganj, Auras, Rashidpur in Unnao district on sodic soil (pH 8.6-9.4) during 2017 and it was observed that crop yield was enhanced from 8.8 to 26.3%. Field pea seed inoculation with liquid bioformulations Halo-Azo + PSB + Zinc resulted in increase of 9.5 to 26.3% as compared to non-inoculation. Similarly, seedling dip of onion with liquid bioformulations Halo-Azo + PSB + Zinc was found to enhance the yield upto 73.7 q ha^{-1} compared to maximum of 65.3 q ha^{-1} where no inoculation was done. Mustard seed treatment with liquid bioformulations Halo-Azo+PSB+Zinc, resulted in increase of yield by 11.4 to 18.7% compared to no-inoculation control.

Effect of bio-inoculation on soil bio-chemical properties

After paddy, wheat and other crop harvest, taken with inoculations of different bioformulations, the soil samples were analysed for bio-chemical properties. After harvest soil showed that these formulations enhanced soil available N and P along with buildup of soil organic C and enzyme activity. After harvest of paddy, the soil samples were analysed to ascertain the changes in soil bio-chemical properties as influenced by application of liquid bioformulations in presence of FYM as substrate. It was observed that soil pH reduced slightly from initial of 9.42 to 8.95 in plots inoculated with consortia or Halo-Mix (Halo-Azo + PSB + Zinc) followed by 9.08 in soil where seedlings were inoculated with Halo-Azo only . Organic carbon content increased from 0.24 % in control (only FYM and no-inoculation) to 0.34% in Halo-Mix inoculation treatment followed by 0.32% both with Halo-Azo and Halo-Zinc treatment. Exchangeable sodium content was reduced while available N and P content increased in after harvest soil with inoculation of halophilic plant growth promoters over un-inoculated control. There was maximum increase of 47.3 and 30.7% in soil microbial biomass C and dehydrogenase enzyme activity, respectively in soil where consortia or Halo-Mix was inoculated with paddy seedlings compared to control (no-inoculation). The study advocates that liquid bioformulations of halophilic plant growth promoters and nutrient mobilizers helps in alleviating salt stress and promote organic farming in salt affected soils.

Assessment and Refinement of Existing Irrigation Practices of major Crops Grown under Sodic environment (UPCAR funded) (Atul Kumar Singh, C. L. Verma, Y. P. Singh and Sanjay Arora)

Keeping in view the importance of efficient water management practices, this project proposes to apply low depth of irrigation at varying interval than normal soils to save irrigation water and pumping energy, and to facilitate favourable soil moisture regime for achieving optimum production of rice (CSR 36) in *kharif* and wheat (KRL 210) and sugar beet (LS 6) in *rabi* in partially reclaimed sodic soils. The method of irrigation adopted was surface with different irrigation schedules during *kharif* and *rabi*. During *kharif* two depths of irrigation *i.e*., 5 cm and 7 cm was applied 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 when cracking in top layer starts. During *rabi* season, wheat and sugarbeet crops were taken. Two irrigation depth *i.e*., 3 cm and 5 cm was applied at 30%, 50% and 70% depletion of soil moisture from field capacity and at IW/CPE ratio of 0.8 and 1.0 besides one schedule as control where irrigation was applied at different crop stages of wheat.

Wheat crop (2016-17)

Water and energy (fuel) used to practice irrigation

The frequency and depth of irrigation water applied and cost of fuel incurred was measured and analysed. The observation shows that in wheat crop during the whole growing period a maximum number of 6 irrigation was applied when irrigation was practiced at 30% and 50% of SMD (applying 3 cm of irrigation depth each) and when scheduled at IW/CPE ratio of 0.8 (applying 3 cm depth of irrigation each). This was followed by 5 number of irrigation at 70% of SMD (3 cm depth of irrigation), 30% of SMD (5 cm of depth of irrigation) and IW/CPE ratio of 1.0 (3 cm depth of irrigation), 4 number of irrigation at 50% and 70% SMD (5 cm irrigation depth), IW/CPE ratio of 0.8 and 1.0 (5 cm of irrigation depth), and under control plots (6 cm of irrigation depth).

The number of irrigation have direct impact on the depth of irrigation water used and fuel consumed to operate the irrigation pump. It was observed that highest depth of irrigation amounting to 25 cm applied and 2.4 litre fuel consumed for pumping when irrigation was scheduled at 30% SMD with 5 cm of irrigation depth followed by 24 cm of irrigation depth applied and 2.3 litre of fuel consumed under control plots, and 20 cm of irrigation depth and 1.9 litre of fuel consumed when irrigation was scheduled incase of 50% and 70% of SMD (5 cm irrigation depth) and IW/CPE ratio of 0.8 & 1.0 applying 5 cm depth of irrigation. The lowest irrigation depth of 15 cm applied during crop growth period (consuming 1.5 litre of fuel) when irrigation was scheduled at 70% of SMD (applying 3 cm depth of irrigation) and IW/CPE ratio of 1.0 (applying 3.0 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 regimes are depicted in Fig. 76. The highest grain yield of 3.8 t ha^{-1} was obtained when irrigation was scheduled at IW/CPE ratio - 0.8 (applying 5 cm depth of irrigation) followed by 3.3 t ha^{-1} incase of IW/CPE ratio of 1.0 (5 cm depth of irrigation).

Irrigation water and energy productivity reflect that highest irrigation productivity of 1.9 kg m^{-3} was achieved when irrigation was scheduled at IW/CPE ratio of 0.8 (applying 5 cm of irrigation depth) and at IW/CPE ratio of 1.0 (applying 3 cm of irrigation depth) followed by 1.6 kg m^{-3} in case of IW/CPE ratio of 0.8 (3 cm depth of irrigation) and IW/CPE ratio of 1.0 (5 cm depth of irrigation), whereas lowest irrigation productivity of 0.9 was achieved when irrigation was scheduled at 70% of SMD (applying 5 cm depth of irrigation). Moreover, similar trends were observed in case of fuel productivity as highest fuel productivity of Rs. 2.3 per unit cost of diesel was achieved when irrigation was scheduled at IW/CPE ratio of 0.8 (applying 5 cm of irrigation depth) and IW/CPE ratio of 1.0 (applying 3 cm of irrigation depth), while the lowest fuel productivity of Rs. 1.1 per unit cost of diesel was observed when irrigation was scheduled at 30% of SMD (applying 5 cm depth of irrigation) and 70% of SMD (applying 5 cm depth of irrigation). The results reflect higher irrigation water and energy productivity when irrigation is scheduled based on IW/CPE ratios as well as grain yield.

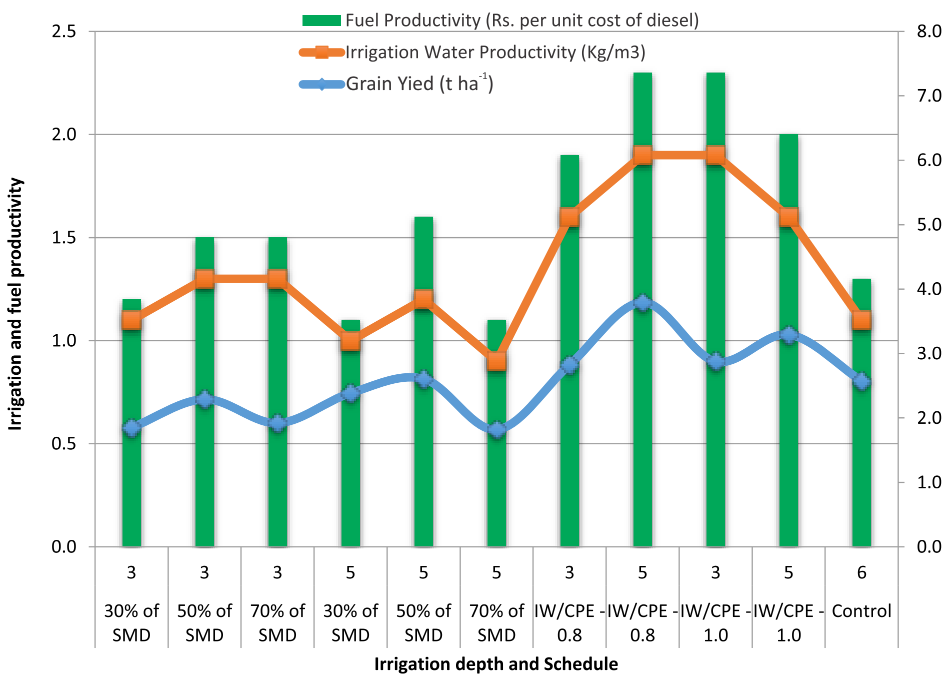


Fig. 76. Water and energy productivity of wheat under varying irrigation regimes

Sugarbeet crop (2016-17)

Water and energy (fuel) used to practice irrigation in sugarbeet

The number of irrigation, depth of irrigation water applied and cost of fuel incurred was measured and analysed. The observation shows that in sugarbeet crop, during the whole growing period, a maximum number of 12 irrigations were applied when irrigation was practiced at 30% of SMD (applying 3 cm depth of irrigation) followed by 10 number of irrigation at 30% SMD (applying 5 cm depth of irrigation) and at IW/CPE ratio of 0.8 (applying 3 cm depth of irrigation), 9 number of irrigation at 50% of SMD (applying 3cm depth of irrigation) and at IW/CPE ratio of 1.0 (applying 3 cm depth of irrigation), 8 number of irrigation incase of70% of SMD (3 cm depth of irrigation), 50% of SMD (5 cm depth of irrigation) and IW/CPE ratio of 0.8 (applying 5 cm depth of irrigation), whereas, lowest number of 7 irrigation was applied incase of 70% of SMD (5 cm depth of irrigation), IW/CPE 1.0 (applying 5 cm depth of irrigation) and under control plots. These irrigation events include one pre germination irrigation of 6 cm depth, which was applied to each irrigation regimes. It is observed that the highest depth of irrigation amounting to 51 cm was applied when irrigation was scheduled at 30% of SMD (5 cm depth of irrigation) followed by 42 cm under control plots, 41 cm at 50% of SMD (5 cm depth of irrigation) and IW/CPE ratio of 0.8 (applying 5 cm depth of irrigation), 39 cm at 30% of SMD (applying 3 cm depth of irrigation), 36 cm at 70% of SMD (5 cm depth of irrigation) and at IW/CPE 1.0 (5 cm depth of irrigation), 33 cm at IW/CPE ratio 0.8 (3 cm depth of irrigation), 30 cm at 50% of SMD and IW/CPE 1.0 (3 cm depth of irrigation) and lowest 27 cm at 70% of SMD (3 cm depth of irrigation). This trend of irrigation depth reflects similar trends in case of fuel consumed to operate the water extraction mechanism. It is observed that a maximum of 5 litre of diesel was consumed to irrigate plots in which irrigation was scheduled at 30% of SMD (5 cm depth of irrigation).

Irrigation water & energy (fuel) productivity and sugarbeet yield trends

The water and fuel productivity and sugarbeet root yield trends under different irrigation regimes are depicted in Fig. 77. It is observed that highest sugarbeet root yield of 35.6 t ha^{-1} was obtained when irrigation was scheduled at IW/CPE ratio 1.0 (applying 3 cm depth of irrigation) followed by 34.6 t ha^{-1} incase of IW/CPE ratio 0.8 (applying 5 cm depth of irrigation), 34.3 t ha^{-1} incase of IW/CPE 1.0 (applying 5 cm depth of irrigation). The lowest root yield reported 13.3 t ha^{-1} when irrigation was scheduled at 30% of SMD

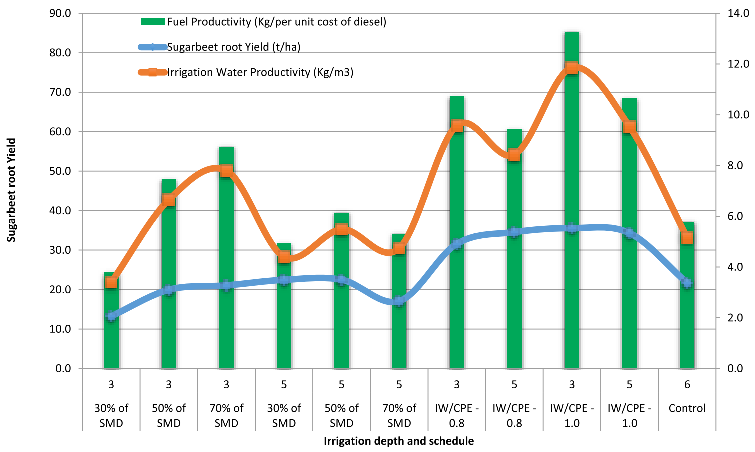


Fig. 77. Water and energy productivity of Sugarbeet under varying irrigation regimes

(applying 3 cm depth of irrigation). The highest irrigation water productivity (kg m^{-3}) observed as 11.9 in case of IW/CPE 1.0 (3 cm depth of irrigation) followed by 9.6 in case of IW/CPE 0.8 (3 cm depth of irrigation), 9.5 incase of IW/CPE 1.0 (5 cm depth of irrigation) and 8.4 incase of IW/CPE 0.8 (applying 5 cm irrigation depth). The lowest irrigation water productivity of 3.4 was recorded in case of 30% of SMD (3 cm depth of irrigation). The fuel productivity (Kg per unit cost of diesel) of these plots also followed the same trend as highest fuel productivity of 85.4 in case IW/CPE 1.0 (3 cm depth of irrigation) and lowest of 24.5 incase of 30% of SMD (3 cm depth of irrigation).

A view of the layout of the experiment

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)

A field experiment with 6 treatments was laid out in plots of 40 m^2 using a randomized block design having 3 replications during *kharif* season taking rice as the first crop. Following the experimental lay-out, the plots were ploughed to fine tilth and the required doses of marine gypsum (MG) and gypsum (GYP) were mixed in soil as per the treatments based on the gypsum requirement (GR), determined in the laboratory. This was followed by ponding of 10 cm water and allowing for vertical leaching as per the treatment design.

The treatments were: T_1- Control; T_2- 50 GR gypsum; T_3- 50 GR (Eq.) Marine gypsum; T_4- 25 GR Gypsum; T_5- 25 GR (Eq.) Marine Gypsum; T_6- 25 GR gypsum+25 GR (Eq.) Marine Gypsum. The water used for irrigation had pH 7.7, EC 0.87 dS m^{-1}, Residual Sodium Carbonate (RSC) 1.0 mmol L^{-1} and sodium adsorption ratio (SAR) 1.16. After 15 days of reaction time, 30 days old rice seedlings (cv. CSR-36) were transplanted as the first crop at 20 cm and 15 cm between rows and hills, respectively. The full dose of P (60 kg P_2O_5), K (40 kg K_2O) and 50 % of recommended doses of N (75 kg N) ha^{-1} were applied as basal dose. The remaining amount of N was applied at the time of tillering (30 days after transplanting) and panicle initiation (75 days after transplanting) in equal proportions.

At maturity, the crop was harvested (in October), sun-dried (5 days) and threshed. The rice grain yield was recorded on 14% moisture basis in t ha^{-1}. Rice yield (3.73 t ha^{-1}) recorded in treatment 50 GR (Eq.) MG was significantly highest followed by 50 GR Gyp, 25 GR MG and 25GR Gyp+25GR MG which were on par with each other (Fig.78).

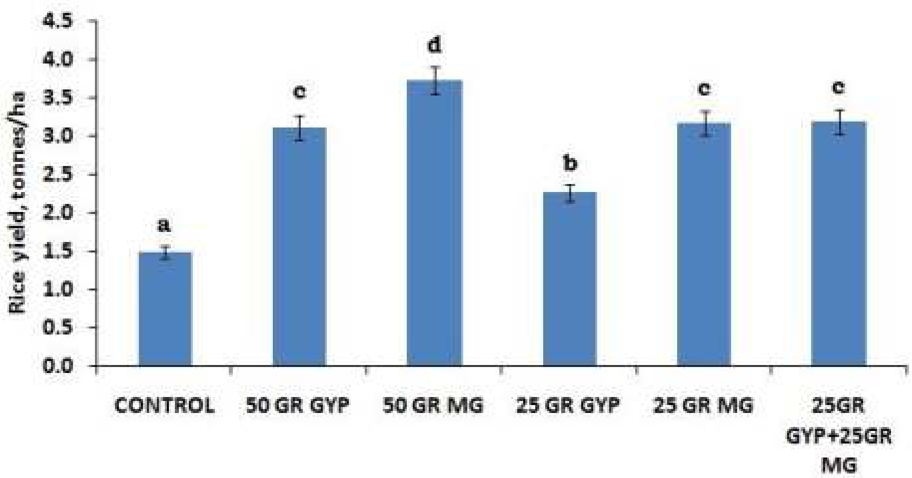


Fig. 78. Yield of rice under various treatments

Table 59: Yield and its attributing parameters under pot experiment

Treatments	Plant height	Productive tillers hill^{-1}	Penicle length	Grains penicle^{-1}	1000 grains wt.	Yield (g pot^{-1})
Control	75.4^{a}	3^{a}	21.2^{a}	53^{a}	21.6^{a}	20.1^{a}
50 GR GYP	118^{c,d}	7^{d}	26.5^{b,c}	106^{c}	26.3^{d,e}	35.4^{d}
50 GR MG	120^{d}	7^{d}	27.8^{d}	110^{c}	27^{e}	36.2^{d}
25 GR GYP	104^{b}	4^{a,b}	24.8^{b}	91^{b}	23.8^{b}	27.8^{b}
25 GR MG	114^{c}	6^{b,c}	25.2^{b}	108^{c}	25.6^{c,d}	31.7^{c}
25 GR GYP + 25 GR MG	117^{c,d}	6^{b,c}	25^{b}	117^{d}	24.9^{c}	34.8^{d}

Different letters represent significant differences at a $p<0.05$.

Soil samples collected after rice harvest were also analyzed. Maximum reduction in pH (0.99 unit) was found in the treatment where 50 GR MG was applied followed by the combined application of MG and Gyp (*i.e.*, 25 GR Gyp + 25 GR MG) with respect to control. No significant difference in electrical conductivity ($EC_{1:2}$) was noticed among the treatments. However, numerically higher EC was observed in the treatment where marine gypsum was added, may probably be due to the increased ionic activity of the solution that provided enough electrolyte concentration in soil solution.

A pot culture experiment was also carried out taking the same treatments with three replications. Eight kg of soil having pH 10.2 was filled in the each earthen pot. The gypsum and marine gypsum were added as per the treatment doses and ponded with water for reaction to take place. The ponding of water was maintained for 15 days, thereafter, rice seedlings (CSR-36) were transplanted. Three seedlings were maintained in each pot. Required doses of NPK were also applied. At maturity, the plants were harvested and the yield and it attributing parameters were recorded which are presented in Table 59.

25 GR GYP + 25 GR MG | 25 GR MG | 25 GR GYP | 50 GR MG | 50 GR GYP | CONTROL

Effect of amendments in different treatments under pot experiment

Crystallization of marine gypsum based product in laboratory

The yields of rice was recorded highest in 50 GR MG (36.2 g pot^{-1}) which was statistically on par with the treatments 50 GR GYP and 25 GR GYP + 25 GR MG. The yield attributing parameters such as plant height and 1000 grain weight coroborated the same trend. The analysis of soil revealed a maximum decrease in pH in the treatment 50 GRMG with pH value of 8.33. This was followed by 25 GR GYP+25GR MG statistically on par with 25 GR MG.

Laboratory preparation of marine gypsum based product (MG-P)

Mineral gypsum had been used extensively as an ameliorant for the management of sodic soils so far but its scarce availability and increasing input costs pose problems in the reclamation process. To tackle this issue, phosphogypsum, fly ash and various organic amendments had been tried earlier as an alternative amendment of mineral gypsum but due to one or the other reason, they could not be applied widely in the reclamation process. Thus, it was imperative to find either a suitable alternative to gypsum or some compound that works efficiently in the process of reclamation. In this backdrop, an attempt was also made for the laboratory preparation of marine gypsum based product (MG-P) on the principle of chelation properties of ligands and crystalized the product in acidic medium .

Analysis of the product revealed an appreciable increase in the calcium content (121 meq L^{-1}) compared to analytical grade gypsum (30 meq L^{-1}) in solution, which was an increase of 4 times than that of gypsum. The solubility of the marine gypsum based product was also quite higher (3.93 g 100 ml^{-1}) compared to only 0.245 g 100 ml^{-1} in gypsum. The order of increase in the solubility amounted to 15.7 times that of gypsum (Table 60). Looking into the dwindling scenario of gypsum in the reclamation of sodic soil on one hand and high calcium and the high solubility of marine gypsum based product

Table 60: Comparison between gypsum, marine gypsum and marine gypsum based product with respect to calcium and solubility

Properties	Gypsum (analytical grade)	Marine Gypsum	Marine Gypsum Based Product	Order of increase w.r.t. gypsum
Ca, meq L^{-1}	28-30	43	121	4 times
Solubility (g 100 mL^{-1})	0.245	1.48	3.93	15.7 times

on the other hand, it might be posible that with the lower doses of the product, the reclamation of sodic soil could be done.

The efficiency of this product (MG-P) in the reclamation was also evaluated under pot culture study using sodic soil (8 kgs) in earthen pots having pH 10.2. The treatment were: T_1- Control; T_2- 12.5 GR MG-P; T_3- 6.25 MG-P and T_4- 12.5 GR Biochar formulation (BC-F). MG-P and BC-F were added as per the treatment doses and ponding of water was maintained for 15 days, thereafter, rice seedling (CSR-36) was transplanted in each pot. Three seedlings were maintained in each pot. Required doses of NPK were also applied. At maturity, the plants were harvested and the yield and it attributing parameters were recorded which are presented in Table 61. The rice grain yield was found to be significantly highest (36.8 g/pot) in 12.5 GR MG-P than the other treatment which is also correlated with number of grains per penicle and the number of productive tillers. The soil pH and EC was determined in the soil after rice harvest, the data of which is presented in Table 62. The pH of the soil in the treatment (12.5 GR MG-P) was found to be significantly lower than the control and other treatments whereas the EC was numerically higher than the control but was statistically non significant.

Table 61: Effects of marine gypsum based product and biochar formulation on yield and its attributing parameters under pot experiment

Treatments	Plant height	Productive tillers hill^{-1}	Penicle length	No. of grains panicle^{-1}	Yield (g pot^{-1})
Control	75.4^{a}	3^{a}	21.2^{a}	53^{a}	20.1^{a}
12.5 GR MG-P	118^{d}	8^{c}	26.5^{b}	123^{c}	36.8^{c}
6.25 GR MG-p	108^{c}	5^{b}	23.3^{a}	107^{b}	29.8^{b}
12.5 GR Biochar formulation (BC-F)	100^{b}	6^{b}	23^{a}	122^{c}	32.6^{b}

Table 62: pH and EC of the soil after rice harvest from the pot

Treatments	pH	EC dS m^{-1}
Control	9.62^{c}	0.35^{a}
12.5 GR MG-P	9.24^{a}	0.46^{b}
6.25 GR MG-P	9.43^{b}	0.41^{ab}
12.5 GR Biochar formulation (BC-F)	9.55^{bc}	0.40^{ab}

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 waste (MSW) is one among the major challenges particularly in urban areas. India produces about 12.74 million tons MSW per day. Several strategies have been applied for its efficient utilization but its performance in reclamation of salt affected soils has not been investigated. Only a few studies have been conducted on use of MSW compost for amelioration of sodic soils and sustaining crop productivity. Therefore, present study was initiated during 2014-15 with the objectives i) to standardize the methodology for on-farm composting of MSW to get aesthetically acceptable and quality compost, ii) to find out the efficacy of inorganic amendments used in conjunction with MSW compost on soil productivity and sustaining crop yield,

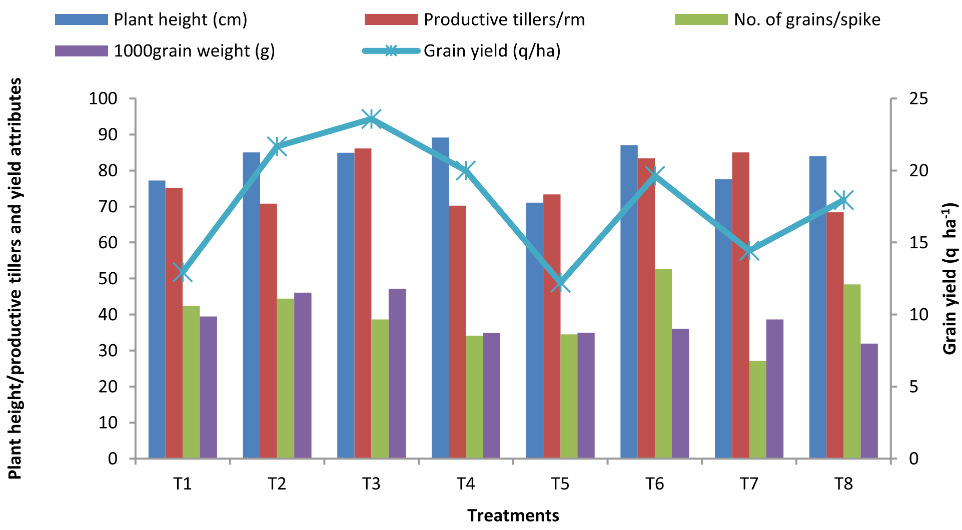


Fig. 79. Synergistic effect of organic and inorganic amendments on grain yield of wheat.

and iii) to monitor the combined effect of organic and inorganic amendments on amelioration of degraded sodic lands. From the on –farm composting protocol study conducted during 2014-15, it was concluded that a cost effective nutrient rich municipal solid waste compost can be produced at farmers level in 95-120 days using 50% municipal solid waste + 50% agricultural waste enriched with earth worms (*Eisenia foetida*) and degrading microbial strains like *Aspergillus terreus*, *Trichoderma harzianum* and *Bacillus cereus*.

To evaluate the synergistic effect of municipal solid waste compost and inorganic amendments on soil properties and productivity of rice-wheat cropping system, third year field experiment with rice- wheat cropping system was conducted at Shivri Experimental Farm, Lucknow. After harvesting of rice 2016, wheat crop with recommended dose of N, P, K and Zinc (120 kg: 60 kg: 40 kg ha^{-1}) was sown with the same treatments. All the relevant observations were recorded at specified interval. Maximum plant height (89.12 cm) was recorded with treatment T_4 (PG @ 25% GR+ MSW compost @ 10 t ha^{-1}) and minimum (71.05 cm) with treatment T_5 (gypsum @ 12.5% GR +MSW compost @10 t ha^{-1}+ PM @10t ha^{-1}). However, there was no significant difference between the treatments in this parameter. Maximum number of grains per spike (52.73) was recorded in treatment T_6 (PG @12.5% GR +MSW compost @10 t ha^{-1}+ PM@10 t ha^{-1}) whereas, maximum 1000 grain weight was observed in treatment T_3(Gypsum @25% GR+ MSW compost@ 10 t ha^{-1}). Highest grain yield was recorded with treatment T_3 (application of gypsum @ 25% GR+ MSW compost @10t ha^{-1}) followed by T_2 (PG @ 50% GR) and the difference between them was statistically significant (Fig. 79).

After harvesting of wheat, 30 days old seedling of rice variety CSR 36 were transplanted on 08.07.2017 with recommended dose of fertilizers (150N: 60P: 40 K). All the relevant data related to plant growth, yield contributing and yield were recorded at certain interval. From the data given in Table 63, it revealed that although maximum plant height (120.83 cm) was recorded with treatment T_3 but there was no significant difference in this parameter due to different treatments. Highest number of effective tillers $hill^{-1}$ (11.86) was recorded in treatment T_4 which were at par with treatment T_3. Highest number of grains/panicle (130.83) was recorded in treatment T_3 but there was no significant

Table 63: Effect of organic and inorganic amendments on growth and yield of rice

Treatments	Plant height (cm)	No. of effective tillers hill^{-1}	No. of grains panicle^{-1}	No. of filled grain	1000 grain wt. (g)	Grain yields (t ha^{-1})
T1	117.40	10.40	120.46	109.83	25.00	3.70
T2	118.20	9.66	116.73	101.10	26.20	4.03
T3	120.83	11.33	130.83	110.96	25.96	4.47
T4	116.93	11.86	111.60	94.86	24.86	4.40
T5	109.86	8.63	100.30	88.31	21.90	3.80
T6	114.94	9.64	104.26	77.86	23.10	3.97
T7	114.20	11.10	107.25	88.62	23.36	4.43
T8	111.60	10.40	106.50	80.30	23.13	4.20
CD (P=0.05)	ns	2.82	ns	6.32	1.31	0.22


Performance of rice crop under different treatments

difference between the treatments. The number of filled grains was significantly higher in treatment T_3 over rest of the treatment but it was at par with T_1. Maximum 1000 grain weight was recorded in treatment T_2 which was significantly higher over treatment T_4, T_5, T_6, T_7 and T_8 but at par with T_1 and T_3. Highest number of filled grains/panicle (110.96) was recorded with T_2 which were significantly higher over treatment T_5 and T_6. Highest grain yield (4.47 t ha^{-1}) was recorded with treatment T_3 (application of gypsum @25% GR + MSWC @ 10 t ha^{-1}) followed by (4.43 t ha^{-1}) T_7 (Gypsum @ 25% GR+ IPMSW @ 10 t ha^{-1}) and the lowest with T_5(gypsum @ 25% GR + MSW compost @ 10 t ha^{-1} + PM@ 10 t ha^{-1}.

To monitor the combined effect of organic and inorganic amendments on amelioration of degraded sodic lands, soil samples were collected from 0-15cm soil depth after two years of rice wheat cropping . It was observed that highest reduction in soil pH was recorded with treatment T_3 (gypsum @ 25%GR+MSW compost @ 10 t ha^{-1}) followed by T_2 (PG @ 50%GR). However, highest reduction in ESP and increment in organic carbon was recorded with T_4 (PG @ 25% GR+ MSW compost @ 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, HCO_3, were also observed due to combined effect of organic and inorganic amendments.

Microbial population increased with the application of organic amendments. Bacterial and fungal population in soil treated with different doses of gypsum or phosphogypsum along with MSW compost followed by rice-wheat cultivation increased over the initial population. Maximum bacterial population (7.8x10^{7} cfu g^{-1}) after one year of experiment was enumerated where soil was treated with gypsum @ 25% GR +MSW compost @ 10 t ha^{-1} (T_3) and it was followed by the treatment T_4 and T_8. However, maximum fungal population (8.0x10^{5}cfu g^{-1}) was observed in treatment T_7 where industrial processed MSW compost was applied in conjunction with gypsum @25% GR. Microbial population increased with increasing time. After two years of experimentation, the bacterial population has increased about 41% over the previous year in soil treated with combined application of organic and inorganic amendments (T_3) followed by T_4 and T_7. Similarly, fungal population has also increased by about 50% under treatment T_4 followed by T_3 and T_7.The increment in bacterial and fungal population due to combined use of organic and inorganic amendments (T_3) has increased about 77.3 and 200% over only application of inorganic amendment (gypsum) after one year and 120 and 125% after two years of study. This indicate the higher improvement in soil microbial flora with the combined application of organic and inorganic amendments compared to only application of inorganic amendments like gypsum or phosphogypsum.

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

1. Participatory Varietal Selection trial

A set of 18 genotypes viz. CSR 55, CSR 02013-IR-42-25, CSR-2013-IR 42-20, CSR-2013-MI-10, CSR-2013-MI-27, BULK 212, CSR 2748-100, CSR 2748-140, CSR 2748-197, CSR-2748-4441-193, CSR-2748-4441-195, CSR 16-18-12, CSR RIL-01-IR 165, CSR RIL-01-IR 75, CSR 36 (CHECK), PET 49, PET 50,and PET 77 was evaluated at Shivri experimental farm Lucknow at pH 9.6. Three times replicated participatory varietal selection trials with 30 days old nursery were transplanted on 11.07.2017. Recommended dose of fertilizers (150: 60: 40kg NPK ha^{-1}) and zinc sulphate @ 25 kg ha^{-1} was applied. Among the genotypes evaluated, two genotype CSR-2013-MI-10 and CSR 16-18-12 ranked 1st and 2nd (Fig. 80).

1. Baby Trials

To scale out the high yielding salt tolerant varieties CSR 36 and CSR 43, farmer managed baby trials were conducted on 30 farmers' field in Maljha and Ulrapur villages in Unnao

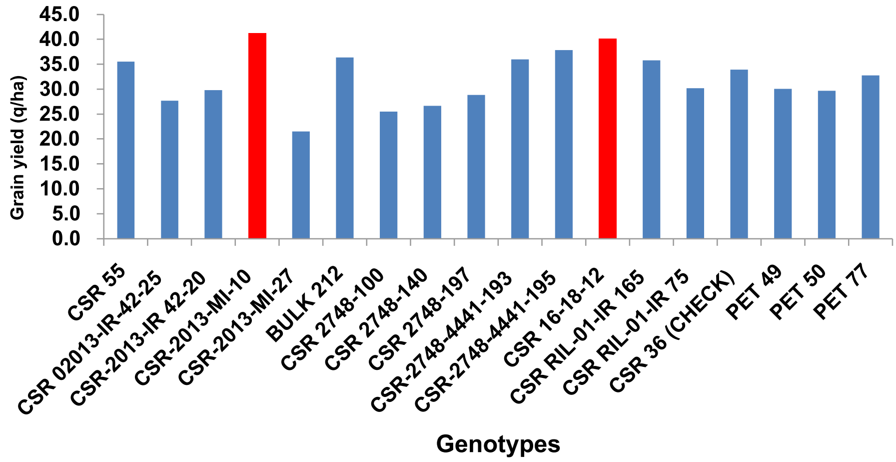


Fig. 80. Grain yield of PVS lines evaluated at research farm

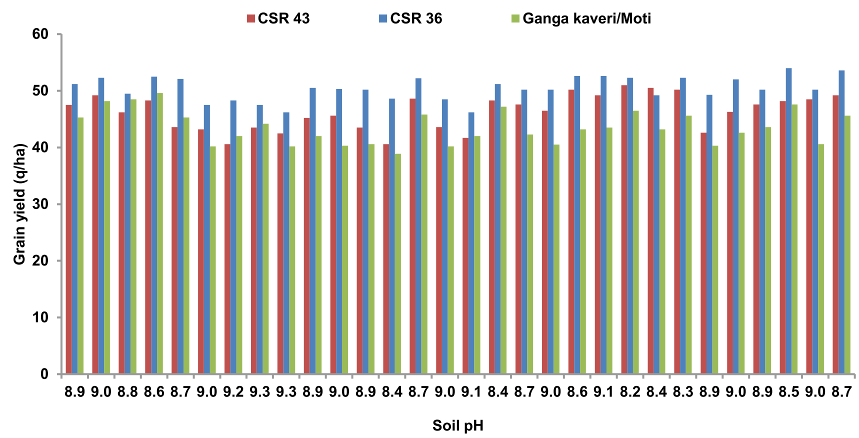


Fig. 81. Performance of salt tolerant and traditional varieties at village (A) Maljha and Ulrapur

district.. These varieties were compared with the traditional varieties like Moti and Ganga Kaveri at pH ranging from 8.3 to 9.3. On the basis of crop cutting yield data collected from 30 farmers fields of Maljha and Ulrapur villages, CSR 36 and CSR 43 yielded 15.92 and 6.41% higher, respectively, over the traditional varieties. Short duration variety CSR 43 matured about 20-25 days earlier than the traditional varieties and saved about 2 irrigation (Fig. 81).

1. Stress Tolerant Breeding Network Trial (STBN)

The experiment, consisting of 88 rice genotypes/cultures, including 7 checks, was conducted at Shivri experimental farm Lucknow in augmented design. The soil pH_2 of the experimental field was about 9.8 and EC 1.2 dS m^{-1}. The recommended dose of fertilizer (150N: 60P: 40K) was applied in three splits. Among the genotypes evaluated, only four genotypes were CR3881-4-1-3-7-2-3, CR 3887-15-1-2-1, CSR 2016-IR 18-3, CR 2838-1-S-2B-9-1, CR 3878-245-2-4-1 were found promising with respect to grain yield. Seventeen genotypes died at establishment stage, 17 completed vegetative stage but no flowering and 25 genotype reached to flowering stage but no grain filling occurred.

4. Front line Demonstration

Front line demonstrations of salt tolerant variety CSR 36 and CSR 43 were conducted on 9 farmer's field at pH 9.0-9.4 in 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.

Performance of different genotypes under STBN trial

Crop and Resource Management Practices for Rainfed Lowland Systems in Eastern India (ICAR-W3) (Y.P. Singh and V. K. Mishra)

Effect of integrated nutrient management on cropping intensity of short duration salt tolerant variety of rice under different sodic environment

To monitor yield optimizing level of sodicity, nutrient requirement and a highly economical and sustainable cropping system with short duration salt tolerant variety 'CSR 43', a field experiment with four sodicity levels viz., S_1 –8.5, S_2 –9.0, S_3 –9.3, S_4 – 9.6 and four integrated nutrient management practices viz. N_1 – recommended dose of fertilizers (RDF) (150:60:40:25 kg Zinc sulphate), N_2 – 75% of RDF + microbial inoculation (Hallo AZO + Hallo PSB), N_3 - 75% of RDF + microbial inoculation (Hallo AZO + Hallo PSB + Hallo zinc)and N_4 - 75% of RDF + CSR Bio + Zinc sulphate and four cropping systems viz. C_1-Rice-wheat, C_2- Rice- cabbage –wheat, C_3-Rice-spinach-wheat, and C_4-Rice-beetroot- wheat was conducted in split plot design with a plot size of 105 m^2 at Shivri Experimental Farm with the objectives 1) To monitor the yield optimizing level of sodicity for short duration variety CSR43 2) Optimizing nutrient requirement through integration of microbial inoculants 3) Increasing cropping intensity of salt affected soils with the introduction of short duration variety CSR 43 and 4) To find out the economically viable rice based cropping system for different sodic environments. Thirty days old seedlings of short duration variety 'CSR 43' was transplanted on 30th June 2017 and harvested on 3rd October, 2017 in all the treatments. After harvesting of rice, short duration crops like cabbage, spinach and beet root were grown in between rice –wheat system. The wheat crop was grown after harvesting of these short duration crops.

From the data given in Table 64, it is evident that as the sodicity level increased plant growth and yields reduced significantly except plant height. Maximum plant height was recorded at S_2 sodicity level. Highest straw and grain yields were recorded at S_1 sodicity level and it reduced with increased sodicity levels. Integrated nutrient management (INM) played significant role in plant growth and yields. Highest straw and grain yield was recorded with recommended dose of fertilizers (RDF) (150:60:40:25 kg Zinc sulphate). Significant interaction between soil pH and INM was observed on grain yield of paddy crop. Maximum grain yield at all the sodicity levels was recorded with N_1 (recommended dose of fertilizers (RDF) (150:60:40:25 kg Zinc sulphate) but it was at par with N_4 (75%RDF+ CSR Bio+ Zinc sulphate) (Table 64).

Table 64: Interaction effect of soil pH and INM on grain yield of rice 2017

Treatments	Grain Yield (q ha^{-1})				Mean
	100% RDF+ 25kg/ha ZnSO4	75%RDF+ MI (Azo+ PSB)	75%RDF+ MI Azo+ PSB + zinc)	75%RDF+ CSR Bio+ Zinc sulphate)	
8.5	58.3	53.3	54.7	54.6	55.22
9.0	51.7	51.6	52.3	51.3	51.70
9.3	46.7	43.7	46.5	45.6	45.62
9.6	40.3	41.0	43.0	41.5	41.45
Mean	49.25	47.4	49.1	48.2	
CD (p=0.05)	1.31				

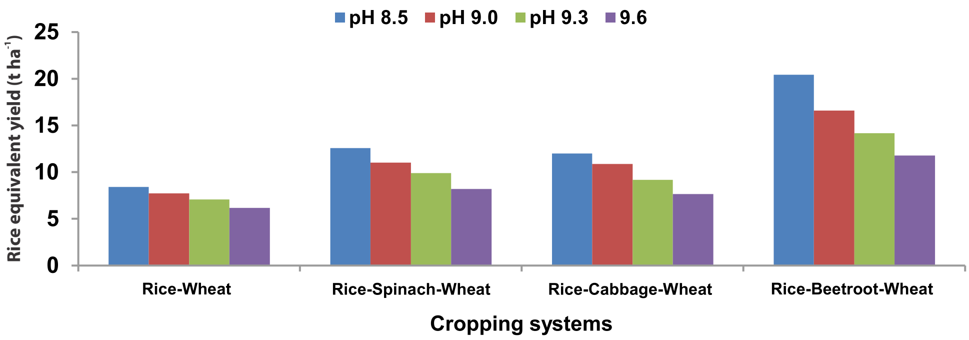


Fig. 82. Rice equivalent yield under different cropping systems

After harvesting of rice 'CSR 43' short duration crops like spinach, cabbage, and beetroot were sown in the same plots. The recommended packages and practices for all the crops were followed. Cost economics of all four cropping systems was calculated on the basis of support price of rice, and the market price of spinach, cabbage and beet root. Maximum income was recorded with rice-spinach-wheat cropping system as compare to rice-wheat, rice-cabbage-wheat and rice-beetroot-wheat cropping systems. However, maximum rice equivalent yield was obtained with rice-beetroot cropping system (Fig. 82) with the introduction of short duration variety 'CSR 43' we can fit an additional short duration crop in between traditional rice-wheat cropping system and fetched an additional income. With the introduction of short duration variety, the cropping intensity of partially reclaimed sodic soils has increased up to 300%. CSR 43's earlier maturation is helpful in saving two to three irrigations costing about Rs.6000/ha. Moreover, such water saving approach could be extremely useful in helping conserve depleting water tables. 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 enhanced the income of the farmers.

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

Wheat

All India Coordinated Wheat Improvement Trial

The All India Coordinated Wheat Improvement trial consisting of 11 entries viz. DBW 246, WH1316, KRL19, DBW248, KRL 386, KRL370, KH 65, DBW 247, KRL 384, KRL 210, and KRL 377 was conducted with 3 replications at Shivri experimental farm Lucknow. The initial soil pH of the experimental field was 9.3. The experiment was laid in Randomized Block design with three replications having row spacing 20 cm and 4m row length with a net plot size of 4 m^2. Wheat crop was sown on 03.12.2016 and harvested on 20.04.2017. Among the genotypes/varieties screened, genotype KRL 386 produced maximum grain yield (34.38 q ha^{-1}) followed by genotypes DBW 246 (3.38 t ha^{-1}) and minimum (3.3 t ha^{-1}) in DBW 247.

All India Salinity /Alkalinity Tolerance Nursery Trial

All India Salinity/ Alkalinity Tolerant Nursery Trial on wheat consisting of 32 entries including 4 checks (Kharchia 65, HD 2009, KRL 19 and KRL 210) with a plot size 1.6 m^2 was conducted at Shivri Experimental Farm Lucknow at pH_2 9.3. Three rows of 2 m length were sown on 03.12.2016 and harvested on 21.04.17. Among the genotypes evaluated, KRL 399, WS 1602 and WS 1603, ranked first, second and third with grain yields of 3.21, 3.08 and 2.96 t ha^{-1}, respectively.

Mustard

All India coordinated Trial on Rapeseed Mustard

An IVT trial consisting of twelve lines with two checks was conducted under alkaline condition (pH_2 9.2) at Shivri experimental farm Lucknow. These lines were sown on 24.10.2016 and harvested on 04.03.2017. Each line was sown at a spacing of 40 x 10cm in a plot size of 8.1 m^2 area and replicated three times. Significant differences were observed in seed yield amongst the genotypes evaluated. Seed yield ranged from 1143.7 to 1473.3 g $plot^{-1}$. Genotype CSCN16-4 (1473.3 g $plot^{-1}$) followed by CSCN16-10 (1407.0 g $plot^{-1}$) and CSCN16-3 (1389.2 g $plot^{-1}$) produced the highest seed yield.

Another AVT trial with nine entries was conducted at the same site. The genotypes were sown on 24.10.2016 and harvested on 05.03.2017. Each genotype was grown in a plot of 16.2m^2. Significant differences were observed in seed yield amongst the genotypes evaluated. Seed yield ranged from 2278.5 to 2868.7 g $plot^{-1}$. Genotype CSCN16-19 produced maximum grain yield (2868.7 g $plot^{-1}$) whereas minimum (2278.5 g $plot^{-1}$) was noted in CSCN16-14.

All India Coordinated Agronomy trial was conducted to evaluate the performance of four promising rapeseed-mustard entries viz., AG-17, AG 18, AG 19 and AG 20 under different fertility levels was conducted at Shivri experimental farm, Lucknow. The genotypes were sown on 19.10.2016 and harvested on 06.03.2017. Each genotype was sown in 13.5 m^2 plot. 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 9.2. Maximum grain yield was recorded with genotype AG 19 at all the N levels.

Rice

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

To evaluate comparative performance of promising elite cultures for alkalinity and inland salinity tolerance a field experiment consisting of 44 lines including one local check (CSR 36) was conducted at Shivri experimental Farm, Lucknow. The pH of experimental field was 9.8. The experiment was conducted in a Randomized Block Design with four replications. The crop was transplanted on 25.07.2017 with 5 rows of 3 m length having plot size of 3.0 m^2. Among the genotypes evaluated 2210, 2209 and 2206 were found promising under highly sodic soils. One genotype (2218) did not flower. Soil pH (0-15cm) was also recorded at maximum tillering and flowering stages.

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

Fifteen advance rice entries including one check (CSR 36) were evaluated under high sodicity conditions (pH 9.6) at Shivri experimental Farm, Lucknow, during Kharif 2016. The trial was conducted in RBD with four replications. Each genotype was planted at 20 x

15cm apart in 10 rows of 4 m length having gross plot size of 8 m^2. Thirty days old nursery was planted on 14.07.2016 and recommended dose of fertilizers was applied. Genotype 2115, 2111, 2119 and 2117 showed the highest grain yield (>4.0 t ha^{-1}) whereas minimum (2.23 t ha^{-1}) was noted in 2108. Genotype 2109 did not produce any grain.

All India Coordinated Agronomy Trial

Nitrogen response trials on selected AVT-2 rice cultures under high and low input management environments was conducted at Shivri expermental farm, Lucknow during Kharif 2017 with the objectives to maximize the yield of recent released varieties under high and low input management and to maximize the rice profits through integrated nutrient management approaches. Treatments consisted of five fertilizer levels (F_1-50% of recommended dose of fertilizers, F_2-100% recommended dose of fertilizers, F_3 -150% recommended dose of fertilizers , F_4 – 50% RDF + microbial inoculation (Halo Azo) and F_5-100% RDF + microbial inoculation (Halo Azo) in main plot and five rice cultures/varieties viz., CSR 36,Ganga Kaveri, Moti, CSR 46 and CSR 43 in sub plots. Three times replicated experiment was laid in split plot design with a plot size of 10.0 m^2. The experiment was conducted at soil pH 8.9. Grain yield of all the entries increased with increasing fertilizer levels. Maximum grain yield was recorded with CSR 36 at all the fertilizer levels. However, grain yield of CSR 36 and Ganga Kaveri was at par with all the fertilizer levels. 150% of recommended fertilizer level produced significantly higher yield over rest of the fertilizer treatments. Addition of microbial inoculation with 100% RDF gave significantly higher grain yield over 100% RDF.

Breeding of salt tolerant polyembryony rootstocks of mango and assessment of bio-efficacy of microbial formulations in the control of *Fusarium* wilt of banana and guava (Inter-Institutional institute funded) (T. Damodaran, S. Rajan, V.K. Mishra, Umesh, S.K. Jha)

The study was conducted to screen the salt tolerant polyembryony mango rootstocks in sodic soils and understand the field tolerance mechanism. In this study, 6salt tolerant polyembryonic accessions that showed tolerance in pot experiments were selected for further evaluation in sodic soils. The homogenous block with no significant difference in soil pH was selected for the experiment. The soil pH ranged from 9.13 in the surface to 9.90 at the depth of 30-60cm. The sodium absorption ratio (SAR) increased from 8.81 at 0-15 cm to 16.03 at 30-60 cm. Sodium was predominantly found in the soil in the form of carbonate and bicarbonate at all depths. The seedlings from polybags were planted in the experimental field of sodic soil during July 2014. The leaf (3^{rd} leaf from terminal portion of seedling) and meristem tip samples were collected at time of planting and at the end of first and second year after planting for analyzing the content of Na^+ and K^+. Salt stress reduced the survival rate of accessions over the period of time (Fig.83). However, significantly higher survival rate was showed by the accessions ML-2, ML-6 and the standard check 13-1 during the experiment period. Salt stress caused a significant variation in the accumulation of sodium and potassium in leaves and growing meristem (Table 65) among the seven accessions. At planting, no significant variations in Na^+ and K^+ uptake among the accessions were observed. However, at 1^{st} YAP, the accessions ML-2, ML-6 and 13-1 showed a significant decrease of Na^+/ K^+ ratio in leaves and growing meristem compared to others (ML-3, GPL-1, GPL-3 and GPL-4). The Na^+ /K^+ ratio of the accessions ML-2 and ML-6 were similar to that of salt tolerant control 13-1. Since Na^+

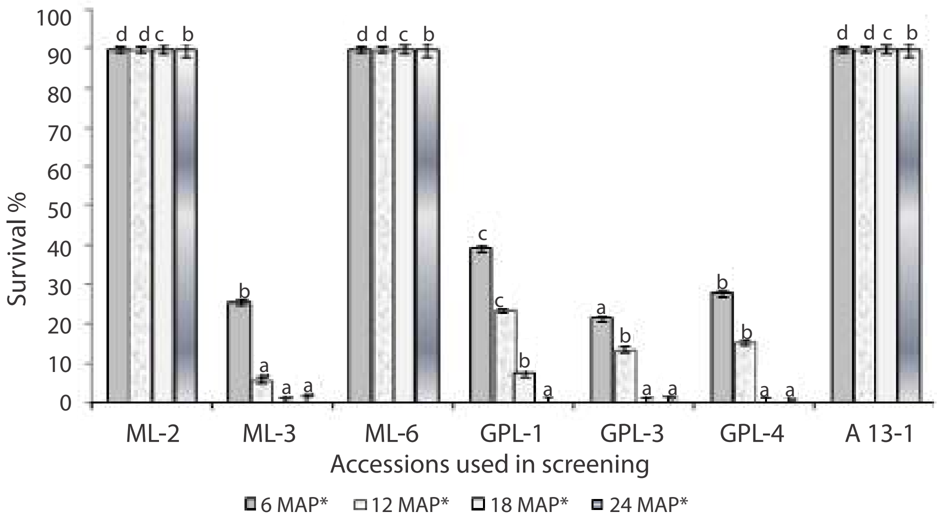


Fig.83. Effect of sodicity on survival percentage of seven polyembryonic mango accessions

*MAP – Months after planting. Values of bars are the means of three replicates. Means in the bars of different accessions followed by the same letter are not significantly different according to Duncan's multiple range test at P=0.05. The vertical bars represent the standard error of the mean, n = 5.

competes with K^+ for major binding sites in many key metabolic processes in the cytoplasm, such as enzymatic reactions, protein synthesis and ribosome functions the plant becomes susceptible to Na^+ injury. Evidence has demonstrated that potential of the plant to hold K^+ has been crucial for increased salt tolerance in the accessions ML-2, ML-6 and 13-1. The study emphasized with the finding that the tolerant accessions (ML-2 and ML-6) possessed higher K^+ ions accumulating ability in their leaves and meristem tips that caused significant reduction in Na^+/K^+ ratio. Thus, the accessions ML-2 and ML-6 can be considered as better salt tolerant polyembryony rootstocks of mango for the tropics and sub-tropics than 13-1. Also, 122 crosses were made between ML-6 and 13-1 for developing polyembroynic hybrid rootstock.

Table 65: Change in sodium (Na), potassium (K) contents and Na/K ratio in meristem tip of seven polyembryonic mango accessions

	At planting			1st YAP			2nd YAP		
Accessions	Na (meq L^{-1})	K(Meq L^{-1})	Na/K	Na(meq L^{-1})	K(meq L^{-1})	Na/K	Na(meq L^{-1})	K(meq L^{-1})	Na/K
ML-2	0.120a	0.954a	0.126a	0.510a	1.390b	0.367a	0.640b	1.532b	0.417b
GPL-3	0.160bc	1.102a	0.145a	1.680b	0.210a	8.000b	0.000a	0.000a	0.000a
ML-3	0.130ab	0.966a	0.135a	1.240b	0.198a	6.263b	0.000a	0.000a	0.000a
GPL-1	0.125ab	1.012a	0.123a	1.890b	0.244a	7.746b	0.000a	0.000a	0.000a
ML-6	0.140ab	1.059a	0.132a	0.468a	1.559b	0.300a	0.583b	1.653b	0.353b
GPL-4	0.242d	1.450a	0.167a	2.440c	0.450a	5.422b	0.000a	0.000a	0.000a
13-1	0.178c	1.264a	0.140a	0.378a	1.264b	0.299a	0.471b	1.427b	0.330b
S.Ed.									

*YAP – Year after planting; ** - plants attained mortality during 2nd YAP
Values are the means of three replicates with the sample size n=5. . Means in the columns followed by the same letter are not significantly different according to Duncan's multiple range test at P=0.05

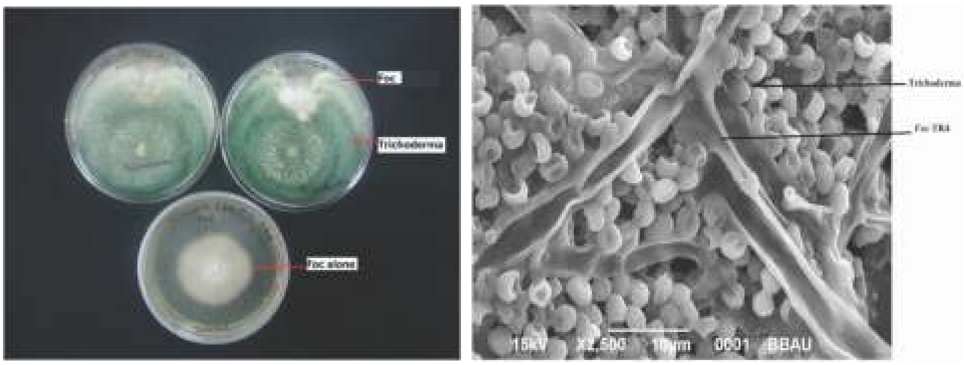
ML-2 Molecular confirmation of *Fusarium oxysporum f.sp.* cubense Race 4

The internal transcribed spacer (ITS) region of the ribosomal RNA amplified using ITS-1 was sequenced (GenBank Accession No.MG430267). The sequence was further compared with database of Gene Bank through nucleotide BLAST search. The results corroborated 98 % similarity to *Fusarium oxyspourum* f.sp. *cubense* race 4 (LT571434). Also, molecular confirmation was made using TR-4 specific primers (*Foc*TR4-F 5´-CACGTTTAAGGTGCCATGAGAG-3´) and (*Foc*TR4-R 5-GCCAGGACTGCCTCGTGA-3)**.** An amplification product of 463 bp specific to VCG 01213 (*Foc* TR4) was obtained confirming the presence of race 4 pathogen. The wounded roots of the plantlet was dipped for 30 min. in 10^6 spores /ml PDA culture broth and was planted in pots with sand media under 28°C (70 % humidity). Five plants each with three replicates were maintained. The control set treated with water and *Fusarium oxysporum* of tomato separately were evaluated simultaneously for disease incidence. free from inoculam. After 45 days of inoculation, internal symptoms were recorded and tissues of the infected plants were placed on ¼ strength of PDA medium. The presence of TR4 was confirmed by performing PCR with specific primers used earlier for confirmation. All the symptomatic plants inoculated with TR4 showed amplification at 463bp confirming the presence of the pathogen. To our knowledge, this is the first report on presence of *Fusarium oxysporum* f.sp.*cubense* TR4 from the Uttar Pradesh region of India. ML-2

Harnessing the rhizosphere diversity with dynamic substrate to induce tolerance to abiotic and biotic stress for commercial cultivation of agri-horticultural crops in partially reclaimed sodic soils (AMAAS Funded- 2017-2020) (T. Damodaran, V.K. Mishra and S.K. Jha)

Recently, there has been a noticeable increase in the area under G-9 banana in the Uttar Pradesh. In June 2017, distinct yellowing symptoms of mature leaves were observed on the leaves of G-9 banana cultivars at the Sohawal block of Faizabad district in the state of Uttar Pradesh. This led to suspect for the wilt of banana caused by *Fusarium oxysporum* f.sp. *cubense*; Fusarium wilt of banana particularly Tropical Race 4 (TR4). The disease causes huge loss to the growers and spreads rapidly in soil and water. The fungus can survive as chalmydospores for more than 40 years and its total eradication becomes difficult. The initial symptom of the disease is characterized by yellowing of margins of the older leaves which progress to the midrib and to the entire leaves. Longitudinal psuedostem splitting will be observed in the affected plants. By September 2017 approximately 42 ha were observed to be affected by the disease. Further survey, confirmed the presence of disease in the regions of Kushi Nagar (latitude 26°73.988'N and longitude 83°88.697'E) and Barabanki (27°10.120'N latitude and 81°31.12'E longitude) districts of the Uttar Pradesh, India.

In order to confirm the prevalence of the disease, the sampling of the infected plants psuedostem tissues were carried out in which a distinct internal vascular discoloration was observed. Infected psuedostem were surface sterilized and plated on ¼ strength Potato Dextrose Agar (PDA) medium with an antibacterial agent. White colonies developed after 48 hrs of inoculation and two single microconidia were generated. All isolates phenotypically resembled *F. oxysporum* .



Antagonistic efficacy of *Trichoderma* on Foc

Assessment of efficacy of the *Trichoderma harzianum* (CSR-T-1) for the control of FOC Race 4

The isolated virulent strain of TR4 was screened for *in-vitro* efficacy against the *Trichoderma harzianum* strain CSR-T-1 which had been used for imparting salt tolerance and tolerance against the *Fusarim* wilt of tomato was tested for efficacy against banana fusarium wilt. . The strain CSR-T-1 explicited antagonistic property in suppressing the growth of 12 hrs old *Fusarium oxysporum* (TR4). Pot experiments were also conducted to confirm the pathogenicity of the fungus and also to validate the formulation using CSR-T-1 in the patented CSR-BIO media with altered substrate. The disease etiology and biocontrol potential of the formulation was documented using Electron microscopy (Fig.4). Based the research data the technology using the virulent strain of *Trichoderma harzianum* (CSR-T-1) cultured on CSR-BIO patented media with the modification in substrate and spore count was mass multiplied using an innovative protocol and applied in severely and moderately affected fields for the control since June 2017. The product and the technology helped in checking the proliferation rate by reducing to 7 % compared to 68 % in untreated fields (Non-adopters).

Field affected by the Fusarium wilt in Uttar Pradesh

Reclamation and management of salt affected vertisols

Breeding and evaluation of field crops for salt tolerance in saline Vertisols (Indivar Prasad, Anil R. Chinchmalatpure and Shrvan kumar)

Selection of salt tolerant crops and their varieties is considered to be one of the best management strategies for the reclamation and management of salt affected soils. Salt tolerant varieties offer a low cost, scalable and easy to adopt solution to overcome salinity problem. Efforts are being made for screening and development of salt tolerant varieties of major field crops *viz.*, cotton, wheat and maize being grown in the salt affected areas of Gujarat state. Breeding experiments of cotton during *kharif* 2016-17 and evaluation/screening experiments of wheat and maize during *rabi* 2016-17 were continued.

Cotton: 400 lines of segregating populations of *G. arboreums* and *G. herbaceums* were planted at Samni Experimental Farm. Generation advancement of segregating population of *desi* cotton (*Gossypium herbaceum* and *G. arboreum*) in saline Vertisols was also done. Breeding programme of *desi* cotton yielded 70 F_6 genotypes (*G. herbaceum*) of eight diverse crosses. These lines were tested in Preliminary Yield trial (PYT) during *kharif* 2017-18. Pedigree selection yielded 76 F_5 progenies of *G. arboreum* which were planted in *kharif* 2017-18 for further selection. These lines were selected and advanced on basis of yield and biochemical parameters recorded during the entire crop duration. New breeding populations were developed in *G. herbaceum* with tolerant parents identified in this project. These crosses were attempted by incorporating salt tolerant and high yielding genotypes identified during previous years. Apart from this, five trials consisting of 100 accessions were evaluated for salinity tolerance and yield; and many tolerant genotypes have been identified (Table 66).

Cotton Experiment in pot culture

Two national trials of All India Coordinated Cotton Improvement Project (AICCIP) were conducted. In trial 32 b (IET of *G. herbaceum*), GShv 362/12 was best performing (681 Kg ha^{-1} seed cotton yield) due to low Na^+uptake (29 µmol g^{-1} DW) and high K^+/Na^+ ratio (9.8) in leaf tissues. Similarly, in trial 22b (IET of *G. arboreum*), FDK 272 was best performing entry (1062 Kg ha^{-1} seed cotton yield) again due to low Na^+ uptake (70 µmol g^{-1} DW) than most of the entries. Salt tolerant *desi* cotton genotypes of G. *arboreum* FDK 272, DWDa 1602, PA 828, GAM 236 and RG 804 identified at RRS, Bharuch have been found top ranking genotypes in terms of yield across three zones of India in AICCIP. Seed cotton yield of these hybrids ranged between 888-1062 kg ha^{-1} at EC_e of 6.6-7.8 dS m^{-1} at Samni Experimental Farm, Bharuch. Similarly, salt tolerant *desi* cotton genotypes of *G. herbaceum* GShv 362/12 and GShv 385/12 identified at RRS, Bharuch were top yielders across zones with more than 681 Kg ha^{-1} seed cotton yield at Samni. AICCIP cotton trial PHY1b (*G. hirsutum* and *G. barbadense*) was planted in pots and harvested. Forty one genotypes were screened for salinity tolerance in pots (EC_{iw}: 8 dS m^{-1} and EC_e: 3.8-4.8 dS m^{-1}). Result showed significant differences in physiological responses and seed cotton yield among genotypes. The highest seed cotton yield was observed in RHH-1007 followed by TCH-1199 and TSH-327 while it was lowest in L-1384 under saline condition. Sodium content was found more in AKH-1301 followed by RB-610, BGSD-1072 and RHH-1007 whereas highest potassium content was recorded in L-1384 followed by GSB-43 and CPD 1601 before flowering. The highest K^+/Na^+ ratio was found in GISV-310, GJHV 477 and L-1384. At flowering stage, highest Na^+ content was found in BGDS-1063 followed by GJHV 516 and RHH 1007 while highest K^+ content was recorded in Suraj followed by BGDS 1072.

Table 66: Generation advancement of G. herbaceum genotypes from F5-F6 generation

Genotype	Pedigree	Genera-tion	Na/K ratio	New Genotype	Seed Cotton Yield (g Plant^{-1})	Code
CSB-1-1-1-2	GBhv 291 x GShv 297/07	F5	14.6	CSB-1-1-1-2-1 CSB-1-1-1-2-2	124 120	CSC-001 CSC-002
CSB-1-1-1-3	GBhv 291 x GShv 297/07	F5	13.2	CSB-1-1-1-3-1 CSB-1-1-1-3-2	116 110	CSC-003 CSC-004
CSB-2-1-1-1	G.Cot.23 x GShv 378/05	F5	13.0	CSB-2-1-1-1-1 CSB-2-1-1-1-2	82 80	CSC-005 CSC-006
CSB-2-1-1-3	G.Cot.23 x GShv 378/05	F5	10.7	CSB-2-1-1-3-1 CSB-2-1-1-3-2	84 76	CSC-007 CSC-008
CSB-2-1-2-1	G.Cot.23 x GShv 378/05	F5	7.0	CSB-2-1-2-1-1 CSB-2-1-2-1-2	100 112	CSC-009 CSC-010
CSB-2-1-2-2	G.Cot.23 x GShv 378/05	F5	9.6	CSB-2-1-2-2-1 CSB-2-1-2-2-2	120 109	CSC-011 CSC-012
CSB-2-1-4-1	G.Cot.23 x GShv 378/05	F5	13.4	CSB-2-1-4-1-1 CSB-2-1-4-1-2	110 104	CSC-013 CSC-014
CSB-2-1-4-5	G.Cot.23 x GShv 378/05	F5	8.0	CSB-2-1-4-5-1 CSB-2-1-4-5-2	112 104	CSC-015 CSC-016
CSB-3-1-4-1	GBhv 287 x GShv 451/08	F5	13.7	CSB-3-1-4-1-1 CSB-3-1-4-1-2	116 120	CSC-017 CSC-018
CSB-3-1-4-2	GBhv 287 x GShv 451/08	F5	12.9	CSB-3-1-4-2-1 CSB-3-1-4-2-2	109 114	CSC-019 CSC-020
CSB-3-1-5-1	GBhv 287 x GShv 451/08	F5	7.8	CSB-3-1-5-1-1 CSB-3-1-5-1-2	70 85	CSC-021 CSC-022
CSB-3-1-5-3	GBhv 287 x GShv 451/08	F5	13.7	CSB-3-1-5-3-1 CSB-3-1-5-3-2	82 79	CSC-023 CSC-024
CSB-5-1-3-1	GShv 451/08 x GBhv 290	F5	15.8	CSB-5-1-3-1-1 CSB-5-1-3-1-2	120 114	CSC-025 CSC-026
CSB-5-1-3-2	GShv 451/08 x GBhv 290	F5	20.1	CSB-5-1-3-2-1 CSB-5-1-3-2-2	124 109	CSC-027 CSC-028
CSB-7-1-4-1	GBhv 291 x GBhv 283	F5	6.6	CSB-7-1-4-1-1 CSB-7-1-4-1-2	82 79	CSC-029 CSC-030
CSB-7-1-4-4	GBhv 291 x GBhv 283	F5	11.4	CSB-7-1-4-4-1 CSB-7-1-4-4-2	90 78	CSC-031 CSC-032
CSB-7-1-5-1	GBhv 291 x GBhv 283	F5	4.2	CSB-7-1-5-1-1 CSB-7-1-5-1-2	70 76	CSC-033 CSC-034
CSB-7-1-5-5	GBhv 291 x GBhv 283	F5	18.1	CSB-7-1-5-5-1 CSB-7-1-5-5-2	69 80	CSC-035 CSC-036
CSB-7-1-8-5	GBhv 291 x GBhv 283	F5	9.2	CSB-7-1-8-5-1 CSB-7-1-8-5-2	60 72	CSC-037 CSC-038
CSB-7-1-10-1	GBhv 291 x GBhv 283	F5	4.9	CSB-7-1-10-1-1 CSB-7-1-10-1-2	55 65	CSC-039 CSC-040
CSB-7-1-10-2	GBhv 291 x GBhv 283	F5	12.5	CSB-7-1-10-2-1 CSB-7-1-10-2-2	59 70	CSC-041 CSC-042
CSB-8-1-3-1	GShv 297/07 x GBhv 290	F5	15.7	CSB-8-1-3-1-1 CSB-8-1-3-1-2	110 106	CSC-043 CSC-044
CSB-8-1-3-4	GShv 297/07 x GBhv 290	F5	21.1	CSB-8-1-3-4-1 CSB-8-1-3-4-2	98 112	CSC-045 CSC-046
CSB-8-1-4-4	GShv 297/07 x GBhv 290	F5	11.4	CSB-8-1-4-4-1 CSB-8-1-4-4-2	120 107	CSC-047 CSC-048
CSB-8-1-6-1	GShv 297/07 x GBhv 290	F5	11.6	CSB-8-1-6-1-1 CSB-8-1-6-1-2	98 90	CSC-049 CSC-050
CSB-8-1-6-5	GShv 297/07 x GBhv 290	F5	17.9	CSB-8-1-6-5-1 CSB-8-1-6-5-2	88 92	CSC-051 CSC-052
CSB-8-1-7-1	GShv 297/07 x GBhv 290	F5	18.0	CSB-8-1-7-1-1 CSB-8-1-7-1-2	113 120	CSC-053 CSC-054
CSB-8-1-7-4	GShv 297/07 x GBhv 290	F5	18.0	CSB-8-1-7-4-1 CSB-8-1-7-4-2	118 111	CSC-055 CSC-056
CSB-8-1-8-1	GShv 297/07 x GBhv 290	F5	10.6	CSB-8-1-8-1-1 CSB-8-1-8-1-2	115 90	CSC-057 CSC-058
CSB-8-1-8-5	GShv 297/07 x GBhv 290	F5	19.3	CSB-8-1-8-5-1 CSB-8-1-8-5-2	82 88	CSC-059 CSC-060
CSB-10-1-1-1	GShv 297/07 x GShv 273/07	F5	15.0	CSB-10-1-1-1-1 CSB-10-1-1-1-2	90 88	CSC-061 CSC-062
CSB-10-1-1-3	GShv 297/07 x GShv 273/07	F5	14.4	CSB-10-1-1-3-1 CSB-10-1-1-3-2	90 92	CSC-063 CSC-064
CSB-10-1-2-1	GShv 297/07 x GShv 273/07	F5	11.1	CSB-10-1-2-1-1 CSB-10-1-2-1-2	110 120	CSC-065 CSC-066
CSB-10-1-2-5	GShv 297/07 x GShv 273/07	F5	8.2	CSB-10-1-2-5-1 CSB-10-1-2-5-2	122 120	CSC-067 CSC-068
CSB-10-1-4-1	GShv 297/07 x GShv 273/07	F5	9.3	CSB-10-1-4-1-1 CSB-10-1-4-1-2	125 130	CSC-069 CSC-070
G Cot 23	Check		4.8		64	Check

Highest K^+/Na^+ ratio was found in TSH-324 followed by CPD 1602 and L 799. Field screening for salinity tolerance (EC_{iw} of 10.6 dS m^{-1} and EC_e of 4.2-5.6 dS m^{-1}) also showed significant differences in physiological responses and seed cotton yield. The highest seed cotton yield was recorded by RHH 1007 and the lowest in L 1384 under saline condition.

Desi cotton trial of Anand Agricultural University, Anand

Six entries *viz.*, V 797, G Cot 13, G Cot 21, ADC-1 and GADC-2 were tested along with check G Cot DH 7 in native saline condition at Samni Experimental Farm (EC_e: 4.5 dS m^{-1}, EC_{iw}: 9.5 dS m^{-1}). Plot size was 3 m x 2.4 m with three replications. Maximum yield was observed in G Cot 21 (15.3 q ha^{-1}) followed by ADC-1 (13.8 q ha^{-1}) and GADC-2 (13.1 q ha^{-1}) whereas G Cot DH-7 yield was 7.6 q ha^{-1}. These entries were also planted in microplot under saline water irrigation along with 10 diverse genotypes in two replications. Under controlled salinity in microplot (EC_e of 4.2 dS m^{-1}, EC_{iw} of 12 dS m^{-1}), these entries were tested with check G Cot 23 and G Cot DH-7. GADC-2 was the highest yielder 353 gm/plot followed by G Cot 21 (350 gm $plot^{-1}$) and check G Cot 23 (322 gm $plot^{-1}$). For ionic parameters in microplot experiments, V 797 was best entry followed by G Cot 21 as it maintained high K/Na (sodium/potassium) ratio in root, shoot and leaf. However, V797 was less yielder. G Cot 21 was high yielding and superior for ionic parameters and was found best among these entries under saline conditions. Small boll size and closed bolls were main limitation in these entries as it make harvesting difficult compared to G Cot 23.

Wheat (*Rabi* 2016-17)

Two wheat trials consisting of 10 and 12 entries were conducted with saline water irrigation (EC_{iw} of 9-11 dS m^{-1}) at Samni Experimental Farm. KRL 345, KRL 351, NW 6096 and KRL 378 were found promising entries (Fig. 84). Wheat genotype KRL 370 was found salt tolerant with 3.88 t ha^{-1} grain yield at EC_e of 8.5 dS m^{-1} under saline water irrigation (EC_{iw} 9-11 dS m^{-1}) under All India Coordinated Salinity/Alkalinity trial conducted at Bharuch during *rabi* 2016-17.

Two trials of *rabi* maize comprising of 24 entries (both hybrid and varieties) were conducted under saline water irrigation (EC_{iw} 3-3.5 dS m^{-1}). DKC-8101 emerged as the best hybrid under saline irrigation while SS-7077 ranked second. For biomass, SS-7077 was the best hybrid. High biomass and maintenance of better K^+/Na^+ ratio were found to be highly correlated with grain yield in the superior hybrids. Among varieties and composites, DMRQPM-0903 and GM-6 were superior for yield and related attributes.

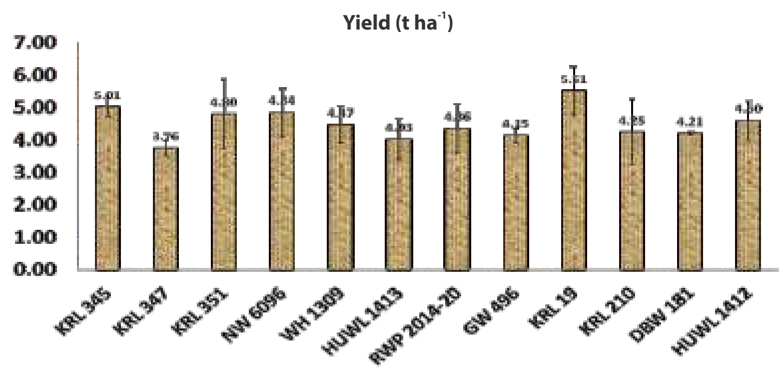


Fig. 84. Performance of wheat genotypes under saline water irrigation during Rabi 2016-17 Maize (Rabi 2016-17)

STV of wheat (KRL 210) on saline Vertisol

Prospects of Cultivating Desi Cotton Genotypes and Salt Tolerant Wheat Varieties in Saline Vertisols (Anil R. Chinchmalatpure)

Salinity is a major factor constraining agriculture in Gujarat. Use of salt tolerant varieties (STV) is one of the viable approaches to overcome this problem. Attempt has been made to demonstrate potential of STV of wheat like KRL 210 and KRL 19 developed by ICAR-CSSRI Karnal, and also STV of *desi* cotton (G.Cot 23) in the study area of Baratract of Gujarat. Study was conducted with more than 70 farmers from Bharuch district during the year 2014-16 for both the crops. Data were collected using personal interview of the farmers using a well structured interview schedule. Soil salinity of the study area was low at surface, but increased with depth. Average EC_e at 0-15 cm layer was less than 4.0 dS m^{-1}, while at lower depth (60-90 cm) it was greater than 4.0 dS m^{-1}, indicating presence of sub-surface salinity.

Economic Analysis STV of wheat (KRL 210) on saline Vertisol : Economic analysis of cultivation of STV of wheat revealed that total input cost involving various operational costs was Rs.23078 ha^{-1}. Owing to less water requirement of wheat STV than other varieties, farmers could save cost of 1-2 extra irrigations. Average yield of wheat STV at farmers' field was 3.0 t ha^{-1} resulting in net income of Rs. 30922 ha^{-1} and B:C ratio of 2.3. Other advantages reported by the farmers are STV had more number of tillers (96%) and less lodging tendency (92%). All farmers agreed that eating quality of wheat STV was good. By growing wheat STV, farmers could increase their incomes by bringing saline lands under cultivation. Based on the data and distribution of wheat STV seed to the farmers in the region in three years and considering the conservative estimates, it is estimated that about 25000 ha area has been under wheat STV and is likely to increase as per the liking and demand of the famers of the region.

In case of *desi* cotton, the gross profit under rainfed conditions was Rs. 34,947 ha^{-1} with B: C ratio 1.9 while it was Rs. 75, 250 ha^{-1} with B: C ratio of 1.7 in irrigated condition. Farmers perceived that cost of cultivation for *desi* cotton is less. *Desi* cotton has inherent ability to withstand abiotic stresses like drought/ water stress, salinity/sodicity etc. In these areas, choice of *desi* cotton is not preferential but obligatory for the farmers. It is tolerant to biotic stresses like curly leaves, bacterial blight, and comparatively tolerant to bollworm complex. Owing to these factors, the cost of cultivation of *desi* cotton is less as compared to that of Bt hybrids and is more eco-friendly.

Perception of the farmers

All the farmers growing wheat STV agreed that cultivation of STV in salt affected areas helped in increasing the farm incomes with mean score of 4.16 on five point scale. In terms of social benefits, about 76% of them perceived that such varieties would help in upliftment of small and marginal farmers. About 96% farmers were positive about use of STV in saline soils having moderately saline groundwater. With reference to agronomic practices, more number of tillers (96%) and less lodging and shattering tendency (92%) were the major benefits perceived by the farmers. All farmers agreed that eating quality of wheat STV was good. This clearly shows overwhelming response by the farmers for wheat STV in saline areas.

In case of desi cotton, survey elicits both positive and negative response of the farmers. Less cost of cultivation was perceived as the biggest advantage of *desi* cotton. Many farmers in this region do not apply fertilisers and pesticides to the *desi* cotton. Farmers perceived that *desi* cotton was better option for them because of harsh environmental conditions like soil and water salinity, and less rainfall. In saline condition, less boll drop was observed in *desi* cotton. Farmers also were happy with lesser incidence of pests-diseases in *desi* cotton resulting in reduced dependence on costly spraying. Farmers believed that cultivating *desi* cotton helps in sustainable agro-ecosystem management. Longer duration was perceived as major disadvantages of the *desi* cotton by the farmers. First, long duration leads to late harvesting (April-May), when weather is hotter resulting in loss of weight and sometimes yellowing of the lint. Second, at this time market price goes down and the farmers get less price for their produce. Third, because of more heat in the months of April and May, labourers refuse to work in the field or demand more money for picking. Agronomic characteristics like small size of boll in case of *desi* cotton was negative aspect reported by the farmers. Moreover, bolls do not open completely causing difficulty in separating seed lint from the dried boll. Whatever limitations of the *desi* cotton, its advantages outweigh disadvantages making it an ideal and solo alternative in saline and rein fed areas. In conclusion, we suggest that high yielding, short duration varieties of *desi* cotton with more number of boll and bigger boll size, which opens completely after maturity (for easily detachment of lint from boll) need to be developed. At the same time efforts can be made for participative seed production of *desi* cotton to meet the seed requirement of the farmers.

It is concluded that farmers in dryland saline areas of Bara tract of Gujarat have no other option but to go for *desi* cotton cultivation. Improved short duration varieties will be a bonanza to these farmers. Availability of quality seeds of improved varieties is likely to have beneficial impact on farmers' livelihoods and agro-ecosystem sustainability. In case of wheat, STV helped them in increasing their income by bringing the saline lands under cultivation. But there is need to create awareness among farmers in salt affected areas of Gujarat about availability such STV of wheat.

Performance of guava orchards with forage intercropping and pruning intensity on saline Vertisols of Gujarat (David Camus. D, Anil R. Chinchmalatpure and Shrvan Kumar)

Experiment I: Performance of forage species in young guava orchards grown on saline Vertisols

The experiment was conducted at the Samni Experimental Farm of ICAR-CSSRI, RRS Bharuch with the objective to compare the yield and quality of three fodder species *viz*., Sorghum CSV 21F, Rijka bajra and Sweet Sudan grass grown as intercrop in 5 m x 5 m spaced 3-y old guava orchard on saline Vertisols in 2017. The experiment was laid out in strip plot design with 3 replications. The standard package of practices for these fodder crops was followed. Irrigation treatments like best available water (BAW) and saline water of 4 dS m^{-1} and 8 dS m^{-1} were given to guava only. Sowing of intercrops was done in late *kharif* season. Maximum plant height was recorded in sorghum CSV 21F (173.8-178.0 cm) followed by sweet sudan grass (162.5-164.2 cm) and rijka bajra (145.8-155.8 cm). The edge effect of irrigating guava plants with saline water had a less significant effect on Sorghum CSV 21F compared to rijka bajra. Saline water irrigation did not have any significant effect on plant height of Sweet sudan grass. Stem diameter of Sorghum CSV 21F ranged from 2.3 to 2.6 cm in sorghum CSV 21F, 0.9 to 1.0 cm in rijka bajra and 1.7 to 1.8 cm in Sweet Sudan grass. The maximum number of tillers (4) was obtained in rijka bajra

Table 67: Yield and quality parameters of forages grown as intercrop in guava orchards on saline Vertisol

Treatments	Green fodder yield ($q\ ha^{-1}$)	Dry matter (%)	Leaf Stem ratio	Crude protein (%)	Crude fibre (%)
F1I1	118	25.50	0.28	7.98	26.28
F1I2	114	24.22	0.27	7.92	27.68
F1I3	113	23.02	0.26	7.76	27.37
F2I1	74	17.76	0.55	9.84	29.51
F2I2	71	16.99	0.51	9.40	31.20
F2I3	70	15.91	0.48	9.34	31.61
F3I1	85	20.03	0.32	7.41	27.37
F3I2	83	19.46	0.30	7.40	28.45
F3I3	81	18.21	0.30	7.23	29.13
Mean	90	20.12	0.36	8.25	28.73
Fodder (LSD0.05)	3.68	4.10	0.03	0.90	1.94
Irrigation (LSD0.05)	ns	1.50	ns	ns	ns

I1 = BAW; I_2 = EC_{iw} 4 dS m^{-1} and I_3= Irrigation with EC_{iw} 8 dS m^{-1}; F_1= sorghum CSV 21F, F_2= rijka bajra and F3=sweet sudan grass

and 2 each in Sorghum CSV 21F and Sweet Sudan grass. The number of leaves was also more in rijka bajra (13-16) closely followed by sweet sudan grass (13-14) and least in sorghum CSV 21F (8-10).

There was less significant difference in green fodder yield and no significant difference in dry matter percent of sorghum CSV 21F grown under guava orchards treated with different irrigation levels. Similar trend was observed in other fodder crops also. However the green fodder yield and dry matter percent of sorghum CSV 21F, 113-118 q ha^{-1} and 23.02-25.50 % respectively were comparatively higher when compared to rijka bajra (70-74 q ha^{-1} and 15.91-17.76 %) and sweet sudan grass (81-85 q ha^{-1} and 18.21-20.12 %). The crude protein was highest in rijka bajra (9.34-9.84 %) while for sorghum CSV 21F and sweet sudan grass, it was 7-8 % . In case of other quality parameters like crude fibre and leaf stem ratio, the quality was better in sorghum CSV 21F (26.28-27.68 % and 0.26-0.28) followed by sweet sudan grass (27.37-29.13 % and 0.30-0.32) and rijka bajra (29.51-31.61 % and 0.48-0.51) (Table 67).

Overall performance of the forages in the intercropping experiment suggests that sorghum CSV 21F performed better in terms of green fodder yield, dry matter percent, plant height, stem diameter, leaf stem ratio and crude fibre compared to rijka bajra and sweet sudan grass and the effect of irrigating guava plants with saline irrigation had minimal effect on its performance.

Experiment II: **Responses of guava to varying levels of pruning and fertilizer application on Saline Vertisols**

The experiment was carried out in 10-y old guava orchards of cv. Allahabad Safeda planted at a spacing of 5 m x 5 m. The experiment was laid out in strip-split plot design with three factors *viz*., pruning, saline water irrigation and nitrogen fertilization in two replications. The study was taken up to understand the maximum tolerance level of Allahabad Safeda to saline water irrigation without affecting fruit yield and quality and the optimal nitrogen dose and intensity of pruning required for them in saline Vertisols. The treatments consisted of three pruning intensities - no pruning (P_1), 25% pruning of current seasons growth (P_2) and 50% pruning of current seasons growth (P_3), three irrigation treatments - Best Available Water (I_1), irrigation water of EC_{iw} 4 dS m^{-1} (I_2) and irrigation water of EC_{iw} 8 dS m^{-1} (I_3) and three nitrogen levels - 500g/tree/year (N_1), 750g tree^{-1} year^{-1} (N_2) and 1000g tree^{-1}year^{-1} (N_3) in two split doses. Pruning was done on the last day of May 2017 to induce fruiting in winter season to get better fruit quality and shelf life compared to rainy season crop.

The individual effects of pruning, saline water irrigation and nitrogen fertilization was highly significant for the parameters studied. The interaction of these factors on fruit yield was also highly significant. 25% pruning of current season's growth produced the maximum number of fruits while 50% pruning of current season's growth produced the maximum fruit weight. Increasing the salinity of water reduced the number of fruits and fruit weight but was significant only at higher level of salinity (8 dS m^{-1}). Increase in nitrogen levels increased both the number of fruits and fruit weight. Increase in pruning had a positive effect on fruit quality parameters like TSS and fruit acidity whereas increase in salinity of irrigation water and nitrogen levels had a positive effect on TSS and negative effect on acidity.

Results revealed that maximum fruit yields of 49.14, 48.75, 48.74 and 45.71 q ha^{-1} were recorded in $I_1P_2N_3$, $I_1P_2N_2$, $I_2P_2N_3$ and $I_2P_2N_2$ treatments, respectively (Table 68). There was no significant reduction in fruit yield between these treatments. The results showed that

Table 68: Fruit yield, its related attributes and fruit quality of 10 year old guava orchard under different treatment combinations on saline Vertisol

Treatments	No. of fruits tree^{-1}	Fruit weight (g)	TSS (° B)	Acidity (%)	Yield (q ha^{-1})
$I_1P_1N_1$	45.50	106.50	10.41	0.32	19.42
$I_1P_1N_2$	48.00	108.50	10.61	0.35	20.73
$I_1P_1N_3$	59.50	119.00	10.71	0.38	28.33
$I_1P_2N_1$	74.50	148.00	10.91	0.31	43.95
$I_1P_2N_2$	77.00	157.50	10.81	0.31	48.75
$I_1P_2N_3$	77.50	158.00	11.31	0.33	49.14
$I_1P_3N_1$	51.00	159.50	11.20	0.27	32.53
$I_1P_3N_2$	62.00	166.50	11.12	0.27	41.26
$I_1P_3N_3$	64.50	174.00	11.66	0.29	44.69
I2P1N1	42.50	107.00	10.71	0.32	18.27
$I_2P_1N_2$	45.00	107.00	11.39	0.35	19.11
$I_2P_1N_3$	45.50	113.50	11.67	0.39	20.77
$I_2P_2N_1$	60.00	144.50	11.12	0.32	34.66
$I_2P_2N_2$	76.00	151.00	11.94	0.32	45.71
$I_2P_2N_3$	77.00	157.50	11.93	0.37	48.74
$I_2P_3N_1$	47.00	158.50	11.26	0.27	29.75
$I_2P_3N_2$	52.00	164.00	12.02	0.29	34.13
$I_2P_3N_3$	60.50	166.00	11.97	0.32	40.18
$I_3P_1N_1$	39.50	95.50	11.41	0.34	15.11
$I_3P_1N_2$	42.50	101.00	11.88	0.36	15.11
$I_3P_1N_3$	42.50	108.50	12.03	0.40	17.19
$I_3P_2N_1$	53.50	131.00	12.12	0.32	28.02
$I_3P_2N_2$	63.00	138.50	12.83	0.32	28.02
$I_3P_2N_3$	71.00	143.00	12.87	0.38	34.92
$I_3P_3N_1$	39.00	153.00	12.63	0.27	23.83
$I_3P_3N_2$	46.00	158.00	12.86	0.29	23.83
$I_3P_3N_3$	46.50	163.50	12.65	0.32	29.04
Mean	55.87	139.20	11.63	0.33	30.93
Irrigation ($CD_{0.05}$)	4.50	3.28	0.20	ns	1.98
Pruning ($CD_{0.05}$)	5.46	2.49	ns	0.04	2.27
Nitrogen ($CD_{0.05}$)	2.84	2.70	0.07	0.01	1.59
I x P x N ($CD_{0.05}$)	Ns	4.77			

N_1= 500 g tree^{-1} y^{-1}, N_2= 750 g tree^{-1} y^{-1} and N_3=1000 g tree^{-1} y^{-1}; P_1 – Control; P_2 – Pruning 25% of current season's growth; P_3 – Pruning 50% of current season's growth; I_1 = BAW; I_2 = EC_{iw} 4 dS m^{-1} and I_3= EC_{iw} 8 dS m^{-1}

25% pruning of current seasons growth gave good yield compared to unpruned and 50% pruned trees. The effect of saline water irrigation of 8 dS m^{-1} had more effect on fruit yield whereas the effect of 4 dS m^{-1} irrigation water was less pronounced and comparable with that of good quality water. Increase in nitrogen levels increased the fruit yield but the difference in yield between 750 kg N tree^{-1} year^{-1} and 1000 kg N tree^{-1}year^{-1} was less visible.

Hence it is recommended to adopt 25% pruning of current season's growth along with saline water irrigation of 4 dS m^{-1} and 750 g N tree^{-1} y^{-1} which gives a fruit yield of 45.71 q ha^{-1}; around 7% less compared to the best treatment. This treatment combination ($I_2P_2N_2$) will help in reducing nitrogen input and save the best available water for arable crop production in saline Vertisols.

Maximization of yield and factor productivity through integrated nutrient management in *desi* cotton-based cropping systems in saline Vertisols (Shrvan Kumar, Indivar Prasad, David Camus D. and Anil R. Chinchmalatpure)

Monocropping is the risky business hence crop diversification is essential for risk coverage and maintaining the soil fertility. Alternative cropping system and management practices such as double-cropping, crop rotation and addition of organic amendments may prove beneficial for making the system sustainable. Crop rotation with legume crops can effectively help in maintaining nutrient balance in soil. Application of Municipal Solid Waste Compost (MSWC) to agricultural land has several beneficial effects similar to other organic manures. Micronutrients always have been ignored in general nutrient management plan. Deficiency of zinc has increased in India due to extensive use of NPK without application of micronutrients. By combining some approaches of integrated nutrient management (INM) and application of micronutrients, yield of field crops can be enhanced and sustainability of the system can be secured. The idea of inclusion of some other crops in the cotton monocrop system along with INM plan can be used for maximization of crop yield. Keeping this in view, experiment was planned with split plot with three cropping systems of cotton in two year crop rotation; C_1- cotton monocropped, C_2-cotton-sorghum-wheat and C_3-cotton-pigeonpea-wheat in main plot and five treatments of INM 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/Rhizobium;* N_5- 50% RDF+ 50 % through MSWC + *Azotobacter/Rhizobium* + Soil application of Zn in three replications.

Table 69: Cotton yield and its parameters affected by various INM treatment under cotton mono-cropped system

Treat-ment	No. of Bolls plant^{-1}	Cotton yield plant^{-1}	Stalk yield plot^{-1}	Cotton yield	Stalk yield plot^{-1}	Cotton yield	Stalk yield	100-seed wt.	GP	LI
		------(g)------		----- (kg) ------		------ (kg ha^{-1}) ----				
N_1	31	68.0	186.5	2.52	6.11	1165.4	2827.3	5.2	40.1	3.5
N_2	34	76.7	220.3	2.95	7.00	1364.9	3242.7	5.3	41.1	3.7
N_3	26	59.1	149.0	2.24	5.28	1036.4	2442.5	5.1	40.7	3.6
N_4	29	69.1	185.6	2.39	6.13	1107.2	2836.8	5.2	41.0	3.6
N5	32	75.7	205.8	2.66	6.68	1229.5	3090.4	5.2	41.4	3.6
LSD (0.05)	3.9	11.36	42.22	0.46	0.97	211.93	447.29	NS	NS	NS

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; MSWC-Municipal solid waste compost, GP- Ginning percentage, LI- Lint index

Yield and yield parameters of cotton under monocropped system: Among INM treatments under cotton mono-cropped system for 1st year, results (Table 69) revealed that N_2 treatment *i.e.* 75% RDF + 25% through MSWC recorded significantly higher values of yield parameters *i.e.* no. of bolls plant^{-1} (34); cotton yield plant^{-1} (76.7 g), stalk yield plant^{-1} (220.3 g), cotton yield plot^{-1} (2.95 kg), stalk yield plot^{-1} (7.00 g), cotton yield ha^{-1} (1364.9 kg ha^{-1}) and stalk yield ha^{-1} (3242.7 kg ha^{-1}) than N_3 and N_4 treatment, which was statistically at par with 50% RDF + 50% through MSWC + *Azotobacter* + Soil application of Zn (N_5) and 100% RDF (N_1) treatment.

Soil fertility status: Under MSWC treatment, significantly higher soil organic carbon (SOC) (medium in range) was found at surface soil layer (0-15 cm depth) under N_5 treatment *i.e.* 50% RDF +50 % through MSWC + *Azotobacter* + Soil application of Zn (0.59 %) which was statistically at par with N2 *i.e.* 75% RDF+25% through MSWC (0.54%) and N_4 *i.e*. 50% RDF + 50% through MSWC + *Azotobacter* (0.55%) treatment and minimum was observed for N_1 (0.45%) treatment. Available NPK was non-significantly different at surface soil layer.

Second Year Experiment: Cotton mono-cropped system (C1):

Maximum plant height was observed at 90 and 120 DAS under the treatment N_5 [50% RDF + 50% through MSWC + *Azotobacter* + soil application of Zn (95.3 cm and 132.8 cm)] followed by N_2 treatment [75% RDF + 25% through MSWC (91.4 cm and 130.5 cm)]. Minimum plant height at 30, 60, 90, and 120 DAS was observed in N_3 treatment (50% RDF + 50% MSWC). Maximum fresh weight (274.1 and 445.4 g) and dry weight (76.9 and 135.9 g) biomass at 90 and 120 DAS was observed under the treatment N_5 followed by N_2 treatment. Minimum fresh weight biomass was observed in N_3 treatment (Table 70).

Cotton-sorghum-wheat system (C2):

Growth parameters of sorghum crop: Results revealed that maximum plant height was observed under the treatment N_5 (50% RDF + 50% through MSWC + *Azotobacter* + Soil application of Zn) followed by N_2 treatment (75% RDF + 25% through MSWC) at 60, 90 and 120 DAS. Minimum plant height at 30, 60, 90, and 120 DAS was observed in N_3 (50% RDF + 50% MSWC). Maximum fresh weight (363.2 g and 629.6 g) and dry weight (77.7 g and 341.8 g) biomass at 90 and 120 DAS was observed under the treatment N_5 followed by N_2. Minimum fresh weight biomass was observed in N_3 treatment (Table 71).

Table 70: Growth parameters (plant height, fresh weight and dry weight biomass) of cotton crop affected by various INM treatment under cotton mono-cropped system (C1).

Treat-ment	Plant height (cm)				Fresh biomass plant^{-1} (g)				Dry biomass plant^{-1} (g)			
	30#	60	90	120	30	60	90	120	30	60	90	120
N_1	10.4	31.4	83.2	121.5	2.9	16.1	238.0	322.6	0.8	3.9	59.3	95.8
N_2	11.2	37.0	91.4	130.5	3.3	19.8	271.0	371.8	0.8	4.5	64.8	121.3
N_3	9.8	33.9	83.7	119.9	2.8	16.1	212.8	308.4	0.7	3.8	53.9	87.2
N_4	10.0	31.1	81.7	122.1	3.1	17.2	245.1	319.9	0.7	3.9	59.3	106.1
N_5	11.6	38.6	95.3	132.8	3.2	19.8	274.1	445.4	0.8	4.9	76.9	135.9
LSD*	NS	NS	6.1	5.4	NS	1.68	18.44	29.35	NS	0.7	3.2	10.5

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; MSWC-Municipal solid waste compost ; *LSD (0.05)

Table 71: Growth parameters of sorghum under various INM treatments in C2 system

Treat-ment	Plant height (cm)				Fresh biomass plant^{-1} (g)				Dry biomass plant^{-1} (g)			
	30#	60	90	120	30	60	90	120	30	60	90	120
N_1	26.4	70.3	183.6	202.6	5.3	22.9	298.5	541.6	0.74	1.10	68.5	309.1
N_2	27.1	76.8	195.9	230.3	5.6	27.5	352.9	601.0	0.73	1.19	77.3	325.4
N_3	24.7	65.0	174.9	199.2	5.0	21.6	301.5	511.9	0.74	0.77	63.0	296.3
N_4	26.7	70.9	187.6	211.8	5.2	25.2	319.2	547.0	0.69	1.02	70.9	310.6
N_5	26.8	78.5	198.3	236.3	5.2	28.2	363.2	629.6	0.74	1.34	77.7	341.8
LSD*	NS	8.8	10.6	11.1	NS	1.7	27	52.6	NS	0.19	7.9	14.4

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; MSWC-Municipal solid waste compost ; *LSD (0.05)

Cotton-pigeon pea-wheat system (C3)

Growth parameters of pigeon pea crop: Results revealed that maximum plant height (64.0 cm, 120.7 cm and 133.8 cm at 60, 90 and 120 DAS, respectively) was observed under the treatment N_5 *i.e.*, 50% RDF + 50% through MSWC + *Rhizobium* + Soil application of Zn followed by N_2 treatment *i.e.*, 75% RDF + 25% through MSWC (63.6 cm, 117.7 cm and 126.1 cm) but at 120 DAS differences were non-significant. Minimum plant height was observed in N_3 treatment *i.e.* 50% RDF + 50% MSWC. Maximum fresh weight (112.7 g and 125.9 g) and dry weight (40.1 g and 49.0 g) biomass at 90 and 120 DAS was observed under the treatment N_5 followed by N_2, but at 120 DAS differences were no-significant. Minimum fresh and dry weight biomass was observed in N_3.

Yield parameters of *kharif* sorghum crop (C2): Results revealed that the treatment N_5 recorded significantly higher values of yield and its parameters *i.e.* ear length (31.7 cm); 1000-seed weight (22.0 g), grain yield plot^{-1} (120.53 g), grain yield plot^{-1} (2.05 kg), grain yield ha^{-1} (721.7 kg ha^{-1}) and fresh biomass plant^{-1} (585.7 g) which was statistically at par with 75% RDF + 25% through MSWC (N_2). Differences for no. of grains ear^{-1} and fresh biomass yield ha^{-1} were non-significant.

Yield parameters of *kharif* pigeon pea crop (C3): Results revealed that the N_5 treatment recorded significantly higher values of yield and its parameters *i.e.* no. of pods plant^{-1} (181.3), no. of seeds pod^{-1} (3.7), seed yield plant^{-1} (37.83 g), stalk yield plant^{-1} (103.5 g), seed yield plot^{-1} (1.60 kg), stalk yield plot^{-1} (6.85 kg), seed yield (592.6 kg ha^{-1}) and stalk yield (2538.3 kg ha^{-1}) which was statistically at par with N_2 treatment. Minimum pigeon pea and stalk yield was observed under N_3 (Table 72).

Table 72: Yield and yield parameters of pigeon pea (C3) under various INM treatments

Treatment	No. of pods plant^{-1}	No. of seeds pod^{-1}	Seed yield plant^{-1} (g)	Stalk yield plant^{-1} (g)	Seed yield plot^{-1} (kg)	Stalk yield plot^{-1} (kg)	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})
N_1	149.6	3.37	30.5	82.5	1.20	5.60	445.7	2074.1
N_2	175.4	3.53	35.8	102.4	1.42	6.67	524.7	2469.1
N_3	150.5	3.27	28.6	64.1	1.16	5.49	430.8	2033.3
N_4	157.5	3.37	33.7	81.1	1.36	6.31	502.5	2335.8
N_5	181.3	3.70	37.8	103.5	1.60	6.85	592.6	2538.3
LSD*	23.8	0.09	5.03	26.7	0.12	0.57	45.4	210.1

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 + *Rhizobium*; N_5: 50% RDF+50% through MSWC + *Rhizobium* + Soil application of Zn; MSWC-Municipal solid waste compost; *LSD (0.05)

Table 73: Yield and yield parameters of early maturing pigeon pea varieties (ICRISAT)

ICPL series	50% flowering	No. of branches plant^{-1}	No. of pods plant^{-1}	Seed yield plant^{-1} (g)	Stalk yield plant^{-1} (g)	Seed yield plot^{-1} (kg)	Stalk yield plot^{-1} (kg)	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Days to maturity
11255	69.0	12.7	161.6	24.0	81.5	0.490	1.786	408.1	1488.6	128
20340	69.0	11.0	79.9	19.7	69.3	0.442	1.635	368.1	1362.8	131
20338	69.0	11.0	131.3	20.6	67.8	0.382	1.350	318.6	1124.7	130
84031	94.0	14.8	217.3	42.5	206.9	1.437	6.644	1197.2	5536.9	141
85010	90.7	12.8	180.2	34.3	147.0	1.053	4.061	877.2	3384.4	139
88034	97.7	15.0	212.3	42.2	184.5	1.341	6.062	1117.8	5051.9	147
LSD (p=0.01)	1.0	2.3	29.2	4.0	25.0	0.350	1.130	289.6	942.6	2.5

Among INM treatments under all cropping system (C1, C2, C3) for first year and also in second year, N_5 treatment (50% RDF + 50 % through MSWC+ *Azotobacter /Rhizobium* + soil application of Zn) was better in terms of yield of the respective crops which saves 25% inorganic fertilizer and also enhance the soil fertility status and improve soil health.

Screening of short duration of cultivars of pigeon pea: An experiment was conducted to screen pigeon pea for early maturity at Bharuch condition using various ICPL series varieties acquired from ICRISAT (11255, 20340, 20338, 84031, 85010 and 88034). Results revealed that significantly higher plant height was observed for 88034 variety at 90 and 120 DAS (140 cm and 154 cm, respectively) but at 90 DAS result was statistically at par with 88034 variety (127 cm). At 90 and 120 DAS, maximum no. of branches plant^{-1} (15), fresh weight biomass (94 g and 147 g, respectively) and dry weight biomass (34 g and 55 g, respectively), leaf area (8004 cm^2 and 16673 cm^2, respectively) and LAI (4.4 and 6.6, respectively) was observed for 84031 pigeon pea variety than other variety, while 85010 and 88034 series varieties were statistically at par for leaf area plant^{-1}. Among six varieties, ICPL 84031 and 88034 pigeon pea variety harvested in 141 to 147 days at Bharuch condition (Table 73). ICPL 84031 variety obtained higher seed yield plant^{-1} (42.5 g), stalk yield plant^{-1} (206.9 g), seed yield plot^{-1} (1.437 kg), stalk yield plot^{-1} (6.644 kg), seed yield (1197.2 kg ha^{-1}) and stalk yield (5536.9 kg ha^{-1}) than other varieties while 88034 variety was statistically at par for seed yield plant^{-1} (g) and seed yield (kg ha^{-1}). But among these two varieties ICPL 84031 was performing well in terms of yield and yield parameters.

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 effluent treatment plant which produces about 500 M^3 of treated effluent from their Aniline unit. The analytical report of the treated effluent indicated that the effluents produced are less toxic as their chemical constituents are within acceptable limits. As the use of effluent needs to be tested for its suitability for irrigation of plants, it is planned to study in *rabi* maize. Maize is a staple food and feed in tribal belt of the state. In Gujarat, maize has been grown on 4.8 lakh ha with production of 8.4 lakh tones and productivity of 1750 kg ha^{-1}. In India, current consumption pattern of maize is 52% as poultry, pig, fish feed, 24% as human consumption, 11% as cattle feed and 1% as starch and seed and brewery industry. In order to understand the feasibility of using these effluents in crops like maize, woody species and their impact on soil properties, salinity development and crop production and produce quality over a long run, field trials were initiated to assess the suitability of the treated effluents.

A. Performance of rabi maize under treated effluent irrigation

A field experiment was conducted with *rabi* maize (*Zea mays* L.) with the application of nitrogen through urea and irrigation using treated effluent in factorial design with three replications. The treatments comprises of (I_1) best available water (BAW) as such *i.e.* effluent: BAW in 0:1 ratio; (I_2) effluent and BAW in 1:1 ratio; and (I_3) effluent as such *i.e.* effluent: BAW in 1:0 ratio with combination of three nitrogen doses (N_1= 80 kg N ha^{-1}; N_2= 100 kg N ha^{-1} & N_3=120 kg N ha^{-1}). The plot was prepared for fine tilth with designed layout. The seed of *rabi* maize (variety SS-7077) was sown in Dec. 2016 and applied irrigation as well as fertilizer as per the design of layout. Initial observations were recorded. Germination percentage was 85-90 percent (Plate 6) in all the treatment combinations.

Soil physico-chemical properties: Soil samples analyzed for pH_s and EC_e from maize field at different depths (0-15, 15-30, 30-90, 90-120 cm). Soil pH values were ranged from 6.8-7.2, 6.6-7.3 and 6.7-7.4 for I_1, I_2 and I_3 treatments, respectively with mean values of 7.0, 7.0 and 7.1. Similarly EC_e values ranged from 1.0-1.9 dS m^{-1}, 1.3 to 4.6 dS m^{-1} and 0.9 to 4.1 dS m^{-1}, respectively for I_1, I_2 and I_3 treatments with mean values of 1.5 dS m^{-1}, 2.7 dS m^{-1} and 2.4 dS m^{-1} (Table 74). In I_2 and I_3 treatments, surface soil having higher electrical conductivity values (> 4.0 dS m^{-1}), while I_1 having lower values at surface layer.

Performance of maize (SS 7077) crop under treated effluent irrigation treatment

Maize growth and yield parameters: Data indicated that maize yield parameters like yield $plot^{-1}$ (kg), biomass $plot^{-1}$ (kg) and single cob weight (g) were found to be higher under effluent (I_2) treated plot which was followed by I_3 treated plot. Effluent application resulted in higher yield of maize crop as compared to BAW. However, effluent diluted with BAW (I_2) gave the highest seed yield (9927 kg ha^{-1}) suggesting the possibility of using the effluent in slightly diluted manner for maximizing the yield which may be due to cumulative nutrient availability from effluent as well as BAW. Under fertilizer treated plots, maize yield (7746 kg ha^{-1}) was found higher under 100 kg N ha^{-1} (N_2 treatment). Cob length (cm) of maize was not showing much variation among three N dose applications (Table 75).

Under different treatment combinations, maize yield parameters like yield $plot^{-1}$ (kg), biomass $plot^{-1}$ (kg), single cob weight (g) as well as maize yield (kg ha^{-1}) showed significant difference. Maximum maize yield (11463 kg ha^{-1}) was noticed both combinations of effluent: BAW:: 1:1 with 100 kg N ha^{-1} treatment (I_2N_2), which was due to

Table 74: Soil properties of maize plots under treated effluents irrigation.

Soil depth (cm)	Treatment					
	I_1= 0:1 (Effluent: BAW)		I_2= 1:1 (Effluent: BAW)		I_3= 1:0 (Effluent: BAW)	
	pH_s	EC_e, dS m^{-1}	pH_s	EC_e, dS m^{-1}	pH_s	EC_e, dS m^{-1}
0-15 cm	6.8	1.0	6.8	4.6	6.8	4.1
15-30 cm	6.9	1.5	6.6	3.2	6.7	3.4
30-60 cm	7.1	1.9	7.1	2.4	7.2	2.3
60-90 cm	7.2	1.8	7.2	1.4	7.3	1.1
90-120 cm	7.2	1.5	7.3	1.3	7.4	0.9
Min	6.8	1.0	6.6	1.3	6.7	0.9
Max	7.2	1.9	7.3	4.6	7.4	4.1
Mean	7.0	1.5	7.0	2.7	7.1	2.4

Table 75: Individual effect of treated effluent and nitrogen on yield parameters of *rabi* maize

Treatments	Yield plot^{-1} (kg)	Biomass plot^{-1} (kg)	Single Cob weight (g)	Cob Length (cm)	Yield (kg ha^{-1})
Effect of treated effluent irrigation on growth and yield					
I_1= Effluent: BAW (0:1)	2.46	3.09	136.0	18.3	4564
I_2= Effluent: BAW (1:1)	5.36	7.75	197.6	19.6	9927
I_3 =Effluent: BAW (1:0)	3.31	4.41	161.3	18.6	6135
Effect of nitrogen on growth and yield					
N_1 =80 N ha^{-1}	3.62	4.92	162.7	18.9	6701
N_2 = 100 N ha^{-1}	4.18	5.79	173.1	18.9	7746
N_3 =120 N ha^{-1}	3.34	4.54	159.1	18.7	6178

BAW= Best available water; Nitrogen application through urea fertilizer

dilution of effluent with water and optimum dose of nitrogen fertilizer, while minimum yield was obtained under I_1N_3 treatment (4216 kg ha^{-1}).

Water productivity: Maximum water productivity of 2.10 kg m^{-3} (Table 76) was noticed in I_2 treatment (treated effluent : BAW in 1:1 ratio), which was due to higher biomass and yield of plant as well as required less amount of water to complete the life cycle. Water productivity was found 2.36 times higher in I_2 treatment (treated effluent: BAW in 1:1 ratio) as compared to I_1 treatment (treated effluent: BAW in 0:1 ratio), while 1.83 times higher than I_3 treatment (treated effluent: BAW in 1:0 ratio).

B. Performance of biomass woody species under treated effluent irrigation

An experiment was conducted to investigate the effect of treated effluent irrigation on growth of three biomass woody species *viz*., *Pongamia pinnata, Terminalia arjuna* and *Eucalyptus spp* with three irrigation intervals (I_1= 10 days, I_2= 20 days and I_3 =30 days). The objective was to study the long term effect of treated effluent application on woody species.

Growth of woody tree species: In this study, spacing was adopted 5m x 5m. Maximum mean values in terms of girth, tree height and volume of trees were found in *Eucalyptus spp* (29.2 cm, 5.1 m & 6.28 m^3 ha^{-1}) followed by *Terminalia arjuna* (20.8 cm, 2.3 m & 1.41 m^3 ha^{-1}) and *Pongamia pinnata* (13.9 cm, 1.9 m & 0.52 m^3 ha^{-1}). Irrigation interval treatments affected girth, tree height and tree volume. There was decrease in these growth parameters with increase in irrigation interval. The difference in variation was minimum between 10 and 20 days interval compared to 30 days interval. This suggests that treated effluents from Aniline-TDI plant did not affect the growth of woody species. Based on individual tree species growth performance, *Eucalyptus spp* can be recommended over *Pongamia* and *Terminalia* for mass cultivation using treated effluents from Aniline-TDI Plant with irrigation interval of 10/20 days.

Table 76: Water productivity on maize crop under treated effluent irrigation

Treatments	Yield plot^{-1} (kg)	Amount of water applied plot^{-1} (m^3)	Water productivity (kg m^{-3})
I_1 Effluent: BAW (0:1)	2.46	2.78	0.89
I_2 Effluent: BAW (1:1)	5.36	2.56	2.10
I_3 Effluent: BAW (1:0)	3.31	2.89	1.15

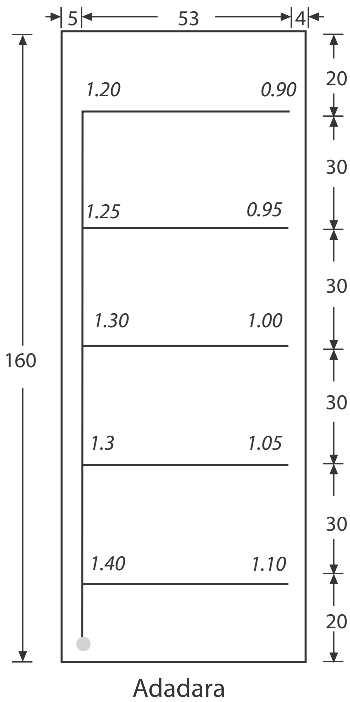
Cost effective Drainage in Waterlogged Saline Vertisols for Improving Crop Productivity in Gujarat (Sagar D. Vibhute, Anil R. Chinchmalatpure, David Camus D., Indivar Prasad and M. J. Kaledhonkar)

Ukai canal command area of Gujarat is facing problem of decline in sugarcane productivity due to waterlogging and soil salinity. The different land drainage approaches *viz.* surface drainage, subsurface drainage, bio-drainage etc. can be undertaken to tackle this situation. Effectiveness of these approaches to come up with a cost effective model in saline Vertisols of Gujarat, was studied. Accordingly, subsurface drainage system was installed on an area of 1 ha each at Ghodadara and Adadara villages of Bharuch district. The performance of the system in terms reduction in soil salinity was observed after its operation after one rainy season.

Installation of SSD system: The installation of SSD was carried out by combined mechanical and manual installation method. The excavation work was carried out with the help of back hoe loader and subsequently pipes were laid in the trencher manually. Two different spacing of 30 m and 35 m was adopted at Ghodadara and Adadara sites, respectively. The detailed layout of the system is shown in Fig. 85. For lateral drains perforated corrugated PVC pipe of 80 mm diameter was used whereas for collector drain 100 mm double wall corrugated PVC pipe was used. The synthetic envelop material was also used for lateral pipes. At each site a cylindrical RCC sump of 0.9 m diameter and 2.5 m height was instslled at the outlet.

Soil and Water Sampling

In order to study the effectiveness of SSD system, pre and post monsoon soil sampling was carried out at both the study sites. This helped to assess the performance of SSD system in terms of improvement in soil salinity. Soil samples were collected at 3 locations at each site from 0-15, 15-30, 30-60, 60-90, 90-120 cm. Subsequently, these samples were analyzed in laboratory for determination of electrical conductivity (EC_e) and pH_s. Average values of EC_e and pHs were plotted against depth for both SSD sites, as shown in Fig. 86 & 87.



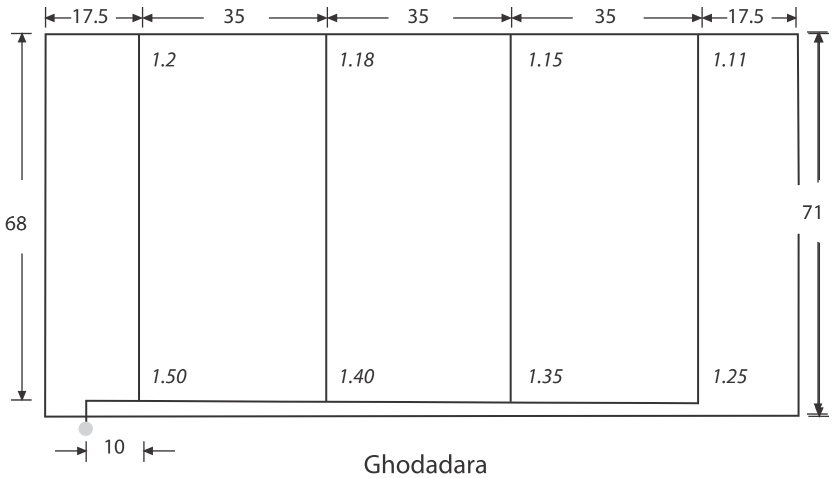


Fig. 85. Layout of installed subsurface drainage systems at Adadara and Ghodadara sites

(All dimensions are in meter. Figure in italics represents depth of the pipe below ground surface)

Mechanical excavation of trenches

Manual laying of SSD pipes

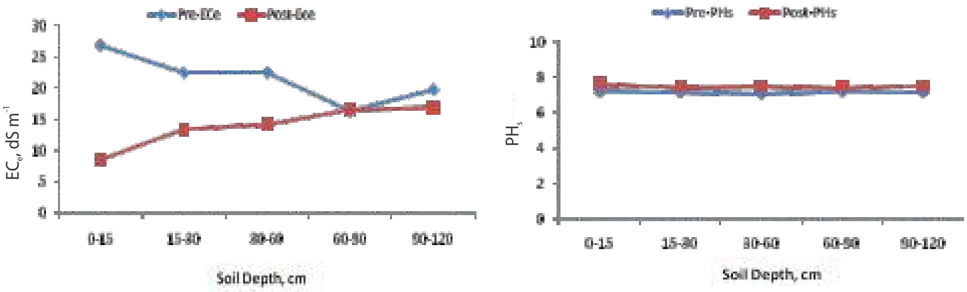


Fig. 86. Pre and Post monsoon comparison of EC_e and pH_s at Adadara

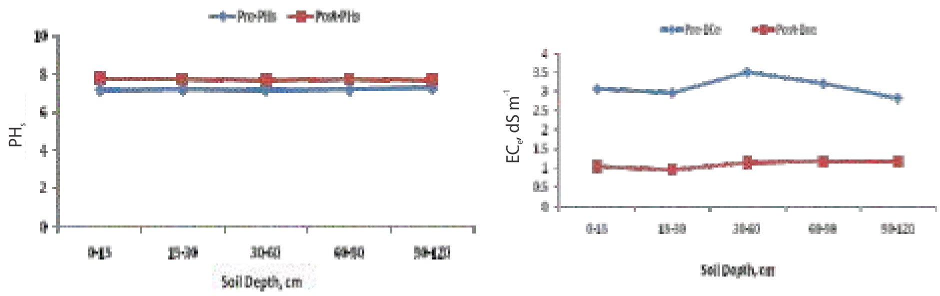


Fig. 87. Pre and Post monsoon comparison of EC_e and pH_s at Ghodadara

Table 77: Quality of drained water at SSD sites

Date	EC (dS m^{-1})	
	Adadara	Ghodadara
06/05/17	7.8	1.06
21/09/17	8.4	1.93
10/12/17	10.3	0.97
12/01/18	8.6	0.98

Results showed that average EC_e values of different soil layers up to 1.2 m depth at village Adadara site was reduced from 16.29-26.86 dS m^{-1} to 8.57-16.83 dS m^{-1} while at Ghodadara site it was reduced from 2.83-3.51 dS m^{-1} to 0.96 to 1.19 dS m^{-1}. The average pH_s values of different soil layers up to 1.2 m depth at Adadara site was slightly increased from 7.09-7.19 to 7.43 –7.64 while at Ghodadara site it was increased from 7.21-7.28 to 7.69-7.79. The outflow from the SSD system was monitored periodically and the EC values of drained water is given in Table 77.

Crop Performance

The farmers at both the sites have taken sugarcane crop after SSD installation. At Ghodadara site sugarcane was sown immediately after installation where as at Adadara site it was sown only after monsoon season. The performance of the sugarcane crop at Ghodadara site was found to be good and the crop was harvested in March, 2018.

Impact Evaluation of Sub-surface Drainage Technology for Reclamation of Water Logged Saline Soils in Maharashtra (Sagar D. Vibhute, Raju. R and Anil R. Chinchmalatpure)

The total area of salt affected soils in Maharashtra is 0.60 million ha and out of this 0.18 million ha area is facing problem of soil salinity mainly in Ahmednagar, Satara, Sangli and Kolhapur districts. The Subsurface drainage (SSD) system has been recommended as the appropriate technique for reclamation of these soils. Accordingly, SSD system was installed by State government at Kasbe Digraj and Dudhgaon villages of Sangli district after getting approval of its design from ICAR-CSSRI, Karnal. The SSD has been installed on 1085 ha area in Dudhgaon and 523 ha in Kasbe Digraj. In present study soil, drainage water and socio-economic data was collected from these sites to assess the impact of SSD in the area.

Table 78: Physico-chemical properties of soils at SSD sites

Site	Depth (cm)	SSD non working site		SSD working site	
		EC_e (dS m^{-1})	pH_s	EC_e (dS m^{-1})	pH_s
Dudhgaon	0-30	24.5	7.53	1.3	7.81
	30-60	16.7	7.72	4.0	7.94
	60-90	11.8	7.96	2.9	7.65
Kasbe Digraj	0-30	31.5	7.59	3.0	7.74
	30-60	24.0	7.61	2.4	7.65
	60-90	20.2	7.50	2.5	7.83

Performance of SSD: The soil and water sampling was carried out in the region in the month of October 2017. Soil samples were taken at the depth of 0-30, 30-60 and 60-90 cm. whereas water samples were collected from various sumps and open drains.

These soil samples were subsequently analyzed in the laboratory for determination of its physico-chemical properties. During the visit of study area, it was found that there is large variation in the quality of SSD installation in the area with some parts giving good results while others are in bad condition. These locations were termed as SSD working sites and SSD non working sites, respectively and soil samples were collected from both these locations. The soil physico-chemical properties at these locations are given in Table 78.

Operation and Maintenance of the system: The SSD system has problem of chocking of drain pipe at some places because of poor maintenance and blockage by sugarcane roots. At some places, open drains have been heavily infested with vegetation which is creating problem in the disposal of drained water. These open drains were initially wide and deep with stone pitching on its side wall but poor maintenance has resulted in its bad performance. The condition of drain pipes and open surface drain is shown in Plate 10. The chocking of drain pipes has resulted in persistence of soil salinity and waterlogging conditions mainly in the fields situated near the outlet of the SSD system.

Interaction with farmers: The detailed discussion with the farmers highlighted some major problems that have resulted in poor performance of SSD at some parts within the SSD sites. To tackle these problems in future, they have also given some possible solutions. These are as follows:

Poor condition of drain pipes and open surface drains

Problems

1. The firm which has been given tender for SSD installation had only supplied pipes and installation work was given to local unskilled workers.
2. Pipe quality was not up to the mark.
3. Installation work did not take place according to the design and there is alteration in the lateral spacing and drain depth and proper slope has not been maintained.
4. The sub surface pipes have been installed within the crop root zone of sugarcane and hence the roots are damaging pipes.

Suggestions

1. SSD installation on large scale is not up to the desired quality and individual farmer's opinions are not considered in such projects.

2. Instead of large scale, SSD installation on individual farmer or group of farmers' basis along with support from government in the form of subsidy (as the case of drip irrigation) should be carried out.

3. The study carried out by Agricultural Research Station, Kasbe Digraj showed that sugarcane roots can grow up to the depth of 6 feet and hence in sugarcane growing areas drain should be deeper than 6 feet.

4. Lateral spacing of 30 m is not effective and it should be reduced.

Groundwater contamination due to geogenic factors and industrial effluents and its impact on food chain (Agri-CRP Water Platform project) (Anil R. Chinchmalatpure, David Camus and Shrvan Kumar)

Discharge of industrial wastes has recently increased in some industrial areas of Gujarat like, Surat, Vapi and Ankleshwar. The present project was taken up to evaluate the impact of industrial effluent being generated in Ankleshwar Industrial Estate (AIE) of Bharuch district of Gujarat on ground water quality. This AIE has more than 1200 industries manufacturing diverse range of chemicals, pesticides, pharmaceuticals, bulk drugs, petroleum products, engineering, textiles, plastics, rubber, and packaging. Surface (0-30 cm) soil samples from the fields irrigated with effluent have been collected. These soil samples were processed for analysing different physico-chemical properties like pH, EC, cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), anions (Cl^{-}, SO_4^{2-}, CO_3^{2-}, HCO_3^{-}) and ion metals (Cd, Cr, Ni, Pb, As, Mn, Cu, Mn, Zn) using standard methods and using atomic absorption spectrophotometer/inductively coupled plasma atomic emission spectroscopy (ICP-AES). Sixty six plant samples of different crops likes sugarcane, fodder sorghum, wheat, pigeon pea, vegetable crops like onion, spinach, coriander, turnip, cucumber, bottle gourd, pointed gourd, dill, cow pea, brinjal, chilli, beans etc., were collected from the affected area. Plant sample were analyzed for different properties and heavy metal concentrations. Analysis of DTPA extract of soil showed that the range of concentration of Fe in soils (0-30 cm) were 5.36 to 35.92 ppm followed by Mn (7.08 to 25.44 ppm), Cu (1.01 to 23.32 ppm), Zn (0.44 to 5.04 ppm), Ni (0.14 to 2.24 ppm), Pb (0.31 to 2.02 ppm), Cr (0.08 to 0.29 ppm) and Cd (0.03 to 0.20 ppm), respectively with their concomitant mean values being 15.27, 13.45, 4.14, 1.33, 0.74, 0.67, 0.20 and 0.08 ppm, respectively (Table 79). As per

Table 79: Heavy metal concentration (mg kg^{-1}) in surface (0-30 cm) soils of the study area

	Cd	Cr	Mn	Ni	Cu	Fe	Pb	Zn
Min	0.03	0.08	7.08	0.14	1.01	5.36	0.31	0.44
Max	0.20	0.29	25.44	2.24	23.32	35.92	2.02	5.04
Avg	0.08	0.20	13.45	0.74	4.14	15.27	0.67	1.33
SD	0.06	0.05	5.30	0.47	4.49	7.57	0.40	1.06

Table 80: Heavy metal recoveries (mg kg^{-1}) by plant samples

	Cd	Cr	Mn	Ni	Cu	Fe	Pb	Zn
Max recoveries	5.52	40.00	164.00	9.09	43.80	3250.00	10.30	66.40
Min recoveries	0.06	5.93	4.07	0.35	5.58	33.70	2.28	10.30
Average recoveries	3.49	20.07	63.14	4.77	19.12	454.32	6.43	33.40
SD	2.52	7.55	40.23	2.55	8.40	567.89	2.54	14.33
No of contaminated villages	40	66	0	54	1	14	41	2
Per cent sample contaminated	60	100	0	82	1.5	21.2	62	3.0
Threshold limit	0.2	5.0	500.0	1.5	40.0	450.0	5.0	60.0

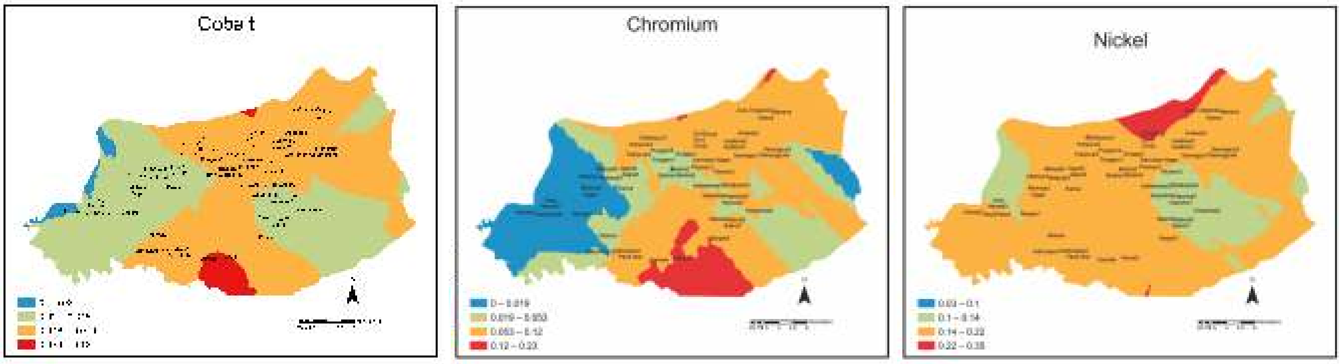


Fig. 88. Maps showing concentration of heavy metals in groundwater in the study area

critical limits of heavy metals, only Mn content was found beyond the safe limits (1.5 to 3.0 ppm) and other heavy metals were below the critical limit. Analysis of the plant samples collected revealed that about 60% of the plant samples were contaminated with cadmium more than threshold limit (0.2 ppm), 100% with chromium (5.0 ppm), 82 % with nickel (1.5 ppm) and 62 % with lead and 21 % showed in iron (Table 80).

Spatial variability mapping of heavy metal in groundwater: Spatial variability maps (Fig. 88) depicting the area with different concentration of heavy metal contamination of ground water have been generated. Out of 40 surveyed villages, along the Amla Khadi, a tributary of the Narmada river (Bharuch, Gujarat), groundwater of 31 villages is affected by heavy metal contamination. Across an area of 590.68 sq km, ground water quality of 22, 24, 15, 18 and 11 nos of villages were affected by Cd, Co, Cr, Ni and Mn, respectively.

Mitigation measures: Four groundwater recharge structures (for mitigation of industrial effluents mediated heavy metal pollution through dilution using rain water) were installed at Kapodra, Kathodara (Panoli), Sakkarpur and Boidra villages in Bharuch district of Gujarat. The groundwater salinity, pH and depth are being monitored (Fig. 89, 90 and 91) regularly. To create awareness among farmers regarding possible impacts of industrial effluent on human health, lecture was delivered to about 400 farmers of the region during Kisan Gosthi /Farmers' day was organized on March 3, 2017 by M/s. Tractor and Farm Equipment Limited (TAFE).

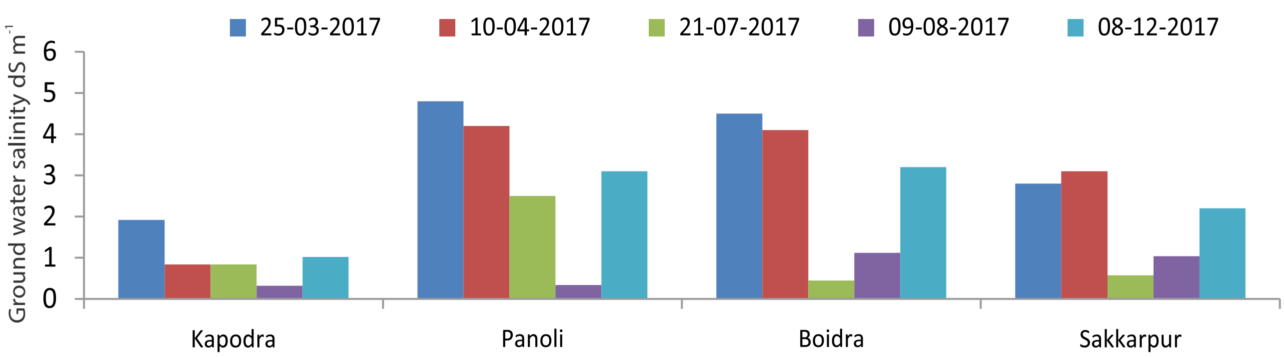


Fig. 89. Temporal variation of groundwater salinity of different recharge structures

Fig. 90. Temporal variation of groundwater pHof different recharge structures

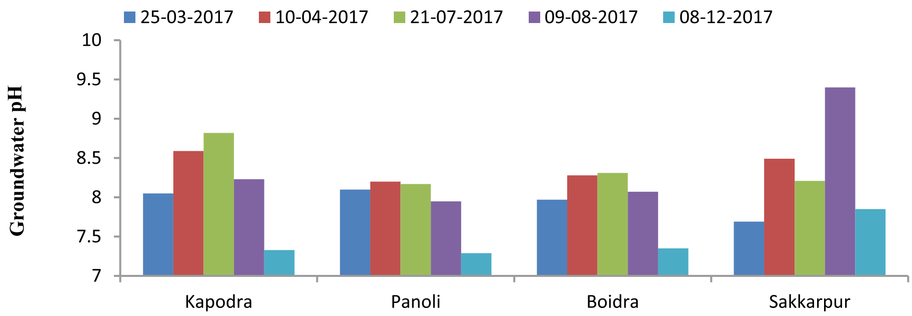
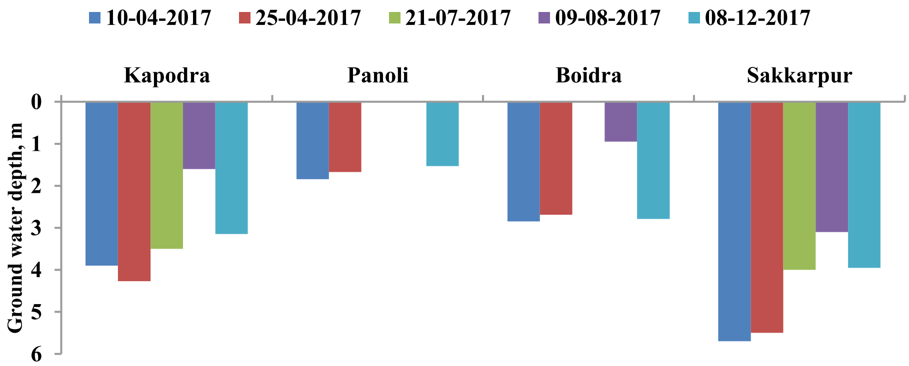


Fig. 91. Temporal fluctuation in groundwater depth of different recharge structures



Revival of village pond through scientific intervention (Anil R. Chinchmalatpure, Shrvan Kumar and Sagar Vibhute)

Soil and water resources are key element for sustenance of life on the earth. The slogan 'more crop per drop' reiterated by our Prime Minister reflects the need to conserve and use water resources judiciously to meet the food and livelihood requirements. Estimated annual precipitation of India is about 4000 BCM, of which 1122 BCM is utilizable water. However if we see in terms of per capita utilizable availability of water (1022 Cu. M), it is much less compared to other countries of the world. Out of total cultivable area of 143 M ha, only 55.9 M ha is irrigated. Considering the fact that water resources are of utmost importance in sustaining agriculture and achieving food security in India, there is need to collect, store, conserve and judicious use of rainwater. Gujarat state is having net sown area of 19.6 M ha and net irrigated area of 2.9 M ha. Gujarat has just 2.28% of India's water resources and 6.39% of country's geographical area. The state has average annual rainfall of 80 mm with low amount of rainfall in Saurashtra and Kachchh region (578 mm). In entire coastal belt, high concentration of salt in ground water makes it unsuitable for irrigation, making farmers totally dependent on rainfall or canal water.

Situation demands the harvesting of rainfall and prevention of runoff by collecting it into lakes, dams or village ponds. Village ponds have been constructed in villages using some indigenous technology and local wisdom of the villagers for the purpose of irrigation, domestic use, ecological and cultural purpose. However with passage of time, many ponds have become dysfunctional. With increase in siltation, storage capacity reduces making water unavailable during summer season. On this context, revival of village ponds has become necessary which will serve the purpose of increasing ground water table, reducing ground water salinity in the region and increasing irrigation potential for sustainable agriculture. With the activities being carried out in this project may find answers to some of the questions such as how much surface runoff can be collected in pond? What type of surface drainage is required in catchment area to avoid damage to standing crops? Is there possibility of using harvested water for supplemental irrigation? The information from this project may be useful to develop larger strategy of surface drainage for Vertisols and judicious use of harvested rainwater as issue of surface drainage in Vertisols is also important particularly in case of inland salinity. Key challenges involved in the project are *in situ*/*ex situ* rainwater harvesting, recharging groundwater, renovation of ponds and improving water productivity at micro-watershed level and conjunctive use of poor quality water.

Output of the project is likely to increase storage capacity of the ponds, improvement in water quality and increase in water productivity. The project work has been initiated in August 2017. Two village ponds each in Samni and Sudi villages of Bharuch district have been identified for taking up the revival study. The catchment area of the each pond has been surveyed for recording the basic features like area of the catchment, slope, topography, soil type, vegetation type, etc. Area of the pond at village Samni is 4.73 ha and at village Sudi is 7.19 ha . The study area is having deep, heavy textured black cotton soils (Vertisols) with subsurface soil salinity. We have surveyed the 10 village ponds in the area and collected basic information like total population, total areas of the village, cultivated area, crops being cultivated, pond size its uses and its history. Siltation is the major problem observed for the dysfunction of the pond and subsequently if desilted without proper specification then the percolation loss is another problem in this area. Hence looking into dysfunctioning of the ponds, some grass species and forestry tree species are to be planted for reduction in the quantity of silt in the pond and also to reduce soil erosion.

Pond at Samni village.

Pond at Sudi village.

Water samples from the pond, nearby tube wells/hand pumps, canal water are being collected at a regular interval and are being analyzed for evaluating water quality. The electrical conductivity of the pond water ranged from 0.44 to 0.85 dS m^{-1} and that of tubewell/hand pump water from 0.65 to 6.7 dS m^{-1} (Table 81) and canal water 0.32 dS m^{-1} at village Samni and similarly at village Sudi, EC of pond water is ranged from 0.11 to 0.31 dS m^{-1} at village pond and that of tubewell/handpump water 1.2 to 2.1 dS m^{-1}. Among the soluble cations, sodium is dominant followed by magnesium, calcium and potassium among all water samples. Among the anions, chloride is dominant followed by carbonate/bicarbonate and sulphate. Soil samples from the catchment area of both the ponds have been collected and auger samples upto a depth of 120 cm with an interval of 30 cm have been collected and analyzed for different properties. The pH soils of the catchment area of both ponds are in the range of 7.9 to 8.9 and EC_e ranged from 0.5 to 6.5 dS m^{-1}. Other properties are being analyzed. The crops being cultivated in the study area consist of sorghum, moong, pigeon pea, cotton, woody species-eucalyptus, and some vegetable crops which are under irrigated as well as rainfed farming.

Table 81: Chemical composition of pond, hand pump and tube well water in the village Samni

Location	pH_w	EC_w	Cations ($me\ l^{-1}$)				Anions ($me\ l^{-1}$)				SAR
		($dS\ m^{-1}$)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO	HCO_3^-	Cl^-	SO_4^-	
Pond	8.31	0.85	1.63	3.38	4.53	0.34	5.00	0.00	5.0	0.02	2.9
Tube well	8.66	2.40	1.00	11.00	16.90	0.08	7.00	0.00	20.0	0.04	6.9
Hand pump-1	8.79	0.65	2.50	2.50	3.63	0.04	9.00	0.00	5.0	0.00	2.3
Hand pump-2	8.86	2.70	0.50	5.50	29.79	0.02	11.00	4.50	17.5	0.02	17.2
Hand pump-3	8.60	6.70	3.00	17.00	62.21	0.10	11.00	0.50	60.0	0.19	7.9
Canal Water	8.74	0.32	1.50	2.00	0.65	0.05	5.00	0.00	5.0	0.00	0.5

Exploration of medicinal and aromatic plants (MAPs) cultivation under different cropping systems and on marginal and degraded lands of semi-arid regions of India

(Anil R. Chinchmalatpure and Indivar Prasad)

In order to meet the growing requirements of indigenous medicines, natural habitats are being overexploited resulting in the loss of valuable medicinal and aromatic plant species (MAPs). There are two options that seem to be feasible to increase the area and production of MAPs. One is crop diversification through inclusion of MAPs in the existing cropping systems (intercropping or crop rotation). In Gujarat about 60 species of MAPs are under cultivation for various purposes which can be incorporated with the existing high value cropping systems. The second option is to increase area under MAPs through cultivation on marginal and degraded lands (*e.g*., saline soils). At present, about 40% area in Gujarat is either left barren or unculturable/culturable wasteland due to different problems like soil salinity and soil and water erosion which can otherwise be put under MAPs. Keeping in view the above facts, the project has been formulated with an objective to up-scale the MAPs based cropping systems on salt affected soils for boosting the area and production of MAPs in the country. So one of the milestones in the project is to develop MAPs based cropping systems for saline lands and ICAR-CSSRI RRS Bharuch, Gujarat is taking up this activity. Season-wise schematic representation of the conventional and alternative systems on salt affected soils is shown in Table 82. The cultivation of these MAPs is to be undertaken with different treatments including organic as well as inorganic fertilizer/manure and bio-fertilizer to study the performance on salt affected Vetisols. The experiment with different treatment details has been initiated at experimental farm, Samni and plantation with Kalmegh and Senna was tried and the experiment is being continued on salt affected black soils using saline water irrigation.

Table 82: Season-wise schematic representation of the convention and alternative systems on salt affected soils

Seasons		Kharif	Rabi	Summer
Conventional cropping system	1	Sorghum	Wheat	Fallow
	2	Cotton	Wheat	Fallow
	3	Sorghum	Chickpea	Fallow
	4	Castor	Fallow	Fallow
Alternative cropping system	1	Kalmegh	Wheat	Fallow
	2	Cotton	Isabgol/ Asalio	Fallow
	3	Kalmegh	Chickpea/Dil	Fallow
	4	Castor + Shankhpuspi		Fallow
	5.	Castor + liquorice		Fallow
	6.	Senna	Wheat	Fallow
	7	Senna	Chickpea	Fallow

Reclamation and management of coastal saline soils

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 T.D. Lama)

The study area covers three different villages of Gosaba Block (Lat. 22° 09'-22°10' N; Long. 88°47'-88°48' E) of South 24 Parganas district of West Bengal (India) coming under three different landforms namely, cultivated deltaic (CD), mudflat (MUD) and depressed lowland (DL) Soil samples were collected for the *rabi* season (Feb.- Mar., 2017) from three different depths (0-20, 20-40, 40-60 cm). The area is mostly monocropped with rice. Soil samples were collected from three different locations (three replications) under each land forms.

The cultivated deltaic (CD) soil showed the highest steady state cumulative infiltration (5.0 cm) followed by mudflat (MUD) soil (3.5 cm) and depressed low land soil (DL) soil (1.9 cm). This result can be verified from the slope of the cumulative infiltration and time curves (Fig. 1). The texture of Mud flat (MUD) and depressed low (DL) soils were sandy clay loam to clay, with a clay content of 38-46 % in the surface layer. Clay content in cultivated deltaic soil (CD) was 30-35 % and was clay loam. In the 20-40 cm and 40-60 cm soil layer for DL soils clay content did not differ much (42-44 %, clay loam). All the soils were medium to high in organic C content (0.54-1.28 %). The highest porosity or saturation water content was found in DL soil (0.63-0.64 cm^{3}cm^{-3}) and the lowest was in CD soil (0.57-0.61 cm^{3}cm^{-3}).The CD and MUD surface soils were slightly acidic (pH 4.8 to 6.0). The EC values of CD soils were low for all depths (3.1 to 4.9 dS m^{-1}); other two soils were having higher EC values (5.2-13.7 dS m^{-1}) (Table 83).

The water content in soils before infiltration varied from 0.01-0.02 cm^{3}cm^{-3} in MUD and 0.02-0.03 cm^{3}cm^{-3} in DL soils, whereas values were 0.02-0.04 cm^{3}cm^{-3} in CD soils. Sorptivity was highest (2.2-2.5 mm min$^{-1/2}$) in CD soil, followed by 2.1-2.2 mm min$^{-1/2}$ in MUD soil and 1.0-1.5 mm min$^{-1/2}$ in DL soils. Sorptivity values differ significantly for three different landforms for different depths. These results can also be verified from the slope of the cumulative infiltration versus square root of time relationship curves. The slope of CD soils in the present study were higher than the MUD and DL soils. In our study the cumulative infiltration of CD soils was about 2.5 times higher than that of DL soils.

In this study, organic carbon percentages for all landforms in general, decreased with soil depths and organic carbon content of MUD soils (0.54-0.60%) were less than that of

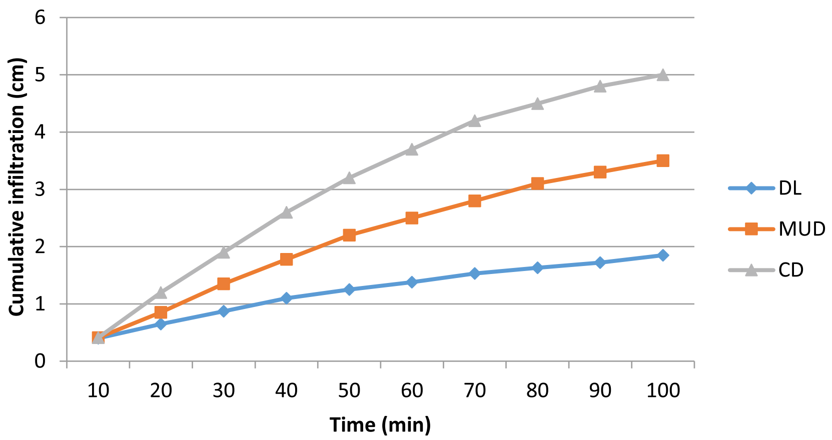


Fig. 93. Cumulative infiltration vs time curve for different soils

Table 83: Physicochemical characteristics of Gosaba soil

Name of soil	Particle size (%)			Texture class	Org. C	pH	EC (dS m^{-1})	s ($m^3 m^{-3}$)
	S	Si	C					
0-20 cm								
CD	30	35	35	Cl	1.28	4.8	4.9	0.57
MUD	34	20	46	C	0.54	6.0	5.2	0.60
DL	26	36	38	Cl	0.86	7.8	13.7	0.63
20-40cm								
CD	38	32	30	Cl	1.20	5.0	3.6	0.58
MUD	44	20	26	Sacl	0.64	6.2	6.0	0.61
DL	20	38	42	C	0.54	7.2	13.7	0.64
40-60cm								
CD	32	34	34	Cl	0.76	5.1	3.1	0.61
MUD	46	18	36	SaC	0.60	6.3	6.0	0.62
DL	28	28	44	C	0.60	7.6	11.0	0.64

S: sand, Si: Silt, C: clay, and l: loam; CD: cultivated deltaic, MUD: mudflat/mangrove, DL: depressed low land

DL (0.54-0.86%) and CD (0.76-1.28%) soils. The saturation moisture content (porosity) of different layer did not vary much because of their similar textural content (Table 83). Similarly, the high porosity of DL soils was associated with high clay content for all the three layers. EC values for CD soils were low (<4 dS m^{-1}) and high for DL and MUD soils (5.2-13.7 dS m^{-1}), which decreased slightly with soil depth. This might be due to accumulation of salts at the surface soils. The relationships between sorptivity and clay, pH, EC, porosity and humic acid were significant exponential and negative (Table 84). Percentage fulvic acid was positively correlated (r= +0.90, 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)

The experiment under drip irrigation was carried out at ICAR-CSSRI RRS Canning Town farm during the *rabi/summer* season of 2016-17 to evaluate the performance of different vegetable crops irrigated with water of different qualities. 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 variety Avantika was taken as the test crop. The treatments were imposed after 20-25 days of

Table 84: Relation between sorptivity (S) and other parameters (X) of soil

Soil parameter	Correlation coefficient (r)	Regression equation
% Clay	-0.81**	$S = 9.8\,e^{-0.04x}$
pH	-0.89**	$S = 9.5\,e^{-0.26x}$
EC (dS m-1)	-0.87*	$S = 3.2\,e^{-0.07x}$
Porosity (%)	-0.88**	$S = 163.3\,e^{-11.2x}$
H.A. (%)	-0.86 *	$S = 2.9\,e^{-3.1x}$
F.A. (%)	+0.90**	$S = 0.65\,e^{7.9x}$

Significant at 5% probability level, **significant at 1% probability level; S is sorptivity (mmmin -1/2)

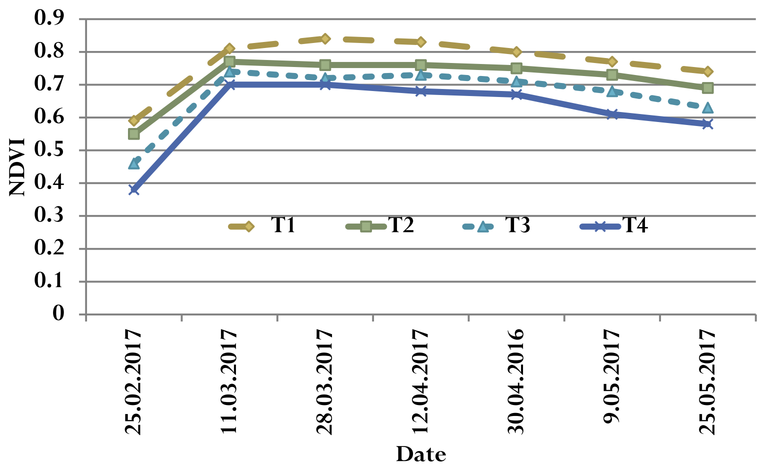


Fig.94.NDVI values for okra crop under different treatments

fresh water irrigation when the crop was established. NDVI value was higher for the irrigation water of lower salinity (T_1>T_2>T_3>T_4) throughout the experimental period.

The highest yield (about 14 t ha^{-1}) was obtained in the treatment T_1 (Fig. 94), where the water was of lowest salinity. There was 46% reduction in yield in T_4 having the highest salinity. The temporal changes in soil salinity in different layers (0-15 cm, 15-30 cm and 30-45 cm) in the root zone were studied. It was observed that the salinity build up was highest at the top layer (0-15 cm) in the root zone for treatment T_4 (Fig. 95). Total amount of water applied to okra crop was 45 cm through 24 number of irrigations. Among the different plant growth and yield parameters, plant height of okra varied from 80-87 cm, root depth from 27-42 cm, and no. of fruits plant^{-1} from 37-47 and there was no clear trend of these parameters under different treatments.

Experiment was conducted with solar power drip irrigation system in the *rabi* season with cauliflower and tomato crops using rain water harvested in the pond. Treatments were T_1: 5 mm irrigation every day, T_2: 15 mm irrigation on 3rd Day, T_3: 25 mm irrigation on 5th Day, T_4: 35 mm irrigation on 7th day. All the treatments were put under either paddy straw mulch or no-mulch. Daily irrigation of 5 mm (T_1) produced best tomato yield (Fig. 96) and T_4 produced the least yield in mulched condition. Under non-mulched condition, T_2 produced the best yield and T_4 produced the least yield. Total amount of water required for tomato was 56 cm.

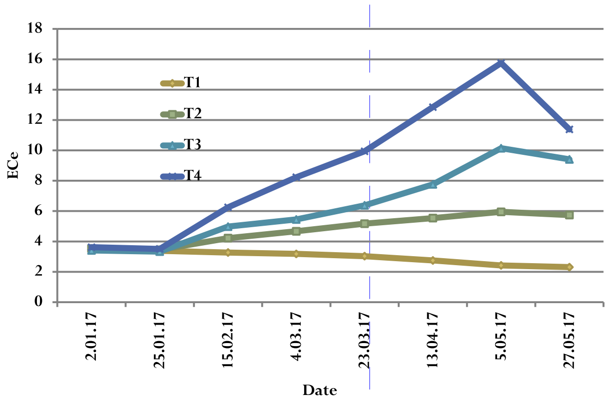


Fig. 95. The Yield of okra under different treatments

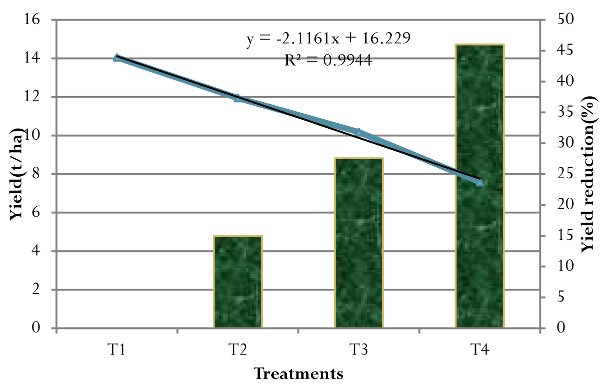


Fig. 96. Change in salinity in the top soil layer (0-15 cm)

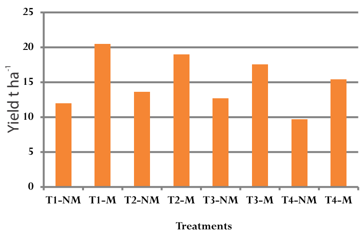


Fig. 97. Yield of tomato under different treatments

Irrigation of 15 mm (T_2) produced best cauliflower yield and T_4 produced the least yield in mulched condition. Under non-mulched condition T_4 produced the best yield and T_3 produced the least yield. Total amount of irrigation water for the cauliflower crop was 26 cm.

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)

The long term impact of land shaping techniques and rain water harvesting on soil and water quality and economics of land shaping techniques was studied. Salinity, pH and concentrations of Ca, Mg, Na, K ad Fe were determined in harvested rain water in farm pond (FP) and deep furrow & high ridge (DFHR) land shaping techniques. The pH of water was in the normal range throughout the year, however, salinity and concentration of other ions varied with seasons and it reached to the highest value before onset of monsoon and lowest during monsoon. The quality of harvested water was found to be suitable for agricultural purposes. The various soil parameters in the different land situations, *i.e.*, high, medium and low land created through land shaping techniques

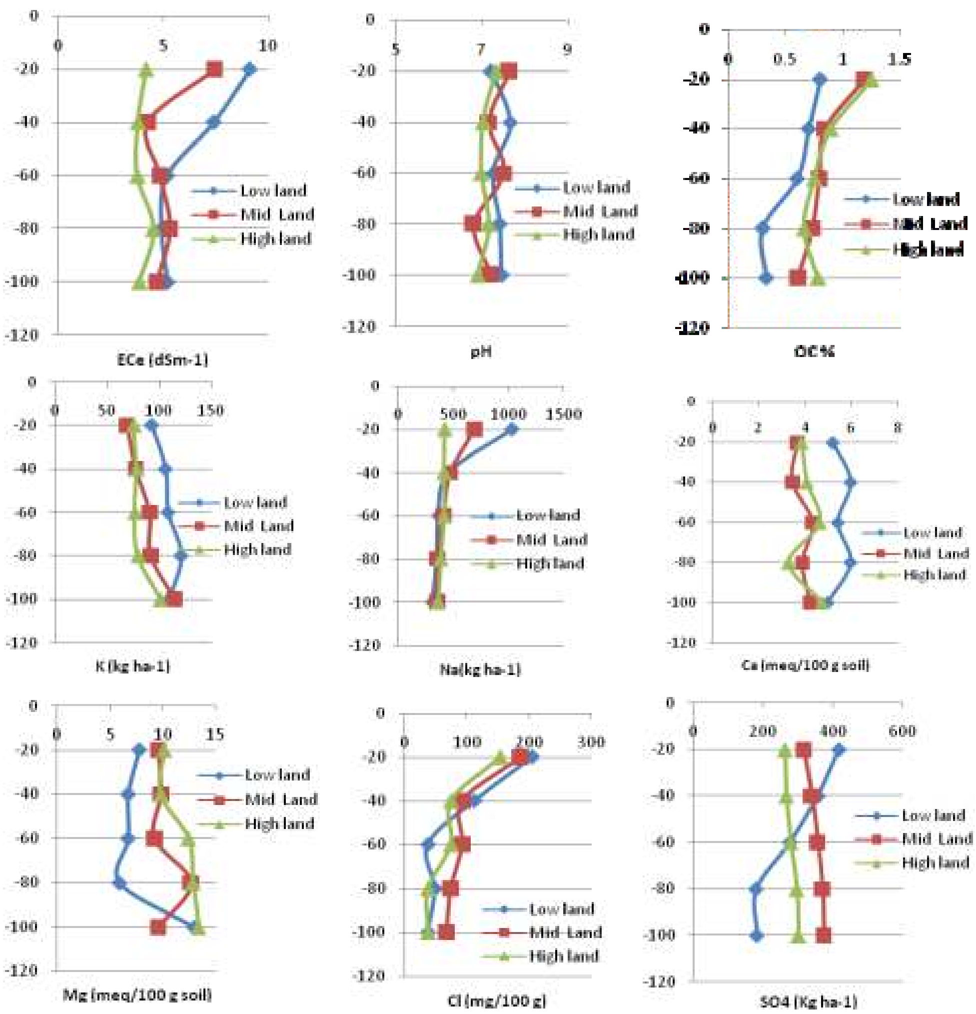


Fig. 98. Soil properties under different land situations created through land shaping techniques

Table 85: Financial feasibility of land shaping models in the coastal areas of West Bengal

Criteria	Farm Pond	Paddy-cum-fish	Deep furrow & high ridge	Remarks
Initial investment (Rs ha^{-1})	145770	135800	87850	Excavation cost
Internal Rate of Return (%)	46	42	36	Favourable for investment
Net Present Value				
(Rs)	285059	232450	96817	Favourable for investment
Benefit Cost Ratio	1.58	1.55	1.20	Favourable for investment
Payback Period (years)	1.41	1.78	2.13	Recovers initial investment quickly

were analyzed during the month of April (Fig. 99). The soil salinity build up in the root zone was less in high land followed by medium and low land. The pH varied from 6.98 to 7.65. The organic content in upper soil layers was higher in high medium land than in low land. The concentrations of available K, Na, Ca, Cl and SO_4 was less in high land situation.

Financial viability of the land shaping models

On-farm demonstrations of the land shaping techniques in farmers' field in Sunderbans have been successful in terms of increasing farm income and providing gainful employment to the farmers. However, all these land shaping techniques involved high amount of initial investment particularly to meet the soil excavation cost. Once the land shaping techniques are constructed, the operational costs incurred and benefits accrued during the project period and these cost-benefit streams were likely to continue over the economic life of the techniques. Financial analyses of these land shaping techniques, farm pond (FP), paddy-cum-fish (PCF) and deep-furrow & high ridge (DFHR) system have been carried out to assess the long term viability of such proposition under the coastal environment. Such investment analysis was needed to find out whether the investment will yield a reasonable rate of return to all resources engaged for an average unit. For this investment analysis, undiscounted cash flow measure of project worth, payback period and discounted cash flow measures of project worth, B: C ratio (BCR), net present value (NPV) and internal rate of return (IRR) were accounted (Table 85). Based on the incremental cost incurred and incremental net return realized from each land shaping techniques, IRR were estimated to be 46%, 42%, and 36% under FP, PCF and DFHR systems, respectively. Similarly, NPV were Rs. 285059, Rs. 232450, and Rs. 96817; BCR were estimated to be 1.58, 1.55, and 1.20 and payback period was calculated to be 1.41, 1.78 and 2.13 years, respectively under FP, PCF and DFHR type of land shaping techniques. Financial analysis of all land shaping techniques under study indicated that investment on such interventions were financially viable for the coastal region in Sunderbans of West Bengal. Government of West Bengal is now implementing these land shaping techniques under PMKSY and RKVY in the different salt affected coastal districts in West Bengal.

Land shaping technique at farmers' field during *rabi* season

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)

The present project aimed to study the soil carbon dynamics and C sequestration potential under long term conservation tillage practices in coastal region of West Bengal. The design of experiment was split-split plot with cropping system (rice-rice and rice-

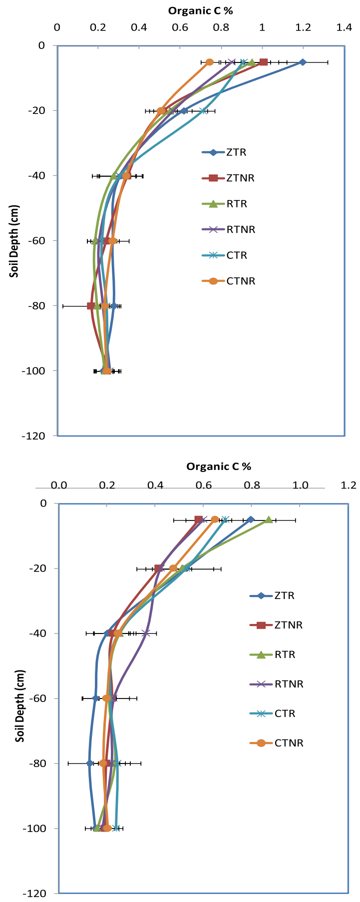


Fig.99. Depth-wise (cm) soil organic C (%) after 6 years of study under different conservation tillage treatments in rice-rice and rice-cotton systems

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 as sub-sub plot treatments. Laboratory chemical analyses of saturation paste extract of soil samples collected after six year of experiment was carried out to determine the concentrations of the individual solutes, i.e., Na^+, Ca^{2+}, Mg^{2+}, K^+, Cl^-, SO_4^- and HCO_3^-. Total soluble salt content was calculated by the summation content of soluble sodium Na^+, K^+, Ca^{2+}, Mg^{2+}, bicarbonate (HCO_3^-), chloride (Cl^-) and sulphate (SO_4^{2-}). Total soluble cations, anions and total soluble salt were significantly higher in rice-cotton system than rice-rice system and residue system had relatively more salt than non residue treatments. The soil organic C was determined up to 100 cm soil depth and zero till with residue under rice-rice showed significantly higher organic C % up to 40 cm depth than any other treatments (Fig. 99). Organic C concentration was higher in rice-rice system than rice-cotton system. Treatment-wise C input was determined for studying the C sequestration potential and the results indicated that for sustenance of SOC level a minimum quantity of 1.03 Mg C yr^{-1} is required to be added per hectare as inputs. For rice-rice system it is just 0.3 Mg C yr^{-1} whereas for rice-cotton system it is 1.41 Mg C yr^{-1}. After six years of experiment in zero tillage, there was 8-10% reduction in yield in case of rice whereas yield reduction was 31% in case of cotton than other treatments. Mean weight diameter of water stable aggregates and % aggregates >0.25 mm was higher in reduced tillage treatment than other treatments (Table 86).

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)

Rice is the major crop during *kharif* season in the coastal areas. However, the productivity of rice crop is low due to several abiotic and biotic stresses. Among the abiotic stresses, flooding/submergence cause significant loss to the conventionally puddled transplanted rice crop. Puddling has also negative effect on the subsequent *rabi* season crops. Another important constraint to crop production is unbalanced application of

Table 86: Mean weight diameter and % aggregates > 0.25 mm of water stable aggregates under different conservation tillage treatments in rice-rice and rice-cotton systems.

Treatments	MWD (mm)	% Aggregates > 0.25 mm
Rice-Rice		
ZTNR	0.46a	38.21a
ZTR	0.69b	42.24a
RTNR	0.71b	41.21a
RTR	0.88b	77.24b
CTNR	0.65b	49.23a
CTR	0.79b	71.22b
Rice-cotton		
ZTNR	0.22c	30.56a
ZTR	0.37ac	31.20a
RTNR	0.48ac	55.23b
RTR	0.74b	63.20b
CTNR	0.61b	59.56b
CTR	0.75b	65.40b

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. Within a column, numbers followed by the same lowercase letter are not significantly different at P<0.05 level.

Observation on NDVI and net photosynthetic rate (Pn) in kharif rice

Use of chameleon soil moisture sensor to monitor soil moisture status in mulched and non-mulched maize plots

nutrients, particularly poor use of organics. To address these issues, this project was started from *kharif* season of 2016 with four *kharif* rice treatments (1) conventional puddled transplanted rice (PTR) with residue removed (PT-R) (2) PTR with 30-40% residue retained (PTR+R) (3) dry direct seeded rice (DSR) with residue removed (DSR-R) & (4) DSR with 30-40% residue retained (DSR+R) in main-plot and four nitrogen application 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 healthiness (NDVI values) and net photosynthesis rate (P_n) of rice crop was observed with the use of Green Seeker and Photosynthetic system respectively. Highest NDVI value of 0.63 was recorded in the treatment DSR+R, which was significantly superior over all other treatments studied (Table 87). Similarly the net photosynthesis rate was also highest in the former treatment (14.48 µmol cm^{-2} sec^{-1}).

Plant height was also significantly highest in DSR+R, however, it was at par with DSR-R. Plant height was about 5% higher in DSR over PRT, irrespective of residue treatments. This shows that DSR can withstand flooding or submergence better than PRT during *kharif* season in coastal areas. Results revealed that retention of maize stover in the field had a significant effect on the grain yield of *kharif* rice (Table 87). Highest grain (3.96 t ha^{-1}) and straw (7.15 t ha^{-1}) yields were recorded in DSR+R and lowest in PTR-R (3.47 and 5.89 t ha^{-1},respectively).

Soil moisture studies were done in the subsequent maize crop with the use of Chameleon soil water sensor. It measures how hard it is for plants to suck water out of soil and the data are displayed in coloured lights. Blue colour is indicated with soil water suction of 0-20 kPa (wet condition), green at 20-50 kPa (moist condition) and red at > 50 kPa (dry condition).

Table 87: Effect of establishment methods and residue on growth and yield of rice (var. Amal-Mana) during *kharif* 2017

Treatment	Grain Yield (t ha^{-1})	Straw yield (t ha^{-1})	Plant height (cm)	NDVI	Pn (µmol cm^{-2} sec^{-1})
DSR – R	3.45	6.46	183.57	0.60	12.88
DSR + R	3.96	7.15	188.60	0.63	14.48
PTR – R	3.47	5.89	176.27	0.56	12.77
PT R+ R	3.94	6.75	179.27	0.59	13.43
LSD (P=0.05)	0.38	0.65	8.53	0.02	1.13

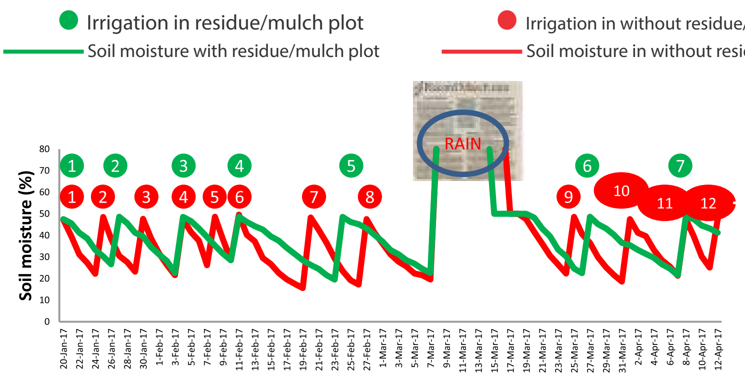


Fig.100. Soil moisture variation and irrigation requirement in mulched and non-mulched plots in maize

Performance of mulched and non-mulched maize crop without application of N

Table 88: Yield and yield attributes of maize under tillage, residue and nitrogen management during *rabi* 2016-17

Treatments	Cobs Plant^{-1}	Kernels Cob^{-1}	1000 Kernel wt (g)	Kernel Yield (t ha^{-1})	Stover Yield (t ha^{-1})
DSR-R	1.42	227.90	237.29	3.06	5.01
DSR+R	1.67	281.71	245.73	3.71	6.54
PT-R	1.42	224.16	234.60	3.04	3.81
PT+R	1.58	259.61	236.97	3.51	5.93
SEm±	0.07	6.87	1.59	0.14	0.30
CD (P=0.05)	NS	23.75	5.49	0.47	1.04
N0	1.00	155.20	214.56	1.91	2.96
N1 (80 kg ha^{-1})	1.58	250.34	237.83	3.41	5.42
N2 (120 kg ha^{-1})	1.75	283.87	250.66	3.92	6.21
N3 (160 kg ha^{-1})	1.75	303.97	251.53	4.07	6.70
SEm±	0.14	10.12	3.86	0.10	0.24
CD (P=0.05)	0.40	29.55	11.28	0.30	0.71

Mulching in maize crop with paddy straw reduced irrigation water requirement and soil salinity. About 5 irrigations can be saved in maize crop by rice residue retention/mulching during *rabi* season (Fig. 101). Irrigation requirements were 39.0, 49.5, 55.0 and 60.0 cm for DSR+R, PRT+R, DSR-R and PTR-R, respectively. Lowest soil salinity was observed in DSR+R (4.5 dS m^{-1}) and highest in PT-R (6.0 dS m^{-1}) during the month of May. There was significant reduction in weed biomass due to residue retention. Weed biomass increased with the age of maize crop and it was higher with higher dose of nitrogen application.

There was significant effect of *kharif* rice establishment and residue management practices on the yield attributes and yield of *rabi* maize (Table 88) except for cobs plant^{-1}, whereas *kharif* rice establishment and residue had non-significant effect. However, cobs plant^{-1} increased due to application of N, with about two cobs plant^{-1} due to application of 120 -160 kg N ha^{-1}. Highest number of kernels per cob (282) was recorded in the plots where previous crop was DSR and residue retained in maize crop. Similarly kernels per cob increased from about 155 with application of N to 304 with application of 160 kg N ha^{-1}, which was at par with 120 kg N ha^{-1} (284 kernels cob^{-1}). Similar trend was observed for kernel weight in maize. Highest kernel (3.71 t ha^{-1}) and stover (6.54 t ha^{-1}) yield in maize was recorded due to the effect of DSR+R. The yields were highest (4.07 and 6.70 t ha^{-1} kernel and stover, respectively) with application of highest dose of 160 kg N ha^{-1}, which was at par with 120 kg N ha^{-1}.

Coastal Saline Tolerant Variety Trial (CSTVT) (S. K. Sarangi)

During *kharif* season 2017 under CSTVT, three trials were conducted. (1) IVT -CSTVT (2) AVT 1-CSTVT and (3) AL & ISTVT. The details of the trials conducted are furnished in the Table 90.

Out of 38 entries under IVT-STVT, highest grain yields were obtained from 5234 (6.15 t ha^{-1}), 5208 (5.23 t ha^{-1}) and 5215 (5.00 t ha^{-1}), the local check variety Sumati produced grain yield of 5.40 t ha^{-1}. Seeds of four entries (5206, 5218, 5225 and 5231) did not germinate. Out of the 34 entries 5208, 5213, 5214, 5215, 5220, 5222, 5229, 5232 and 5234 were found to be highly tolerant to salinity. Local check (Sumati) flowered in 122 days 25 entries flowered before local check. Plant height varied from 83 cm in entry 5236 to 144 cm in entry 5234.

Table 89: Details of Coastal Saline Tolerant Variety Trial - CSTVT at Canning Town during Kharif 2017

Particulars	IVT-CSTVT	AVT 1-CSTVT	AL & ISTVT (TP)
No. of entries	38	15	V=4, M=5
Replication	4	4	4
Spacing	15 × 15 cm	15 × 15 cm	15 × 15 cm
Local checks	Sumati	Utpala	-
Date of sowing	30.06.2017	30.06.2017	14.07.2017
Date of transplanting	28.07.2017	01.08.2017	13.08.2017
Net plot size (m2)	3.24	3.24	0.72

Table 90: Monitoring of soil salinity and pH in CSTVT trials at Canning Town during kharif 2017

Date	CSTVT	Soil EC_e (dS m^{-1})		Soil pH	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
28.07.2017	IVT	5.42	4.32	6.66	6.75
	AVT_{-1}	4.16	4.95	6.70	6.92
	AL&ISTVT	7.63	7.69	7.34	7.02
31.08.2017	IVT	3.69	5.92	6.74	6.74
	AVT -1	4.25	5.42	6.58	6.74
	AL&ISTVT	6.41	6.71	7.25	7.07
07.10.2017	IVT	3.49	4.07	6.08	6.89
	AVT -1	3.40	5.20	6.33	6.39
	AL&ISTVT	4.10	4.37	7.11	7.03

Out of 15 entries under AVT 1- CSTVT, highest grain yields were obtained from entry no. 5112 (6.10 t ha^{-1}) and entry no. 5101 (6.05 t ha^{-1}), the local check variety Utpala produced grain yield of 5.89 t ha^{-1}. Days to flowering varied from 87-134 days. Entries 5113 and 5114 flowered in 87 days, whereas entry no. 5104 flowered in 134 days. The local check variety Utpala flowered in 118 days. Plant height was shortest (78 cm) in entry no. 5103 and longest (135 cm) in entry no. 5101.

Under AL & ISTVT five treatments involving nutrient management and microbial inoculation [F_1: Low input (50% RDF), F_2: Medium input (100% RDF), F_3: High input (150% RDF), F_4: 50% of N ha^{-1} of RDF + microbial inoculation (Halo Azo + Halo PSB) and F_5: 100% of N ha^{-1} of RDF + microbial inoculation (Halo Azo + Halo PSB)] were taken in main-plot and four varieties (V_1: Utpala, V_2: Dadsal, V_3: SR 26B and V_4: Chamarmani) were taken in sub-plot. Highest mean grain yield of 5.41 t ha^{-1} was recorded in Utpala due to 100% RDF + inoculation. Grain yield was lowest (3.33 t ha^{-1}) in Dadsal with 50% RDF.

Evaluation of microbial formulations for crop productivity and soil health under coastal agro-ecosystem (S. K. Sarangi and T. D. Lama)

An experiment was conducted to evaluate the microbial formulations like Halo-Azo and Halo-PSB on the performance of *kharif* rice (Sumati) during 2017. The treatments were T_1: Uninoculated + VC 2.5 t ha^{-1} + 100% RDF, T_2: Uninoculated + VC 2.5 t ha^{-1} + 75% RDF, T_3: HaloAzo + VC 2.5 t ha^{-1} + 100% RDF, T_4: HaloPSB + VC 2.5 t ha^{-1} + 100% RDF and T_5: HaloAzo + HaloPSB+ VC 2.5 t ha^{-1} + 100% RDF evaluated in RBD with three replications. The liquid bioformulations of Halo-Azo and Halo-PSB were applied as seed treatment as well as at the time of transplanting as seedling root by dissolving both (Halo-Azo and Halo-PSB) the 100 ml bottles in 20 litres of water in a tub with 2 kg of cow dung slurry to form a mixture. The seedling roots were dipped in the mixture for 1 h and thereafter transplanted in the field/plots. The remaining left over mixture was then mixed in the ponded water of the respective plot.

Grain yield of rice variety Sumati was highest (5.12 t ha^{-1}) with combined application of microbial formulations, vermin-compost and 100% recommended dose of fertilizer. Whereas it was 4.69 t ha^{-1} in uninoculated control along with vermin-composed 100% RDF.

Seed production, maintenance and evaluation of rice germplasm (S. K. Sarangi)

Seed production of released varieties of ICAR-CSSRI was undertaken in *Kharif* 2017. TL seeds were produced in Bhutnath, Sumati, Utpala, SR 26B, Sabita, Canning 7 and CST 7-1. Conservation of salt tolerant germplasm for semi-deep, low, medium, upland situations and *rabi* season was done. *Sub 1* introgressed genotypes (Chirang-*Sub 1*, CR 1009- *Sub 1*, Swarna-*Sub 1*, Samba Mahsuri-*Sub 1*, IR 64-*Sub 1*, BR 11-*Sub 1*) were evaluated. Bhutnath was identified as national check for CSTVT under AICRIP.

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 2017. Twenty nine ICAR-CSSRI varieties were evaluated during *kharif* 2017. Under semi-deep water situation with stagnant flooding, 25 entries. Twenty two entries were evaluated under low land situation

Six *Sub 1* gene introgressed rice varieties (Ciherang - *Sub 1*, CR 1009 - *Sub 1*, IR 64 - *Sub 1*, BR 11 - *Sub 1*, Samba Mahsuri - *Sub 1* and Swarna-*Sub 1*) and two check varieties (DRR 39 and Sabita) were evaluated under stagnant flood condition during *kharif* 2017. None of the *Sub 1* introgressed varieties performed better than local check variety Sabita (grain yield 3.4 t ha^{-1}) under stagnant flooding situation. Among the *Sub 1* varieties, highest grain yield of 2.87 t ha^{-1} was produced by CR 1009 - *Sub 1* followed by Samba Mahsuri - *Sub 1* (2.61 t ha^{-1}). Evaluation of *Sub 1* introgressed varieties were also done under flash flood situation. Under this situation, highest grain yield of 3.43 t ha^{-1} was produced by CR 1009- *Sub 1*, while the local variety Sabita produced grain yield of 1.94 t ha^{-1}. Lowest grain yield of 0.74 t ha^{-1} was produced by IR 64 –*Sub 1* (Table 91).

Participatory evaluation of these *Sub 1* introgressed rice varieties were conducted on 29 November, 2017. Farmers and farm women from nearby villages participated in the evaluation. Under stagnant flooding situation, highest preference score (27) was recorded for Sabita, whereas under flash flooding situation, highest preference score (20) was for CR 1009- *Sub 1*.

Rice seed production plots and preferential analysis during kharif 2017

Table 91: Performance of Sub 1 introgressed varieties under stagnant and flash flooding situations during *Kharif* 2017 at Canning Town

Varieties	Grain Yield (t ha^{-1}) under stagnant flooding	Grain Yield (t ha^{-1}) under flash flooding
Ciherang - Sub 1	1.37	2.47
CR 1009 - Sub 1	2.87	3.46
IR 64 - Sub 1	0.64	0.74
BR 11 - Sub 1	2.61	2.19
Samba Mahsuri – Sub 1	1.56	1.00
Swarna - Sub 1	1.62	2.35
DRR 39	1.62	1.29
Sabita	3.40	1.95
LSD (P=0.05)	1.11	0.34

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)

A field experiment was conducted during the *rabi* 2016-17 to study the salt dynamics and crop productivity under deficit irrigation in a heavy textured coastal saline soil. The experimental design was split-plot with water quality (GW- good quality water, SW_1 - saline water with EC 4.0 dS m^{-1} and SW_2 - saline water with EC 8.0 dS m^{-1}) as main plot treatments and irrigation levels [I_1 -125%, I_2 -100%, I_3 -75% and I_4 -50% of cumulative pan evaporation (CPE)] as sub-plot treatments. The electrical conductivity (EC) of good quality water was 1.15 dS m^{-1} having 11.73, 0.14, 0.77 and 2.44 meq L^{-1} of Na^+, K^+, Cl^- and SO_4^{-2}, respectively. In saline irrigation water having EC 4.0, their contents were 28.98, 0.43, 2.34 and 4.71, respectively, while it was 53.12, 0.7, 4.30 and 5.60 meq L^{-1} in irrigation water having 8.0 dS m^{-1} salinity.

Soil samples from 0-15, 15-30, 30-45 and 45-60 cm depths were sampled at regular intervals for measurement of EC_e and Na^+, K^+, Cl^- and SO_4^{-2} in the saturation extract. The soil EC_e showed an increasing trend with the progress of the crop growing season and at harvest, highest EC_e of 7.1 dS m^{-1} was observed in the surface soil layer with the application of irrigation water having salinity level 8.0 dS m^{-1}. The soil EC_e at harvest was 4.1 with good quality water and 4.7 with irrigation water having EC_e of 4.0 dS m^{-1} (Fig. 102). Soil EC_e at harvest showed an increasing trend with the application of decreasing level of good quality water. However, with application of saline water in increasing amounts, the EC_e increased due to addition of more salts into the soil. The effect was more pronounced with application of irrigation water having EC 8.0 dS m^{-1} due to high salt content. The contents of Na^+, K^+, Cl^- and SO_4^{-2} in the soil saturation extract was closely related to the soil EC_e with R^2 values of 0.84, 0.54, 0.87 and 0.65, respectively (Fig. 102).

Periodic measurements of soil moisture content at different depths were carried out during the crop growth period. In general, the soil moisture content increased in the deeper soil layers. At harvest, higher surface soil moisture contents of 17.2 and 15.6 % were observed with irrigation levels of 125 and 100 % of CPE as compared to 14.5 and 14.0 % in deficit irrigation of 75 and 50 % of CPE, respectively.

Highest kernel yield of maize (3.50 t ha^{-1}) was obtained with good quality irrigation water at 125% CPE and least (1.74 t ha^{-1}) with saline irrigation water (8.0 dS m^{-1}) at 50 % CPE (Table 92). The mean kernel and stover yields were reduced by 24.2 and 18.5%, respectively, in

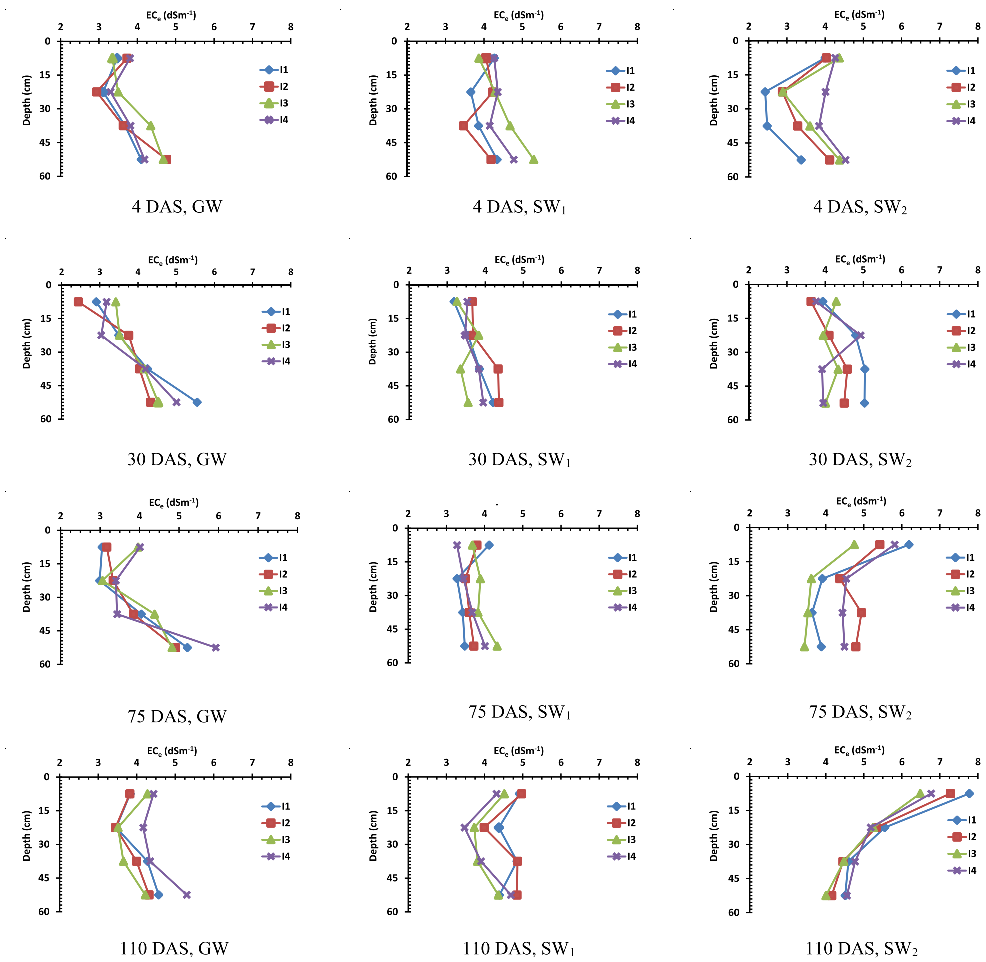


Fig. 101. Effect of irrigation water salinity and deficit irrigation on soil salinity

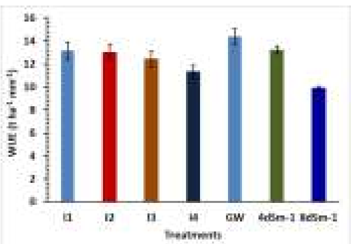


Fig. 102. Water use efficiency (WUE) under different treatments

deficit irrigation treatment (50% CPE) as compared to irrigation level of 100% CPE. Statistically at par kernel and stover yields were obtained at 125 and 100 % CPE and also at 100% and 75% CPE. Irrigation with saline water having EC of 8.0 dS m^{-1} significantly reduced the kernel, stover and cob yields of maize to the extent of 31.1, 46.4 and 26.2 % than that obtained with good quality water. However, the differences in kernel yield of maize irrigated with good water to that with saline water of 4.0 dS m^{-1} was nonsignificant. The 1000 grain weight of maize at different irrigation water salinities were statistically at par, while it was highest at 120% CPE irrigation level which was at par with 100% CPE.

Highest water use efficiency (WUE) of 13.2 t ha^{-1} mm^{-1} was obtained at 125% CPE irrigation level followed by 13.0, 12.4 and 11.3 t ha^{-1} mm^{-1} at 100, 75 and 50% CPE, respectively. On the other hand, WUE was 14.4, 13.2 and 9.9 t ha^{-1} mm^{-1} with good quality water, 4 dS m^{-1} and 8 dS m^{-1}, respectively (Fig 102)

Table 92: Effect of deficit irrigation and irrigation water salinity on yield parameters of maize

Treatments	Kernel Yield (t ha^{-1})				Stover yield (t ha^{-1})				Cob Yield (t ha^{-1})				1000 grain wt. (g)			
	GW	SW1	SW2	Mean	GW	SW1	SW2	Mean	GW	SW1	SW2	Mean	GW	SW1	SW2	Mean
I1	3.50	3.31	2.64	3.15A	15.99	13.89	8.47	12.78A	4.68	4.31	3.86	4.28A	189.74	185.15	177.65	184.18A
I2	3.38	3.25	2.28	2.97AB	15.04	12.81	7.78	11.88AB	4.58	4.28	3.32	4.06A	184.60	182.30	176.86	181.25AB
I3	3.14	2.90	2.13	2.72B	14.11	10.43	7.69	10.74BC	4.55	3.95	2.88	3.79A	180.66	180.20	175.40	178.75B
I4	2.75	2.27	1.74	2.25C	12.89	8.97	7.19	9.68C	3.60	3.11	2.79	3.16B	179.44	178.82	174.60	177.62B
Mean	3.19A	2.93A	2.20B		14.50A	11.53B	7.78C		4.35A	3.91A	3.21B	Mean	183.61A	181.62A	176.13A	

Means with at least one letter common are not statistically significant

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)

Often the impact, in terms of loss of production is not realised at the macro level, but is a serious concern at the regional level. Yield losses are particularly detrimental at a local scale because salt-affected soils are not uniformly distributed and threaten the continued existence of agriculture in coastal regions of the countries. Quantification of farm level agricultural risks and their ways of mitigation is important for making the production systems profitable. Sources of various farm level risks identified were pests and diseases, salinity, lack of quality seeds availability, waterlogging situation due to excess rainfall and heavy rainfall in a very short time (flash rain) particularly during harvest time. Marketable surplus of major crops grown in the study area has been estimated through primary survey on sample farmers that includes farmers growing *kharif* rice (45 no.), *rabi* rice (45 no.), tomato (45 no.), mung (41 no.) and potato (45 no.). The quantification loss due to various identified sources of risks were estimated based on production system of best and worst either/or with and without approach. Besides, opportunities for increasing farm income have been assessed through evidence based cropping intensification options in the study area.

The average quantity of production of major crops grown by the farmers were estimated to be 0.82 t, 1.24 t, 3.45 t, 0.19 t and 4.73 t household^{-1} with marketable surplus of 15.5%, 64%, 84.5%, 33.5% and 75% for the crops *kharif* rice, *rabi* rice, tomato, mung and potato, respectively. Source-wise damage and production loss estimation indicated that together with all sources of risks the loss of production for *kharif* rice and *rabi* rice were 0.33 t ha^{-1} and 0.89 t ha^{-1}, respectively. The value of production loss was estimated as Rs. 3960 and Rs. 7280 ha^{-1} for *kharif* and *rabi* rice, respectively (Table 93). Salinity and insect pest were major contributors of crop loss in *rabi* rice whereas excess rain (waterlogged) and lack of quality seeds were the major sources of crop loss for *kharif* rice. Similarly, the

Table 93: Sources of risk and estimated crop loss for *kharif* & *rabi Rice* in study area of *Sunderbans*

Source of Risk	Area Cultivated (ha)		Area Affected (%)		Crop damage (%)		Production obtained (t ha^{-1})		Production loss (t ha^{-1})		Value of production Loss (Rs)	
	kh. rice	rabi rice	kh. rice	rabi rice	kh. rice	rabi rice	kh. rice	rabi rice	kh. rice	rabi rice	kh. rice	rabi rice
Pest	23	14	90	90	3.5	3	2	4	0.07	0.12	840	1680
Disease	23	14	95	95	3	2	2	4	0.06	0.08	720	1120
Salinity	23	14	low	100	2	4	2	4	0.04	0.16	480	2240
Lack of Quality Seeds	23	14	95	58	4	1	2	4	0.08	0.04	960	560
Excess water	23	14	97	98	3	2	2	4	0.06	0.08	720	1120
Flash rain at harvest	23	14	low	85	0.5	1	2	4	0.02	0.04	240	560
Total	23 (45 HH)	14 (45HH)		16	13			0.33	0.89	3960	7280	

Table 94: Sources of risk and estimate crop loss for Tomato and Potato in the study area of Sunderbans

Source of Risk	Area Cultivated (ha)		Area affected (%)		Crop damage (%)		Production obtained (t ha^{-1})		Production loss (t ha^{-1})		Value of production Loss(Rs ha^{-1})	
	T	P	T	P	T	P	T	P	T	P	T	P
Pest	10.4	10	95	75	9	5	15	22.5	1.5	1.13	10500	6780
Disease	10.4	10	90	80	9	4	15	22.5	1.5	0.9	10500	5400
Salinity	10.4	10	100	100	3	6	15	22.5	0.45	1.35	3150	8100
Lack of Quality Seeds	10.4	10	90	80	3	3	15	22.5	0.45	0.68	3150	4080
Lack of irrigation	10.4	10	90	95	7	4	15	22.5	1.2	0.9	8400	5400
Heavy Rainfall	10.4	10	0	0	0	0	0	0	0	0	0	0
Total	10.4 (45HH)	10(45HH)			31	22	22.5	5.1	5.41	35700	29760	

Note: T is Tomato and P is Potato

crop loss was estimated for other cash crops (tomato and potato) in the study area and the crop loss was estimated to be 5.1 t ha^{-1} and 5.41 t ha^{-1} for tomato and potato, respectively (Table 94). The value of loss was quantified as Rs. 35700 ha^{-1} and Rs. 29760 ha^{-1}, for tomato and potato, respectively. Pest and disease attack, high salinity and lack of timely irrigation (non-availability of good quality water) were the major sources of crop loss for both the crops. Damage in terms of crop loss and monetary loss was also estimated for moong as 0.19 t ha^{-1} and Rs. 4158 ha^{-1}, respectively.

Occupation pattern and Households level farmers' income

Primary survey was conducted to understand the baseline income and occupation pattern of the farm households in coastal areas of West Bengal through different ongoing and completed socio-economic research project carried out through ICAR-CSSRI, RRS Canning Town. The occupational pattern indicated agriculture was the dominant occupation (43%) followed by migration of labourers (32%) and agricultural labourers (7%). In coastal areas of West Bengal, large number of agricultural labourers migrates (seasonally) to nearby cities or at distance places for alternative livelihoods option. The migrant labourers are actually the agricultural labourers and they used to migrate, particularly during non *kharif* season, due to lack of daily jobs in farming operations. Overall the households' level income was estimated to be Rs.45278 year^{-1} or Rs 3773 month^{-1} for all sources. However, the income from agriculture was quite low (Rs 1557 month^{-1} household^{-1}) and much lower than income from migrant labourers earning (Rs 3897 month^{-1}) indicating the reasons behind large scale seasonal migration from this region.

Intensification of Cropping System for enhancing income

Cropping system in the coastal region of West Bengal was dominated by mono-cropping of *kharif* rice. The cropping intensity was low (114%) and more than 80% of the farm land remained fallow during *rabi* season. However, despite having many constraints, the farming in coastal region has good potential to enhance farmers' income through scientific intervention of soil and water resources. For example, implementation of land-shaping models (modification of land suitable for on-farm water harvesting) like farm pond, paddy-cum-fish and deep-furrow-and-high-ridge system along with scientific management of soil, water and nutrient management were capable to increase the cropping intensities significantly (from 114 to 186%). Such intervention (land shaping) created the opportunities of higher cropping system intensification from existing monocropping. Various options were rice-rice, rice-fish (paddy-cum-fish), rice-vegetables and rice-fish-vegetable cropping system. All these cropping systems have been demonstrated at large number of farmer's field in coastal areas and were found to be quite successful in terms of increasing farmers' income substantially and sustainably. Results from demonstration indicated, farmers' income (net income) could be increased from merely Rs. 470 month^{-1} (*kharif* rice) to as high as Rs. 11999 month^{-1} (rice-fish-vegetable cropping system). Besides, growing betel vine (perennial crop) was also a good option to realise higher farmers' income (Rs.5667 month^{-1}). As the farmers in this region were operating on average holdings of 0.60 ha, therefore the return calculation was also shown on average land holdings. It indicated, the net return (income) per month on average holdings could increase from Rs. 282 month^{-1} (*kharif* rice) to Rs. 7199 month^{-1} (rice-fish-vegetables) and Rs. 3400 month^{-1} for betel vine cultivation. The cropping system intensification in the coastal region indicated there was feasible options to increase the farmers' income significantly and in fact much higher than the baseline income at regional level (Rs. 3773 month^{-1}) or state level (Rs. 3980 month^{-1}). Therefore, achieving higher farmers' income was possible but challenge remained to make the benefits inclusive across the farmers groups.

Key observations

Despite production risk due to different sources, agriculture continues to be major occupation and livelihoods in the region. Mitigating farm-level risks needs micro management like regular weather advisory services, disease or pest attack forecasting (weather aberrations are more critical factor). Farm-level risks very often does not qualify (<33% area damage) for obtaining the compensation from insurance, hence farmers are reluctant. Cropping system intensification and crop diversification are the suitable options for risk mitigation at farm level and can increase farm income significantly, despite the prevailing risk.

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(NICRA) (UK Mandal, B Maji, KK Mahanta, S Raut; PI: AK Bhardwaj, CSSRI, Karnal)

Considering land shaping techniques as most important climate resilient technology for coastal region, the hydrological impacts of rainwater harvesting in different land shaping models through water balance approach were studied. A water balance model consisting four sub-model situations *i.e.*, for non rice field, rice field, fallow land and on farm reservoir, under three land shaping system *viz.*, farm pond (FP), deep furrow and high ridge system (RF) and paddy cum fish (PCF) system as well as rice monocrop and rice-rice system was used to study the hydrological impact. Water balance models were run during three consecutive years *i.e.*, 2012, 2013 and 2014 which were normal, excess and deficit rainfall year, respectively. As rainfall and rainy days were the highest during 2013, the runoff generated was also high. Out of three land shaping models, the maximum runoff harvested was under FP followed by RF and the lowest under PCF system. On an average, amount of runoff harvested was 2708.6, 1650.3 and 1168.9 m^3 of water in FP, RF and PCF system.

The amount of runoff going out of system was 19.5% , 29.1% and 34.6% of annual rainfall in FP, RF and PCF systems whereas in case of rice-rice and rice-monocrop system around 34.5% and 29.4% of rainfall was going out as runoff. As the region received a good amount of rainfall the harvested total rainwater was calculated as 4069, 3970 and 2006 m^3 in FP, RF and PCF land shaping systems, respectively, during three years of study. Though the year 2013 received excess annual rainfall, the maximum runoff was harvested during 2012 in case of FP system whereas it was during 2014 in case of RF and PCF while 2014 was a deficit rainfall year. Around 42%, 26% and 39% of harvested rainwater in case of FP, RF and PCF systems were used for irrigation. Around 332-496 mm of rainwater which accounts 19-29% of average annual rainfall goes out as runoff under different land modification systems. Under rice-rice and rice-fallow system, around 29-35% of rainfall goes out as runoff and the field remained water logging for long time.

Water productivity based on grain yields was the highest in RF followed by FP, PCF and rice-rice system and the lowest in control with rice-monocrop. The water footprint (WF) of each system is sum of the water evaporated /evapotranspired from field/crop during its life cycle and the volume of water used to leach excess salt due to salinity build up during summer. As rice during kharif was grown as rainfed crop no blue water was used and the gray water was used to leach out excess salt developed during summer. The lowest WF was recorded under FP systems (Table 95) on the other hand; the WF was higher under rice-monocrop system. The blue water footprint under land shaping system was harvested rainwater where as under rice-rice system blue water came from ground water (Table 96).

Table 95: Hydrologic data description under different land shaping situation during 2012, 2013 and 2014.

Description	2012	2013	2014	Average
Total rainfall (mm)	1582.5	2164.2	1368.3	1705
Rainy days (> 2.5 mm)	72	83	73	76
Farm Pond				
Runoff generated (mm)	624.48	1028.38	358.31	670.39
Runoff collected (on hectare basis with 20% area under farm pond of 3 m depth) m^3	3014.07	2868.9	2242.84	2708.6
Runoff going out of the system (mm)	247.72	669.77	77.96	331.82
Net water harvested m3 on hectare basis	4196.9	4748.1	3261.3	4068.8
Harvested water used for irrigation (m^3)	1700	2000	1450	1716.7
Deep furrow & high ridge (DF)				
Runoff generated (mm)	670.1	1077.18	401.33	716.2
Runoff collected (on hectare basis with 25% area under furrow and 25% area under ridge with a depth of 1 m) m^3	1803.6	1334.77	1812.41	1650.3
Runoff going out of the system (mm)	429.62	899.21	159.68	496.2
Net water harvested m^3 on hectare basis	3452.5	4859.4	3598.9	3970.3
Harvested water used for irrigation (m^3)	1062	937.5	1125	1041.7
Paddy-cum-fish (PCF)				
Runoff generated (mm)	558.42	977.32	294.74	610.2
Runoff collected (on hectare basis with 12% area under trench of 1.5 m depth) m^3	1000.85	938.46	1567.32	1168.9
Runoff going out of the system (mm)	428.44	870.67	116.64	471.92
Net water harvested m^3 on hectare basis	1000.15	3016.5	2001.1	2005.9
Harvested water used for irrigation (m^3)	797.5	750	825	790.8
Rice-fallow system runoff generated (mm)	538.51	948.36	281.42	589.4
Rice-rice system runoff generated (mm)	441.9	881.2	180	510.1

Table 96: Water footprint and water productivity under different land shaping systems

Land modification system	Water productivity kg m^{3-}	Green water footprint ($m^3 t^{-1}$)	Blue water footprint ($m^3 t^{-1}$)	Gray water footprint ($m^3 t^{-1}$)	Total water footprint ($m^3 t^{-1}$)
Rice-monocrop	0.50a	3113.6a	0.0	531.1a	3644.8a
Rice-Rice	0.68b	974.2b	702.4a	206.9b	1883.5b
Farm pond system	1.81c	608.2c	103.1b	97.3c	808.5c
Deep furrow & high ridge system	1.94c	783.7d	75.3c	117.2d	976.2d
Paddy cum fish system	1.78c	836.2d	63.3c	129.7d	1029.2d

Stress-Tolerant Rice for Africa and South Asia (STRASA - Phase 3) Sub Project - 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 Canning Town Experimental Farm during *rabi* and *kharif* seasons in 2017 under Bill and Melinda Gates Foundation (BMGF) funded project. Soils of the experimental site have Hyperthermic temperature and Aquic moisture regimes. Soil is heavy in texture (silty clay) and normal in soil reaction. During *rabi* season, soil salinity (EC_e) varied from 5.40-8.20 dS m^{-1}. The *rabi* experiment consisted of 66 rice genotypes including 5 check varieties (PUSA 44, CSR 10, CSR 27, CSR 36 and CSR 7-1) and 1 local check variety (Annada). Same set of genotypes except the local check was evaluated during *kharif* 2016. Out of 66 genotypes 12 genotypes did not flower and CR3909-192-1-7-2 died 2 weeks after transplanting during *rabi* season.

Days to 50 % flowering of the entries in the trial ranged from 100 days (CSR-2748-4441-22) to 145 days (RAU 1397-14) with a mean of 126 days. Plant height of the entries varied from 58.8 cm (TR 09027) to 103.5 cm (CR3903-161-1-3-2) with a mean height of 75.5 cm. Total number of tillers per plant of the entries ranged from 8 to 13 (CSR-2748-4441-111) with a mean value of 10. Number of reproductive tillers varied from 7 (PAU 7114-3480-1-1-1-0, CSAR 1611, RP-106-22-4-1-3) to 13 with a mean value of 9. Panicle length of the different entries under trial ranged from 15.7 cm (KR 15003) to 24.3cm (CR3882-7-1-6-2-2-1) with a mean of 19.9 cm. Number of filled grains per panicle varied from 35 (CSR-2748-4441-22) to 91 (RP-320-4-3-2-1) with a mean value of 54. Number of un-filled grains per panicle varied from 10 (CSR 10 (Check) to 49 (CR3879-3-1-6-1-3-1) and mean value for the entries is 26. Spikelet fertility of the entries under trial ranged from 56.9% (PAU 3835-36-6-3-3-4) to 86.1% (Annada (Local Check) with a mean of 67.7%. In the trial, 1000 grain weight of the entries varied from 18.2 g (KR 15003) to 30.1 g (CR3881-M-3-1-5-3-1-1) with a mean weight of 23.6 g. At reproductive stage, stress score varied from 1 (CR3879-3-1-6-1-3-1, CSAR 1604, RP-320-4-3-2-1, NDRK 11-22, CSR-2748-4441-193, IRRI-147, CSR-2748-4441-15, CSR-2748-4441-22, CSR-2748-4441-104, CSR-2748-4441-104 and Annada (Local Check) to 5 (CR2838-1-S-2B-9-1) with a mean value of 2. Grain yield of the entries varied from 395.8 to 2931.3 kg ha^{-1} with mean yield of 1139.0 kg ha^{-1}. Out of all the entries maximum grain yield was recorded in Annada (Check 6) (2931.3 kg ha^{-1}) followed by RP-320-4-3-2-1 (2804.9 kg ha^{-1}).

The STBN trial during *Kharif* 2017 was conducted at the same site of *rabi* experiment at Canning Town Experimental Farm. The soil salinity of the experimental site varied from 2.88-6.57 dS m^{-1}. The experiment consisted of 88 rice genotypes including 6 check varieties (CSR 10, CSR 27, CSR 36, CST7-1, PUSA44 and Sambha *Sub 1*) and 1 local check variety (Amal-Mana). Days to 50 % flowering of the entries in the trial are ranging from 78

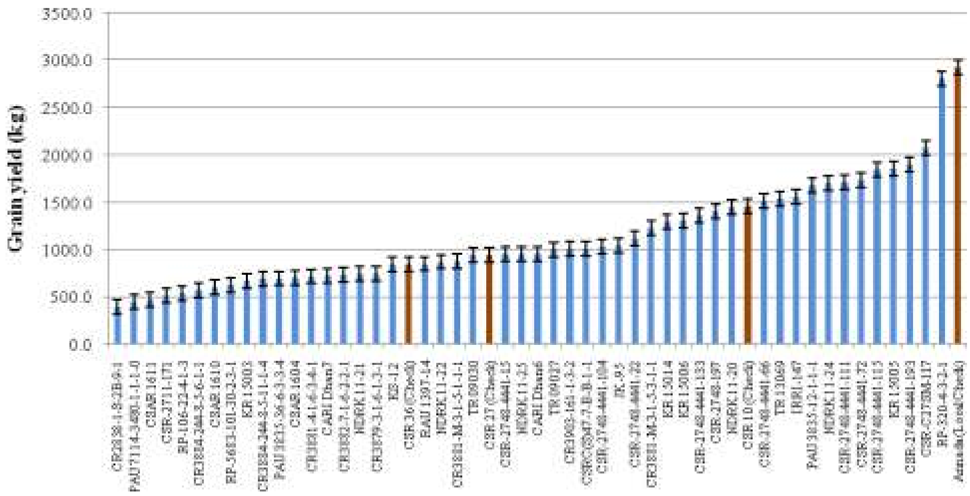


Fig. 103. Grain yield of entries under STBN trial

days (KR 15010) to 130 days (CR 2859-S-B-2-1-B-7) with a mean of 102 days. Plant height of the entries varies from 79 cm (TR 09027) to 149 cm (CR 2843-1-S-1-6-B-S-B-1) with a mean height of 106 cm. Number of tillers per plant of the entries are ranged from 9 (Sambha *Sub 1* (Check), CSAR1620, KR15006, CR 3912-221-1-3-1, CR3887-15-1-2-1, CR 3883-3-1-5-2-1-2 and RP 5690-20-6-3-2-1) to 16 (IR 10206-29-2-1-1 and CR 3878-245-2-4-1) with a mean value of 11. Number of productive tillers varied from 8 (RP 5690-20-6-3-2-1 and CR 3883-3-1-5-2-1-2) to 16 (CR 3878-245-2-4-1) with a mean value of 1. Panicle length of the different entries under trial is ranging from 14.8 cm (CR 3878-245-2-4-1) to 27.1 cm (IR 52280-117-1-1-3) with a mean of 20.9 cm. Number of filled grains per panicle varies from 36 (IR 10206-29-2-1-1) to 117 (CR 3912-221-1-3-1) with a mean value of 66. Spikelet fertility of the entries under trial ranged from 54.6 % (CSR 2016-IR18-10) to 87.3 % (CSR RIL-01-IR165) with a mean of 74.2%. In the trial, 1000 grain weight of the entries varied from 14.6 g (Sambha *Sub 1* (Check)) to 32.6 g (CR3887-15-1-2-1) with a mean weight of 24.8 g. At reproductive stage, stress score varies from 1. Grain yield of the entries varied from 919.1to 5401.7 kg ha^{-1} with mean yield of 3576.8 kg ha^{-1} (Fig. 103). Out of all the entries higher grain yield was recorded with Amal-Mana (Local Check) (5401.7 kg ha^{-1}).

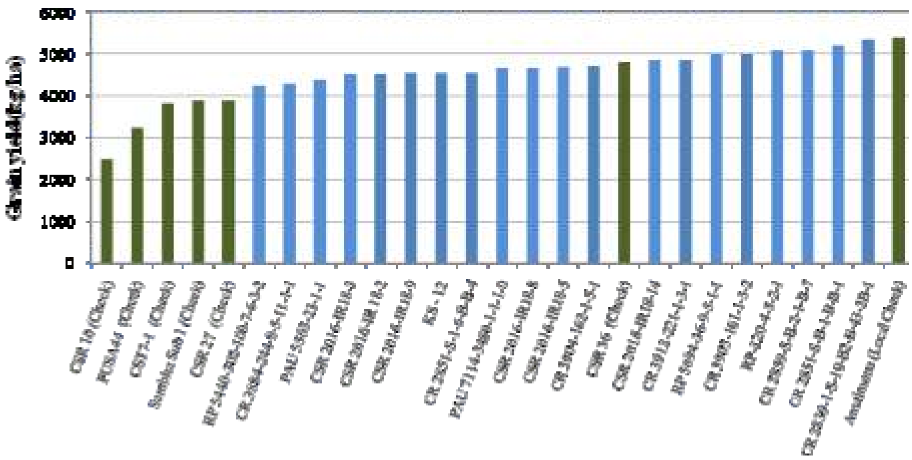


Fig. 104. Grain yield of selected entries under STBN trial

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. Mandal and K .K Mahanta)

The ACIAR funded project on 'Cropping systems intensification in the salt affected coastal zones of Bangladesh and West Bengal, India' implemented both during wet (*kharif*) and dry (*boro*) seasons at Canning Town Experimental Farm (on-station) as well as at farmers' fields (on-farm) during the reported period. The project is in operation in India and Bangladesh. ICAR-CSSRI, RRS, Canning Town is implementing the project at the Sonagaon village in the Gosaba island of South 24 Parganas district.

Project activities were implemented in about 94 farmers' fields to increase the cropping intensity through introduction of improved management practices, new crops and varieties. Periodic monitoring of depth, salinity and pH of ground water is continuing. During the period, the depth of ground water was closest to the surface in August (0.28 to 0.38 m), the mean salinity of the ground water varied from 6.25-12.01 dS m^{-1} and the mean pH varied from 7.28-8.20. Out of four mulching treatments (black, white, paddy straw and control), black plastic mulching resulted in the highest yield in three vegetable crops (okra, cucumber and bitter gourd). Mean yield was 43, 73 and 101% higher in paddy straw, white and black plastic mulching over control. During *rabi* season maize and potato are suitable crops. Zero tillage potato after rice is a very good option followed by maize/green gram/onion/vegetables, thereby cropping intensity can be increased to 300%. Rice variety Amal-Mana was grown in soils with pH varying from 4.6-4.8 with and without green manuring. During the first year there was no significant difference between green manuring and without green manuring plots. The mean grain yield varied from 2.69 to 3.45 t ha^{-1} under lower and higher soil pH respectively.

ACIAR Project site at Gosaba Island, Sundarbans

During *kharif* season of 2017, experiment was continued for the second year in three farmers fields to study the effect of *kharif* crop establishment methods and variety on rice crop. Four treatments (conventional puddled transplanting, unpuddled transplanting, DSR and drum seeding) were taken in main-plot and two rice varieties (V_1: CR 1009; V_2: CR 1017) in sub-plot. Root length under DSR was significantly higher compared to other establishment methods. The plant height was highest in DSR up to 75 days after sowing (DAS), however it was at par in all treatments at 90 DAS. Root length was higher (17.74 cm) in CR 1009, whereas it was 17.38 cm in CR 1017 at 45 DAS. On the other hand plant height was higher in CR 1017 (65.29 and 96.9 cm at 45 and 75 DAS respectively) compared to CR 1009 (44.37 and 89.38 cm at 45 and 75 DAS respectively). The grain and straw yields were at par in DSR (6.47 and 8.35 t ha^{-1} respectively) and PTR (6.52 and 8.39 t ha^{-1} respectively). The two varieties did not differ with respect to grain yield, however the straw yield was highest in CR 1017 compared to CR 1009 (Table 97).

After the harvest of rice, soil parameters like bulk density (BD) and soil moisture were observed under different establishment methods. It was observed that soil BD was lowest in UNPRT and DSR compared to PRT (in the experimental plot as well as in the adjacent farmers plots). The soil moisture was better distributed in soil profile under DSR with less moisture in the upper layer facilitating earlier establishment of subsequent *rabi* crop.

Second field experiment was conducted at 10 farmers' fields on acid saline soil managed by liming in rice based cropping systems. The pH of the soils varied between 4.83-5.64. The rice variety CR 1017 was taken during *kharif* season with green manuring (GM) and

Table 97: Grain and straw yields of kharif rice varieties under different establishment methods

Treatments	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
PTR	6.52	8.39
UNPTR	5.43	7.11
DSR	6.47	8.35
LSD (P=0.05)	0.17	0.18
Varieties		
CR 1009	6.18	7.46
CR 1017	6.19	8.45
LSD (P=0.05)	NS	0.22

Table 98: Rice yield under acid saline soil management

Treatments	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
Control	3.96	5.43
Green Manuring	4.45	6.49
Lime @ 1.5 t ha-1	4.23	6.15
RP @ 0.25 t ha-1	4.17	6.26
Lime+ RP	4.68	6.29
GM+Lime	5.74	6.36
GM+RP	6.04	6.53
GM+Lime+RP	6.17	6.54
LSD (P=0.05)	0.34	0.22

without green manuring. Treatments on soil amendments (control: no amendment, lime @ 1.5 t ha^{-1}, rock phosphate (RP) @ 0.25 t ha^{-1} and lime @ 1.5 t ha^{-1} + RP @ 0.25 t ha^{-1}) were imposed during previous rabi season. Lime requirement was as per soil pH of the site and the calculated amount of lime was applied before the *rabi* crop. Rock phosphate was applied to *rabi* crops as a source of P.

Highest grain and straw yields of rice were observed in case of the treatment with GM + lime + rock phosphate which was at par with GM + RP (Table 98). Grain yield increased from 3.96 t ha^{-1} to 4.45 t ha^{-1} due to GM and to 5.74 t ha^{-1} in GM + lime treatment. Therefore, GM and application of soil amendments can sustain higher yield in these poor quality soils of Sundarbans.

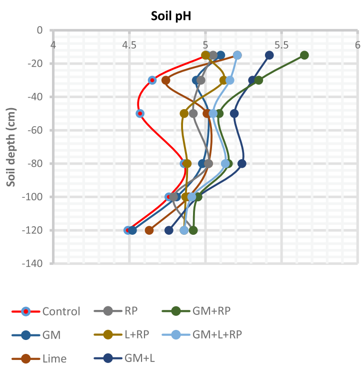


Fig. 105. Effect of green manuring and amendments on soil pH

There was significant improvement of soil pH due to GM and application of rock phosphate (Fig. 105). Soil pH increased from about 5 to more than 5.5 due to these treatments. The effect of soil amendments were also observed on *rabi* maize crop. The growth parameters (plant height and root length), kernel weight and kernel yield were increased in all the treatments over control. Highest kernel yield of 6 t ha^{-1} was observed due to application of rock phosphate in acid saline soils, which was at par with application of lime (5.6 t ha^{-1}), however there was not advantage due to application of both lime and rock phosphate.

Experiment on solar drip irrigation for improving water productivity and profitability in high value crops was continued during *kharif* season of 2017. Crops like okra, cucumber and bitter gourd were evaluated under four treatments [without mulching (control), black plastic mulching, white plastic mulching and paddy straw mulching]. The average yield of vegetables was significantly higher under black plastic mulching compared to other mulch materials (Table 99).

Table 99: Effect of Mulching on weed biomass and yield of vegetables during *Kharif* 2017

Treatment	Yield (kg plot^{-1})*	Weed Biomass (t ha^{-1})
Crop		
Okra	152.25	0.73
Cucumber	166.38	0.67
Bitter gourd	91.53	0.77
LSD (P=0.05)	3.43	0.03
Mulching		
Control	88.58	1.75
Black plastic	178.35	0.14
White plastic	153.31	0.18
Paddy straw	126.64	0.81
LSD (P=0.05)	4.10	0.05

*Net plot size = 153 m2 under each crop

During *rabi* season, vegetables like chilli, knoll khol, okra and bitter gourd are under evaluation in solar drip irrigation under different mulching treatments. After the harvest of kharif vegetables, knoll-khol, chilli and okra were taken. Knol-khol was harvested and then bitter gourd was taken. Therefore, with introduction of this technology farmers can take two (vegetable-vegetable) or three (vegetable-vegetable-vegetable) crops in a year to achieve 200 -300% cropping intensity. To reduce the initial expenditure under this

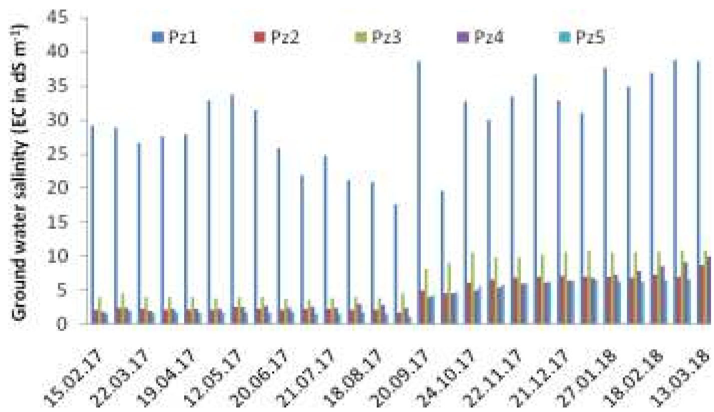


Fig. 106. Ground water salinity in peizometers installed at Sonagaon village

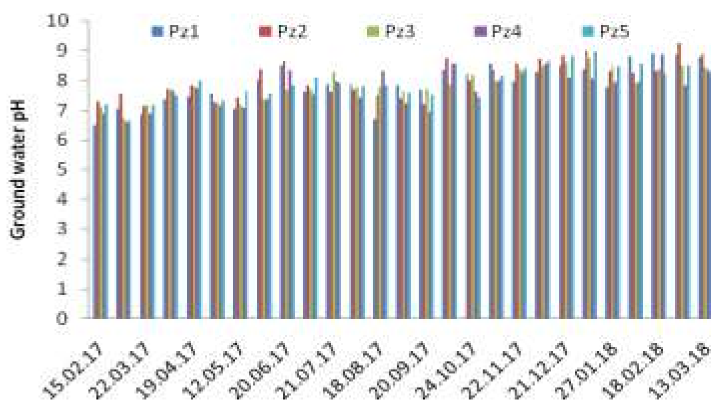
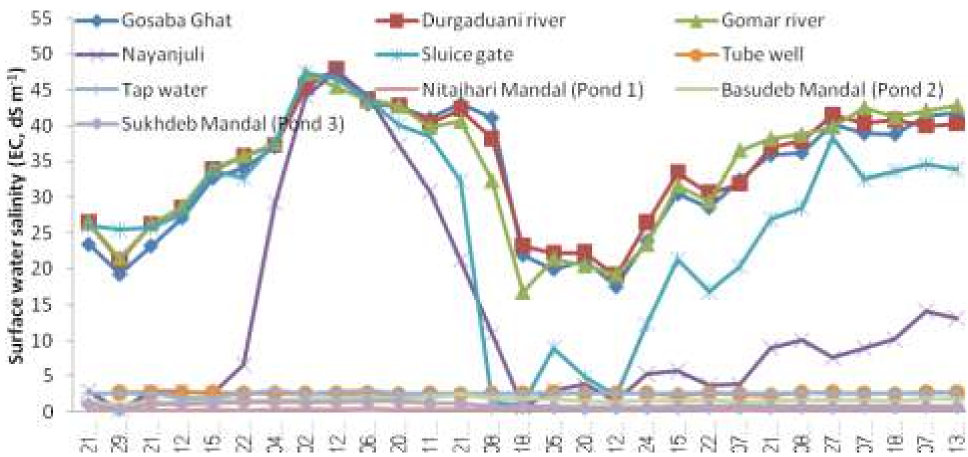


Fig.107.Ground water pH in peizometers installed at Sonagaon village

Fig. 108. Salinity of surface water resoureces of Sonagaon village in the Gosaba Island



technology, low cost drip irrigation systems are under evaluation. Apart from rice and maize, a number of other crops are also evaluated under this project.

Ground and surface water study under the ACIAR Project

The observations from five numbers of piezometers installed in January 2017 at 20 feet below ground level at the project sites were continued. These were installed at locations to represent the Island. Periodic monitoring of depth, salinity and pH of ground water is continuing and data collected are presented in graphs. It was observed that salinity of ground water varies with the distance from sea. The piezometer installed nearest to the sea showed highest salinity (Fig. 106). The pH of ground water varied between 6.5- 8.9 (Fig. 108). The water table was within 2 m depth from ground level.

Studies on surface water resources

Quality (salinity and pH) of surface water resources from ten different sources (Gosaba Ghat, Durgaduani river, Gomar river, Nayanjuli, Sluice gate, Tube well, Tap water, 3 number of ponds) were monitored in the Sonagaon village of Gosaba Island. The salinity of river water was highest during the month of May (47.9 dS m^{-1}). The salinity of pond water was lowest (0.29- 2.44 dS m^{-1}) among different sources of water (Fig. 108). The pH of the surface water resources was monitored and it was found that pH varied between 6.76-9.15.

Introduction of successful Broccoli cultivation

To increase the cropping intensity as well as income of farmers, new crops such as broccoli, linseed, sunflower, capsicum, mustard and Indian spinach were introduced during the *rabi* season of 2017-18. There was tremendous success in cultivation of Broccoli and Indian Spinach, particularly under early sowing. Broccoli was first time introduced in this region by this project. One of the women farmers Mrs. Sumitra Giri was very successful in the cultivation of Broccoli crop. She got net income of Rs. 1192.50 (Rs.170357 ha^{-1}) from an area of 70 m^2 apart from meeting home consumption. This crop not only increased her income, but also she could provide nutritious vegetables to her family. She plans to cultivate this crop in larger scale in the next year.

Inter-institutional projects

Land use options for enhancing productivity and improving livelihood in Bali Island of Sundarbans - Collaborative research project (TSP fund) (K. D. Sah, K. Das, S. K. Reza, A. K. Sahoo, D. C. Nayak, Subhasis Mandal, D. Burman and P.P. Chakraborty)

Under fund support from TSP, the collaborative (NBSS&LUP, CSSRI and CIFA) project has been undertaken under extremely disadvantaged areas in coastal Sunderbans with key 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 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.

Project was initiated with 7 farmers in 2014 and increased to 32 farmers in 2015. During 2016, 23 additional tribal farm families have been included. Currently project activities have been extended over 60 farm households during 2017. Inputs for soil management, growing vegetables and fish has been provided with emphasis on women tribal farmers group. Details of operational area operated by women tribal farmers, their income during both *kharif* and *rabi* season has been calculated. Success stories have been documented through video film. Women (tribal) farmers (22 no.) income during *rabi* (2016-17) was in the range of Rs. 11800 to Rs. 42360/- and the same was Rs. 24445/- to Rs. 51105/- during *kharif* (2017-18) season. Crops grown during *rabi* season were coriander, amaranthus, potato, spinach, lady's finger and cauliflower. During *kharif* season they grew rice, yam, pumpkin, bitter gourd, lady's finger, chilli, tomato and brinjal. Some farmers grew fish and backyard poultry. Most of the production systems under tribal farmers group were under homestead production system.

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 (Rameshwar Lal Meena, Babu Lal Meena, Anshuman Singh, M.J. Kaledhonkar and S.K. Sanwal)

Vegetables grown under protected structures during off-season fetch remunerative prices. However, precise information about the effects of saline water on crop growth and yields under protected cultivation is limited. In this backdrop, three vegetable crops namely, capsicum (var. Indra), chilli (var. Kranti) and tomato are being tested in a naturally ventilated polyhouse with saline water irrigation at ICAR-CSSRI, Karnal to study improvements in crop productivity and profitability along with feasibility of such structures in ensuring livelihood security to resource poor farmers. During first year, these vegetables produced very good yields under high saline water irrigation. These vegetables were grown consecutively for the second season from first week of September 2016. Six saline water irrigations with EC_{iw} ranging from 0.8 dS m^{-1} (Best available water: BAW) to 10 dS m^{-1} were used for irrigation. Capsicum, chilli and tomato seedlings were transplanted on 8th September 2016 on raised beds of 15 cm at spacing of 45 cm x 30 cm. Drip system operated under gravity flow was used to apply saline irrigation water. The vegetables were harvested on regular interval till third week of June 2017.

Effects on plant growth and yield: In capsicum, the maximum plant height (165.4 cm) was noted in BAW irrigated plants. The lowest plant height (105.3 cm) was recorded with EC_{iw} 10 dS m^{-1}. Maximum stem girth (2.35 cm) was recorded under BAW which was at par with other saline water treatments. Number of fruits plant^{-1} differed non-significantly and the maximum fruits plant^{-1} (20.0) was recorded under EC_{iw} 8 dS m^{-1} followed by EC_{iw} 10 dS

Table 100: Plant growth and fruit yield in saline irrigated vegetable crops (2016-17)

Treatments EC_{iw} (dS m^{-1})	Plant height (cm)	Stem Girth (cm)	Fruit plant^{-1} (no.)	Fruit weight (g)	Fruit yield (q ha^{-1})
Capsicum					
BAW	165.38^{A}	2.35	18.65	62.33^{A}	499.08
2	148.50^{A}	2.22	18.53	59.55^{AB}	475.23
4	131.20^{B}	2.09	16.43	63.63^{A}	445.43
6	121.30^{BC}	2.11	19.00	56.20^{BC}	457.78
8	128.58^{B}	2.17	20.03	51.10^{C}	437.88
10	105.28^{C}	2.17	19.53	53.60^{C}	448.85
EC_{iw} (dS m^{-1})	Chilli				
BAW	155.63^{BC}	1.84^{B}	114.88^{D}	6.19^{A}	305.64^{B}
2	174.75^{AB}	2.00^{AB}	141.78B^{CD}	5.25^{B}	320.55^{B}
4	181.88^{A}	1.98^{AB}	162.55^{AB}	6.64^{A}	463.11^{A}
6	179.08^{A}	2.10^{A}	187.13^{A}	5.99A	476.76^{A}
8	152.38^{C}	1.58^{C}	146.38^{BC}	5.11^{B}	318.21^{B}
10	151.68^{C}	1.61^{C}	124.60^{CD}	5.09^{B}	275.16^{B}
EC_{iw} (dS m^{-1})	Tomato				
BAW	638.28	0.92^{B}	40.16^{D}	38.89^{D}	670.68^{C}
2	653.68	0.84^{C}	39.79^{D}	39.44^{D}	674.98^{C}
4	664.75	1.06^{A}	51.23^{BC}	45.04^{AB}	991.95^{B}
6	674.50	1.04^{A}	49.75^{C}	44.70B^{C}	954.98^{B}
8	650.65	1.02^{A}	53.63^{AB}	42.33^{C}	973.10^{B}
10	631.73	1.04^{A}	55.86^{A}	47.51^{A}	1139.87^{A}

Means with at least one letter common are not statistically significant using Duncan's Multiple Range Test at 5% level of significance.
*Non-significant

m^{-1} (19.5). Fruit weight of capsicum was significantly higher with BAW (62.3 g) which was at par with EC_{iw} 2 and 4 dS m^{-1} compared to other treatments. Highest fruit yield of capsicum (49.9 t ha^{-1}) was obtained with BAW which is at par with the fruit yield obtained under EC_{iw} 2, 4, 6, 8 and 10 dS m^{-1}. Plant height of chilli differed significantly with saline water irrigation, highest plant height (181.9cm) was observed under EC_{iw} 4 dS m^{-1} which was at par with EC_{iw} 6 dS m^{-1} (179.1cm). Stem girth differed significantly and the maximum stem girth (2.10 cm) was recorded under EC_{iw} 6 dS m^{-1} which was at par with that of EC_{iw} 2 and 4 dS m^{-1}. The maximum number of fruits plant^{-1} (187.1) were obtained at EC_{iw} 6 dS m^{-1} which was at par with EC_{iw} 4 (162.5). Fruit weight of chilli was significantly higher with EC_{iw} 4 dS m^{-1} (6.64 g) which was at par with BAW (6.19 g) and 6 dS m^{-1} (5.99 g). Fruit yield of chilli differed significantly and the highest fruit yield (47.6 t ha^{-1}) was obtained with EC_{iw} 6 dS m^{-1} followed by EC_{iw} 4 (46.3 t ha^{-1}). In tomato, plant height differed non-significantly among treatments. Stem girth also showed marginal differences. The highest (55.86) and the lowest (39.79) number of fruits plant^{-1} were recorded at 10 and 2 dS m^{-1} salinity levels. Both fruit weight and total fruit yield increased with increase in salinity and their highest values, 47.51 g and 1139.87 q ha^{-1}, were observed at the highest salinity of 10 dS m^{-1} (Table 100).

Capsicum grown under saline water irrigation

Effects on Na and K contents: Na^+ and K^+ ion content on dry weight (%DW) basis partitioning in shoot and root tissues of capsicum showed that Na content increased significantly while K content decreased with increase in salinity of irrigation water and further Na/K ratio increased with each increment in salinity of irrigation water. Na^+ and K^+ (% DW) content in shoot and root tissues of chilli showed that these ion concentrations differed significantly with saline water irrigation. Na^+ content increased while K^+ content decreased with salinity levels and Na^+/K^+ ratio increased with each increment in salinity of irrigation water . Na^+ (%DW) content in leaf, shoot and root tissues of tomato increased while K^+ content decreased with salinity levels and Na^+/K^+ ratio increased with each increment in salinity of irrigation water (Fig. 110). Results of second year experimentation were also found very promising and confirmed that these vegetables could be grown with saline water irrigation without much yield reduction under naturally ventilated protected structures with saline water irrigation.

Changes in soil salinity: After harvesting of vegetables, soil samples from three depths (0-15 cm, 15-30 cm and 30-45 cm) were collected and analyzed for EC_2 and pH_2 build-up under saline water irrigation in vegetables. It was found that in capsicum grown beds, soil

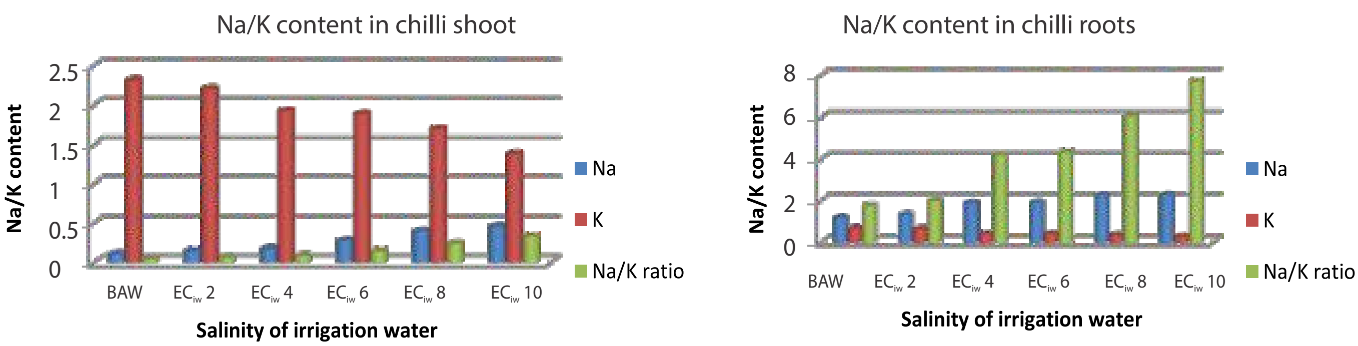


Fig. 110. Na^+ and K^+ partitioning in shoot and root tissues of Chilli

EC_2 gradually increased upto EC_{iw} 4 dS m^{-1} and thereafter, the increase was comparatively low. The highest EC_2 (2.88 dS m^{-1}) was observed with EC_{iw} 10 dS m^{-1} in 0-15 cm soil depth while it was comparatively less with increase in soil depth. No much variation in soil pH_2 was found with saline water irrigation. In case of chilli, soil EC_2 build-up was more than under capsicum beds and maximum EC_2 (2.93 dS m^{-1}) was observed with EC_{iw} 10 dS m^{-1} saline water irrigation in upper 0-15 cm soil depth. Soil pH_2 build-up was almost similar up to 10 dS m^{-1} in all depths under saline water though the highest pH_2 (8.55) was found in 0-15 cm soil depth. Build-up in soil EC_2 under tomato ranged between 0.24-2.55 dS m^{-1} in 0-15 cm soil depth and it was less with increased soil depth and pH_2 build-up was similar to that of capsicum and chilli. This shows salinity build-up was less under tomato in all depths as compared to capsicum and chilli crop.

Total soluble sugars (TSS) in tomato fruits was observed using Refractometer (Brix meter) and it was found that TSS ranged between 4.35-4.93 Brix under different salinity treatments. Highest TSS (4.93%) was observed with EC_{iw} 6 dS m^{-1} followed by 4.70 and 4.66% with EC_{iw} 8 and 10 dS m^{-1}, respectively.

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)

Salinity and sodicity are the serious problems in arid and semi-arid regions of the world affecting agricultural production. Decreased activities of micronutrients especially zinc (Zn) and iron (Fe) in salt-affected soils of north-western India due to high pH and EC result in their low availabilities. It is a major constraint for crop production. Hence, a field experiment at Nain Experimental Farm was conducted to understand the mechanism of distribution of Zn and Fe in different fractions as result of Zn and Fe application methods and different doses for pearl millet-mustard crop rotation to know their retention in soils and release to plants. There were 12 treatments replicated thrice 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 of pearl millet as well as mustard. Foliar sprays of respective nutrients were also applied with same chemicals 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 pearl-millet crop only. In case of mustard, same treatment without FYM was implemented.

Results indicated that combined application of 5 kg Zn+10 kg Fe +10 t FYM (T_9) significantly increased the water + exchangeable fraction of Zn (0.55 mg kg^{-1}) and Fe (1.85 mg kg^{-1}) that were 52.8% and 33.1% higher over control in soil (0-15 cm) at harvest of mustard crop. Among the treatments, T_9 significantly reduced the carbonate associated Zn and Fe by 16.1 and 22.9% than control, respectively. It might be due to dissolution of carbonate in the soil and thus decrease in CO_3-Zn/Fe in the soil. Whereas, a significant increase in the organic bound Zn (1.15 mg kg ha^{-1}) and Fe (19.6 mg kg^{-1}) was observed in the treatment which received 5 kg Zn+10 kg Fe+ 10 t FYM ha^{-1} (T_9) followed by T_8 than control (Table 101). Foliar application of Zn and Fe did not influence the distribution of Zn and Fe. Further, it was observed that treatment which received Zn (5.0-7.5 kg Zn ha^{-1}) and Fe (7.5.0-12.5 kg Fe ha^{-1}) through soil application of $ZnSO_4$ and $FeSO_4$ influenced mostly water soluble + exchangeable, organic bound and carbonated fractions of Zn and

Performance of pearl millet in straight soil application of 7.5.Zn kg ha[-1]

Performance of mustard in straight soil application of 7.5.Zn kg ha-1

Table 101: Distribution of Fe in different fractions (mg kg^{-1}) in post-harvest soil of mustard as influenced by rate and methods of Zn and Fe application

Treatment	Zinc Fractions (mg kg^{-1})			Iron Fractions (mg kg^{-1})		
	WSEx-Zn	CA-Zn	OM-Zn	WSEx- Fe	CA-Fe	OM-Fe
T1- Control	0.36	1.30	0.67	1.39	5.76	16.7
T2- 5 kg Zn ha^{-1}	0.40	1.39	0.76	1.41	5.92	17.3
T3- 6.25 kg Zn ha^{-1}	0.43	1.43	0.84	1.41	5.61	17.8
T4- 7.5 kg Zn ha^{-1}	0.47	1.46	0.91	1.43	5.44	17.9
T5- 7.5 kg Fe ha^{-1} 0.37	1.32	0.77	1.46	5.29	18.8	
T6- 10 kg Fe ha^{-1} 0.37	1.32	0.80	1.47	5.31	17.9	
T7- 12.5 kg Fe ha^{-1}	0.38	1.39	0.84	1.49	5.05	18.4
T8- 5 kg Zn+10 kg Fe ha^{-1}	0.46	1.36	0.92	1.49	5.12	18.5
T9- T8 +10 t FYM ha^{-1}	0.55	1.09	1.15	1.85	4.44	19.6
T10- 0.5% $ZnSO_4$ sprays twice	0.37	1.27	0.73	1.39	5.49	17.1
T11- 1.0% $FeSO_4$ sprays twice	0.37	1.26	0.72	1.40	5.28	17.3
T12- Combined sprays (T10+T11)	0.37	1.23	0.71	1.44	5.61	17.0
CD (P=0.05)	0.07	0.19	0.16	0.07	0.67	1.39

Note:Water soluble + Exchangeable (WSEx-Zn/Fe); (carbonate bound, CA-Zn/Fe); Organically bound (OM-Zn/Fe)

Fe as compared to oxide, residual and total. The four years pooled data also indicated that combined soil application of 5 kg Zn+10 kg Fe +10 t FYM significantly increased the pearl millet grain yield (36.6 q ha^{-1}) and mustard seed yield (22.7 q ha^{-1}) by 57.1% and 42.8% higher over control, however, yield improvement was 35.6 and 20.7 % due to application of 5 kg Zn+10 kg Fe without FYM, respectively, in pearl millet and mustard over control. On the basis of experiment results, it is concluded that combined soil application of Zn and Fe with FYM was effective in increasing the available Fe and Zn in soils by enhancing the pools of exchangeable and organic matter fractions of Zn and Fe through altering the physical and chemical characteristics of salt affected soils.

Development of salinity yield relations for different crops under micro-irrigation for updating water quality guidelines (R. K. Fagodiya, B. L. Meena, R.L. Meena, M. J. Kaledhonkar, D. S. Bundela and P. C. Sharma).

Groundwater is broadly classified for irrigation purpose into three broad categories namely, good, saline and alkali. In India, share of these waters is assessed at 20, 37 and 43%, respectively, in the total poor-quality groundwater. The limited availability of good quality water in semi-arid regions compels farmers to use such marginal and poor-quality waters. Generally, the effect of salinity/alkalinity stress on crop is directly proportionate to salinity/ alkalinity of irrigation water while inversely proportionate to tolerance level of plant. Keeping these things in mind, guidelines for using poor quality groundwater for irrigation purpose at national level were prepared and published during 1994 by CSSRI, Karnal. These guidelines were mainly applicable for surface irrigation methods which consider irrigation water quality, crop tolerance, soil texture and climate. In recent time, micro irrigation methods (drip and sprinkler) are being used for saline/alkali water application. Experimental data are also available for such experiments under different agro-climatic conditions. Therefore, there is scope to update the existing guidelines for irrigation water with respect to microirrigation. It is proposed to use available experimental data generated at AICRP on SAS&USW Centres. As first step, review of existing work was done and summary is provided below:

AICRP Centes	12
Centres working with poor quality waters	4 (Agra, Bikaner, Bapatla and Hisar)
Saline water experiments	31 (EC range 0.25-12 dS m^{-1})
Alkali water experiments	3 (RSC range 0.25-15 meq l^{-1})
Surface irrigation	12
Drip irrigation	24
Sprinkler	8
No. of crops	*22 (mostly vegetable crops)

*Tomato, Brinjal, Onion, chilli, radish, palak, cauliflower, bittergaurd, capsicum, okra, fenugreek, clusterbean, mothbean, cowpea, isabgol, fennel, tulsi, groundnut, mustard wheat, pearl millet and cotton

Assessment and mapping of salt affected soils of Raichur district of TBP command of Karnataka (Gangavathi)

Soil salinity and water logging are the twin problems of TBP command due to unscientific land and water management and neglect of recommended cropping pattern over the years. Majority of the reports vary in their estimates on the extent of soil salinity. A proper delineation of the area through intensive ground truth is thus imperative in arriving at a close approximation of salt affected area. No such delineation of salt affected soils in TBP command is available. With the aid of GPS and toposheet, soil samples were collected on a grid basis (9 x 9 km) from Sindhanur, Manvi, Devadurga and Raichur taluks in Raichur district during May, 2015. A total of 339 soil samples (0-15, 15-30, 30-60 and 60+ cm) from 53 grids (107 sampling points) were collected. Similarly, during May 2016 a total of 172 soil samples (0-15, 15-30, 30-60 and 60+ cm) from 27 grid points (52 sampling points) were collected from Bellary taluk in Bellary district.

In case of Raichur district, at surface soil (0-15 cm) $pH_{1:2.5}$, pHs, $EC_{1:2.5}$ and EC_e varied from 9.0 to 5.80, 8.49 to 4.86, 21.0 to 0.13 (dS m^{-1}) and 47 to 0.14 (dS m^{-1}), respectively with an average of 8.09, 7.56, 1.19, and 2.68, respectively (Table 102). Among cations, average Na content (390.1 meq L^{-1}) was more than Ca+Mg (9.54 meq L^{-1}) followed by K. In case of

Table 102: Characterization of soil samples collected from Raichur district, Karnataka for soil salinity appraisal.

Properties	Depth (cm)											
	0-15 cm			15-30 cm			30-60 cm			60+ cm		
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
$pH_{1:2.5}$	9.0	5.80	8.09	9.66	6.14	8.33	9.21	6.54	8.38	9.58	7.87	8.67
$EC_{1:2.5}$	21.0	0.13	1.19	12.5	0.11	1.08	6.90	0.24	1.32	5.40	0.30	1.26
pH_s	8.49	4.86	7.56	8.42	6.66	7.75	8.24	6.94	7.66	9.03	7.48	8.14
EC_e (dS m^{-1})	47.0	0.14	2.68	24.0	0.28	2.25	14.0	0.38	2.70	11.6	0.52	2.51
Cations/Anions (meq L^{-1})												
Ca+Mg	154.8	1.20	9.54	49.2	2.1	7.44	31.5	1.90	7.16	25.80	2.20	6.93
Na+	4400	7.83	390.1	110.9	1.39	15.11	117	1.80	17.9	123.9	3.48	22.2
K+	5.36	0.02	0.22	0.43	0.02	0.12	0.68	0.02	0.10	0.26	0.02	0.08
HCO_3^-	144.0	4.0	9.77	18.0	3.5	7.79	14.0	3.00	7.69	19.0	4.00	9.28
Cl^-	139.0	7.0	17.84	115.0	5.0	14.35	76.0	5.50	14.6	53.0	7.00	14.1
SO_4^{2-}	2.50	Tr	0.46	2.08	Tr	0.32	2.40	0.02	0.46	1.96	0.04	0.59
SAR	615.5	3.18	187.9	57.07	1.02	8.42	33.2	1.23	9.78	36.9	2.79	11.8
$(CO_3+HCO_3)/(Cl+SO_4)$	7.94	0.14	0.68	1.51	0.12	0.72	1.40	0.06	0.72	1.72	0.16	0.75
$Na/(Cl+SO_4)$	76.8	0.24	21.27	7.67	0.12	1.14	7.33	0.21	1.31	2.89	0.41	1.39

Note: Total number of samples was 107, 102, 71 and 43 at 0-15, 15-30, 30-60 and 60+ depth, respectively

Table 103: Percent distribution of soil samples collected from Raichur district, Karnataka for soil salinity appraisal

Soil Depth (Cm)	pH_s			ECe (dS m^{-1})			$(CO_3+HCO_3)/(Cl+SO_4)$		$Na/(Cl+SO_4)$		SAR	
	<7.5	7.5-8.5	>8.5	<2.0	2-4	>4	<1	>1	<1	>1	<13	>13
0-15	31.8 (34)	68.2 (73)	0	64.5 (69)	22.4 (24)	13.1 (14)	94.4 (101)	5.6 (6)	64.2 (68)	35.8 (39)	84.0 (89)	16.0 (18)
15-30	15.7 (16)	84.3 (86)	0	66.64 (68)	23.5 (24)	9.80 (10)	87.2 (89)	12.7 (13)	51.9 (53)	48.1 (49)	88.2 (90)	11.8 (12)
30-60	32.4 (23)	67.6 (48)	0	62.0 (44)	22.5 (16)	15.5 (11)	84.5 (60)	15.5 (11)	40.8 (29)	59.2 (42)	73.2 (52)	26.8 (19)
60+	2.33 (1)	97.7 (42)	0	48.8 (21)	34.9 (15)	16.3 (7)	79.1 (34)	20.9 (9)	46.5 (20)	53.5 (23)	65.1 (28)	34.9 (15)

Note: Total number of samples was 107, 102, 71 and 43 at 0-15, 15-30, 30-60 and 60+ depths respectively. Numbers in parenthesis indicate number of samples under each category.

anions, average Cl_- content was more (17.84 meq L^{-1}) than HCO_3^{1-} (9.77 meq L^{-1}) followed by SO_4^{2-}. Nearly 13% of surface samples had EC_e > 4.0 dS m^{-1} reflecting that these soils are saline. However, per cent of samples with >1 $(CO_3+HCO_3)/(Cl+SO_4)$ and $(Na/(Cl+SO_4)$ ratios were to the extent of nearly 6 and 36 respectively indicating that the soils could be sodic or developing into sodic. Accordingly, nearly 16% of surface samples had SAR >13 (Table 103).

Sub-surface (15-30 cm) soils had $pH_{1:2.5}$, pH_s, $EC_{1:2.5}$ and EC_e varying from 9.66 to 6.14, 8.42 to 6.66, 12.5 to 0.11 dS m^{-1}, and 24 to 0.28 dS m^{-1}, respectively, with an average of 8.33, 7.75, 1.08 dS m^{-1} and 2.25 dS m^{-1}, respectively. Similar to surface soils, average Na content (15.1 meq L^{-1}) was more than Ca+Mg (7.44 meq L^{-1}) followed by K. In case of anions, average Cl^- content was more (14.35 meq L^{-1}) than HCO_3^- (7.79 meq L^{-1}) followed by SO_4^{2-}. Nearly 10% of sub-surface (15-30 cm) soils samples were considered to be saline as EC_e of these samples was >4.0 dS m^{-1}. The overall mean of the $(CO_3+HCO_3)/(Cl+SO_4)$ and $Na/(Cl+SO_4)$ was less than 1. However, about 13 and 48% of these samples had values more than 1 indicating that these samples could be considered as salt affected soil in particular sodic or developing into sodic. About 12% of samples analyzed had SAR >13. Though a slight increase in soil pH was observed at 30-60 and 60+ cm depths compared to upper layers while not much variations were observed with respect to mean EC_e, Ca+Mg, K^+, Cl^-, HCO_3^-, $(CO_3+HCO_3)/(Cl+SO_4)$ and $Na/(Cl+SO_4)$ contents at 30-60 and 60+ cm depths. However, Na^+ and SAR values were higher than the corresponding 0-15 and 15-30 cm depths. As far as per cent distribution is considered, 30-60 and 60+ cm depths samples had higher percentage of EC_e (>4.0 dS m^{-1}), SAR (>13), and $(CO_3+HCO_3)/(Cl+SO_4)$ and $Na/(Cl+SO_4)$ >1 compared to respective 0-15 and 15-30 cm depths. The relationship between EC_e and $EC_{1:2.5}$ revealed that the conversion factor from $EC_{1:2.5}$ to EC_e (saturation paste extract) would be around 2.24 to 2.42 at 0-15 cm and 2.13 to 1.83 at 15-30 cm depths for soils of Sindhanur and Manvi taluks, respectively. For the district as a whole, the factor was 2.29 and 1.80 for surface and sub-surface soils, respectively.

Effect of sea water intrusion on ground water quality in coastal belt of Krishna Zone Andhra Pradesh (Bapatla)

The whole study area falls under three districts. A uniform strip of 50 km wide along the sea coast covering the three districts, *viz.,* Krishna, Guntur and Prakasam, was selected and four routes (Machilipatnam, Kanaparthy, Suryalanka and Nizampatnam) perpendicular to sea coast were identified. Ground water sampling was done from 120 points from this strip. The route wise pH, EC, RSC and SAR values for pre-monsoon and post monsoon period are given in Table 104 and Table 105.

Table 104: Route wise pH, EC, RSC and SAR values during pre monsoon period (Jun. 2016)

S. No.	Route	pH	EC (dS m^{-1})	RSC (me L^{-1})	SAR
1	Machilipatnam	7.1 to 8.3	1.00 to 5.10	0 to 13.60	2.56 to 19.15
2	Kanaparthi	7.0 to 8.0	0.50 to 4.60	0 to 10.40	1.21 to 22.68
3	Suryalanka	6.6 to 8.0	0.30 to 10.70	0 to 6.20	0.67 to 22.66
4	Nizampatnam	7.1 to 7.8	0.9 to 8.6	0 to 13.00	2.44 to 19.94

Table 105: Route wise ranges of pH and EC values during post monsoon period (Dec. 2016)

S. No.	Route	pH	EC (dS m^{-1})	RSC (me L^{-1})	SAR
1	Machilipatnam	6.9 to 7.6	0.40 to 5.40	0 to 4.40	1.72 to 13.30
2	Kanaparthi	6.7 to 7.8	0.50 to 4.20	0 to 8.20	1.25 to 25.11
3	Suryalanka	6.9 to 8.1	0.60 to 9.40	0 to 9.80	1.91 to 18.51
4	Nizampatnam	7.1 to 8.0	0.70 to 7.90	0 to 9.00	2.60 to 17.03

As per pre monsoon data, higher EC values were observed along Suryalanka route (0.30 to 10.70 dS m^{-1}) followed by Nizampatnam route (0.9 to 8.6 dS m^{-1}), Machilipatnam route (1.0 to 5.10 dS m^{-1}) and Kanaparthi route (0.50 to 4.60 dS m^{-1}). Data related to post-monsoon period indicated slight reduction in all the parameters studied compared to pre-monsoon period in majority of samples, except Machilipatnam. The ground water samples for pre and post monsoon periods were analyzed for different ions and ionic ratios and the following observations were made about sea water intrusion:

- Majority of the samples from the four routes showed a high $Cl^-/(CO_3^{2-} + HCO_3^-)$ of > 1, comprising of 87, 100, 100 and 90% of the samples from Machilipatnam, Kanaparthy, Suryalanka and Nizampatnam routes indicating seawater intrusion, while around 13, 6, 33 and 3% samples, respectively, were injuriously contaminated.
- Out of the samples collected from the four routes (Machilipatnam, Kanaparthy, Suryalanka and Nizampatnam), 50, 33, 40 and 77% of the samples showed a high Ca^{2+}/Mg^{2+}(>1) indicating seawater intrusion.
- On basis of Na^+/Cl^- (<0.86), 27, 33, 33 and 13% of the samples, respectively, from Machilipatnam, Kanaparthy, Suryalanka and Nizampatnam routes showed seawater intrusion.
- In general, sea water intrusion was observed up to a distance of 30 km from the sea. However, certain locations, there were variations in different ionic ratios indicating local effects of surface and ground water hydrology.

Survey and characterization of ground waters of Palwal district for irrigation purpose (Hisar)

The Palwal district forms the southern part of the Haryana state with a total geographical area of 136996 ha. The developmental blocks of Palwal district are Hathin, Hassanpur, Palwal and Hodal with a total of 282 villages. The climate of the study area is subtropical, semi-arid with hot dry summer and cold winter. The soils of the district represent a typical alluvial profile of Yamuna origin. According to USDA classification, the soils of the study area belong to sandy loam to silty loam textural classes. The dominating cropping system in this region is rice-wheat under surface irrigation (flooding and basin). Other main crops grown in the area are sorghum, bajra, sugarcane and cotton. A total of 317

Table 106: Range and mean of different water quality parameters for different blocks of Palwal district

Quality Parameter	Range	Mean	Range	Mean	Range	Mean	Range	Mean
	Hassanpur		Hathin		Hodal		Palwal	
pH	6.6 – 8.20	7.33	6.69 – 8.35	7.49	6.48 – 8.84	7.62	6.48 – 9.45	7.46
EC (dSm^{-1})	1.05 -5.66	2.45	0.77 -11.99	4.21	1.03 - 0.94	3.80	0.79 -10.55	3.05
RSC ($me\ l^{-1}$)	Nil – 5.90	0.63	Nil – 5.40	0.44	Nil – 4.70	0.87	Nil – 5.50	0.79
SAR ($mmol\ l^{-1})^{1/2}$	3.36 – 5.69	7.87	5.64 – 19.98	11.92	5.66-19.94	11.72	2.51 – 23.41	9.05
Ca_2+ ($me\ l^{-1}$)	0.70 – 4.50	2.02	0.30 – 8.40	2.88	0.50 – 7.70	2.49	0.60-7.20	2.33
Mg_2+ ($me\ l^{-1}$)	1.15 – 13.5	5.56	0.90 - 26.20	8.55	1.5 – 23.10	7.29	1.75 – 22.40	6.97
Na^+ ($me\ l^{-1}$)	5.65-40.10	15.84	5.23 -83.11	29.30	6.80-78.01	26.85	3.89-73.56	20.2
K^+ ($me\ l^{-1}$)	0.05 -0.62	0.15	0.04 -0.76	0.20	0.04- 2.80	0.33	0.04 -0.93	0.2
CO32– ($me\ l^{-1}$)	Nil – 5.40	1.78	0.20 – 4.80	1.78	0.35 – 4.80	1.90	Nil – 4.00	1.6
HCO_3^- ($me\ l^{-1}$)	0.5 - 7.20	3.25	1.30 - 7.20	3.83	1.4 – 6.90	3.72	Nil – 10.5	4.3
Cl^- ($me\ l^{-1}$)	4.50 – 48.50	15.19	3.00 – 96.80	31.63	4.9 - 98.60	26.29	4.10 – 82.10	20.9
SO_4^{2-} ($me\ l^{-1}$)	Nil – 16.66	2.48	0.03 - 13.5	3.24	0.10 – 21.38	4.63	0.29 – 11.5	2.9
NO_3^- ($me\ l^{-1}$)	Nil-1.37	0.45	Nil-1.21	0.50	Nil-1.06	0.53	Nil-1.06	0.3

water samples were collected from four blocks of Palwal district from running tube wells and their locations were recorded in the form of latitudes and longitudes angles by using hand held GPS. The samples were collected in thoroughly cleaned, properly labelled and carefully corked plastic bottles and brought to laboratory for chemical analysis. Samples were analyzed for various chemical parameter viz., pH, EC, cations (Na^+, Ca^{+2}, Mg^{+2} and K^+) and anions (CO_3^{-2}, HCO_3^-, Cl^- and SO_4^{-2}). Subsequently, SAR and RSC were calculated for these samples. The range and mean of different water quality parameters for these blocks are presented in Table 106.

The spatial distribution of EC and different groundwater quality categories in different blocks of Palwal were also worked out. The pH values ranged from 6.48 to 9.45 with mean as 7.48 while EC values ranged from 0.77-11.99 with mean as 3.36 dS m^{-1}. The average chemical composition of groundwater samples of electrical conductivity classes were grouped into 12 different classes with an interval of one unit. The distribution of sample in different EC classes is shown in Fig. 111. The highest percentage (31.8) was found in EC class of 1-2 dS m^{-1} and its lowest percentage (0.3) was found in EC class 11-12 dS m^{-1}. In EC range of 0-2 dS m^{-1}, there were 35.0% samples which is nearly an indication of good quality groundwater according to AICRP criteria on the basis EC only.

According to AICRP classification, it was found that 30.3% samples were of good quality, 55.2 saline and 14.5% alkali in nature. Out of the saline water, 22.4, 2.8 and 30.0% were in marginally saline, saline and high SAR saline categories, respectively. In alkali group, 3.5, 0.9 and 10.1% samples were in marginally alkali, alkali and high alkali groups, respectively. Out of seven categories of water, maximum 30.3% of the samples were found in good quality followed by marginally saline (22.4%) and minimum (0.9%) were found alkali. Although 30.3% samples were under good category, spatial variable map of block indicates less area under good quality. This is due to higher concentration of tubewells in that area and accordingly more samples were collected. Good category groundwater is mostly lying in Palwal and Hassanpur blocks of the district and highly scattered in other blocks. Area of the district having EC < 2 dS m^{-1} come under good quality category but among these area where SAR < 10 and RSC ≥ 2.5 fall under marginally alkali and alkali. On comparing spatial variable map of EC with water quality map (Fig. 111), most of the area where EC is more than 4 dS m^{-1} fall under high SAR saline

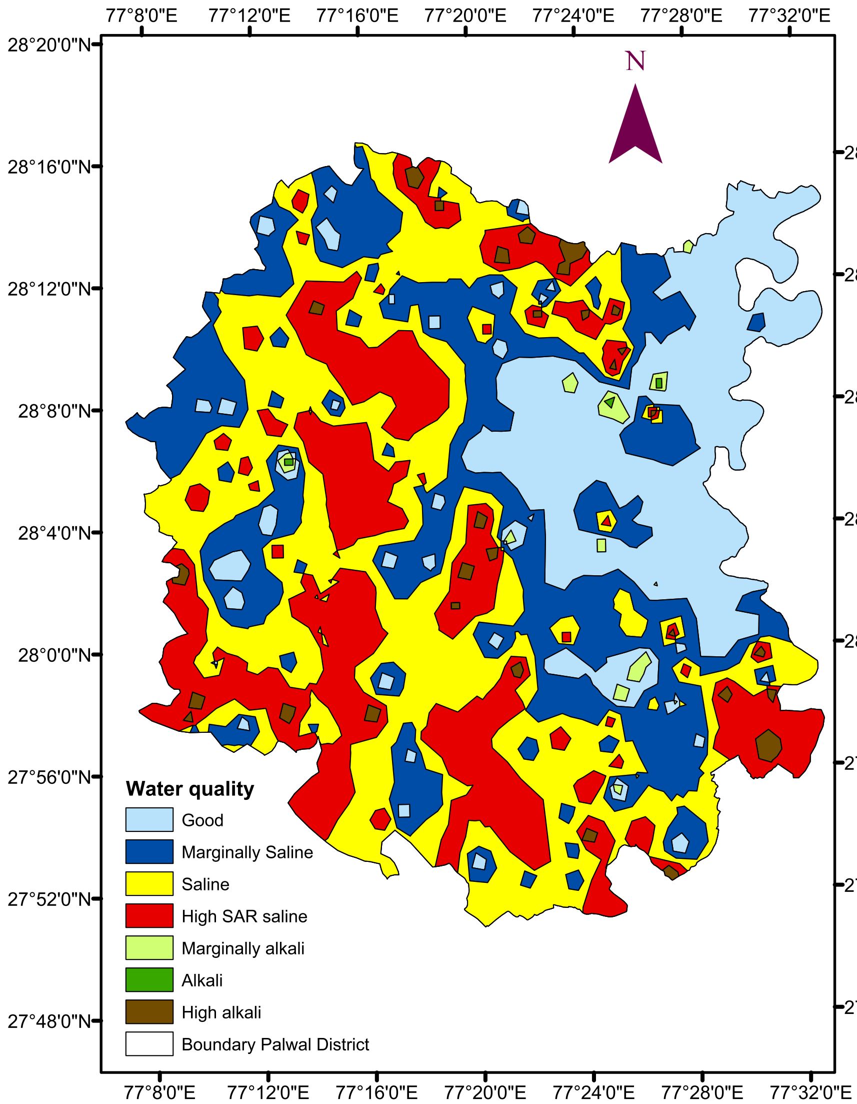


Fig. 111. Groundwater quality map for Palwal district according to AICRP criteria

in comparison to saline condition, whereas, in both condition EC is more than 4 dS m^{-1}. With this fact, area under high SAR saline has increased and area under saline condition reduced. There is a little problem of alkalinity in groundwater of the district because marginally alkali and alkali categories were observed very scattered with small polygons.

Survey, characterization and mapping of ground water quality in the coastal areas of Kerala (Vytilla)

Ernakulam district: The analytical data showed that pH values of water samples ranged from 6.54 to 7.74 while electrical conductivity (EC) values ranged from 0.05 to 49.0 dS m^{-1}. Carbonate and bicarbonate values were below detectable levels of 1.6 and 0.2 to 6.0 me L^{-1}, respectively. Chloride, sulfate, sodium, potassium, calcium and magnesium values of water samples ranged from 1.0 to 430.0, 0 to 16.91, 1.20 to 398.49, 0.09 to 4.22, 0.08 to 9.74 and 0.04 to 0.50 me L^{-1}, respectively. Boron values ranged from 0.01 to 0.67 ppm. Electrical conductivity and SAR of all water samples were in good category for irrigation purpose except the water samples from Malippuram, Kuzhuppilli, Poyapalli and Chirakkakam which are near the sea. The RSC of water samples collected from Fort Cochi, Munambam, Vadakkekara and Edappally is high. It is due to high bicarbonate content of water samples collected from these areas. Out of 29 samples, good samples were 86.90%, highly SAR saline were 11.95%, marginally alkali were 1.19% while both alkali and highly alkali were nil.

Alappuzha district: The analytical data showed that pH values of water samples ranged from 5.16 to 8.09 mostly belonging to strongly acidic to moderately alkaline categories. EC values ranged from 0.03 to 1.03 dS m^{-1}. Potassium content of water samples ranged from 0.03 to 0.56 me L^{-1}. Carbonate and bicarbonate values ranged from 0 to 2.8 and 0.8 to 5.2 me L^{-1}, respectively. Chloride values ranged from 1.0 to 10.0 me L^{-1}. Nitrate values ranged from 0.1 to 15.4 me L^{-1}. Calcium and magnesium contents ranged from 0 to 5.61 and 0.02 to 90.88 me L^{-1}, respectively. Iron and zinc contents ranged from 0 to 0.65 and 0 to 0.74 ppm, respectively. Sulphur, copper and manganese contents were not in the detectable level. Mg/Ca ratio ranged from 0.02 to 59.54. The highest value of SAR is 4.36 and lowest value is 0.25. RSC of water samples ranged from -91.21 to 4.54 me L^{-1}. EC and SAR of ground water samples of Alappuzha district are in safe category. RSC of ground water samples collected from places *viz.*,Valavanad, Thuravur, Eramallur and Aroor of Alappuzha district was in marginally alkali category (2.38% samples) for irrigation and samples of Cherthala, Kalavamkodam and Pattanakkad belonged to alkali category (1.78% samples). Only these two categories were found and rest 95.83% belonged to good category.

Thrissur district: Survey of Thrissur district was completed by collecting 33 ground water samples from the coastal areas of the district. The analytical data showed that pH values of water samples ranged from neutral (7.13) to moderately alkaline (8.15) while EC

Table 107: Effect of saline water, drip geometry and irrigations on pod yield and straw yield of groundnut

Particular	Pod yield (q ha^{-1})				Straw yield (q ha^{-1})			
	2014	2015	2016	Pooled	2014	2015	2016	Pooled
EC_{iw}								
BAW	35.34	26.00	33.42	31.58	56.02	45.33	55.35	52.23
4 dS m^{-1}	34.19	25.33	33.41	30.98	58.47	43.78	54.27	52.17
8 dS m^{-1}	10.39	8.34	17.54	12.09	46.65	23.31	31.47	33.81
12 dS m^{-1}	7.69	5.59	6.75	6.67	37.19	17.45	10.33	21.66
S.Em.±	0.63	0.25	0.69	0.33	3.93	0.61	0.95	1.38
C.D. (0.05)	1.86	0.73	2.02	0.93	11.57	1.81	2.78	3.89
Drip Geometry								
60 x 30	24.18	18.95	25.81	22.98	54.44	36.21	42.45	44.36
90 x 30	19.62	13.68	19.75	17.68	44.72	28.73	33.26	35.57
S.Em.±	0.45	0.17	0.48	0.23	2.78	0.43	0.67	0.97
C.D. (0.05)	1.32	0.51	1.43	0.66	8.18	1.28	1.97	2.75
PE								
0.6V	16.70	12.48	19.01	16.06	35.07	24.53	30.80	30.13
0.8V	24.36	18.03	24.18	22.19	54.04	35.88	41.00	43.64
1 V	24.64	18.43	25.15	22.74	59.64	36.99	41.76	46.13
S.Em.±	0.40	0.27	0.36	0.20	2.16	0.62	1.49	0.89
C.D. (0.05)	1.15	0.77	1.02	0.55	6.15	1.76	4.24	2.50

values ranged from 0.04 to 3.4 dS m^{-1}. Potassium content of water samples ranged from 0.48 to 6.96 me L^{-1}. Carbonate and bicarbonate values ranged from 0.2 to 1.4 and 0.2 to 1.4 me L^{-1}, respectively. Chloride values ranged from 1.0 to 443 me L^{-1}. Sodium values ranged from 0.21 to 261.1 me L^{-1}. Calcium and magnesium content ranged from 0.09 to 16.03 and 0.03 to 0.62 me L^{-1}, respectively. Iron and zinc content ranged from 0.03 to 0.62 and 0.02 to 0.23 ppm, respectively. Sulphur content ranged from 0 to 19.51 me L^{-1}. Copper and manganese contents were found in lowest range with 0 to 0.043 and 0.02 to 0.23 ppm, respectively. Mg/Ca ratio ranged from 0.02 to 0.8. The highest value of SAR is 91.33 and lowest value is 0.7. RSC of water samples ranged from -14.56 to 1.51 me L^{-1}. The electrical conductivity for all samples except in Poyya 2 and Enanmavu 1 are in good category. The samples belonging to Poyya 2 and Enanmavu 1 belong to highly SAR saline category (4.04%). This may be due to sea water intrusion. Remaining samples belonged to good category (95.95%)

Optimization of water requirement of groundnut-wheat cropping sequence using saline water under drip irrigation (Bikaner)

An experiment was initiated at Bikaner centre to optimize water requirement of groundnut-wheat cropping sequence using saline water under drip irrigation. The treatments comprised of four levels of EC_{iw} (BAW, 4 dS m^{-1}, 8 dS m^{-1} and 12 dS m^{-1}), two drip geometries (60 cm x 30 cm and 90 x 30 cm) and 3 levels of water requirement (0.6, 0.8 and 1.0 PE). Results of *rabi* component could not be included due to failure of crop during 2014-15 and 2015-16. Pooled analysis of groundnut data indicated that different treatments had significant effect on pod yield of groundnut. Increase in EC_{iw} beyond 4 dS m^{-1} caused significant reduction in pod yield. As compared to BAW, EC_{iw} of 8 dS m^{-1} and 12 dS m^{-1} caused significant reductions of 61.7 and 78.9%, respectively. Drip laterals spaced at 60 cm resulted in 30.0% higher pod yield as compared to laterals spaced at 90 cm. In so far as water requirement is concerned, in comparison to 1.0 PE and 0.8 PE, volume 0.6 PE showed significant reduction of 29.4 and 27.6%, respectively, in pod yield. Volume 1.0 PE and 0.8 PE, however, did not differ significantly to each other in this respect. Similar trend was noticed in respect of straw yield (Table 107).

Combined effects of treatments on pod yield were also found significant (Table 108). Salinity of irrigation water beyond 4 dS m^{-1} significantly decreased the pod yield under both the drip geometries *i.e*. 60 cm x 30 cm and 90 cm x 30 cm. Under both the drip geometries tried, 0.6 PE resulted in significant reduction in pod yield as compared to 1.0 and 0.8 PE. It was also noted that when EC_{iw} increased from BAW to 4 dS m^{-1}, difference in yield was not significant, further increase in ECiw caused significant reduction in pod yield at all the levels of PE.

Table 108: Combined effect of treatments (drip geometry x ECiw) on pod yield (q ha^{-1}) (pooled)

Drip geometry	EC_{iw} levels			
	BAW	4 dS m^{-1}	8 dS m^{-1}	12 dS m^{-1}
60 x 30 cm	36.04	34.98	13.18	7.72
90 x 30cm	27.13	26.97	11.00	5.62
S.Em.±	0.46			
C.D.	1.31			

Response of cotton to drip irrigation in saline soils under conservation agricultural practices (Gangavathi)

The experiment was initiated during *Kharif* 2013 and continued in *Kharif* 2016 on response of cotton to fertigation in saline soils under conservation agriculture practices at Agricultural Research Station, Gangavati. The initial soil salinity of the experimental plot ranged from 5.3 to 7.0 dS m^{-1} and 5.27 to 9.24 dS m^{-1} at 0-15 and 15-30 cm depth, respectively, and initial pH of the block ranged from 8.38 to 8.62 and 8.15 to 8.44 at 0-15 and 15-30 cm depth, respectively. From the eight observation wells, the water table depths of different treatment were monitored. Bt Cotton verity Ajit was sown in paired row (0.60 x 1.20x 0.60 m) system with 0.6 m plant to plant distance. The 4 LPH emitters were punched for every two plants on 12 mm lateral and soluble fertilizers were supplied with venturi though drippers. Soil was saline but irrigation water quality was good. The recommended dose of fertilizers for cotton (100%) is 120:60:60. Main treatments were : i) With mulch (Paddy Straw) and ii) without mulch while sub-treatments were : a) 50% Recommended dose of fertilizer, b) 75% Recommended dose of fertilizer; c) 100% Recommended dose of fertilizer; and d) 125% Recommended dose of fertilizer. Details of the experiment (2016-17) were as below (Table 109).

Table 109: Combined effect of treatments (drip geometry x EC_{iw}) on pod yield (q ha^{-1}) (pooled)

SN	Item	Details	SN	Item	Details
1	Crop	Bt.Cotton	9	Residue	Paddy straw @ 6.85 t/ha
2	Variety/Hybrid	Ajit	10	Date of sowing	15.07.2016
3	Number of treatments	8	11	Sowing method	Paired row
4	Number of replications	3	12	Row spacing	0.6 x 1.2 x 0.6 m
5	Design	Split plot	13	Plant spacing	60 cm
6	Plot size	6m x 6m	14	Dripper discharge	4 lph
7	Treatment size	10.2m x 10 m	15	Dripper spacing	0.6 m
8	Fertilizer	120:60:60 kg NPK ha-1 RDF	16	Plants per dripper	2

The soil moisture content on dry weight basis at mid season and at harvest of cotton at different depth (0-15 and 15-30 cm) revealed that significantly higher soil moisture was retained in mulch compared to no mulch treatments. Among fertilizer level, there was no significant difference was observed. Data on vegetative parameter such as germination percentage, plant height, number of monopodial and sympodial branches, bolls per plant and boll weight are given in Table 110. There was no significant difference between mulch and no mulch treatment and also in fertilizer level treatments with respect to germination percentage. In general, nearly 92% germination was observed in all the plots. Significant difference in plant height was observed under without mulch (121.5 cm) and with mulch (125.6 cm) treatments. Similarly, in case of fertilizer levels, significantly higher plant height (125.8 cm) was observed in 125% RDF compared with 50 % RDF (120.0 cm). No significant difference in monopodial branches per plant was observed either due to mulch, fertilizer levels or interaction. Significantly higher sympodial branches were observed in mulch treatment as compared to no mulch treatment. In case of fertilizer levels, significantly more sympodial branches were observed in 125% RDF level treatments as compared to furrow irrigated treatment (Table 110).

Table 110: Growth attributes of cotton as influenced by different fertigation level and conservation practices.

Treatments		Germination %	Plant height (cm)	Monopodial branches	Sympodial branches	Bolls plant^{-1}	Boll weight (g boll^{-1})
Conservation Practice (CA)	Without	92.50	121.5	3.3	29.2	30.0	5.31
	With mulch	94.4	125.6	3.6	31.4	33.2	5.74
	SE m +/-	0.65	0.4	0.1	0.3	0.8	0.05
	CD (0.05)	NS	1.6	NS	1.3	2.7	0.32
Fertilizer level (FL)	50 % RDF	92.40	120.0	3.2	28.3	29.3	5.03
	75 % RDF	93.60	123.8	3.3	30.0	31.3	5.53
	100 % RDF	94.60	124.0	3.8	31.3	32.0	5.54
	125 % RDF	93.10	125.8	3.7	31.8	34.0	6.00
	SE m +/-	0.91	1.6	0.3	0.8	1.1	0.21
	CD (0.05)	NS	3.5	NS	1.7	2.4	0.54
Interaction (CA x FL)	SE m +/-	1.30	2.3	0.4	1.1	1.6	0.30
	CD (0.05)	NS	NS	NS	NS	NS	NS

Table 111: Seed cotton yield as influenced by different fertigation levels and mulching

Fertilizer level	Cotton Yield (q ha^{-1})		
	Without mulch	With mulch	Mean
	M1	M2	
S1	22.5	25.8	24.13
S2	22.7	28.0	25.37
S3	23.7	28.3	26.00
S4	25.3	29.3	27.30
Mean	23.5	27.9	
	SE m +	CD (0.05)	
M	0.2	1.0	
S	0.9	2.1	
M x S	1.3	NS	

It was recorded that, among mulch and no mulch treatments, significantly more numbers of bolls per plant and higher single boll weight was obtained in case of mulch treatment (33.2 and 5.74 g boll^{-1}), respectively. In case of fertilizer level treatments, more number of bolls per plant was recorded in 125% RDF level (34.0 and 6.0 g/boll) which was on par with 100% RDF (32.0 and 5.54 g boll^{-1}), followed by 75% RDF (31.3 and 5.53 g boll^{-1}) and least in case of 50% RDF (29.3 and 5.03 g boll^{-1}) treatment, respectively. Seed cotton yield was significantly higher in 125% RDF (27.3 q ha^{-1}) compared to 50% RDF (24.13 q ha^{-1}) but was on par with 75 % (25.37 q ha^{-1}) and 100% RDF (26.0 q ha^{-1}). In case of conservation practices, significantly higher seed cotton yield was recorded in mulch treatment (27.9 q ha^{-1}) compared to no mulch treatments (23.5 q ha^{-1}) (Table 111). The interaction effects between main and sub plots were non-significant. This experiment was concluded.

Technology Assessed and Transfered

Subsurface Drainage Technology for Restoring the Productivity of Watrelogged Saline Soils

Haryana: Twelve subsurface drainage (SSD) projects out of 15 projects installed in Haryana covering 8,178 ha waterlogged saline lands and 5,918 beneficiary farmers in 8 districts were studied for operational performance. Site surveys of 12 projects in Sonipat, Jind, Rohtak, Charkhi Dadri, Bhiwani, Fatehabad, Sirsa and Palwal districts were carried out to assess the conditions of pump sets, pump houses, manholes, and sump wells and link/open drains. The inputs from beneficiary farmers and project authority on pump operating hours of SSD systems and functioning of farmers' drainage societies (FDS) were collected. Results showed that on an average only 47% pump houses out of 185 were constructed, 90% diesel pump sets were delivered to beneficiary farmers, 75% diesel fuels were distributed to farmers, and 48% drainage blocks were handed over to the registered societies. In Sonipat SSD project, 100% implementation tasks were achieved whereas in Charkhi Dadri project, zero percent achievement on delivery of pump sets, diesel fuel and handover to drainage blocks to societies was made. Farmers' drainage societies which were registered at the time of implementation could sustain till end of the project period and became non-functional during post-project period.

Based on project operational ranking, three SSD projects with the first, fourth and eleventh ranks at Jagsi (Sonipat), Mokhra Kheri (Rohtak-I) and Siwana Mal (Jind) were intensively studied for improvement in soil salinity and crop performance and suitable interventions for further improving the project impact. Jagsi site with 10 drainage blocks (430 ha), Siwana Mal site with 7 blocks (295 ha) and Mokhra Kheri site with 13 blocks (600 ha) implemented in May 2009, June 2012 and June 2012, respectively, were monitored for reduction in soil salinity and improved crop performance using the multi-date Landsat ETM + and OLI imageries for pre- and post-project periods. From pre-project Landsat imagery of 12 February 2007, 63-80% area in 10 drainage blocks at Jagsi site was affected by moderate soil salinity (EC_e >8 dS m^{-1}). In post-project period, soil salinity was reduced to 26% of the area on 4 April 2011 imagery and disappeared completely from Landsat imagery of 28 May 2014 and 22 February 2016. This is mainly attributed to adequate pumping of SSD systems by progressive farmers for achieving full reclamative leaching. Drainage water was also reused for irrigation of both rice and wheat crops in the project area. Rice and wheat yields ranged from 3.50-4.20 and 4.90-5.64 t ha^{-1}, respectively, at Jagsi site during *Kharif* 2017 and *Rabi* 2016-17. In Siwana Mal and Mokhra Kheri sites, small patches of soil salinity were still found from the satellite data during post-project period due to late distribution of diesel pump sets and diesel fuel and sporadic response of farmers on pumping operation. The significant improvements in four blocks each in both project sites (JD-1, 2, 5 and 6, and RK-8, 9 10 and 11) were observed from field surveys. Rice and wheat yields from improved blocks of Siwana Mal site ranged from 2.15-3.50 and 3.55-4.54 t ha^{-1}, respectively, during 2017-18 whereas the yields of rice and wheat from improved blocks of Mokhra Kheri site ranged from 2.10-3.10 and 3.15-4.40 t ha^{-1}, respectively.

Installation of SSD system and bumper paddy crop during post SSD project at village Jagsi (Sonipat)

Karnataka: The impact assessment of SSD technology was carried out at project area of village Ugar Budruk in Athani Taluk of Belgaum District of Karnataka where SSD systems were installed between 2009-10 to 2012-13 covering about 925 ha area and 644 farmers. Cost of saline land reclamation through SSD installation was estimated at Rs. 52,000 ha^{-1}.

Table 112: Economics of sugarcane cultivation with and without SSD

Particulars	With SSD	Without SSD	Per cent change
Yield (t ha^{-1})	105	72	45.83
Gross Returns (Rs ha^{-1})	241500	164749	46.59
Cost of cultivation (Rs ha^{-1})	178813	157961	13.20
Net Returns (Rs ha^{-1})	62687	6788	823.50
Cost of production (Rs t^{-1})	1704	2217	-23.14
Benefit-Cost Ratio	1.35	1.04	29.81

Findings revealed that cropping intensity increased from 63% during pre-SSD to 78% during post-SSD period. Overall increase in cropping intensity was about 24% due to SSD installation showing a positive impact of drainage technology on reclamation of saline soils. Soil and drain water salinity in the project area varied across 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 during pre-SSD was 6.6 dS m^{-1} which reduced to 2.6 dS m^{-1} in post-SSD phase. Nearly, 76% of the soils sampled were non-saline, 15% slightly saline and 9% moderately saline during the post-SSD period. The impact study made comparison between with and without SSD situations. It revealed that the yield advantage was about 46.0% higher in SSD area compared to without SSD (Table 112). For sugarcane crop, gross returns were 46.6% higher in SSD with 13.20% higher cost of production. The increase in cost may be attributed to better performance of crops after reclamation prompting farmers to apply more fertilizer, pesticides and irrigation water. The higher benefit-cost ratio (1.35) was obtained with SSD compared to without SSD (1.04). The increase in net income and B: C ratio was largely related to the increase in crop yield with the intervention of SSD. Cost of production was lower (Rs. 1704 t^{-1}) with SSD in comparison to without SSD (Rs. 2217 t^{-1}). Increase in yield due to land reclamation led to lower cost of production in SSD area indicating the worth of SSD technology for reclaiming waterlogged saline soils. Post-reclamation study also revealed a gradual shift from other crops to sugarcane cultivation. Cropping intensity increased by 24% within a short span of 3 years of SSD installation.

Field with subsurface drainage, Village Ugar Budruk (Belgaum, Karnataka)

Table 113: Benefit-Cost Ratio of adopters and non-adopters of CSR BIO in Southern India

Crop	Non-adopters	Adopters	Change
Banana	1.18	1.28	0.10
Paddy	1.42	1.50	0.08
Red gram	1.03	1.28	0.25
Sugarcane	1.73	1.89	0.16
Turmeric	1.26	1.34	0.07
Ixora	3.90	4.21	0.31

'CSR-Bio' Technology for improving Crop Yields in Sodic Soils: CSR-BIO is an eco-friendly bio-growth enhancer consisting of a consortia of microbes *viz*., CSR-B-2 (*Bacillus pumilus*), CSR-M-16 (*Bacillus licheniformis*) and CSR-T-1 (*Trichoderma harzianum*) cultured on dynamic ecofriendly media. It acts as a nutrient mobilizer, soil conditioner, plant protectant against soil born diseases and growth enhancer for crops grown in normal and alkali soils. Impact assessment study revealed significant differences in crop yields for CSR BIO adopters and non-adopters. The highest yield difference was noted for ixora (12.83%) followed by red gram (11.43%) and banana (10.26%). Due to increased crop yields and quality, CSR BIO adopters obtained higher net returns than non-adopters. Among the crops grown with the application of CSR BIO, banana showed maximum net return (Rs. 51035 ha^{-1}) followed by ixora (Rs. 46678 ha^{-1}) and red gram (Rs. 26656 ha^{-1}). Similarly, B: C ratio was the highest (4.21) in ixora followed by sugarcane (1.89), paddy (1.50), turmeric (1.34), banana (1.28) and red gram (1.28) (Table 113). CSR-BIO is economically viable and helps augment crop yields by 6-13% in sodic and normal soils. Change in net returns due to CSR-BIO ranges between Rs. 7449 (paddy) to Rs. 51035 (banana). It also has a favorable impact on product quality. Uncertainty in availability of required quantity (47%) and non-availability (12-38%) of CSR-BIO products are the major hurdles coming in the adoption of CSR-BIO suggesting the need to improve the availability of CSR-BIO in the market through the input retailers.

Participatory Sodic Soil Reclamation Turns the Fortunes of Farmers in Central Indo-Gangetic Plains: Sodicity induced land degradation continues to be a threat to the livelihoods of small and marginal farmers in 2.8 million ha are of Indo-Gangetic plains. Santaraha village in Hardoi district of Uttar Pradesh was selected for farmer participatory sodic soil reclamation programme by ICAR-CSSRI RRS, Lucknow. Majority of the farmers belonged to marginal category having average land holding of 0.62 ha with crop production contributing 68% of the total household income in the area. After collecting all the basic information, the reclamation process started April, 2011. Proper reclamation protocol was followed. On-farm development works like bunding, field drains, irrigation channels, leveling and construction of link drain were initiated. To ensure water availability for leaching of salts as well as irrigating crops, one tube well was established at each 4.0 ha land stretch. Soil analysis results revealed that pH ranged 8.5 to 10.1 and the gypsum requirement (GR) from 8.2 to 14.8 t ha^{-1}. Gypsum was provided to the farmers @ 25% of estimated GR value. Gypsum was mixed uniformly in the top soil (0-15cm) in June, 2012. After gypsum mixing, fields were ponded with 10 cm water for about 10 days to displace the reaction product of Ca-Na exchange down to the root zone. After proper leaching of salts, pressmud collected from sugar mill containing S (0.23%), Ca (11%), Mg (1.65%), total C (26%), total N (1.33%), total P (1.08%) and total K (0.53%) was broadcasted uniformly (10 t ha^{-1}) and mixed into the top soil. During the whole process, all the initial pre-reclamation activities were managed by the farmers on their own cost while technical help and seed of salt tolerant rice variety 'CSR 36' were provided by the ICAR-CSSRI RRS, Lucknow. After three years of reclamation, all the previously barren lands were put under cultivation. After reclamation, the yield loss compared to the normal soils reduced drastically. Wheat yield loss during pre-reclamation in slightly sodic and moderately sodic soils was 22.74 and 61.09%, respectively, whereas in sodic and severely sodic soils there was no crop. After post reclamation, yield loss in slightly sodic, moderately sodic, sodic and severely sodic soils reduced to the levels of 10.87, 21.84, 34.21 and 50.92% compared to the normal soils. Technical guidance is still being provided to the beneficiary farmers for sustained yields. Results of this study showed that dissemination of improved technologies to the farmers' fields can make substantial improvements in crop yields and incomes.

Improving farm productivity through sustainable use of alkali waters at farmer's field: The 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 as gypsum and pressmud used either individually or in combination for sustained use of sodic waters in sodicity affected soils. Three year mean yield data indicated that yield decreased by 16% in both rice and wheat crops with the increase in RSC_{iw} from 5 meq L^{-1} (site I) to 7 meq L^{-1} (site II). Among rice varieties, salt tolerant Basmati CSR 30 performed relatively better compared to Pusa 1121 with yield reduction of 13.7% compared to 17.9% in Pusa 1121. Similarly, salt tolerant wheat variety KRL 210 suffered lesser yield reduction (13.5%) ascribed to its better physiological adaptation to salt stress compared to HD 2967. Regardless of the neutralization treatment, yield superiority in Pusa 1121 of 15.5% at site II (RSC ~5 meq L^{-1}) reduced to 8.6% at site I (RSC ~7 meq L^{-1}) in comparison to Basmati CSR 30. In contrast, yield superiority of KRL 210 further enhanced from 10.8% (Site II) to 14.7% (Site I) with the increase in residual alkalinity in irrigation waters. Varietal intervention through inclusion of salt tolerant varieties KRL 210 and Basmati CSR 30 basmati can be an important strategy to overcome yield reduction under stress conditions. Neutralization of RSC water through amendments (gypsum/pressmud) either individually or in combination resulted in 12.7-19.2% (mean 16.3%) higher system productivity (WEY). The overall yield increment due to neutralization treatments (irrespective of amendment used) in comparison to irrigated waters used without neutralization was higher (16.0%) at site I (RSC~7 meq L^{-1}) compared to 14.7% at site II (RSC~5 meq L^{-1}) indicating relatively better performance of neutralization ameliorants (Table 114).

Table 114: Interactive effect of RSCiw neutralization treatments and crop varieties on system productivity in RWCS (mean data of 2 locations and 3 years crop rotation)

Cropping sequence		System productivity (Wheat equivalent yield in kg ha^{-1})			
		RSC water	Gypsum	Gypsum + Press mud	Gypsum
Basmati CSR 30	HD 2967	7.78	8.79	9.10	9.24
	KRL 210	8.09 (+4.0%)	9.18	9.59	9.73
Pusa 1121	HD 2967	7456	8.36	8.60	8.82
	KRL 210	7.84 (+5.1%)	8.82	9.14	9.34
Mean		7.79	8.78 (+12.7%)	9.11 (+16.8%)	9.29 (+19.2%)

System productivity (3 yrs mean) calculated on the actual price received by the farmer

CSR 36 in Pattijunia (Patiala) in sodic soils with high RSC water

KRL 210 in Budhmor (Patiala) in sodic soils with high RSC water

Technological interventions to improve crop productivity in sodicity affected areas in Punjab: ICAR-CSSRI, Karnal has been assisting the farmers of Patiala district of Punjab since 2009 to restore the productivity of their sodicity affected lands. Steadily rising alkali groundwater and the accompanying land degradation had a detrimental effect on crops as evidenced by moderate (30-40%) yield losses in rice and wheat. A multidisciplinary team of ICAR-CSSRI scientists after investigating the problem suggested the farmers (n=35) to adopt improved practices such as laser leveling, gypsum treatment of sodic soils and sodic irrigation water and adoption of salt tolerant cultivars to sustain crop yields in heavy textured soils having high soil pH_2 (up to 9.5), moderate salinity (EC_2 ~0.9 dS m^{-1}) and high RSC in groundwater (3.5-4.0 meq L^{-1}). Soils were also found to be deficient in organic carbon, available N and P. Due to these efforts, 60% of the selected farmers started applying gypsum, 40 % adopted leser leveling, 15 % tested chiseling and 5 % adopted gypsum-bed technology for neutralizing RSC in irrigation water. Average rice yield was 4.4 t ha^{-1} in salt tolerant cultivar CSR 36 compared to 4.0 t ha^{-1} in Pusa-44 under similar conditions. Gypsum application, either in soil or through irrigation water, also considerably improved Basmati CSR 30 yields enabling the farmers to harvest ≈2.1 t ha^{-1} grain yield since 2010.

Subsequent to astonishing success in rice crop, efforts were also started to enhance wheat yields under similar conditions. In this area, farmers grew wheat variety PBW-343 during 2008-2012 and obtained average yields of 3.8 t ha^{-1}. During 2013-2017, several farmers started cultivating HD 2967 which gave relatively higher average yields of 4.4 t ha^{-1}. In the mean time, in 2015, salt tolerant wheat cultivar KRL 210 was demonstrated on selected farmers' fields where it outperformed both PBW-343 and HD 2967. The mean grain yield of KRL 210 (4.9 t ha^{-1}) was ≈29% and 10.0% higher compared to PBW 343 and HD 2967, respectively, under identical levels of soil pH and irrigation water RSC. A strong majority of the studied farmers (85%) informed that lack of government subsidy was the major hindrance to the adoption of gypsum-bed technology which involves one-time lump sum investment of ≈Rs. 35,000 $unit^{-1}$ for constructing the specialized chambers. As a consequence, though aware of potential benefits, most of the small and medium farmers are unable to adopt this technology. Experiences gained during participatory trials with the farmers of Patiala district suggests that a single technology may not provide desired benefits in areas grappling with multiple stressors including soil sodicity, poor fertility, high RSC in irrigation water and climate variability. The need of hour is to ensure integrated adoption of two or more proven technologies for harnessing the productivity of salt-affected lands in the study area.

Front line Demonstrations of salt tolerance varieties

A total of 30 demonstrations were conducted for comparing the efficiency of pre-emergence application of pendimethalin @ 2 l ha^{-1} followed by post-emergence application of recommended herbicide (clodinafop/pinoxaden) (IP) compared to farmers practices (FP). Pre-emergence pendimethalin application followed by post-emergence application of clodinafop/pinoxaden resulted in better weed control efficiency at 30-35 DAS and 115-120 DAS in comparison to farmer's practice. Improved practice resulted in 4.13 t ha^{-1} mean wheat yield than 3.89 t ha^{-1} in farmers' practice. Considering the rapidly declining fresh groundwater in the study area due to excessive pumping, a total of six recharge structures- 2 with radial type filtration and 4 with

Table 115: FLDs on KRL 210 in sodic soils of Begampur village (district Karnal)

Sr. No.	Farmer name	Village	pH_2 (0-15 cm)	pH_2 (15-30 cm)	EC_2	Yield (t ha^{-1})
1	Sunita	Begampur	9.04	9.31	0.21-0.15	4.25
2	Anita	Begampur	9.12	8.98	0.18-0.16	4.00
3	Krishna	Begampur	9.08	9.12	0.14-0.14	4.00
4	Bimla	Begampur	8.89	8.93	0.15-0.18	4.80
5	Sheela	Begampur	9.01	9.25	0.15-0.30	4.13
6	Nirmla	Begampur	8.81	8.98	0.15-0.13	5.00
7	Sunita	Begampur	9.23	9.58	0.22-0.29	4.80
8	Nisha	Begampur	8.72	9.41	1.30-1.89	5.00
9	Urmila	Begampur	9.00	9.12	0.22-0.31	4.80
10	Shymo	Begampur	9.17	9.34	0.28-0.16	4.63
		Mean yield	9.01	9.20	--	4.54

integrate filtration unit- were also installed in the adopted villages for augmenting ground water, improving quality (reduction in salinity and residual alkalinity) and saving crops through recharge of excess run-off water. Periodic monitoring indicated rise in water table beneath the recharge structure and improvement in ground water quality as evidenced by reduction in RSC.

This year, the FLDs on salt tolerant wheat variety was conducted in sodic soils owned by women. The emphasis was given to provide opportunity to the women farmer for leading the CSSRI technology and making them more empowered with various interventions including salt tolerant wheat variety and agroadvisory services (e.g. soil health cards and location specific cropping system management such as crop residue incorporation, inclusion of chickpea and muskmelon). A total of 10 FLDs on KRL 210 was conducted. The soils where these FLDs were conducted had pH_2 varied between 8.72 to 9.23 in the depth of 0-15 cm, while pH_2 for depth 15-30 cm of soils varied between 8.98 to 9.41. The yield of KRL 210 was recorded to be between 4.0 to 5.0 t ha^{-1} with average yield 4.54 t ha^{-1}. Farmers observation indicated that delayed sowing of seed (by about 20 days) due to smoggy weather in last week of October to first week of November (2017), abrupt changes in weather (temperature) and individual management practices have affected yield of KRL 210 which otherwise could have been higher as was in past years in the same locality (Table 115).

Demonstration of salt tolerant wheat variety KRL 210 in sodic soils on a woman farmers' field

Table 116: Estimated impact of the salt tolerant varieties of rice, wheat and mustard-during the year 2017-18

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	2017	27.0	172800	149.5	172949.5	570733.4	1141466.7	1470	1677.9
Non-basmati (CSR 10, CSR 13, CSR 23, CSR 27, CSR 36, CSR 43)		2017	28.0	179200	21.1	179221.1	591429.4	1182859.3	1450	1715.1
Wheat										
KRL 19, KRL 1-4, KRL 210, KRL 213	1:20	2016-17	52.6	21040	315.5	21355.5	21355.5	64066.5	1625	104.1
Mustard										
CS 52, CS 54, CS 56	1:100	2016-17	0.02	200	18.1	218.1	3641.9	3641.9	3700	13.5
Total			107.7	373240	504.2	373743.7	1187160.4	2392034.4		1832.7

**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}

Impact of Salt Tolerant Varieties in terms of additional food grain production and revenue generation: During the year 2017-18, about 2.7 t Basmati rice, 2.8 t Non-basmati rice, 5.26 t wheat and 0.002 t Indian mustard Breeder seeds of salt tolerant varieties were produced and distributed to various seed multiplication agencies, farmers and other stakeholders. In addition TL seeds (14.95 t of Basmati CSR 30, 2.11 t non basmati and 31.55 t wheat) were produced and distributed to farmers of different states. The total estimated area coverage by these salt tolerant varieties of rice, wheat and mustard was 1.18 Million ha. The value of additional production obtained due to adoption of ICAR-CSSRI salt tolerant varieties of rice, wheat and mustard during 2017-18 would be 2.4 million tonnes giving estimated revenue of Rs1837.74 Crores at the national level (Table 116).

Planned Adaptations, and Co-Production of Adaptive Knowledge to Agroecological Stressors: Perspectives of Multi-stakeholders of North-Western India (Ranjay K. Singh, Anshuman Singh, R.K. Yadav, Parveen Kumar & P.C. Sharma)

The rationale behind this research was to understand the trends and pattern of salinity related issues being raised by various stakeholders and adaptation actions taken to effectively address the issues. Based on the objectives, a literature search from regional committee meetings report, grey literature and online resources were made for the period of 1992 to 2016. Direct participation by the team of this research in research and policy discussions during 2012, 2014 and 2016 provided insight to review the stressors and action patterns. The year 1992 was considered as a base since policy initiations and debate on stressors relating to resources stressors and scientific knowledge development undertaken by the national Regional Committee for the Northwestern Region of India from this period. A combination of qualitative with semi-quantitative approach was adopted to explore, analyze and interpret the data.

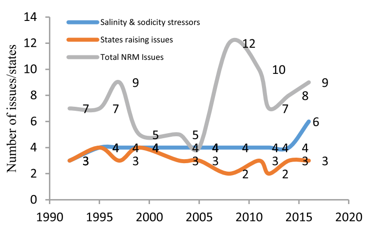


Fig.112. Trend of salinity and sodicity stressors being identified, raised and debated among stakeholders of north-west India during

Trends of salinity and sodicity stressors being debated in north-west India

Results revealed that since 1992 various stressors relating to natural resources

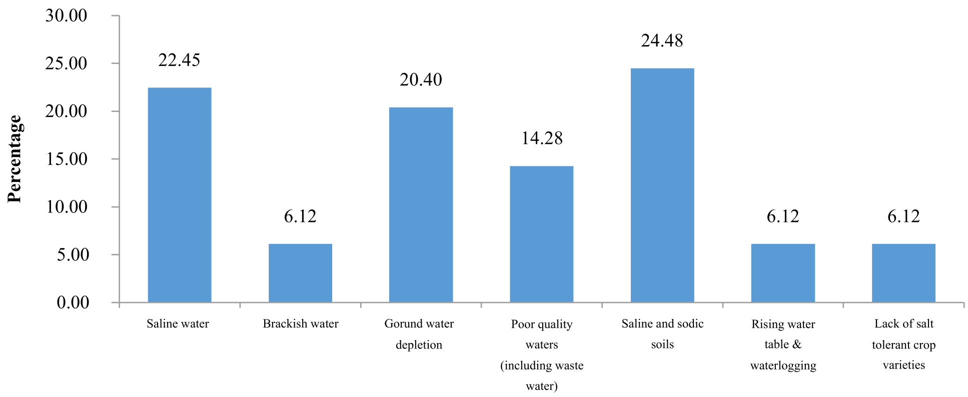


Fig. 113. Typology of stressors identified and debated by stakeholders of north-west India during 1992-2016

management (NRM) are being raised by state agencies. Till date 82 times such issues were debated among the stakeholders (policy makers, research mangers, developmental agencies and farmers) of northwest India. Out of these issues, on an average 4 stressors relating to soil and water salinity were raised and discussed each year between 1992 to 2014 and reached upto 6 stressors in 2016 (Fig. 112). Maximum number of NRM related stressors was debated to be 12 in 2008 followed by 10 stressors in 2011 and lowest 5 each during 1999 and 2003. Particularly, the stressors of soil and water salinity and sodicity have been raised by mostly three states, except the years 1995 and 1999 when four states (Haryana, Rajasthan, Gujarat and Punjab) have raised salinity as stressors.

Typology of salinity and sodicity stressors identified and debated in north-west India: The detailed analysis of salinity and sodicity related stressors being raised and debated among various stakeholders for the period of 1992 to 2016 indicated that maximum emphasis was given on saline and sodic soils (24.48%) followed by saline water (22.45%) (Fig. 113). Underground water depletion (20.40%) and poor quality waters (sewage, waste and heavy metal contaminated waters) (14.28%) found to be another set of major stressors those were flagged on by the northwestern states for the solutions. Brackish water, rising water table and water-logging, and lack of salt tolerant crops varieties (as a biological interventions) were given equal weitage (6.12% each), and emerged as ecological stressors during the debate.

Stakeholder's typology and their participation in developing and executing *top-bottom* knowledge: The data presented in Table 117 revealed that percentage of participation of research and technology mangers was always greater than the policy makers and developmental agencies and farmers over the period of 1992-2016 in developing the *top-bottom* knowledge, its execution and adapting the salinity and sodicity stressors. Farmers' role in the entire process was as low as 6.67 and 6.90 per cent (in three different years: 1997, 2003 and 2005) and maximum 28.67% during 2014. As compared to research and technological developmental agencies, the percentage of policy and developmental agencies in executing the *top-bottom* knowledge has been relatively fewer and varied from about 12.0 to over 33.33 per cent.

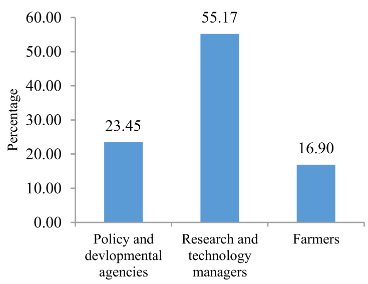


Fig. 114. Typology of stakeholders who were involved in finding solutions, formulating policies and enabling adaptation strategies over the time

Overall, research and technological institutions were higher with 55.17% role to develop scientific knowledge followed by policy and developmental institutions (23.45%) as executors while farmers as the users of *top-bottom* knowledge (16.90) in adapting the salinity and sodicity stressors (Fig. 114).

Actions at different scales in managing and adapting soil salinity and sodicity, and poor quality waters: It is evident from the data presented in Fig. 115 that at national scale, efforts were made with about 39 per cent (lowest 26.7 in 1995 to 57.1% in 2003) in developing *top-bottom* knowledge to manage and adapt soil salinity and sodicity and poor quality waters. The action taken at state scale (northwestern states including Punjab, Haryana, Rajasthan and Gujarat) by the concerned stakeholders to pass on and execute the *top-bottom* knowledge was relatively higher and appreciable with about 42 per cent (22.2% in 2005 and 60% in 1995) over the period of 1992 to 2016. The action really required executing *top-bottom* knowledge in adapting stressors on soil salinity and sodicty and poor quality waters did not took place at district and village (farmers) level.

Data further revealed that on average 17.7 % actions were taken at the local scale (farmers and district) to adopt *top-bottom* knowledge in managing soil salinity and sodicity and poor quality waters during 1992 to 2016. This could vary from 3.6 % during 2003 to 28.6 in 2011. Therefore, there was a gap of 21.3 % percent between national to local scale and 24.3% from state to local scales. This could be inferred that more efforts are required in integrated mode at the local scale (farmers/district level) to follow *top-bottom* knowledge in managing soil and water salinity related stressors in the northwestern region of India.

Overall, there is urgent need to look at the mechanism (*bottom-top*) to enhance farmers' participation in entire process of identifying the stressors and developing knowledge on soil salinity and poor quality waters so that rate and pace of managing and adapting such stressors could be made more inclusive with *top-bottom* knowledge.

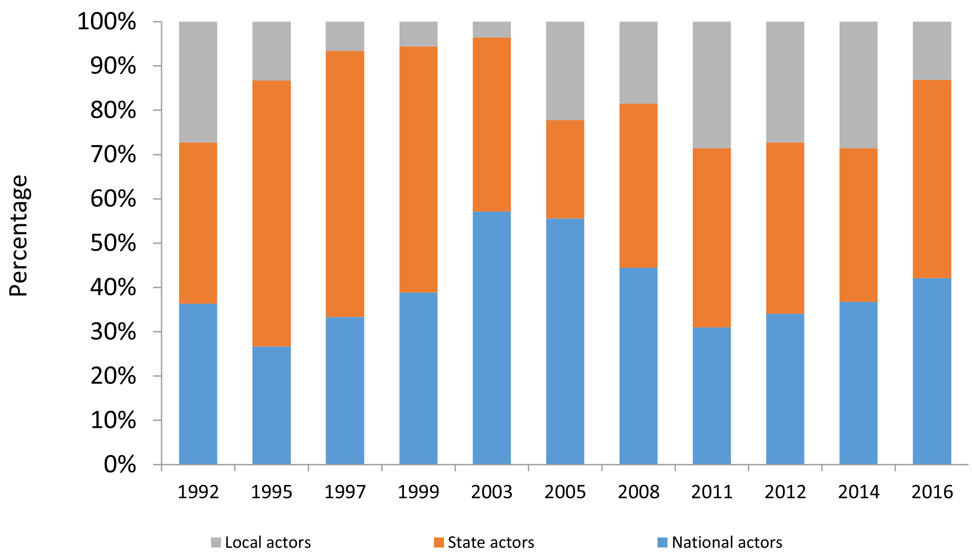
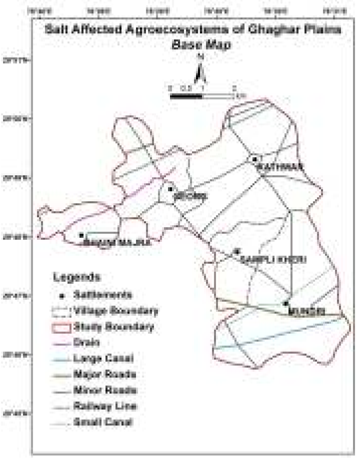


Fig.115.Spatial distribution of actors participating in management and adaptation of soil and water salinity and sodicity management



1. Mundri
2. Geong
3. Sampli Kheri
4. Kathwar
5. Bhaini Majra

Ground positioning of adopted villages under FFP

Farmer FIRST Project "Empowering farmers through selective interventions in salt affected agroecosystems of Ghaghar Plains" (Parvender Sheoran, R.K. Yadav, R.K. Singh, Satyendra Kumar, Arvind Kumar, R. Raju, Arijit Burman, S.K. Sanwal, K. Punnusamy and Sohanvir Singh)

The Farmer FIRST Programme (FFP) is an ICAR initiative with main focus on farmer's Farm, Innovations, Resources, Science and Technology (FIRST) to privilege the smallholder agriculture and complex, diverse and risk prone realities of farmers. Enhancing Farmer–Scientist Interface; Technology Assemblage, Application and Feedback; Partnership and Institution Building and Content Mobilization are the main components of FFP keeping farmer in a centric role for research problem identification, prioritization and conduct of experiments and its management in farmers' conditions.

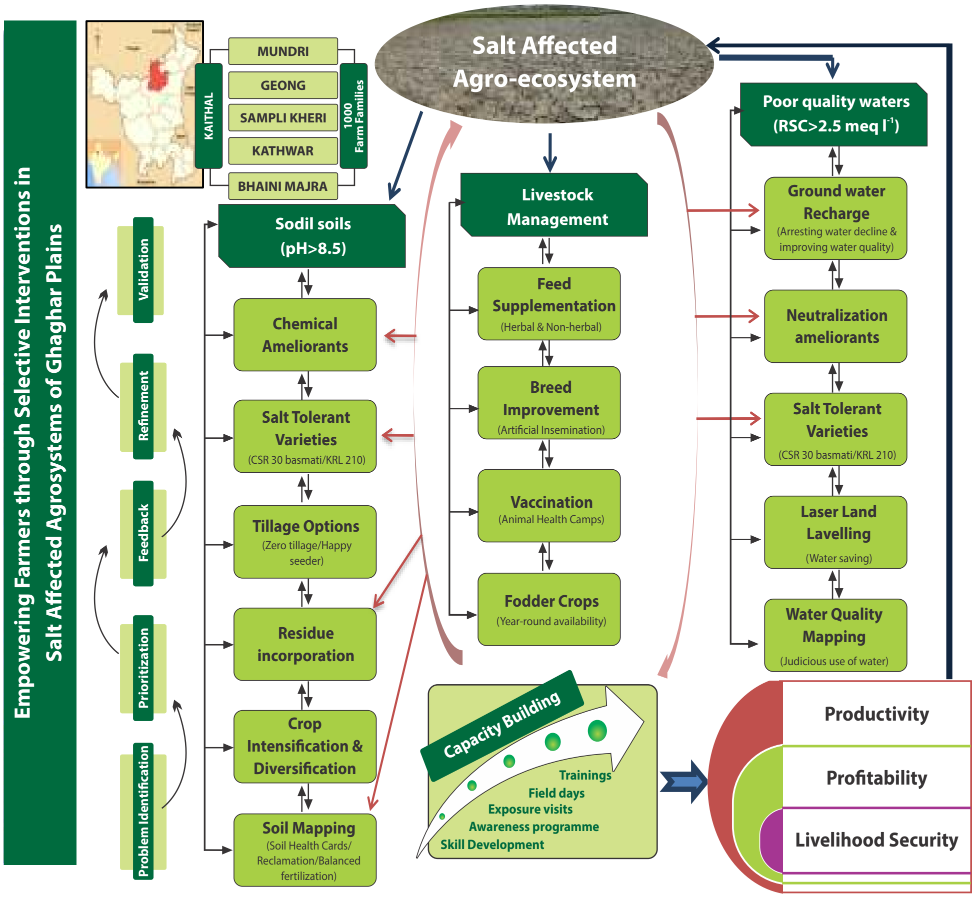
Five villages namely Mundri, Geong, Kathwar, Sampli Kheri and Bhaini Majra in Kaithal district of Haryana state were purposefully selected to fulfill the objectives of FFP operative at CSSRI, Karnal (Fig. 1). This region is dominated by rice-wheat cropping system. Sodic soils (pH>8.2) and high residual alkalinity in irrigation water (RSC>2.5meq l^{-1}) are the characteristic features of the region. Focused group discussion and transcend walk were held with the famers to diagnose their socio-economic and agro-ecological stressors *vis-a-vis* general, agriculture and livestock related problems (Table 117).

The agriculture and livestock based technological modules were finalized keeping farmers in a centric role and the location specific technological interventions were prioritized to experiment upon in the marginal salt affected environments. The conceptual framework depicting interrelationship of stressors and technological interventions was prepared for enhancing their farm productivity, profitability and livelihood security.

Majority of the farmers have farm holding less than <2 ha, growing two crops in a year under irrigated conditions. Most of the soils are medium to heavy textured sandy loam (normal to sodic soils). The description of farming situation in the adopted villages is given in Table 118.

Table 117: List of module-wise problem indentified in adopted villages

Category	Problem
i) General	• Water drainage: Chocking of drains with dung.
	• General cleanliness/sanitation/waterlogging in common areas.
	• Requirement of RO system for drinking purpose.
ii) Agriculture	• Poor quality water (RSC)
	• 40-50% area is sodic soil
	• Awareness regarding soil and water testing, balanced fertilization, IPM, Govt. policies
	• Reproductive sterility (Ukasa) in rice cultivated in highly sodic soils
	• Herbicide resistance particularly Phalaris minor in wheat
	• Non-availability of good quality seed
	• Spurios pesticides
	• Labour scarcity during crucial time
	• Provision of compensation for climatic hazards should be given to leaser only (instead of land owner)
iii) Livestock	• Prolaps, Mastitis, Repetitive breeding, Fever, Cold, Haemorrhagic Septicaemia, Foot & Mouth Disease

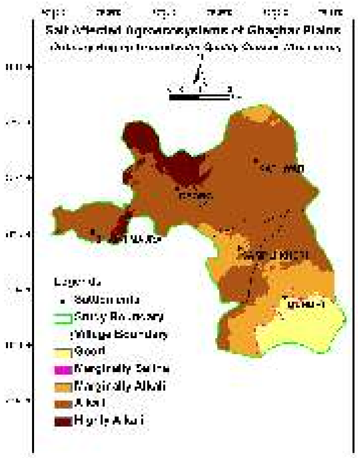


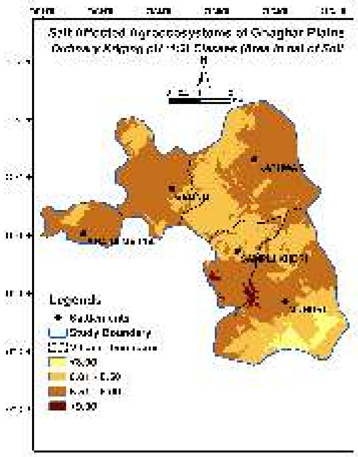
Conceptual framework for problem identification and technological interventions

Table 118: An account of farming situation in adopted villages

Sr. No.	Size of Holdings	Village				
		Mundri	Geong	Kathwar	Sampli Kheri	Bhaini Majra
1.	Total number of farm families including landless involved in farming (indicating the total household)	1124 (5740)	1008 (5286)	657 (3782)	185 (967)	193 (983)
2.	Land holdings (in %)					
(i)	Small farmers (<2 ha)	72.4 (814)	65.8 (663)	75.6 (497)	78.9 (146)	69.9 (135)
(ii)	Medium farmers (2-4 ha)	1.6 (18)	1.0 (10)	3.8(25)	3.2 (6)	14.6 (28)
(iii)	Large farmers (>4 ha)	0.7 (8)	0.5 (5)	1.5 (10)	1.6 (3)	-
(iv)	Landless farmers	25.3 (284)	32.7 (330)	19.1 (125)	16.3 (30)	15.5 (30)
3.	Cultivable land/ Net sown area (ha)	936/920	490/480	946/946	278/270	216/210
4.	Total area (ha)	1084	550	1039	340	234
5.	Cropping intensity (%)	196	188	191	193	191
6.	Irrigated (%)	100	100	100	100	100
7.	Soil type	Heavy textured sandy loam (normal to sodic soils)				

Figures in parentheses indicate no. of farmers





Soil pH (pH_2)	Yield Prediction (t ha^{-1})		Yield difference (%)
	KRL 210	HD 2967	
8.00	5.37	5.50	-2.47**
8.25	5.06	5.04	0.30^{ns}
8.50	4.78	4.65	2.79**
8.75	4.53	4.31	4.91**
9.00	4.31	4.03	6.53**
9.25	4.13	3.82	7.56**
9.50	3.97	3.66	7.86**

Significant improvement in yield with STV KRL 210 was observed with soil pH_2>8.5

Soil Sodicity and Water Quality Maps

A total of 354 soil and 283 water samples were collected to prepare village-wise geo-referenced maps delineating the status of soil sodicity (soil pH) and residual alkalinity in irrigation waters (RSC) in the adopted villages.

About 40.1% of tested soil samples were found with soil pH_s>8.2, indicating the sodic nature of soils. About 8.5% tested water samples were of good quality while 90% samples were confirmed with residual alkalinity in irrigation water of variable nature including 16.3% to marginally alkali, 61.8% to alkali and 11.7% highly alkali category. Management of RSC waters need to be considered on priority basis. The soil sodicty problem which is predominant in half of the cultivable land, if irrigation water is not used judiciously and management practices were not taken care off seriously, agriculture in the area will face tragic situation in the time to come.

Salt tolerant varieties

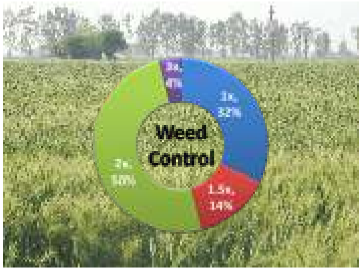
Non-availability of good quality seed of improved varieties and lack of knowledge about the salt tolerant varieties is one of the major concerns limiting crop production to a greater extent in sodic soils irrigated with high RSC waters. A total of 126 varietal demonstrations were conducted for evaluating the performance of salt tolerant wheat variety KRL 210 vis-a-vis traditional varieties. Salt tolerant wheat variety KRL 210 gave overall 4.6% higher yield as compared to other cultivated varieties in the area. The performance of KRL 210 was relatively better where the soil pH was more than 8.5 coupled with high residual alkalinity in irrigation waters (Table 119). The demonstrated variety matured earlier (5-7 days) showing its higher per day productivity compared to than other wheat varieties in the area. Varietal intervention through inclusion of salt tolerant wheat variety KRL 210 can be an important strategy to counter yield reduction under salty environments.

Weed management in wheat

During PRA, the farmers pointed out *Phalaris minor* in wheat as a noxious weed difficult to control developing high degree of herbicide resistance owing to faulty management practices. A total of 80 farmers, 16 in each village were randomly interviewed through a questionnaire for identifying the cause of concern *vis-a-vis* adoption pattern of weed

Table 119: Productivity potential of KRL 210 at farmers' fields

Village	N	Yield (kg ha^{-1})		Yield advantage (%)	Soil pH (pH_2)	RSC (meq l^{-1})
		KRL 210	Farmer's practice			
Mundri	25	4689 (3643-5555)	4463 (3143-5388)	5.18 (-3.9 to 13.7)	8.68 (8.06-9.23)	4.61 (2.2-7.2)
Geong	25	4422 (3388-5855)	4260 (3020-5776)	4.21 (-3.4 to 12.0)	8.63 (7.54-9.17)	4.66 (2.1-6.4)
Sampli Kheri	25	4592 (4103-5409)	4394 (3847-5640)	4.51 (-4.3 to 9.5)	8.88 (8.09-9.42)	5.95 (3.1-7.7)
Kathwar	25	4632 (3615-5643)	4419 (3569-5487)	4.79 (-3.8 to 10.2)	8.60 (8.21-9.12)	5.36 (3.3-7.5)
Bhaini Majra	26	4292 (3373-5315)	4151 (3209-5412)	4.31 (-3.2-9.61)	8.98 (8.22-9.79)	5.22 (3.4-6.5)
Mean	126	4489	4303	4.56	8.68	5.12



Farmers' perception regarding weed management in wheat ('X' represents recommended herbicide application rate)

Table 120: Adoption pattern for weed management in wheat

Parameters	Percent adoption
Timely application of herbicides	20
Over-dosing of herbicides	68
Recommended rate of water	5
Use of flat fan nozzle	1.5

control practices in wheat. Faulty management practices including over-dosing (68%) of recommended herbicides, recommended water quantity (5%) and spay nozzles (1.5%) were identified as the major constraints. One-third of the farmers are mixing different group herbicides without giving due consideration to herbicide compatibility. Almost all the farmers criticized the spurious quality of pesticides as factor affecting in obtaining the desired herbicide efficiency (Table 120).

A total of 30 demonstrations were evaluated comparing of pre-emergence application of pendimethalin @ 2 l/acre followed by post-emergence application of recommended herbicide (clodinafop/pinoxaden) (IP) *vis-a-vis* farmers practices (FP) in farmers' participatory mode. Technological intervention including pre-emergence application of pendimethalin @ 2 l/acre followed by post-emergence application of recommended herbicide (clodinafop/pinoxaden) resulted in better weed control efficiency at 30-35 DAS and 115-120 DAS in comparison to farmer's practice. Improved practice resulted in 4132 kg/ha mean wheat yield as against the 3888 kg/ha of farmer's practice with a yield superiority of 6.24 per cent over the later.

Ground water recharge structures

The average water level and fluctuation in Kaithal block (Table 121) indicated that the ground water level in the last 10 years is going down by more than twice (-1.33 m/year) in last 10 years compared to 40 years average data (-0.61 m/year); owing to excessive pumping for water requirements of predominant rice-wheat cropping system.

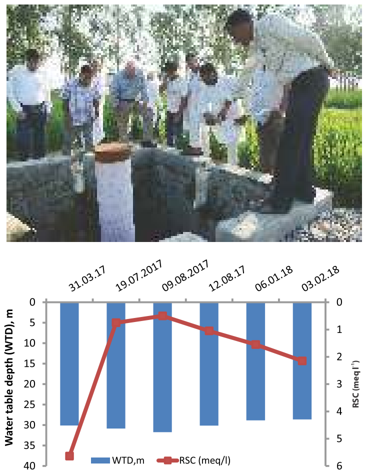


Fig.116.Water table depth of recharge structure installed in FFP adopted village

Table 121: Average water level and fluctuation in Kaithal block representing the study domain of FFP adopted villages

Parameter	Average water level and fluctuation
1974	4.70 m
2014	28.26 m
2005	16.36 m
2015	29.65 m
Fluctuation over 10 yrs. (2005-15)	-13.30 m
Fluctuation over 41 yrs. (1974-2015)	-24.95 m
Rate of Decline over 10 yrs. (2005-15)	-1.33 m
Rate of Decline over 41 yrs. (2005-15)	-0.61 m

Table 122: Description of recharge structure installed in FFP adopted villages

Structure	Village/site	Cavity depth (feet)	Filter Type
RS-1	Mundri	170	Integrated (sand + gravel + boulder) + Radial type
RS-2	Sampli Kheri	165	
RS-3	Gyong	205	Radial type
RS-4	Gyong	205	
RS-5	Kathwar	235	Integrated (sand + gravel + boulder) + Radial type
RS-6	Kathwar	235	

A total of six recharge strictures, 2 with radial type filtration and 4 with integrate filtration unit (Table 122) have been installed in adopted villages for augmenting ground water, improving its quality (reduction in salinity, alkalinity) and enhancing farmers income by saving submerged crops through recharge of excess water. Periodic monitoring by taking water samples indicated Rise in water table beneath the structure and improvement in ground water quality as indicated by reduction in RSC.

Sowing technique in wheat

The area is dominated by soil sodicity (pH>8.5) and high residual alkalinity (RSC>2.5 meq l^{-1}) in irrigation water having poor soil structure and physical properties (infilteration, soil permeability etc.). The applied waters remain stagnant for longer period of time. The survey data collected from 80 farmers regarding irrigation management in wheat indicated that 56% farmers apply only two irrigations in wheat while 44% farmers apply need based third irrigations. The farmers scheduled first irrigation at 33 DAS (22-47 DAS), second irrigation at 80 DAS (56-94 DAS) and third irrigation at 104 DAS (85-117 DAS). The recommendation of first irrigation (21-25 DAS) in wheat generally gets delayed owing to poor tolerance capacity of wheat to high RSC waters at early seedling stage. Therefore the farmers have the tendency to delay the first irrigation by 7-10 days of recommended one

The farmers generally sow wheat crop with rotavator further adding to creation of hard pan in subsoil interfering water intake capacity of soil. To counter this problem, a total of 52 demonstrations, 11 in Mundri, 13 in Kathwar, 12 in Gyong, 11 in Sampli kheri and 5 in Bhaini Majra were carried out to showcase the impact of direct sowing of wheat with Zero-till seed drill with farmers practice of broadcasted seed mixed by rotavator. The farmers were impressed with the performance of ZT sown wheat.

MISCELLANEOUS






Trainings in India and Abroad

Sr.No.	Name and Designation	Subject	Duration	Place
1.	Dr. Parvender Sheoran Principal Scientist	Random control trial method at NAIP, New Delhi	16.05.2017	ICAR-NAIP, New Delhi
2.	Dr. Kailash Prajapat, Scientist	Summer school on Waste to wealth: Biocompost production and utilization innovations in organic agriculture	10.08.2017–30.08.2017	ICAR-IARI, New Delhi
3.	Madan Singh Sr. Technical Officer	Networking: Basic and management techniques or technical personnel	04.09.2017-08.09.2017	ICAR-IASRI, New Delhi
4.	Dr. B.L. Meena Scientist	Short course on "Advances in nutrient dynamics for improving nutrient and water use efficiency of crops"	05.09.2017-14.09.2017	ICAR-IISS, Bhopal
5.	Prabhu Dass, Tractor Driver	Automobile maintenance, road safety and behavioral skill for regular drivers in technical grades	19.09.2017-23.09.2017	ICAR-CIAE-Bhopal
6.	Dr. Anil Kumar, Principal Scientist	Developing business proposal for producer companies and start up in agribusiness	19.09.2017-23.09.2017	ICAR-NAARM, Hyderabad
7.	Dr. Parvender Sheoran, Principal Scientist Dr. R. Raju, Scientist	Methodological framework for implementation of Farmer First Project	23.10.2017-26.10.2017	ICAR-IARI, New Delhi
8.	Akshay Kumar, TO P.K. Parekh, Assistant	Training program on "ICAR- ERP"	22.12.2017-27.12.2017	ICAR-IASRI, New Delhi
10.	Dr. D. Burman Pr. Scientist Dr. U. K. Mandal Pr. Scientist Dr. S. K. Sarangi Pr. Scientist	Introduction to electromagnetic induction techniques for soil salinity Investigations	12.02.2018- 14..02.2018	Bangladesh
11.	Dr. RK Fagodiya, Scientist	Statistical advances for agricultural data analysis	03.03.2018-23.03.2018	ICAR-IASRI, New Delhi

Deputation of Scientists Abroad

Sr.No.	Name and Designation	Subject	Duration	Place
1.	Dr.B. Maji Principal Scientist	16th Review planning and steering committee meeting of consortium for unfavourable rice environment	09.05.2017-11.05.2017	Vietnam
2.	Dr. Krishnamurthy SL Scientist	Protocols for the reproductive salinity screening in rice	16.11.2017-23.11.2017	Philippines
3.	Dr. Gajender Scientist	Endeavour Research Fellowship 2017	28.11.2017-11.05.2018	Australia
4.	Dr. P.C. Sharma Director	Lunching workshop of JIRCAS project development of sustainable resources management systems	18.12.2017 – 22.12.2017	Japan
5.	Dr. Ashim Datta Scientist	India-UK Fellowship	01.01.2018 – 31.03.2018	U.K.
6.	Dr. D. Burman Principal Scientist Dr. U. K. Mandal Principal Scientist Dr. S. K. Sarangi Principal Scientist	Introduction to electromagnetic induction techniques for soil salinity investigations	12.02.2018-14.02.2018	Bangladesh

Awards and Recognitions

- Hari Om Ashram Trust Award in Natural Resources Management and Agricultural Engineering was conferred to Dr. S.K. Kamra, Dr. Satyendra Kumar and Dr. Bhaskar Narjary for the Year 2014-15 by Indian Council of Agricultural Research (ICAR), New Delhi
- Dr. Parveen Kumar, Principal Scientist received Hari Om Ashram Trust Award of ICAR, New Delhi for Biennium 2014-15 for Crop and Horticultural Sciences on 16 July 2017
- Dr. Assim Datta was selected for NEWS (Newton Bhabha Virtual Centre on nitrogen efficiency of whole cropping systems) India UK fellowship (3 months) for conducting research on "Whole farm modelling of carbon sequestration and organic resource use at case study sites in India" at University of Aberdeen, UK.
- Dr. Shrvan Kumar, Scientist has been awarded the Chancellor Gold Medal Award for securing the Highest Overall Grade Point Average and presenting quality research work for the degree of Ph.D. (Soil Sci. & Agril. Chem.) in the year 2016-17 during Convocation of NAU, Navsari on 19-01-2018
- Dr. Sanjay Arora received Dr. J.S.P. Yadav Memorial Award' conferred by Indian Society of Soil Science, New Delhi for Excellence in Soil Science during 2017
- Dr. Sanjay Arora received J.S. Bali Award 2016' for contribution in Reclamation and Management of Saline and Sodic Soils through Microbial Techniques for Sustaining Agricultural Productivity and Soil Health Management, Conferred by SCSI, New Delhi
- Dr. Ashim Datta received Best Poster Award (Second)- "Potassium availability under conservation agriculture with sustainable intensification in Western IGP" Datta A., Yadav A.K., Choudhary V., Jat H.S., Choudhary M., Sharma P.C. and Jat M.L. In: The International conference on "Advances in Potassium Research for Efficient Soil and Crop Management" held at NASC complex, New Delhi during 28-29, August 2017
- Dr. Sanjay Arora received Best Paper Award 2017, SCSI at 26th National Conference at CPGS, CAU, Barapani
- Dr. Ajay Bhardwaj received Best Poster Award in the 26th National Conference on "Natural Resource Management for Climate Smart Sustainable Agriculture (NRMCSSA-2017)", held during 11-13 September at Barapani, Meghalaya, India, for presentation entitled, "Guiding principles for potassium nutrition in vineyards: Simple estimates for soil, plant, and fertilizer levels"

Linkages and collaborations

Collaborative Programmes at Main Institute, Karnal

International Collaboration

- Stress Tolerant Rice for Poor Farmers of Africa and South Asia (funding IRRI-BMGF)
- Marker Assisted Breeding of Abiotic Stress Tolerant Rice Varieties with Major QTL for Drought, Submergence and Salt Tolerance (funding DBT, India)
- CV Raman Fellow visiting scientist from Soil and Water Department, Faculty of Agriculture,Cairo University, Egypt

National Collaborations

- Transgenics in Crops-Salinity Tolerance in Rice: Functional Genomics Component (funding ICAR, New Delhi)
- Monitoring and Evaluation of Large-Scale Subsurface Drainage Projects in the State of Haryana (funding by Haryana Operational Pilot Project, Department of Agriculture, Haryana)
- Multi-locational Evaluation of Bread Wheat Germplasm (funding by NBPGR, New Delhi)
- AMAAS-Application of Micro-organism in Agriculture and Allied Sectors (funding by ICAR, New Delhi)
- Intellectual Property Management and Transfer/Commercialization of Agricultural Technology System (funding by ICAR, New Delhi)
- Inter-institutional Collaborative Project on Evaluation of Salinity Tolerance of Coriander, Fennel and Fenugreek Seed Spices (funding by NRCSS, Rajasthan).

Collaborative Programmes at Regional Research Station, Canning Town

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 – for project on cropping system intensification in the salt affected coastal zones of Bangladesh and West Bengal, India

National Collaborations

- Coastal salinity tolerant variety trial (CSTVT) with IIRR (formerly DRR), Hyderabad.
- Bidhan Chandra Krishi Viswavidyalaya (BCKV), West Bengal.
- National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Kolkata Centre

- 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
- Tagore Society for Rural Deveopment (TSRD), West Bengal.
- World Wide Fund (WWF)

Collaborative Programmes at Regional Research Station, Lucknow

International Collaborations

- Future Rainfed Lowland Rice Systems in Eastern India (Development of Crop and Nutrient Management Practices in Rice) (ICAR –W3) (IRRI funded).

National Collaborations

- Utilization of Fly Ash for Increasing Crop Productivity by Improving Hydro-Physical Behavior of Sodic Soils of Uttar Pradesh (DST Funded)
- Assessment of Municipal Solid Waste in Conjunction with Chemical Amendments for Harnessing Productivity Potential of Salt Affected Soils (UPCAR funded).

Collaborative programmes at Regional Research Station, Bharuch

National Collaboration

Linkages and Collaboration in Research Projects/Consultancies

- 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
- VIKAS-NGO, Ahmedabad.
- ATAPI Seva Foundation, NGO Jambusar
- Bidhan Chandra Krishi Visva Vidyalaya, Kalyani (West Bengal)
- Water Technology Centre, TNAU, Coimbatore
- Krishi Vikas Kendra, Surat,
- Krishi Vikas Kendra, Dediapada, Narmada
- Krishi Vikas Kendra, Chaswad, Bharuch

- Subham Seeds, Hyderabad (Maize)
- Monsanto India Limited
- Maharashtra Hybrid Seeds Co Pvt Ltd. (MAHYCO)

New Linkages with National and International Agencies

- 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; Deenbandhu Chhotu Ram University of Science & Technology, Murthal, 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
- Project Director, NCP, IGBP, IIRS, NRSA, Department of Space, Dehradun, Uttrakhand
- CCSHAU, Hisar, Haryana for collaborative research
- 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.
- SHIATS, Allahabad (U.P.)
- JIRCAS, Tsukuba, Japan

Publications

Arora, Sanjay and Sharma, V. 2017. Reclamation and management of salt affected soils for safeguarding agricultural productivity. *Journal of Safe Agriculture,* 01:1-10.

Babu, N.N., S. Gopala Krishnan, Vinod, K. K., Krishnamurthy,S.L., Singh, V.K., Singh, M.P. Singh, Renu, Ellur, Ranjith K., Rai,Vandna, Bollinedi, Haritha, Bhowmick, Prolay K., Yadav, Ashutosh, Nagarajan, M., Singh, Nagendra, K., Prabhu, K.V. and Singh, A. K. 2017. Marker aided incorporation of Saltol, a major QTL associated with seedling stage salt tolerance, into *Oryza sativa* 'Pusa Basmati 1121'. *Frontiers in Plant Science*, doi: 10.3389/fpls.2017.00041.

Babu, N.N., Vinod, K.K., Krishnamurthy, S.L., Krishnan, S. G., Yadav, A., Bhowmick, P.K. Nagarajan, M., Singh, N.K., Prabhu, K.V., Singh, A.K. 2017. Microsatellite based linkage disequilibrium analyses reveal saltol haplotype fragmentation and identify novel QTLs for seedling stage salinity tolerance in rice. *Journal Plant Biochem. Biotechnol,* 26:310–320, DOI 10.1007/s13562-016-0393-3.

Barman, A., Pandey, R.N., Singh, B. and Das, B. 2017. Manganese deficiency in wheat genotypes: Physiological responses and manganese deficiency tolerance index. *Journal of Plant Nutrition* 40: 2691 – 2708.

Basak, N., Mandal, B., Datta, A., Mitran, T., Biswas, S., Dhar, D., Badole, S., Saha, B., Hazra, G.C. 2017. Impact of long-term application of organics, biological, and inorganic fertilizers on microbial activities in rice-based cropping system, *Communications in Soil Science and Plant Analysis*, 48:2390-2401.

Baskar, M., Balasubramaniam, P., Pandiyarajan, P. and Kaledhonkar, M.J. 2017. Effect of treated distillery effluent for long-term effects on soil properties, ground water quality and yield of sugarcane. *Journal of Soil Salinity and Water Quality*, 9: 62-68.

Bhaskar, Narjary, Jangra, Pardeep, Abhishek, Ramesh, Kumar, Neeraj, Raju, R., Thimappa,K., Meena, R.L., Kumar, Satyendra, Kumar, Parveen, Chichmatalpure, A.R. and Kamra, S.K. 2017. Quantitative assessment of soil salinity using electromagnetic induction technique and geostatistical approach. *Journal of Soil Salinity and Water Quality*, 9: 156-166.

Bhatt, R., Arora, Sanjay and Busari, M.A. 2017. Zero tillage for sustaining land and water productivity in northern India. *Journal of Soil and Water Conservation*, 16:228-233

Burman, D., Maji, B., Singh, Sudhanshu, Mandal, Subhasis, Sarangi, S.K., Bandyopadhyay, B.K., Bal, A.R., Sharma, D.K., Krishnamurthy, S.L., Singh, H.N., delosReyes, A.S., Villanueva, D., Paris, T., Singh, U.S., Haefele, S.M., Ismail , Abdelbagi M. 2018. Participatory evaluation guides the development and selection of farmers' preferred rice varieties for salt and flood affected coastal deltas of South and Southeast Asia. *Field Crops Research* 220: 67-77.

Chaitanya, A. K., Majumder, S.P., Padhan, D., Badole, S., Datta, A., Mandal, B., Gade, K.R. 2017. Carbon dynamics, potential and cost of C sequestration in double rice. *Journal of Soil Science and Plant Nutrition* (Accepted).

Chandra, P. and Chandra, A. 2017. Identification and molecular characterization of *Castellaniella ginsengisoli* isolated from sugarcane-wheat cropping system. *International Journal of Current Microbiology and Applied Sciences,* 6:3509-15.

Chandra, P. and Chandra, A. 2017. Elucidation of rRNA secondary structure and phylogenetic analysis of *Salmonella enterica* based on 16 s RNA. *International Journal of Current Microbiology and Applied Sciences*, 6:4056-63.

Chandra, P. and Shilpa,V. Molecular characterization and identification of bioactive peptides producing *Lactobacillus* sps. based on 16S rRNA gene sequencing 2018. *Food Biotechnology,* 32:1-4.

Choudhary, Madhu, Datta, A., Jat, H.S., Yadav, A.K., Gathala, M.K., Sapkota,T.B., Das, A.K., Sharma, P.C., Jat, M.L., Singh, R. and Ladha, J.K. 2018. Changes in soil biology under conservation agriculture based sustainable intensification of cereal systems in Indo-Gangetic Plains. *Geoderma,* 313: 193–204.

Datta, A., Basak, Nirmalendu, Chinchmalatpure, A. R., Banyal, Rakesh and Chaudhari, S.K. 2017. Land-use influences soil properties of sodic land in Northwest India. *Journal of Soil Salinity and Water Quality,* 9:178-186.

Datta, A., Mandal, B., Basak, N., Badole, S., Chaitanya, K., Majumder, S.P., Thakur, N.P., Kumar, P., Kachroo, D. 2017. Soil carbon pools under long-term rice-wheat cropping system in Inceptisols of Indian Himalayas, *Archives of Agronomy and Soil Science*, DOI: 10.1080/ 03650340.2017.1419196.

Datta, Ashim, Basak, Nirmalendu, Chinchmalatpure, A.R., Banyal, Rakesh and Chaudhari, S.K. 2017. Land-use influences soil properties of sodic land in Northwest India. *Journal of Soil Salinity and Water Quality,* 9:178-186.

Dixit, A. K., Kumar, Sunil, Rai, A. K., Palsaniya, D. R. and Choudhary, Mukesh. 2017. Nutrient management in fodder sorghum + cowpea – chickpea cropping system for higher system productivity and nutrient use. *Range Mgmt. & Agroforestry*, 38:82-88.

Fagodiya, R.K., Kumar, S., Naresh and Harit, R. 2017. Impacts of short-term sequential stresses on maize (*Zea mays* L.) and its simulation using Info Crop-Maize Model. *International Journal of*

Current Microbiology and Applied Sciences, 6:911-921.

Fagodiya, R.K., Pathak, H., Bhatia, A., Kumar, A., Singh, S. D., Jain, N. and Harith, R. 2017. Simulation of maize (*Zea mays* L.) yield under alternative nitrogen fertilization using infocrop-maize model. *Biochemical and Cellular Archives*, 17: 65–71.

Garg, R. K., Yadav, R.K., Sheoran, P., Kumar, A., Narjary, B., Meena, M.D., and Sharma, D.K., 2017. Enhancing productivity potential of saline soil through agroforestry system using saline irrigation. *Indian Forester,* 143: 856-861.

Gupta, R.D. and Arora, Sanjay. 2017. Characteristics of the soils of Ladakh region of Jammu and Kashmir. *Journal of Soil and Water Conservation, India* 16:260-266.

Jat, H. S., Datta, A., Sharma, P. C., Kumar, V., Yadav, A. K., Choudhary, M., Choudhary, V., Gathala, M. K., Sharma, D. K., Jat, M. L., Yaduvanshi, N. P. S., Singh, G. and McDonald, A. 2017. Assessing soil properties and nutrient availability under conservation agriculture practices in a reclaimed sodic soil in cereal-based systems of North-West India. *Archives of Agronomy and Soil Science*, (DOI: 10.1080/03650340. 2017.1359415)

Jha, S. K., Mishra, V. K., Damodaran,T., Sharma, D. K. and Kumar, Parveen 2017. Arsenic in the groundwater: Occurrence, toxicological activities, and remedies. *Journal of Environmental Science and Health, Part C,* 35: 84-103.

Khandkar, U.R., Tiwari, S.C., Sharma, R.K., Verma, S.K., Meena, R.L. and Kaledhonkar, M.J. 2017. Relative efficiency of amendments for reclamation of sodic vertisols and their effects on crop production. *Journal of Soil Salinity and Water Quality*, 9:187-193.

Kisku, T.K., Datta, A., Basak, N., Mandi, S., Hembram, S., Roy, R. 2017. Evaluation of saturated hydraulic conductivity from soil properties in an *Inceptisol* using different land cover and depths. *Journal of Applied and Natural Science* 9:1482 -1488.

Krishnamurthy, S. L., Sharma, P. C., Sharma, D. K., Ravikiran, K. T., Singh,Y. P., Mishra, V. K. Burman, D., Maji, Buddheswar, Mandal, S., Sarangi, S. K., Gautam, R. K., Singh, P. K., Manohara,K. K., Marandi, B. C., Padmavathi,G., Vanve, P. B., Patil, K. D., Thirumeni, S., Verma, O. P., Khan, A. H., Tiwari, S., Geetha, S., Shakila, M., Gill, R., V. Yadav, K. S., Roy, K. B., Prakash, M., Bonifacio, J., Ismail, A.M., Gregorio,G. B., Singh, R.K. 2017. Identification of mega-environments and rice genotypes for general and specific adaptation to saline and alkaline stresses in India. *Scientific Reports*, DOI:10.1038/s41598-017-08532-7.

Kumar, A., Bhatia, A., Fagodiya, R.K., Malyan, S.K., Meena, B. L. 2017. Eddy Covariance Flux Tower: A promising technique for greenhouse gases measurement. *Adv Plants Agric Res*, 7: 00263. DOI: 10.15406/apar.2017.07.00263

Kumar, Ashwani, Goyal, S. C., Lata, Charu, Sharma, Neelam, Pooja and Parshad, Jagdish. 2017 Rapid efficient direct and indirect regeneration protocol of *Dioscorea deltoidea* wall. *National Academy Science Letters*, 40:237-240.

Kumar, Ashwani, Lata, Charu, Krishnamurthy, S.L., Kumar, Arvind, Prasad, K.R.K. and Kulshreshtha, N. 2017. Physiological and biochemical characterization of rice varieties under salt and drought stresses. *Journal of Soil Salinity and Water Quality,* 9:167-177.

Kumar, G., Chandra, P., and Choudhary, M. 2017. Endophytic Fungi: A promising source of bioactive compounds. *Chemical Science Review and Letters,* 6:2373-81.

Kumar, Parveen, Singh, Kailash, Kumar, Ashwani, Singh, Rakesh, Mishra, A.K., Rai, Poornima Chaudhari, S.K. and Sharma, D.K. 2017. Residual effect of nitrogen management on physiological traits of green gram in reclaimed sodic soil. *Journal of Soil Salinity and Water Quality*, 9: 94-103.

Lata, Charu, Kumar, Ashwani, Sharma, S.K., Singh, Jogendra, Sheokand, Shital, Pooja, Mann, Anita and Rani, Babita. 2017. Tolerance to combined boron and salt stress in wheat varieties: Biochemical and molecular characterization. *Indian Journal of Experimental Biology,* 55: 321-328.

Lohan, S.K., Jat, H.S., Yadav, A.K., Sidhu, H.S., Jat, M.L., Choudhary, Madhu, Peter, J.K., Sharma, P.C. 2018. Burning issues of paddy residue management in north-west states of India. *Renewable and Sustainable Energy Reviews,* 81: 693-706.

Mandal, A. K. 2017. Characterization of salt affected soils and poor quality waters of Kaithal district in central Haryana for reclamation and management. *Journal of the Indian Society of Soil Science*. 64: 419-426.

Mandal, Subhasis., Burman, D., Mandal, U.K. Lama., T.D., Maji, B. and Sharma, P.C. 2017. Challenges, options and strategies for doubling farmers' income in West Bengal – Reflections from Coastal Region. *Agricultural Economics Research Review*, 30 :89-100.

Mandal, U.K., Sharma, K.L., Venkanna, K., Pushpanjali, Adake, R.V., Masane, R.N., Prasad, J.V.N.S., Venkatesh, G., and Srinivasarao, Ch. 2017. Sustaining soil quality, resilience and critical carbon level under different cropping systems in semi-arid tropical Alfisol soils. *Current Science*, 112:1882-1895.

Mangalassery, Shamsudheen, Dayal, Devi, Kumar, Arvind, Bhatt, Karan, Nakar, Rupesh, Kumar, Ashwani, Singh, J.P.

and Mishra, A.K. 2017. Pattern of salt accumulation and its impact on salinity tolerance in two halophyte grasses in extreme saline desert in India. *Indian Journal of Experimental Biology,* 55:542-548.

Meena, B.L., Rattan, R.K. and Datta, S.P. 2017. Solubility relationships of iron and evaluation of its fertility status in degraded soils. *Communications in Soil Science and Plant Analysis*, 48:1059-1067.

Meena, M.D., Narjary, B., Sheoran P., Jat, H.S., Joshi, P.K., Chinchmalatpure, A.R., Yadav, G., Yadav, R.K., and Meena, M.K. 2018. Changes of phosphorus fractions in saline soil amended with municipal solid waste compost and mineral fertilizers in a mustard-pearl millet cropping system. *Catena,* 160*:* 32-40.

Meena, M.D., Narjary, B., Sheoran, P., Jat, H.S., Joshi, P.K., Chinchmalatpure, A.R., Yadav, G., and Yadav, R.K., 2018. Effect of Rice straw compost and mineral fertilizers on yield and nutrient uptake by Indian mustard in saline soil. *Journal of Oilseed Brassica*, 9:10-16.

Mishra, V.K, Srivastava, S., Jha, S. K., Sharma, D. K. , Damodaran, T., Singh, Y.P. and Nayak A.K . 2017. Temperature induced changes in wheat (*Triticum aestivum*) growth and yield under salt affected environment of Indo-gangetic plains. *Arid Land Research and Management* , http:// dx.doi.org /10.1080/153249 82.2017.1298684 A267 .

Narjary, B., Meena, M.D., Pathan, A.L., Kumar, N., Kumar, Satyendra., Kamra, S.K. and Sharma, D.K., 2017. Assessing spatio-temporal variations in groundwater table depth and salinity using geostatistics and its relation with groundwater balance in a salt affected soil. *Indian Journal of Soil Conservation*, 45: 235-243.

Narjary, Bhaskar, Jangra, Pradeep, Abhishek, Ramesh, Kumar, Neeraj, Raju, R., Thimappa, K., Meena, R.L., Kumar, Satyendra, Kumar, Parveen, Chinchmalatpure, A. R. and Kamra, S.K. 2017. Quantitative assessment of soil salinity using electromagnetic induction technique and geostatistical approach. *Journal of Soil Salinity and Water Quality,* 9:155-166.

Paul, N., Datta, A., Giri, U., Saha, D. 2017. Effect of organic matter vis-a-vis humic acid on nutrient availability and yield attributes of rice-mustard cropping sequence. *Journal of the Indian Society of Soil Science,* 65: 210-221.

Prajapat, K., Vyas, A.K., Dhar, S., Jain, N.K., Mohd. Hashim and Choudhary, G.L. 2018. Energy input-output relationship of soybean-based cropping systems under different nutrient supply options. *Journal of Environmental Biology*, 39:93-101.

Pushpanjali, Tejaswi, P.B., Sharma K.L., Mandal, U.K, Solomon Raju, A.J., Venkanna, K., Masanne, R., Samuel J., and Karthikeyan, K. 2017. Soil quality and heavy metal contamination of soils in Mindi industrial area, Visakhapatnam, Andhra Pradesh, India. *Indian Journal of Ecology*, 44:774-777.

Rajkumar, Gora, J.S., Kumar, R., Singh, A., Kumar, A. and Gajender. 2017. Effect of different growing media on the rooting of pomegranate (*Punica granatum* L.) cv. 'Phule Arakta' cuttings. *Journal of Applied and Natural Science*, 9**:**715-719.

Rajkumar, R.H., Vishwanatha, J., Anand, S.R., Karegoudar, A.V., Dandekar, A.T. and Kaledhonkar, M.J. 2017. Effect of laser land leveling on crop yield and water production efficiency of paddy (*Oryza sativa*) in Tungabhadra Project Command. *Journal of Soil Salinity and Water Quality*, 9:213-218.

Raju, R., Thimmappa, K., Kumar, P. Kumar, S. and Tripathi, R.S. 2017. Adverse effect of land degradation on farm productivity and income in North-West India. *Indian Journal of Economics and Development*. 13:490-495.

Raju, R., Thimmappa, K., Kumar, P., Kumar, Satyendra and Tripathi, R.S. 2017. Adverse effect of land degradation on farm productivity and income in North-West India. *Indian Journal of Economics and Development,* 13: 490-495.

Rane, Jagadish, Kaledhonkar, M.J. Sharma, P.C. and Singh, N.P. 2017. Improvement of Salt Tolerance in Crop Plants: Emerging Opportunities in Plant Phenomics. *Journal of Soil Salinity and Water Quality*, 9:47-52.

Raut, Shishir., Maji, B. and Burman, D. 2017. Study of soil physicochemical parameters and organic matter humic components in relation to salinity in a coastal soil of West Bengal. *Int. J. Geology Agriculture and Environmental Sciences,* 5: 1-4.

Ravikiran, K.T., Krishnamurthy, S.L., Warraich, A.S. and Sharma, P.C. 2017. Diversity and haplotypes of rice genotypes for seedling stage salinity tolerance analyzed through morpho-physiological and SSR markers. *Field Crops Research,* https://doi.org/ 10.1016/j.fcr.2017.04.006 .

Sanwal, S. K., Kumar, Ashwani, Mann, Anita and Kaur, Gurpreet. 2018. Differential response of pea (*Pisum sativum*) genotypes exposed to salinity in relation to physiological and biochemical attributes. *Indian Journal of Agricultural Sciences,* 88 : 149-56.

Sarangi, S.K., Maji, B., Mandal, U.K., Mandal, S. and Sharma, P.C. 2017. Direct seeded rice followed by zero tillage rapeseed increase system yield and profitability in coastal saline soils.

Journal of Soil Salinity and Water Quality, 9:219-225.

Sarangi, S.K., Maji, B., Mandal, U.K., Mandal. S. and Sharma, P.C. 2017. Effect of establishment methods in rainy season (*kharif*) and tillage practices in winter season (*rabi*) on yield and economics of rice (*Oryza sativa*)–maize (*Zea mays*) cropping system under coastal saline ecosystem. *Indian Journal of Agronomy,* 62:407-416.

Sarangi, S.K., Maji, B., Singh, S., Mahanta, K.K. and Sharma, D.K. 2017. Water productive and profitable dry season crops for tropical coastal region of India. *E-planet,* 15:96-101.

Selvamurugan, M., Baskar, Balasubramaniam, M., Pandiyarajan, P.P. and Kaledhonkar, M.J. 2017. Integrated farming system in salt-affected soils of Tamil Nadu for Sustainable income generation. *Journal of Soil Salinity and Water Quality*, 9:237-240.

Sharma, D. K. and Singh, Anshuman. 2017. The challenge to produce more food with less water: harnessing the potential of poor quality water resources. *African Asian Journal of Rural Development*, 50: 45-77.

Sharma, K.L., Indoria, A.K., Reddy, S.K. and Mandal, U.K. 2017. Soil quality-concepts, methods of assessment and strategies for improvement. *Indian Journal of Fertilisers*, 30: 28-42.

Sheoran, Parvender, Sardana, Virender, Singh, Sher, Chander, Subhash, Kumar, Ashwani, Mann Anita and Sharma, Pushp. 2017. Nutrient management for sustaining productivity of sunflower-based cropping sequence in Indian Semiarid Regions. *Communications in Soil Science and Plant Analysis*,48: 581-593.

Singh, A., Singh, R.,K., Kumar, N., Kumar, Satyendra, Upadhyay, A., Goswami, A. Sharma, P.C. 2018. Genetic erosion of crop landraces: trends in the conservation of locally adapted "Newar' radish in Jaunpur district, Uttar Pradesh, India. *Indian Journal of Traditional Knowledge*, 17:344-352.

Singh, A.K., Arora, Sanjay, Singh, Y. P., Verma, C. L., Srivastava, Anurag, and Sharma Navneet. 2017. Enhancing irrigation water productivity in paddy grown under sodic environment. *Journal of Soil and Water Conservation*, 16:67-71.

Singh, Jogendra, Singh, Vijayata and Sharma, P.C. 2018. Elucidating the role of osmotic, ionic and major salt responsive transcript components towards salinity tolerance in contrasting chickpea (*Cicer arietinum* L.) genotypes. *Physiology and Molecular Biology of Plants*, DOI:10.1007/s12298-018-0517-4.

Singh, R. K., Zander, K. K., Kumar, S., Singh, Anshuman, Sheoran, P., Kumar, A., Hussain, S. M., Riba, T., Rallen, O., Lego, Y. J., Padung, E. and Garnett, S. T. 2017. Perceptions of climate variability and livelihood adaptations relating to gender and wealth among the Adi community of the Eastern Indian Himalayas. *Applied Geography*, 86: 41-52

Singh, R.P., Setia, R., Verma, V.K., Arora, Sanjay, Kumar, P. and Pateriya, B. 2017. Satellite remote sensing of salt-affected soils: Potential and limitations. *Journal of Soil and Water Conservation, India,* 16:97-107.

Singh, S. R, Verma, C. L. and Singh, A.K. 2017. Weighted average of viscous and drag resistance models with and without matching parameters for estimating hydraulic conductivity of soils. *Journal of Soil and Water Conservation,* 16:37-46.

Singh, Y.P., Arora, S., Mishra,V.K., Dixit, H. and Gupta, R.K. 2017. Composting of municipal solid waste and farm wastes for its use as amendment in sodic soil. *Journal of Soil and Water Conservation,* 16:172-177.

Singh, Y.P., Nayak, A.K., Gautam, R.K., Singh, R.K. and Mishra, V.K. 2017. Assessment of technical efficiency of rice production in sodic lands of Indo-Gangetic Plains. *Journal of Soil Salinity and Water Quality,* 9:136-144.

Singh,Y.P., Singh, G.B., Sharma, D.K. and Arora, Sanjay. 2017. Evaluation of different agro-forestry systems for their effect on alkali soils. *Journal of the Indian Society of Soil Science,* 65: 42-47.

Singhai, A., Das, S., Kalashetty, M., Kadam, A.K., Shukla, J.P., Bundela, D.S. and Kalashetty, M. 2017. GIS-based multi-criteria approach for identification of rainwater harvesting zonesin upper Betwa sub-basin of Madhya Pradesh, India. *Environ Dev Sustain*, DOI 10.1007/s10668-017-0060-4.

Sonam, C., Dorje, A., Phunchok, A., Tsewang, T. and Singh, R. K. 2017. Traditional knowledge and heirloom root vegetables: Food security in trans-Himalayan Ladakh, India. *Indian Journal of Traditional Knowledge*, 17:191-197.

Srivastava, R., Sethi, M., Yadav, R. K., Bundela, D.S., Singh, Manjeet, Chattaraj, S., Singh, S. K., Nasre, R.A., Ram, Sita, Dhale, Sanjay, Mohekar, D. S. and Barthwal, A. K. 2017. Modelling laboratory measured soil reflectance spectral data for rapid prediction of soil salinity in the Indo-Gangetic Plains of Haryana. *Journal of Indian Soc Remote Sens,* 45:307–315.

Sundha, P., Basak, N., Rai, A.K., Yadav, R.K., Sharma, D.K., Sharma, P.C. 2017. N and P release pattern in saline-sodic soil amended with gypsum and municipal solid waste compost. *Journal of Soil Salinity and Water Quality,* 9:145-155.

Conference/ Seminar/ Symposia/Workshop papers

Arora, Sanjay, Singh, Y.P. and Sahni, D. 2017. Halophilic microbial formulations for enhancing productivity of wheat grown on sodic soil. In: *26th National Conference on "Natural Resource Management for Climate Smart Sustainable Agriculture*" held at CPGS, CAU(I), Barapani, Shillong, Meghalaya, during 11 - 13 September, 2017.

Basak, N., Gobinath, R., Rai, A.K., Sundha, P., Yadav, R.K., Narjary, B., Gajender, Kumar, S. and Sharma, D.K. 2017. Deficit saline water irrigation and mulch affect root zone salinity and micronutrient availability in salt-affected soil. In: *National Seminar on "Nutrients and pollutants in soil-plant-animal-human Continuum for sustaining soil, food and nutritional security – way forward"* held at BCKV, Kalyani, during 9-10 June, 2017.

Bandyopadhyay, B.K., Maji, B. and Lama, T.D. 2017. Land degradation due to salinity, extent of losses in crop yield and strategies for management (Sanyal, S.K. Ed.). In: *Souvenir of 82nd Annual Convention and National Seminar of Indian Society of Soil Science,* New Delhi held at Amity University Kolkata, during 11-14 December, 2017. pp. 103-119.

Bhardwaj, A.K., Singh, Ranbir, Kaphaliya, Bhumija, Chaudhari, S.K. and Sharma, D.K. 2017. Sustainable crop and soil management strategies for rice wheat systems in marginal productive areas of Indo-gangetic plain, and their relevance to climate resilience. In: *26th National Conference on "Natural Resource Management for Climate Smart Sustainable Agriculture (NRMCSSA-2017)* held at Barapani, Meghalaya, during 11-13 September, 2017.

Datta, A., Yadav, A.K., Choudhary, V., Jat, H.S., Choudhary, M., Sharma, P.C. and Jat, M.L. 2017. Potassium availability under conservation agriculture with sustainable intensification in Western IGP" In: *International conference on "Advances in Potassium Research for Efficient Soil and Crop Management*" held at NASC complex, New Delhi, during 28-29 August, 2017.

Krishnamurthy, S. L. 2017. Development of mini core and evaluation of for salinity tolerance of Indian Rice Germplasm". In: *National conference on Agricultural Science and food technologies for sustainable productivity and national security* held at Barkattullah University, Bhopal, during 23-24 Nov., 2017.

Kumar, Naresh, Lata, Charu, Kumar, Ashwani and Mann, Anita.2018. Elucidation of Salt Tolerance Mechanisms of Halophyte *Dichanthium Annulatum* Under Salt Stress. In: *International Conference on Sustainable Agriculture, Energy, Environment and Technology (Icsaeet-2018)"* held at MDU, Rohtak, during 24 -25 February, 2018.

Kumar, Naresh, Lata, Charu, Kumar, Ashwani and Mann, Anita. 2017. Halophytes: Adaptations and the salt tolerant mechanisms. In: *National Conference of Plant Physiology "Emerging Role of Plant Physiology for Food Security and Climate Resilient Agriculture*" held at IGKV, Raipur ,Chhattisgarh, during 23-25 November, 2017.

Lama, T.D., Burman, D., Sarangi, S.K. Mahanta, K.K. Maji, B. and Mandal, U.K. 2017. Effect of deficit irrigation on salinity dynamics and productivity of maize in coastal saline soil. In: *Abstracts 82nd Annual Convention and National Seminar of Indian Society of Soil Science,* held at Amity University Kolkata, New Town, Kolkata, during 11-14 December, 2017.

Lata, Charu, Kumar, Ashwani, Rani, Sulekha and Mann, Anita. 2017. Characterization of salt-tolerance mechanisms of halophytic Grass, *Sporobolus marginatus*. In: *National Conference of Plant Physiology "Emerging Role of Plant Physiology for Food Security and Climate Resilient Agriculture*" held at IGKV, Raipur, Chhattisgarh, during 23-25 November, 2017.

Maji, B., Sarangi, S. K., Mandal, U. K., Mandal, S., Mahanta, K. K., Burman, D., Sharma, P. C. and Mainuddin Mohammed. 2017. Challenges and options for sustainable intensification of cropping system in the salt affected coastal zone of Indian Sundarbans. In: *International Tropical Agriculture Conference on "High impact science to nourish the world"* held at Brisbane Convention & Exhibition Centre, Australia during 20-22 November, 2017.

Mandal, A. K., Joshi, P. K., Singh, Ranbir and Sharma, D. K. 2017. Characterization of some salt affected soils in Punjab for reclamation and management. In: *National Seminar on "Developments in Soil Science 2017"*Annual convention organized by Indian Society of Soil Science, held at Kolkata, during 11-14 December, 2017.

Mandal, B., Singha Roy, S., Basak, N., Mandal, A. 2017. Measuring resilience and resistance of soils for its rehabilitation. In: *National Seminar on "Nutrients and pollutants in soil-plant-animal-human Continuum for sustaining soil, food and nutritional security – way forward"* held at BCKV, Kalyani, during 9-10 June, 2017.

Mandal, S. 2018., Implementing Minimum Support Price Scheme in West Bengal – Effectiveness and Policy Needs during Policy Dialogue on Innovations in Ensuring Remunerative Prices (MSP) to Farmers. In: *Challenges and Strategies*, organised by IFPRI-NAAS-ICAR-NIAP held at NAAS Complex, New Delhi, on 23rd March 2018.

Mandal, U.K., Burman, D., Mandal, S., Mullick, S., Nayak, D.B., Maji, B., Mahanta, K.K., Raut, S., and Bhardwaj, A.K. 2017. Assessing climate variability and to develop adaptation strategies for coastal salinity management in Indian Sundarbans through land shaping and crop diversification. In: *Abstract in 82nd Annual Convention of Indian Society of Soil Science*, held at Amity University, Kolkata, during 11-14 December, 2017.

Mann, Anita, Kumar, Naresh, Lata, Charu, Kumar, Ashwani and Kumar, Arvind. 2018. Effect of salinity on the antioxidant system of salt tolerant grasses. In: *International Conference on "Bio & Nano Technologies for Sustainable Agriculture, Food, Health, Energy and Industry"* held at Guru Jambheshwar University of Science and Technology, Hisar, during 21-23 February, 2018. Nagaraja, M.S., Naraboli,V.C., Srikanth, S., Bhardwaj, A.K., Meti, S. and Alur, A.S. 2017. Guiding principles for potassium nutrition in vineyards: Simple estimates for soil, plant, and fertilizer levels. In: *26th National Conference on "Natural Resource Management for Climate Smart Sustainable Agriculture (NRMCSSA-2017)* held at Barapani, Meghalaya, during 11-13 September, 2017.

Narjary, B., Meena, M.D., Kumar, S., Kamra, S.K. and Sharma D.K. 2017. Spatiotemporal evaluation of soil salinity using Electromagnetic induction techniques. In: *National Seminar on Development of Soil Science-2017, Indian Society of Soil Science*, held at Amity University, Kolkata, during 11-14 December, 2017.

Purakayastha, T.J., Bhaduri, D., Biswas, S., Basak, **N**., Mandal, B. 2017. Soil health for posterity-Indian perspective. In: *National Seminar on "Nutrients and pollutants in soil-plant-animal-human Continuum for sustaining soil, food and nutritional security – way forward"* held at BCKV, Kalyani, during 9-10 June, 2017.

Singh, Ranbir, Chaudhari, S.K., Rai, A.K., Kumar, Satyendra and Yadav, R.K. 2017. Long term influence of crop residue and tillage management on nutrients availability and crop productivity under RWCS in partially reclaimed sodic soil. In: *National seminar on "Nutrients and pollutants in soil-plant-animal-human continuum for sustaining soil, food and nutritional security - way forward"* held at BCKV, Kalyani, during 9-10 June, 2017.

Raut, Shishir, Maji, B., Sarangi, S.K. and Lama, T.D. 2017. Study of soil salinity and organic matter under different landforms in coastal West Bengal using remote sensing and GIS. In: *Abstracts - 82nd Annual Convention and National Seminar of Indian Society of Soil Science,* held at Amity University Kolkata, during11-14 December, 2017.

Raju, R. 2017.Adverse Effect of Land Degradation on Farm Productivity and Income in North-West India". In: *4th National Seminar on Doubling Indian Farmer's Income by 2022*. *Opportunities and Challenges* held at PAU, Ludhiana, on 7th April 2017.

Vyas, A.K., Jain, N.K., Prajapat, K. and Singh, T. 2017. Managing natural resources through agronomic interventions for doubling farmer's income by 2020. In: *Souvenir, 3rd International Conference on Bioresource and Stress Management* held at Jaipur, Rajasthan during 08-11 November, 2017.

Sahni, D., Arora, Sanjay and Singh, Y.P. 2017. Halophilic phosphate solubilizing bacteria for enhancing productivity of crops. In: *4th Lucknow Science Congress,* held at BBAU, Lucknow, during 3-4 March, 2017.

Books /Training Mannual/Chapter

Arora Sanjay, Singh Atul Kumar and Singh Y. P. 2017. *Book on "Bioremediation of Salt Affected Soils: An Indian Perspective"*. 1st edition, Springer, pp.342. [ISBN:978-3-319-48256-9]

Chinchmalatpure, A. R. and Vibhute, Sagar. 2017. Characteristics and Drainage Interventions for Management of Vertisols. In: *Technological Interventions for Enhancing Farm Productivity in Salt-affected Vertisols.* (Eds: Indivar Prasad, Shrvan Kumar, Anil R. Chinchmalatpure and P. C. Sharma) ICAR-CSSRI/Bharuch /Technical Manual/2017/07, ICAR-CSSRI, Karnal, pp. 64.

Chinchmalatpure, A.R. 2017. Reclamation and management of salt affected soils for increasing Farm Productivity. In: *Technological Interventions for Enhancing Farm Productivity in Salt-affected Vertisols.* (Eds: Indivar Prasad, Shrvan Kumar, Anil R. Chinchmalatpure and P. C. Sharma) ICAR-CSSRI/Bharuch /Technical Manual/2017/07, ICAR-CSSRI, pp. 64.

Chinchmalatpure, A.R. and Kumar, Shrvan. 2017. Soil Properties and Nutrient Availability of Saline *Vertisols* of Bara Tract under Sardar Sarovar Canal Command of Gujarat State. In: *Technological Interventions for Enhancing Farm Productivity in Salt-affected Vertisols. (Eds:* Indivar Prasad, Shrvan Kumar, Anil R. Chinchmalatpure and P. C. Sharma) ICAR-CSSRI/Bharuch /Technical Manual/2017/07, ICAR-CSSRI, Karnal, p. 64.

Kumar, Shrvan, Rajeshwar Rao, M.V.S. and Chinchmalatpure, A.R. 2017. Protocols for Soil Sampling, Soil and Water Analysis. In: *Technological Interventions for Enhancing Farm Productivity in Salt-affected Vertisols. (Eds:* Indivar Prasad, Shrvan Kumar, Anil R. Chinchmalatpure and P. C. Sharma) ICAR-CSSRI/Bharuch /Technical Manual/2017/07, ICAR-CSSRI, Karnal, p. 64.

Lata, Charu, Kumar, Naresh, Kaur, Gurpreet, Mann, Anita and Kumar, Ashwani. 2018. *Mahila krishkon ka krishi mein mehtvpuran yogdaan aur samsyaen*. In: *Lawan prabhavit mrudaon mein santulit urvark prabandhan*. Training Manual, ICAR-CSSRI, Karnal, pp.79-82.

Mann, A., Kumar, Ashwani, Meena, B.L., Kumar, Arvind, Sheoran, P., Yadav, R.K., Sanwal, S.K. and Sharma, P.C. 2018. *Lavan prabhavit mardaon mein santulit urvark prbandhan*, Training Manual/ICAR-CSSRI/ Karnal, pp.82.

Prasad, Indivar, Kumar, Shrvan, Chinchmalatpure, A.R. and Sharma, P. C. 2017. *Technological Interventions for Enhancing Farm Productivity in Salt-affected Vertisols.* ICAR-CSSRI/Bharuch /Technical Manual/2017/07, ICAR-CSSRI, Karnal, pp.64.

Rajkumar, Kumar Ashwani, Singh, Anshuman, Kumar, Rajender and Sharma, P.C. 2018. *Lavan parbhavit khetro kai antergat phaldhar variksho ki kheti kai vavsae kai avsar evam parbhandhan*, CSSRI/Karnal/Training Mannual. pp. 110.

Rajkumar, Kumar, Arvind and Singh, Anshuman. 2018. Nursery management and vegetative propagation for enhancing salt tolerance in fruit crops. ICAR-CSSRI/Karnal/Training Manual. pp. 33.

Raju, R., Prajapat, K., Sheoran, P., Kumar, A., Kumar, Navin and Sharma, P.C. 2018. *Krishi upadon ke vipnan hetu kisano ka koshal vikash*. Training manual, ICAR-CSSRI, Karnal.pp. 83.

Sheoran, P., Raju, R., Kumar, Naveen,Verma, Ramesh, Singh, R.K. and Sharma, P.C. 2017. *Fasal utpadhan mai chhidkow taknik ka mahatav*. CSSRI/Training Mannual. pp. 70.

Sheoran, P., Singh, R.K., Prajapat, K., Raju, R., Kumar, A., Singh, A. and Sharma, P.C. 2017. *Lawan-grast mardaon evam nimn gunwatta jal ka phasal utpadan me samgatisil prabandan*. Training manual/ICAR-CSSRI/ Karnal.pp. 74.

Kumar, Shrvan, Rao, M.V.S. Rajeshwar, and Chinchmalatpure, A. R. 2017. Protocols for Soil Sampling, Soil and Water Analysis. In: *Technological Interventions for Enhancing Farm Productivity in Salt-affected Vertisols. (Eds:* Indivar Prasad, Shrvan Kumar, Anil R. Chinchmalatpure and P. C. Sharma) ICAR-CSSRI/Bharuch /Technical Manual/2017/07, ICAR-CSSRI, pp. 64.

Singh, Anshuman and Rajkumar 2017. *Lavan parbhavit mirdao mai phalo ki kheti. Lavangrasth mirdao evam niman gunvanta jal ka fasal utpatan mai sangthishel parbandhan*, Training Mannual/2017/6, ICAR-CSSRI, pp.74.

Book/Manual /Chapter

Ahalawat, D.S. and Sheoran, P. 2017. Bijopchar: Sawasth kheti ka aadhar. In: *Fasal utpadhan mai chhidkow taknik ka mahatav* (Eds. Parvender Sheoran et. al.), CSSRI/Training Mannual, pp.18-22.

Arora, Sanjay, Singh, A. K., and Divya, Sahni. 2017. *Bioremediation of Salt-Affected Soils: Challenges and Opportunities, Book Chapter Published in Book on "Bioremediation of Salt Affected Soils: An Indian Perspective"* (Eds Sanjay Arora, Atul Kumar Singh and Y. P. Singh.). 1st edition, Springer, pp. 275 -301.

Arora, Sanjay and Rao, G.G. 2017. Bio-amelioration of salt-affected soils through halophyte plant species. In: *Bioremediation of Salt Affected Soils: An Indian Perspective* (Arora *et al.* eds.), Springer, pp. 71-85.

Arora, Sanjay and Vanza, M. 2017. Microbial approach for bioremediation of saline and sodic soils. In: *Bioremediation of Salt Affected Soils*: An Indian Perspective (Arora *et al.* eds.), Springer, pp. 87-100.

Arora, Sanjay. 2017. Diagnostic properties and constraints of salt-Affected soils. *In*: *Bioremediation of Salt Affected Soils: An Indian Perspective* (Eds.Arora *et al.*), Springer, pp. 41-52.

Asrey, Ram, Kumar, Satyendra and Meena, N.K. 2017. Influence of water quality on postharvest fruit and vegetable quality. In: *Preharvest modulation of postharvest fruit and vegetable quality*. (Eds.W. Siddiqui) *Elsevier Inc*, pp. 169-187.

Chand, Mehar, Singh, Narender and Sheoran Parvender. 2017. *Kharpatwar Niyantaran*: *Chhidkao karte samay dhyan rakhne yogea bhaten*. In: *Fasal utpadhan mai chhidkow taknik ka mahatav* (Eds. Parvender Sheoran et. al.), CSSRI/Training Mannual, pp.4-11.

Charu, Lata, Kaur, Gurpreet Mann, Anita, Kumar, Ashwani, Singh, Jogendra and Sanwal, S.K. 2017. *Lawan sahishnuta mein dwitiya kchyapachyon* (secondary metabolites) *ki bhumika*. *Krishi Kiran*. pp. 85-89.

Chinchmalatpure, A.R. 2017. Management of salt affected Vertisols for increasing farm productivity and farmers' income. In: *Reference manual of 21 days ICAR sponsored winter school at NAU, Bharuch on "Approaches for doubling farmers' income"* (Eds. Patel *et. al.*), Navsari Agricultural University, pp. 201-210.

Chinchmalatpure, A.R. 2017. Management of salt affected Vertisols for increasing farm productivity and farmers' income. In: *Reference manual of 21 days ICAR sponsored winter school at NAU, Bharuch on "Approaches for doubling farmers' income"* (Eds. Patel *et al*), Navsari Agricultural University, pp. 201-210.

Devi, Ritu, Chaudhry, Madhu, Rani, Martina, Yadav, A.K., Dutta, Assim, Sharma, P.C., and Jat, H.S. 2016. *Shariye evam sudhri hue Shariye mirdoo mai padap varidhi jadiye jivanvo ka mahatav*. Krishi Kiran, ICAR-CSSRI, pp. 58-61.

Fagodiya, R.K., Meena, B.L., Prajapat, K., Meena, R.K., Barman, A. and Kumar, M. 2016-17. *Tikav krishi utpadan ke liye uchit nitrogen prabandhan*. *Krishi Kiran*, 9: 39-45.

Gill, S.C., Chokkar, R.S., Meena, R., Tripathi, S.C., Prajapat, K., Kajla, Mamta, June, Vikash and Sharma, R.K. 2017. *Badlate jalvayu me gehun ke poshan prabandhan ki samasya evam samadhan*. In: *Jalwayu smart krishi dwara khadayan evam poshan suraksha*. (Eds. Sendhil, R. *et al*.). ICAR-IIWBR, Karnal, pp. 108-111.

Kumar Ashwani, Prajapat K., Lata C. Mann A. Kumar A., Meena BL and Sanwal S.K. (2018). *Faslo mein khnij poshak tatvon ka prbandh*. In: *Lavan prabhavit Mardaon mein santulit urvark prbandhan*. Training Manual (Eds. A. Mann *et al.*). ICAR-CSSRI, Karnal, pp.62-69 .

Kumar, Arvind, Prajapat, Kailash, Kumar, Ashwani, Mann, Anita and Sanwal, S.K. 2018. *Lawan prabhavit shetron ke liye genhu ki kheti aur prabandhan padtiyan*. In: *Lawan prabhavit mrudaon mein santulit urvark prabandhan*. Training Manual, ICAR-CSSRI, pp. 39-49.

Majumder, S. P., Krishna, Chaitanya, A., Datta, A., Padhan, D., Badole, S. and Mandal, B. 2017. Dynamics of carbon and nitrogen in agricultural soils: Role of Organic and Inorganic Sources. In: *Soil Management and Climate Change: Effects on Organic Carbon, Nitrogen Dynamics, and Greenhouse Gas Emissions*. (Eds. Raúl Zornoza Belmonte) (Elsevier publication), pp.151-169.

Meena, B.L., Meena, R.L., Kanwat, M., Kumar, A. and Dotaniya, M.L. 2017. Impact of climate change under coastal ecosystem and adaptation strategies *In: Climate Change and Sustainable Agriculture* (Eds. P.S. Kumar et al.), pp.55-66.

Meena, B.L. and Fagodiya, R.K. 2018. *Zinc ki kami wali mridaon ka prabandhan aevam fasalwar sifarisen*. In: *Lawan prabhavit mridaon mein santulit urvarak prabandhan*. (Eds. Mann et al.,). ICAR-CSSRI. pp. 50-56.

Meena, B.L., Fagodiya, R.K., Meena, R.L., Kumar, Parveen, Kumar, Ashwani, Kaledhonkar, M.J. and Prajapat, Kailsh. 2016-17. *Fasloutpadan mein uchit zinc prabandhan ka mahtv*, *Krishi Kiran,* ICAR-CSSRI.pp. 20-26.

Meena, B.L., Meena, R.L., Kumar, Parveen, Kumar, Ashwani and Kaledhonkar, M.J. 2016. In: *Integrated management of zinc and iron deficiencies in mustard in salt affected soils.* Salinity News, 22: 2.

Meena, R.L., Fagodiya, R.K. Meena, B.L. and Prajapat Kailash. 2016-17. *Dhan ki seedhi bijaee: badalte pryavaran parivesh mein uttam praudygiki*. *Krishi Kiran,* 9: 46-51.

Meena, R.L., Kaledhonkar, M.J. and Sheoran, Parvender. 2017. *Nimn gunvata lavania avam kshariye jal ka fasal utpadhan mai satat upyog*. In: *Lawan-grast mardaon evam nimn gunwatta jal ka phasal utpadan me samgatisil prabandan* (Eds. Sheoran et. al.), CSSRI/Taining Mannual, pp.35-44.

Pooja, Kumar, Ravinder, Chand, Mehar, Kumar, Ashwani and Kulsherstha, N. 2017. *Ganne ki phasal aur sukha tnaao- Parbhao evam bachao haitu taknikia*, *Krishi Kiran*, pp. 77-84.

Prajapat, K., Chaudhary, G.L., Meena, R.P., Fagodiya, R.K., Meena, B.L., Kumar, A., Meena, R.K. and Kumar, Ashwani. 2016-17. *Mradaon mein paushak tatvon ki kamee evam sudhar ke upay*. *Krishi Kiran,* 9: 27-34.

Prasad, Indivar. 2017. Doubling farmer's income: selection of crop and varieties for salt affected soils. In: *Reference manual of 21 days ICAR sponsored winter school at NAU, Bharuch on "Approaches for Doubling Farmers' Income"* (Eds. Patel, KG et. al.), Navsari Agricultural University, pp. 172-180.

Rai, A.K., Basak, N., Kumar, K., Sundha, P., Dixit, A.K., Yadav, R.K. 2017. Forage production in problematic soil: Indian perspectives. In: *Approaches Towards Fodder Security in India*. (Eds. Ghosh, P.K., Mahanta, S.K., Singh, J.B., Vijay, D., Kumar, R.V., Yadav, V.K. and Kumar, Sunil), *Studera Press,* New Delhi. pp. 151-172.

Raju, R. and Prajapat, K, 2017. *Lawan-grastmrida sudhar taknikiyon ka aarthik mulayankan*. In: *Lawan-grast mardaon evam nimn gunwatta jal ka phasal utpadan me samgatisil prabandan*. (Eds. Sheoran, P. *et al.*). ICAR-CSSRI, Karnal, pp. 69-74.

Raju, R., Prajapat, Kailash, Fagodiya, R.K., Sheoran, Parvendra and Sharma, Anil. 2018. *Krishi Vipnan: Aayam samasyayain aevam samadhan. In: Krishi utpadon ke vipnan hetu kisanon ka Kaushal vikas,* (Eds. R. Raju et al.,). Training Manual, ICAR-CSSRI. pp.9-18.

Sanwal, S.K., Kumar, Ashwani, Lata, Charu, Kaur, Gurpreet, Kumar, Naresh and Mann, Anita. 2018. *Lawan prabhavit shetron mein sabjiyon ki kheti keliye vibhin prabandhan padtiyan*. In: *Lawan prabhavit mrudaon mein santulit urvark prabandhan*. Training Manual, ICAR-CSSRI, pp. 29-38.

Sharma, P.C., Singh Jogendra and Vineeth, TV. 2016. Salt tolerance in Brassicas: Present Status and future thrust area. In: *Plant Stress Physiology*. (eds. P.C. Trivedi). Pointer Publishers, India, pp. 2-27.

Sharma, P.C., Singh, Anshuman, Sheoran, Parvender and Singh, R.K. 2017. *Lavangristh bhumio kai liya CSSRI dwara vikshit taknikia*. In: *Lawan-grast mardaon evam nimn gunwatta jal ka phasal utpadan me samgatisil prabandan* (Eds. Sheoran et. al.), Training Manual/ICAR-CSSRI/ Karnal, pp.1-9.

Sharma, P.C., Singh, Anshuman, Sheoran, Parvender, Kumar, Anil, Raju, R. and Parjapat, Kailash. 2017. *Lavangristh mirdao mai safal fasloutpadhan haitu CSSRI ki unnat taknikia*. In: *Lawan-grast mardaon evam nimn gunwatta jal ka phasal utpadan me samgatisil prabandan* (Eds. Raju, R. et. al.), Training Manual/ICAR-CSSRI/ Karnal, pp.1-9.

Sheoran, P. and Parjapat, Kailash. 2018. *Dhan-Gehoon fasal paddti mai samanvit posak Tatav parbandhan.*2018. *Lavan prabhavit Mardaon mein santulit urvark prbandhan*, (Eds. Anita Mann, Ashwani Kumar, B.L. Meena, Arvind Kumar,Parvender Sheoran, R.K. Yadav,S.K. Sanwal and P.C. Sharma) Training Manual/ICAR-CSSRI/ Karnal, pp. 20-23.

Sheoran, P., Gajendra, Prajapat, K. and Yadav. R.K. 2017. *Lawniye evam kshariye mridaon ka chinhikaran, sudhar evam phasal prabandan*. In: *Lawan-grast mardaon evam nimn gunwatta jal ka phasal utpadan me samgatisil prabandan*. (Eds. Sheoran, P. *et al.*). Training Manual/ ICAR-CSSRI/Karnal, pp. 16-27.

Sheoran, Parvender, Kumar, Naveen and Parjapat Kailash. 2017. *Gehoo ki fasal mai kharpatwar parbandhan.* In: *Fasal utpadhan mai chhidkow taknik ka mahatav* (Eds. Parvender Sheoran et. al.), Training Manual/ ICAR-CSSRI/Karnal, pp.44-66.

Singh, R. K. and Agrawal, A. 2018. Perceived weather anomalies and climate change: Community based adaptation in sustaining natural resources and livelihoods by *Adi* and Monpa communities of Arunachal Pradesh, eastern Himalaya. (Eds. Pandey CB, Kumar M K and Aaur MK and Goyal RK), In: *Climate Change and Agroforestry Adaptation, Mitigation and Livelihood Security*, NIPA, New Delhi, pp. 21-58.

Singh, Y.P. 2017. Crops and cropping sequences for harnessing productivity potential of sodic soils. In: *Bioremediation of Salt Affected Soils*: An Indian Perspective", Springer, ISBN No: 978-3-319-48256-9.

Singh, Y.P. 2017. Multifunctional Agroforestry Systems for Bio-amelioration of Salt Affected Soils. In: *Bioremediation of Salt Affected Soils*: An Indian Perspective", Springer, ISBN No: 978-3-319-48256-9.

Yadav, R.S., Mahatma, M.K., Thirumalaisamy, P.P., Meena, H.N., Bhaduri, D., Arora, Sanjay and Panwar, J. 2017. Arbuscular Mycorrhizal Fungi (AMF) for sustainable soil and plant health in salt-affected soils. In: *Bioremediation of Salt Affected Soils: An Indian Perspective* (Arora *et al*. eds.), Springer, pp. 133-156

Yadav. R.K., Sheoran, P. and Prajapat, K. 2017. *Satat utpadan evam adhik krishi aaye hetu mrida evam jal prikshan*. In: *Lawan-grast mardaon evam nimn gunwatta jal ka phasal utpadan me samgatisil prabandan*. (Eds. Sheoran, P. *et al*.). Training Manual/ICAR-CSSRI/ Karnal pp. 10-15.

Technical Bulletin

Bundela, D.S., Kaledhonkar, M.J., Gupta, S.K., Kamra, S.K., Sharma, D.K., Sharma, P.C. and Chaudhari, S.K. 2017. *Guidelines and cost of Sub-Surface Drainage Technology for large scale reclamation of waterlogged saline soils*. Technical Folder, ICAR-CSSRI/Karnal.

Chinchmalatpure, A.R., Sethi, M., Kumar, Parveen, Meena, M. D., Sidhu, G.S., Surya, J.N., Khurana, M.L., Ram, Sita, Jangra, Sunil, Yadav, Anil and Yadav, R.K. 2016. *Assessment and Mapping of Salt Affected Soils using Remote Sensing and GIS in Southern Districts of Haryana State*. Technical Bulletin, ICAR-CSSRI/ Karnal/2016/1, pp. 49.

Mann Anita, Meena, B.L., Kumar, Ashwani, Sheoran, P., Yadav, R.K. and Sharma, P.C. 2018. *Mrada svasthy kard apanayen, santulit urvrak prabandhan dwara fasal utpadan badhayen*. ICAR -CSSRI/ Karnal/ Extension bulletin /2018/ 02, pp. 28.

Popular Article

Barman, Arijit, Mandal, A. K., Sivastava, R., Yadav, R. K. and Sharma, P. C. 2017. Soil salinity characterization using hyper-spectral remote sensing data. *ICAR News October-December*, pp.11-12.

Basak, N., Biswas, S., Tamang, A., Basak, P., Murmu, S., Hazra, G.C., Mandal, B. 2017. Impact of inorganic fertilizers on soil biological health. *Fertilizer and Environment News*. 3: 13-16.

Dixit, H., Singh, Y.P., Mishra, V.K., Arora, Sanjay and Gupta, R.K. 2017. *Mahanagariy Avseshon dwara Usar Bhumi Ka Sudhar. Kheti, March* 2017, pp.14-16.

Gulati, I.J., Yadava, N.S., Singh, A.K., Gupta, Deepak, Meena, R.L. and Kaledhonkar, M.J. 2017. Wheat cultivation with saline groundwater irrigation using drip in arid Rajasthan. *Salinity News*, 23:4.

Kumar, P., Ali, S., Bundela, D.S., Singh, R. K., Singh, A. and Sharma, D.K. 2016. *Banaspatik jaiv vividhita sanrachhan: Jalwayu tatha anukulan. Krishi Kiran*, 8:71-74.

Mandal, A.K., Datta, Ashim, Kumar, Manish, Singh, Jogendra, Singh, Vijayata and Singh, R. K. 2017. Basmati CSR-30: Doubling farmer's income in sodic soils. *ICAR News October-December*, pp.10-11.

Raju, R and Sharma, P.C. 2017. Socio-economic benefits of Salt affected reclamation in India. *Salinity News*. 23,1:4.

Sarangi, S. K. and Maji, B. 2016. Promising rice germplasm for flood-prone and saline coastal soils. *Salinity News*, 22:2, pp. 3.

.Singh, R.K., Sheoran, P, Prajapat, K. and Sharma, P.C. 2017. Farmer strikes gold with salt tolerant wheat variety: KRL 210. *ICAR-Repoter, Oct.-Dec., 2017*, pp.10-11.

Singh, Vijayata, Singh, Jogendra, Singh, Awtar, Barman, Arijit, Vibhute, Sagar and Tolia, R.S. 2017. "Genetic erosion: a threat to biodiversity depletion. *Innovative Farming*. 2: 63-65.

Singh, Vijayata, Singh, Jogendra, Vineeth, T.V and Sharma, P.C. 2017. *Prosopis juliflora*: a tree for rehabilitating salt affected soils. *Innovative Farming*. 2: 80-83.

Singh,Y.P., Gupta,R.K., Dixit, Himanshu, Mishra,V.K. 2017. Cultivation of Beetroot in between Rice-wheat cropping system. *Kheti,* December, 29-31.

Singh,Y.P., Kumar, Amresh, Nayak, Sharma, D.K., Gautam, R.K., Mishra, V. K., Singh Dhananjay. 2017. Evaluation of Rice Varieties /Genotypes for Salt Tolerance through Farmers Participatory Approach, *Krashika,* 5:2 , 20-26.

Verma, N.K., Singh,Y.P., Singh, A.K., Mishra, V.K. 2017. *Dhan Ki Adhik Pedawar Ke Liye Dhaincha Ki Hari Khad. Kheti*, August, 2017, 30-31.

Participation In Conference/Seminar/Symposium/Workshop

Name	Title	Period
Dr. R. Raju	National Seminar on "Doubling Indian Farmer's Income by 2022. Opportunities and Challenges" held at PAU, Ludhiana	07.04.2017
Dr. Y.P. Singh, Dr. S. K. Sarangi	52nd Rice Group Meeting at Assam Agricultural University, Jorhat	07.04.2017-11.04.2017
Dr. Krishnamurthy, S. L., Scientist	52nd All India Annual Rice Group Meetings at Hyderabad	08.04.2017-11.04.2017
Dr. S.K. Jha	3rd International Conference on status and future of the World's Large Rivers New Delhi	18.04.2017-21.04.2017
Dr. Y.P. Singh Dr. Anil Kumar	Annual review and planning workshop of " Stress Tolerant Rice for Africa and South Asia" (STRASA) NASC Complex, New Delhi	30.04.2017-02.05.2017
Dr. R. Raju	Workshop on "Impact Assessment of Agricultural Technologies" held at ICAR-NIAP, New Delhi	13.05.32017
Dr. R. Raju	Workshop on "Presentation and Persuasion skills for enhancing communication for South Asia Researchers " IFPRI, New Delhi	15.05.2017
Anil R. Chinchmalatpure	Two -day take off workshop of the research project on revival of village pond at PAU Ludhiana	21.07.2017-22.07.2017
Dr. B L Meena	Drought Research and Management at NASC Complex, New Delhi	21.07.2017
Dr. Uttam Kumar Mandal Dr. S. K. Sarangi	Farmers Scientist Interaction Programme under National. Food Security Mission, at Narayanpur, Canning-II. Block, South 24 Parganas	23.08.2017
Indivar Prasad	Annual Crop Meeting of wheat at BHU, Varanasi	25.08.2017-28.08.2017
Assim Dutta	International Conference on "Advances in Potassium Research for Efficient Soil and Crop Management" NASC, New Delhi	28.08.2017-29.08.2017
Dr. Sajay Arora Anil R. Chinchmalatpure	26th National Conference on Natural Resource Management for Climate Smart Sustainable Agriculture, CPGS, CAU(I), Baranapni, Shillong, Meghalaya. Planning and Development Committee of Navsari Agricultural25.09.2017 . University, Navsari	11.09.2017-13.09. 2017
Dr. R.K. Singh	Evidence based policy on land management and ecosystem services, held at German Embassy, New Delhi	26.10.2017
Anil R. Chinchmalatpure Dr. Sanjay Arora	82nd Annual Convention of ISSS and National Seminar, Salt lake, Kolkata	11.12.2017-13.12.2017
Madhu Choudhary	58th Annual Conference of Association of Microbiologists of India (AMI-2017) & International Symposium on. "Microbes for Sustainable Development: Scope & Applications" (MSDSA-2017) BBAU, Lucknow, UP	16.11.2017-19.11.2017
Dr. Uttam Kumar Mandal	Attended meeting of the Scientific Advisory Committee of Ramkrishna Ashram Krishi Vigyan Kendra, Nimpith, South 24 Parganas	18.11.2017
Dr. Y.P. Singh Dr. Priyanka Chandra	National Seminar on "Healthy Soil for Healthy Life" December 5, 2017 organized by Lucknow Chapter, Indian Society of Soil Science at IISR, Lucknow.	05.12.2017
Dr. B. Maji, Dr. D. Burman, Dr. U. K. Mandal,	82nd Annual Convention and National Seminar of Indian Society of Soil Science, New Delhi at Amity University Kolkata, New Town, Kolkata	11.12.2017-14.12.2017
Dr. S. K. Sarangi, Dr. Tashi Dorjee Lama, Dr. Y.P. Singh	National seminar on development of soft skills for attaining excellence in Science held at IISR, Lucknow	12.09.2017
Anil R. Chinchmalatpure	Agriculture Research Council meeting of Anand, Agricultural University, Anand	21-12-2017
Dr. S. Raut	One day Inter-disciplinary National Conference on "Indian Agriculture: Challenges and Opportunities" organized by SVACS College, Buldana, Maharashtra	23.12.2017
Indivar Prasad	"Germplasm Field Day-2017" for selection and collection of germplasm lines, segregating materials and introgressed derivatives, ICAR-CICR Nagpur	04-01-2018
Anil R. Chinchmalatpure	Conference on "Farmers First for Conserving Soil and Water Resources in Western Region"	01.02.2018-03.02.2018
Dr. Uttam Kumar Mandal and Dr. S. K. Sarangi	National Workshop on "Watershed Management under Pradhan Mantri Krishi Sinchayee. Yojana- (WC-PMKSY)" at B. R. Ambedkar Institute of Panchayats And Rural Development, Kalyani, West Bengal organized by National Institute of Rural Development & Panchayati Raj, Hyderabad	05.03.2018-06.03.2018

List of On-going Projects

Institute Funded Projects

Priority area - Data Base on Salt Affected Soils & Poor Quality Waters

1. NRMACSSRISIL201700500929. Spectral characterizations of saline soil located at Nain experimental farm of ICAR-CSSRI in Panipat district of Haryana. (Arijit Burman, R. Srivastava, A.K. Mandal, Jogendra Singh and R.K. Yadav)

Priority Area - Reclamation and Management of Alkali Soils

2. NRMACSSRISIL201400600864. Nutrient and residue management of ZT-DSR basmati rice-ZT wheat cropping system under partially reclaimed sodic soils. (Parveen Kumar, R.K. Yadav, A.K. Rai and Ashwani Kumar)
3. NRMACSSRISIL201500100877. Impact assessment of CSR-BIO on livelihood security of farmers in salt affected regions. (Raju R., T. Damodaran and Thimmappa K.)
4. NRMACSSRISIL201501300889. Impact of secondary salinization and other stressors on agricultural systems: constraints analysis in South-Western Punjab. (R.K. Singh, Satyendra Kumar, Anshuman Singh and Nirmalendu Basak)
5. NRMACSSRISIL201600400902. Farmer participatory enterprise mix diversification on reclaimed sodic land (Gajender, R. Raju, A.K. Rai, R.K. Yadav, Madhu Choudhary, Raj Kumar, Anil Kumar and K.S. Kadian)
6. NRMACSSRISIL201600100899. Characterization and application of sewage sludge and municipal solid waste compost for reclamation of sodic soils. (Parul Sundha, A.K. Rai, Gajender, Nirmalendu Basak and Priyanka Chandra)
7. NRMACSSRISIL201700100925. Isolation, identification and assessment of salt tolerant zinc solubilising bacteria for enhancing availability and use efficiency of zinc in salt affected soils. (Awtar Singh, R.K. Yadav, A.K. Rai and Madhu Choudhary)
8. NRMACSSRISIL201700200926.Dynamics of nitrogen and organic matter fractions in soils under long-term conservation agriculture in reclaimed sodic soil. (Ashim Datta, Madhu Choudhary and P.C. Sharma)
9. NRMACSSRISIL201700300927.Sustainable nutrient management strategies for partially reclaimed salt affected soils. (Ajay Kumar Bhardwaj, Priyanka Chandra and Bhaskar Narjary)
10. NRMACSSRISIL201700600930. Development of endo-rhizospheric fungal consortia to increase salt tolerance in crops. (Priyanka Chandra, Awtar Singh and Kailash Prajapat)
11. NRMACSSRISIL201701500939. Planned adaptations and co-production of adaptive knowledge to agro-ecological stressors: Perspectives of multi-stakeholders of North-Western India. (Ranjay K. Singh, Anshuman Singh, R.K. Yadav, Parveen Kumar and P.C. Sharma)

Priority Area - Drainage Investigations and Performance Studies

12.NRMACSSRISIL2014001000868. Impact assessment of subsurface drainage technology in canal command areas of Karnataka. [(R. Raju, Thimmappa K., Aslam Latif Pathan]

13.NRMACSSRISIL201501400890. Performance evaluation of subsurface drainage systems in Haryana and to implement interventions for improving operational performance and impact. (D.S. Bundela, Bhaskar Narjary Aslam Latif Pathan and R. Raju)

14.NRMACSSRISIL201701000934. Developing guidelines for suitability of geosynthetic filter materials for Sub-Surface Drainage systems in different agro-climatic. (A.L. Pathan, R.S. Tolia and D.S. Bundela)

15.NRMACSSRISIL201701100935. Studies on salt load dynamics of drainage water and improvement in soil salinity in sub surface sites in Haryana, (R.S. Tolia, A.L. Pathan, Kailash Prajapat and D.S. Bundela)

Priority Area - Management of Marginal Quality Waters

16.NRMACSSRISIL201300200847. Hydro-physical evaluation of a rain water harvesting system under saline soil and groundwater environment. (Bhaskar Narjary, Satyendra Kumar and M.D. Meena)

17.NRMACSSRISIL201400300861. Improving farm productivity through sustainable use of alkali waters at farmer's field in rice-wheat production system. (Parvender, R. K. Yadav, Nirmalendu Basak and R.K. Singh)

18.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, Nirmalendu Basak, Satyendra Kumar, Bhaskar Narjari and Gajender)

19.NRMACSSRISIL201500300879. Evaluation of commercial vegetable crops under protected cultivation structures in saline environment (R.L. Meena, B.L. Meena, Anshuman Singh and M.J. Kaledhonkar)

20.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 and Madhu Choudhary)

21.NRMACSSRISIL201502100897. Isolation, identification and evaluation of plant growth promoting bacteria for mitigating salinity stress in crops. (Madhu Choudhary, Gajender and Awtar Singh)

22.NRMACSSRISIL201700900933. Development of salinity yield relations for different crops under micro-irrigation for updating water quality guidelines. (Ram Kishor Fagodiya, B.L. Meena, R.L. Meena, M.J. Kaledhonkar, D.S. Bundela and P.C. Sharma)

Priority Area - Crop Improvement for Salinity, Alkalinity and Waterlogging Stresses

23.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)

24.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)

25.NRMACSSRISIL201500800884. Identification of high yielding and salt tolerant genotypes in pomegranate. (Raj Kumar, R.K. Yadav, Anita Mann, Murli Dhar Meena and Anshuman Singh)

26.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)

27.NRMACSSRISIL201501000886. Improvement of salt tolerance in chickpea through physiological and breeding approaches. (Anita Mann, Jogendra Singh and P.C. Sharma)

28.NRMACSSRISIL201501100887. Development of rice genotypes for salt tolerance in rice: Conventional and Molecular approaches. (Krishnamurthy, S.L., P.C. Sharma, Ravi Kiran K.T., Y.P. Singh and S.K. Sarangi)

29.NRMACSSRISIL201700400928. Development of Soybean [*Glycine max* (l.) Merrillis] genotypes for higher yield under Salt Stress. (Vijayata Singh and S.K. Sanwal)

30.NRMACSSRISIL201700600930. Development of endo-rhizospheric fungal consortia to increase salt tolerance in crops. (Priyanaka Chandra, Awtar Singh and Kailash Prajapat)

31.NRMACSSRISIL201700700931. Development of salt tolerant and high yielding Indian Mustard (*Brassica juncea* L.Czern & Coss) genotypes using Classical and Modern breeding approaches. (Jogendra Singh, P.C. Sharma and Vijayata Singh)

32.NRMACSSRISIL201700800932. Morpho-physiological characterization and standardization of agronomic practices of quinoa (*Chenopoium quinoa*) for salt affected ecosystems. (Kailash Prajapat, S. K. Sanwal and P.C. Sharma)

33.NRMACSSRISIL201701300937. Wheat improvement for salt and waterlogging tolerance thorugh conventional and molecular approaches. (Arvind Kumar, P.C. Sharma, Ashwani Kumar, Indivar Prasad and Y.P. Singh)

Priority Area - Agroforestry in Salt Affected Soils

34.NRMACSSRISIL201600200900. Performance of *Eucalyptus* plantations on water logged saline ecologies. (R. Banyal, Ajay K. Bhardwaj, Gajender and Ashlam Latif Pathan)

35.NRMACSSRISIL201701200936. Evaluation of potential Olive germplasm for salt affected soils. (Manish Kumar and Rakesh Banyal)

36.NRMACSSRISIL201701300938 Enhancing productivity potential of saline soils through agroforestry interventions. (R. Banyal, A.K. Bhardwaj, Parveen Kumar, Raj Kumar and Rahul Tolia) through agroforestry interventions. (R. Banyal, A.K. Bhardwaj, Parveen Kumar and Rahul Tolia)

Priority Area - Reclamation and Management of Coastal Saline Soils

37.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)

38.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)

39.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)

40.NRMACSSRISIL201600600904. 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 T.D. Lama)

41.NRMACSSRISIL201600700905. Assessment and coping strategies of agricultural risk under coastal region of West Bengal – a social-economic analysis. (Subhasis Mandal, U.K. Mandal and T.D. Lama)

42.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)

43.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

44.NRMACSSRISIL201200400845. Breeding and evaluation of field crops for salt tolerance in saline Vertisols. (Indivar Prasad, Anil R. Chinchmalatpure and Shrvan Kumar)

45.NRMACSSRISIL201500200878. Performance of guava orchards with forage intercropping and pruning intensity on saline vertisols of Gujarat (David Camus. D., Anil R Chinchmalatpure and Shrvan Kumar)

46.NRMACSSRISIL201501200888. Impact evaluation of sub-surface drainage technology for reclamation of water logged saline soils in Maharashtra. (Sagar Vibhute D., R. Raju and Anil R. Chinchmalatpure)

47.NRMACSSRISIL201601000908. Cost effective drainage in waterlogged saline Vertisols for improving crop productivity in Gujarat. (Sagar Vibhute D., Anil R. Chinchmalatpure, David Camus. D, Indivar Prasad and M.J. Kaledhonkar)

48.NRMACSSRISIL201601100909. Maximization of yield and factor productivity through integrated nutrient management in desi cotton based cropping systems in saline vertisols. (Shrvan Kumar, Indivar Prasad, David Camus. D and Anil R. Chinchmalatpure)

Priority Area - Reclamation and Management of Alkali Soils of Central and Eastern Gangetic Plains

49.NRMACSSRISIL201500700883. Ground water recharge for remediation of fluoride contaminated water in Unnao district of U.P. (Chhedi Lal Verma, S.K. Jha and V.K. Mishra,)

50.NRMACSSRISIL201601200910. Breeding 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 and S.K. Jha, CSSRI RRS, Lucknow) S. Rajan, Meenakashi Mishra, Muthu Kumar M. (CISH, Lucknow)

51.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)

52.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 and Y.P. Singh)

Externally Funded Research Projects

1. Stress tolerant rice for poor farmers in Africa and South Asia (STRASA Phase 3). Krishnamurthy S.L, P.C. Sharma, Ravi Kiran K.T., B. Maji, D. Burman, S.K. Sarangi, S. Mandal, Vinay Kumar Mishra and Y.P. Singh)- BMGF

2. Intellectual property management transfer/commercialization of agricultural technologies renamed as. (Parveen Kumar, Anita Mann, Rakesh Banyal, Raju R. and Bhaskar Narjary) – (NAIF) ICAR

3. 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 Vinay Kumar Mishra) -UPCAR

4. NRMACSSRISOL201401400872. Bio-remediation of Salt Affected Soils of UP through Halophilic microbes to promote organic farming. (Sanjay Arora and Y.P. Singh) -UPCAR

5. NRMACSSRISOL201401500873. Land Modification based integrated farming system under waterlogged and waterlogged sodic conditions. (Chhedi Lal Verma, Y.P. Singh, T. Damodaran, Atul Kumar Singh, S.K. Jha ,V.K. Mishra and S.K. Singh (NBFGR)} -UPCAR

6. NRMACSSRISOL201401600874. Assessment and refinement of existing irrigation practices of major crop grown under sodic environment. (Atul Kumar Singh, Y.P. Singh, Chhedi Lal Verma and Sanjay Arora) –UPCAR

7. NRMACSSRICOP201500400880. Climate change mitigation and adaptation strategies for salt affected soils. (Ajay K. Bhardwaj, Ranbir Singh, R.K. Singh, Parul Sundha, U.K. Mandal, Shishir Raut, K.K. Mahanta, B. Maji, V.K. Mishra and Rakesh Banyal)-NICRA, ICAR

8. NRMACSSRISOL201501600892. Molecular genetic analysis of resistance/tolerance in rice, wheat, chickpea and mustard including sheath blight complex genomics. [(Rice: component 1): Krishnamurthy, S.L. and P.C. Sharma, (Chickpea: component

3): P.C. Sharma, Anita Mann and Jogendra Singh) (Mustard: component 4): P.C. Sharma and Jogendra Singh)] – ICAR, New Delhi

9. NRMACSSRISOL201501900895. Identification of salt tolerant ber (*Zizyphus mauritiana* Lam.) rootstocks in a farmer participatory mode. (Anshuman Singh, Ashwani Kumar, Parvender Sheoran, Raj Kumar and R.K. Yadav - RKVY

10. 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, R.K. Yadav, D.S. Bundela, B.L. Meena and A.K. Mandal) – RKVY

11. NRMACSSRISOL201502200898. CRP on Conservation Agriculture 'Productive utilization of salt affected soils through conservation agriculture". (Ranbir Singh, Arvind Kumar Rai, Parvender and Aslam Latif Pathan)-ICAR

12. NRMACSSRISOL201601500913. Strategic Research Platform on Climate Smart Agriculture "Developing and defining climate smart agricultural practices portfolios in South Asia". (P.C. Sharma, Ashim Datta and Madhu Chaudhary) ICAR-CCAFS

13. NRMACSSRISOL201601600914. Perceived climatic variability & agricultural adaptations by material resource-poor farmers in salt affected agro-ecosystems: Implications for food & livelihood security. [Ranjay K. Singh, Anshuman Singh, Satyendra Kumar, Pervender and Dheeraj Singh, KVK, Pali (CAZRI)]-ICAR

14. NRMACSSRISOL201601800916. Efficient groundwater management for enhancing adaptive capacity to climate change in sugarcane based farming system. [Satyendra Kumar(CCPI) and Aslam Latif Pathan]-ICAR

15. NRMACSSRISOL201602000918. CRP on water "Evaluation of irrigation system and improvement strategies for higher water productivity in canal command". (Chhedi Lal Verma, A.K. Singh, Dr. Y.P. Singh, Sanjay Arora, T. Damodaran, V. K. Mishra S.K. Jha and C.S. Singh)

16. NRMACSSRICOP201602100919. CRP on water "Groundwater contamination due to geogenic factors and industrial effluents and its impact on food chain" (Anil R. Chinchmalatpure, David Camus D. and Shrvan Kumar)-ICAR

17. NRMACSSRICOP201602200920. Cropping System intensification in the salt-affected coastal zones of Bangladesh and West Bengal, India (LWR/2014/73/KGF). (B. Maji, D. Burman, U. K. Mandal, S. K. Sarangi, Subhasis Mandal and K.K. Mahanta)- ACIAR.

18. 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

19. NRMACSSRICOL201602400922. Developing the alternate strategies for reclamation of sodic soils. [Arvind Kumar Rai, Nirmalendu Basak, R. L. Meena, R. K. Yadav, P.C. Sharma, Parul Sundha, S.K. Jha and U.R. Khandkar, AICRP (MSUSWA), Indore]- RIL

20. NRMACSSRISOL201602500923.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, Ashwani Kumar and B.L. Meena) -RKVY

21.NRMACSSRISOL201602600924. Empowering farmers through selective interventions in salt affected agroecosystems of Ghaghar Plains. {(Parvender, R.K. Yadav, R.K. Singh, Satyendra Kumar, Arvind Kumar, R. Raju, Arijit Burman, S.K. Sanwal and K. Punnusamy (NDRI)}-ICAR

22.Developing low cost ameliorating amendments for reclamation of sodic soils by using municipal solid waste. (Gajender, R.K. Yadav, Madhu Choudhary, Bhaskar Narjary and Ashim Datta)-DST

23.Potential gene mining from salt tolerant grasses for improvement of stress tolerance in crops. {(Anita Mann, Ashwani Kumar, Arvind Kumar, B.L. Meena, Monendra Grover & D.C. Mishra (IASRI, New Delhi), and Parameswaran C. (NRRI, Cuttack)}-NASF-ICAR

24.Phyto-remediation potential of selected halophytes for salt affected lands of Haryana. (Ashwani Kumar, Arvind Kumar, B.L. Meena and Anita Mann) –RKVY

25.Identification of salt tolerant scion and rootstocks in mango and low chill temperate fruits. (Rajkumar, Anshuman Singh, Ashwani Kumar, R.K. Yadav and P.C. Sharma)-RKVY

26.Developing alternatives to gypsum using nanotechnology-based approaches for efficient and cost-effective reclamation of sodic soils. (Ajay Kumar Bhardwaj)-LBS Award

27.Network project on Functional Genomics and genetic modification in crops (NPFGGM) salt tolerance in rice. (S.L. Krishnamurthy and P.C. Sharma) – ICAR- NPTC, New Delhi

28.CRP on Agro-Biodiversity—Component 2 -Evaluation of rice germplasm accessions against biotic/abiotic stresses. (Krishnamurthy S.L. and P.C. Sharma)-ICAR

29.Agricultural livelihood in Eastern coastal region of India under climate and environmental Risk (Subhasis Mandal) --LBS Award project

30.Revival of village pond through scientific intervention (Anil R. Chinchmalatpure, Shrvan Kumar and Sagar Vibhute D.)-DST

31.Development of High Zinc rice varieties.(Krishnamurthy S.L. and P.C. Sharma)-IRRI

32.CRP on Agro-Biodiversity- Sub. Project 1. Characterization, Multiplication and evaluation for important biotic and abiotic traits of plant genetic resources of selected crops (NBPGR) Component II (Biotic and abiotic evaluation) under sub-project-I (Arvind Kumar and P.C. Sharma)

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 of 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. Development of bioformulation (s) for low input organic farming. [(T. Damodaran, CCPI) collaboration with NBAIM, Mau)]

4. Characterization and mining genetic variability in sugarcane germplasm against abiotic stress (Salinity/Alkalinity and low temperature) under subtropical India (Karnal). [(Ashwani Kumar, Co-PI) collaboration with ICAR-SBI,RRS, Karnal)]

5. Exploration of medicinal and aromatic plants cultivation under different cropping systems and on marginal and degraded lands of semi-arid regions of India. {(Anil R. Chinchmalatpure, Co-PI) collaboration with ICAR-DMAPR, Anand, Gujarat)

Consultancy

1. Subsurface Drainage for Heavy Soils of Maharashtra, Karnataka, Gujarat, AP & Telangana (Team Leader: Dr. PC Sharma DS Bundela (PI), Satyendra Kumar, Anil Chinchmalatpure, R. Raju, Aslam Pathan, Sagar Vibhute and Rahul Singh Tolia)

2. Evaluation of BAYER rice hybrids under salinity stress phase II. (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 D. and P.C. Sharma)

4. Utilization of treated effluent from Aniline –TDI Plant of GNFC Unit II in *rabi* Maize and its long term impact on properties of Vertisols" M/s Gujarat Narmada Valley Fertilizer and Chemicals Ltd, Bharuch Gujarat

Contract Research

1. Testing of Agro-chemical/herbicide supplied by AkzoNobel India Limited. (Parvender and Kailash Prajapat)

INSTITUTE ACTIVITIES

Institute Joint Staff Council Meeting

Institute Joint Staff Council Meeting was held at ICAR-CSSRI, Karnal on 10th August, 2017 under the Chairmanship of Dr. P.C. Sharma, Director. It was attended by Dr. R.K. Yadav, Head, SCM, Div., Dr. S.K. Sanwal, Head (A) CI, Div. Sh. Abhishek Srivastava, SAO, Sh. N.K. Vaid, OIC, Estate and Sh. Tarun Kumar, Sh. Suresh Pal Rana, Sh. Purshotam Lal, Sh. Devender Kumar, Sh. Zile Singh and Sh. Sukhbir Singh. 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

IJSC meeting in progress

QRT Meetings

The ICAR constituted Quenquennial Review Team (QRT) under the chairmanship of Dr. I.P. Abrol (former DDG (SAE) for the period 2011-2017). Dr. Raj K Gupta, Dr. Mahimai, Dr. K.V.G.K. Rao, Dr. V.P. Singh and Dr. J.P. Sharma are the member of QRT while Dr. M.J. Kaledhonkar is the member secretary to review achiements of ICAR-CSSRI and AICRP on Salt Affected Soils & Use of Saline Water in Agriculture and to provide future direction to salinity /sodicity research in the country.

The first meeting of the above said QRT was held at ICAR-CSSRI during 17-18 Nov. 2017. Director, ICAR-CSSRI, Heads of Divisions, RRSs, and OIC (PME) participated in the meeting. Dr. P.C. Sharma, Director, ICAR-CSSRI explained various technologies developed besides the extension works being undertaken by the institute during the period under report. The institute has initiated nano-technological research with state of art laboratory. AICRP Centres in collaboration with ICAR-CSSRI also have calibrated and validated applicable concepts and developed technologies suiting to agro-climatic regions and benefitting farmers in respective regions. Challenges ahead are less availability of good quality gypsum, deteriorating ground water quality, higher cost of subsurface drainage installations, subsoil sodicity in Gangetic plain and subsoil salinity in Vertisols, inherent soil salinity in coastal soils and climate change. The Heads of Divisions and Regional research stations also presented progress and provided details of future plans. The QRT also interacted with staff of the institute. The QRT is of firm opinion that ICAR-CSSRI should develop technologies for reducing salts and improving water availability in root zone for better crop growth irrespective agro-climatic region. There should be focus on improving soil organic carbon, soil physical, chemical and biological properties. Technologies developed by ICAR-CSSRI and AICRP centres should be climate resilient.

QRT Meeting in progress

Institute Management Committee Meeting

The 42[st] Institute Management Committee meeting was held on 6[th] March, 2018 at Karnal and was attended by the following IMC Members.

1.	Dr. P. C. Sharma, Director, 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. Dey, Project Co-ordinator, IISS, Bhopal	Member
5.	Sh. Naresh Kumar Arora, FAO, ICAR, New Delhi	Member
6.	Sh. Tejbir Singh, CTO, ICAR, New Delhi	Member
7.	Sh. Abhishek Srivastava, SAO, CSSRI, Karnal.	Member Sec.

The Meeting started with the confirmation of the proceedings of the last meeting held on 8[th] March, 2017. Subsequently, the research achievements of different Divisions, Regional Research Stations and Project Coordinating Unit were discussed for the period of May-December, 2017. This was followed by discussion on other activities carried out during May-December. 2017. 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.

IMC Meeting in progress

Workshop, Seminar, Training, Foundation Day and Kisan Mela organised

Pre-Kharif Kisan Goshthi

A pre-kharif kisan gosthi was organized under 'Mera Gaon Mera Gaurav' programme in Mandi Khurd village of Jind district on 12th May, 2017. In this Goshthi, about 100 farmers participated and discussed their soil and water related problems with the scientists. Dr. Ajay Bhardwaj explained the objective of the Goshthi while Dr. Rakesh Banyal apprised the farmers about the salinity management technologies developed by the Institute and the recent government schemes and initiatives to double the farmer's income. Dr. Yash Pal Malik, Scientist, KVK, Jind informed the farmers about integrated insect and disease management in rice and cotton crops. Dr. Rajinder Garg, Veterinary Officer, informed the farmers about the management of different livestock diseases. Farmers were requested to stop crop residue burning to prevent the environmental pollution. Soil and water samples were collected from the farmers of these villages for testing. Such pre-*Kharif* goshthis were also organized under Farmer FIRST project in Mundri, Geong, Kathwar, Sampli Kheri and Bhaini Majra villages of Kaithal district during 5-7 May, 2017. A total of 180 farmers participated in these goshthis and acquainted themselves about improved nursery management in rice, fungicide treatment for managing foot rot and bakane disease and soil testing for the balanced nutrient management in rice crop. Farmers were informed about the importance of soil health and were urged to get their Soil Health Cards prepared. They were also informed about improved techniques and salt tolerant cultivars for obtaining higher crop yields from the salt affected lands.


Scientist Farmers Interaction

Training programme for Maharashtra Farmers

A four days training programme on 'Sustainable management of crop productivity in salt affected soils and poor quality waters' was organized for 15 farmers of Ahmednagar district of Maharashtra State from 5-8 June, 2017. Dr. A.K. Singh, DDG (Agric. Extn.), ICAR, New Delhi inaugurated the training programme. Dr. Singh appreciated the noteworthy contributions of ICAR-CSSRI in the reclamation of vast tracts of salt affected soils in different parts of the country. He emphasized that continued salinization of soil and water is a cause of concern as it causes huge crop and monetary loss in Maharashtra and other parts of the country. He advised the farmers to have regular contact with the scientists of ICAR Institutes and Krishi Vigyan. Kendras located in Maharashtra and take advantage of recent schemes such as e-kisan portal for enhancing the farm incomes. Dr. P. C. Sharma, Director, ICAR-CSSRI, Karnal explained in detail about the gypsum technology, sub-surface drainage method and salt tolerant varieties of different crops released by the Institute which have been instrumental in augmenting the productivity of over 2 million ha salt affected area in different parts of the country. He informed that a new project for the management of problematic soils of Maharashtra state with financial assistance from the World Bank is to be initiated shortly. The farmers attending this programme brought their soil samples which were analyzed and the information was summarized in 'Soil Health Cards' subsequently handed over to the respective farmers.

Dr. A.K. Singh, DDG (Agric. Exten.) with farmers of Maharastra

Technical Committee Meeting for HOPP Project

ICAR-CSSRI, and Agriculture & Farmers' Welfare Department, Govt. of Haryana jointly organized the 'First Meeting of Technical Committee for Haryana Operational Pilot Project (HOPP) on Sub Surface Drainage (SSD)' on 12th July, 2017at ICAR-CSSRI Karnal to review the current status of SSD projects in Haryana and to discuss the project agenda for its faster implementation during 2017-22. About 25 senior officers and scientists participated in the meeting. Dr. P.C. Sharma, Director, ICAR-CSSRI & team leader of the project welcomed the participants and stressed, to expedite the pace of implementation of SSD projects for addressing reclamation of waterlogged saline lands in the state in time bound manner to strengthen the livelihood security of the affected farmers. Dr. D.S. Bundela, PI (HOPP Project) presented the current status of SSD projects in Haryana and time period required to reclaim the total area affected. Some noted experts in the field discussed the 10 point agenda thoroughly in the meeting. Responses on each agenda were obtained from the concerned officers/ scientists and then the final decisions were made. The work plan for HOPP Project for 2017-18 was also finalized.

Technical committee meeting in progress

Van Mahotasava

'Van Mahotsava' was celebrated in collaboration with Forest Department, Haryana on 8th August, 2017. At the outset, Dr. Rakesh Banyal threw light on the importance of the event that was marked by the planting of 400 plants of different forest, landscape, medicinal and aromatic plants including 200 saplings of *Prosopis*. Dr. P.C. Sharma, Director explaned that trees play a critical role in our lives and stressed that Institute is committed to increase tree cover in degraded salt affected lands. Chief Guest Dr. Gurbachan Singh informed that environmental pollution has attained serious levels in different parts of the world and it can be checked by the large scale plantation of different tree species. *Prosopis* and cactus were promising species for the revegetation of salt affected and water stressed areas. He stressed the need to fast track research on *Prosopis*. Sh. Bijender

Dr. Gurbachan Singh, Former Chairman, ASRB planting a tree

Singh, DFO, Guest of Honour on the occasion exhorted that people should be sensitized to plant more trees on the occasion of 'Van Mahotsava'.


Farmers participating in the camp

Awareness-cum-Training Camp on Animal Health

An animal health camp and awareness programme was organized in village Kathwar of Kaithal district on 11th August, 2017 to sensitize the farmers about balanced feeding, management practices for fodder availability round the year, clean milk production, proper sanitation in the animal sheds and precautionary measures for keeping their animals healthy. About 170 farmers participated in the programme. Dr. Parvender Sheoran, PI, briefed about the project activities highlighting the importance of animal component in agriculture for income generation. He advised the farmers to adopt multi-enterprise agriculture model particularly small and marginal farmers to fulfill their dietary requirements and nutritional security. Dr. Mahender

Singh, NDRI, Karnal advised the farmers for breeding improvement through artificial insemination, use of mineral mixture for balanced rationing, proper vaccination and management practices to reduce the problems of mastitis and repeat breeding in animals. He

sensitized the farmers for proper sanitation in the animal sheds and deworming for better health. A total of 80 animals were medicated for different diseases and about 20 animals were artificially inseminated. Mineral mixture was distributed among the participating farmers.

Hindi Pakhwara

The Institute organised 'Hindi Pakhwara' during September 14-28, 2017 which was inaugurated by Dr. R.R.B. Singh, Director, ICAR-NDRI, Karnal on 14th September, 2017. On this occasion, he praised the efforts of the institute to use hindi in day-to-day official work. He told that India is a country of diversity and Hindi language alone is capable of integrating the diverse features. Realising this fact, Mahatma Gandhi used hindi language as medium of communication during the freedom struggle. He emphasized that hindi is language of our pride and national unity. It is simple and scientific language which needs to be strengthened by doing maximum official work in this language. On this occasion Dr. P.C. Sharma, Director, ICAR-CSSRI informed that using Hindi in official work is our constitutional responsibility. Hindi is a language spoken by third largest number of people in the world and in modern digital world also hindi is gaining much importance.

During the Pakhwara, different competitions in Hindi such as *Ashu Bhashan, Nibandh Lekhan, Aavedan Patra, Computer mein hindi typing, Tippani evam masauda lekhan, Prashanottari Pratiyogita, Chal vaijayanti Pratiyogita, Sarkari Kamkaj me Mool Hindi Aalekhan, Hindi Geet Antakshari* and *Takniki Poster Pradarshani* were organized. The Hindi Pakhwara concluded on 28th September, 2017 with *Kavita paath prtiyogita* and report presentation by Dr. Anil Kumar, Chairman of Hindi Pakhwara Samiti. On this occasion, the Chief Guest Dr. Priyanka Soni, IAS and Commissioner, Municipal Corporation Karnal distributed prizes to the winners of different competitions organised. In her valedictory address Dr. Soni told that English is spoken worldwide, the importance of Hindi cannot be overlooked. We always think in our mother tongue and then convert the thought in other

Chief Guest Dr. R.R.B. Singh, Director, NDRI addressing the gathering

language. She expressed satisfaction over the extent of use of official language in the institute for day-to-day work.

Hindi week celebration in RRS, Bharuch

The Bharuch Research Station celebrated Hindi week during 14-20 September 2017 during which events like quiz, letter writing, essay writing, precise writing and elocution were organized and all the staff participated in these events. The concluding event of the Hindi Week was inaugurated by the Chief Guest Dr Ravi Mohan Sainy, ASP (IPS), Ankleshwar, Bharuch. The chief guest distributed the gifts to all the participants/winner in different events. The chief guest has well appreciated the work culture and different activities being undertaken in this Office.

Independence Day Celebration

Independence day was celebrated on 15th August, 2017 at the Institute. On this occasion,Dr. P.C. Sharma, Director unfrurled the National Tricolour Flag. He exhorted the scientists and other employees to make strenuous efforts for ensuring food and nutritional security of about 125 crore people. Currently about 100 research institutes and 70 agricultural universities are working to develop technologies for enhancing the farmers' income in different parts of the country to achieve the Prime Ministers vision of

Dr. P.C. Sharma, Director, ICAR-CSSRI addressing the institute staff doubling farmers income by 2022. In this regard, the institute has initiated research and extansion work in several salinity affected villages.

Training programme on Importance of Spray Technique in Crop Production

A three days training programme on "Importance of Spray Technique in Crop Production" was organized at Krishi Vigan Kendra, Kaithal during September 6-8, 2017. About 57 farmers from Farmer FIRST adopted villages were acquainted with management practices for insect-pests and weed management in rice-wheat cropping sequence, critical points to be kept in mind while

purchasing, selection & use of pesticides, dosage, spraying technologies as well as precautionary measures. Herbicide resistance in *Phalrais minor* is the major cause of concern limiting wheat production to a greater extent as well as putting additional expenses towards production cost. The farmers were asked to follow recommended package of practices for managing the weeds through direct sowing with zero drill machine, early wheat sowing, pre-emergence application of pendimethaline, rotational use of post-emergence herbicides, recommended water quantity and use of flat fan nozzle. Identification of key pests and their control measures in rice, wheat, sugarcane and vegetables was the focussed course content of the said training.

Dr. P.C. Sharma, Director, ICAR-CSSRI addressing the farmers

Field day on Rice Residue Management

A field day on residue management in rice was organized in village Kathwar at farmer's field on 2nd October, 2017 with the aim to sensitize the farmers about the ill effects of residue burning on soil health and environmental quality. Dr. Parvender Sheoran, PI, said that residue incorporation will not only enhance the soil quality but will also improve the water intake capacity of sodic soils leading to overall increased crop productivity and

Demonstration of Happy Seeder

profitability. He further stressed that residue burning results in the release of harmful gases which case pollution and health problems. Live demonstration on managing residue with '*Mulcher*' and wheat sowing with *'Happy Seeder'* in anchored rice stubbles were shown to the farmers. Residue incorporation and direct wheat sowing not only improve the soil fertility status and quality in long run but also increases yield and saves money. The farmers were also cautioned about the government initiatives for imposing fine if somebody found guilty for residue burning. On this occasion of Gandhi Jayanti, Dr. Sheoran also highlighted the need of cleanliness drive by our beloved Prime Minister by maintaining proper sanitation in the surroundings and delivered his message on *'Swachhta hi Sewa'.*

Mahila Kharif Kisan Mela

A *Mahila Kharif Kisan Mela* was organized on 15th October, 2017 in village Sikandar Kheri of Kaithal district of Haryana. Chief Guest Dr. Ramesh Yadav, Chairman, Haryana Kisan Ayog appreciated the efforts being made by the ICAR-CSSRI in the transfer of salinity management technologies for benefitting the farmers in the salinity affected areas. He advised the farmers to have a close contact with the scientists for the adoption of improved 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. S.K. ADG (SWM), ICAR Chaudhari informed the farmers about different government initiatives for sustainable resources use and doubling the farm incomes. Dr. P. C. Sharma, Director, ICAR-CSSRI urged the farmers to adopt salt tolerant varieties of wheat and mustard developed by ICAR-CSSRI. He also advised the farmers to stop crop residue burning and use more organic inputs such as FYM and green manures for sustaining the soil health. A '*Farmer-Scientist Interaction Workshop*' was also organized during the *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.

Dr. Ramesh Yadav, Chairman, Haryana Kisan Ayog addressing the farmers

Dr. Gurbachan Singh, Former Chairman, ASRB addressing the delegates

International training Programme on Use of Poor Quality Water in Agriculture

An International training programme on "Use of Poor Quality Water in Agriculture" was organized during 10-24 November 2017. This programme was sponsored by African-Asia Rural Development Organisation (AARDO). In this training programme, 10 delegates from 10 different African-Asian countries (Bangladesh, Sri Lanka, Taiwan, Syria, Sudan, Egypt, Palestine, Jordan, Malaysia and Nigeria) participated. In the concluding session, Chief Guest Dr. Gurbachan Singh, Ex Chairman, ASRB, New Delhi emphasized on the importance of the subject for the upliftment of the agriculture and rural development. He also mentioned that the collaborative efforts should be made on the management of salt affected soils and use of poor quality water in agriculture among other countries to address the issues globally and CSSRI has to play a lead role for the countries affected severely by the problems of water quality. The Guest of Honour, Secretary General (AARDO), His Excellency Engg. Wassfi Hassan EL-Sreihen appreciated the effoprts and cooperation of ICAR and CSSRI for organizing such programmes since 2010, the 18 member countries are benefited by the 52 delegates trained on the aspect. He also thanked ICAR and Ministry of Rural Development, Govt. of India for support and cooperation extended for these programmes. Dr. P.C. Sharma, Director, CSSRI, Karnal assured the Secretary General, AARDO for international cooperation to tackle the problems in a coolaborative approach for the use of poor quality water in agriculture.

Farmers' Goshthis: Co-Learning and Co-Production of Knowledge for Community Based Management of Sodic Agroecosystems

Two different farmers' goshthis were organized in village Begampur of Karnal district. The first goshthi was held with about 40 women farmers with objective to enhance the capacity building of women to sustain the livelihoods under risk-prone sodic agroecosystems. Soil health cards, zero/reduced-till agriculture, use of rice residues, interventions of salt tolerant varieties like wheat KRL-210 for higher production and developing seed-based micro-enterprises among women, and community based adaptations in sodic agroecosystem were focal points of discussion during this goshthi. Women showed keen interest to have the soil health cards based agroadvisories, knowledge on climate variability induced stressors, standard protocol of farmer-led seed

Scientist - Women farmer interaction meeting

production and knowledge on policies relating to agricultural adaptations. Soil samples were also collected from the field of 10 women farmers to develop Soil Health Cards. Begampur village has about 40 ha of sodicity affected land where technological interventions like gypsum-based package and salt tolerant varieties can be implemented for higher productivity. The second Goshthi was also held in Begampur village on 14th November 2017 with 20 farmers to enhance the knowledge network and adaptation process using a multi-stakeholders' approach. The issues discussed earlier in the first Goshthi, were discussed again in greater details. Village Panchayat has passed a resolution on zero-burning of crop residues on Panchayat land. This policy can be further strengthened by providing Happy Seeder machine on custom hiring basis to the farmers who take Panchaytat land on lease basis. ICAR- CSSRI, Karnal, will provide technological support to the Village Panchayat. An exercise on participatory mapping of sodicity affected lands was done followed by transect walks across the landscape for understanding soil health and sodicity pattern. A total of 20 soil samples were taken from the Panchayat lands and individual farmers to develop Soil Health Card for the effective management of community land. Dr. Ranjay K. Singh Co-ordinated these gosthies.

Celebration of Kisan Diwas

Kisan Diwas and farmers' training under skill development programme with financial assistance from M/s Gujarat State Bio-Technology Mission, Gandhinagar was celebrated on 03-11-2017 in which 100 farmers participated from Jambusar, Amod, Vagra and Hansot talukas of Bharuch district and officials from agricultural department (Bharuch, Amod, Jambusar, Vagra), Agricultural College Bharuch, NABARD, various NGO and KVK participated. The programme was inaugurated by Dr. C. J. Dangaria, Hon'ble Vice Chancellor of Navsari Agril. University, Navsari. Lectures were arranged from different resource persons from KVK, Chaswad, College of Agriculture, Bharuch and from RRS Bharuch. Certificate to progressive farmers and seed of KRL 210 distributed to 50 farmers under MGMG program.

Dr. C.J. Dangaria addressing the farmers

World Soil Day

The Institute organized World Soil Day on 5th December 2017 at Karnal. The celebration was marked by the distribution of Soil Health Cards to 60 Farmers adopted by the Institute. These cards were distributed by the Chief Guest of the function Honorable Member of Legislative Assembly, Assandh (Haryana State), Sh. Bakhshish Singh Virk in the presence of Guest of Honour Dr. S.K. Chaudhari, ADG (S&WM), ICAR and Dr. P.C. Sharma, Director, ICAR-CSSRI, Karnal Chief Guest Sh. Bakhshish Singh Virk called upon the farmers to maintain good soil health for achieving higher agricultural productivity. Dr. S.K. Chaudhari highlighted the importance of World Soil Day and stressed the need for awareness among farmers with regard to nutrient use and maintaining soil fertility based on Soil Health Card. Dr. P.C. Sharma assured the farmers for all the help in soil testing and other facilities. The World Soil Day programme was attended by 60 farmers, 100 students and 21 teachers of local schools of Karnal and employees of ICAR-CSSRI, Karnal. Video/short film of World Soil Day was displayed on this occasion during the main function.

Sh. Bakhshish Singh Virk with Farmers

Agricultural Education Day

Agricultural Education Day was celebrated at ICAR-CSSRI, Karnal on 5th December, 2017. The purpose of this event was to provide exposure to the school students with regard to educational and job opportunities in the field of agriculture.

The event was marked by Quiz and Debate Competitions for the students of 8-10 standards and a presentation by the Institute scientist on educational and job opportunities in agriculture. The Topic of the debate was "Is burning Crop Residues by Farmers a Necessary Evil?". A total of 19 schools sent their student teams for Quiz and Debate competitions. A total of 100 students along with 21 teachers accompanying them participated in the programme. Prizes and certificates were distributed to the winner students for both the competitions.

Director along with Students

ICAR-Mid Term Review Meeting of Regional Committee Zone-V

ICAR- Mid Term Review Meeting of Regional Committee Zone-V (Punjab, Haryana & Delhi) was held at ICAR-CSSRI, Karnal on 12th December, 2017. More than 50 Participants from ICAR Institutes, SAUs and State Agriculture Departments of Punjab, Haryana & Delhi states participated in review meeting and discussed about the Action Taken Report and recommendations made in 24th ICAR Regional Committee Zone–V meeting held at ICAR-IARI, New Delhi during 3-4 October, 2016. At the onset of the meeting Dr. P. C. Sharma, Director, ICAR-CSSRI welcomed the Chief Guest, Dr. Joykrushna Jena, DDG (Fisheries Science) and other delegates. He also expressed his views about the technologies developed by the ICAR-CSSRI, Karnal.

The Chief Guest, in his opening remarks highlighted various important, achievements and its contribution in country's food grain productions. He emphasized about the, deteriorating soil health, depleting groundwater, crop diversification, crop residue burning, building salinity tolerant varieties for the region, climatic changes leading to declining profits for the farmer and

Mid term review meeting in progress

IFS model with incorporation of fisheries. He emphasized that there is need to promote saline Aquaculture farming as it is a great potential profitable enterprise in the region. He told that a fisheries farmer can earn income of Rs. 5 lakh in short duration of four months only. Other major issues highlighted were the development of appropriate resource conserving technologies, frost and salt-tolerant wheat, rice, mustard varieties, drip irrigation, feed blocks, post harvest losses in horticultural crops, peri-urban horticulture, dairy entrepreneurship, goatery and piggery, *in situ* conservation of important animal breeds. He further urged all the participating Vice-Chancellors, Directors and Senior Officers from State Departments to prioritize research and development programs targeting farmers' needs. He emphasized that this meeting is a mechanism of ICAR to reach to various states and through this mechanism we can understand the various problems of states and can address them through innovative technology and tools. He emphasized his focus on the honorable Prime Minister's dream of doubling the farmer's income by 2022, however, he urged the researchers and policy makers to work hard to make it possible till 2020. At the end of the meeting Dr. R.K. Yadav, Head, Soils & Crop Management proposed a vote of thanks to the dignitaries.

Training on *"Lavan Prabhavit Mridayon Mein Santulit Urvark Prabhandhan"*

A short training on "Lawan prabhavit mrudayon mein santulit urvark prabhandhan" was organised at CSSRI, Karnal for three days from 15-17 February 2018 under RKVY funded project entitled *"Mineral Nutrient Diagnostic and Site Specific Nutrient Management Demonstrations to Improve Agricultural Productivity of Salt Affected Soils in Haryana".* This training programme was formulated as per the objective of the project "Capacity building of farmers for nutrient diagnosis in sustainable management of salt affected soils and irrigation water". Twenty five farmers participated from the selected villages under this programme from the adopted villages under Mera Goan Mera Gaurav scheme, e.g. Jagsi (Sonepat), Nain (Panipat), Sanch, Mundri and Barsana (Kaithal). The training was inaugurated byDr P.C. Sharma, Director, CSSRI, Karnal. He informed the farmers that CSSRI is working on

Dr. Randhir Singh, ADG, distributing the certificates

improvement of saline and alkaline soils since the day of its inception. The institute has reclaimed 2 million hectare land out of 6.73 million hectare saline land. The director emphasized the use of soil health cards and insisted the farmers to get it for their land to enhance the productivity with proper management of fertilizers. During three days programme, the farmers were imparted knowledge on sustainable and cost effective management of natural resources. Live interactions were held with the scientists on different aspects of mineral nutrient management. Detailed presentations on importance of regular testing of soil and water, necessity of Soil Health Card, deficiency symptoms of nutrients an proper use of fertilizers with appropriate dose of macro and micro nutrients in different crops, conservation agriculture etc were given by the subject experts of the institute. A visit to Gharaunda Center of Excellence was also conducted to make the farmers awareabout alternate farming. The farmers were also taken to the experimental farm of CSSRI and various experiments with technologies were explained in detail. The interaction at field was very much informative to the farmers and they were eager to explore each and every corner of the experimental farm of CSSRI. Dr Randhir Singh, ADG (Extension), ICAR was the Chief Guest on the concluding day of programme. He informed the farmers that already ten crore Soil health cards have been distributed across the country and the remaining will be covered very soon. The chief guest urged the farmers to get their soils tested and get the card if not have earlier done. He also asked the farmers to use the proper amount of fertilizers with prior discussion with the scientists or subject matter specialists for better productivity and to save our earth. The chief guest distributed the participatory certificates to the farmers.

Farmers Model Training programme on "*Identification of high yielding and salt tolerant genotypes of pomegranate*"

A Five-day Model Training programme was organized on the Occupation and Management of the cultivation of fruit trees under the salinity-affected areas at Central Soil Salinity Research Institute, Karnal from 19-23 February, 2018. In this training program, 20 farmers from 6 districts of Haryana participated.

During this program, various topics like salt affected soils (SAS) and poor quality water areas in India,Use of Poor Quality Water in Horticulture, management of salt-affected soils, scientific techniques for the cultivation of fruit trees under salt affected soils using poor quality water, identification of salt tolerant species in fruits, advanced nursery management in fruits and vegetables, forestry-horticultural methods for salt-affected soils, Integrated pest and disease management in fruit trees were presented by scientists/experts.

Director, ICAR-CSSRI addressing the farmers.

Various schemes run by Government of Haryanafor the promotion and development of horticulture industry and techniques for the value addition in horticultural crops and post-harvest handling of the horticultural commodities to get higher revenues were also discussed. Apart from this, exposure visit was organized at the Bajwa Mushroom Farm, Kurukshetra; Zero budget farming model established in Kurukshetra Gurukul; Indo-Israel Center for Excellence, Ladwa; National Horticulture Research and Development Establishment, Salaru; Hara Farm Yamuna Nagar; Harbir Nursery Shahbad and Karan Vermicompost unit, Sikri farm to develop the entrepreneurship skills in farmers.

Skill Development Programme *Chief Guest along with participants*

Dr. Ramesh Yadav along with participants

A three days Skill Development Programme on "Marketing of Agricultural Produce" was organized under Farmer FIRST project (FFP) at ICAR-CSSRI, Karnal during 26-28 February 2018. A total of 29 farmers from FFP adopted villages participated. Dr. Raqmesh. Yadav, Chairman, Haryana Kisan Ayog inaugurated the training programme. He stressed upon the creation of farmers interest groups and importance of geographical indicators (GI) in the present agricultural scenario. A total of 10 lectures were delivered including agriculture marketing scenario, food processing, crop and livestock insurance, government policies, E-NAM, quality seed production, processing and value addition to the agricultural produce. A panel discussion involving Scientists, NABARD representative and progressive farmers was also organized to sensitize the participating farmers regarding importance of farmers producing organizations (FPOs) in the present scenario to add value to their produce and earn more profit. In the Valedictory function, Dr. R.K. Yadav, Head, SCM highlighted that scientist/extension functionaries and farmers should interact together to set their priorities and find out the relevant solutions in tackling the location specific field problems.

Farmers-Scientist Interface Meeting-cum-Field Day on Farmers' Participatory CSSRI's Technological Adaptation in Sodic Agroecosystems.

On 27th February, 2018 a farmers-scientist interface meeting and field day was organized in Kathwar village under Farmer FIRST Project. A total of 200 farmers and NGOs workers, officials from state agriculture department participated in the programme. Dr. Parvender Sheoran, PI, briefed about the on-going project activities and shared the experiences

Dignataries interacting with the farmers

achieved so far. Dr. A. K. Singh DDG (Agril. Extension) and Dr. V.P. Chahal, ADG (Agril. Extension), ICAR, New Delhi visited major fields and interacted with farmers where interventions of ground-water recharge, salt tolerant wheat variety KRL 210, soil and irrigation water based gypsum and pressmud application and rice residue management.

The farmers Explained that demonstrated interventions have shown tremendous potential, being able to save their crops during intense rains (e.g. rice was saved in 2017), improving underground water quality, arresting ground water depletion, reclaiming sodic soils, enhancing soil fertility and crop resilience. Dr. V. P. Chahal raised the issue of increasing women participation in the extension activities and enabling them in agricultural decision making. Dr. P.C. Sharma, Director opined that CSSRI will provide knowledge and expertise support to the line departments for the cause of promoting technologies in the salt affected lands to enhance their resilience.

Foundation Day

50th Golden Jubilee Foundation day of ICAR-CSSRI celebrated on 1st March 2018 at Karnal ICAR-CSSRI has celebrated its 50th Golden Jubilee Foundation Day on 1st March 2018 with gaiety and fervor Sh. Chhabilendra Roul, Special Secretary, DARE and Secretary ICAR was the Chief Guest. In this auspicious occasion, former Directors of ICAR-CSSRI; Drs. DR Bhumbla, IP Abrol, NK Tyagi, GB Singh and DK Sharma were also felicitated. Dr. PC Sharma, Director ICAR-CSSRI welcomed the guests and briefed the house regarding the institute research achievements, research activities and new initiatives and new challenges being

Sh. Chhabilendra Roul delivering the foundation day lecture taken by the institute. In their remarks, all the formers Directors appreciated the research achievements of ICAR-CSSRI and recall their association with the institute. They emphasized that research science must influence the country's policies for the betterment of the farmers. In his Golden Jubilee Foundation Day lecture Sh. Chhabilendra Roul also appreciated the efforts and zeal of ICAR-CSSRI scientists to bring laurels to the Institute as well as to the NRM division by reclaiming 2.14 million ha of salt affected land which is contributing more than 16 million metric tons of food grains annually to the national food basket. He urged the scientist that in the climate change scenario achieving nutritional security to all the people is the main challenge in the future. For achieving this goal, a holistic approach for sustainable agriculture needs to be developed. Dr. Parveen Kumar and Dr. Anita Mann anchored this programme

Swarna Jayanti Rabi Kisan Mela

In the Golden Jubilee Year, the institute organized '*Swarna Jayanti Rabi Kisan Mela*' on 10th March, 2018 in the institute premises in which more than 2500 farmers including 200 farm women from different districts of Haryana and adjoining Uttar Pradesh participated. The Mela was inaugurated by Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers Welfare, Govt of India who lauded the efforts of CSSRI in reclaiming the salt-affected lands and making them suitable for crop production. He urged the farmers to adopt sustainable crop management practices and to keep themselves in close contact with the scientists for obtaining farm advisory and enhancing farm profits. The Minister highlighted the schemes of Union Government such as *Soil Health Card Scheme*, *Pradhan Mantri Fasal Bima Yojana, Pradhan Mantri Krishi Sinchayee Yojana* and *Mera Gaon Mera Gaurav* for sustainable agricultural development in the country. He appreciated the efforts of CSSRI in 50 adopted villages under MGMG and informed that around 20000 agricultural scientists all over the country are directly interacting with the farmers under MGMG programme.

Welcoming the dignitaries on the dias, the agri-entrepreneurs and the farmers, Dr. P.C. Sharma, Director, ICAR-CSSRI, Karnal apprised the audience about the achievements and technologies of CSSRI and the impacts thereof. He informed that the institute has been instrumental in reclaiming around 2.14 million hectares of salt-affected land in the country which is estimated to contribute about 16 million tonnes of foodgrains to the

Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers Welfare addressing the farmers national pool. The Mela was graced by other dignitaries like Karnal Lok Sabha MP Sh. Ashwini Chopra, two MLAs from Karnal district (Sh. Bakhshis Singh Virk & Sh. Baghwan Das Kabirpanthy) and several high level officials of ICAR (Dr. J.K. Jena, DDG Fisheries and Dr. S.K. Chaudari, ADG, S&WM) and state departments of Haryana and Uttar Pradesh.

The Mela witnessed 70 exhibition stalls put up by different ICAR institutes, government agencies and private companies to showcase their technologies and products. About 15 exhibition stalls were put up by progressive farmers and self help groups of farmwomen. The institute put up its Division-wise exhibition stalls to showcase different technologies/ activities and made arrangement for free of cost analysis of soil and water samples of farmers' fields, and seed sale of improved salt tolerant varieties of rice. On this occasion a Farmer-Scientist Goshthi was also organized to answer the queries of farmers by the subject matter specialists. The Chief Guest Hon'ble Shri Radha Mohan Singh distributed awards to 21 progressive farmers, 4 exhibition stalls and 4 stakeholders in land reclamation for their outstanding work.

Mobile App *"Salinity Expert"* under Farmer FIRST Project

The mobile app *'Salinity Expert'* was launched by Shri Radha Mohan Singh, Hon'ble Union Minister for Agriculture and Farmers Welfare during the Golden Jubilee Kisan Mela organized by ICAR-Central Soil Salinity Research Institute, Karnal on March 10, 2018. Agriculture Minister suggested that mobile enabled Information and Communication Technologies can complement the role of extension services in disseminating the research outputs to the end users more widely and swiftly. Dr. P.C. Sharma, Director ICAR-CSSRI briefed that this mobile app is an initiative towards digital India to fast track the dissemination of farmer friendly technologies under salt affected agro-ecosystems, bridging the barriers of time and space and aim to doubling the farmers' income by 2022


Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers Welfare releasing the App

Dr. Parvender Sheoran, Principal Scientist (Agronomy) and PI of the project described it a user friendly app available in hindi version compatible to Andriod phone featuring:

- Knowledge base digital compendium including management practices for rice, wheat and mustard crops under salty environments right from sowing to harvesting
- User friendly query handler to raise queries either as text messages or in graphic/recorded form. The queries then will be attended by the administrator via message sorting, short message service, email etc.
- Aadhar/Mobile Login ID based digitization of soil health cards (SHCs) including farmer's basic information, soil fertility and water quality analysis
- Methodology and precautionary measures while taking soil and irrigation water samples
- Estimated gypsum requirement considering inherent soil sodicity (pH) and residual alkalinity in irrigation water (RSC) and their concomitant effect on crop yields (yield predictions)
- Digitization of soil fertility status and water quality maps of study domain under farmer FIRST project
- Updated agro-advisories and information pertaining to training programmes and other important events

The application can be freely downloaded from the Google play store mentioning 'Salinity Expert' or Plains".https://play.google.com/store/apps/details?id=com.dev.cssri.farmerfirst&...This app has been developed under the Farmer FIRST project entitled "Empowering farmers through selective interventions in salt affected agro-ecosystem of Ghaghar

International Training on "Advance and innovative technologies for sustainable management of salt affected soils"

An International Training on "Advance and innovative technologies for sustainable management of salt affected soils" was organized under Indo-African Forum during 15 – 26 March 2018 at ICAR-Central Soil Salinity Research Institute, Karnal (Haryana). This programme was sponsored by Ministry of External Affairs, Govt. of India for 12 days as a part of coordination, exchange of experience and cooperative action for furthering the objective of development of rural areas. In this training programme, 14 delegates from 5 different African countries viz., Nigeria, Ethiopia, Zambia, Uganda and Comoros participated. The programme was inaugurated on 15 march 2018 by Dr P.S. Minhas, Ex Director, ICAR-NIASM, Baramati and presently Emeritus Scientist (ICAR). In his inaugural deliberation he emphasized on the concerted efforts to be made on emerging issues and dissemination of technologies developed for the problematic areas of different countries. During valedictory function Dr R.R.B. Singh, Director, ICAR-NDRI, Karnal was the Chief Guest, who emphasized the role of salt affected conditions all over the globe. He also stated that inclusion of dairy component in resource poor conditions adds to the sustainable improvements of poor soil conditions. He also emphasized on the importance of the subject for the upliftment of the agriculture and rural development. He also mentioned that the collaborative efforts should be made on the management of salt affected soils and use of poor quality water in agriculture among other countries to address the issues globally and CSSRI has to play a lead role for the countries affected severely by the problems of water quality. Dr P.C. Sharma, Director, ICAR-CSSRI, Karnal presented detailed technological developments by the Institute and thanked to the Indo-African Forum for such programmes and assured the delegates for future cooperation in the field of agriculture particularly salt affected conditions to tackle the problems in a collaborative approach for the use of poor quality water in agriculture

Dr. P.S. Minhas, Chief Guest along with Indo-African delegates

List of Scientific, Technical and Administrative Personnel

Parbodh Chander Sharma, Ph.D., Director

Division of Soil & Crop Management

R.K. Yadav, Ph.D., Head

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. (23.06.2017)[a]

Nirmalendu Basak, Ph.D.

Ashim Dutta M.Sc.

Parul Sundha, Ph.D.

Raj Kumar, Ph.D.

Arijit Burman, M.Sc.

Awtar Singh, M.Sc.

Priyanka Chandra, Ph.D.

Manish Kumar, M.Sc

R. Mukhopadhyay, M.Sc. (13.10.2017)[b]

Technical Officers

Naresh Kumar, Ph. D.

Raj Kumar

Dilbag Singh

Division of Crop Improvement

S.K. Sanwal, Ph.D. Head, (A)

Anita Mann, Ph.D.

S.L.Krishna Murthy, Ph.D

Joginder Singh, Ph.D.

Ashwani Kumar, Ph.D

Arvind Kumar, Ph.D.

Vineeth TV, M.Sc.

Ravi Kiran, M.Sc.

Vijayata Singh, Ph.D.

PS to Head

Sunita Malhotra

Technical Officers

G.C. Purty

Division of Irrigation and Drainage Engineering

D.S. Bundela, Ph.D., Head

Satyender Kumar, Ph.D.

Bhaskar Nurjury,Ph.D.

Pathan Aslam Latif , M.Tech.

R.S. Tolia, M.Tech.

Dar Jaffer, M.Sc. (13.10.2017)[b]

Technical Officers

Rajiv Kumar, M.Sc.

S.K. Srivastava, Diploma (04.02.2018)[d]

Jai Parkash, M.Sc.

S.K. Dahiya

Mohinder Pal

Sat Pal

Division of Technology Evaluation and Transfer

A. Kumar, Ph.D. Head (A) (01.09.2017)[b]

R.K. Singh, Ph.D.Head (A) 31.08.2017)[a]

Parvender Sheoran, Ph. D.

M. Raju, Ph.D

Kailash Prajapat, Ph.D.

AICRP (Saline Water)

M.J. Kaledhonkar, Ph.D., P.C.

R.L. Meena, Ph.D.

Babu Lal Meena, Ph.D.

Technical Officers

Anil Kumar Sharma, M.A.

Regional Research Station, Canning Town

D. Burman, Ph. D., Head(A)

B. Maji, Ph.D. (28.02.2018)[c]

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.

S. Mandal, B.Sc.

A.K. Pramanik

L.K. Nayak,

D. Mukherjee

D. Banerjee

PS to the Head

A.K. Nandi, B. Sc. (30.11.2017)[c]

Regional Research Station, Bharuch

Anil R. Chinchmalatpure, Ph.D., Head

Sharwan Kumar, Ph.D

Indivar Parshad, M.Sc.

Monika Shukla, M.Sc.

David Cames D., M.Sc.

Vibuti Sagar, M.Tech.

B. Gorain, M.Sc. (16.10.2017)[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, SAO

Anil Sidharth , FAO

Ishwar Dayal, AO

A.K. Mishra, AAO (16.08.2017)[a]

Tarun Kumar, Asstt. Admn. Officer

Ranjeet Singh, Asstt. Admn. Officer

Randhir Singh, JAO (09.11.2017)[a]

Dinesh Gugnani

Rit Ahuja

RTI Cell

Parvender Sheoran, Ph.D., CPIO

Rajeev Kumar

Vinod Kumar, M.A.

Transparency 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.

Publication and Supporting Services Unit

Anshuman Singh, Ph. D., OIC

Technical Officer

Madan Singh, M.A.

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.

Farm Section

H.S. Tomar, M.A., FM (31.08.2017)[c]

Jai Parkash, M.Sc.,FM (01.09.2017)[b]

Chander Gupt

Seth Pal

Jaswant Singh

Library

Meena Luthra, M.A., M. Lib. Sci., OIC,

Medical Unit

Dr. (Mrs.) M. Parkash, M.B.B.S.,OIC

Sunita Dhingra

Chanchal Rani

Geeta Rani

Estate Section

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 31.3.2018.

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	03	65	68	9	9.23	5	7.70
Lowest rung of Class-1	-	04	04	01	25	-	-
Class-II	-	23	23	05	21.73	02	8.69
Class-III	-	88	88	14	15.90	08	9.09
Class-IV (excluding sweepers)	-	40	40	10	25	04	10
Class-IV (only sweepers)	-	04	04	04	100	-	-
Total	03	224	227	40	17.62	19	8.37

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 31.3.2018.

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 2017

Main Institute, Karnal

During the year 2017, a total rainfall of 793.4 mm was recorded at Agro-met Observatory at Karnal as compared to the mean annual rainfall of 737.4 mm (for the last 46 years). The year was a normal rainfall year (108% of the long-term mean annual rainfall) whereas the year 2016 was also a normal rainfall year (85% of the long-term mean annual rainfall). The maximum monthly rainfall of 239.2 mm was recorded during June. During the monsoon season, the highest rainstorm of 140.4 mm was recorded on 28th June and the second highest of 127.8mm on 2nd September. During January there was a good amount of rainfall of 85.8 mm which substantially met the irrigation demand of *Rabi* crops and this has yielded into bumper *Rabi* crop production. The winter rainfall (March) was 7.8 mm as compared to the last year winter rainfall (46.2mm). The scanty winter rainfall resulted in slight increase in irrigation demands for different *Rabi* crops during February and March, which were met either from canal water or groundwater or both, particularly for wheat crop. There were 44 rainy days as compared to 47 days during the last year.

The minimum and maximum air temperatures, 1.6° and 45.4 °C were recorded on 11th January and 5th June, respectively. The air relative humidity was lowest (9%) on 10th April and 14th April while the highest (100%) was recorded on several occasions during the year. The highest soil temperatures at 5, 10 and 20 cm depths were 42.0, 41.5 and 40.5 °C on 2nd June, respectively. The lowest values at same depths were recorded as 5.0, 6.0 and 8.0 °C on 11th Jan. (5 and 10 cm). The total open pan evaporation during the year was 1324.0 mm, which is more than 1.67% than the annual rainfall. The lowest evaporation of 0.4 mm was recorded on 8th January and the highest of 12.3 mm was on 5th June. The average sunshine hours per day were 7.4. The highest and lowest vapour pressure values were 29.5mm on 5th August and 5.7 mm on 13th January, respectively. The average wind speed was 2.9 km per hour. The monthly weather parameters recorded at agro-meteorological observatory, ICAR-CSSRI, Karnal for the year 2017are presented in Table 1.

Regional Research Station Bhauach

Agro-meteorological observations (Table 2) recorded at Regional Cotton Research Station, NAU, Bharuch during 2017 revealed that this region received normal rainfall of 520 mm spread over 47 days. Season's highest rainfall 170.3 mm was received during August followed by 166.0 mm, 95.4 mm and 53.8 mm during July, June and September 2017, respectively. Maximum air temperature ranged from 29.1°C (Dec) to 40°C (May) and minimum air temperature varied from 13.7°C (Jan) to 27.3°C (May). Pan evaporation varied from 3.0 mm day^{-1} during December to 14.0 mm day^{-1} during May. The average bright sunshine hours varied from 3.5 during July to 9.8 hr/day during December. Mean relative humidity varied from 41.7 per cent during March to 79.7 per cent in July. The average wind speed varied from 2.1 kmph during November to 10.0 kmph during June 2017.

Regional Research Station, Canning Town

Total annual rainfall of 1944.5 mm was recorded by the meteorological unit of this institute during 2017. The maximum of 567.4 mm rainfall was recorded in the month of July, but the maximum rainy days (18) were recorded in the month of August. There was total 82 rainy days in this year. The average daily sunshine hour was moderate. The minimum temperature reaches its lowest (total mean monthly average 12.7 ^{o}C) in the month of January. The average mean monthly temperature of 19.20^{o}C in January raised very rapidly to 31.7^{o}C in the month of May and the maximum temperature of 38.0^{o}C was recorded on May 19, 21, 23 &26. The relative humidity remains quite high throughout the year, which causes several problems of infestation in seeds, pest and diseases. The mean monthly weather parameters recorded at RRS, Canning, are presented in Table 3.

Table 1: Mean monthly weather parameters for the year 2017 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.	19.1	6.8	2.0	8.2	18.2	8.1	14.3	8.2	10.0	99	64	23.4/03	12.0/18	13.0/26	1.6/11
Feb.	23.1	8.4	3.9	10.4	22.7	9.7	16.7	8.8	10.7	91	52	29.0/21	19.2/08	13.5/17	4.4/09
Mar.	28.0	11.6	5.3	14.9	27.6	13.3	18.5	10.7	10.7	83	40	36.5/30	21.2/13	17.5/29	5.0/13
Apr.	37.6	18.9	9.3	23.3	36.3	18.0	21.2	12.6	9.4	57	21	43.0/21	31.0/05	27.5/21	12.4/10
May	38.9	23.4	11.0	27.3	37.5	21.1	23.4	14.9	13.0	55	28	43.0/16	34.2/23	27.5/16	17.5/01
Jun.	36.5	25.1	12.9	27.9	34.9	23.7	25.0	19.4	17.7	70	46	45.4/05	26.0/29	33.0/05	21.0/07
Jul.	33.6	26.4	13.9	28.4	32.6	26.1	27.6	23.9	24.6	82	67	37.4/20	28.5/01	28.8/09	24.2/11
Aug.	33.0	25.9	14.1	27.4	31.7	26.0	27.8	24.4	26.0	86	72	39.5/23	29.0/03	27.0/09	24.2/28
Sept.	32.3	23.1	10.9	25.3	31.4	24.3	26.5	22.4	23.5	92	67	34.0/21	29.2/23	25.2/10	20.6/20
Oct.	32.8	17.4	8.0	19.9	31.8	19.0	22.6	16.1	15.1	92	43	35.0/03	28.6/31	20.6/04	13.8/28
Nov.	25.0	11.1	6.3	12.8	23.7	12.8	17.4	10.7	11.0	93	49	30.0/06	21.6/17	17.4/01	6.2/24
Dec.	21.4	7.7	3.7	9.1	20.4	8.6	14.8	8.2	9.3	94	54	26.0/11	12.0/15	12.0/12	4.6/04
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	**30.1**	**17.1**	**8.4**	**19.5**	**29.0**	**17.5**	**21.3**	**15.0**	**15.0**	**83**	**50**	-	-	-	-

Month	Soil temperature, °C (Depth-wise)						Rainfall*			Evaporation		Sunshine (hr/day)	Wind speed (km/hr)
	5 cm		10 cm		20 cm		Monthly (mm)	No of rainy days	Heavy/ date	mm/ day	mm/ month		
	I	II	I	II	I	II							
Jan.	9.6	17.5	10.6	15.9	12.0	14.6	85.8	7	41.2/27	0.9	28.1	5.2	2.8
Feb.	11.8	22.1	12.7	19.6	13.6	17.6	0.0	0	-	2.0	56.5	7.3	3.2
Mar.	16.0	26.0	16.9	24.4	17.7	23.0	7.8	2	-	2.9	89.8	9.3	2.9
Apr.	25.1	34.0	33.7	33.2	26.8	32.1	3.4	2	-	5.7	170.5	10.4	4.0
May	29.0	38.3	29.9	37.2	30.9	36.3	4.8	2	-	6.5	201.6	10.1	5.1
Jun.	28.3	35.4	29.2	34.5	30.2	34.0	239.2	9	140.4/28	6.7	194.9	9.2	5.0
Jul.	28.2	35.0	29.0	34.4	29.7	33.8	56.6	9	21.0/31	4.7	146.3	8.8	3.5
Aug.	27.5	34.1	28.1	33.7	28.4	33.5	162.8	7	65.4/07	4.2	124.7	6.3	1.4
Sept.	26.2	33.4	26.9	32.8	27.5	32.3	226.0	6	127.8/02	3.4	99.7	7.3	1.6
Oct.	21.6	32.0	22.7	31.1	23.5	19.0	0.0	0	-	3.4	103.9	6.2	0.9
Nov.	17.4	23.6	18.5	22.6	19.2	21.9	1.8	1	-	1.9	56.0	3.9	1.7
Dec.	11.6	17.6	12.3	16.9	12.9	16.5	5.2	1	-	1.7	52.0	4.5	4.5
Total	-	-	-	-	-	-	**793.4**	**46**	-	-	**1324.0**	-	-
Average	**21.0**	**29.1**	**22.5**	**28.0**	**22.7**	**26.2**	-	-	-	**3.7**	-	**7.4**	**3.1**

* Rainfall < 2 mm is drizzle or trace.

Table 2. Monthly average agro-meteorological parameters at Bharuch during 2017

Month	Air Temperature (°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	29.9	13.7	0.0	0	52.4	10.6	10.1	2.6	7.8	7.5
February	33.4	17.4	0.0	0	44.6	11.5	9.5	3.0	9.1	9.5
March	35.5	19.9	0.0	0	41.7	14.2	9.6	3.5	8.5	11
April	38.5	24.1	0.0	0	51.4	20.5	13.4	7.3	9.6	12
May	40.0	27.3	0.0	0	53.8	23.9	16.8	9.1	9.4	14
June	36.2	26.6	95.4	8	66.7	24.9	22.6	10.0	7.4	10
July	31.3	24.8	166.0	18	79.7	24.1	24.6	9.7	3.5	5.2
August	31.8	24.8	170.3	11	75.6	23.6	22.1	7.1	5.0	4.8
September	33.3	24.1	53.0	6	73.8	23.8	22.9	2.3	4.9	7.1
October	35.9	22.0	30.5	3	59.4	19.8	17.5	2.1	7.9	6.2
November	33.6	18.3	0.0	0	46.1	13.0	11.4	2.1	8.6	4.6
December	29.1	15.6	5.2	1	53.9	11.3	10.5	3.9	9.8	3.0
Total			520	47						

Table 3. Mean monthly weather parameters at Canning Town (latitude: 22015 N, longitude: 88040°E, altitude (AMSL): 3.0 m) during the year - 2017

Month	TEMPERATURE(°C)			RH (I) (%)	RH (II)(%)	Rainfall (mm)	Rainy Days (no.)	Evaporation (mm)	Av. WIND (km h^{-1})	BSSH (day^{-1})
	MAX.	MIN.	MEAN							
Jan	25.7	12.7	19.2	77.9	42.7	0.0	0	3.3	0.6	7.6
Feb	29.4	17.0	23.2	81.0	40.3	0.0	0	5.3	1.2	7.1
Mar	31.4	21.5	26.4	81.9	52.6	49.0	4	4.2	3.4	6.9
Apr	34.2	26.0	30.1	76.8	57.0	12.6	2	3.1	6.8	5.0
May	36.6	26.9	31.7	72.5	26.6	66.6	4	5.0	7.5	8.4
Jun	35.0	27.4	31.2	80.0	68.5	170.8	12	2.5	7.3	5.4
Jul	31.7	26.7	29.2	90.6	84.5	567.4	17	0.6	5.8	2.7
Aug	32.8	27.0	29.9	86.3	79.6	420.3	18	0.4	5.1	3.8
Sep	33.7	27.2	30.5	85.7	73.7	173.6	7	1.4	3.7	4.6
Oct	31.4	24.9	28.2	88.2	75.6	420.8	11	0.5	4.1	5.5
Nov	29.3	19.1	24.2	76.8	56.3	34.6	5	0.6	2.0	6.9
Dec	25.7	15.6	20.7	86.7	61.7	28.8	2	0.2	2.0	5.9
Total	376.9	272.1	324.5	984.4	719.1	1944.5	82	27.2	49.4	69.6
Avg.	31.4	22.7	27	82	60			2.3	4.1	5.8

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch

ICAR - Central Soil Salinity Research Institute

Karnal, Haryana- 132 001