वार्षिक प्रतिवेदन

ANNUAL REPORT 2022

ICAR-Central Soil Salinity Research Institute
Karnal, Haryana- 132001

2022

भाकृअनुप
ICAR

वार्षिक प्रतिवेदन
Annual Report
2022

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

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Salt tolerant varieties of Mustard (CS 61 and CS 62) and Linseed in sodic soil

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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

Soil salinity poses a significant and widespread challenge in the modern era, impeding global food security and environmental sustainability in arid and semi-arid regions. This issue severely impacts global agricultural production and biodiversity. Currently, over 900 million hectares of land, making up approximately 20% of total agricultural land and 33% of irrigated agricultural land, are affected by salinity worldwide. Furthermore, coastal and waterlogged areas are particularly vulnerable to salinity due to factors such as sea water intrusion and inundation, which are linked to global climate change. The increased salt stress in soil is a result of various factors, including the growing global population, intensive agricultural practices, and long-term climate change. As a result, we anticipate facing new challenges in the future, driven by climate change and anomalies in land use. This could lead to a significant increase in the area affected by salinity in the coming decades. India is dedicated to achieving Land Degradation Neutrality and has recently raised its target for restoring degraded lands from 21.0 to 26.0 million hectares by 2030, aligning with the Sustainable Development Goals (SDGs). Land restoration practices play a crucial role in promoting human well-being and reflect our unwavering commitment to society. At ICAR-CSSRI, we strive to bring hope and prosperity to farmers in salt-affected areas.

The Annual Report for the year 2022 brings out some major achievements in the areas of technology development and dissemination to the farmers' fields. Some major research breakthroughs during the period under report were: Development of salt tolerant Indian Mustard varieties CS 61 and CS 62 for irrigated sodic conditions of Uttar Pradesh, Identification of potential willow clones for sodic conditions, 3-dimensional representation of soil salinity using electromagnetic induction technique, Effect of sowing windows and irrigation on yield of field bean grown under zero tillage in coastal saline soils of Konkan (Panvel), Community level physiological profiling of microbes under salt affected soils and Performance of salt tolerant mustard varieties under different dates of sowing on saline Vertisols.

During the year 2022, The institute organized a Kharif Kisan Mela on March 15, 2022 in collaboration with Department of Agriculture and Farmers' Welfare, Govt. of Haryana at playground of the institute. Sh. Sanjeev Kumar Verma, Divisional Commissioner of Karnal Division graced the occasion as chief guest. In his address to the participating farmers, he emphasized on the role of integrated and traditional farming practices in providing resilience production and diversity of products. He also appraised about the farmers' welfare schemes announced by the state government and called upon to get maximum benefit out of them. Guest of Honour, Dr. Gurbachan Singh, Chairman GSFERD, Karnal told that adoption of multienterprise based integrated farming system model can increase income by

3-4 times and this also lowers the risks under small land holding farming situation. Dr. Aditya Pratap Dabas, Deputy Director Agriculture, Karnal emphasized on different crop residue management technologies and urged the farmers to manage crop residues in the field for better soil health and protecting the environment.

A three days Kisan Mela cum Exhibition was organized at CSSRI, RRS Lucknow jointly with Agriculture Department, U.P. on "Khet ki Chunotiya evam Samadhan" during January 7-9, 2022. The Mela was inaugurated by Shri Kaushal Kishore ji, Minister of State for Housing and Urban Affairs, Government of India.

CSSRI celebrated its 54th Foundation Day on 3rd March 2022. Chief Guest, Prof. B.R. Kamboj, Vice Chancellor, Chaudhary Charan Singh Haryana Agricultural University, Hisar, inaugurated the function. The chief guest in his address talked about the important role that CSSRI has played in the reclamation of salt affected soils throughout the country, the technologies that this Institute has given to the farmers and the overall impact that it posses towards increasing the GDP of India.

Training on "Mini STL kit based Soil and Water Testing" sponsored by State Department of Agriculture and Farmers' Welfare, Govt. of Haryana was organized by ICAR-CSSRI, Karnal. The training was provided to 19 Assistant/Associate Professors from different Govt. Colleges of Haryana State during 05-07 July 2022 and to 36 GSSS Science teachers from different Govt. Schools of Haryana State during 12-14 July 2022. In these training programmes, major aspects of soil and water testing viz., scope and importance of soil and water testing in India, salinity and its impact on nutrients and water availability, orientation to mini STL kit and other instruments used for soil and water testing were covered. Practical's on preparation and processing of Soil/Water samples for analysis, preparation of solution/reagent for mini STL kit, Estimation of EC, pH, carbon, phosphorus, potassium, micronutrients, sulphur, calcium and magnesium of soil using mini STL kit were trained. Pre- and post-training evaluation of all trainees was also carried out which showed that the percentage increase in knowledge from pre training evaluation test to post training evaluation test was found to be 27.00% for Assistant/Associate Professors and 32.7 % for GSSS Science teachers.

Institute Research Committee (IRC) meeting was held in dual mode this year under the Chairmanship of Dr. P.C. Sharma, Director, ICAR-CSSRI, to review the progress of the ongoing research projects and to take up new research project proposals at the main institute, and its three regional research stations at Bharuch (Gujarat), Canning Town (West Bengal) and Lucknow (U.P.). Total 89 projects, 45 institute funded and 44 external funded projects reviewed during this IRC Meetings. All Heads of Divisions/Stations and Scientists of the Institute participated in this Meeting.

I express my gratitude to Dr. Himanshu Pathak, Secretary, DARE and Director General, ICAR, and Dr. S.K. Chaudhari DDG (NRM), ICAR for their continued guidance and support. The efforts of Dr. Madhu Choudhary, Dr. Subhasis Mandal and Sh. Yudhvir Singh Ahlawat in compilation, editing and timely printing of the Annual Report are commendable. I thank my colleagues for providing the material for the timely publication of the report.

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

(Parbodh Chander Sharma)

Director

सारांश

भाकृअनुप–केंद्रीय मृदा लवणता अनुसंधान संस्थान (सीएसएसआरआई), करनाल, हरियाणा, देश के विभिन्न कृषि–पारिस्थितिक क्षेत्रों में लवण प्रभावित मिट्टी के प्रबंधन और निम्न गुणवत्ता वाले सिंचाई जल के उपयोग पर बहु–विषयक अनुसंधान कार्यों के लिए समर्पित है। मुख्यालय में बहु–विषयक अनुसंधान कार्यक्रम चार प्रभागों– मृदा एवं फसल प्रबंधन, सिंचाई एवं जलनिकास अभियांत्रिकी, फसल सुधार और सामाजिक विज्ञान अनुसंधान द्वारा संचालित किए जाते हैं। विभिन्न कृषि जलवायु क्षेत्रों की विशिष्ट अनुसंधान आवश्यकताओं को पूरा करने के लिए संस्थान तीन क्षेत्रीय अनुसंधान केंद्र– कैनिंग टाउन (पश्चिम बंगाल), भरूच (गुजरात) और लखनऊ (उत्तर प्रदेश) क्रमशः तटीय लवणता, लवणग्रस्त वर्टिसोल और मध्य–पूर्वी गंगा के मैदानों के क्षारीय मृदा संबंधी समस्याओं के निवारण के लिए कार्यरत हैं। संस्थान में एक अखिल भारतीय समन्वित अनुसंधान परियोजना लवणग्रस्त प्रभावित मिट्टी के प्रबंधन और खारे पानी का कृषि में उपयोग हेतु विभिन्न पारिस्थितिक क्षेत्रों–आगरा, बापटला, बीकानेर, गंगावती, हिसार, इंदौर, कानपुर, तिरुचिरापल्ली, बठिंडा, पनवेल, पोर्ट ब्लेयर एवं व्यत्तिला में कार्य कर रहा है। रिपोर्टाधीन अवधि के लिए विभिन्न महत्वपूर्ण क्षेत्रों में संस्थान की कुछ प्रमुख शोध उपलब्धियां निम्नानुसार हैंः

उत्तर प्रदेश की सिंचित क्षारीय स्थितियों के लिए लवण सहिष्णु भारतीय सरसों की किस्मों (सीएस 61 और सीएस 62) का विकास

भा.कृ.अनु.प.–केन्द्रीय मृदा लवणता अनुसंधान संस्थान, करनाल द्वारा विकसित भारतीय सरसों की दो लवण सहिष्णु किस्मों को उत्तर प्रदेश की सिंचित क्षारीय स्थितियों के लिए उत्तर प्रदेश राज्य उप–समिति बीज और फसल किस्म (यूपी–एसवीआरसी) द्वारा संस्तुति किया। ये किस्में हैंः–

सीएस 61ः किस्म सीएस 13000–3–2–2–5–2 (सीएस 61) को उत्तर प्रदेश राज्य उप–समिति बीज और फसल किस्म (यूपी–एसवीआरसी) की 34वीं वार्षिक समूह बैठक द्वारा वर्ष 2022 (कार्यालय आदेशः एसएफ/296.टी/एसवीएन–08/2019–20/रा.बी.उ.स. 2020–22/2022–23) में उत्तर प्रदेश की सिंचित, क्षारीय मृदा और समय पर बिजाई (25 अक्टूबर तक) हेतु जारी किया गया है। इसकी उपज क्षारीय मृदा (पीएच 9–9.3 तक) में 21–22 क्विंटल/हेक्टेयर और सामान्य मृदा एवं जल में 25–27 क्विंटल/हेक्टेयर है तथा इसमें लगभग 39 प्रतिशत तेल की मात्रा है। यह किस्म लगभग 132 दिनों में परिपक्व हो जाती है। इसके पौधों की लंबाई 181 सेमी है। यह किस्म अल्टरनेरिया ब्लाईट, 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।

सीएस 62ः किस्म सीएस 15000–1–1–1–4–2 (सीएस 62) को उत्तर प्रदेश राज्य उप–समिति बीज और फसल किस्म (यूपी–एसवीआरसी) की 34वीं वार्षिक समूह बैठक द्वारा वर्ष 2022 (कार्यालय आदेशः एसएफ/296.टी/एसवीएन–08/2019–20/रा.बी.उ.स. 2020–22/2022–23) में उत्तर प्रदेश की सिंचित, क्षारीय मृदा और समय पर बिजाई (25 अक्टूबर तक) हेतु जारी किया गया है। इसकी उपज क्षारीय मृदा (पीएच 9–9.4 तक) में 20–22 क्विंटल/हेक्टेयर और सामान्य मृदा एवं जल में 25–28 क्विंटल/हेक्टेयर है तथा इसमें लगभग 39.5 प्रतिशत तेल की मात्रा है। यह किस्म लगभग 136 दिनों में परिपक्व हो जाती है। इसके पौधों की लंबाई 168 सेमी है। यह किस्म अल्टरनेरिया ब्लाईट, 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 भूमि के लिए संभावित विल्लो क्लोनों की पहचान

विल्लो (सेलिक्स) की आजकल दुनिया भर में बड़े पैमाने पर इसके विशिष्ट विविध गुणों के कारण खेती की जा रही है। इस का महत्व विशेष रूप से खेल उद्योगों (क्रिकेट बैट) और अन्य विविध उपयोगों के लिए अधिक है। छह विल्लो क्लोनों क्रमशः J799, SI –64–017, 131 / 25, PN731, UHFS62 और UHFS85 का मूल्यांकन करने के लिए एक नर्सरी परीक्षण जिसमें चार क्षारीय व्यवस्थाओं जिनका पीएच मान लगभग 8.2, 8.6, 9.0 और 9.4 रखा गया ताकि अर्ध–शुष्क क्षेत्रों में क्षारीय भूमि के लिए उपयुक्त क्लोनों की पहचान की जा सके। प्रत्येक क्षारीय व्यवस्था में 6 सेमी लंबाई की कटिंग लगाई गई और अच्छी गुणवत्ता वाले पानी से सिंचित किये गए। चार महीने तक अंकुरण प्रतिशत, उत्तरजीविता, पौधे की ऊंचाई (सेमी) और मोटाई (मिमी) के आंकड़े दर्ज किए गए। पीएच 8.2 पर अंकुरण प्रतिशत उच्चतम (97.9%) था और पीएच में 8.6 से 9.4 की वृद्धि के साथ कमी (92.1%) दर्ज की गई। क्लोन 131 / 25 में सभी क्लोनों से सबसे अधिक अंकुरण प्रतिशत (99.1%) और पीएन731 में सबसे कम (90.7%) पाया गया। उत्तरजीविता पीएच 8.6 पर उच्चतम (90.3%) और पीएच 9.4 पर सबसे कम (82.3%) थी। अधिकतम उत्तरजीविता (94.0%) क्लोन 131 / 25 में और न्यूनतम (78.4%) पीएन731 मे देखी गई। क्लोन J799 ने अन्य पांच क्लोनों की तुलना में उच्चतम (53.9 सेमी) ऊंचाई दी। पौधे की ऊंचाई क्रमशः पीएच 8.2 (59.5 सेमी), 8.6 (57.4 सेमी), 9.0 (53.2 सेमी) और 9.4 (45.2 सेमी) रही। सभी क्लोनों के पौधों की मोटाई पीएच 8.2 पर सबसे अधिक दर्ज की गई और पीएच 9.4 तक की वृद्धि के साथ लगातार कमी पायी गई। क्लोन J799 में पौधों की मोटाई उच्चतम (8.93 मिमी) दर्ज की गई और क्लोन UHFS85 (5.93 मिमी) सभी क्षारीय व्यवस्थाओं में सबसे न्यूनत्म स्तर पर रहा। परीक्षण से यह अनुशंसा की जाती है कि क्लोन J799 उत्तरजीविता और विकास विशेषताओं के मामले में क्षारीय परिस्थितियों में सर्वश्रेष्ठ प्रदर्शनकर्ता के रूप में उभरा है। हालाँकि, यह भी पाया गया कि क्लोन 131 / 25 और UHFS62, J799 के बराबर थे और अर्ध–शुष्क क्षेत्रों में J799 क्लोन के साथ–साथ क्षारीय भूमि में रोपण के लिए एक विकल्प सावित हो सकते हैं।

विद्युत चुम्बकीय प्रेरण तकनीक का उपयोग करके मिट्टी की लवणता का त्री–आयामी निरुपण

मिट्टी की लवणता की स्थानिक विविधताओं (स्पैसियल वैरिएशन) का त्री-आयामी (3डी) निरुपण करने से लंबवत और क्षैतिज रूप में होने वाली मिट्टी की लवणता में भिन्नता को समझने में मदद मिल सकती है, और लवणता की गम्भीरता निर्धारित करने और प्रबंधन रणनीतियों को विकसित करने में मदद मिल सकती है। मृदा स्वास्थ्य और कृषि उत्पादकता पर लवणता के प्रभाव के संबंध में फसल और मिट्टी के प्रबंधन प्रभावों का त्री.आयामी (3डी) चित्रण की विधि विकसित करने के लिए रोहतक (हरियाणा) जिले के बंसी गांव में सर्वेक्षण एवं अध्ययन किया गया। प्रक्षेत्र में स्पष्ट विद्युत चालकता (ECa) को मापने के लिए एक विद्युत चुम्बकीय प्रेरण उपकरण (EM–38MK–2) का प्रयोग किया गया। मापी गयी स्पष्ट विद्युत चालकता (ECa) को गहराई विशिष्ट वास्तविक विद्युत चालकता (σ) में परिवर्तित करने के लिए क्वासी–त्री–आयामी इनवर्जन एल्गोरिदम (EM4Soil–V302) का उपयोग किया गया। मिट्टी की ऊपरी सतह (0–0. 15 मीटर), उपसतह (0.30 –0.60 मीटर), और (0.60 –0.90 मीटर) उप–परतों में मापी गई स्पष्ट विद्युत चालकता (σ) एवं मिट्टी की लवणता (ईसीई) में सहसंबद्ध स्थापित किया गया। ऊपरी सतह, उपसतह और उप–परतों के लिए सहसंबद्ध प्रतिगमन गुणांक क्रमशः 0.83, 0.95 और 0.82 पाया गया।

लवणग्रसित काली मृदाओं में विभिन्न बुवाई के समय के साथ लवण सहिष्णु सरसों की किस्मों का प्रदर्शन

भारत में खाद्य तिलहनों में सरसों का दूसरा स्थान है। लवणग्रसित काली मृदाओं वाले बारा ट्रैक्ट में उगाई जाने वाली फसलों का चुनाव केवल लवण सहनशील फसलों तक ही सीमित है। भाकृअनुप–सीएसएसआरआई ने सरसों की छह लवण सहिष्णु किस्में विकसित की हैं और इन क्षेत्रों में इन्हें एक नई फसल के रूप में पेश किया जा सकता है। किसी भी फसल के अच्छे प्रदर्शन के लिए उपयुक्त बुवाई की तारीख एक बहुत महत्वपूर्ण पहलू है अतः इसके तहत सरसों की विभिन्न किस्मों के साथ अध्ययन किया गया। सरसों की लवण सहिष्णु तीन किस्मों सीएस 56, सीएस 58 और सीएस 60 को 13 अक्टूबर 2020 से 02 दिसंबर 2020 तक 6 अलग–अलग तारीखों में 10 दिनों के अंतराल पर बोया गया। फसल को जरूरत पड़ने पर उपलब्ध खारे भूजल (ईसी– 6–8 ds/m^{-1}) से सिंचाई की गयी। बुवाई की प्रारंभिक तीन तारीखों में उच्च तापमान और प्रारंभिक अंकुर अवस्था में कीटों के हमले के कारण फसल स्थापित नहीं हो पायी। 12 नवंबर तथा उसके बाद की बुवाई की तीन तारीखों में फसल स्थापित हुई। सरसों की तीनों किस्में लवणग्रसित काली मृदाओं में अच्छी तरह से अंकुरित हुईं और वृद्धि और उपज मानकों के संदर्भ में समकक्ष प्रदर्शन किया। हालांकि, सीएस 58 ने उच्चतम बीज उपज, भूसा उपज और हार्वेस्ट इंडेक्स दिया। अच्छा अंकुरण और फसल प्रदर्शन 12 नवंबर को बुवाई करने में देखा गया। 12 नवंबर को बुवाई से फसल में 55 दिनों में फूल आये और बाद की तारीखों में 50 और 45 दिनों में फसल में फूल आये। 12 नवंबर को फसल की बुवाई के साथ सबसे अधिक प्राथमिक और सह शाखाओं की संख्या, फली/पौधे की संख्या, बीज/फली की संख्या, परिपक्वता के दिन, बीज उपज/पौधे, बीज और भूसा उपज क्विंटल/हैक्टेयर, 1000 दानों का वजन और हार्वेस्ट इंडेक्स दर्ज किया गया। प्रयोग से यह निष्कर्ष निकाला जा सकता है, कि लवणग्रसित काली मृदाओं में सरसों की किस्मों की सर्वोत्तम उपज (5.83 क्विंटल/हेक्टेयर) 12 नवंबर को बोने पर प्राप्त की जा सकती है और सीएस 58 किस्म ने अन्य किस्मों की तुलना में बेहतर प्रदर्शन किया।

लवण प्रभावित मृदाओं में सूक्ष्म जीवों की सामुदायिक स्तर की शारीरिक रूपरेखा

लवण प्रभावित मृदाओं में उपस्थिति लवणों की चर प्रकृति और विभिन्न सान्द्रता में उपलब्धता के कारण मिट्टी के भौतिक–रासायनिक और जैविक गुणों पर प्रतिकूल प्रभाव डालती है। सूक्ष्मजीवीय कार्यात्मक विविधता को समझने के लिए, 5 प्रकार की मृदा यानी अत्यधिक लवणीय, मध्यम लवणीय, अत्यधिक क्षारीय, मध्यम क्षारीय और सामान्य का मूल्यांकन उनके सब्सट्रेट उपयोग पैटर्न का उपयोग करके समुदाय–स्तरीय शारीरिक रूपरेखा (सीएलपीपी) के लिए किया गया था। सतही मिट्टी (0–15 सेमी) में अधिकतम पीएच, सीईसी और ईएसपी अत्यधिक सोडिक मिट्टी (क्रमशः 10.04, 10.19 सेंटीमोल $किग्रा^{-1}$ और 76.15) में देखे गए, हालांकि अत्यधिक लवणीय मृदा (13.53 ds/m^{-1}) में ईसीई उच्चतम था। विभिन्न प्रकार की मृदा में चर औसत कूप रंग विकास (AWCD) दर्शाया गया है। अत्यधिक क्षारीय मृदा को छोड़कर सतह परत में, इनक्यूबेशन अवधि के दिनों की संख्या के साथ AWCD में वृद्धि हुई। अमीनो एसिड, एमाइन, कार्बोक्जिलिक एसिड, फेनोलिक यौगिकों और पॉलिमर का उपयोग सामान्य मृदा के लिए सबसे अधिक पाया गया, इसके बाद मध्यम लवणीय और सबसे कम अत्यधिक क्षारीय मृदा के लिए दर्ज किया गया। कार्बोहाइड्रेट उपयोग के लिए ध्यान आकर्षित करने वाला परिणाम देखा गया, इसका पैटर्न विशेष रूप से अन्य सब्सट्रेट उपयोग पैटर्न से अलग था। अत्यधिक लवणीय मृदा में कार्बोहाइड्रेट के लिए AWCD सबसे अधिक था और उसके बाद अत्यधिक क्षारीय मृदा में था। विविधता सूचकांक (H) सामान्य मिट्टी में उच्चतम (3.19) और अत्यधिक क्षारीय मृदा (1.57) के साथ सबसे कम पाया गया। हालांकि, सब्सट्रेट समृद्धि (SR) सामान्य मृदा (24.07) में उच्चतम और अत्यधिक क्षारीय मृदा (4.53) में सबसे कम पाई गई। डिहाइड्रोजनेज एंजाइम (DHA) और

एरीलसल्फेटेज की उच्चतम गतिविधि सामान्य मृदा (क्रमशः 31.58 माइक्रोग्राम TPF प्रति ग्रा मिट्टी प्रति 24 घंटे और 288.84 माइक्रोग्राम PNP प्रति ग्रा. मृदा प्रति घंटे) के तहत पाई गई और अत्यधिक नमकीन मृदा के साथ सबसे कम (क्रमशः 12.12 माइक्रोग्राम टीपीएफ प्रति ग्रा मिट्टी प्रति 24 घंटे और 65.36 माइक्रोग्राम PNP प्रति ग्रा. मृदा प्रति घंटे)। मध्यम लवणीय मृदा (258.76 माइक्रोग्राम PNP प्रति ग्रा. मृदा प्रति घंटे) में अम्लीय फॉस्फेट गतिविधि (ACP) सबसे अधिक पाई गई, इसके बाद अत्यधिक लवणीय मृदा (195.76 माइक्रोग्राम PNP प्रति ग्रा. मृदा प्रति घंटे) पाई गई। क्षारीय फॉस्फेट गतिविधि (ALP) अत्यधिक क्षारीय (308.67 माइक्रोग्राम माइक्रोग्राम PNP प्रति ग्रा. मृदा प्रति घंटे) और सामान्य मृदा (287.95 माइक्रोग्राम PNP प्रति ग्रा. मृदा प्रति घंटे) में उच्चतम थी। लवणीय मिट्टी में सेल्युलेस अधिक पाया गया जबकि अत्यधिक क्षारीय मृदा (339. 11 माइक्रोग्राम यूरिया प्रति ग्रा. मृदा प्रति घंटे) के तहत यूरिया गतिविधि। इन परिणामों से संकेत मिलता है कि मृदा की एंजाइम गतिविधियां, कार्यात्मक विविधता और सूक्ष्मजीवों का समुदाय लवण की प्रकृति और उनकी एकाग्रता से प्रभावित थे।

कोंकण क्षेत्र की तटीय लवणीय मृदाओं में शून्य जुताई के अन्तर्गत उगायी गई बीन की उपज पर बुवाई की समयावधि और सिंचाई का प्रभाव

कोंकण के तटीय क्षेत्र में धान की फसल की कटाई के बाद मिट्टी में उपलब्ध नमी (अवशिष्ट नमी) से दलहन (बीन) की फसल ली जाती है। भूजल उथला होने से कोशिका वृद्धि द्वारा लवण जमीन की उपरी सतह पर आकर जम जाते हैं। यह प्रक्रिया तटीय क्षेत्रों की भूमि लवणीय होने का मुख्य कारण है। महाराष्ट्र के कोंकण क्षेत्र की तटीय मिट्टी में शून्य जुताई के अन्तर्गत उगायी गई बीन की उपज पर उपयुक्त बुवाई के समय (बुवाई की उपयुक्त अवधी) और सिंचाई के प्रभावों का अध्ययन करने के लिए एक प्रयोग किया गया जिसमें 3 सिंचाई के स्तरों को मुख्य उपचार के रुप में जैसे कि बिना सिंचाई, फूल आने पर एक सिंचाई और दो सिंचाई फूल एवं फली बनने पर जबकि बुआई के समय के तीन तरीकों को जैसे कि धान की कटाई के बाद, कटाई के 10 दिन बाद और कटाई के 20 दिन बाद उप–उपचारों के रुप में लिया गया। खेत के प्रयोग के परिणामों से पता चलता है कि धान की कटाई के तुरंत बाद बीन की बुवाई करने पर बीन की उपज (9.45 क्विंटल/हेक्टेयर) में सार्थक बढोतरी दर्ज की गई जोकि बुवाई के अन्य समय वाले उपचारों की तुलना में काफी अधिक थी। जैसे कि कटाई के 10 दिन बाद बीन की उपज (7.58 क्विंटल/हेक्टेयर) और कटाई के 20 दिन बाद उपज (7.04 क्विंटल/हेक्टेयर) थी। सिंचाई वाले विविध उपचारों को देखा जाए तो यह पाया गया कि फूल आने पर एक सिंचाई करने से उपज में अन्य सिंचाई उपचारों की तुलना में सार्थक बढोतरी दर्ज की गयी। जोकि बिना सिंचाई (9.03 क्विंटल/हेक्टेयर) तथा दो सिंचाई में उपज अनुमानता 7.01 व 8.0 क्विंटल/हेक्टेयर रही। संक्षेप में धान की फसल के तुरंत बाद दलहनी फसल की बुवाई व फूल बनने के समय सिंचाई करने पर अवशिष्ट नमी का उचित उपयोग किया जा सकता है एवं मिट्टी की लवणता के प्रतिकूल प्रभाव से भी बचाया जा सकता है।

पुरस्कार एवं मान्यताएं

- डॉ. पी.सी. शर्मा, निदेशक, आईसीएआर–सीएसएसआरआई को आज एपी शिंदे संगोष्ठी हॉल, एनएएससी, पूसा, नई दिल्ली में 94वें आईसीएआर स्थापना दिवस समारोह में कृषि विज्ञान में उत्कृष्ट शोध के लिए प्रतिष्ठित रफी अहमद किदवई पुरस्कार प्रदान किया गया।
- डॉ. परवेन्दर श्योराण, प्रधान वैज्ञानिक, आईसीएआर–सीएसएसआरआई को आज एपी शिंदे संगोष्ठी हॉल, एनएएससी, पूसा, नई दिल्ली में 94वें आईसीएआर स्थापना दिवस समारोह में स्वामी सहजानंद सरस्वती उत्कृष्ट विस्तार वैज्ञानिक पुरस्कार 2021 प्रदान किया गया।
- डॉ. पी.सी. शर्मा को राष्ट्रीय कृषि विज्ञान अकादमी, नई दिल्ली के फेलो से सम्मानित किया गया।

- डॉ. एच.एस. जाट को राष्ट्रीय कृषि विज्ञान अकादमी, नई दिल्ली के फेलो से सम्मानित किया गया।
- डॉ. सत्येन्द्र कुमार को इंडियन सोसाइटी ऑफ एग्रीकल्चरल इंजीनियर्स, नई दिल्ली के फेलो से सम्मानित किया गया।
- डॉ. सत्येन्द्र कुमार को आईसीएआर—सीएसएसआरआई उत्कृष्टता पुरस्कार—2021 मिला।

कार्यशाला

- कृषि विभाग, उ.प्र. के संयुक्त तत्वावधान में सीएसएसआरआई, आरआरएस लखनऊ में 7—9 जनवरी, 2022 दौरान खेत की चुनौती एवं समाधान विषय पर तीन दिवसीय किसान मेला सह प्रदर्शनी का आयोजन किया गया।
- कृषि एवं किसान कल्याण विभाग, हरियाणा सरकार के सहयोग से 15 मार्च 2022 को संस्थान के खेल के मैदान में खरीफ किसान मेले का आयोजन किया गया था। इस अवसर पर करनाल मंडल के मंडलायुक्त संजीव कुमार वर्मा मुख्य अतिथि के रूप में उपस्थित हुए।
- सीएसएसआरआई ने 3 मार्च 2022 को अपना 54वां स्थापना दिवस मनाया। मुख्य अतिथि, प्रोफेसर बी.आर. कंबोज, कुलपति, चौधरी चरण सिंह हरियाणा कृषि विश्वविद्यालय, हिसार ने समारोह का उद्घाटन किया।
- संस्थान ने कृषि क्षेत्र में उपलब्धियां हासिल करने वाले किसानों को सम्मानित करने के लिए 23 दिसंबर, 2022 को करनाल जिले के गांव डाबरी में किसान दिवस का आयोजन किया। कार्यक्रम में डॉ. एस.के. चौधरी, डीडीजी (एनआरएम), आईसीएआर मुख्य अतिथि थे और डॉ. ए. वेलमुरुगन, एडीजी (एसडब्ल्यूएम), आईसीएआर सम्मानित अतिथि थे।
- आईसीएआर—केंद्रीय मृदा लवणता अनुसंधान संस्थान, करनाल ने 16 से 31 दिसंबर, 2022 तक स्वच्छता पखवाड़ा मनाया।
- संस्थान में 14 से 28 सितम्बर 2022 तक हिन्दी पखवाड़ा का आयोजन किया गया।
- मेरा गांव मेरा गौरव (एमजीएमजी) और एससी—एसपी कार्यक्रम के तहत विभिन्न गतिविधियां और समारोह आयोजित किए गए।

क्षेत्र प्रदर्शनी व भ्रमण

वर्ष 2022 के दौरान 798 हितधारकों ने संस्थान के सूचना प्रौद्योगिकी केन्द्र व प्रायोगिक फार्म का दौरा किया जिसमे 485 किसान, 380 विद्यार्थी, 50 प्रसारकर्मी और वस्तु विषय विशेषज्ञ, 12 भारतीय व विदेशी वैज्ञानिक आए थे।

किसान सलाहकार सेवा

किसानों की मृदा लवणता, क्षारीयता व जल गुणवत्ता संबंधित समस्याओं के त्वरित और समुचित समाधान हेतु संस्थान के 18001801014 नम्बर पर निःशुल्क फोन सेवा चल रही है। वर्ष 2022 के दौरान देश के विभिन्न क्षेत्रों से कृषि संबंधित समस्याओं संबंधित 116 कॉल प्राप्त हुई और संस्थान के वैज्ञानिकों द्वारा इन समस्याओं के निदान हेतु वैज्ञानिक उपाय सुझाए गए। इसके अलावा, संस्थान के साथ वाट्सएप ग्रुप से जुड़े 480 किसानों को लवण प्रभावित क्षेत्रों के लिए फसल और मिट्टी प्रबंधन पर पाक्षिक परामर्श दिया गया।

क्षमता विकास

2022 के दौरान एस.सी.—एस.पी. कार्यक्रम के तहत 1227 किसानों के लिए कुल 5773 क्षमता विकास प्रशिक्षण, 431 प्रदर्शनी और 05 गोष्ठियों का आयोजन किया गया।

अंतर्राष्ट्रीय सहयोग

- जलवायु परिवर्तन, कृषि एवं खाद्य सुरक्षा (सीसीएएफएस) (सीआईएमएमवाईटी, मैक्सिको)
- उच्च जिंक चावल की किस्मों का विकास, वर्षा आधारित पारिस्थितिकी में विशेष खोज, चावल के दाने और पोषण की गुणवत्ताः कम आर्सेनिक वाले चावल, चावल में बायोएक्टिव्स और कम जीआई वाले चावल (आईआरआरआई)
- भारत के जल संवेदनशील क्षेत्रों में सतत संसाधन प्रबंधन प्रणालियों का विकास (जेआईआरसीएएस)।
- जलवायु स्मार्ट प्रबंधन प्रणालियां (आईआरआरआई)
- बांग्लादेश और पश्चिम बंगाल (भारत) के लवण प्रभावित तटीय क्षेत्रों में फसल प्रणाली सघनता (एसीआईएआर, ऑस्ट्रेलिया)

प्रकाशन

- संस्थान द्वारा प्रमुख जरनलों में 129 अनुसंधान आलेख के साथ–साथ 45 पुस्तक/मैनुअल/अध्याय, 22 तकनीकी बुलेटिन/फोल्डर/प्रचलित आलेख छपवाये गये और 53 आलेख सेमीनार/सिमपोसिया एवं कानफ्रेन्सों में प्रस्तुत किये गये।

Executive Summary

ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal, Haryana is dedicated to pursue multi-disciplinary research on management of salt affected soils and use of poor quality irrigation water in different agro-ecological zones 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 Social Science Research Division. 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 inland sodicity 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:

Development of salt tolerant Indian Mustard varieties CS 61 and CS 62 for irrigated sodic conditions of Uttar Pradesh

Two varieties of the salt tolerant Indian Mustard developed by ICAR-CSSRI, Karnal were released by Uttar Pradesh State Sub-Committee on Seed and Release of Crop Varieties (UP-SVRC) for Irrigated Sodic conditions of Uttar Pradesh as: -

CS 61: This variety CS 13000-3-2-2-5-2 (CS 61) has been released by the Uttar Pradesh State Sub-Committee Seeds and Crop Varieties (UP-SVRC) during 34th Annual Group Meeting in the year 2022 (office order: SF/296.T/SVN-08/2019-20/रा.बी.उ.स.2020-22/2022-23), for irrigated sodic soils and timely sowing (by 25 October) in Uttar Pradesh. Its yield is 21-22 q/ha in sodic soil (pH up to 9-9.3) and 25-27 q/ha in normal soil and water and has about 39 percent oil content. This variety matures in about 132 days. The height of its plants is 181 cm. This variety is resistant to Alternaria blight, white rust, powdery and downy mildew, stag head and sclerotinia stem rot and also less infestation of aphid.

CS 62: This variety CS 15000-1-1-1-4-2 (CS 62) has been released by the Uttar Pradesh State Sub-Committee Seeds and Crop Varieties (UP-SVRC) during 34th Annual Group Meeting in the year 2022 (office order: SF/296.T/SVN-08/2019-20/रा.बी.उ.स.2020-22/2022-23), for irrigated, sodic soils and timely sowing (by 25 October) in Uttar Pradesh. Its yield is 21-22 q/ha in sodic soil (pH up to 9-9.3) and 25-28 q/ha in normal soil and water and has about 39.5 percent oil content. This variety matures in about 136 days. The height of its plants is 168 cm. This variety is resistant to Alternaria blight, white rust, powdery and downy mildew, stag head and sclerotinia stem rot and also less infestation of aphid.

Identification of potential willow clones for sodic conditions

Willow (Salix spp.) is nowadays extensively cultivated worldwide owing to its distinct multifarious properties especially for sports industries (cricket bat) and other multifarious uses. A nursery trial for evaluation of six willow clones J799, SI-64-017, 131/25, PN731, UHFS62 and UHFS85 under four sodicity regimes of pH ≈8.2, ≈8.6, ≈9.0 and ≈9.4 was conducted in quasi controlled conditions to identify the suitable clones for sodic lands in semi-arid regions. Cuttings of 6 cm in length were planted in each sodicity regime and irrigated with good quality water. Sprouting (%), survival (%), sapling height (cm) and collar diameter (mm) were recorded for four months. Sprouting per cent was highest (97.9 %) at pH 8.2 and decreased with increase in pH from 8.6 to 9.4 (92.1 %). Clone 131/25 gave highest sprouting percentage (99.1 %) and lowest in PN731 (90.7 %) among all the clones. The survival was highest (90.3 %) at pH 8.6 and lowest (82.3 %) at pH 9.4. The maximum survival (94.0%) was observed in clone 131/25 and minimum (78.4 %) with PN731. Clone J799 gave highest (53.9 cm) seedling height compared to other five clones and also exhibited significantly higher height value across pH regimes of 8.2 (59.5 cm), 8.6 (57.4 cm), 9.0 (53.2 cm) and 9.4 (45.2 cm). Collar diameter of all the clones was higher at pH 8.2 and consistently decreased with the increase in the pH upto 9.4. Clone J799 gave highest collar diameter (8.93 mm) and UHFS85 clone (5.93 mm) was with lowest value in all the sodicity regimes. It is recommended that clone J799 emerged as best performer under the sodic conditions in terms of survival and growth attributes. However, it can also be found that clones 131/25 and UHFS62 were at par with J799 and would be an option for planting in the lands affected by sodicity along with J799 clone in semi-arid regions.

3-dimensional representation of soil salinity using electromagnetic induction technique

Quantifying spatial variations of soil salinity in three dimensions (3D) can help in understanding soil salinity variation in both vertically and horizontally. It also help in determining the degree of salinization and developing management strategies. Developing 3D salinity maps confers maps in terms of crop and soil use and management implications with respect to effect of salinity on soil health and agricultural productivity. We have demonstrated a method for 3-dimensional mapping of soil salinity across a study field at Bansi village, Rohtak, Haryana, India. An electromagnetic induction EM38MK-2 instrument was used to measure apparent electrical conductivity (ECa) in the field. Quasi-3-dimensional inversion algorithm (EM4Soil-V302) was used to invert apparent electrical conductivity (ECa) data to get depth specific true electrical conductivity (σ). This true electrical conductivity (σ) was correlated with measured soil salinity (ECe) in the topsoil (0–0.15 m), subsurface (0.3–0.6 m), and subsoil layers (0.6–0.9 m). Regression coefficient of 0.83, 0.95 and 0.82 was observed respectively, in topsoil (0–0.15 m), subsurface (0.3–0.6 m), and subsoil layer (0.6–0.9 m) between soil salinity (ECe) and apparent electrical conductivity (σ).

Effect of sowing windows and irrigation on yield of field bean grown under zero tillage in coastal saline soils of Konkan (Panvel)

The field bean (a pulse crop) is broadcasted in coastal soils during rabi season immediately after harvest of rice crop and it is grown using residual soil moisture. The soil salinity development during rabi season in coastal soils is observed due to capillary rise from shallow water table. An experiment was planned to study effects of suitable sowing time (sowing windows) and irrigation on yield of field bean grown under zero tillage in coastal soils of Konkan region of Maharashtra with 3 irrigation levels such as no irrigation, one irrigation at flowering and two irrigations at flowering and pod formation as main treatments while 3 sowing windows such as sowing after harvest of rice, 10 days after harvest and 20 days after harvest as sub treatments. The results of field experiment showed that sowing of field bean immediately after rice harvest produced significantly higher yield (9.45 q ha-1) compared to other late sowing windows such as 10 days after harvest (7.58 q ha-1) and 20 days after harvest (7.04 q ha-1). Also irrigation water application at time of flowering recorded significantly higher yield of 9.03 q ha-1 compared to two irrigation at time of flowering & pod formation (8.04 q ha-1) and no irrigation (7.01 q ha-1). In brief, sowing of pulse crop immediately after rice crop and irrigation at time of flowering were important for judicious utilization of residual moisture, avoiding adverse effect of soil salinity and enhancing pulse productivity on coastal saline soils.

Community level physiological profiling of microbes under salt affected soils

The Salt affected soils (SASs) adversely affect the soil physico-chemical and biological properties due to presence of variable nature and concentration of available salts. To understand the microbial functional diversity, 5-types of soils i.e. highly saline, moderately saline, highly sodic, moderately sodic and normal were evaluated for community-level physiological profiling (CLPP) using their substrate utilization pattern. The maximum pHs, CEC and ESP in surface soil (0-15 cm) were observed of highly sodic soils (10.04, 10.19 cmol kg-1 and 76.15, respectively), however ECe was highest in highly saline soils (13.53 dS m-1). Different types of soils depicted variable average well color development (AWCD) (Fig). In surface layer except highly sodic soils, AWCD increased with number of days of incubation period. Utilization of amino acids, amines, carboxylic acids, phenolic compounds and polymers was found highest for normal soils followed by moderately saline and lowest being recorded for highly sodic soils. Attention-grabbing result was observed for carbohydrate utilization, its pattern was exclusively unlike from other substrate utilization pattern. AWCD for carbohydrates was highest in highly saline soils followed by highly sodic soils. Diversity index (H) was found highest (3.19) in normal soils and lowest with highly sodic soils (1.57). However, substrate richness (SR) was found highest in normal soils (24.07) and lowest in highly sodic soils (4.53). Highest activity of dehydrogenase enzyme (DHA) and arylsulfatase was found under normal soil (31.58 µg TPF g-1 soil 24 h-1 and 288.84 µg p-NP g-1 soil h-1, respectively) and lowest with highly saline soil (12.12 µg TPF g-1 soil 24 h-1 and 65.36 µg p-NP g-1 soil h-1, respectively). Acidic phosphatase activity (ACP) was found highest in moderately saline soil (258.76 µg p-NP g-1 soil h-1) followed by highly saline soils (195.76 µg p-NP g-1 soil h-1). Alkaline phosphatase activity (ALP) was highest in highly sodic (308.67 µg p-NP g-1 soil h-1) and normal soil (287.95 µg p-NP g-1 soil h-1). The cellulase was found to be higher in saline soils while urease activity under highly sodic soils (339.11µg urea g-1 soil h-1). These results indicate that the soil enzyme activities, functional diversity, and community of microbes were influenced by the nature of salts and their concentration.

Performance of salt tolerant mustard varieties under different dates of sowing on saline Vertisols

Rapeseed-mustard occupies the second position among edible oilseeds in India. The choice of crop grown in the Bara tract area of Gujarat having saline Vertisols is limited to salt tolerant crops only. Salt-tolerant varieties of mustard developed by ICAR-CSSRI may be introduced as a new crop in this area. A suitable sowing date is very important aspect for good agronomic performance of any crop so the present study was planned. Three salt tolerant mustard varieties CS 56, CS 58 and CS 60 were sown in 6 different dates from 13th October 2020 to 2nd December 2020 with 10 days interval. Irrigation has been given whenever needed to the crop with available saline groundwater (EC- 6-8 dS m-1). On first three dates of sowing the crop was unable to establish due to higher temperature and some unidentified insect attack in the very initial seedling stage. On later three dates of sowing crop established and results revealed that all varieties germinated well under saline Vertisols. All three salt tolerant varieties of mustard performed comparable in context of growth and yield parameters. However, CS 58 gave highest seed yield, stover yield and harvest index. Sowing on 12th November reflected good germination and establishment of crop. With sowing on 12th November crop came to flowering at 55 days and for subsequent dates crop came to flower at 50 days and at 45 days. Significantly highest values for all parameters i. e. number of primary and secondary branches, no. of pods/plant, no. of seeds/pod, days to physiological maturity, seed yield/plant, seed and stover yield, test weight and harvest index was recorded with sowing of crop on 12th November. From the experiment it can be concluded that best yield (5.83 q/ha) of mustard varieties can be achieved when sown on 12th November and variety CS 58 performed better than other varieties.

Awards and Recognitions

- Dr. P.C. Sharma, Director, ICAR-CSSRI was presented with prestigious Rafi Ahmed Kidwai Award for outstanding research in agricultural sciences today at 94th ICAR Foundation Day Celebration at A P Shinde Symposium Hall, NASC, PUSA, New Delhi.
- Dr. Parvender Sheoran, Principal Scientist, ICAR-CSSRI was presented with Swami Sahajanand Saraswati Outstanding Extension Scientist Award 2021 today at 94th ICAR Foundation Day Celebration at A P Shinde Symposium Hall, NASC, PUSA, New Delhi.
- Dr. P.C. Sharma was conferred Fellow of the National Academy of Agricultural Sciences, New Delhi.
- Dr. H. S. Jat was conferred Fellow of the National Academy of Agricultural Sciences, New Delhi.
- Dr. Satyendar Kumar was conferred Fellow of Indian Society of Agricultural Engineers, New Delhi.
- Dr. Satyendra Kumar received ICAR-CSSRI Excellence Award -2021.

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

- A three days Kisan Mela cum Exhibition was organized at CSSRI, RRS Lucknow jointly with Agriculture Department, U.P. on “Khet ki Chunotiya evam Samadhan” during January 7-9, 2022.
- The Kharif Kisan Mela was organised on March 15, 2022 in collaboration with Department of Agriculture and Farmers' Welfare, Govt. of Haryana at playground of the institute. Sh. Sanjeev Kumar Verma, Divisional Commissioner of Karnal Division graced the occasion as chief guest.

- CSSRI celebrated its 54th Foundation Day on 3rd March 2022. Chief Guest, Prof. B.R. Kamboj, Vice Chancellor, Chaudhary Charan Singh Haryana Agricultural University, Hisar, inaugurated the function.
- The Institute organized Kisan Diwas on 23rd December, 2022 at village Dabri of Karnal district to honour the farmers having extra-ordinary achievements in the farming sector. In this programme, Dr. S.K. Chaudhari, DDG (NRM), ICAR was the Chief Guest and Dr A. Velmurugan, ADG (SWM), ICAR was the Guest of Honor.
- ICAR-Central Soil Salinity Research Institute, Karnal celebrated the 'Swachhta Pakhwada' from 16 to 31 December, 2022.
- Hindi Pakhwada was organized in the Institute from 14th to 28th September 2022.
- Various activities and functions were organized under Mera aon Mera Gaurav (MGMG) and SC-SP Programme.

Field Exhibition and Visit

During 2022, a total of 798 stakeholders including 485 farmers, 380 students, 50 extension workers and 12 scientists 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 the year 2022, a total of 116 agro-advisories were provided 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. Besides, fortnightly advisories on crop and soil management for salt affected areas were given to 480 farmers associated through WhatsApp groups with the institute.

Capacity building

During 2022, a total of 50 capacity building trainings, 431 demonstrations and 05 Goshthis were organized for 5773 marginalized farmers and farm women under SC-SP programme.

International Collaboration

- Climate change agriculture and food security (CCAFS)- (Funding CIMMYT)
- Development of high Zinc rice varieties; Trait discovery rain fed ecology; Rice grain quality and nutritional quality: Low arsenic rice, Bioactives in rice and Low GI rice (Funding IRRI)
- Development of Sustainable Resource Management Systems in Water Vulnerable Regions of India (Funding JIRCAS)
- Climate smart management practices (Funding IRRI)
- Cropping system intensification in the salt-affected coastal zones of Bangladesh and West Bengal, India (Funding ACIAR Australia)

Publications

The Institute published 129 research papers in peer reviewed journals, 45 Book/Manual/ Chapter, 22 Technical Bulletins/Folder/popular articles. Besides, 53 papers were presented in different National and International Seminar/Symposia and Conferences.

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 4th Five Year Plan period. The Institute started functioning at Hisar (Haryana) on 1st March, 1969. Later on, it was shifted to Karnal in October, 1969. In February 1970, the Central Rice Research Station, Canning Town, West Bengal was transferred to CSSRI, Karnal to conduct the 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. Focus on conservation agriculture based management practices in cereal systems to address the secondary salinization. In the post reclamation phase, focus is on developing climate smart agriculture, and development of farming system models for marginal 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. Scaling of individual farmer based groundwater recharge technologies, subsurface drainage for amelioration of waterlogged saline soils and development of methodology for large scale soil mapping through non-destructive soil mapping using EM-38 and GIS 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 focus areas of the Division of Crop Improvement. The Division of Social Science Research 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 and mustard and the biological reclamation of salt affected soils through salt tolerant multipurpose trees. A microbial consortia namely CSR- GROW SURE as a plant growth enhancer and Halo- CRD as a residue decomposer has been developed. Land shaping technologies for the productive utilization of waterlogged sodic soils and coastal saline soils have been advocated for scaling in domain area. Nearly 2.14 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 72,000 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. Conservation agriculture based management technologies are developed by the institute for reclaimed sodic soils to conserve natural resources and to improve soil and environmental quality.

An International Training Centre to impart training at national and international level was established during 2001 under Indo-Dutch collaborative research programme. The Institute serve as center of education for the Ph.D students of CCS Haryana Agricultural University, Hisar. The Institute faculty also serve as guest teachers and advisors for the Post Graduate education and research programmes of other 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 JIRCAS sponsored programme on reclamation of waterlogged saline agro-ecosystem.

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 and central laboratory with modern equipments has been established.

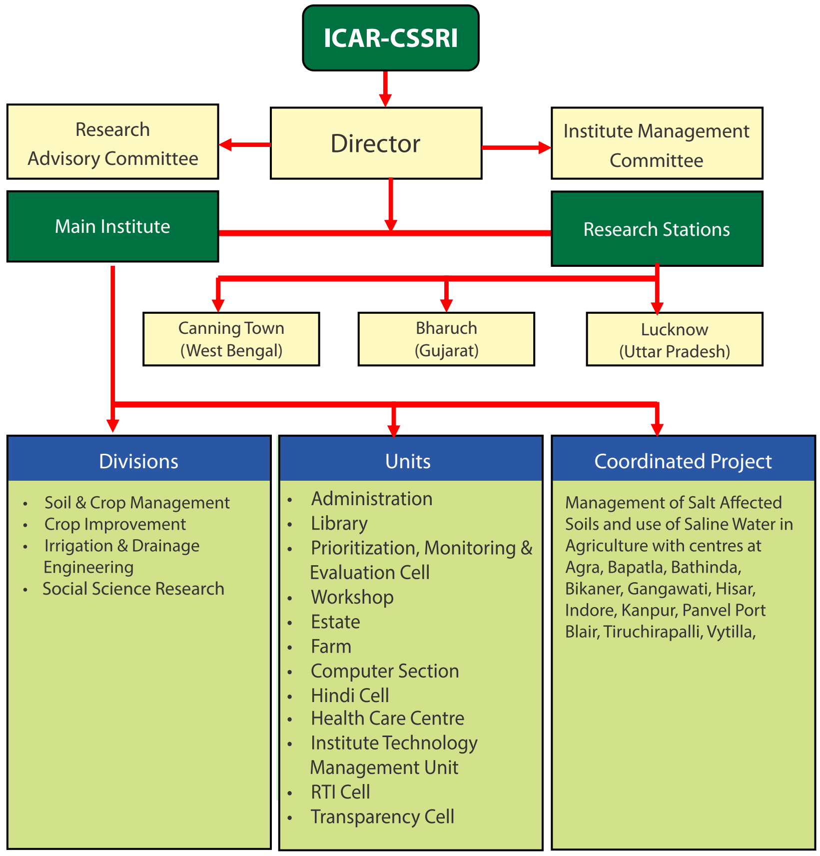
Mandate

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

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

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, Straw bailer, Riper binder, Jet sprayer, Rotavator, bund maker and 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 and orchards 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. A seed processing plant is also installed

Productivity of crops at CSSRI farm

Crop	Variety	Average yield (t ha^{-1})
	Rabi 2021 - 22	
Wheat[#]	*KRL-210*	*4.71*
	KRL-213	*5.45*
	KRL-283	*4.03*
*Mustard**	*CS 58*	*1.18*
	CS 60	*2.11*
	CS 56	*1.43*
	CS 54	*1.72*
Chick Pea[#]	*Karnal chana 1*	*1.57*
	Kharif 2022	
Paddy[#]	CSR 30	2.28
	CSR 56	4.58
	CSR 60	4.38

*Breeder Seed Production
[#]TL Seed production

to provide quality of seed of salt tolerant varieties to the farmers. During the period under report, the farm unit generated revenue of Rs. 68 lakh. To reduce the emission of green house gases, most of area has been put under minimum tillage and residue burning is not practiced in the farm. Agro-forestry system is practiced on 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.

Social Media and Web Presence

ICAR-CSSRI, Karnal has one official website, three official social media accounts and one official YouTube Channel.

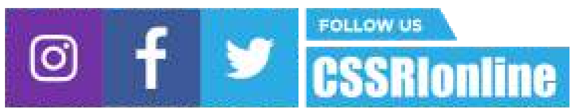
Website: https://cssri.res.in/

Facebook Account URL: https://www.facebook.com/CSSRIonline

Twitter Account URL: https://twitter.com/CSSRIonline

Instagram Account URL: https://www.instagram.com/cssrionline/

YouTube Acc.URL: https://www.youtube.com/channel/UCJZ2S2AIm1-uH38wiKdiKcg



All important updates and news regarding Institute are posted on the official website of the Institute. Photos and program updates are posted on social media platforms. Institute website also has a separate section for publications where softcopy of all the latest technical bulletins, folders, Annual Reports, Salinity News Letters and *Krishi Kiran* are available to download. Digital Salinity Newsletter (in Hindi) is also available on the publication webpage of the Institute's website.

Finances

Summary of allocation and expenditure (Rs. in lakhs) during the year 2022-23 under Plan and Non-Plan budget is presented below:

Head	Progressive Expenditure (other than NEH & TSP expenditure)	Progressive Expenditure (TSP)	Progressive Expenditure (NEH)	Grand Progressive Expenditure
Capital (Grant for creation of capital assets)	162.51	-	-	162.51
Establishment Expenses (grant in aid-salaries)	2842.91	-	-	2842.91
Grant in aid general	1128.25	-	-	1128.25
Grand Total	4133.67	-	-	4133.67
Loan and advance	0.00	-	-	0.00

Staff

The total staff strength of the institute is 301. The category wise details are:

Category of post	Sanctioned	In position	Vacant	% Vacant
Scientific	81	67	14	17.28
Technical	117	65	52	44.45
Administrative	55	31	24	43.64
Skilled Supporting Staff	48	31	17	35.42
Total	**301**	**194**	**107**	**35.55**

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 15736 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, Kjeldahl 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. A multimedia laboratory is also present 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 Uttar Pradesh using Remote Sensing and GIS (A.K. Mandal, Arijit Burman, R.K. Yadav, P.C. Sharma V.K. Mishra Sanjay Arora, Sunil Jha and M.J. Kaledhonkar)

An updated database on salt affected soils in Uttar Pradesh state was prepared based on IRS LIS III Resource SAT data (23.5 m spatial resolution embedded in 4 bands- visible and infrared bands) of 2018-19. NDVI studies have indicated large areas of wastelands as evidenced by the low NDVI values (<1.0 to -0.5). A thematic layer for base map (boundaries-state and district, irrigation/drainage, settlements and infrastructure) was prepared from the Survey of India maps on 1:50,000 scale using UTM projections in GIS. The mapping methodology was adopted from NRSA (2007) that was used for mapping land degradations on 1:50,000 scale using multi-temporal satellite imageries and further compiled in a GIS environment at the country scale.

The soils are primarily sodic (alkaline) in nature with varying degrees of development in Upper, Middle- and Lower Gangetic plains. Soil pH at surface (0-15 cm) and sub-surface depths (15-30 cm) was ranging from slight (pH_s = 8.2) to strong (pH_s = 11.4). ECe values were varying from low to high depending topography of the region. Saline soil profiles with high ECe have been developed by poor quality saline/sodic GW application in Mathura district. About 1766 soil sampling sites were used for authentication of the image interpretation units. These were superimposed with the base map prepared on 1:50,000 scale and the thematic layer of delineated units for salt affected soils, stored in GIS format. Based on the characteristics of the soil samples both at surface and sub-surface depths the label points of the soil units were identified and stored as a point map in GIS format. Such map was integrated with an attribute table containing details of the physico-chemical characteristics of soils for pHs and ECe values, locational information such as names of the village, tehsil, district, soil classification, and soil management options. A relational database was also prepared integrating spatial distribution of salt affected soils with physico-chemical properties. An areas about 3.8 million ha (15.8% of the TGA) of salt affected soils have been estimated in Uttar Pradesh (TGA = 24 million ha). Strongly sodic soils were dominant (2.2 million ha) that covers 57% of the total SAS followed by slightly sodic (0.7 million ha, 18%), moderately sodic (0.45 million ha, 11.8%) and strong saline-sodic soils (0.35 million ha, 9.2%) in the major canal command areas such as Sharda Sahayak, Upper- and Lower Ganga canals. These data was found in agreement with the NRSC (Sreenivas et al. 2021) that has reported 2.8 million ha (11.6% of the TGA) of soil degradations / desertification for Uttar Pradesh state.

Reclamation and Management of Alkali Soils

Micronutrient biofortification in cereal based systems using nano-micronutrient fertilizer forms (A.K. Bhardwaj and R.K. Yadav)

Soil fertility and crop nutrition management is one of the key technologies contributing to major increase in yield, especially under salt affected conditions. Biofortification via nanofertilizers is a new concept. Precision nanotechnology has opened a good scope for both improvements in nutrient uptake efficiency and precision application. Nano-sized entities or materials represent the transition zone between the individual atom or molecules and their bulk materials that exhibits extraordinary properties as compared to the bulk counterparts in terms of reactivity and other physic-chemical properties. Less amount of nanomaterial can do same or better job (several fold) than their bulk forms. This will enhance the nutrient availability and uptake by plants, minimize runoff and leaching losses of nutrients, and would have minimal impact on soil health.

Four formulations of micronutrients for Zinc, Iron and Copper have been tested at CSSRI [Nano-Zinc, Nano-Iron, Nano-NMN (liquid combination of Zn, Fe, Cu), and Nano-ECO (granular combination of Zn, Fe, Cu)] with particle size of 15-20 nm as confirmed with Litesizer 500 nanoparticle size analyzer and Transmission Electron Microscope. These formulations can be used to fortify the respective micronutrients in the crop plants. The objective of the project is to compare the performance of micronutrient fertilizer forms, conventional and nano, on the biofortification, and to understand the effect of mode of application on the biofortification of the nutrient in the in rice-wheat cropping.

There were twelve treatments including, 1) Nano-Zn (foliar application of Nano-Zinc), 2) Nano-Fe (foliar application of Nano-Iron), 3) Nano-ZnFeCu (foliar application of Nano-NMN), 4) Granular Nano-ZnFeCu (soil application of Nano-ECO), 5) Soil Conv. $ZnSO_4$ (soil application of Conv. $ZnSO_4$ @10 kg $acre^{-1}$), 6) Soil Conv. $FeSO_4$ (soil application of Conv. $FeSO_4$ @ 10 kg $acre^{-1}$), 7) Soil Conv. $ZnSO_4$ + Conv. FeSO4 + Conv. $CuSO_4$ (soil application of Conv. $ZnSO_4$ + Conv. $FeSO_4$ + Conv. $CuSO_4$ @30 kg $acre^{-1}$), 8) Foliar Conv. $ZnSO_4$ (foliar application of Conv. $ZnSO_4$ 0.5% solution), 9) Foliar Conv. $FeSO_4$ (foliar application of Conv. FeSO4 0.5% solution), 10) Foliar Conv. ZnSO4 + Conv. $FeSO_4$ + Conv. $CuSO_4$ (foliar application of Conv. $ZnSO_4$ + Conv. $FeSO_4$ + Conv. $CuSO_4$ 0.5% solution), 11) Control (no micronutrient fertilizers applied), and 12) Absolute Control (no macronutrient or micronutrient fertilizer applied). Foliar application of fertilizer materials was done at 30, 45, 60 days after rice transplanting and at 60, 75, 90 days after wheat sowing. Soil application of fertilizer materials @ 20 kg $acre^{-1}$ at the time of transplanting (rice)/ sowing (wheat). The field experiment was laid out in randomized complete block design with a plot size of 5 x 5 m and four replications. A pot experiment with three types of soils (micronutrient poor soil, micronutrient rich soil and sand in three replications) was also laid out in pothouse for the same treatments.

In rice crop during year 2021, significant improvement was noted in Zn content in grain under different biofortification strategies. The foliar application of nano-Zn had significantly higher concentration of Zn in rice grain, compared to rest biofortification strategies except foliar application of nano-ZnFeCu and soil application of granular nano-ZnFeCu. The Fe content in rice grain was higher in foliar application of nano-Fe. However,

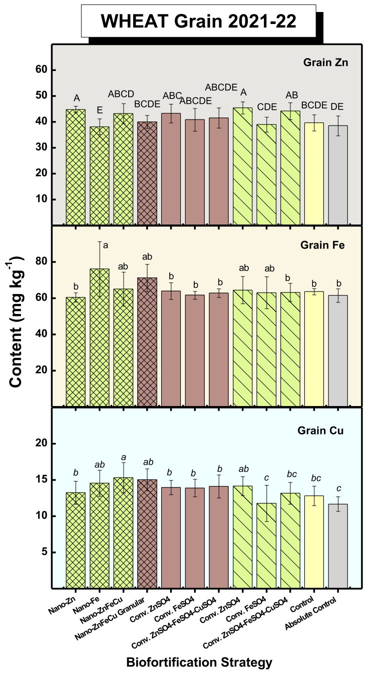


Fig 1. Effect of different biofortification strategies on the micronutrient content in wheat grains during 2021 season.

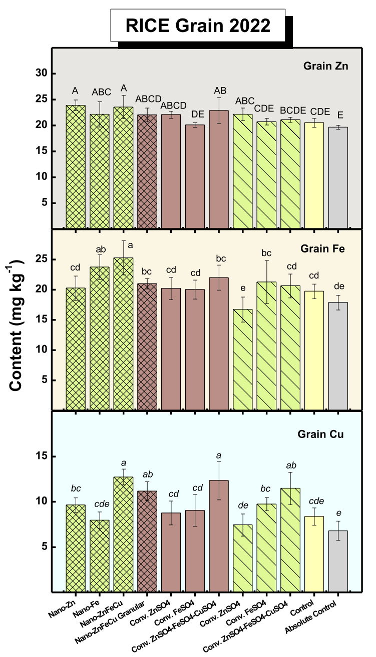


Fig 2. Effect of different biofortification strategies on the micronutrient content in rice grains during 2022 season.

all treatments had statistically similar Fe content in rice grain. While, Cu content in rice grain was significantly higher in foliar application of nano-ZnFeCu compared to Conv. $FeSO_4$ but statistically at par with rest of treatments. The improvement in Zn, Fe, and Cu content in rice grain was achieved in foliar application of different nano fertilizers, compared to soil and foliar application of different convention fertilizers.

In wheat crop during 2022, The Zn content in wheat grain was significantly higher with foliar application of nano-Zn and Conv. $ZnSO_4$ yet statistically similar to foliar application (nano-ZnFeCu, and Conv. $ZnSO_4$ + $FeSO_4$+$CuSO_4$) and soil application of fertilizers (Conv. $ZnSO_4$, Conv. $FeSO_4$ and Conv. $ZnSO_4$ + $FeSO_4$+$CuSO_4$) (Fig. 1). Whereas, Fe content was significantly higher in foliar application of nano-Fe, compared to soil application of conventional fertilizer, control and absolute control. However, foliar and soil application of nano-ZnFeCu, and foliar application of Conv. $ZnSO_4$ and Conv. $FeSO_4$ had similar Fe content in wheat as achieved in foliar application of nano-Fe. The foliar application of nano-ZnFeCu had significantly higher Cu content in wheat grain but statistically at par with soil application of granular nano-ZnFeCu and foliar application of nano-Fe and Conv. $ZnSO_4$.

In rice crop during year 2022, Zn content in rice grain was significantly higher with foliar application of nano-Zn and nano-ZnFeCu (Fig. 2). However, biofortification strategies including Nano-Fe, granular nano-ZnFeCu, conv. $ZnSO_4$ (foliar and soil application) have statistically similar Zn content in rice grain. The Foliar application of nano-ZnFeCu had significantly higher Fe content in rice grain compared to rest of treatments except nano-Fe. However, Cu content in rice grain was significantly higher in foliar application of nano-ZnFeCu and soil application of Conv. $ZnSO_4$ + $FeSO_4$+$CuSO_4$.

In rice crop, the grain yield was significantly higher with soil application of Conv. $ZnSO_4$ + $FeSO_4$ +$CuSO_4$ but statistically at par with foliar and soil application of nano fertilizers (nano-Zn, nano-Fe, and nano-ZnFeCu), soil application of Conv. $ZnSO_4$ and foliar application of Conv. $FeSO_4$ and control (Fig. 3). In case of wheat crop, the grain yield was significantly higher with foliar application of nano-ZnFeCu and soil application of Conv. $ZnSO_4$ + $FeSO_4$+$CuSO_4$ but at par with foliar application of nano-Fe and soil application of Conv. $FeSO_4$.

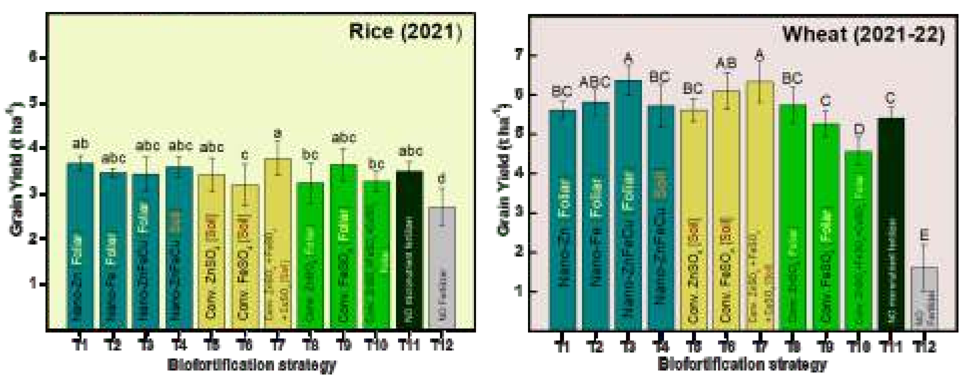


Fig 3. Effect of different biofortification strategies on the grain yield during the 2021-22 rice-wheat cycle.

Biofortification strategies using different forms of micronutrients improved the nutrient profile of the grain and straw with variable responses in rice and wheat. Nano-formulation can be efficient fortifiers of micronutrients. Favorable yield responses were noted yet varied with crop and season. Burning symptoms with foliar application of conventional sulphate forms was noted in wheat and reflected in yield loss.

Elemental S based formulations-an alternate to gypsum in reclamation of sodic soil
(A.K. Rai, N. Basak, R.L. Meena, R.K. Yadav, P.C. Sharma, Parul Sundha, S.K. Jha, K.S. Bangar, R.V. Jasra, C. Chudasama, P. Kumar, K. Sidhpuria, S. Rawalekar, Y. Shah, C. Gadipelly, Sunil Soni, N. Kumar, J. Kumpatla and H. Katti)

Elemental Sulphur based formulation was developed as an alternative technology for reclamation of sodic soils. *Acinetobacter lwoffii, Exiguobacterium profundum, Aureimonas ureilytica, Acinetobacter radioresistens, Rhodococcus qingshengii,* and *Aureimonas ureilytica* were isolated from from different sodicity affected region of the country showed 15-20% increase in RFS oxidation in different soils. Three categories of the formulations were developed for different soil conditions (Table 1). Based on the finding of the different experiment carried out in different cropping systems and agroecologies following protocol were standardized for RFS based sodicity reclamation:

1. All the reclamation work should be carried out in Pre-kharif season

2. Field levelling and soil sampling for determining the RFS requirement (5% of the gypsum requirement estimated in laboratory)

3. Application of two tonnes ha^{-1} of FYM or crop residue uniformly in the field.

4. Applying the RFS pellets preferably in flooded soil followed by light harrowing to ensure disintegration of swollen pellets and mixing in top 5-7 cm soil depth. If water availability is problem, apply the RFS in moist field and irrigate the field after mixing in top 5-7 cm soil depth.

5. Transplant the salt tolerant rice varieties after 15-20 day of application of amendment

6. Salt tolerant rice (CSR-56, CSR36) and wheat varieties (KRL 210) should be grown during initial 2-3 years of reclamation

7. Follow the alternate wetting and drying condition to ensure oxidation and leaching of the salt produced during reclamation

Note:

- Combined application of RFS and 15-25% gypsum gives better response
- Inoculation of microbial consortia of S oxidizers with FYM or crop residue also enhance the efficiency of reclamation

Table 1. Description of the formulations developed for sodicity reclamation

Category of formulations	Formulations	Suitability
CSSRI-RIL formulation I	GypRCFS10, CalRCFS10	Suitable for sodic soil with low (<1.0%) $CaCO_3$ content in Punjab, Haryana and UP and Bihar (1.79 mha)
CSSRI-RIL formulation II	GypRCFS5, GypRCFS5	Suitable for sodic soils having medium (1-2%) $CaCO_3$ content in Punjab, Haryana and parts of UP (1.68 m ha)
CSSRI-RIL formulation III	RFS, SAP-II	Suitable for sodic soils with high (>2.0%) $CaCO_3$ in MP, Maharastra, Telangana, TN, Rajasthan, AP, Karnataka (~1.98 mha)

Exploring the potential use of the silicious chalk in agriculture: sodicity reclamation and nutrient source (A.K. Rai, N. Basak, Parul Sundha, P. Chandra, H.S. Jat, R.K. Yadav and P.C. Sharma)

Silicious-chalk are the amorphous materials recovered from the gypsum mines. It is mainly composed of silica, Ca, Mg and Al. The Calcium oxide content of this mineral varies from 17.06-26.2 in different mines. It also contains an appreciable quantity of Si and other micronutrients. It can serve as the source of Ca for sodic soil reclamation as well as nutrient source for different crops. Therefore, this collaborative project was developed in collaboration with FCI Aravali Gypsum and Minerals India Ltd, Jodhpur, Rajasthan, to

Table 2. Effect of gypsum replacement by silicious chalk on the pHs of the sodic soils

Replacement (%)	pHs	pH_2	EC_2	ECe
0	8.3	8.7	1.07	2.95
10	8.2	8.6	1.65	4.18
20	8.3	8.5	1.76	3.84
30	8.3	8.6	1.67	4.24
40	8.3	8.7	1.77	5.01
50	8.7	9.3	1.06	2.82
100	8.6	9.2	0.96	2.68
Control	8.5	9.2	0.93	2.53

Table 3. Effect of gypsum replacement by silicious chalk on the performance of the rice crop under sodic soil

Replacement (%)	Straw weight (kg/m^2)	grain wt (kg/m^2)	GSR	HI	Chaffey grain (%)
0	0.51	0.12	0.23	0.19	14.33
0	0.50	0.30	0.60	0.37	10.51
10	0.47	0.20	0.43	0.30	9.86
20	0.56	0.30	0.53	0.35	11.19
30	0.51	0.26	0.52	0.34	8.25
40	0.44	0.25	0.81	0.44	8.70
50	0.33	0.13	0.39	0.28	12.90
100	0.38	0.22	0.58	0.37	12.37

Effect of slicious chalk in sand culture as source of silica assessing the sodic soil reclamation potential of the silicious chalk in different soil conditions, its nutrient supplying capacity and possibility of biological interventions to augment the solubilization of the mineral constituents for developing value added product for different agricultural usage. Gypsum replacement by Silicious chalk showed impact on sodic soil pH. About 10-20 % replacement of gypsum had non-significant effect on soil pH lowering compared to 100% gypsum. Grain and straw yield was also declined in proportion to increased replacement; however, 10-20 % replacement had similar grain yield (Table 2). Siliciuos chalk was effective as Ca source as compared to silica in nutrition of rice crop.

Effect of slicious chalk in sand culture as source of calcium


Coulometer

Effect of reclamation techniques on $CaCO_3$ dissolution and its implications on soil carbon dynamics in a calcareous sodic soil (Ashim Datta, R.K. Yadav, P.C. Sharma and S. Mehetre)

Precise measurement of $CaCO_3$ is very important for its reporting. Similarly inorganic carbon is calculated from $CaCO_3$ value by mass basis. In general, in most of the laboratories titrimetric method involving simple acid base titration is used for $CaCO_3$ measurement. Calcimeter consisting of a hanging water column is also used for $CaCO_3$ measurement. In both the methods, there are every chances of occurrence of errors thereby leading to underestimation of $CaCO_3$ content and subsequently inorganic carbon content of the soil. To overcome all the shortcomings of these two methods, an instrument named Coulometer is developed which utilizes the principle of Faraday's law involving cathode and anode for precise measurement of inorganic carbon content of soil and water.

Soil samples after harvesting of rice and wheat were collected from a field experiment conducted in a sodic soil using eight soil management treatments namely Control, Farmers practice around the area, Recommended doses of fertilizers (RDF NPK), 50% N & recommended doses of P & K+ 50% N by organic (FYM), Recommended doses of fertilizers (RDF NPK) + Gypsum 50% GR, 50% N & recommended doses of P & K+ 50% N by organic (FYM) + 50% GR, RDF+ Organics@10t/ha and Organics@10t/ha. $CaCO_3$ content was measured using above mentioned three methods of 144 samples (72 samples each from 0-15 and 15-30 cm soil depth collected after harvesting of rice and wheat). Inorganic carbon content by mass basis was calculated from all the samples. Then attempt was made to develop a relationship between titrimetric and coulometric and Calcimeter and Coulometer method of inorganic C measurement. Results showed that a significant relationships between calcimeter and coulometer method (y=0.47x+0.05, R^2= 0.86, $p<0.05$) and titrimetric and coulometric method (y=1.08x-0.05, R^2= 0.88, $p<0.05$) of inorganic carbon were observed after harvesting of rice (Fig. 4 & 5). Similar significant relationships were also observed after wheat harvesting. These equations can be used to obtain precise results of inorganic carbon.

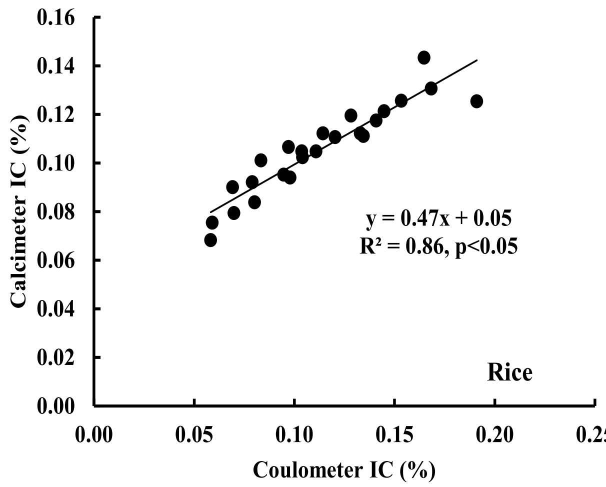


Fig 4. Relationship between inorganic carbon measured by calcimeter and coulometer after rice harvesting

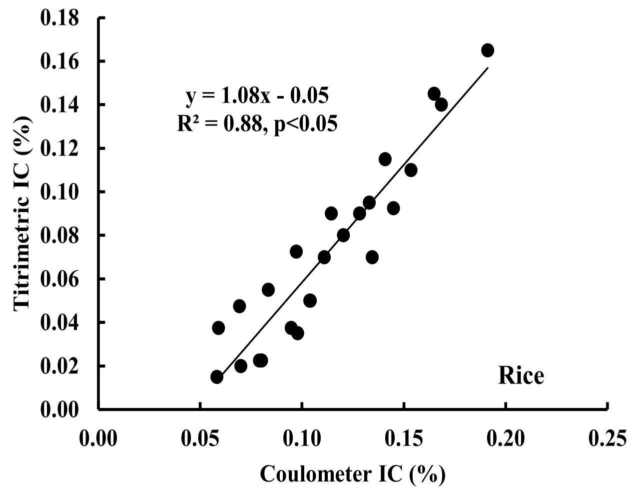


Fig 5. Relationship between inorganic carbon measured by titrimetric method and coulometer after rice harvesting

Effect of rice straw retention, incorporation and residue decomposition on productivity, profitability, soil health and environment under RW system (Awtar Singh, Raj Mukhopadhyay and RK Fagodiya)

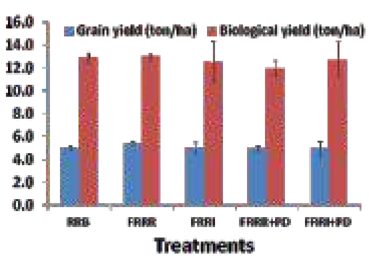


Fig 6. Effect of different residue management practices on wheat yield (2021-22)

Burning of stubble or crop residues is the most widespread practice for residue management. Specially the rice straw/stubble left in the field after the grain harvest are intentionally burned. Therefore, an experiment was started in 2021-22, at the research farm of ICAR-CSSRI Karnal, for evaluation of different cost-effective and farmer friendly residue management options (residue retention, incorporation and use of residue decomposer etc.) under the rice-wheat system. Treatments include T1: Residue burning (RRB), T2: Full rice residue retention (FRRR), T3: Full rice residue incorporation (FRRI), T4: Full rice residue retention + Pusa decomposer spray on rice residues (FRRR+PD), T5: Full rice residue incorporation + Pusa decomposer spray on rice residues (FRRI+PD). The popular variety of rice (PR 126) and wheat (HD 2967) were used for the study. The rice was harvested with the help of combine harvester having super SMS. Rice was transplanted into all the plots and various treatments were imposed on the wheat crop. The results showed that the grain as well as biological yield of wheat (2021-2022) remained unaffected under various treatments in the first years of the experiments (Fig. 6).

Changes in seed quality development of rice-wheat irrigated with residual alkalinity water [Gajender, R. K. Yadav, Nirmalendu Basak, Anita Mann, Vanita Pandey (IIWBR)]

In this study the effect of differential alkalinity induced by RSC water application during crop growth and seed development on seed quality and germination of rice and wheat is being investigated. The experiment is being conducted in filled lysimeters (2 m × 2 m × 2 m size with drainage outlets opening to a common gallery) in the experimental farm of the ICAR-Central Soil Salinity Research Institute, Karnal, India. The irrigation water treatments consisted of two types of alkali waters having similar amount of salts (total electrolyte concentration, TEC 30 me L^{-1}) and sodium adsorption ratio (SAR_{iw} 10 mmol L^{-1}), with varying residual sodium carbonate, RSC (5 me L^{-1} and 10 me L^{-1}), and 10 me L^{-1} RSC ameliorated to neutralize RSC equivalent to 5 me L^{-1} with either sulfuric acid or gypsum. These treatments were compared to irrigation with good quality water as control. The experiment was conducted with rice cvs CSR 60 and PR 126.

Various basic chemical characteristics of surface 15 cm soil, including ECe, pHs, sodium, CEC and HCO_3 content are given in Table 4. The soil pH (varying between 8.08 and 9.41 in surface 15 cm) was the maximum with RSC 10 and this was followed by RSC 5 and those ameliorated with either sulfuric or gypsum which maintained a little lower pH than RSC 5.

Table 4. Soil chemical properties under different RSC induced alkalinity treatments (October 2022)

TREATMENT	pH_s	EC_e	Na (ppm)	HCO3 (me/l)	ESP (me/100 g)	CEC (cmol/kg)	SAR
Control	8.08	1.26	101.55	5.1	1.48	11.29	1.24
RSC 5	8.99	3.2	496.22	6.55	4.86	14.83	8.04
RSC_10_5_Gypsum	9.14	2.9	459.96	5.86	4.95	15.83	8.33
RSC_10_5_H2SO4	9.04	2.77	434.55	6.53	4.58	16.68	7.59
RSC-10	9.41	2.49	411.45	6.63	5.48	15.29	8.01

Seed moisture content was estimated on the fresh weight basis using the high-constant-temperature-oven method with ground seed (ISTA, 2020). The seed moisture dry down trend was similar across the RSC treatments, but the rate was faster in Var. PR 126. Seed moisture content declined from over 48% to below 15% between 7 and 25 days after anthesis (DAA) in Var. PR 126, whereas cvs CSR 60 had taken 30 DAA for declination of moisture content from 51.5% to 15% (Fig. 7).

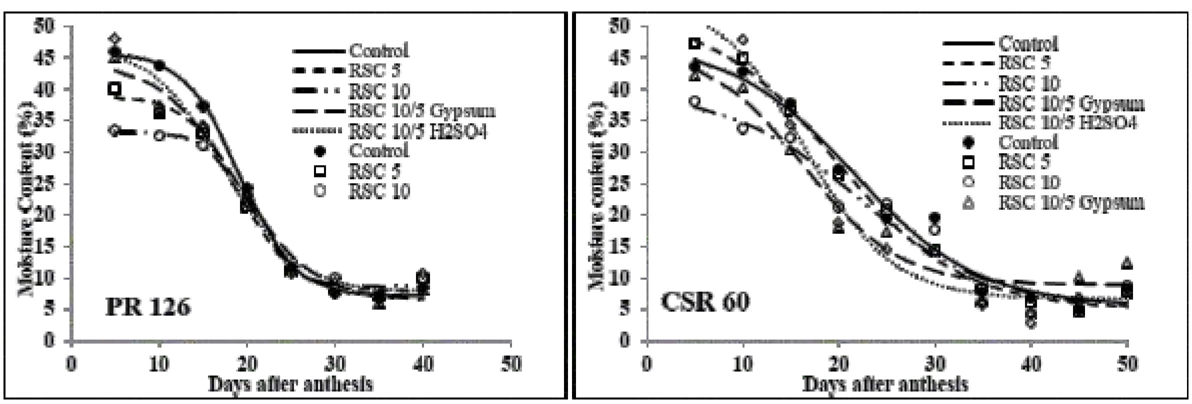


Fig 7. Changes in moisture content of fresh seeds of rice cv. PR 126 and CSR 60 in differential RSC induced alkali water irrigation regimes.

Mean seed dry weight was calculated from fresh weight and moisture content. The average seed weight (mg) was reduced significantly at RSC 5 and further at RSC 10. The mean seed weight of CSR 60 was significantly higher than the PR 126 across the treatments (Fig. 8). The overall reduction in mean seed dry weight from Control to RSC 10 was ~27.8% in Cv PR126 and ~12.5% in Cv. CSR 60.

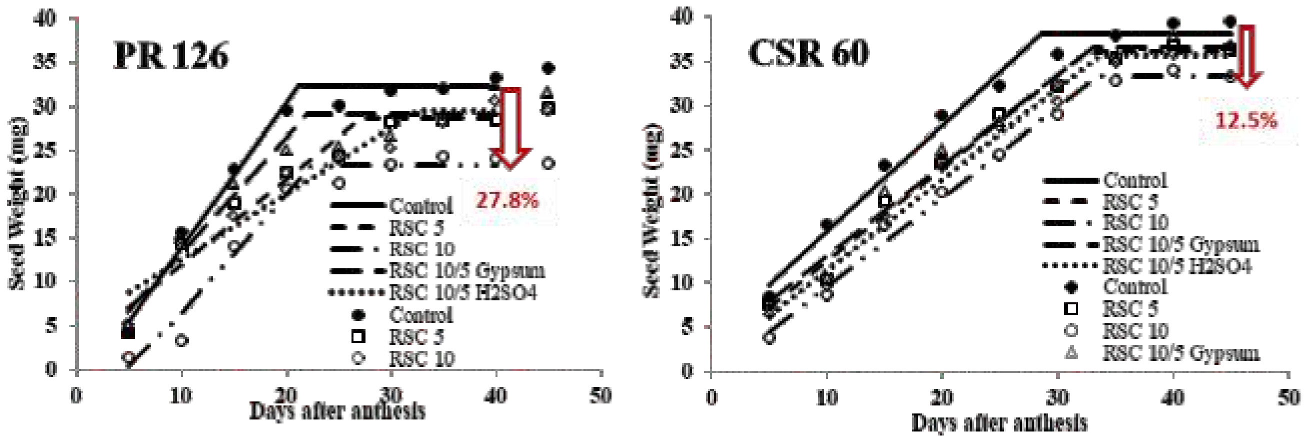


Fig 8. Changes in seed filling period and mean seed dry weight (mg) of rice cv. PR 126 and CSR 60 in differential RSC induced alkali water irrigation regimes.

In cv. CSR 60, the mean seed weight of control was 39.5 mg, whereas the mean seed weights of RSC 10 were 33.2 mg. The mean seed weight of RSC 5 and RSC 10 neutralized with H_2SO_4 and Gypsum was 33.2, 36.75 and 36.67 mg, respectively. The control treatment seed had taken 28 DAA to attain maximum seed weight, whereas RSC 10 treatment had taken 33 DAA for the same. All other treatments had taken 32 DAA to attain maximum seed weight. In cv. PR 126, the mean seed weight of control was 32.29 mg, whereas the mean seed weight of RSC 10 was 23.3 mg. The mean seed weights of RSC 5 and RSC 10 neutralized with Gypsum and H_2SO_4 were 28.7, 29.07 and 29.49 mg, respectively. The control treatment seed had taken 21 DAA to attain maximum seed weight, whereas RSC 10 treatment had taken 22 days for the same. The average seed weight (mg) was reduced significantly at RSC 5 and further at RSC 10. The seed weight was higher in Var CSR 60. RSC 5 neutralized with Gypsum or H2SO4 slightly increased the seed filling period.

Assignment for study and development of practices for application of FGD Gypsum for sodic soil reclamation and its effect on environment (Parul Sundha, Nirmalendu Basak, A.K. Rai, Raj Mukhopadhyay, R.K. Yadav and P.C. Sharma)

The flue gas desulfurized gypsum (FGDG) has potential in reclamation of sodic soil and could be an alternate to mine gypsum. CSSRI and NTPC has jointly initiated a collaborative research project to study the efficiency and efficacy of FGDG in reclamation of sodic soils and monitoring of the heavy metal(s) uptake, crop growth and quality of soil and water in FGDG amended soils under rice-wheat cropping system. The X-ray-diffraction analysis (XRD) indicates that gypsum ($CaSO_4{\cdot}2H_2O$) is the dominant crystalline phase in the FGD gypsum and trace of quartz and calcite were also detected. Investigation of SEM-EDS showed that the FGD gypsum particles occur as large flaky crystals that are primarily composed of Ca and S with the trace of other elements (such as Si and Mg).

The sodic soil reclamation experiment was initiated with the application of different doses of FGDG in lysimeters and micro–lysimeters following the rice-wheat cropping system. There was a significant change in the pH_s of soil after the harvest of three crops *i.e.* rice–wheat-rice (2020–22) at 0–15 cm soil depth (Fig. 9). The pH_s declined significantly compared to control and fallow treatments at 0–15 cm depth after the harvest of all the crops. Overall pH_s decline was higher in 100 FGDG (7.77) followed by 50 FGDG (7.93) ≈ 75 FGDG (7.94) and 50GR gypsum (8.02). A greater decline in pH_s was observed in 100 FGDG (8.14).

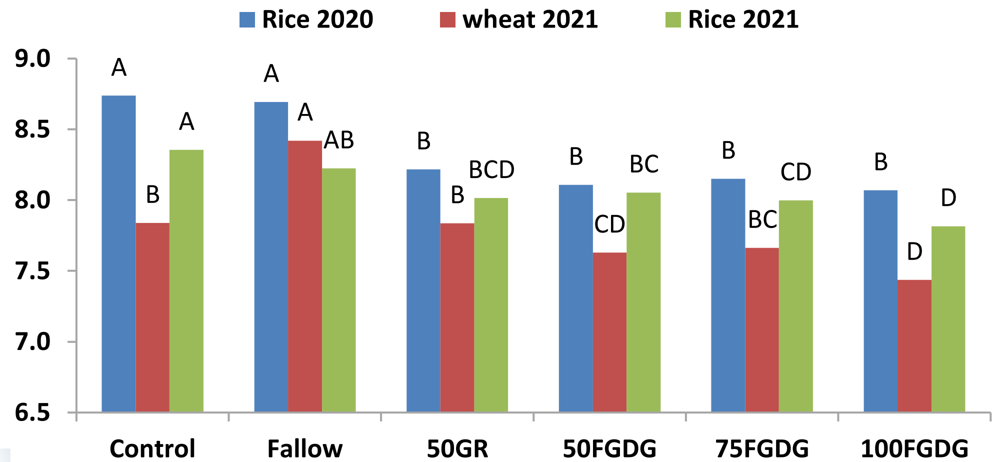


Fig 9. Effect of different levels of FGDG on pHs of surface soil (0–15 cm); different capital letters (A-D) on the bars are significantly different within years.

An overview of the rice (in grain filling stage) under sodic soil conditions treated with different levels of FGDG in lysimeter, Karnal

Application of amendments had a significant effect on the EC_e values of the soil at 0–15 (Fig. 10). A higher value of EC_e was observed in 100 GR FGDG after rice-wheat crop and was significantly higher than the lower rate FGDG application (50FGDG and 75FGDG) and mined gypsum (50GR). Overall lowest EC_e was recorded in control (2.13 dS m^{-1}) and fallow (1.72 dS m^{-1}) treatments. The EC_e remained on the higher side for treated soil compared to control and fallow and an overall decline in the value of EC_e was observed in the soil after the second rice crop compared to the initial rice crop. Similarly, the sodium adsorption ratio (SAR) of leachates during the progress of sodicity reclamation recorded a significant decrease in amended soil (100FGDG, 75FGDG, 50FGDG and 50GR gyp) than in the unamended control (Fig. 11).

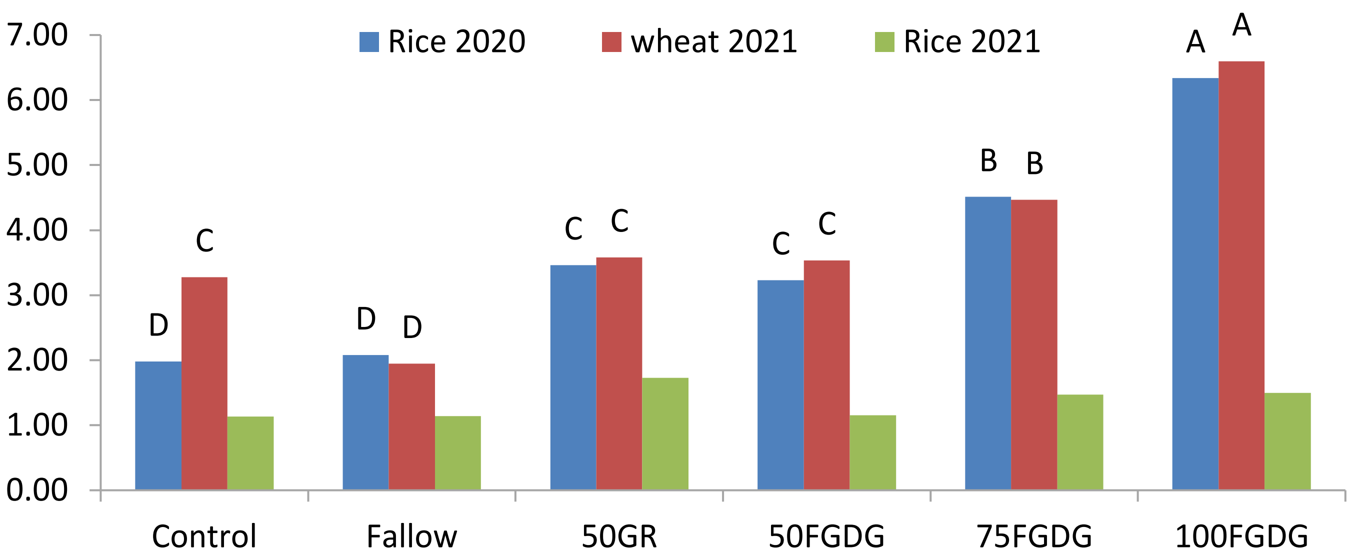
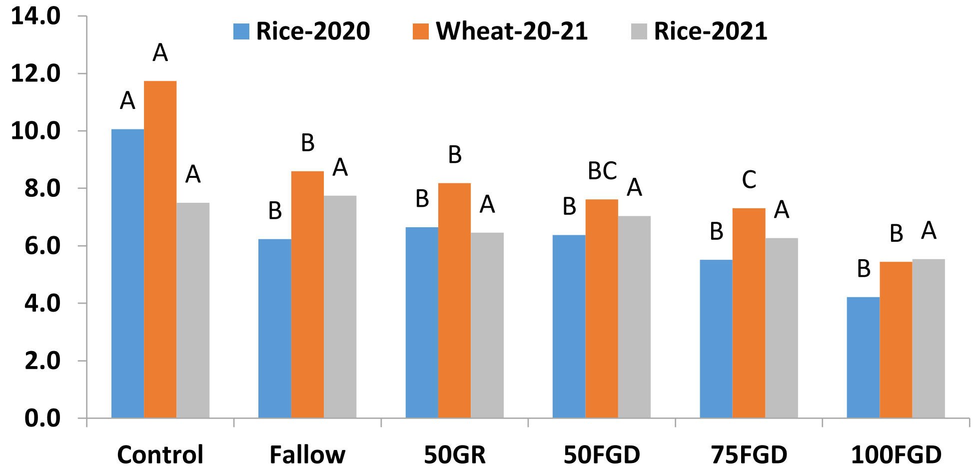


Fig 10. Effect of different levels of FGDG levels on ECe (dS m^{-1}) of surface soil (0–15 cm). Different capital letters (A-D) on the bars are significantly different within years.

Fig 11. Effect of different levels of FGDG application on the sodium absorption ratio (SAR) in leachates ($cmol^{1/2}L^{-1/2}$) of soil; different capital letters (A-D) on the bars are significantly different within years.



Rice at the tillering stage of FGDG treated field in Sitamai, Karnal, Haryana

The paddy grain and straw yield increased by amending soil with gypsum or FGDG application compared to the unamended soil of Haibatpur. Further, a greater amount of paddy grain and straw yield was recorded with the application FGDG than gypsum. However, the first-year paddy grain and straw yield showed at par amount for different doses of FGDG (50GR, 75 GR, and 100GR). The grain yield was severely affected because of high alkalinity, but the application of amendments resulted in greater biomass production. However, this soil showed a reduction in crop growth.

Sodicity reclamation experiments initiated in different farmers' fields [Sitamai and Sitamai (Karnal, Haryana), Patti Jhungian (Patiala, Punjab), Markeshnagar (Unnao, UP) and Chirkihit (Azamgarh, UP)] reported that the application of FGD improved the rice and wheat straw and grain yield and yield related attributes. The wheat grain yield increased to 3.40 and 7.76 Mg ha^{-1} than unamended control (1.06 and 3.36 Mg ha^{-1}) on amending with 50GR FGD in Sitamai and Pundrak (Karnal, Haryana). The rice grain yield increased to 6.69, 10.17, 8.0, 5.08, 7.37, Mg ha^{-1} than unamended control (5.01, 8.18, 3.0, 3.6 and 2.72 Mg ha^{-1}) in Pundrak, Sitamai (Karnal, Haryana), Patti Jhungiya (Patiala, Punjab), Markeshnagar (Unnao, UP) and Chirkihit (Azamgarh, UP), respectively.

Productive utilization of reclaimed sodic soil through conservation agriculture under rice –wheat cropping system (R.K. Fagodiya, A. K. Rai, Parvender Sheoran and Priyanka Chandra)

A field experiment is continuing since year 2006 with revised treatments from 2011 to evaluate the effect of different resource conservation strategies viz., tillage, residue and irrigation systems for enhancing crop productivity and sustaining soil health in semi-reclaimed sodic soils. High yielding variety of rice (Arize 6129 Gold) and wheat (DBW 222) were taken as test crops for year 2022. The results of different tillage and residue management practices, and irrigation systems are presented in Figure 12. Rice grain yield in Sc1 (puddled transplanted rice; PTR) was 5.76 t ha^{-1} and wheat residue incorporation in PTR (Sc2) increased rice yield by 4.51 % compared to Sc1. Scenario 4 (reduced tillage direct seeded rice with wheat residue incorporation; RTDSR+RI) produced 9.72% lower yield (5.20 t ha^{-1}) compared to Sc1, and 2.07 % lower compared to reduced tillage direct seeded rice without wheat residue (RTDSR) (5.31 t ha^{-1}), respectively. Zero tillage DSR with anchored wheat residue (ZTDSR+RR) produced 16.3% lower (4.82 t ha^{-1}) yield than the conventional PTR. The lower yield in the reduced tillage and Zero tillage DSR was mainly because of the higher weed population and lower plant population and tillering as compared to the PTR. In wheat, non-significant higher grain yield (5.22 t ha^{-1}) was recorded in Sc1 (conventional tilled wheat; CTW) compared to CTW with rice residue incorporation (RI) (Sc2). Reduced tillage wheat without rice residue (RTW) in Sc3 produced grain yield of 5.44 t ha^{-1}, which was 4.21 and 3.62 % higher compared to Sc1 and Sc4 (reduced tilled wheat with rice residue; RTW+RI), respectively. Grain yield in zero tillage wheat with anchored rice residue (ZTW+RR; Sc6) was at par with Sc1, and lowered by 7.41% than zero tilled wheat without rice residue incorporation (ZTW; Sc5). Results showed that zero/reduced tillage plays an important role in increasing wheat grain yield, minimum soil disturbance helps to protect soil organic carbon and saved from deformation of soil physical properties. However, the residue retention under reduced and zero tillage leads to considerable loss in wheat yield. The results of rice and wheat under different micro-irrigation systems in tillage and residue management practices during 2021-22 is presented in Figure 12 (from Sc7 to Sc10). Rice yield under drip irrigation system in reduced tillage DSR (DRIP-RTDSR; Sc7) was higher by about 10% as compared surface irrigated RTDSR (Sc8; 5.17 t ha^{-1}). Mini sprinkler irrigation system showed 5.73 and 5.36 t ha^{-1} grain yield in RTDSR (Sc9) and RTDSR with 33% wheat residue incorporation (Sc10), respectively. Rice yield declined by 0.52 and 6.94% in Sc9 and Sc10 compared conventional PTR (Sc1), however it was higher compared to SIS-RTDSR (Sc8). The grain yield of zero tillage wheat under drip irrigation with rice residue mulch (Sc 7) was 5.25 t ha^{-1}, which was at par to CTW (Sc1). Surface irrigation system in wheat with 100% rice residue mulch (Sc8) produced grain yield of 5.05 t ha^{-1} which lowest among the different micro irrigation scenarios. Zero tilled wheat with 100% rice residue mulch under mini sprinkler irrigation system produced grain yield of 5.19 t ha^{-1} (Sc10) to 5.22 t ha^{-1} (Sc9) which was at par to CTW. It was observed that retention of 100% rice residue mulch in wheat crop with different irrigation methods maintained the favourable soil temperature and moisture condition to facilitate the better wheat germination, growth and yield during the wheat crop growth period. Retention of 100% rice residue mulch in wheat crop with different irrigation methods showed that 100% rice residue mulch with turbo happy seed drill machine for wheat sowing is feasible option for better plant stand, higher crop growth and yield.

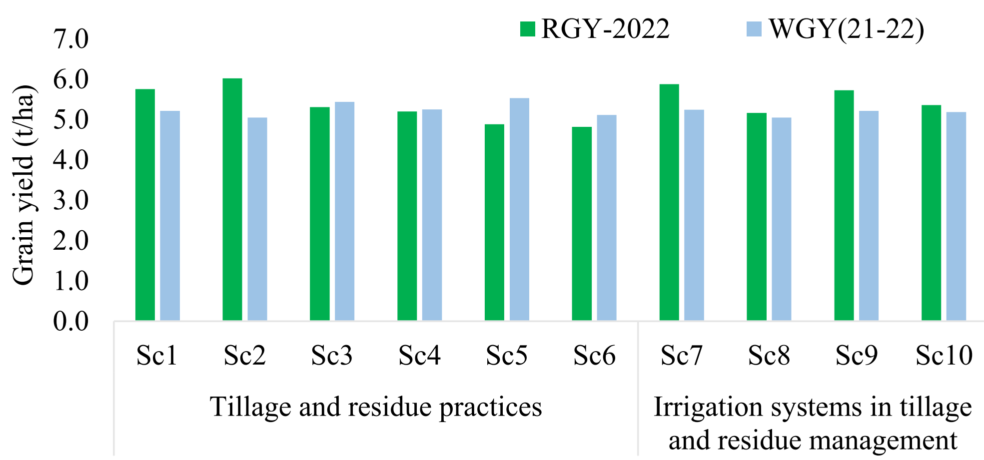


Fig 12. Effects of tillage and residue management practices, and different irrigations systems on grain yield of rice 2022 and wheat 2021-22.

Sc1= PTR/CTW; Sc2= PTR+RI/CTW+RI; Sc3= RTDSR/RTW; Sc4= RTDSR+RI/RTW+RI; Sc5= ZTDSR/ZTW; Sc6= ZTDSR+RR/ZTW+RR; Sc7= DRIP-RTDSR/ZTW+RRM; Sc8= SIS-RTDSR/ZTW+RRM; Sc9= MSIS-RTDSR/ZTW+RRM; Sc10= MSIS-RTDSR+RI/ZTW+RRM
PTR= Puddled transplanted rice; CTW= Conventional tilled wheat, RTDSR = Reduced tilled direct seeded rice, RTW = Reduced tilled wheat, ZTDSR = Zero tilled direct seeded rice, ZTW = Zero tilled wheat, RI = residue incorporation, RR = residue retention/anchored residue, RRM = Rice residue mulch, DRIP = Drip irrigation, SIS = Surface irrigation, MSIS= Mini-Sprinkler irrigation.

Climate smart management practices: Sub project 2.1- Climate smart management practices (H.S. Jat, S.L. Krishnamurthy, Y.P. Singh, S.K. Sarangi and B.M. Lokeshkumar)

In rice based systems, systems' sustainability has become a major concern owing to alarming depletion of groundwater table, soil degradation and environmental quality degradation and that resulted in to diminishing farm profitability. Developing and defining climate smart agriculture practices (CSAPs) for crops and cropping systems is the new avenues for site-specific research for development (R4D) in IGP to achieve the systems' sustainability while conserving natural resources in the context of climatic change scenario. IRRI-CSA flagship project-2 in Indian IGP was implemented for designing next generation resource efficient, productive and sustainable cereal systems suited to current climatic and socio-economic settings under salt affected agroecosystems (saline, sodic, coastal). A larger number of CSAPs related to water, nutrient, carbon, energy etc. were deployed in rice based systems. The CSAPs in rice were deployed in optimal combination to fine tune and provided better adaptability to extreme weather vagaries. Varied trials has been carried at the main campus and regional centers (Lucknow and Canning town) of ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal to evaluate and assess the CSA practices under saline, sodic and coastal ecosystem.

At ICAR-CSSRI experimental farm, the yield of wheat cultivar DBW187 ranged from 4.6 to 6.01 Mg ha^{-1} amongst the varied tillage, crop establishment and water management methods (Table 5). The yield of DBW 187 was highest in Sc7 (6.01 Mg ha^{-1}) followed by Sc4, Sc3, Sc6, Sc2, and Sc5 (5.62-5.00 Mg ha^{-1}) and the lowest in Sc2 (4.60 Mg ha^{-1}). Similarly, the yield of DBW 222 was highest in Sc7, Sc4, Sc6 and Sc5 (6.61-5.67 Mg ha^{-1}) followed by Sc3, Sc2 and Sc1 (5.47-4.82 Mg ha^{-1}). The yield of DBW 303 was highest in Sc5 and Sc4 (4.97-4.90 Mg ha^{-1}) followed by Sc3, Sc1, Sc7 and Sc2 (4.77-4.08 Mg ha^{-1}) and lowest in Sc6 (3.96 Mg ha^{-1}). Similarly, the yield of PBW 869 was highest in Sc7 and Sc1 (5.30 and 4.82 Mg ha^{-1}) followed by Sc2, Sc6, Sc4, (4.72-4.10 Mg ha^{-1}) and lowest was found in Sc3 and Sc5 (4.00 Mg ha^{-1}). Among the four wheat varieties, DBW 222 performed better under all types of tillage, crop establishment and water management methods, but it performed better under bed planting method of wheat seeding. All Wheat cultivar performed good under all types tillage, crop establishment and water management methods, but it performed better under bed planting methods.

At CSSRI regional station, Lucknow, after the harvest of rice, salt tolerant varieties of wheat were grown along with the different doses of fertilizers. Half dose of N, full dose of P and K was applied as basal and the remaining N was applied in two equal splits after 25 and 50 days of sowing. In terms of grain yield, no significant difference was observed among the genotypes across nutrient management practices. Numerically, KRL283 recorded highest yield (2.51 Mg ha^{-1}) and lowest yield was registered by HD2967 (1.98 Mg ha^{-1}). However, there was a significant difference between different nutrient management practices. Highest grain yield was observed in 150% RDF (2.73 Mg ha^{-1}) which was almost at par with farmer's practice (2.57 Mg ha^{-1}). Nutrient management with 100% RDF registered a grain yield of 2.23 Mg ha^{-1} while the lowest was in 50% RDF, i.e., 1.59 Mg ha^{-1}. This indicates that 150% RDF doesn't provide any additional yield advantage over farmer's practice.

At CSSRI Canning Town station, during the *Boro* season, the field experiment on the evaluation of silicon fertilizer was conducted in split-split plot design by using two

Table 5. Effect of different management practices on yield (Mg ha^{-1}) and water use (mm ha^{-1}) of wheat in different scenarios of rice cultivation

Scenarios	Crop establishment methods	What Yield (Mg ha^{-1})				Irrigation (mm ha^{-1})
		DBW187	DBW222	DBW303	PBW869	
Sc1	PTR-CTW	4.60D	4.82F	4.64CD	4.82B	526.6A
Sc2	CT-Dry DSR-ZTW	5.01C	5.16E	4.08E	4.72B	503.3B
Sc3	CT-Vattar DSR-ZTW	5.07C	5.47D	4.77BC	4.00D	502.7B
Sc4	ZT DSR- ZTW	5.62B	6.12B	4.90AB	4.10D	492.3C
Sc5	ZT-Vattar DSR- ZTW	5.00C	5.67C	4.97A	4.00D	489.0C
Sc6	Rice- Furrow Planting- PBW	5.06C	5.72C	3.96E	4.29C	406.3D
Sc7	Rice- Bed Planting-PBW	6.01A	6.61A	4.56D	5.30A	401.3D

varieties Canning 7 (tolerant) and IR 29 (susceptible) in the main plot. The sub plot treatment consisted of application methods *viz*. 100% basal with the recommended dose of fertilizers (RDF), 75% basal with RDF + 25% foliar at maximum tillering and 50% foliar spray + 50% foliar spray before panicle initiation. The sub-subplot consisted of Si fertilizer doses viz. 0 kg/ha, 75 kg sodium metasilicate/ha, 105 kg sodium metasilicate/ha, 170 kg sodium metasilicate/ha and 230 kg sodium metasilicate/ha. The treatments were replicated thrice. Source of Si was sodium meta silicate (23% Si). The grain yield of tolerant variety Canning 7 was significantly higher over the susceptible variety IR 29. With increasing the silicon dose, the grain yield of *Boro* rice increased in coastal saline soils.

Climate smart management practices: DSR Consortium (Sub Project- 2.4) (H.S. Jat, Krishnamurthy S.L., S.K. Sarangi and Lokeshkumar B.M.)

The agricultural scenario in South Asian countries during the mid- 1960s to 1990 was in favour of high input and high productivity technology, which resulted in production enhancement to meet food grain demand of the accelerating population. However, the decade of 1990- 2000 witnessed over-exploitation, causing widespread deterioration in soil and water resources. The conventional systems created problems of high production cost, low input-use efficiency, decline in groundwater, deterioration in soil health, and environmental pollution. The intensive use of water in conventional puddled transplanted rice (CT-TPR) cultivation in northwest IGP is depleting aquifers at the rate of 11-13 km^2 annually. Therefore, it has been imperative to use conservation agricultural techniques for sustained production. The demand of cereals to meet the food requirements of the burgeoning population is increasing while on the other hand most vital inputs of agriculture viz. water and labour are depleting in the area. The conventional system of rice production (CT-TPR) in this region is basically water, labour and energy intensive, adversely affecting the environment. Therefore, to sustain the long term production of rice, more efficient alternative methods of rice productions are needed. For this, Dry direct Seeded Rice (DSR) is the technology which is water, labour and energy efficient along with eco-friendly characteristics and can be a potential alternative to CT-TPR.Varied trials has been carried at the main campus and regional center (Canning town) of ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal to evaluate and assess the DSR under saline and sodic ecologies. Also the demonstration of DSR has been conducted at farmers' field for its faster adoption.

The rice crop was sown during *Kharif* 2022 under coastal saline agro-ecosystem of the West Bengal under the different tillage and crop establishment management scenarios. The plant height was found at par with different management scenarios. However, with cultivars, it was varied and recorded highest with Sabita compared to rest of the three

Table 7. Effect of rice establishment methods and genotypes on plant height and population

Establishment methods	Plant height (cm)	Root length (cm)	Grain yield (tha-1)	Straw yield (tha-1)
PTR	130.7a	28.4a	4.05c	4.28a
DSR	132.4a	28.3a	4.56a	4.85a
UPTR	128.3a	28.9a	4.28b	4.47a
PTR+GP	128.7a	27.5a	4.65a	4.75a
Varieties				
Sabita	167.0a	29.4a	5.15a	5.46a
CSR 46	112.1c	28.1a	3.91b	4.05b
BRRIdhan 78	120.1bc	27.3a	3.46c	3.54c
CR1009-Sub1	121.0b	28.4a	5.00a	5.30a

varieties (Table 7). The root length was neither affected by management scenarios and cultivars. Highest grain yield was observed in PTR+GP (4.65 t ha^{-1}), which was at par with DSR (4.56 t ha^{-1}). Lowest yield of 4.05 t ha^{-1} was observed in PTR. Among the varieties Sabita (5.15 t ha^{-1}) and CR1009-Sub1 (5.00 t ha^{-1}) were at par, followed by CSR 46 (3.91 t ha^{-1}) and lowest grain yield of 3.46 t ha^{-1} recorded in case of BRRIdhan78. Establishment methods did not affect the straw yield, however among the varieties highest straw yield was observed in Sabita (5.46 t ha^{-1}) and CR1009-Sub1 (5.30 t ha^{-1}), followed by CSR 46 (4.05 t ha^{-1}). Lowest straw yield was observed in BRRIdhan 78 (3.54 t ha^{-1}). After harvest of rice, four maize genotypes (Silver M, Asha 3501, Bio-Zenith and Rohini) were sown in the place of rice genotypes on 21.12.2022 on the same layout.

Studies on AGROTAIN Incorporated Urea Produces with N-TEGRATIONTM Technology as an Enhanced Efficiency Fertilizer for use in Major Cropping Systems in India (H.S. Jat, Ashim Datta, Madhu Choudhary and P.C. Sharma)

Low nitrogen use efficiency is one of the major challenges not only for agricultural productivity and farm profits but also for environmental quality being highest contributors to agriculture's footprints. India is one of the major consumers of the fertilizer nitrogen having significantly low Agronomic Efficiency of Nitrogen (AE_N). Most fertilizer N in India is consumed by rice, wheat, maize and sugarcane with low AE_N. The Prime minister of India recently emphasized to reduce the fertilizer N use by 20% in agriculture sector which force to improve the AE_N dramatically using new tools, techniques, molecules to reduce the volatilization losses of N and improve crop uptake. New products such as AGROTAIN incorporated urea produces with N-TEGRATIONTM technology has shown potential to reduce the volatilization losses and increase AE_N in many countries across the world. However, it has not received wide research attention in India. Therefore, a systematic research has been initiated by ICAR/NARS and CIMMYT for Improving AE_N using AGROTAIN incorporated urea in major cropping systems (Rice-Wheat, Rice-Rice, Maize-Wheat, Rice-maize and Sugarcane) at seven locations covering major soil orders and agro-ecologies of India.

The results from different cereal-based cropping systems (rice-wheat, rice-rice, rice-maize and wheat-maize) indicated that the grain yields of all three cereals (rice, wheat and maize) with 80% dose of AGROTAIN incorporated urea (AIU) were statistically similar to that of 100% neem coated urea (NCU). The N use efficiency calculated as agronomic efficiency (AE_N) and partial factor productivity on nitrogen (PFP_N) were improved with 100% and 80% AIU compared to 100% NCU in all the cropping systems. Across sites and cropping systems, grain yields, AE_N and PF_N with 100% AIU tended to be higher compared

Table 8. Effect of different N- doses on grain yield, system yield, agronomic efficiency of N (AE_N) and partial factor productivity of N (PFPN) of maize–wheat system at Karnal

Treatment	Maize				Wheat				System (wheat equivalents)			
	Yield (Mg ha^{-1})	AEN (kg grain kg N^{-1})	PFPN (kg grain kg N^{-1})	NR (INR ha^{-1})	Yield (Mg ha^{-1})	AEN (kg grain kg N^{-1})	PFPN (kg grain kg N^{-1})	NR (INR ha^{-1})	Yield (Mg ha^{-1})	Net returns (INR ha^{-1})	AEN (kg grain kg N^{-1})	PFPN (kg grain kg N^{-1})
Control	5.43d	-	-	56075d	1.69c	-	-	36895c	7.08c	92969d	-	-
100% NCU	9.47b	26.93c	59.63c	124534b	5.61a	20.48d	38.13d	101475ab	14.82a	226009b	25.78a	49.39c
100% AIU	9.99a	30.53b	63.27c	134104a	5.94a	22.31c	40.00c	105930a	15.16a	240033a	26.93a	50.55c
80% AIU	9.66a	35.25a	76.17b	128292ab	5.66a	26.32b	48.42b	101762ab	14.66a	230054ab	31.55a	61.07b
60% AIU	8.47c	33.75a	88.31a	107933c	4.93b	30.85a	60.33a	93165b	12.84b	201098c	32.00a	71.36a

*Means followed by similar lowercase letters within a column are not significantly different at 0.05 level of probability using LSD test

to that of the 100% NCU indicating overall superior efficacy of N when applied with AGROTAIN. On a whole cereal systems basis, compared to 100% NCU, grain yields (GY) with 80% AIU ranged from -0.33 to + 12.10% and AE_N increased from 2.6-20.9% (23.75%) and PFP increased from 14.51-20.76% -whereas with 100% AIU, grain yield increased from 0.69-19.26% and AE_N from 7.77-15.73% and PFP 5.55-7.4% (9.25%) in four crops (Wheat; Rice; Maize; Sugarcane) compared to 100% NCU.

At CSSRI- Karnal station, the grain yield of maize and wheat increased by 5.49% and 5.88% with 100% AIU, respectively as compared to 100% NCU. However, the system yield (wheat equivalents) was 2.29% with 100% AIU, respectively in comparison to 100% NCU (Table 8). The 100% and 80% AIU recorded higher net returns in maize by 7.7% and 3.0% as compared to 100% NCU, respectively. The system net returns were 6.2% higher with 100% AIU over 100% NCU. The agronomic efficiency of N (AE_N) and partial factor productivity of N (PFP_N) was decreased with the increased doses of N. Higher AE_N was observed with 100% AIU as compared to 100% NCU (Table 8). Compared to NCU, AE_N and PEP_N of the system increased 22.38% and 23.65% under 80% AIU. Our study revealed that new stabilized urea fertilizer (AIU) saved 20% (30 kg N ha^{-1}) of NCU at similar or higher yields and N-use efficiency in maize-wheat system of north-west India. The AIU urea with neem was more efficient than neem alone and may play a great role in reducing the N-losses. AIU with neem could allow farmers to achieve equal to or higher yields to neem alone while using 20% less nitrogen fertilizer.

Developing and defining climate smart agriculture practices portfolios in South Asia (H.S. Jat, Madhu Choudhary and P.C. Sharma)

Climate smart agriculture practices

The sustainable crop production is top priority not only to address the food security but also to sustain our natural resources and environmentally quality. Climate-smart agriculture (CSA) is considered a pragmatic approach to ensuring food security in a changing climate in partially reclaimed sodic soils. Adaptation strategies based on the principles of CSA can counter the impacts of climate change, such as the promotion of conservation agriculture, the sustainable management of natural resources and the promotion of climate-smart crops. CSA options include water, energy, nutrient, carbon, weather and knowledge-mart technologies, practices and services suitable for various crops and cropping systems in the region.

During *kharif* 2022, rice yield was significantly higher in scenario 2 (6.66 t/ha) followed by

Table 9. Yield and water use under different scenarios during rice/maize 2022

Scenario	Systems	Residue management	Productivity (Mg ha^{-1}) (REY)	Irrigation water (mm ha^{-1})	Water productivit (kg grain m^{-3})
I- farmers practice	Rice-wheat (CT/TPR)	No residue	6.28	1089	0.58
II- partial CA based	Rice-wheat-mungbean (TPR-ZT-ZT)	Full (100%) rice & mungbean and anchored wheat	6.66	983	0.68
III- full CA based	Rice-wheat-mungbean (ZT-ZT-ZT)	Full (100%) rice and mungbean; anchored wheat	6.22	491	1.27
IV- full CA based	Maize-wheat-mungbean (ZT-ZT-ZT)	Maize (65%) and full mungbean and anchored wheat	11.14 (11.58)	60	19.30
V- full CA+ based with SSD	Rice-wheat-mungbean (ZT-ZT-ZT)	Full (100%) rice and mungbean; anchored wheat	6.39	208	3.07

[a]Values in parenthesis indicate the actual yield of crop

scenario 5 (6.39 t/ha), scenario 1 (6.28 t/ha) and lowest in scenario 3 (6.22 t/ha). The yield of rice was higher by 6.6% in scenario 2 over scenario 3. About ~4.8 higher maize yield was recorded in scenario 6 over scenario 4. In rice, irrigation water application was highest in scenario 1 (1089 mm/ha) followed by scenario 2 (983 mm/ha), scenario 3 (491 mm/ha) and lowest in scenario 6 (24 mm/ha). The irrigation water application of rice was lower by 50.05% in scenario 3 over scenario 2. About 61.81% lower maize irrigation water application was recorded in scenario 6 over scenario 4. The water productivity was significantly lower in scenario 6 (50.54 kg grain m^{-3} water) over scenario 1. The water productivity of rice was lower by 46.46% in scenario 2 over scenario 3. About 61.81% lower maize water productivity was recorded in scenario 4 over scenario 6 (Table 9).

The experiment was started during the monsoon 2022 in the on-going CA research trial, with seven treatments referred to as scenarios (S) at the research farm of Indian Council of Agricultural Research (ICAR) - Central Soil Salinity Research Institute (CSSRI) (29◦70′ N, 76◦95′ E), Karnal, India. It falls under Typic Natrustalf category. The term scenario can be described as it is a portfolio of practices where more than two agronomic interventions are included in each treatment to see the combined effect of different management agronomic practices.

Transforming Agri-food Systems

The strategic research trials have been formulated on conservation agriculture (CA)-based crop diversification options to ensure food and nutritional security while sustaining the natural resources in the NWPZ of India. Seven-cropping system based on station trial was initiated at ICAR-CSSRI, Karnal in Kharif season. The experiment details / scenarios (portfolios of practice) and management practices are presented in Table 10.

Table 10. Treatment details

Scenarios	Drivers of change	Crop Rotations	Tillage	Crop Establishment Method	Residue Management
Sc1	Business as usual (farmer's practice)	Rice-wheat -fallow	PTR-CT	rice: transplanting; wheat: broadcast -on flats	full rice and partial wheat residue burning
Sc2	Improved production, income, and nutrition through intensification	Rice-potato-spring pearl millet	CT DSR-CT-CT	rice: drill seeding on flats; potato: manually; pearl millet: drill seeding -on fresh beds	all crop residue removal
Sc3	Sustainable intensification to address the issues of labor, water, energy, malnutrition, soil health degradation	Rice-wheat–mung bean	ZT DSR-ZT-ZT	rice: drill seeding; wheat: drill seeding; mung bean: drill/relay -on flats	full (100%) rice; anchored wheat (25-30%) and full mung bean residue retention
Sc4	Sustainable intensification to address the nutrition along with labor, water, and soil health	Maize- mustard- mung bean	ZT-ZT-ZT	maize: drill seeding; mustard: drill seeding; mung bean: drill/relay -on permanent beds (pbs)	anchored maize (60-70%) and mustard (30-40%) and full mung bean residue retention
Sc5	Sustainable intensification to deal with human and animal demand for nutritious food and fodder	Baby corn-carrot- cowpea (dual purpose)	ZT-CT-CT	baby corn: drill seeding; carrot: manually; cowpea: drill seeding -on fresh beds	anchored cowpea (15-20%) residue retention
Sc6	Sustainable intensification to address labor, water, nutrition, and animal green fodder	Soybean- wheat-sorghum (fodder)	ZT-ZT-ZT	soybean: drill seeding; wheat: drill seeding; sorghum: drill seeding-on pbs	anchored soybean (~20%) and wheat (~30%) and sorghum (~15%) residue retention
Sc7	Sustainable intensification to address labor, water, and nutrition	Pearl millet-pea- sunflower	ZT-ZT-ZT	pearl millet: drill seeding; pea: drill seeding; sunflower: drill seeding -on pbs	pearl millet (~15%); full pea and sunflower residue retention

During first kharif season, highest crop yield was recorded with maize crop (non bio-fortfied-11.8 t/ha; bio fortified- 7.8 t/ha) under Sc4 followed by rice (5.8, 5.4, 5.2 t/ha) under Sc3, Sc2 and Sc1, respectively and it was followed by baby corn (4.7 t/ha under Sc5). The lowest yield was recorded under Sc7 in pearl millet (non bio-fortfied-3.1 t/ha; bio-fortified- 3.0 t/ha) followed by soybean in Sc6 (2.3 t/ha).

Management of Waterlogged/Saline Soils

Technical Guidance and Monitoring & Evaluation of Large Scale SSD & VDS Projects in Haryana (D.S. Bundela, Satyendra Kumar, R.L. Meena, Bhaskar Narjary, R.K. Fagodiya, Jaffer Y. Dar, Raj Mukhopadhyay, Arijit Barman, Kailash Prajapat and P.C. Sharma)

Rehabilitation of existing SSD projects

Rehabilitation of 55 drainage blocks under the existing SSD projects was completed with installation of 55 solar pump sets and construction of 52 pump houses in ten SSD projects in Bhiwani-I, Charkhi Dadri-II, Fatehabad, Rohtak-II & III, Kathura (Sonipat-II& III), Sirsa, Palwal and Hisar, out of pending 55 pump sets and 98 pump houses. The performance of SSD systems was improved by significant reduction of soil salinity to 4.0 -5.5 d S/m and lowering of water table below 1.5 m. Waterlogged saline area reclaimed by SSD (Sub surface drainage) technology after rehabilitation was 11,429 ha (28,573 acres) benefitting 8,305 beneficiaries under 14 SSD projects in Haryana whereas area reclaimed by vertical drainage system (VDS) was 200 ha (500 acres) up to June 2022 benefitting 100 beneficiaries under a VDS project at Sikrona (Faridabad) and another VDS project at Sirsa was under implementation. Thus, the total reclaimed in the Haryana state up to June 2022 was 11, 629 ha (29,073 acres).

Evaluation of design and layout of SSD system

The design and layout of a SSD system with one drainage block under Sonipat-III SSD project at Bilbilan site (BN-3) covering an area of 42.8 ha was technically evaluated for permissible length of lateral pipes, drainable area of collector pipes, flow directions, lateral and collector slope, and discharge capacities. The design of the SSD system was verified and found that the actual length of lateral pipes was lesser than the maximum permissible lengths for 60 m spacing and the actual area drained by the collectors was lesser than the maximum permissible areas (Table 11). Further, it was verified that its layout was prepared taking advantage of natural field slope existing in the drainage block so as to keep the excavation minimum. The HOPP prepared design and layout was in conformity with the national drainage guidelines. Therefore, design and layout of the SSD system for S-III-BN-3 at Bilbilan site was approved and recommended for the implementation during 2022-23.

Monitoring & evaluation of five SSD projects

Monitoring & evaluation (M&E) study of five SSD projects with 67 drainage blocks covering reclaimed area of 2,443 ha and 1,863 beneficiary farmers installed at Gharwal,

Table 11. Hydraulic evaluation of design of a SSD drainage block at Bilbilan (Sonipat)

S.No.	SSD Block	Gross area (ha)	Net area (ha)	Lateral pipe size (mm)	Actual lateral length used (m)	Permissible lateral length (m)	Actual drained area (ha) by collector pipe size (mm)			
							160	200	250	294
Sonipat-III SSD Project (Bilbilan)										
1.	BN-03	42.8	33.17	80	60-200*	621.5*	--	20.19	33.17	--
Total	**42.8**	**33.17**								

(Note: 60 m* and 67 m** lateral drain spacing based on field or ientation; Maximum areas drained, 17.13 and 30.17 ha based on 160, and 200 mm collector pipe sizes)

Pumping of drainage water from a SSD block into Kahni open drain

Katwara, Siwana Mal, Mokhra Kheri and Kharkhara under Sonipat-II & III, Jind, and Rohtak-I and II projects, respectively, was conducted during 2022 for improvement in soil salinity and crop yield (photo). Field data were collected and information on Rabi and Kharif crops were collected through mobile phones from beneficiary farmers. The average yields of paddy and wheat crops increased by 38-196% and 26-87%, respectively, for adequate pumping operations done by farmers for achieving reclamative salt leaching in almost drainage blocks. Out of 67 drainage blocks, adequate pumping was achieved in 65 blocks (97%). This technology has transformed barren waterlogged saline lands into good croplands in 2-3 year period and reduced the soil salinity (ECe) from 15.1-38.2 to 4.11-8.15 dS/m and water table below 1.5-2.1 m from the ground surface. It can be conclusively stated that SSD projects resulted in significantly enhancing crop yield and doubling farmers' income provided adequate pumping for full reclamative salt leaching was ensured with farmer's support.

M&E of a pilot vertical drainage project

Visit of team to vertical drainage system at Sikrona (Faridabad)

M&E of a pilot vertical drainage system installed at Sikrona site (Faridabad district) in Nov 2019 was conducted in September 2022 (photos). Most of twelve vertical drainage tubewells was non-functional at Sikrona site due to shift of solar control units by farmers from the adjoining villages in view of increased downstream drain water salinity due to vertical drainage pumping. Water samples from the Sikrona drain and farmer's tubewells were collected and analyzed and it was found that the tubewell water salinity was 33.5 dS/m and drain water salinity was 2.40 dS/m when most of tubewells were non-operational. Highly saline effluent water from vertical drainage was disposed off into Sikrona drain (45 cusecs capacity) which has spiked the water salinity and affected the wheat crop of the adjoining areas of Kabulpur and Bhanakpur villages in 2021-22 when the drain water was reused by farmers for irrigation when canal allocation to drain was quite low.

The vertical drainage tubewells was operating in most of 10 months when solar power is available during day time and there is no regulating mechanism for operation of vertical drainage tubewells. It has caused environmental impact for downstream farmers and significant crop yield loss to farmers, when drain water was reused for irrigation by farmers of Sikrona, Kabulpur, Bhanakpur and Mahola villages. Pumping of vertical drainage tubewells should be done mainly during the rainy season when drains are running full and water demand of drain water is quite low. Successful operation of vertical drainage has reduced soil salinity, controlled water table below 1.0 m and increased wheat-rice yield significantly, but it also brought drain water salinity impact to downstream areas and farmers due to higher salt mobilization from deeper ground water and through resalinization of area and crop yield loss. Vertical drainage has not been successful at Sikrona site. Therefore, vertical drainage is not recommended wherever groundwater salinity (EC) is more than 4.0 dS/m. In specific cases, vertical drainage is recommended for higher salinity groundwater with higher disposal capacity (Main/feeder canals) with fully meeting irrigation/drinking water quality standards. There is further need to study to have an optimal schedule for pumping operation for solar powered vertical drainage tubewells as their operation should not be done at critical stage of crop growth.

Hindon Roots Sensing (HIROS)-River Rejuvenation through Scalable Water and Solute Balance Modelling and Informed Farmers Actions (D.S. Bundela, Raj Mukhopadhyay, PR Bhatnagar, Bhaskar Narjary, Subhasis Mandal, R.K. Yadav, Awtar Singh, Satyendra Kumar, Suresh Kumar and Madhu Chaudhary)

Four sugarcane dominant agricultural districts viz. Saharanpur, Muzaffarnagar, Shamli and Baghpat were identified out of seven districts in the Hindon basin using suitability criteria. Six sites for Farmer's Platforms (FPs) for evaluating hydrological and environmental impact of sugarcane cultivation in the Hindon basin were identified in these four districts (Table 12). Then, three Agro-Innovation Platforms (AIPs) on field scale experimentation were established at Nandi Firozpur (Saharanpur district), Titawi (Muzaffarnagar) and Doula (Baghpat) in the upper, middle and lower Hindon basin where sugarcane agriculture is dominant. Sugarcane crop with five different agri-water management scenarios was planted at Nandi Firozpur AIP in the autumn season and Titawi AIP in the spring season and Doula AIP proposed in summer season (Table 13). Drip irrigation system with fertigation unit was installed at Nandi Firozpur and Titawi AIPs for precision water and fertilizer application (photos) and the crop growth and other field data were regularly collected and analyzed.

Four FPs were established, first at Nandi Firozpur with support of the Padma Shri awardee farmer, Titawi and Mansurpur with IPL-Titawi and Dhampur-Manusrpur sugar units, and

Table 12. Specifications and Location and of five selected FPs and three AIPs

S No	Name of AIP & FP Site	Cropping system	Channel partner	Command/ Irrigation source	Name of drain	FP area and gauging site Coordinates
Upper Hindon Basin						
1.	Nandi Ferozpur* (Saharanpur district)	Mixed- Sugarcane, Rice-wheat with popular agroforestry	Padma Shri Awardee farmer	Non-command Tubewel l irrigation	Hindon river (Almost Dry bed channel)	1,000 ha, 29.869022 N 77.572997 E
Mid Hindon Basin						
2.	Jalalpur (Shamli) on West of Krishni river	Sugarcane	KVK Shamli	Yarpur disty (EYC) / Conjunctive	Mahabatpur drain	1,034 ha, 29.482289 77.368659
3.	Titati* (Muzaffarnagar) on East of Hindon river	Sugarcane	IPL Titawi Sugar mill	EYC/Tubewell Conjunctive irrigation	Khusropur drain	2,483 ha, 29.448252 77.501858
4 .	Mansurpur (Muzaffarnagar) on East of Kali river	Sugarcane	Dhampur Bio Organic Sugar mill	Jauli disty (UGC)/Canal irrigated	Bupara-Mansurpur -drain	954 ha, 29.365121, 77.768598
Lower Hindon Basin						
5.	Atali Rajputana (Baghpat)	Sugarcane	ICAR-IIFSR, Meerut	Tubewell irrigated (EYC)	--	751 ha 29.365121, 77.768598
6.	Doula* (Baghpat)	Mixed–Sugarcane and rice-wheat	Jalpurush's GPVS Society	Daula disty (EYC)/ Conjunctive irrigation	Budhera drain	1,691 ha 28.968422, 77.341632

Note: * shows site selected for both AIP and FP platforms.

Table 13. Five scenarios of different combinations of irrigation, fertilizer and pesticide managements in sugarcane cultivation under AIP experimentation

Scena-rio	Practices	Crop	Water Management	Pesticide Management	Fertilizer Management
1.	Farmers' practice (FP)	Sugarcane	Flood Irrigation	FPP	FFP (200:60:60 kg/ha)
2.	Improved FP with Recommended Dose	Sugarcane	Flood Irrigation	RDP	RDF (150:60:60 kg/ka)
3.	Improved FP with 85% of Recommended dose via surface drip system	Sugarcane	Surface drip irrigation	85% of RDP	85% of RDF
4.	Improved FP with 70% of Recommended dose via subsurface drip system	Sugarcane	Sub Surface drip irrigation	70% of RDP	70% of RDF
5.	Improved FP with intercropping	Inter-cropping (Sugarcane + other crop)	Flood Irrigation	85% of RDP	85% of RDF

RDF & RDP: Recommended doze of fertilizer and pesticides

Sugarcane experimental fields irrigated with drip system at Nandi Firozpur AIP (Saharanpur) and Titawi (Muzaffarnagar) in the Hindon basin

Doula with society of Waterman of India (GPVS society). The catchment area and drain of Nandi Firopzur Titawi, Mansurpur and Doula FPs were jointly verified and the catchment area was subsequently modified based on ground surveys and gauging site for each FP was identified and needs to be instrumented before onset of the S-W monsoon season for recording runoff and water quality parameters. Farmers' survey and geo-mapping of 20-40 farmers' fields of Nandi Firzopur AIP and FP were done and satellite remote sensing based daily IrriWatch data were analyzed for monitoring of sugarcane growth and other ten parameters. Mobile based farmer's advisory on crop growth and irrigation and other practices was demonstrated to cane farmers using Tablet computers at Nandi Firozpur AIP and FP.

Astral Consultancy on Sub Surface Drainage for Reclamation of Waterlogged and Saline Heavy Soils of Maharashtra, Karnataka and Gujarat (D.S. Bundela, Anil Cinchmalatpure, Sagar Vibhute Subhasis Mandal and P.C. Sharma)

Consultancy services on new site identification, design approval of new projects, pre-drainage investigations and field surveys, etc. for reclamation of waterlogged and saline black soils in Maharashtra, Karnataka and Gujarat states were provided to M/s Astral Ltd, Ahmedabad (Gujarat) during 2022. Three new sites for SSD projects at Kavathesar, Kolhapur and Islampur, Sangli (Maharashtra) and Bidaj, Kheda (Gujarat) with total waterlogged saline black area of 338 ha were identified using the site feasibility criteria for designing of SSD system with controlled drainage (photos). At Bidaj site, the fodder productivity declined by 50-60% in fields irrigated with sprinkler irrigation system and affected lands with both shallow waterlogging (<1.5 m depth) and soil salinity-sodicity due to rise of water table and improper conjunctive use of brackish groundwater. Fields have low to very high salinity (ECe) ranging from 6.4 to 54.0 dS/m, moderate to high sodicity (ESP) from 25.95 to 72.05 in 0-15 cm layer whereas salinity (ECe) in 15-30 cm layer ranges from 4.7 to 23.0 dS/m, sodicity (ESP) from 28.69 to 40.89 as per the report of RRS, Bharuch. A SSD system with gypsum/press mud application and green manuring has ben suggested to reclaim and manage the affected farm. The SSD project is suggested for which topographic survey and designs of SSD system are recommended.



Condition of barren inland waterlogged saline-sodic fields with salt incrustation, and poor foddar growth in the affected fields under Sabarmati Ashram Gaushala at Bidaj, Kheda district and Kavathesar (Kolhapur)

The design of SSD systems for reclamation of waterlogged saline black lands at Sarsa village and Malarpura farm in Bidaj (Kheda) covering a total area of 88.00 ha was technically evaluated (Table 14). The designs of the SSD system were verified and found that the actual lengths of lateral pipes were lesser than the maximum permissible lengths for 20 m spacing and the actual areas drained by the collectors were lesser than the maximum permissible areas. It was further verified that the layout of the systems was prepared taking advantage of natural field slope existing in drainage area so as to keep excavation minimum. The design was in conformity with the national drainage guidelines. Therefore, design of SSD systems with controlled drainage for zone-1 with gravity outlet and zone-2 with pump outlet at Bidaj site has been technically recommended for the implementation.

After recommendation of a pilot SSD study for reclamation and management of coastal waterlogged and saline-sodic heavy lands at ARS Farm, Mahuva, Bhavnagar (Gujarat) under Junagadh Agricultural University, a pilot SSD system was installed with four lateral lines at 20 m spacing in approximately one-hectare area in Nov 2021 with pump outlet and extended collector line to a temporary open earthen sump well (photos). The affected field has clay soil texture and is of saline-sodic nature with shallow water table within 1.5 m and soil depth up to 1.00-1.50 m. The problem was developed due to irrigation with brackish groundwater to coconut plantations due to the drastic shift in annual rainfall pattern in view of climate change.

Table 14. Evaluation of design of a SSD Project in at Bidaj farm (Kheda) in Gujarat

Name of project	Area (ha)	Lateral length range (m)	Collector		Piped Drain		Extended Piped Drain	
			Size (mm)	Max Length (m)	Size (mm)	Length (m)	Size (mm)	Length (m)
Sarsa and Malapura Zone-1 (Gravity outlet)	72	36-190	90	280	100-400	2110	400	300
Sarsa and Malapura Zone-2 (Pump outlet)	16	24-171	90	241	100-160	900	--	--
Total	**88**							

Controlled drainage was implemented to farmers' society funded SSD projects in 760 ha with 20 m spacing in Kolhapur district during 2022 and three farmers' fields were monitored to improve crop yield and to save irrigation water and nitrogen fertilizer (photos). This resulted in savings of 15.1-18.4% irrigation water and 9-10% nitrogen and cane yield increased from 0-53.5 to 81.4-117.8 t/ha. In the controlled drainage design, a control structure was designed and installed at the end of collector pipe for every 0.50-

Field condition of a pilot SSD system for salt leaching and a temporary storage sump well filled with drainage effluent water from the SSD system

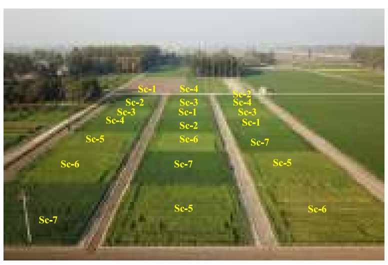
Installation of SSD system, transformed barren field into lush green cane field at Majrewadi (Kolhapur)

4.00 ha area (4-6 farmers) inside a RCC pipe inspection chamber. Drainage material requirement for one ha controlled SSD block design was worked out to facilitate the transfer of RKVY subsidy component to individual farmer in Maharashtra. Planning and installation of a technical sound SSD system/project with impactful results for reclamation of waterlogged and saline vertisols require a highly skilled and trained manpower/team, apart from other technical inputs for reclamation of waterlogged and saline-sodic black lands in western and southern India. Therefore, multi-stage custom trainings are suggested to be organized to build a new Astral team for designing and installation of a sound SSD system.

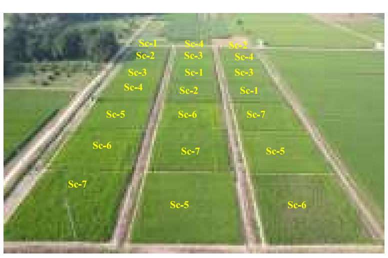
Low Budget natural farming for sustainable crop production (P. C. Sharma, Raj Mukhopadhyay, Ram Kishor Fagodiya, Awtar Singh, H.S. Jat, Arjun Singh, S. K. Jha, D. Burman, U.K. Mandal, S.K. Sarangi and T.D. Lama, Anil R. Chinchmalatpure, Monika Shukla, Vineeth TV and Sagar Vibhute)

Natural farming' refers to a farming approach that emphasizes the importance of co-production of crops relying on easily available 'ingredients' to build up soil fertility and microbial population. The approach is built on the 'four wheels' of Low Budget Natural Farming (LBNF) (1) stimulation of microbial activity to make nutrients available to plants and protect against pathogens using a microbial inoculum, '*jiwamrita*'; (2) supply of plant nutrients through organic fertilizer prepared using 'indigenous' cow dung, cow urine, jaggery and pulse meal, '*ghanajiwamrit*'; (3) production of stabilized soil organic matter and conservation of top-soil by mulching '*acchadana*' and (4) soil aeration ('*whapahasa*') by improving soil structure and reducing tillage. The inputs made from locally available materials like cow dung and urine, pulse flour, buttermilk etc., therefore, farmers can easily arrange the raw material and make these input on their own farms that will ultimately reduce the cost of external high-cost chemical used for farming.

CSSRI, Karnal



Overview of LBNF experiment of wheat (2021-22) at 80 days after sowing



Overview of LBNF experiment of rice (2022) at 30 days after sowing/ transplanting

A field experiment was conducted with seven treatments and three replications in RBD under rice-wheat cropping system (RWCS) at Research farm of ICAR-CSSRI, Karnal. Rice variety: basmati rice (var: CSR-30) and wheat salt-tolerant variety (var: KRL-210) and maize hybrid variety (Pioneer 3378) were used. The treatments were: (i) Scenario (Sc-1): R(rice)-W(wheat)- F(Fallow) with conventional tillage (CT) and without residue retention, and 100% N through chemical fertilizers, (ii) Sc-2: Transplanted Rice (TPR) - zero tillage wheat (ZTW) – zero tillage dhainca (ZTD) with full residue retention and 100% N through chemical fertilizers, (iii) Sc-3: Same as Sc-2 and 100% N through farm yard manure (FYM)/vermicompost, (iv) Sc-4: Same as Sc-2 with 50% N through FYM/vermicompost and 50% N through chemical fertilizers, (v) Sc-5: Same as Sc-2 and nutrients source through LBNF components (vi) Sc-6: zero tillage rice (ZTR)- ZTW- ZTD with full residue retention and nutrients source through LBNF components, and (vii) Sc-7: zero tillage rice (ZTR)- ZTW- ZTD with full residue retention and nutrients source chemical fertilizers components.

The experimental results for *rabi* season (2021-22) wheat suggested that the grain yield under Sc-1, 2, and 7 was at par and ranged between 34.7 to 40.0 q ha^{-1}. However, under Sc-3 and Sc-5, Sc-6 of organic and LBNF source components grain yield lowered significantly by 37 and 48, 60%, respectively as compared to conventional R-W system (Sc-1) (photos). Similarly, wheat straw yield under Sc-1, Sc-2 and Sc-7 was in the range of 57.2-66.6 q ha^{-1}.

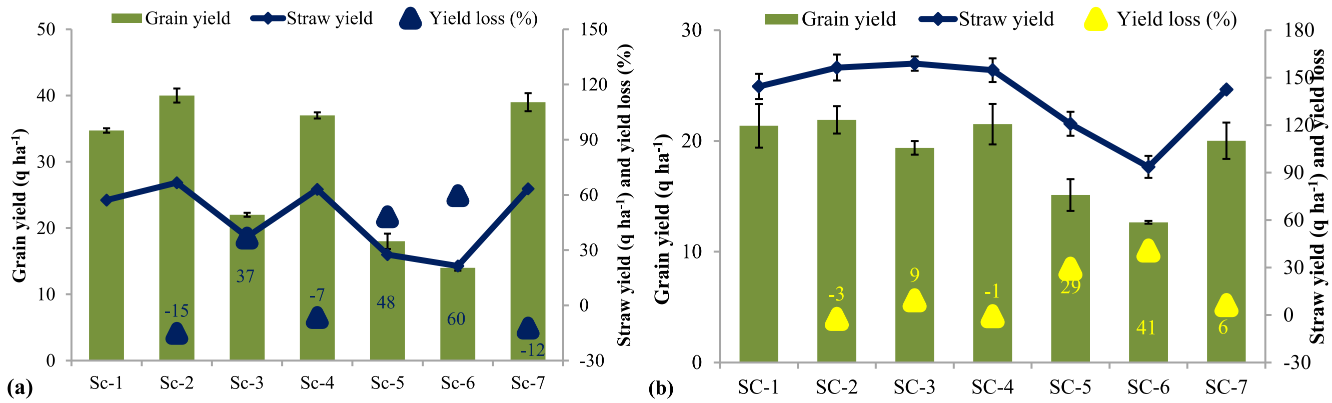


Fig 13. Straw, grain yield (q ha-1) and yield loss (%) under different scenarios of (a) wheat and (b) rice

However, the lowest straw yield (21.38 q ha^{-1}) was observed under Sc-6 under LBNF components as nutrient source followed by Sc-5 with zero tilled wheat under LBNF components (27.55 q ha^{-1}) and Sc-3 (37.0 q ha^{-1}). The lowest wheat grain and straw yield under the scenarios of LBNF components occurred might be due to supply of less nutrients and the exhaustive use of native soil nutrients during rice cultivation. During *kharif* (2022) rice cultivation, the yield of rice was comparatively lower than the usual trend under all the scenarios. The rice grain yields were almost at par in all the scenarios varied from 21.91-19.38 q ha^{-1} except Sc-5 (15.12 q ha^{-1}) and Sc-6 (12.65 q ha^{-1}) where transplanted and direct seeded rice were cultivated through chemical and LBNF source of nutrients. However, significant the yield loss of 9, 29, and 41% were observed under Sc-3, Sc-5 and Sc-6 (Fig. 13). The maximum straw yield was obtained under Sc-3 (159 q ha^{-1}), whereas the minimum straw yield was observed under Sc-6 (94 q ha^{-1}) where direct seeded rice was grown through nutrient source of LBNF components. Hence, the study suggested that external source of nutrients through farm yard manure, compost and biochar must be supplied to minimize the yield losses under LBNF. Moreover, optimizing of doses of *Jiwamrit* and *Ghana Jiwamrit* should also be taken under consideration.

RRS Lucknow

In the third cropping cycle of the project, effect of the natural farming component was evaluated on growth and productivity of the rice and wheat. Six treatments among which 2 treatments (viz; Sc-1 and Sc-2) were based on recommended chemical input-based farming practices whereas 4 treatments (viz; Sc-3, Sc-4, Sc-5 and Sc-6) were based on package and practices of LBNF components. The field experiments were conducted with rice varieties CSR 46 and wheat variety KRL210. In case of wheat, the organic carbon level of the natural farming treatments ranged from 0.41 to 0.45% whereas treatments plots receiving chemical inputs showed a decrease in the OC levels. With respect to the OC data in rice natural farming registered increase in OC levels from 0.42 to 0.46 %. Whereas the control treatments Sc1 and Sc2 had OC levels showed no significant increase under rice. The Available nitrogen content of the soil under wheat and rice registered significant decrease under natural farming treatments, from the initial N content of 0.0049 % it decreased to 0.0042 %, the data also correlated with the decrease in total chlorophyll content of the crops. Whereas it remained unchanged in control plots (Sc1 and Sc2). Changes in soil microbial biomass were estimated in terms of dehydrogenase activity. It was found that dehydrogenase activity increased in all the natural farming treatments, under wheat it increased from initial valued of 92.66 to 100.62 IU/ml, whereas under rice it

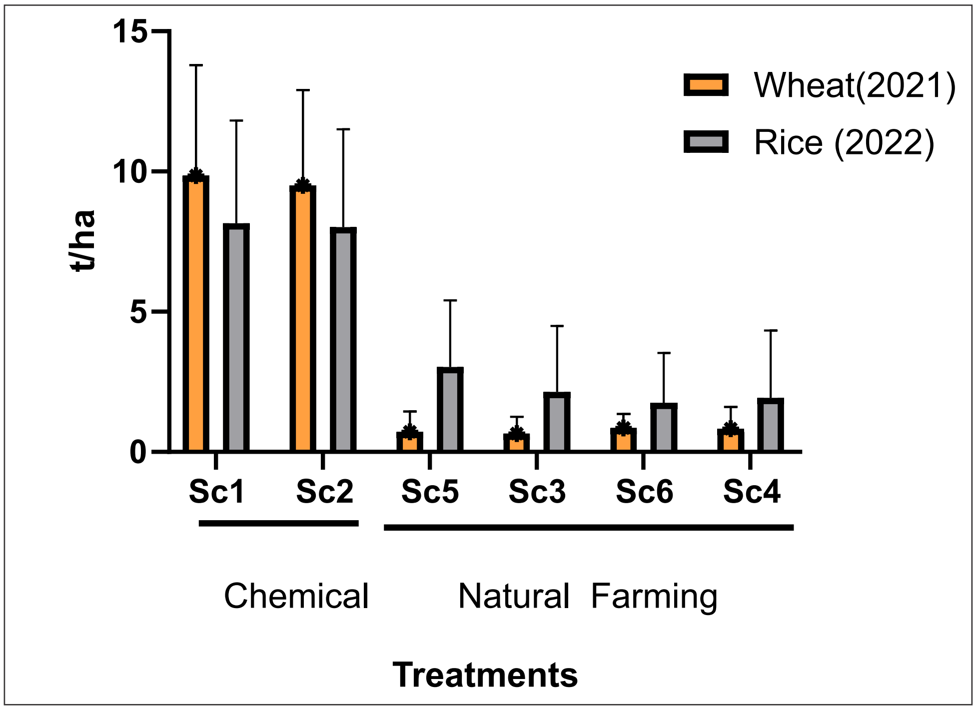


Fig 14. Yield response of rice and wheat under natural farming and chemical farming practices

increased from 155.09 to 215.22 IU/ml. Although the treatments receiving natural farming components showed improvement in soil OC content and also microbial load. But the yield responses of the rice and wheat cultivar were low under the application of natural farming components. In case of wheat the yield reduced from 9.86 t/ha to 0.83 t/ha, whereas in case of yield reduced from 8.16 t/ha to 1.93 t/ha (Fig. 14) The use of natural faming components increased the microbial biomass of the soil and improved its soil organic carbon and nitrogen. But still the recommended doses of the components are not sufficient to meet out the yield potential of rice and wheat.

RRS, Canning

The field expriment was conducted during 2021-22 at RRS, Canning Town to evaluate the components of low budget natural farming under coastal agro-ecosystem. The experiment consisted of the following scenarios, S1: Rice-Maize-Fallow (CT-CT) (Rice-transplanted, maize-dibbling, all residue removed, Nutrient: farmers' recommendation); S2: Rice-Maize-Dhaincha (CT-ZT-ZT) (Rice-transplanted, maize-dibbling, dhaincha-broadcast; full rice and maize leaf residue retained, dhaincha incorporated; rice – RDF, maize – RDF); S3: Rice-Maize (CT-ZT) (Rice-DSR, maize-dibbling, full rice and maize leaf residue retained; rice – RDF, maize – RDF (N through FYM + CSSRI Formulation)); S4: Rice-Maize (CT-ZT) (Rice-DSR, maize-dibbling, full rice and maize leaf residue retained, Nutrient: 50% through organic & 50% through inorganic); S5: Rice-Maize-Dhaincha (CT-ZT-ZT) (Rice-transplanted, maize-dibbling, dhaincha-broadcast, full rice and maize leaf residue retained, dhaincha incorporated; Nutrients – Nil; Low budget natural farming (LBNF)); S6: Rice-Maize-Dhaincha (ZT-ZT-ZT) (Rice- unpuddled transplanted, maize-dibbling, dhaincha-broadcast, full rice and maize leaf residue retained, dhaincha retained; Nutrients – Nil; Low budget natural farming (LBNF)); S7: Rice-Maize-Dhaincha (CT-CT-CT) (Rice-transplanted, maize-dibbling, dhaincha-broadcast, anchored rice and maize leaf residue retained, dhaincha incorporated; Nutrients: rice – 50% RDF, maize –

Table 15. Maize growth and productivity under different scenarios

Scenarios	Cob yield(t ha^{-1})	Stover yield(t ha^{-1})	Kernel yield(t ha^{-1})	100 grain wt. (g)
S1	1.51a	2.56ab	1.02a	16.23ab
S2	1.41a	2.81a	0.90a	16.70a
S3	0.17b	0.73c	0.06b	17.57a
S4	0.55ab	1.45abc	0.37ab	16.28ab
S5*	0.00	0.25c	0.00	0.00
S6*	0.00	0.31c	0.00	0.00
S7	0.11b	2.61a	0.75ab	16.21ab
S5-LP*	0.00	0.94bc	0.00	0.00

Table 16. Rice growth and productivity under different scenarios

Scenarios	Grain yield(t ha^{-1})	Straw yield(t ha^{-1})	Ear bearing tillers $hill^{-1}$	Panicle length (cm)
S1	3.67a	8.21cd	7.80a	24.43a
S2	2.27bcd	13.77a	9.73a	24.86a
S3	1.39d	9.67abcd	8.37a	24.22a
S4	2.54bc	12.66ab	8.13a	24.18a
S5	3.13ab	10.59abc	7.38a	24.00a
S6	3.67a	5.95d	7.3a	25.17a
S7	2.01cd	11.48abc	6.17a	25.09a
S5-LP	2.67abc	9.33bcd	8.57a	21.70b

50% RDF; Low budget natural farming (LBNF)). The plot size was 6.5 m x 11.5 m. In addition, one large plot of 10 m x 50 m was also used for laying out of scenario S5.

During *rabi* 2021-22 maize (variety Zenith) and during *kharif* 2022 rice (variety Amalmana) were taken as test crops as per the senarios. The performance of maize crops was not satisfactory under all the scenarios and the highest kernel yield of only 1.02 t ha^{-1} was obtained in scenario S1 [Rice-Maize-Fallow(CT-CT), no residue] followed by 0.90 in scenario S2 [Rice-Maize-Dhaincha (CT-ZT-ZT)-RDF, residue retained] and 0.75 t ha^{-1} in scenario S7 [Rice-Maize-Dhaincha (CT-CT-CT) - LBNF with 50% RDF, residue retained] (Table 15). However, no No significant difference in kernel yield was recorded among S1 and S2 scenarios. The maize crop growth was severely affected under the LBNF treatments. The highest grain yield of rice (3.67 t ha^{-1}) was obtained under scenario S1 and S6 [Rice-Maize-Dhaincha (ZT-ZT-ZT), residue retained] (Table 16). The performance of rice crop under LBNF was better as compared to those with use of chemical fertilizers. This year rice yield was affected due to high wind and rainfall during gain filling stage especially under senarios where nutrient was supplied as RDF (Chemical fertilizer) (S2), modified LBNF (S7), LBNF in large plot, RDF (N through FYM + CSSRI Formulation) (S3) and RDF (50% through organic & 50% through inorganic) (S4). At the end of 2nd cropping cycle of maize, no significant variations in the soil properties like EC_2, pH_2, OC, enzyme activity and nutrient availability were observed, except in few cases. EC_2 in 0-5 cm layer was found to be highest in scenario S1 and S5-LP.

RRS, Bharuch

Due to failure of *kharif* experiment, the cropping system component was removed for the data analysis for different parameters. So, there were four treatments of RDF and LBNF practices with conventional and minimum tillage. Data were recorded for different growth and yield parameters and it was observed that there was significant difference in

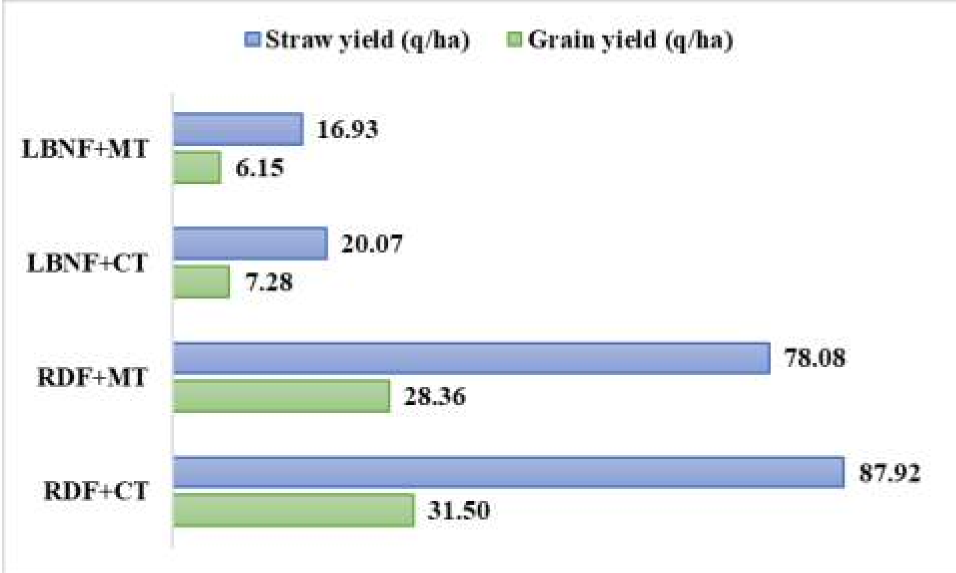


Fig 15. Grain and straw yield of wheat crop under different treatments

RDF- Recommended dose of fertilizers, CT-Conventional Tillage; MT-Minimum Tillage

the growth and yield of wheat crop under RDF and LBNF treatments, however tillage practices doesn't affect the growth and yield of wheat crop individually. Results revealed that the highest plant height of wheat; highest dry weights per plant were recorded with RDF with conventional tillage (T1). However much lower plant height and dry weight per plant as compare to RDF was recorded in LBNF treatments for the same intervals. Similar pattern was followed for the yield parameters as total numbers of tillers/plant, numbers of productive tillers/plant and spike length were recorded significantly highest under the RDF with conventional tillage (T1). Minimum values for above parameters were recorded with treatment LBNF with minimum tillage (T4). The difference in growth and yield parameters under RDF and LBNF treatment was very well reflected in grain and straw yield of wheat. Significantly highest grain yield (31.50 q/ha) and straw yield (87.92 q/ha) was observed with RDF with conventional tillage (T1). The yield drastically reduced (80% reduction) under LBNF treatment and lowest grain yield (6.15 q/ha) and straw yield (16.93 q/ha) recorded with LBNF with minimum tillage (T4). Highest seed index (4.27 g) was observed with RDF with conventional tillage (T1) and lowest seed index (3.67 g) was observed with LBNF with minimum tillage (T4). There were no any significant difference in yield was found with minimum and conventional tillage practices, however numerically slightly higher yield was obtained with conventional tillage with both RDF and LBNF treatments (Fig. 15).

Long-term impact of SSD on clay mineralogical transformation, physic-chemical properties and hyperspectral signatures of waterlogged saline soils under Inceptisol and *Vertisol* (Raj Mukhopadhyay, Bhaskar Narjary and D. S. Bundela)

The textural classification along with other physico-chemical properties such as bulk density (BD), pHs, EC_e and cation, anions of different long-term SSD soils of Kavthesar and Shedshal under *Vertisol* were evaluated. The soils of Kavthesar (control & 3 years old SSD) and Shedshal (Control & 5 years old SSD) had clayey textured soil across the depth (0-120 cm). The BD varied from 1.10-1.20 g/cm^3 across the soil depth irrespective of SSD and control sites. However, the EC_e of the soil in Shedshal became 13.72 from 33.21 dS/m after

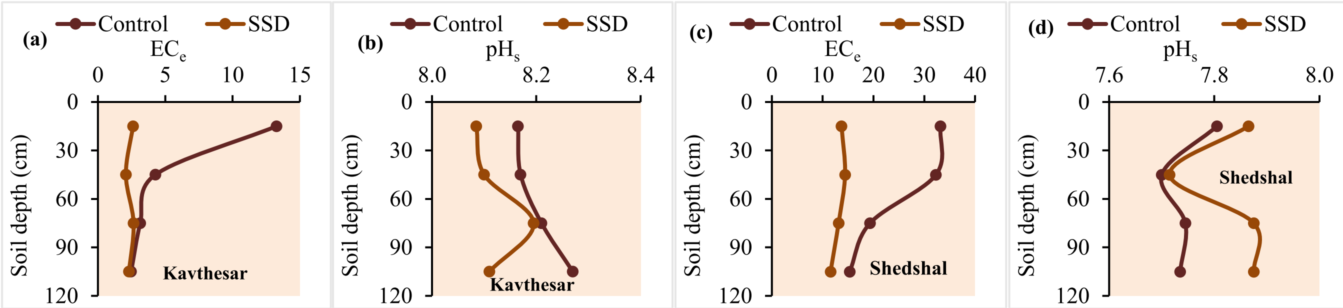


Fig 16. pHs and ECe of control and SSD soils of (a, b) Kavthesar and (c, d) Shedshal sites under Vertisols

Table 17. Solution cations and anions in Control and SSD site of Shedshal under Vertisol

Site/ Depth	Na^+(meq/L)	K^+ (meq/L)	Ca^{2+}(meq/L)	Mg^{2+} (meq/L)	Cl^- (meq/L)	SO_4^{2-} (meq/L)
Shedshal Control 0-30 cm	8.57	0.43	32.1	28.4	25.1	18.69
30-60	11.22	0.57	23.1	10.3	28.2	16.20
60-90	7.18	0.26	24.6	34.1	42.8	13.08
90-120	4.45	0.14	8.3	16.2	17.6	16.05
Shedshal SSD (0-30 cm)	5.54	0.36	9.2	12.1	12.1	7.73
30-60	6.23	0.30	6.3	9.5	11.6	15.04
60-90	5.95	0.14	8.1	7.5	12.1	15.08
90-120	5.39	0.23	4.3	7.1	9.1	16.02

Table 18. Solution cations and anions in Control and SSD site of Kavthesar under Vertisol

Site/ Depth	Na^+(meq/L)	K^+ (meq/L)	Ca^{2+}(meq/L)	Mg^{2+} (meq/L)	Cl^- (meq/L)	SO_4^{2-} (meq/L)
Control 0-30 cm	3.26	0.29	4.2	6.3	3.20	29.45
30-60	2.83	0.14	2.2	4.5	1.80	16.56
60-90	2.15	0.13	3.5	3.5	3.00	10.40
90-120	1.20	0.17	1.5	0.5	1.90	2.70
SSD site (0-30 cm)	1.75	0.25	1.5	2.0	0.60	3.26
30-60	1.86	0.11	0.3	0.7	1.40	2.65
60-90	1.91	0.14	1.5	2.1	0.90	5.66
90-120	0.92	0.13	1.6	2.7	0.80	4.42

SSD in upper surface soil (0-30 cm) and became lower down the profile. The Kavthesar soils had lower EC_e than Shedshal site and the EC_e ranged from 13.27 – 2.47 in control soil, while in SSD treated soils had 2.08 to 2.61 dS/m throughout the soil profile (Fig. 16). In Kavthesar, pH_s of the soil varied from 8.17-8.27 in control and 8.09-8.20 in SSD soils while the corresponding values were 7.70-7.81 in control and 7.72-7.88 in SSD soils of Shedshal (Fig. 16). Similarly, the solution cations and anions like Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^- and SO_4^{2-} were evaluated. The Na^+ concentration varied from 11.22-4.45 meq/L in control soil whereas the range varied from 6.23-5.39 meq/L in SSD soils of Shedshal. However, the K^+ concentration was comparatively lower than Na^+ in both soils and Ca^{2+} and Mg^{2+} concentration maintained a ratio of 1.1:1. The Cl^- and SO_4^{2-} concentration were higher in control soils than SSD soils of Shedshal (Table 17). However, in Kavthesar, Na^+ concentration varied from 3.26-1.20 meq/L in control while it ranged from 1.75-0.92 meq/L in SSD. The Ca^{2+}, Mg^{2+}, Cl^- and SO_4^{2-} in soil solution of Kavthesar soils also reduced in SSD soils than control soil which likely due to removal of salts through drained water (Table 18). These results indicated that SSD influenced the improvement of soil physicochemical properties of the Vertisol.

Table 19. Prediction of Soil salinity using machine learning methods

Methods	Full data set				
	MSE	RMSE	MAE / MAD	MAPE	R^2
Random Forest Regression	7.50	2.74	1.95	63.78	0.73
Regularized Linear Regression	12.73	3.57	2.72	90.83	0.52
K-Nearest Neighbors Regression	13.44	3.67	2.68	82.30	0.49
Support Vector Machine Regression	16.39	4.05	2.89	84.44	0.44
Boosting Regression	12.7	3.6	2.7	94.7	0.53
Decision Tree Regression	10.3	3.2	2.3	69.9	0.61

Methodology for rapid detection, characterization and 3-D representation and risk zone identification of hot spots soil salinity in Rohtak district, Haryana using electromagnetic induction and remote sensing techniques (Bhaskar Narjary, Raj Mukhopadhyay, Arijit Barman and DS Bundela)

For soil salinity prediction from remote sensing, machine learning regression techniques was adopted. At the first step different environmental covariates used in the study were correlated with soil salinity (EC_e) and significant correlating factors were selected as model environment covariates (viz. Blue, Green, Red, NIR, SWIR1 and SWIR2 band and spectral indices SI1 and SI2, NDSI, SR, Spectral ratio). In these study, Random Forest (RF), Regularized Linear (RL), K-Nearest Neighbors (NNR), Support Vector Machine (SVM), Boosting and Decision Tree Regression machine leaning techniques was used to to predict soil salinity from environmental covariates and their prediction accuracy presented in table 19. It was observed that random forest regression had the highest predicting accuracy with high coefficient of determination (R^2-0.73) and highest RMSE 2.74. These random forest regression model select for estimating soil salinity.

Soil salinity map of Rohtak district was prepared based on random forest regression model and presented in figure 17 and salinity classification presented in table 20. From

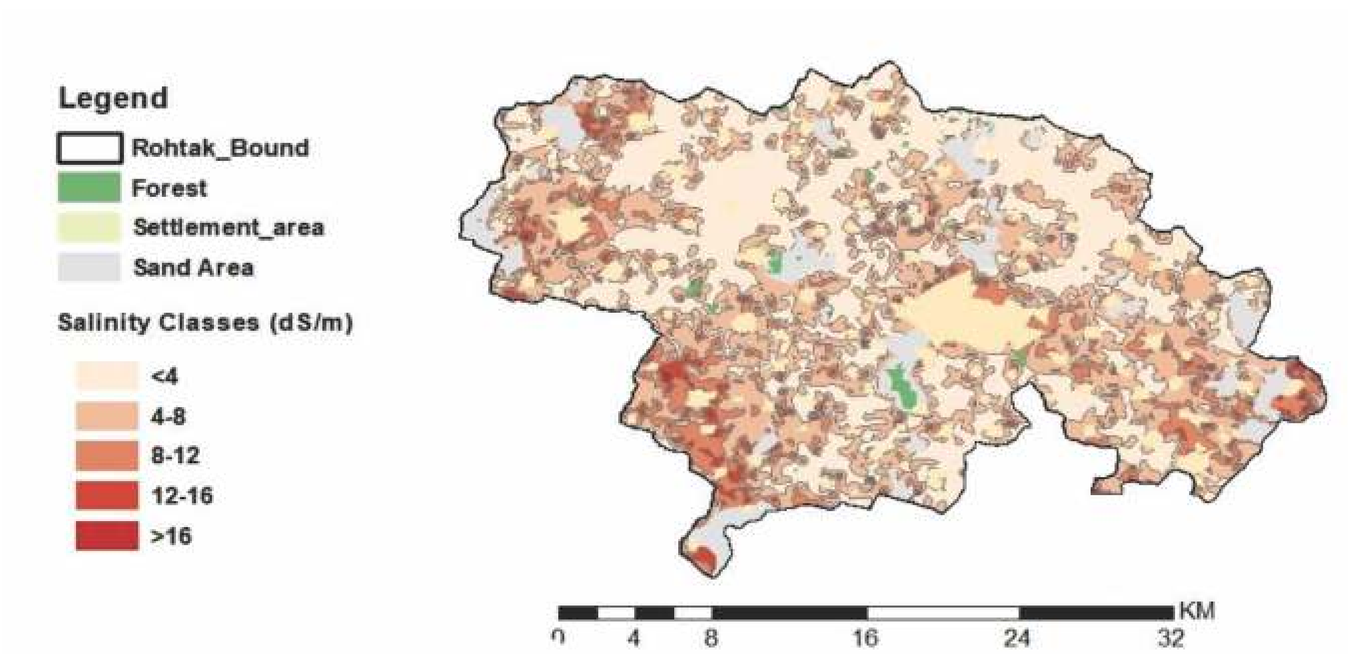


Fig 17. Soil salinity map predicted using best machine learning method (Random forest)

Table 20. Soil salinity classification of Rohtak District (Random forest)

Saline Classes (dS m^{-1})	Sand Area (km^2)	Settlement Area (km^2)	Saline area (km^2)
< 4 (Non saline)	10.86007522	14.26561035	595.7
4-8 (Morderately Saline	55.22731651	69.09274288	568.4
8-12 (Highly Saline)	32.90779586	66.49798705	179.3
12-16 (Very Highly saline)	26.88910523	6.214664902	35.1
16-20 (Extremely saline)	2.99454014	0.062114136	1.4
Total salt affected area	**784.073**		

the analysis of the results revealed that in Rohtak district 784 km^2 area was affected by salinity and waterlogging. This area was 56% percentage of total area of the Rohtak district. Majority part of the Rohtah district was affected by moderate salinity and moderately saline area is 568.4 km^2, followed by high (179.3 km^2), very high (35.1 km^2) and extreme saline area (1.4 km^2), while 595.7 km^2 area was non saline normal soil.

Management of Marginal Quality Water

Conjunctive water use strategies with conservation tillage and mulching for improving productivity of saline soils under high SAR saline water irrigation

(Arvind Kumar Rai, Nirmalendu Basak, Bhaskar Narjary and Gajender Yadav)

Conservation tillage, deficit irrigation (DSI) and crop residue mulching approaches were effective in managing the crop water requirement with 40% saving of irrigation water and reduced salt loading under saline water irrigation. Soil biological properties responded to management-induced changes in soil processes. Irrigation water quality affects the salinity build-up in the order of saline water of 8 ds m^{-1} (SW) > Conjunctive use of 8 ds m^{-1} (CW) > good water of 0.8 ds m^{-1} (GW) (P< 0.05). It was around two times more in *rabi* (winter) season than *kharif* (monsoon). The leaching of the salts was associated with increasing soil pH. The pH of the aqueous saturation paste extract (pH_e) was higher than that of saturation paste (pH_s). Dehydrogenase activity (DHA) was higher in GW followed by fallow, CW, and SW; while, alkaline phosphatase activity (ALP) was higher in SW. Irrigation with SW and CW reported similar values of β- and α- glucosidases (BG and AG)

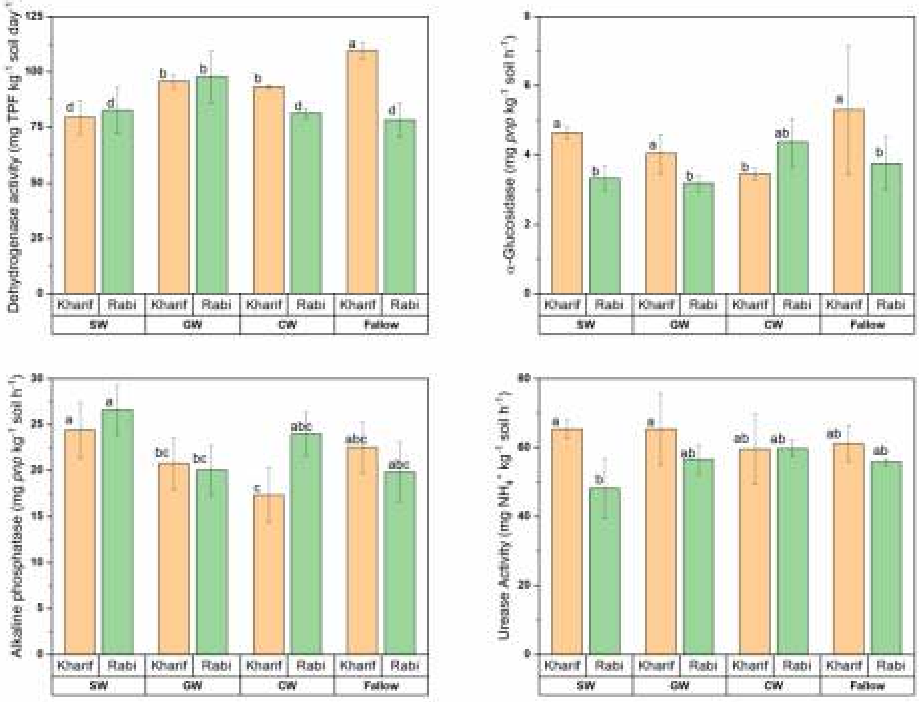


Fig 18. Effect of the irrigation water quality and season interactions on soil enzyme activities of barren saline soil converted for agricultural land use

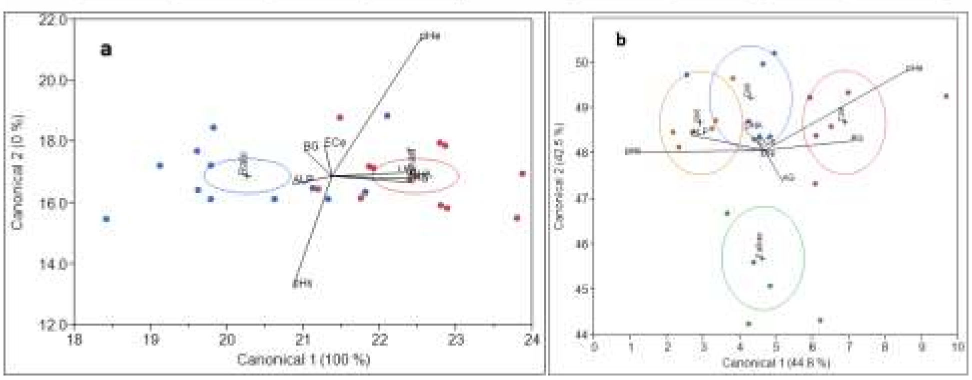


Fig 19. Canonical discriminant functions for separating soils among (a) season and (b) irrigation management

and urease activities (Ure) (Fig. 18). DHA and AG were more sensitive to conversion from fallow to cultivation. The DHA, ALP, and BG showed high resistance to seasonal changes under different irrigations. However, Ure and AG were more sensitive to seasonal change under cultivated soils. The multivariate analysis discriminates the land-use conversion, switching from irrigation water quality, and seasonal changes (Fig. 19). These findings highlight the varied functional stability of soil enzymes against land use change and seasonal disturbances associated with heat and moisture stress.

Granulation Machine

Development of reclamation materials with high gypsum equivalent for productive utilization of alkali soil and water (A.K. Rai, N. Basak, Parul Sundha, R.K. Yadav and P.C. Sharma)

Alkali water deleteriously impacts crop production in irrigated areas. About 25 percent of groundwater resources in Punjab and Haryana are under high sodicity class (residual sodium carbonate, RSC> 2.5 me L^{-1}), and prolonged use of such water leads to soil sodification, loss of crop productivity, and increase in the cost of crop production. Different combinations of the high gypsum equivalent materials were developed as an alternative to gypsum using granulation machines (Photo). Microbial consortia inoculated in the granules showed extended shelf life upto 12 month. Material dried at high temperature showed shorter shelf life.

Briquettes of high gypsum equivalence for RSC neutralization

Effect of saline environment and plastic mulch on vegetable crops under naturally ventillated polyhouse conditions (R.L. Meena and Bhaskar Narjary)

Tomato (NS 4266) seedlings of 40 days old were transplanted on 17 Sept. 2021 in polyhouse beds of 75 cm width with 70 cm spacing between two beds. The seedlings were planted in two rows in each bed. The row to row spacing was maintained at 45 cm in double dripline treatment and 30 cm in single drip line treatments and plant to plant spacing was 30 cm in both double and single drip line treatments. The seedlings were transplanted in slightly moist beds and irrigation was applied after planting. Saline water treatments were started at 15 DAP. Water soluble fertilizers NPK (19:19:19) and (0:0:50) were mixed well in overhead water tanks of 300 litres capacity. Calcium nitrate and Magnesium sulphate nutrients were applied twice a month and micronutrient mixture was sprayed twice a month. Drip system operated under gravity flow is being used to apply saline water treatments. Harvesting of tomato fruits commenced from 15 Dec. 2021 and lasts up to 19 May 2022. The observations on number of fruits and fruit yield were recorded with each harvesting and observations on fruit length, fruit width, fruit wt/fruit and TSS of fruits were recorded at regular intervals. Plant height, stem girth and root length was recorded at the end of final harvesting of fruits.

Effect of plastic mulch cover on growth, yield attributes and fruit yield of tomato

The data were analysed statistically using opstat and perusal of data showed that growth and yield attributes viz., number of fruits/plant, fruit weight/fruit, fruit length, fruit width, fruit yield (t/ha), stem girth, and TSS (%) were differ on-significantly with mulch cover while plant height, fruit yield /plant, root length, and root girth differ significantly with mulch and no mulch treatments. Mean plant height (cm) at harvest of tomato plants showed decreased height as compared to previous year and it was significantly higher (515.8 cm) with no-mulch than mulch (501.8 cm) treatment. The mean number of fruits/plant differ non-significantly and it was 47 and 45.9, fruit wt./fruit was 48.2 and 48.5

g, fruit length was 5.08 and 5.04 cm, fruit width was 5.49 and 5.53 cm respectively which were non-significant with mulch cover. Fruit yield /plant differ significantly with mulching and it was 2.48 and 2.22 kg with no-mulch and mulch respectively. Fruit yield (t/ha) of tomato differ non-significantly it was (101.8 t/ha) with no mulch and (99.7 t/ha) with mulch treatment though the fruit yield/plant was significant. The fruit yield (t/ha) during this season was not true representation of treatment effects as it was reduced drastically due to setback of more than 45 days because of adverse effect of contaminated insecticide sprayed on the crop. TSS (%) of tomato fruits was recorded during March was found non-significantly higher with no mulch and it was 5.03 and 4.98% with no mulch and mulch cover treatments.

Effect of saline water and single/double drip line on growth, yield attributes and fruit yield of tomato

There were 6 treatment combinations of saline water and single and double dripline irrigation viz., T_1: EC_{iw} 3 dS/m + SDL ; T_2: EC_{iw} 6 dS/m + SDL; T_3: EC_{iw} 9 dS/m + SDL; T_4: EC_{iw} 3 dS/m + DDL; T_5: EC_{iw} 6 dS/m + DDL; T_6: EC_{iw} 9 dS/m + DDL. After establishments of seedlings for 15 days, saline water irrigation was initiated. Perusal of data showed that plant height, no. of fruits/plant, fruit yield /plant and fruit yield yield (t/ha), and TSS (%) differ significantly with saline water treatment (table 21). Plant height (cm) was significantly higher with EC 3 dS/m (529.9 cm) in DDL and minimum with EC 9 dS/m (492.8 cm) in DDL. Plant height ranged between 522.4 to 495.3 cm in SDL and it was 529.9 to 492.8 cm in DDL with EC 3,6,9 dS/m saline water irrigation respectively. It means application of saline water of EC_{iw} 9 dS/m hindered the normal growth of the plant in both single and dripline irrigation. Number of fruits/plant was significantly higher with treatment T_6 (EC_{iw} 9 dS/m + DDL) produced 53.2 fruits/plant which was at par T_3 (EC_{iw} 9 dS/m + SDL) as compared to other treatments. Fruit weight (g) per fruit was also found significantly higher (51.3g) with treatment T_1 : EC_{iw} 3 dS/m + SDL which was at par with T_6 : EC_{iw} 9 dS/m + DDL (50g) followed by 49.1, 49.0 g with application of T_4 and T_2 treatments respectively. Fruit weight (kg) per plant was highest with T_5 (2.80kg) which was at par with T_6 (2.67kg) as compared to other treatments. Fruit length differed non-significantly and ranged between 5.14cm – 4.94cm in SDL and 5.30cm – 5.01cm in DDL with EC 3,6,9 dS/m respectively. Fruit width also differed non-significantly and it was higher with T_4 (5.73 cm) followed by T_1 (5.61cm) and T_6

Table 21. Effect of mulching and saline water irrigation with single and double dripline system on growth, yield and yield attributes of tomato under naturally ventilated polyhouse conditions. (Year 2021-22)

Treatments	Plant height (cm)	No. of fruits/ plant	Fruit weight /fruit (g)	Fruit weight/ plant (kg)	Fruit length (cm)	Fruit width (cm)	Fruit yield (t/ha)	TSS (%)	Stem girth (cm)	Root girth (cm)	Root length (cm)
Mulching											
No Mulch	515.8a	47.0	48.2	2.48a	5.08	5.49	101.8	5.03	1.13	1.27a	36.5a
Mulch	501.8b	45.9	48.5	2.22b	5.04	5.53	99.7	4.98	1.04	1.21b	32.4b
Saline water irrigation + Dripline (Single/Double)											
ECiw 3 dS/m-SDL	522.4ab	37.6d	51.3a	1.94d	5.14	5.61	86.9e	4.50c	1.12	1.27	39.3
ECiw 6 dS/m-SDL	510.2bc	45.9b	49.0b	2.25bc	4.95	5.39	100.9bc	4.94b	1.14	1.30	33.7
ECiw 9 dS/m-SDL	495.3cd	52.2a	44.6c	2.33b	4.94	5.37	104.6b	5.02ab	1.03	1.20	31.1
ECiw 3 dS/m-DDL	529.9a	43.3c	49.1b	2.13c	5.30	5.73	95.6cd	5.05ab	1.07	1.22	35.7
ECiw 6 dS/m-DDL	502.3cd	46.7b	46.2c	2.80a	5.04	5.45	97.0cd	5.23ab	1.07	1.21	35.0
ECiw 9 dS/m-DDL	492.8cd	53.2a	50.0ab	2.67a	5.01	5.52	119.6a	5.29a	1.11	1.25	32.0

(5.52cm) treatment. Stem girth, root length and root girth differ non-significantly with saline water treatments. Tomato fruit yield differ significantly with different treatments, though it was reduced drastically as compared to previous season and fruit yield (t/ha) was significantly higher (119.6 t/ha) with T_6 (EC_{iw} 9 dS/m + DDL) as compared to other treatments. TSS (%) was observed significantly higher in double dripline treatments combined with saline water irrigation and maximum TSS was with observed with T_6 (5.29) which was at par with $T_{5,}$ T_4 and T_3 treatments.

Effect of residue management on soil microbial activities under salt affected soils in rice-wheat system (Madhu Choudhary, H.S. Jat, Rakesh Kumar, Sanjay Arora and R.K. Yadav)

Effect of microbial treatment on residue under incorporation treatment

Rice-wheat (RW) cropping system is one of the world's largest agricultural production systems, spread over the Indo-Gangetic Plains (IGP) in South Asia and China. This cropping system generates huge quantities of crop residue. Majority of rice and wheat is harvested by combine harvester leaving residues in the field. Most of the residue is left in the field for burning which adversely affects overall sustainability of the RW system. Management of rice straw, rather than wheat straw is a serious problem, because of very little turn-around time between rice harvest and wheat sowing. Besides burning, other options available to farmers for crop residue management, are *in situ* incorporation of rice straw in the soil with tillage and complete/partial retention on the surface as mulch using zero tillage systems. Addition of the microbial consortia is an effective alternative for the management of rice straw as it promotes sustainable agriculture and environmental protection, improving the soil's physical, chemical, and biological properties. In the continuation of the project in the three experiments for Normal, saline and sodic soils, rice-wheat crop cycle was adopted. For rice crop variety CSR 46 and for wheat crop variety KR210 were taken. After harvesting of rice crop, straw were incorporated and placed on the surface. Spray of consortia of fungal (*Penicillium* spp. and *Alternaria* spp.) and bacterial (PSB) was done twice. Wheat (KRL 210) is grown after rice crop in all three types of soils.

Residue was placed in litter bags and according to treatments they were placed on the surface and at 10-12 cm below surface. Analysis of residue and soil samples was done. Residue sampling was three time and data for weight loss after harvesting of wheat is

Table 22. Weight loss in % of rice residue after harvest of wheat crop

	Weight %loss		
Treatment	**Normal soil**	**Saline soil**	**Sodic soil**
Residue-R	42.37	37.77	19.83
Residue+Media-R	33.09	42.83	43.83
Residue+fungi-R	42.49	44.71	42.39
Residue+fungi+bac-R	48.33	44.23	59.71
Residue+Halo+fungi+bac-R	-	-	53.81
Residue+Halo-R	-	-	50.67
Residue-I	59.49	56.93	29.66
Residue+Media-I	56.76	59.34	42.54
Residue+fungi- I	63.26	62.87	48.90
Residue+fungi+bac-I	64.63	63.47	44.94
Residue+Halo+fungi+bac-I	-	-	61.10
Residue+Halo-I	-	-	53.77

Okra and tomato in lysimeter in kharif and rabi seasons

Installation of drip irrigation set up and vegetable planting in filed reclaimed with soil amendments

Cauliflower grown at farmers' field, Nagawan, Kartarpur, Patiala, Punjab

shown in table 22. Maximum weight loss under normal and saline soils was observed under fungi+bacteria treatment in both types of residue placements. Under sodic soils maximum loss was observed under retention of straw in fungi+bacteria treatment but under incorporation it was found maximum under Halo+fungi+bacteria.

Development of Technologies for Sustainable use of Sodic Groundwater Enhancing Agricultural Livelihood (Nirmalendu Basak, A.K. Rai, Parul Sundha, Satyendra Kumar, R.K. Singh, R.K. Yadav and P.C. Sharma)

Groundwater plays a major role in the expansion of the area under irrigated agriculture. Managing high RSC (residual sodium carbonate) water is unable to completely address the problem of soil sodification and loss of crop productivity. The problem is further aggravated because of the insufficient supply of quality gypsum required for the preparation of gypsum bed. Therefore it is the need of the hour to refine of the existing sodic water reclamation technology for utilization of high RSC water for irrigation purposes. We hypothesize that this can be achieved by adopting three-pronged strategies of RSC neutralization with manipulation of ionic ratios, reduced loading of the residual carbonates and bicarbonates through drip irrigation systems, and reduction of the incipient soil sodicity. Amendment application decreased soil pH_s in fortified gypsum [GypS@50GR (8.28)] and rapid acidulated municipal city waste compost [RAMSWC10 (8.4)] whereas, irrigation with RSC water 7.5 developed greater soil pH_s (8.60) followed by RSC 6 (8.48) ≥ normal tap water [NTW (8.40)] and RSC 3 (8.38)**.** Application of amendments GypS@50GR, and RAMSWC10 improved soil organic carbon content than unamended soil ($P< 0.05$). The Okra and tomato yield were at par when irrigated with RSC water neutralized with different sodicity reclamation amendments. pH of tomato pulp reduced on amending with acid neutralizer, liquid S and sulphur reaction product (CSRP) ($P \le 0.05$). Lycopene content improved in tomato on adoption of sodicity neutralization approaches (neutralizing acid neutralizer, liquid S and sulphur reaction product). The total antioxidant content in tomato fruit was greater in RSC3 than RSC6. Soil pH_s was greater in soil (20 cm from stem of tomato plant) away dripper (8.23) than the near to dripper (8.13). Application of soil amendments reliance formulated S (RFS) improved rice yield 14.3, 37.8, 28.0 and 59.8% in Site I amd II in Pattijuianjian, Budhmore and Bibipur, respectively and wheat yield 53.4, 49.0, 29.6 and 37.8% in Site I amd II in Pattijuianjian, Budhmore and Bibipur, respectively under irrigation with RSC water in the range of 5–6 meq L^{-1}. The application of amendment neutralised alkalinity and decreased soil $pH_{1:2}$ of surface soil and thereby decreased soil $pH_{1:2}$ between 8.5–8.7 at Nagawan, Kartarpur, Patiala. Improved soil conditions made it possible to profitably grow the vegetables like bitter gourd, pumpkin, bottle gourd and ridge gourd and cauliflower.

Development of Arbuscular Mycorrhizal Fungi (AMF) based plant biostimulant to enhance the productivity of salt affected soils (Priyanka Chandra, A.K. Rai, Kailash Prajapat, Nirmalendu Basak, Parul Sundha and R.K. Yadav)

Arbuscular Mycorrhizal Fungi (AMF) forms a mutualistic association with crops under stressed conditions by improving access to growth limiting resources. As components of soil-plant natural ecosystems, the symbiosis with AM fungi can ameliorate the plant's response to salinity and have beneficial effects on plant growth and yield, which made AM fungi suitable candidates to bio-ameliorate salt stress. Hence, a study was planned to evaluate the abundance of native AMF in salt affected areas. The nine soil samples from

Table 23. Native AMF abundance in salt affected areas

Location	pH	EC (dS m^{-1})	Colonization (%)	Arbuscule abundance (%)	Spore count (per root bit)	Hyphal length density (m/g)	Hyphal length per unit root length (µm/cm)	Mycorrhizal root mass (g /plant)	Mycorrhizal root length (m/plant
Site 1	9.11	3.28	49.0a	28.3a	14.3a	87.09b	0.171b	0.343c	1.753c
Site 2	8.51	4.61	44.4ab	24.3ab	11.3ab	97.48a	0.202a	0.602b	2.913b
Site 3	8.99	1.46	35.3c	13.3d	10.3b	79.29bc	0.195a	1.036a	4.037a
Site 4	8.53	1.10	23.6d	11.6de	9.6b	66.55c	0.138c	0.40c	1.737a
Site 5	8.53	1.10	28.3d	16.3c	8.6b	68.63c	0.124c	0.23d	1.268c
Site 6	8.29	1.98	36.6bc	22.0b	9.0b	98.31a	0.162b	0.326c	1.949d
Site 7	8.74	0.95	47.0a	22.3b	8.3b	97.10a	0.183ab	0.363c	1.903c
Site 8	8.32	5.72	30.3cd	17.3c	8.6b	85.53b	0.144c	0.151e	0.905e
Site 9	8.52	1.91	23.0c	9.3e	8.6b	50.37d	0.082d	0.143e	0.849e

Site 1,2,8: Pattijuinjian; site 3,9,6: Budhmore; site 4,5,7:Nagawan P atiala

Table 24. Comparison of different substrates for propagation of AMF

	Colonization (%)	Arbuscule abundance (%)	Spore count (per root bit)	Hyphal length density (m/g)	Hyphal length per unit root length (µm/cm)	Mycorrhizal root mass (g /plant)	Mycorrhizal root length (m/plant
Conventional (soil:sand)	67.2 b	20.5 a	12.3 b	109.4 b	0.434 b	0.256 b	0.646 b
Coco-peat	68.0 a	13.3 b	13.3 a	130.3 a	0.527 a	0.352 a	0.868 a

different salt affected areas of rice –wheat cropping system were collected. The abundance of AMF colonization was studied in wheat roots. The results demonstrated that colonization (49.0%), arbuscule abundance (28.3%), and spore count (14.3 per root bit) was highest at site 1 which has highest soil pH (9.11) (Table 23). The hyphal length density and hyphal length per unit root length was highest at site 6 (98.31 m/g) and site 2 (0.202 µm/cm), respectively (Table 23). The propagation of AMF for large-scale application is still limited due to their obligate biotrophic nature that renders them dependent on the host plant for their survival. Various cultivation strategies have been employed including soil- and substrate-based techniques like pot cultures, and substrate free methods like hydroponics and aeroponics for the mass production of AMF in the presence of roots. The most widely used method is substrate-based as it is less artificial and cost-efficient. Previous studies reported that the use of substrate-based methods such as pot cultures resulted in the easy production of a large amount of AMF inoculum by the farmers and higher colonizing efficiency in the host plants. Hence, two different substrates (sand:soil and coco-peat) were evaluated which support better mycorrhizal colonization. The results demonstrated that coco-peat supported better colonization (68.0 %) and spore count (13.3 per root bit) while formation of arbuscules (20.5 %) was higher in conventional method (Table 24).

Development of sustainable resources management systems in the water-vulnerable areas of India (ICAR-JIRCAS) (R.K. Yadav, D. S. Bundela, Satyendra Kumar, A. K. Rai, Gajender, Bhasker Najary and P. C. Sharma)

Poor quality groundwater is extensive (32–84%) in arid and semiarid parts of India and its indiscriminate use poses a serious threat to the sustainability of the natural resources and environment. In Haryana state, the area covered by salt affected soils is 0.31 million ha, of which sodic and saline soil covered 0.17 and 0.14 million ha, respectively. The problem of salinity especially in poorly drained saline soils is increasing. It needs an 'on farm technology' solution that can be adopted at individual farm/farmer level. Cut-soiler based low-cost preferential drainage technologies were successfully applied in the multipurpose paddy fields of Japan. These technologies could be remunerative alternative for the sustainable management of soil and water and crop production on salt affected soils of India.

With this background, a collaborative research project to provide sustainable resource management system for waterlogged and saline arid regions of India has been started Indian Council of Agricultural Research -Central Soil Salinity Research Institute (ICAR-CSSRI), in association with Japan International Research Centre for Agricultural Sciences (JIRCAS). Cut-soiler-constructed preferential shallow subsurface drainage (PSSD) to improve the drainage function of soil layers. A Cut-soiler is a tractor-mounted farm implement that uses and manages the surface lying material, *viz.,* residue, scattered straw, or remaining stems for making residue-filled subsurface drains while running on the field. Cut-soiler PSSD has been found to be effective in the management of surface waterlogged rice fields of Japan and tested in other parts of the world. The improved drainage seen when using a Cut-soiler could make it a remunerative alternative for the management of dry land, salt-affected soils in India for sustainable crop production. Keeping the above aspects in view, this study evaluated the effect of Cut-soiler-based salinity management on salt and water dynamics and the subsequent improvements in growth and yield of crop in semi-arid saline regions.

The Japan International Research Center for Agricultural Sciences (JIRCAS) is undertaking collaborative research with the Indian Council of Agricultural Research - Central Soil Salinity Research Institute (ICAR-CSSRI) to evaluate the irrigation and drainage technologies for cultivating arable crops, in experimental fields situated in the salt affected area of Hisar, Haryana. The desalinization effect of CS in different soil type with use of saline irrigation water and its subsequent effect mustard growth and yield. However, the changes in groundwater dynamics with the application of CS will lead to salinity reduction is not clear. Therefore, the purpose of this study was to quantitatively analyze the salinity-reduction effect of CS with the change in groundwater level and salinity. The field experiment Cut-soiler line by a material-filled subsurface drain machine (Cut-soiler) in salinized fields of arid zone is under progress in semi controlled lysimeters at ICAR-CSSRI, Karnal, IIWBR Experimental Farm at Hisar, Haryana. The feasibly trial effectiveness of Cut-soiler for precision alkalinity management being conducted at five sites in farmers' field in Pattijhugia, kharabgarh and Budhmor villages of Patiala (Punjab).

The field experiment was laid out in 1.5 ha area at IIWBR research farm in Hisar. Cut-soiler drains and main drains were constructed. The layout of field experiemt is provided in figure 20. The weather station and ground water table observation wells were installed in the field at Hisar.

In total thirty-six polyvinyl chloride (PVC) observation wells, which are classified as edge strainer type, were installed to monitor the changes in groundwater level and salinity in the observation field in March 2022. Figure 21 shows the layout of CS and without CS plots in the groundwater observation field in Hisar. Groundwater surfaces levels were measured, and EC was observed at both shallow depths near the groundwater surface and strainer depths in each observation well to attain the research objectives.

Fig 20. Layout of the field in Hisar

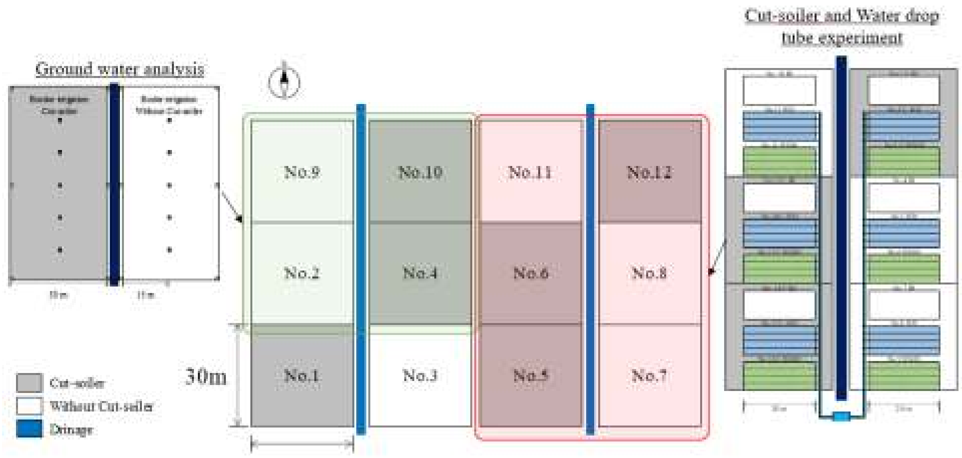
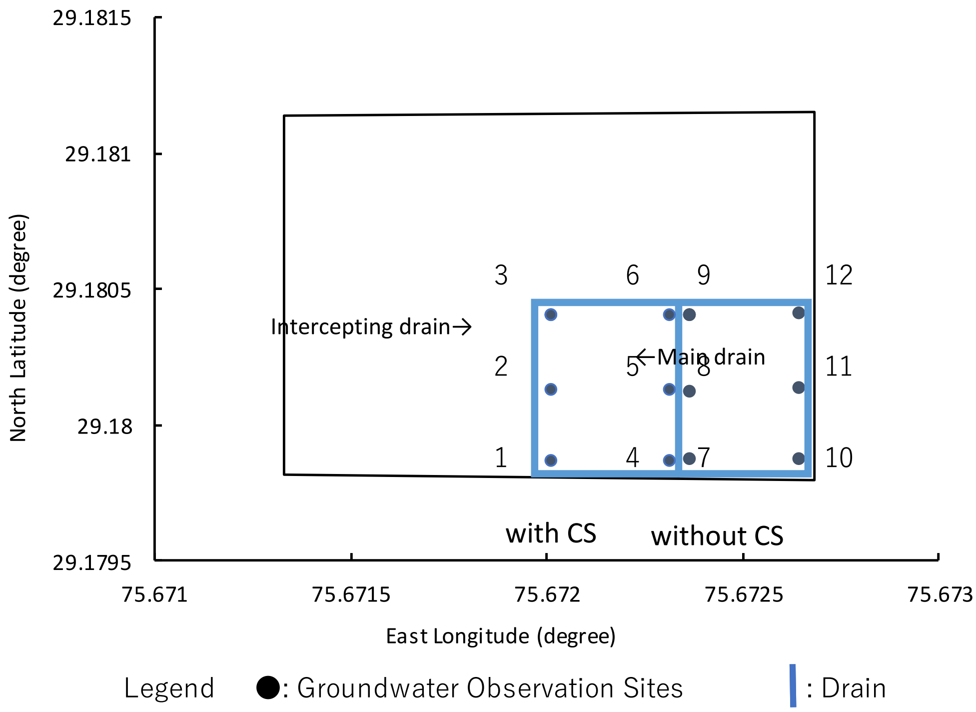
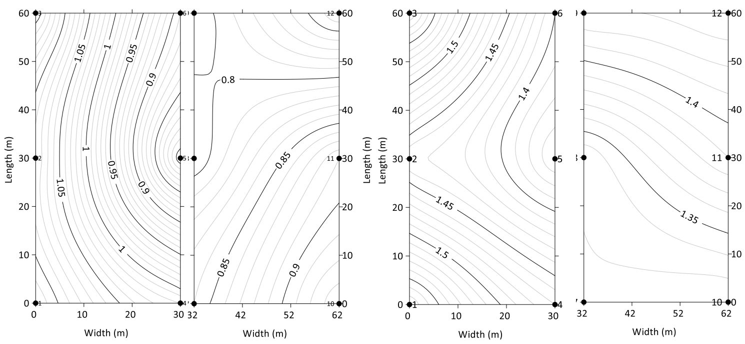


Fig 21. Layout of the groundwater observation field in Hisar



The ground level survey was conducted to improve the accuracy of groundwater observation results after installation of the groundwater observation wells. The fiducial point was set to the crown head of ground observation well No.4 (depth 1 m) because the point did not exist in and around the observation field in Hisar. The results of the groundwater observations with and without CS treatments in the observation field were compared to evaluate the effects of CS on salinity reduction.

The groundwater observation observations were started from April 2022 was at approximately 15 days intervals and all observations completed in a single day and the results were recorded at approximately 15 days intervals from April 2022 onwards. Figure 22 shows the groundwater surface depth from observation well No.4 (depth 1 m) in the observation field. The contour intervals were set to 0.01 m. The observation field was under stabilization after the CS operation and no crops have yet been cultivated. The groundwater surface depth in the subplot "With CS" plot was deeper than that in the "Without CS" subplot for all measurements. The difference in Thus, the CS operation



(a) October 3, 2022 (b) March 9, 2023

Fig 22. Groundwater surface depth (rainy and dry seasons)

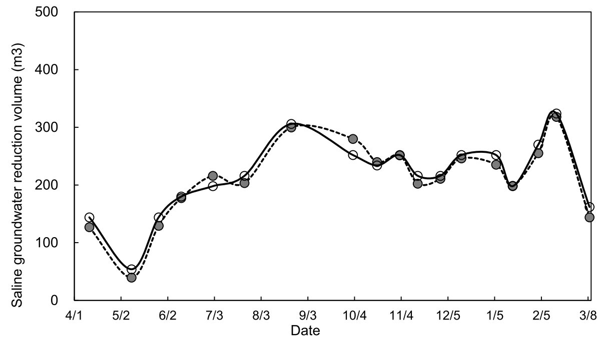


Fig 23. Change in the saline groundwater reduction volume

resulted in a difference in the groundwater surface depth between "With CS" and "Without CS" which was ranged from 0.03 to 0.18 m that was mainly due to drainage effect of Cut-soiler. The difference of the groundwater surface depth between October 3 and March 9 was 0.46 m "With CS" and 0.45 m "Without CS," which was almost same regardless of the use of CS, and which this difference was recorded lower in the dry season was lower. The groundwater surface depth in the CS plot was recorded shallower near the center of main drain.

The change in the saline groundwater reduction volume were recorded, which was calculated from April 2022 to March 2023 (Fig. 23). The reduction in saline groundwater was calculated as the difference between the "with CS" and "without CS" treatment plots. The observed values of the reduced volume were obtained using the average groundwater surface depth at the observation wells. In contrast, the estimated values were derived from the groundwater surface depth contours. The saline groundwater reduction volume calculated from the observed values ranged from 54 to 324 m^3, which was higher even in the dry season due to the preliminary irrigation.

This study shows the effectiveness of CS constructed preferential shallow sub-surface drainage (PSSD) in lowering the groundwater surface in comparison to without CS. The results showed that the effect of CS on saline groundwater reduction volume ranged from 54 to 304 m^3. It was estimated that fresh groundwater existed, which was brought by not only the CS function, but also the reverse flow in the main and intercepting drain caused by the heavy rainfall.

View of field experiment at ICAR-IIWBR research farm Hisar

Crop Improvement for Salinity, Alkalinity and Waterlogged Stresses

Genetic improvement of rice genotypes for salt tolerance using conventional and molecular breeding methods (S. L. Krishnamurthy, P. C. Sharma, B. M. Lokeshkumar, H. S. Jat, Ravi Kiran K.T., Vineeth T.V. and Devanna)

This project aims at identification of salt tolerant donors from different backgrounds its utilisation for breeding of new salt tolerant genotypes. It also aims to develop, evaluate and disseminate better salt tolerant rice genotypes through station trails and AICRP trails. To achieve the objectives, following trials were conducted and the breeding material was advanced during *Kharif* 2022.

A. National trail

a) Initial Variety Trial - Alkaline and Inland Saline Tolerant Variety Trial (IVT-AL&ISTVT) 2022

The IVT-Alkaline and Inland Saline Tolerant Variety Trial (IVT-AL&ISTVT) comprised of 24 entries including check variety (CSR 36, CSR 23, CSR 10, Pusa 44 and FL-478) and one local check (LC) which were evaluated across five salt stress locations in Randomized Block Design with three replications. Four entries namely 5414, 5411, 5419, and 5418 were the ideal genotypes with highest mean values under both saline and sodic condition over the saline check CSR 27 and sodic check CSR 36 across 5 locations.

b) Advanced Variety Trial 1-Alkaline and Inland Saline Tolerant Variety Trial (AVT1-AL&ISTVT) 2022

The AVT-Alkaline and Inland Saline Tolerant Variety Trial (AVT-AL&ISTVT) comprising of 15 entries including check variety (CSR 36, CSR 23, CSR 10, Pusa 44 and FL-478) and one local check were tested across five salt stress locations in Randomized Block Design with three replications. The three entries namely 5301, 5309 and 5304 has performed very well under both saline and sodic condition over the saline check CSR 27 and sodic check CSR 36.

c) AVT2- Alkaline and Inland Saline Tolerant Variety Trial-2022

The AVT2- Alkaline and Inland Saline Tolerant Variety Trial (AVT2-AL&ISTVT) comprising of 13 entries including check variety (CSR 36, CSR 23, CSR 10, Pusa 44 and FL-478) and one local check were tested across five salt stress locations in Randomized Block Design with three replications. The four entries namely 5210, 5201, 5215 and 5212 has performed very well under both saline and sodic condition over the saline check CSR 27 and sodic check CSR 36.

d) IVT Basmati Varietal Trial-2022

The IVT-BT trail comprising of 26 entries including check varieties (Pusa Basmati 1, Taroari Basmati, Pusa Basmati 1121 and Basmati CSR30 (Local check) were tested in Randomized Block Design with three replications at CSSRI Karnal. The three entries namely, 1810, 1802 and 1804 were top performing entries with a yield of 6.76 t/ha, 6.66 t/ha and 6.51 t/ha, respectively.

e) IVT and AVT- Biofortification trial 2022

The IVT and AVT-Biofortification trail 2022 comprised of 46 entries were tested in Randomized Block Design with three replications in CSSRI Karnal. The three entries namely, 5119, 5124, and 5103 were top performing entries. The entry 5119 recorded highest yield of 6.9 t/ha yield.

f) IVT and AVT - Aerobic trial 2022

The IVT-Aerobic trial 2022 comprised 64 entries and were tested in Randomized Block Design with three replications at CSSRI Karnal. The three entries namely, 4718, 4733 and 4727 were top performing entries with highest yield of 5.58 t/ha recorded by entry 4718. On the other hand AVT-Aerobic trial has 31 entries with highest yield recorded by entry 4603 (5.55 t/ha) and two entries 4608, 4613 also performed well with good recorded yield.

g) IVT - Coastal Saline Tolerant Variety Trial (IVT-CSTVT) 2022

IVT-CSTVT comprising of 30 entries including local check variety (CSR 27) were evaluated in RBD with 4 replications at farmers field in Khanpur village of Tarapur taluk, Anand district, Gujarat. The average soil EC_e of the field during the cropping season was 5.5 dS m^{-1}. Highest yield was recorded by entry no. 5614 (3.08 t ha^{-1}), followed by entry no. 5619 (3.07 t ha^{-1}), 5606 (3.03 t ha^{-1}) and 5617 (3 t ha^{-1}).

h) AVT 2&1-CSTVT 2022

The Advanced Variety Trial- Coastal Saline Tolerant Variety Trial (AVT 2&1-CSTVT) comprising of 9 entries including local check variety (CSR 27) were evaluated in RBD with 4 replications at farmers field in Khanpur village of Tarapur taluk, Anand district, Gujarat. The average soil EC_e of the field during the cropping season was 5.7 dS m^{-1}. Highest yield was recorded by entry no. 5508 (2.74 t ha^{-1}), followed by entry no. 5503 (2.50 t ha^{-1}).

B. Station Trials

Monitoring, maintenance and development of breeding materials

Many salt tolerant lines were used in hybridization with high yield varieties and to enhance the genetic variation and to transfer the salt tolerance in high yielding varieties. Many numbers of segregating populations were screened under high salinity (EC_{iw} ~ 12 dS/m) in micro plots and stress field.

Evaluation of promising lines under DSR

A total of 80 genotypes of different genetic background were evaluated under DSR (medium plot) in area of 15 m^2 at CSSRI Karnal. The top performing genotypes under DSR conditions were CSR2021-IR294-134 (7.59 t/ha), CSR2021-IR294-194 (7.09 t/ha) and CSR2021-IR294-112 (6.89 t/ha)

A total of 50 genotypes of different genetic background were evaluated under DSR (Larger plot) in area of 30 m^2 at CSSRI Karnal. The top performing genotypes under DSR conditions were CSR-MAGIC-80 (6.23 t/ha), CSR 49 (5.69 t/ha) and YET 75 (CSR 90) (5.57 t/ha).

Varied germplasm including 69 genotypes collected from different parts of India (13-Navsari, 10-ICAR-CSSRI, 5- ICAR-CIARI, Andaman, 7-ICAR-NRRI, Cuttack, 10-Vytilla rice research station, Kerala, 4- KAU, Kerala and 20-Anand Agricultural University), were evaluated in RBD having 3 replications at farmers field in Khanpur village of Tarapur taluk, Anand district, Gujarat. The average soil EC_e of the field during the cropping season was 5.6 dS m^{-1}. Two genotypes namely CSR 13 (3.24 t ha^{-1}) and Ezhome 3 (3.12 t ha^{-1}) were the ideal genotypes with highest mean values under saline conditions over the saline check CSR 27 (2.11 t ha^{-1}).

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 (5.0 Q) CSR36 (7.0 Q), CSR 43 (5.0 Q), CSR 46 (5.0 Q), CSR 49 (1.0 Q), CSR 52 (1.0Q), CSR 56 (7.0Q), CSR 60 (10.0Q), CSR 76 (5.0 Q) was produced to meet the demand of seed producing agencies as per DAC (Department of Agriculture and Cooperation) during 2022.

Rice entries nominated to AICRP during 2022

Based on the performance of rice lines across the locations, across the stresses and across the season the following entries nominated for testing under AICRP rice (Table 25,26 & 27):

Table 25. List of new nominated Entries to AICRP trail 2022

Trial	Name
IVT-CSTVT	CSR2018-43-18, CSR2018-43-36, CSR2018-43-37, CSR2018-43-16
IVT-ETP	CSR M1- 5, CSR M1-4, CSR AP10
IVT-Aerobic	CSR BT-252-201, CSR BT-252-41, CSR BT-252-197
IVT- Biofortifictaion	CSR HZR 1, CSR HZR 5
IVT-AL&ISTVT	CSR 141-11-107, CSR 141-11-112, CSR 103-10-2, CSR 104-10-2, CSR 116-10-2
IVT-BT	CSR BT-252-227, CSR BT-252-42, CSR BT-252-127 (YET74), CSR BT-252-19, CSR BT-252-35
NILs (SalTol+BLB Xa 13+ Xa21)	CSR 389-16-22
NILs (SalTol+BLB Xa13)	CSR 389-16-6

Table 26. List of promoted entries from AVT 1 to AVT 2 in AICRP trail 2022

Trial	Name
AVT2- MS	CSR27SM160
AVT2-AL&ISTVT	CSR YET 8 CSR YET 59 CSR TPB 159 CSR CPB 69 CSR YET 55
AVT2- Aerobic	CSR88

Table 27. List of promoted entries from IVT to AVT 1 in AICRP trail 2022

Trial	Name
AVT-CSTVT	CSR2019 IRBD78
AVT-MS	CSR27SM132
AVT-AL&ISTVT	CSR-189-11-122
AVT-Aerobic	CSR PET 27
AVT-Aerobic	CSR YET 78

Salt tolerant rice line CSR MAGIC 157:

IET 27823 (CSR MAGIC 157) with a pedigree of Fedearroz 50/ SHZ-2 // PSBRc 82 / PSBRc 158 //// IR 77298-14-1-2-10 / IR 4630-22-2-5-1-3 // IR 45427-2B-2-2B-1-1 / Samba Mahsuri + Sub 1. Tested in AL&ISTVT during 2018-2021. During 2018, under alkaline stress with 3.02 t/ha recorded 6.4% yield superiority on overall basis. IET 27823 during 2020 found promising in Z-II with 3.71 t/ha and 5.0% yield advantage over best check under inland saline conditions. During 2021, this culture found promising in Z-II under both alkaline and inland saline conditions with required yield superiority. Quality wise, IET 27823 recorded 69.8% HRR, 25.34 AC, ASV of 5.0 and 22 mm of GC at IIRR Hyderabad, while at NRRI, Cuttack this culture recorded 60% HRR, 19.2% AC, ASV of 7.0 and 49 mm of GC. Based on three year of performance, IET 27823 (CSR MAGIC 157) is found promising. This can be released as a variety for Zone II or Haryana state or it can also be used as genetic stock as donors for salt tolerance.

Salt tolerant line CSRM1-7

IET 28606(CSRM1-7) derived from cross IR 71730-51-2/NSIC Rc106 tested in the AL&ISTVT from 2019 to 2021. During 2018, this culture recorded a mean grain yield of 3.87 t/ha exhibited superiority with 23% yield superiority under Alkaline, and with 4.14 t/ha and 24% yield superiority under saline conditions in Z-II. During, 2020, IET 28606, recorded 9.5% yield advantage over best check on overall basis under alkaline conditions. This culture also recorded the required yield advantage in Z-II under both alkaline and inland saline conditions and hence promising. Similarly, during 2021, IET 28606 found promising in Z-II with 3.22 t/ha and 15% yield advantage over best check under alkaline conditions, with 4.25 t/ha and 25% yield superiority found promising. Quality wise, IET 28606 recorded 66.6% HRR, 23.73 AC, ASV of 7.0 and 44 mm of GC at IIRR Hyderabad, while at NRRI, Cuttack this culture recorded 61% HRR, 21.0% AC, ASV of 5.0 and 41mm of GC. Based on three year of performance, IET 28606 (CSRM1-7) is found promising. This can be released as a variety for Zone II or Haryana state or it can also be used as genetic stock as donors for salt tolerance.

Salt tolerant line CSR449S-13

IET 28608(CSR 449S-13) derived from the cross CSR 30 / CSR 36. Tested in AL&ISTVT trials since 2019 to 2021. During 2019, under alkaline stress, this culture exhibited 6% yield superiority over best check with 3.34 t/ha grain yield on overall basis, found promising in Z-II with 3.74 t/ha and 19 % yield advantage over best check. Under inland salinity (2019), this culture is also found promising in Z-II with 3896 kg/ha and 19 % yield advantage over best check. During 2020, IET 28608 exhibited superior performance in Z-II with 3930 kg/ha and 12% yield advantage over best check under inland saline conditions. During 2021, this culture found promising in Z-II under both alkaline and inland saline conditions with required yield superiority. Quality wise, IET 28608 recorded 69.1% HRR, 26.22 AC, ASV of 4.0 and 22 mm of GC at IIRR Hyderabad, while at NRRI, Cuttack this culture recorded 66% HRR, 21.37 AC, ASV of 3.0 and 40 mm of GC. Based on three year of performance, 28608 (CSR 449S-13) is found promising. This can be released as a variety for Zone II or Haryana state or it can also be used as genetic stock as donors for salt tolerance.

Network project on functional genomics and genetic modification in crop (NPFGGM): Salt Tolerance in Rice (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 NRC on Plant Biotechnology, New Delhi (for genotyping). A total of 140 RILs developed from cross combination of MTU 1001 × Kalanamak were phenotype in sodic condition (pH ~9.9) during *Kharif* 2022. The grain yield was ranged from 0.37 t/ha to 4.46 t/ha (RIL-51) with mean 1.6 t/ha under sodic condition. Descriptive parameters of RILs under sodic condition are presented in table 28.

Table 28. Top performing RILs under sodic condition

Top RILs	Plant height (cm)	Panicle number	Panicle length (cm)	Yield (t/ha)
RIL-51	75.88	12	22.71	4.46
RIL-141	86.04	14	34.37	3.46
RIL-145	100.37	17	25.84	3.42
RIL-107	111.4	14	22.84	3.37
RIL-129	103.77	13	16.15	3.13
RIL-17	105.63	11	21.95	3.06
RIL-57	102.71	14	24.43	3.04

Consortium Research Platform (CRP) on Agro-biodiversity - Component 2 - evaluation of rice Germplasm accessions against biotic/abiotic stresses (ICAR funded) (S.L. Krishnamurthy and P.C. Sharma)

The main objective of this project is to screening of rice Germplasm under salinity stress at seedling stage. A total of 496 genotypes including two checks (IR 29- sensitive check and FL478- tolerant check) were phenotyped for seedling stage salinity tolerance. The nutrient solution was salinized (EC ~ 10.0 dS m^{-1}) on 14th day after sowing by adding NaCl salt. Standard Evaluation Score (SES), root and shoot lengths were measured on 28th day after sowing. Out of 496 genotype, 16 genotypes fail to germinate. Vigor score (SES) ranged from 3 to 9 under saline conditions. Forty eight genotypes were found tolerant (score-3), 189 genotypes were moderately tolerant (score-5), 123 were moderately sensitive (score-7) and 120 genotypes were highly sensitive (score-9). From 2013-2022 we have evaluated a total of 7502 rice genotypes for seedling stage salinity tolerance out of this we found 241 rice lines exhibited seedling stage tolerance.

From QTL to Variety: Marker Assisted Breeding of Abiotic Stress Tolerant Rice Varieties with Major QTLs for Drought, Submergence and Salt Tolerance (DBT Funded) (S.L. Krishnamurthy and P.C. Sharma)

The project is aimed to transfer of major quantitative trait loci (QTL) for salinity tolerance into high yielding varieties of rice by using molecular marker-assisted backcross breeding. The material generated from this project was nominated to AICRP trail and their performance was surpassing the yield of recurrent parent. The line CSR 189-11-122 was developed from the cross SARJOO 52 / FL478 // SARJOO 52 *3 for saline (ECe = 10 dSm^{-1}) and alkaline areas (pH-9.5). This line recorded mean yield of 4111 kg/ha in Zone II and 3448 kg/ha in zone III under alkaline stress during 2022. Another line CSR 179-11-215 was developed from the cross PUSA44 / FL478 // PUSA 44 * 3 for saline areas ECe = 10 dSm^{-1}. It showed yield superiority over CSR 23 (Inland Saline Check), CSR 10 (Early duration saline check), FL 478 (Saline tolerant check), Pusa 44 (Sensitive Check) and Local Check. Therefore CSR 179-11-215 was promising in the states of Haryana and Karnataka under inland salinity.

Molecular genetic analysis of resistance/tolerance in rice wheat chickpea and mustard including sheath blight complex genomics (Sub-project 1: Rice component) (ICAR funded) (S.L. Krishnamurthy, 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 (CSR 20/VSR 156) for salinity tolerance

A total of 178 genotypes including 176 RILs derived from CSR 20 x VSR 156 cross along with two parents were evaluated in 2 environments normal and saline stresses (EC~ 8) during *Kharif, 2022*. Grain yield (kg/ha) ranged from 0.83 to 3.67 t/ha under saline conditions. Under saline stress, the RIL21, RIL142, RIL157, RIL46 showed the highest grain yield above 3.5 t/ha.

Development of high Zinc rice varieties (IRRI funded) (S. L. Krishnamurthy, P. C. Sharma and B. M. Lokeshkumar)

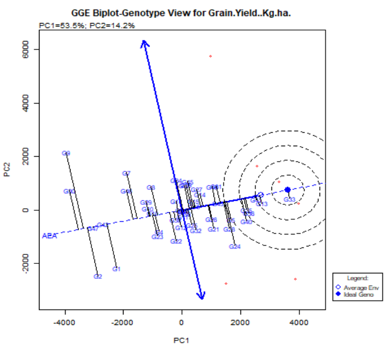


Fig 24. GGE Biplot analysis of bio fortified rice lines for grain yield

A total of 47 rice genotypes along with 2 checks were evaluated in two replications at ICAR-CSSRI, Karnal in 2022. The grain yield ranged from 1984 to 6688 kg/ha, the following entries IR15M1293, IR15M1315, IR 99637-123-1-3-B, IR15M1330 and IR 95080:1-B-9-12-17-3 performed very well with highest grain yield of above 5500 kg/ha. Entry IR 95040:12-B-3-10-2-GBS recorded the highest Zn content > 25ppm while, entry IR14M123 reported highest Fe content>10 ppm. The combined analysis of six years grain yield suggested that the genotypes IR15M1293, IR 95080:1-B-9-12-17-3, IR15M1330 were ideal genotypes with highest mean value and had recorded stable yield across year (Figure 24). Hence based on desirable traits IR15M1293 and IR15M1341 were nominated for AICRP rice under Bio-fortification trials.

Rice grain quality and nutritional quality: Low arsenic rice, Bioactives in rice and Low GI rice (IRRI funded) (S. L. Krishnamurthy, P. C. Sharma, S K Sarangi, B M Lokeshkumar and Nitish Rajan Kumar)

The twenty-six rice lines from previous season (Rabi 2021-22) were evaluated in the Kharif-2022. Data were obtained for morphological traits such as plant height (in centimetre), number of tillers, number of ear bearing tillers, grain weight per plot, straw weight per plot, Days to fifty percent flowering and days to harvesting. The grain yield ranged from 0.18 (IARS 6)- 2.03 (IARS22) t/ha. The average days to 50% flowering were 114 days, while IARS19, IARS24, IARS5 and IARS7 was early flowering. The average grain and straw yield were 930kg/ha. Based on the Genotype Biplot analysis of 26 genotype for 3 years, genotype IARS 23, IARS 24 and IARS 28 turned out to be the stable and ideal genotypes with highest mean value.

Trait Discovery: Rain-fed Ecology (IRRI Funded) (S.L. Krishnamurthy, P. C. Sharma and B. M. Lokeshkumar)

A set of 330 genotypes of 3K sets of rice from IRRI was screened in hydroponics using Yoshida culture solution. Seedling stage salt tolerant FL 478 was used as tolerant check and IR 29 as susceptible check. Salt stress of EC_{iw} 10 dS m^{-1} is given on 12^{th} day after sowing. The data recorded after the complete death of susceptible check under salt stress. About 109 genotypes were not properly germinated, 12 genotypes turned out to be highly salt tolerant, while 18 genotypes were identified as moderately salt tolerant. A genome-wide association study (GWAS) for salt tolerance was performed using MLMM models of analysis. About 121 SNP were significantly associated with salt tolerance related traits like seedling vigor-SES score (54 SNP), shoot length (36 SNP) and root length (31 SNP) under stress conditions with LOD score of >3.5.

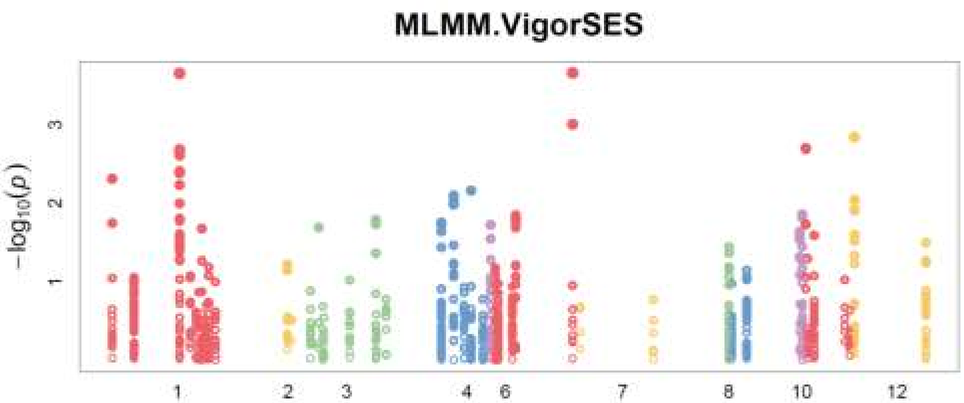


Fig 25. Manhattan plot representing gene Based GWAS for salinity tolerance in rice

Table 29. Variability for grain yield (t/ha) and yield contributing characters in 3K rice panel

Parameter	Days 50%	Plant Height (cm)	Panicle Length (cm)	Productive tiller per plant	Grain yield (t/ ha)
Mean	105	108.46	26.30	7.23	3.11
Minimum	62	59.50	15.00	3.50	0.69
Maximum	146	161.00	122.00	13.00	8.56

The candidate genes responsible for salt tolerant stress were identified from public databases like QTARO and fun rice genes databases. The study has also explored differential expression of genes present within salt responsive QTL regions under control and/or stress (salinity) in rice cultivars IR64/Pokkali and IR64/N22 in public microarray data and salt stress responsible genes from several studies. 48 genes were short listed for association study. Coding sequences of all the 48 genes were used for association analysis. Results indicated that the genes Os06g0701700 encoding for ion transporter, Na^{+}/K^{+} symport (Os06t0701700-01); similar to Cation transporter HKT1. (Os06t0701700-02) and Os01g0678500 encoding for voltage-gated Ca^{2+} channel protein, elicitor-induced defense responses, and hypersensitive cell death, an activator of MAPK cascade were significantly associated with the trait of interest (Figure 25).

Screening of Anteena Pannel genotypes

A set of 58 genotypes from Antenna Pannel rice genotypes were sown in May and after 30 days these were transplanted in normal field condition. The data on minimum, maximum and mean values for days to 50 % flowering, plant height, panicle length tiller per plant and grain yield Kg/ ha was recorded and presented in table 29. Among the genotypes the highest yield was recorded in IRRI 154, F50, NSIC Rc240 , Sahel 177, Oryzica 1, MINGHUI 63 with more than 6 t/ha with an average yield of 3.11 t/ha. The highest yield was recorded in IRRI 154 and F50 with 8.56 and 7.4 t/ha respectively. Based on previous year data, best performing early matured line CSR-AP10 (IR77186-122-2-2-3) were nominated to AICRP for IVT-ETP trail.

Marker-assisted pyramiding of blight and blast resistance genes in Basmati CSR30 rice (Krishnamurthy S. L., P. C. Sharma and Lokeshkumar B. M.)

The project aims to transfer major quantitative trait loci (QTL) for Blast and bacterial blight resistance in salt-tolerant high yielding basmati CSR 30 rice varieties by using molecular marker-assisted pyramiding breeding. The donor parent PUSA 1609 for blast and PUSA 1718 for bacterial blight crossed with the recipient parents CSR 30 for introgression of blast and blight resistance. Recurrent parent CSR 30 is basmati salt-tolerant rice variety grown over a large salt-affected area but susceptible to blast and blight disease. Donar parents Pusa 1609 for blast resistance (*Xa 13 &Xa 21* gene) and Pusa 1718 for blight resistance (*Piz5 and Pi54* gene) was selected for marker-assisted pyramiding. The 446 and 488 F_1 seeds developed form CSR 30 X Pusa Basmati 1609 and CSR 30 X Pusa Basmati 1718, respectively were tested to identify true F_1. These F_1 plants were sown in staggered sown for development of BC_1F_1.

The F_1 Plants were subjected to True to type test and used for development of BC_1F_1. A total of 356 true F_1 plants were identified from cross CSR 30 X Pusa Basmati 1609 while 412 true F_1 plants of CSR 30 X Pusa Basmati 1718 were obtained. About 1540 and 1440 BC_1F_1 seeds developed from CSR 30 × Pusa Basmati 1609 and CSR 30 × Pusa Basmati 1718 crosses. These BC_1F_1 were sown in six staggered sowings and Transplanted to develop BC_2F_1 plants. The donor and recipient were sown on six dates with an interval of one week to synchronize the flowering. These plants were subjected to marker assisted selection using RM 206 and AP 5930 SSR Marker in cross CSR 30×Pusa Basmati 1609 and Xa13 and Xa21 SSR Markers in CSR 30×Pusa Basmati 1718 respectively and used for development of BC_2F_1 plants.

Deciphering molecular mechanism of salinity tolerance at reproductive stage in rice landrace - Bhatada Rashi 1 (Krishnamurthy S.L., P.C. Sharma and Lokeshkumar B M)

The aim of this project is identification of robust QTLs conferring tolerance to the reproductive stage salt stress. A total of 195 RILs (F_8) developed from cross combination of BPT 5204 x Bhatada Rashi 1. These RILs along with parents were evaluated under saline (ECe~ 10 dS/m) stress at reproductive stage in microplot during *Kharif* 2022. Descriptive parameters of RILs under saline condition are presented in table 30. We have also evaluted these lines for seedling stage salinity tolerance and we found 12% and 9% of the genotypes exhibiting salinity tolerance and moderately tolerant RILs. And we obtained a 19% of susceptible and 60% of lines highly susceptible RILs.

Genetic approaches to improve wheat (*Triticum aestivum* L.) germplasm for salt tolerance (Neeraj Kulshreshtha, Arvind Kumar, Ashwani Kumar, Ravi Kiran, Vineeth, T.V. and P.C. Sharma)

The project was initiated with the objective to improve existing salt tolerant lines with reference to grain yield, grain colour, disease resistance and other physiological and morphological characters and to develop salt tolerant lines for different stress situations.

Varietal development

Two salt tolerant varieties KRL 370 and KRL 386 were recommended for release for sodic soils of Uttar Pradesh in the State Level Research Advisory Committee Meeting held at

Table 30. Descriptive statistics of recorded traits under saline stress at reproductive stage.

Parameter	Days - 50 % Flowering	Plant Height (cm)	Panicle Length (cm)	Total Tiller	Productive Tiller	Yield (kg/ha)
Average	98.26	80.15	16.80	4.80	2.74	341.27
Maximum	128.00	121.00	22.50	8.50	5.50	3555.54
Minimum	72.00	45.00	10.50	2.50	1.00	74.07

Table 31. Characteristics of KRL 370 and KRL 386

Name of the entry	KRL-370	KRL 386
Plant height (cm)	85-104	100-111
Maturity duration (days)	133-137	133-142
1000-seed weight (g)	36-45	40-45
Salinity tolerance (ECe-dS m^{-1})	Up to 8.6	Up to 8.6
Sodicity tolerance (pH_2)	Up to 9.3	Up to 9.3
Poor quality water (EC_{iw}, RSC)	6-10 dSm^{-1}/ 3-8meq l^{-1} (RSC Water)	6-10 dSm^{-1} / 3-8meq l^{-1} (RSC Water)
Waterlogging tolerance (days)	10-15 days at seedling stage	10-15 days at seedling stage
Date of sowing	5 November to 20 November	5 November to 20 November
Grain yield in normal soil (q/ha)	56-60 qt/ha	58-62 qt/ha
Grain yields in salt affected soils (q/ha)	36-40 qt/ha	33-41 qt/ha

Yojana Bhavan Lucknow on 16 September 2022. Both varieties have multiple stress resistance to biotic stresses- (Stripe Rust, Brown Rust, Karnal bunt, loose smut, flag smut, powdery mildew, leaf blight, foot root) and abiotic stresses (salinity and sodicity). KRL 370 has additional tolerance to moisture stress (table 31).

Hybridization and generation advancement:

To transfer the salt tolerance from elite or released cultivars (KRL 370, KRL 3-4, KRL 351, KRL 119, KRL 99, KRL 210, KRL 213, KRL 283, KRL 19, KRL1-4, KRL 119, KRL 2006, KRL 2020, KRL 327, KRL 330, KRL 238, KRL 2001, KRL 2014, KRL 2021, KRL 2025, KRL 2029, KRL 2103, KRL 2104, KRL 2106, KRL, 2117) developed at CSSRI, Karnal in elite, popular varieties and genetic stocks (DBW 17, DBW 187, DBW 222, DBW 252, DBW 303, FKW 1, FKW 3, FLW 21, FLW 22, FLW 23, FLW 25, FLW 26, FLW 27, FLW 28, FLW 29, FWW2, GW 322, HD 2009, HD 3132, HD 3159, HD 3170, HD 3171, HD 3226, HD 3237, HI 1624) which are carrying the high yielding genes as well as gene pyramids for resistance to rust and other major diseases, 417 new cross combinations were attempted and approximately 2000 ear heads were emasculated and hybridized to create the variability for desired traits.

During the year 2021-22, a total of 417 new cross combination involving different targeted donors were advanced to diversify base, improving tolerance against disease resistance, waterlogging tolerance and salt tolerance. Under advanced/segregation generation F_1 (1022 crosses), F_2 (200 Crosses), F_3 (55 Crosses), F_4 (8 Crosses), F_5 (24 Crosses), F_6 (18 Crosses) and F_7 (30 Crosses) were advanced under intensive selections pressure of salt stress and rust diseases. Selections were made on the basis on salt tolerance, disease resistance and agro-morphological traits during the *rabi* season 2021-22.

Development and advancement of mapping populations for salt tolerance: During the cropping season three mapping populations namely IC564103-A/Kharchia 65 (population size 290 in F_6 generation), HD2985/Kharchia Local (population size 360 in F_5 generation) and KRL 283/IC 401976 (size 120 in F_7 generation) were advanced.

Evaluation of wheat varieties for salt stress in Microplots:

During the cropping season 2021-22, forty six wheat genotypes including 32 advanced lines were evaluated under four environments (Control, Saline: irrigation with saline water of 10 EC_{iw}, Sodic; pH_2 9.4 ± 0.13 and Sodic waterlogged: pH_2 9.4 ± 0.17) for their *per se* performance in micro plots. Genotypes were evaluated in CRBD with three replications.

Genetic variation among wheat lines in waterlogged sodic microplots (pH_2 9.4 ± 0.13)

Following is the performance of genotypes in different microplots.

- Normal microplots - top performing genotypes were KRL 2005 followed by KRL 2022, KRL 2014, KRL 2004, KRL 2002, KRL 2018 and KRL 2003.
- Saline microplots - KRL 3-4 was the top performer followed by KRL 2008, KRL 2003, KRL 2004, KRL 99, KRL 2004 , KRL 210, KRL 283, Kharchia 65 and KRL 2027
- Sodic microplots - KRL 3-4 was the top performer followed by Kharchia 65, KRL 99, KRL 2030, KRL 2001 and KRL 2016, KRL 2020, KRL 210, KRL 283 and KRL 2027.
- Sodic waterlogged microplots - KRL 3-4 was the top performer followed by Kharchia 65, KRL 2020, KRL 2001, KRL 99, KRL 283, KRL 2016, KRL 2026, KRL 2010, KRL 210 and and KRL 2005.

Entries contributed for IPPSN 2021-22

During the cropping season ten promising wheat entries were sent for evaluation against rust diseases in Initial Plant Pathological Screening Nursery (IPPSN).

Entres Promoted/nominated

- Salt tolerant entries KRL 423 and KRL 1803 were promoted for the Uttar Pradesh Salinity trial 2022-23 where as KRL 2002 and KRL 2020 were nominated as new entries.
- ·NIVT-1A-IR-TS-TAS, 2022-23: KRL 2106
- Entries submitted to SATSN 2022-23: KRL 2101, KRL 2105, KRL 2106, KRL 2112, KRL 2114, KRL 2201, KRL 2202, KRL 2203, KRL 2204, KRL 2205
- ·IPPSN 2022-23: KRL 2206, KRL 2207, KRL 2208, KRL 2209, KRL 2210, KRL 2211, KRL 2212, KRL 2213, KRL 2214, KRL 2215.

Trials/nurseries conducted

During 2021-22 different trials and nurseries were conducted and the data was sent to the coordinating centers for compilation: Alkalinity Salinity trial 2021-22 at ICAR-CSSRI Karnal (pH_2: 8.9), Alkalinity Salinity trial 2021-22 at Anjanthali (pH_2: 9.4), Alkalinity Salinity trial 2021-22 at Bathinda Through AICRP, Alkalinity Salinity trial 2021-22 at Agra Through AICRP, National genetic stock nursery 2021-22 and AVT-SST Barley trial at CSSRI farm with 14 entries. These trials were helpful in genotypic evaluation under stress, enrichment of new germplasm sources at ICAR-CSSRI and promotion of new entries to the salinity alkalinity trial.

Experiments at ICAR CSSRI RRS Bharuch

Experiment no. 1

Twenty five genotypes, including KRL series and other popular released varieties of ICAR-CSSRI, Karnal and IIWBR, Karnal were evaluated in RBD with three replications on salt affected *Vertisols* (ECe 6-8 dS m^{-1}). Plant height varied from 78.9 cm (KRL 283) to 119.8 cm (C 306) with a mean value of 97.7 cm. 19 genotypes showed increased plant height than the check variety KRL 210, with only KRL 283 showing dwarf nature. Days to 50% flowering and days to maturity did not show any significant variation among the tested genotypes. Four genotypes, namely KRL 2020 (1085 g), KRL 2024 (1067g), KRL 3-4 (1051g) and Kharchia 65 (1028g) showed significantly higher yield as compared to the check variety, KRL 210 (809 g). Eight genotypes, namely, KRL 2024, KRL 2014, KRL 2020, KRL 2025, HD 3226, HD 3086, Kh 65 and KRL 3-4 showed significantly higher biomass than the check variety KRL 210 (1733 g).

Experiment no. 2

256 genotypes from CIMMYT were evaluated on salt affected *Vertisols*, irrigated with saline water of EC_{iw} 7-8 dS/m in an augmented completely randomised block design. Based on grain yield, biomass yield, test weight, phenology and panicle architecture, we identified 10 superior high yielding genotypes as depicted in table 32.

Experiment no. 3

210 advanced breeding lines from ICAR-CSSRI were also evaluated on salt affected *Vertisols*, irrigated with saline water of EC_{iw} 7-8 dS/m in an augmented completely randomised block design. Based on grain yield, biomass yield, test weight, phenology and panicle architecture, we identified 10 superior high yielding genotypes as depicted in table 33.

Experiment no. 4:

Ten genotypes, including KRL series and varieties of PAU, Ludhiana were evaluated in RBD with three replications on salt affected *Vertisols* (ECe 6-8 dS m^{-1}). In general, the PAU genotypes showed delayed flowering as compared to KRL series genotypes. Three genotypes showed significant early flowering (KRL 2028, KRL 2001 and PAUSAT 3) as

Table 32. Yield and yield attributes of superior bread wheat genotypes identified during the 2021-22 season on saline Vertisols

Top 10 genotypes	Grain yield (g/single line of 2m)	Biomass yield (g)	Test weight (g)	Plant height (cm)	Days to 50% F	Panicle length (cm)	Panicle weight (g)	No. of grains/ spike
1118	586	1200	36.2	92	60	9.4	2.9	56
1229	416	930	45.4	83	68	6.4	2.8	48
1027	390	892	42.0	91	64	7.2	1.9	38
1230	341	672	45.8	94	52	7.8	2.8	44
1228	330	672	51.1	95	61	8.8	3.2	51
1071	328	546	49.3	92	63	8.0	3.0	51
1001	322	683	41.8	96	62	8.8	3.1	56
1070	320	662	44.5	95	64	10.3	4.1	70
1241	317	716	42.1	94	53	10.3	2.3	58
1002	314	664	45.4	90	62	8.3	2.7	45

*Days to 50% F: Days to 50% flowering

Table 33. Yield and yield attributes of superior bread wheat genotypes identified during the 2021-22 season on saline Vertisols

SL No.	Top 40 Genotypes	Yield (g/2 lines of 2m each)	Biomass yield (g)	Test weight (g)	Days to 50% F	Panicle length (cm)	Panicle weight (g)
1	KRS 21179	760	1520	42.3	63	9.4	2.8
2	KRS 21045	695	1685	47.5	68	10.1	4.2
3	KRS 21196	690	1426	45.0	58	9.7	4.2
4	KRS 21165	670	1543	43.7	66	8.6	2.6
5	KRS 21188	640	1340	41	58	9.7	3.1
6	KRS 21152	625	1330	41.9	66	9.0	2.6
7	KRS 21135	615	1252	43.6	66	10.5	3.7
8	KRS 21091	614	1316	39.2	58	10.1	3.1
9	KRS 21162	610	1358	44.7	66	10.1	3.3
10	KRS 21195	608	1250	45.1	58	9.0	1.9

*Days to 50% F: Days to 50% flowering

compared to the check variety KRL 210 (57 days). The check variety displayed the highest grain yield (627 g), followed by KRL 2001 (555 g) and KRL 2028 (504 g). Only one genotype ie. KRl 2020 (1863 g) displayed significantly higher biomass yield than the check variety KRL 210 (1520 g). Only one genotype ie. KRl 2028 (45.39 g) displayed significantly higher test weight than the check variety KRL 210 (41.63 g).

AICRP National trial 2022-23

SATSN trial consisting of 18 entries in RBD is being carried out at RRS Bharuch on salt affected Vertisols (ECe 6-8 dS m^{-1}) during *Rabi* 2022-23.

Maintenance of germplasm

All genotypes, varieties and breeding lines under different experiments were grown in the field for multiplication and maintenance of the rich germplasm and for future use in breeding programmes.

Breeder/ nucleus seed production and seed multiplication: Breeder seed of CSSRI varieties KRL 210 (32.4 qt), KRL 213 (1.0 qt) and KRL 283 (12.2 qt) were distributed to various public and private seed producing agencies. Breeder seed of KRL 210 (6 qt), KRL 213 (0.50 qt) and KRL 283 (2.20 qt) varieties was also provided to the seed production unit for the production of truthful labelled (TL) seed. In addition nucleus seed of five released varieties KRL 1-4, KRL19, KRL 210, KRL 213, KRL 283 and 20 advanced lines was produced at CSSRI experimental farm for use in the next cropping season. During the crop season, entries of IPPSN and SATSN, and two entries contributed in NIVTs were also multiplied. In addition, the seed of important germplasm such as Kharchia 65, KRL 99, KRL 3-4 and Kharchia local was multiplied to meet out the demand as checks.

Germplasm characterization and trait discovery in wheat using genomics approaches and its integration for improving climate resilience, productivity and nutritional quality (DBT Project) (Arvind Kumar and Neeraj Kulshreshtha)

During rabi season 2021-22, a mini core set of bread wheat (325) was received from BISA, Ludhiana for salt tolerance screening. Two trials consisting of 325 accessions of bread wheat was conducted in Augmented Randomized Block Design with 10 blocks (size 63 m^2) under normal soils and salinity stress. A total of five checks namely Kharchia 65, KRL

Drone view of the field experiments

210, HD 3226, DBW 303, HD 2851 was randomized within 325 accessions. For creating the salinity stress, all the irrigations were applied with saline water (ECiw ~15 dS m^{-1}). A total of three irrigations of artificial saline water (15 EC_{iw} and SAR 20) and good water quality irrigations were applied to the experiments. To prepare the chloride dominated saline water (SAR ≈ 15, Ca^{++} : Mg^{++}ratio= 3:1, Cl^- : $SO4^-$ ratio =7:1), estimated quantity of various salts viz. NaCl (4.665 mg, 99% Pure), $CaCl_2.2H_2O$ (5.343 mg, 99% Pure), $MgCl_2,6H_2O$ (2.450 mg, 99% Pure) and Na_2SO_4 (1.793 mg, 99% Pure) @ per litter were dissolved in best available water under 1000 litter plastics drum and measured the EC and SAR in laboratory. Every block was saturated at every irrigation with the help of estimated bulk density and water holding capacity of the soil. However, in control condition field trial was irrigated with normal tube well water. In the experiment quantitative data on days to 50 % flowering, days to maturity, number of effective tillers, plant height (cm), spike length, spikelets per spike, flag leaf area, flavonoid content, thousand grain weight, grain filling ratio, grain yield and above ground biomass were recorded to observe the effect of salinity stress. Crop views in the experiments can be seen in the given photo.

In the experiment conducted under salinity stress, a total of 40 genotypes were seemed superior than the salt tolerant national check (KRL 210). To confirm the sources of salinity tolerance, same set of bread wheat were also be tested under in vitro salinity stress (under hydroponics condition) at division of plant physiology, IARI, New Delhi. Early growth response and other growth parameters recorded under Hydroponics experiment indicated that, out of 40 selected genotypes, only 15 genotypes were also performed better under hydroponics. Analytical results indicated that, a total of 40 genotypes were seemed superior to the salt tolerant national check (KRL 210). To confirm the sources of salinity tolerance same set of bread wheat were also be tested under in vitro salinity stress (under hydroponics condition) at division of plant physiology, IARI, New Delhi. Early growth response and other growth parameters under Hydroponics experiment and yield response in field trials (control and salinity stress) indicated that, out of 350 genotypes, only 15 genotypes (IC252928, IC534300, IC531275, IC445332, IC252431, IC416053, IC531950, IC443738, IC530051, IC527448, IC252844, IC252785, IC531233, IC321916 and IC335683) were also performed better under hydroponics as well as in field conditions and could be consider sources for salt tolerance.

Development of salt tolerant and high yielding Indian mustard (*Brassica juncea* L. Czern & Coss) genotypes using classical and modern breeding approaches

(Jogendra Singh, PC Sharma and Vijayata Singh)

Development of salt tolerant Indian mustard varieties

Release and notification of salt tolerant Indian mustard variety CS 61 and CS 62

The CS 13000-3-2-2-5-2 (CS 61) and CS 15000-1-1-1-4-2 (CS 62) variety has been released by the Uttar Pradesh State Sub-Committee Seeds and Crop Varieties (UP-SVRC) during the year 2022 and notified by Central Sub-Committee on Crop Standards, Notification & Release of Varieties (CVRC) vide Gazette notification S.O. 1056(E), dated on 6th March, 2023, for irrigated, sodic soils and timely sowing (by 25 October) of Uttar Pradesh. Their yield are 2.1-2.2 t/ha in sodic soil (pH up to 9-9.3) and 2.5-2.8 t/ha in normal soil and water. CS 61 has about 39 percent oil content while CS 62 has 39.5 percent. CS 61 matures in about 132 days with plant height 181cm while CS 62 in 136 days with plant height 168 cm. These varieties are resistant to alternaria blight, white rust, powdery and downy mildew, stag head and sclerotinia stem rot and also less infestation of aphid.

Development and Evaluation of advanced breeding lines (PYT) in semi– reclaimed alkali soils

Eighty-one advanced breeding lines including five checks (CS 60, CS 58, RH 749, Kranti and Giriraj) were evaluated in PYT for seed yield in normal and reclaimed alkali soils (pH_2 8.5 to 9.3) at Karnal. Seed yield ranged from 1.38 to 2.84 t ha^{-1} (Mean 1.96 t ha^{-1}, $CD_{(0.05\%)}$ 0.35 t) under normal condition while it ranged from 1.03 to 2.07 t ha^{-1} (Mean 1.52 t ha^{-1}, $CD_{(0.05\%)}$ 0.90 t) under alkali condition. One lines CS 2005-193 (2.84 t ha^{-1}) gave significantly higher yield over the best check CS 60 (2.49 t ha^{-1}) under normal condition, while three lines gave significantly higher yield over the best check CS 60 (1.94 t ha^{-1}) with RIL87 (2.07 t ha^{-1}) followed by CS 18000-3-2 (2.03 t ha^{-1}) recorded maximum seed yield.

Development and Evaluation of advanced breeding lines (YET) in semi– reclaimed alkali soils

A total of 19 advanced breeding lines including five checks (CS 60, CS 58, RH 749, Kranti and Giriraj) were evaluated in YET for seed yield in normal and reclaimed alkali soils (pH_2 8.5 to 9.3)


Salt tolerant Indian mustard variety CS 61


Salt tolerant Indian mustard variety CS 62

at Karnal. Seed yield ranged from 1.83 to 2.76 t ha^{-1} (Mean 2.31 t ha^{-1}, CD $_{(0.05\%)}$ 0.39 t) under normal condition while it ranged from 1.21 to 2.10 t ha^{-1} (Mean 1.75 t ha^{-1}, CD $_{(0.05\%)}$ 0.92 t) under alkali condition. Four lines gave significantly higher yield over the best check CS 60 (2.49 t ha^{-1}) with RIL249 (2.76 t ha^{-1}) followed by CS 2013-8 (2.73 t ha^{-1}) under normal condition, while three lines gave significantly higher yield over the best check CS 60 (1.94 t ha^{-1}) with CS 2013-8 (2.10 t ha^{-1}) followed by CS 2009-263 (2.03 t ha^{-1}) recorded maximum seed yield.

Development and Evaluation of multistress tolerance advanced breeding line (drought, frost and heat and salt stresses) conditions-2022

The objective behind these crosses was to develop multi-stresses (salinity, heat, drought and frost) tolerant mustard genotypes with higher yield. A total 31 advanced breeding lines including four checks [CS 60 (salinity tolerance), Pusa Bahar (heat tolerance), RH-781(drought & frost tolerance), and RH-819 (drought tolerance)] were evaluated for seed yield under multi-stress (drought, frost and heat stresses along with sodic soils pH_2 9.78) conditions at SKN Agriculture University, Agricultural Research Station, Fatehpur-Shekhawati, Sikar (Rajasthan). Results for seed yield under the drought stress are given in table 34.

Monitoring and Evaluation of promising salt tolerant strains of Indian mustard (Brassica juncea) in AICRP on Rapeseed Mustard Salinity/Alkalinity Trial-2021-22

A total of six entries were evaluated in IVT under saline condition (ECe 12.0 dS/ m) in alkali condition (*p*H 9.3) at Karnal. Significant differences were observed in seed yield amongst the genotypes evaluated, under alkalinity stresses. The seed yield ranged from 1.32 to 2.08 t ha^{-1} (Mean 1.64 t ha^{-1}, CD $_{(0.05\%)}$ 0.37 t) under high alkaline conditions (*p*H 9.3) at Karnal. Entry CSCN-21-10 (2.08 t ha^{-1}) followed by CSCN-21-4 (1.84 t ha^{-1}) showed highest seed yield under the salt stress condition (Table 35).

Table 34. Development and Evaluation of multistress tolerance advanced breeding line-2022

S.N.	Drought stress			Salt stress (pH_2 9.78)			Heat and frost stress (-5 to 420C)		
	Genotype	Pedigree	Seed Yield (t/ha)	Genotype	Pedigree	Seed Yield (t/ha)	Genotype	Pedigree	Seed Yield (t/ha)
1	CS2020-4	Rohini x CS 54	2.53	CS2020-22	CS 330-1-1 x RH 781	2.59	CS2020-1	CS 204-2-2 x Rohini	2.28
2	CS2020-5	Pusa Bahar x CS 330-1	2.47	CS2020-27	CS 54 x Rohini	2.40	CS2020-13	CS 204-2-2 x Pusa Bahar	1.67
3	CS2020-14	CS 330-1 x Q 2061-41	2.44	CS2020-1	CS 204-2-2 x Rohini	2.24	CS 60	CS 60	1.53
4	CS2020-2	RH 781 x CS 204-2-2	2.38	CS2020-15	Q 2061-41 x CS 56	2.24			
5	CS2020-10	RH 781 x CS 56	2.28	CS2020-16 Rohini	CS 330-1 x	2.11			
Mean seed yield (t/ha)			1.64			1.71			0.63
CD 5%			0.13			0.70			0.32
Range			0.68-2.53			0.83-2.59			0.12-2.28
Best check			CS 60 (1.39)*			CS 60 (1.96)*			CS 60 (1.53)*
No. of Superior lines over best check			23			8			2

*Figures in parentheses are yield (t/ha)

Table 35. Performance of mustard strains in IVT (saline/alkaline conditions)- 2021-22

S. No.	Code	Strain	Seed yield (t/ha)	1000-Seed wt. (g)	Oil Content (%)
1	CSCN-21-1	RH 1927	1.59	5.7	38.18
2	CSCN-21-2	CS- 54 (Check)	1.70	5.6	39.30
3	CSCN-21-3	Kranti (NC)	1.46	3.7	37.97
4	CSCN-21-4	CS- 60 (LR)	1.84	5.1	39.48
5	CSCN-21-5	NPJ 256	1.32	4.6	37.81
6	CSCN-21-6	CS 2009-234	1.69	5.8	39.36
7	CSCN-21-7	CS 2020-4	1.63	4.9	39.43
8	CSCN-21-8	NPJ- 231	1.57	4.7	38.73
9	CSCN-21-9	CS 2013-64	1.70	5.2	39.29
10	CSCN-21-10	CS 2020-10	2.08	5.1	39.53
11	CSCN-21-11	RH 1928	1.51	4.8	38.38
GM			1.64		
CD (5%)			0.37		
DOS			20.10.2021		
CV (%)			13.2		
ECe (dS/m)/ pH			9.3		

Table 36. Seed yield (t/ha) of salinity/alkalinity entries of Indian mustard influenced by different fertility levels and planting geometry during 2021-22

Entries	Fertility levels			Mean seed Yield (kg/ha)
	100% RDF	125% RDF	150% RDF	
Ag-24= CS 2005-143	2308	2655	2623	2529
Ag-25= CS 54 (NC)	1606	1909	2093	1869
Ag-26= CS 60 (LR)	1989	2404	2345	2246
Ag-27= Kranti (NC)	1483	1612	1966	1687
Ag-28= Filler (CS 54)	1525	1879	2186	1863
Mean	1782	2092	2243	
CD (5%)	Entries (E) = 265.87	Fertility (F) = 182.22		Interaction (E x F) = NS (F x E) = NS
DOS: Oct 15/10/2021; Recommended fertility level: 80kg N; 40 kg P_2O_5/ha				

Monitoring and Evaluation of Salinity/alkalinity entries of Indian mustard influenced by different fertility levels in All India Coordinated Research Project on Rapeseed Mustard Trial-2021-22

Five genotypes were evaluated in Agronomy trial alkaline conditions (pH_2 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. Ag 24 and Ag 26 responded favourably to the additional doses of fertilizer (NPK). Further, 100% RDF was found economically suitable for these genotypes (Table 36).

Commercialization of salt tolerant varieties developed at ICAR-CSSRI Karnal and released by CVRC through Production and distribution of breeder seeds

During the year 2021-22, breeder seed (graded) of Indian mustard varieties; CS 52 (0.050 t), CS 54 (0.10 t), CS 56 (0.20 t), CS 58 (0.50 t) and CS 60 (1.20 t) was produced and distributed to stake holders, central and state govt. agencies.

Output during period under report

- Developed and maintained 1000 lines of 4 Recombinant Inbred Lines (RILs) population (250 lines of each) in $F_{2:10}$ generation and 1250 advanced breeding line (F_{12}, F_{14} and F_{15}, Mutant, BILs) of Mustard according to objectives of project.

- Developed genotypes CS 2020-10 and submitted to AICRP on Rapeseed & mustard for AVT-I Salinity/Alkalinity trial-2022-23.
- Developed genotypes CS 2009-234, RIL 249, CS 2005-193, CS 16000-1-1 and submitted to UP State Adaptive Trial 1st year under Sodic condition-2022-23.
- Developed genotypes CS 2007-165, CS 2009-154, CS 2009-313, CS 2009-335 and submitted to UP State Adaptive Trial 2nd year under Sodic condition-2022-23.
- Developed genotype CS-2002-99 and submitted to UP State Adaptive Trial 3rd year under Sodic condition-2022-23.

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. Component 4: Indian Mustard (ICAR funded) (Jogendra Singh, PC Sharma and Vijayata Singh)

Identification of candidate genes involved in the salt tolerance of *Brassica juncea* by *GWAS*

To identify the prominent genomic loci associated with the Salt tolerance in mustard, we utilized a panel of 210 diverse genotypes. All the accessions were planted at normal conditions (ECe 1.5 dS/m) and soil salinity (ECe 12 dS/m). Each accession was planted in two rows representing 50-60 plants (plot size of 5 m x 0.90 m) and replicated thrice. A total of 27 different yield related traits were recorded for each accession. Each trait for each accession was measured thrice for each environment and year and averaged out.

Population structure and relative kinship analysis

By conducting the GWAS using Illumina HiSEQ 4000, a total of 1.39 million quality-assured SNPs were obtained from the total panel by aligning the sequences to the reference genome of *Brassica juncea* downloaded from (http://brassicadb.org/brad/datasets/pub/Genomes/Brassica_juncea/V1.5/) and all SNPs were filtered at minor allele frequency 5% MAF and 10% missing rate (minimum 90% sample have that particular SNPs), only 74877 chromosomal SNPs (Fig. 26) in 210 samples were used for downstream analysis

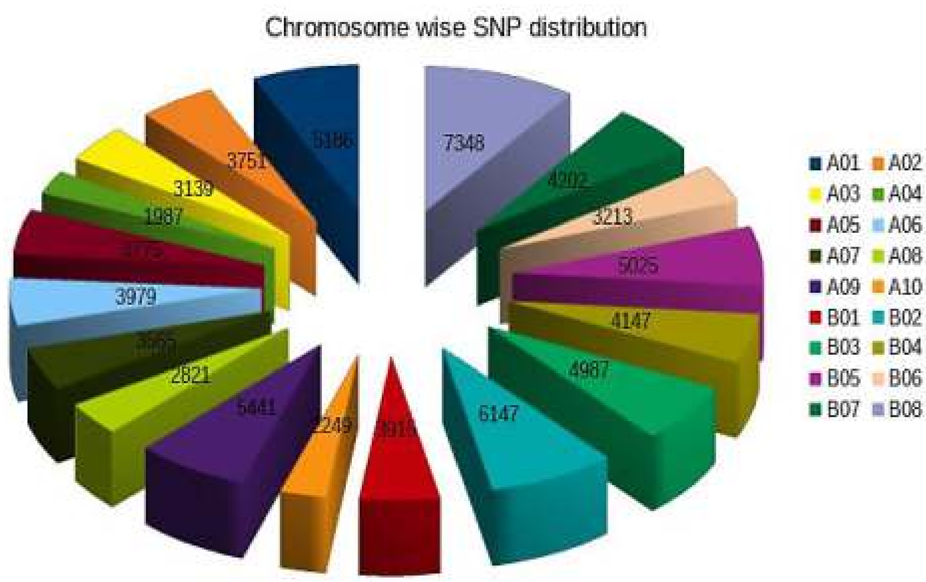


Fig 26.Significant chromosomal SNPs

Table 37. Summary of major QTLs identified for salinity tolerance in mustard using CMLM method

Trait name	QTL	SNP	Chromosome	R2	PEV(%)	Overlapping genes
Siliqua density on main shoot	qSDSB08.1	SB08_32948374	B08	0.19	12.94	BjuB041358-BjuB041359
No of seed per siliqua	qNSSA07.1	SA07_29052025	A07	0.21	31.13	BjuA027368-BjuA027369
Yield per plant	qYPA04.1	SA04_4559149	A04	0.15	13.97	BjuA014967-BjuA014968

(population structure and relative kinship). Population structure was estimated using a Bayesian Markov Chain Monte Carlo model (MCMC). The most probable K-value was determined by Structure Harvester, using the log probability of the data [LnP(D)] and delta K (ΔK) based on the rate of change in [LnP(D)] between successive K-values 2 population.

Genome-Wide Association Analysis

Compressed Mixed Linear Model (CMLM) was done using GAPIT (version 3), that performs Genome-Wide Association Study (GWAS) and genome prediction (or selection). A total 74877 of chromosomal SNPs were used for association using CMLM method with 27 phenotype traits for each control and salinity along with kinship and population file. SNPs were considered significant at log10 pvalue $<1.33\times10^{-5}$ threshold. Total 82 SNPs were identified as significant in Salinity. QTL was identified for all significant markers in every trait with QTL start and end ranging 500kb upstream and 500k downstream the position of significant SNP and the LD statistic $r^2 \geq 0.2$, the markers were regarded as identifying the same QTL. We mined the 150 × sequencing data available for the 210 elite lines, for the presence of favourable allele under salt tolerance QTLs and found that various lines harbored 82 different QTLs.

Out of a total of 82 QTLs, a set of 79 QTLs showed loci with minor to moderate effects across the genome, and their phenotypic variation explained (PVE) was low, and ranged between 0.2% and 7.7%. Importantly, there were 3 major QTLs conferring higher PVE values were accounted for 58.048% variation, shown in table 37. These QTLs accounted for the shared variation and explained 72.18% of the total PVE, when all the identified QTLs were considered.

Candidate Gene Identification

The genes within the candidate genomic regions were defined as candidate associated genes (CAGs). Both Gene Ontology (GO) analysis and KEGG pathway analysis were carried out on the CAGs using Uniprot database (https://www.uniprot.org/uploadlists/) and KAAS (https://www.genome.jp/kegg/kaas/), and provided information about in which biological processes these genes were involved. Under saline condition gene annotation of the 250kb genomic regions that centred on the peak SNPs, which had been identified to be associated with the studied agro-physiological traits found total 4750CAGs, while the major traits conferring salinity tolerance accounted as 148 CAGs for no. of seed per siliqua; 145 CAGs for siliqua density on main shoot and 79 CAGs for yield/plant. Further 38% candidate associated with molecular function (catalytic activities and binding function); 33% gene associated with cellular function and 29% gene conditioned the biological function (metabolic process).

Genetic Improvement of chickpea for salt tolerance (S.K. Sanwal, Anita Mann and Jogendra Singh)

The basic objective of this project is to development of salt tolerant genotypes/varieties and identification of salt tolerant QTLs.

Table 38. Performance of CSG-15-3 at 31 locations in IVT

Traits	Phule G1302-35	GL18149	CSG-15-3	RLBG-10	Best performing check (JG 315)	CSG-15-3 over check (%)
Yield (Kg/ha)	2110	2029	2002	1994	1851	8.16
Days to 50% flowering	61	68	63	60	63	
Days to maturity	110	110	109	111	109	
100 seed wt. (g)	23.1	15.6	18.4	22.0	16.8	

Table 39. Best performing advance breeding lines under saline condition.

Traits	Yield/ plant (g)	Days to 50% flowering	Days to maturity	100 seed wt. (g)	Performance over check
CSG 21-1	29.35	102	154	21.15	16.77-34.0 % higher yield than check
CSG 21-3	30.75	107	146	19.56	
CSG 20-6	28.26	96	149	23.40	
CSG 21-8	32.45	101	153	26.30	
Karnal Chana-1 (C)	24.20	104	151	16.40	
ICCV-10 (C)	23.80	95	144	20.60	
CV	11.24	9.15	12.14	8.78	
CD at 5%	3.68	11.42	9.45	3.14	

Multi-locational evaluation of advance line CSG-15-3 through AICRP-chickpea

Salt tolerant chickpea entry CSG-15-3 were evaluated in IVT timely sown desi irrigated trials at 31 locations in five zones (NWPZ 8, NEPZ 7, WCZ 9, ECZ 4, SZ 5) along with 43 entries with 5 checks (JG-313, Indira chana-1, RG-2015-8, JAKI-9218, JG-16).CSG-15-3 ranked 3 on the basis of yield and it has around 8.16 % higher yield than best check JG 315 and promoted to advance varietal trial (table 38).

Identification of salt tolerant genotypes and evaluation under multilocational trials

Sixteen advance breeding lines were evaluated under saline condition (EC_{iw} 6 dS/m) along with salt tolerant check Karnal Chana-1. On the basis of two year performance (2020-21 & 2021-22), four lines were selected which have higher yield than salt tolerant check and submitted to AICRP chickpea, Kanpur for multi-locational evaluation (table 39).

Generation advancement of breeding material

Several progeny families in different stages of inbred development were grown, selection was exerted on single plants for desired traits (salt tolerance, high yield, suitable plant type) and seeds were collected for further advancement of generation.

Screening of chickpea germplasm lines for salinity tolerance

A total of 84 genotypes collected from ICRISAT were evaluated under two environmental conditions, control and salinity (EC_{iw} 6 dSm^{-1}), during the rabi cropping season of 2021-2022 to check the salt tolerance ability of these genotypes. Salinity reduced the seed grain yield with a mean genotypic reduction of 31.4% w.r.t control, with maximum reduction shown by the genotype 5775 with 72% and minimum reduction was observed in the genotype 8030 with 12.4%. A total of 15 genotypes namely, 5709, 6662, 6162, 5804, 6134, 5287, 7416, 6830, 8052, 7443, 5810, 6607, 6980, 5960 and 8030 showed less than 20% reduction in yield under salinity when compared with the control.

The antioxidative defense system in these chickpea genotypes was studied and the effect of salinity on hydrogen peroxide (H_2O_2) and malondialdehyde (MDA) content and the activity of four antioxidative enzymes, namely, Superoxide dismutase (SOD), Catalase (CAT), Ascorbate peroxidase (APX) and Peroxidase (POX) was monitored. The H_2O_2 content raised with salinity as the average value of 6.56 was observed under the control conditions which raised to 20.12 under salinity. Similarly, the product of lipid peroxidation, MDA, raised with salinity. The average value from 1.7 raised to 9.2 under saline environment. Although, H_2O_2 and MDA content raised with salinity but more increment was observed in the genotypes that showed less enhancement in the activity of the antioxidative enzymes. Genotypes 5709, 6662, 6162, 5804, 6134, 5287, 7416, 6830, 8052, 7443, 5810, 6607, 6980, 5960 and 8030 showed more than 70% increment in CAT, APX and POX activity w.r.t control.

Hybridization and generation advancement

High yielding salt sensitive varieties were selected for crossing with salt tolerant genotypes. A total of 72 cross combination were made and pods were harvested and will be evaluated in next year.

Maintenance of germplasm and parental lines

A total of 346 germplasm lines and 45 parental lines were maintained for their use in future breeding programme.

Breeder seed production

During 2021, 3.0 q breeder seed of the salt tolerant variety Karnal Chana-1 was produced to meet the demand of different stakeholders

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 (S.K. Sanwal and P.C. Sharma)

The basic objective of the project is to identify QTLs/genes controlling salt tolerance traits in chickpea. This is a network project involving various components with salinity/sodicity component being dealt by ICAR-CSSRI, Karnal and genotyping at IARI, New Delhi and IIPR Kanpur

1. Raising of F_1 seeds for heterozygosity identification for fine mapping.

For development of NIL population, extreme RILs were identified and crosses were made and seeds were harvested. These harvested F1seeds were sown in rabi season 2021-22 and true F1s were identified with the help of polymorphic markers. The extreme RILs which used for crossing are RIL 63× RIL 172, RIL51 × RIL84, B200 × B195, and A132 × A63 (table 40).

Table 40.List of crosses made and no. of true F1 plants

S. No.	Crosses	True F1 plant
1	RIL132 x RIL163	6
2	RIL63 x RIL 172	10
3	RIL200 x RIL195	8
4	RILC95 x RILC79	5
5	RIL51 x RIL84	2

2. Introgression of salt tolerant QTLs into elite chickpea cultivars

The mega varieties which are high yielding and higher in demand but susceptible to salinity are used for introgression of salt tolerant genes from tolerant genotypes ICCV 10 and CSG 8962. The mega varieties used for this purpose are JG-11, Vijay and BG-1103 (table 41).

Table 41. List of breeding materials in different generation

F1	BC1F1	BC2F1
BG 1103, HC5, JG16, Vijay, JG 11 X CSG 8962 and ICCV 10	Vijay, HC5 JG11 X CSG 8962 and ICCV 10	JG16, HC5 X CSG 8962 and ICCV 10

Table 42. Performance of different genotypes under saline environment (EC_{iw} 6 dS/m).

S. No.	Name of genotype	Yield/plant (g)	K^+/Na^+ ratio	Proline content (mg/g FW)	RWC (%)	Membrane stability index (%)
1	CSG-19-10	36.15	3.06	14.35	74.10	72.80
2	CSG-19-7	34.80	2.90	12.90	70.46	69.40
3	CSG-20-2	37.20	2.56	15.45	72.50	71.36
4	CSG-20-11	34.10	2.48	13.20	75.15	70.88
5	CSG-18-9	37.90	2.98	13.85	69.40	69.42
6.	DCP92-3 (S)	21.30	1.82	9.21	64.25	61.40
7.	Karnal Chana-1 (C)	30.25	2.72	13.26	71.60	72.22


Tolerant genotype


Susceptible genotypes

3. Multilocational evaluation of salt tolerant genotypes

After three year evaluation under saline environment, five salt tolerant genotypes were identified for multilocational evaluation either through AICRP Chickpea, Kanpur or through AICRP SAS&USW, Karnal. These lines recorded 11-26% higher yield than salt tolerant check Karnal Chana-1. This year these lines will be put in AICRP for multilocational trials (table 42).

Characterization of Chickpea Germplasm Resource to Accelerate Genomics-assisted Crop Improvement (DBT funded) (PC Sharma and Jogendra Singh)

The objective of this project to identify salinity-tolerant chickpea germplasm which is nowadays important to ensure the production of food and the sustainability of the food industry.

Phenotypic screening of Chickpea germplasm

The 1000 diverse panel of chickpea germplasm along with national checks CSG 8962 (salt tolerant) and HC5 (salt sensitive) were sown in normal and salinity (EC_{iw} 6 dS m^{-1}) conditions for phenotypic screening (Fig. 27). Experimental design: Augmented Block Design; National Checks: CSG 8962 (salt tolerant), HC 5 (salt sensitive)

Descriptive statistics of phenotypic traits

The mean performance, standard error of mean (Sem), range and coefficient of variation (CV) of test entries (Chickpea accessions) and the check varieties for all traits are given in the table 43. The perusal of the results indicate that checks are superior than the test entries for all the traits studied except for germination, yield/plant and no. of filled pods under the normal condition.

Analysis of variance of augmented block design

The Analysis of variance revealed significant mean sum of squares for all traits for different sources of variation. The Block effect (both ignoring treatments and eliminating treatments) were non-significant for all traits under the normal and salinity condition, indicating homogeneity of evaluation blocks. The treatment effects (both ignoring treatments and eliminating treatments) were significant for all the traits except Na^+ conc. shoot, Na^+ conc. root, K^+ conc. root and Cl^- conc. root under the non-saline and saline ecology exhibit the presence of variability among the test entries (Chickpea accessions). Similarly, the effects due to checks and varieties were significant. However, the mean square due to check and checks v/s varieties was significant for all the traits, indicating thereby that the checks and test entries were responded significantly different from each-other under the normal and saline environment.

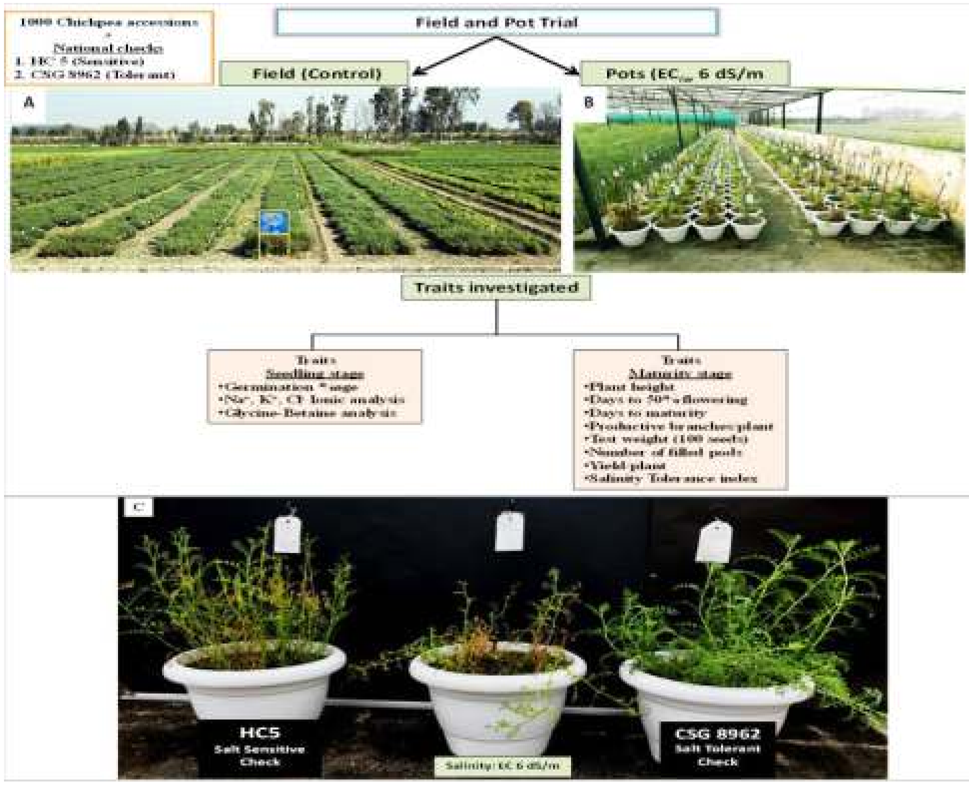


Fig 27. Phenotypic screening of Chickpea germplasm (A) Drone image of chickpea field (control), (B) Salinity evaluation of chickpea germplasm grown in pots supplemented with water of ECiw 6 dS/m, (C) Comparison of genotype with national checks.

Table 43. Descriptive statistics of parameters for 1000 accession of Chickpea

Traits	Mean						Range				CV (%)	
	Normal			Salinity			Normal		Salinity		Normal	Salinity
	Mean Test entries	Mean Checks	SE±	Mean Test entries	Mean Checks	SE±	Test entries	Checks	Test entries	Checks		
Germination (%)	98.38	93.00	0.65	56.23	69.00	2.31	50.00-100.00	70.00-100.00	10.00-100.00	40.00-100.00	6.54	30.80
Yield/plant (g)	61.34	38.15	2.85	1.07	17.41	3.10	5.00-156.00	24.23-52.89	0.02-16.99	3.30-32.40	6.42	39.63
Plant height (cm)	57.84	66.88	1.27	43.27	47.06	1.53	35.00-100.00	53.40-81.60	14.30-83.00	27.00-68.00	6.67	13.31
Productive branches	6.92	11.05	0.73	2.01	7.35	1.67	2.00-15.00	8.00-15.00	1.00-13.00	4.00-11.00	11.88	37.83
No. of filled pods	144.86	76.55	4.27	6.46	36.25	3.72	24.00-377.00	64.00-88.00	1.00-45.00	13.00-63.00	9.44	36.31
100 Seed weight (g)	13.82	19.71	1.15	4.17	11.50	2.41	4.10-48.44	9.80-29.20	0.18-34.14	4.00-20.00	11.28	39.74
Na+ conc. shoot (mg/dw)	4.05	4.44	1.55	15.94	7.87	3.20	0.49-23.52	2.36-8.20	2.00-82.30	3.46-16.25	7.01	10.07
K+ conc. shoot (mg/dw)	10.85	21.99	2.34	22.96	19.58	2.41	1.21-58.60	16.32-26.31	2.87-66.94	8.33-31.02	10.97	14.24
Cl- conc. shoot (mg/dw)	1.85	0.98	0.78	3.46	4.67	0.65	0.06-6.21	0.48-1.58	0.53-10.72	1.82-8.05	7.62	13.18
Na+ conc. root (mg/dw)	5.95	3.43	1.75	14.82	6.65	2.82	0.50-33.63	1.11-6.98	2.27-98.93	2.98-12.30	7.76	9.22
K+ conc. root (mg/dw)	4.41	14.45	1.72	11.41	14.94	2.35	0.26-22.51	8.91-20.32	0.98-59.77	5.66-26.89	9.67	14.48
Cl- conc. root (mg/dw)	1.79	1.05	0.84	4.17	2.51	0.87	0.06-5.64	0.45-1.83	0.56-14.10	0.60-5.00	6.75	9.79
Days to 50% flowering	112.28	94.85	0.47	56.26	103.80	6.99	90.00-123.00	90.0-113.00	74.00-117.00	98.00-107.00	4.42	33.19
Days to maturity	146.50	136.90	0.50	73.96	132.60	7.96	135.00-159.00	129.00-146.00	119.00-145.00	120.00-140.00	4.12	32.56

In this research, we identified traits like; productive branches, no. of filled pods, 100 seed weight and yield per plant as important traits across the environments. However; some traits were also identified as important for specific ecology like Na^+ and K^+ concentration in root, Cl^- conc. in shoot and root under normal condition while Na^+, K^+ and Cl^- concentration in shoot and root under salinity.

Leveraging genetic resources for accelerated genetic improvement of Linseed using comprehensive genomics and phenotyping approaches (S.K. Sanwal and Jogendra Singh)

Phenotyping of Linseed germplasm under salt stress

A total of 2657 lines including 5 high yielding and salt tolerant checks received from NBPGR, New Delhi were sown on 2-3.10.2021, 5-6.11.2021 and 8.9.11.2021 in experimental fields for evaluation under alkaline (pH_2 9.3-9.5), control and saline (8.8-9.3

Table 44. Mean, range and percent reduction of different characters of 2657 germplasm lines evaluated under control, salinity and alkalinity

S. No.	Characters	Mean			Range			% reduction over control	
		Control	Salinity	Alkalinity	Control	Salinity	Alkalinity	Salinity	Alkalinity
1	NDVI	0.47	0.37	0.38	0.29-0.60	0.10-0.57	0.15-0.62	21.28	19.15
2	SPAD	57.21	52.66	56.04	37.37-77.57	30.97-71.67	33.13-73.37	7.95	2.04
3	Days to 50% flowering	95.30	88	97.59	46-132	54-118	59-135	7.66	-2.40
4	Plant height (cm)	73.68	63.06	57.94	43.28-130.20	20.60-103.40	21.48-103.24	14.41	21.36
5	Days to physiological maturity	147.08	137.46	147.79	139-161	113-162	129-161	6.54	-0.48
6	Number of seeds per capsule	7.70	7.24	7.34	3.30-10.35	0.35-10.10	2.60-10.35	5.58	4.67
7	Number of capsule per plant	269.29	147.88	130.18	83.33-1066.32	2.17-656.11	13.22-403.73	45.09	51.66
8	1000-seed weight (g)	5.97	5.06	5.24	1.05-10.79	1.32-10.30	0.99-10.88	15.24	12.22
9	Seed yield per plant (g)	11.93	7.12	6.57	3.27-28.29	0.10-17.56	0.26-17.16	40.32	44.93

Table 45. Top 20 best performing accessions on the basis of higher yield under control, salinity and alkalinity conditions

Environment	Accessions
Control	IC0498561, IC0591123, IC520865, IC0427794, IC0499060, EC0041469, EC0718831, IC0345411, IC0385331, IC0498437, IC0498383, EC0041650, IC0498466, EC0001388, IC0498845, IC0498618, EC99001, IC0385352, IC0096707 and IC0096629
Saline	IC0499060, IC0498412, IC0394132, EC0520247, IC0525913, IC0498561, IC0498759, IC0498755, EC0001388, IC0394136, IC0498981, EC0000522, IC0498947, IC0498821, IC0498596, IC523094, IC0498935, IC0356227, IC0356165 and IC0526045
Alkaline	IC0498452, EC0001388, IC0498446, IC0498702, IC0498816, IC0526021, IC0498671, IC0096721, IC0498981, IC0498786, IC0096693, IC0053295, IC0498599, EC0041650, IC0096480, IC0096518, IC0499106, IC0498822, IC0499127 and IC0621688

Crop performance under control, alkaline and saline condition

dS/m) conditions, respectively for seed yield and other yield contributing traits at CSSRI, Karnal and ICAR-IIWBR research farm, Hisar. The data was recorded on seedling vigour index, total chlorophyll, days to 50% flowering, plant height, days to physiological maturity, number of seeds per capsule, number of capsule per plant, 1000-seed weight and seed yield per plant.

The mean, range and percent reduction under saline and alkaline condition for different traits were given in Table 44. Salt stress affects all the traits studied. Huge variability was observed for different traits. NDVI, SPAD and plant height reduced under salt stress. Days to 50% flowering and days to physiological maturity were early under saline condition while late in alkaline condition. Number of seeds per capsule, number of capsule per plant, 1000 seed weight and seed yield per plant reduced under saline and alkaline condition but wide range of genotypic variation was observed. On the basis of seed yield/plant tolerant genotypes were selected in salinity and alkalinity. Under alkaline condition, 667 lines perform better than salt tolerant check Heera and around 704 lines perform better in saline condition (table 45). The percent reduction was drastic for seed yield per plant in saline condition (40.32%) compared to control while in alkaline condition it was 44.93%.

Genetic improvement of lentil (*Lens culinaris* medikus) for salt tolerance using conventional and molecular breeding approaches (Vijayata Singh and Ravi Kiran)

The main aim of this project is the development of salt tolerant lentil genotypes,

Table 46. Top 10 best performing genotype under control, salinity and alkalinity.

S. No.	Control		salinity		Alkali	
	Genotype	Yield/Plant (gm)	Genotype	Yield/Plant (gm)	Genotype	Yield/Plant (gm)
1	L 4717	72.00	EC 329164	40.3	L 4147	72.00
2	L 4594	64.00	EC 955432	33.21	LL 931	64.00
3	LL 931	63.00	EC 955431	32.68	L 4717	63.00
4	IPL 526	62.00	IC 73121	32.61	IPL 316	62.00
5	HUL 57	58.00	EC 223237 B	30.3	DPL 62	58.00
6	IC 22666	57.00	EC 223235	30.27	IC 316132	57.00
7	IC 541007	56.00	IC 241531	30.11	IC 148333	56.00
8	DPL 62	56.00	EC 223243	22.83	IC 560153	56.00
9	EC 27659	54.00	IC 260010	21.73	IC 541007	54.00
10	KM 1	50.00	IC 78387	20.19	EC 223241	26.00

identification of donors for salt tolerance to introgression into high yielding cultivars of lentil and development of mapping population from the most contrasting parental line for salt tolerance QTL identification. Screening advanced breeding line (germplasm, cultivars, segregating generations and elite line) under salinity ECe 7 and EC_{iw} 7-10 dS/m) and sodicity (pH_2 9.3) for target traits along with high seed yield during 2020-21.

Identification of ideal donor genotype and ideal screening environment for development of salt tolerant lentil cultivars

A total of 367 accessions (released varieties, elite line, and wild accession) collected from PAU, Ludhiana and ICAR-NBPGR, New Delhi were evaluated in different level of salinity stress such as control, 9, 12, 15 and 18 dS/m. Only 14 genotypes survived till maturity under saline condition. The higher salinity significantly reduced 71.69% yield/plant and 40.54% reduced 100 seed weight. Crossing most contrasting parents to develop RILs for mapping of QTLs governing salinity and sodicity tolerance and selecting true to type crosses. Intogression of salt tolerance from identified donors in to elite Lentil genotypes for development of pre-breeding lines (table 46).

Physiological and molecular dissection of root system architecture (RSA) in wheat under salt stress (Anita Mann, Arvind Kumar, Ashwani Kumar and Neeraj Kulshershtha)

180 wheat diverse germplasm were taken for the study with control and salinity level of EC_{iw} 10 dS/m with four checks including two tolerant (KRL3-4 & KRL 210) and two sensitive (HD 3226 & HD 2851) lines in Augmented Randomized Block Design. Significant variations in root traits were observed between wheat lines. With salinity, root angle changed by 5.7%. Root length was not much affected by stress while root volume, surface area and diameter changed significantly with saline irrigation showing 21.2, 8.2 and 14 % decrease respectively. Root fresh weight was more with salinity (~43%) due to more number of root tips (1321.64±664.69) under salinity while a significant decrease of 12 % was observed with salinity showing moisture loss. The root traits of check KRL 210 showed better root architecture in terms of less root orientation, more root length, higher root volume, diameter and surface area (figure 28) than KRL 3-4.

In terms of ionic contents, both Na^+ and K^+ were more in shoot than roots thus, maintaining a lower Na^+/K^+ ratio in roots. The analysis of contribution of plant traits towards yield in control conditions showed that plant biomass, plant height, number of tillers, shoot fresh weight, shoot Na^+/K^+ ratio and root angle were the major traits contributing towards grain yield. On the other hand, in saline conditions, root

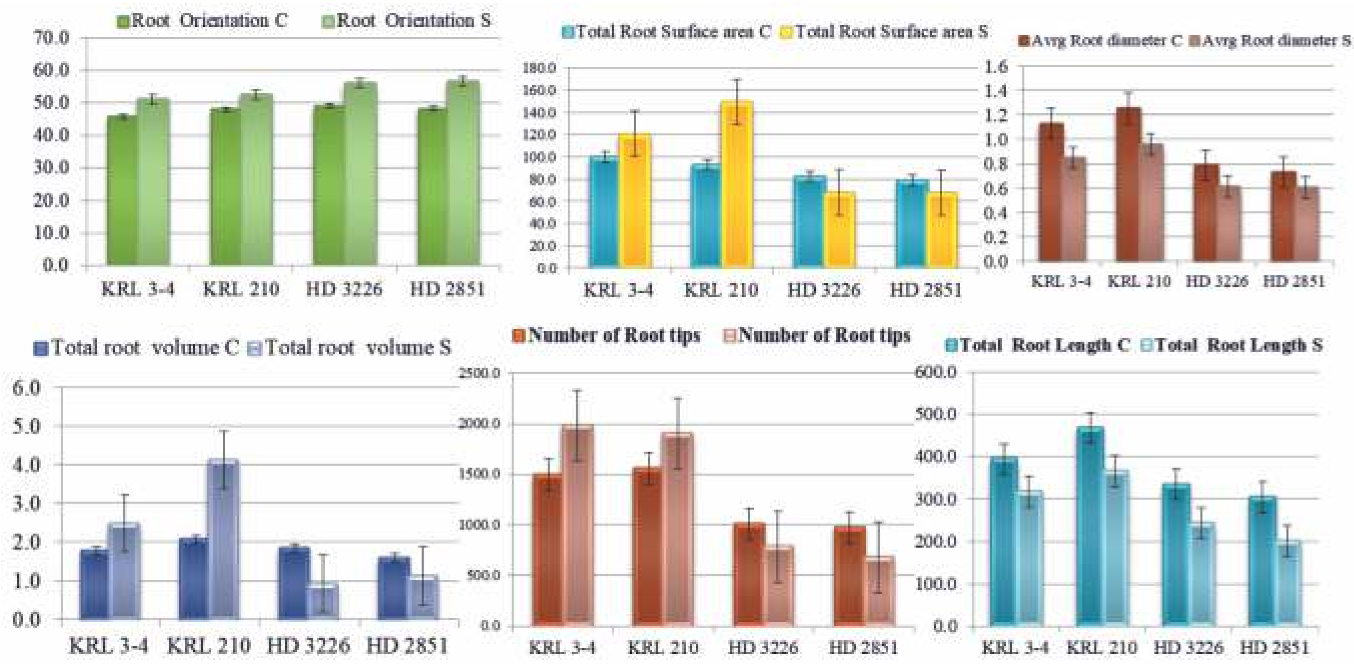


Fig 28. Effect of salinity on root traits on wheat check varieties

phosphorus content (P), plant biomass, plant height, shoot fresh weight were contributing towards grain yield. Further, aassociation of phosphorus acquisition by roots with other root attributes showed a significant interaction of root sodium content, Fe, Zn, Mn and number of root tips. Test weight ranged from 22.8 - 50.8 under control conditions which decreased to 13-44 with salinity. Similarly number of tillers was reduced from 5-18 to 4-14 under salt stress. On an average, 80-85 wheat lines were performing equal to or better than check varieties based on grain yield and plant biomass.

Enhancing nutrient use efficiency using nano-fertilizers in rice-wheat cropping system under salt stress (IFFCO funded contract research project) (Ashwani Kumar, Parvender Sheoran, Anita Mann and A.K. Bhardwaj)

Wheat Crop

Salt tolerant variety KRL 210 was sown in the same plots (*10.7 x 6.15* m) that were earlier used for rice crop during *kharif* season. Treatments: Control (No-nitrogen) – T1, Full N through Urea (3-splits) – T2, 1/3rd through Urea + 1/3rd through Urea, +1/3rd through Nano-N (33% replacement) – T3, 1/3rd through Urea + /3rd through Urea + Nano-N (50:50) +1/3rd through Nano-N (50% replacement) – T4, 1/3rd through Urea + 1/3rd through Nano-N +1/3rd through Nano-N (66% replacement) – T5, 100% RDN through Nano-N (Seed priming + Foliar spray) – T6. The data on different morphological and physiological traits recorded at reproductive stage revealed that replacing one-third dose of N through urea with nano-N (33% replacement) had numerically higher values for plant growth (plant height, LAI) and gas exchange parameters, but these were statistically at par with T2. On average, the number of tillers were 50.5; being maximum under treatment T3 (55.8) followed by T2 (54.9). Though there are slight variations among the studied treatments but the values were more or less statistically at par with each other except for treatment T1 and T6. Similar trend was observed for the number of effective tillers. 1000-grain weight was 55.23 g under RDN through urea which increased by 3.95% under T3 (33% N replacement through nano-N). Highest grain yield of 4206 kg/ha was recorded with treatment receiving 33% N replacement through Nano-N, which was found to be at par with RDN (4183 kg/ha) and 50% N replacement through Nano-N (4079 kg/ha). Further increase in N replacement (66% replacement) yielded 2.4% reduction compared to recommended N through urea (T2). Similar trend was observed for biological yield in response to N fertilization through different sources

Rice crop

In addition to 6 treatments, we have imposed 4 other treatments based on the observation of IRC to compare the response of urea spray with nano-N i.e. T7- 1/3rd N through Urea (basal only), T8- 1/3rd N through Urea (basal) + 1/3rd N through Nano-N, T9- 1/3rd N through Urea + 1/3rd N through Urea + 2% Urea spray and T10- 1/3rd N through Urea + 2% Urea spray + 2% Urea spray.

Significant differences were noted among different treatments for the studied morpho-physiological traits (table 48) and found that replacing urea with nano-N resulted statistically at par growth of rice in terms of plant height. RWC recorded at reproductive stage showed significant differences and found that T3 (33% replacement of N with nano-N) had statistically higher water content (81.1%) than RDN through Urea (T2) and 50% (T4) and 66% (T5) replacement of N with nano-N.

Photosynthetic rate of 18.40 μmol/m^2/s was noted under T2 which increased by 2.83% with 33% replacement of N through nano-N (table 47). Further replacement of N through

Table 47. Response of different nitrogen sources (urea/nano-N) on yield attributing traits in wheat

Treatment	Number of tillers/mrl	Effective tillers/mrl	Spike length (cm)	Spike weight (g)	Spikelets/ spike	Ear filling ratio	Grains/ spike	Grain weight/ Spike (g)
T1	37.3D	31.2F	7.63E	2.22E	13.7G	0.41E	37.7E	0.91E
T2	54.9AB	49.8ABC	10.49A	2.88A	17.9ABC	0.75BC	53.1AB	2.16B
T3	55.8A	50.3AB	10.38AB	2.85AB	18.8A	0.81A	55.2A	2.31A
T4	53.3AB	48.8ABC	9.95C	2.71B	17.4BCD	0.78B	51.6ABC	2.11BC
T5	52.1AB	47.8BC	9.84C	2.62C	17.5BCD	0.82A	53.8AB	2.15BC
T6	39.9D	35.3E	8.43D	2.53D	15.5F	0.54D	43.3D	1.37D

Means with similar letter represents non-significant differences @ 5%

Table 48. Response of different nitrogen sources (urea/nano-N) on yield attributing traits in rice

Treatment	Number of tillers/mrl	Effective tillers/mrl	No. of filled grains/panicle	Biological yield (Kg/ha)	Grain yield (Kg/ha)
T1	35.75g	31.50e	53.50f	8552.80e	1463.50d
T2	60.50a	49.50a	92.00a	13602.93ab	3707.18a
T3	59.25ab	48.75a	95.00a	13406.20ab	3789.15a
T4	52.25abcd	47.50a	88.25ab	13187.77ab	3463.69ab
T5	50.00bcde	43.00abcd	85.00abcd	12149.01bc	3418.42ab
T6	39.00fg	39.00bcde	67.75e	9759.98de	2677.40c
T7	41.50efg	35.75de	72.75e	8948.99e	2371.90c
T8	43.50defg	36.25cde	75.50cde	9024.50e	2774.96c
T9	54.50abc	46.50ab	85.75abc	11073.40cd	3432.13ab
T10	49.75cde	43.50abc	78.50bcde	10779.84cd	3422.85ab

Means with similar letter represents non-significant differences @ 5%

nano-N decreased photosynthetic rate in comparison to T2. Number of tillers and effective tillers showed significant variability`s and found maximum tillers/effective tillers in T2 (60.50 and 49.50/mrl) followed by T3 (59.25 and 48.75/mrl). Urea spray @ 2% was not effective and showed reduction of 9.92% and 6.06% under T9 and 17.76% and 12.12% under T10 in number of tillers and effective tillers (table 48). Number of grains/panicle also showed similar results and found maximum grains/panicle in T3 (104.0) followed by T2 (103.0), T9 (101.5) and T14 (100.5). Urea spray @ 2% was not effective and showed reduction of 2.43% and 3.37% under T9 and 4.37 % and 5.29% under T10 in comparison to T2 and T3. Similar results were noted for number of filled grains/panicle. Maximum biological yield was found in T2 (13602.93 kg/ha) followed by T3 (13406.2 kg/ha) while grain yield was maximum in T3 (3789.15 kg/ha) followed by T2 (3707.18 kg/ha). Though treatment T4 and T5 produced statistically at par yield but the values were lower in comparison to T2 and T3. Replacing 2nd and 3rd dose of N through urea spray was not as effective as urea applied basally and showed reduction of 18.6% and 20.75% reduction in biological yield while 7.42% and 7.67% reduction in grain yield under T9 and T10 in comparison to T2.

Exploring production potential of Quinoa (*Chenopodium quinoa*) under saline Agro-ecosystems of India (Kailash Prajapat, S.K. Sanwal, Monika Shukla, Vineet TV, Nitish Ranjan Prakash and Ravi Kiran KT)

A field experiment was conducted at ICAR-CSSRI, Karnal research farm with 4 dates of sowing as 15th October, 30th October, 15th November and 30th November in randomized block design with three replications. Sowing was done manually in moist soil at 1-2 cm depth using 08 kg/ha seed rate as per different sowing dates. The crop was fertilized with 60 kg N/ha and 30 kg P_2O_5/ha. The N was applied in two equal splits at 30-35 DAS and at 60-70 DAS. During 2021-22, the plant height of quinoa significantly highest under 15th October sowing and decreased as the sowing time delayed up to 30th November except at 90 DAS where plant height statistically similar between 15th and 30th October sown crop. The SPAD, NDVI values and dry matter accumulation at 120 DAS were significantly higher under 15th and 30th October sown quinoa over 15th and 30th November dates of sowing.

The crop growth rate of quinoa during 0-30, 30-60 and 60-90 DAS was significantly maximum under 15th October date of sowing being statistically on par with 30th October sowing at 60-90 DAS. The relative growth rate of quinoa in terms of mg dry matter increase over each g existing dry matter per day, was significantly highest under 15th October sowing with statistically at par with 30th October and 15th November dates of sowing (Figure 29). The no. of branches/plant at 45 and 60 DAS (35.4 and 36.7), length of main panicle (16.1 cm), grain yield (3.44 t/ha), and Stover yield (3.50 t/ha) and harvest index were observed significantly highest when quinoa was sown on 15th October over rest of the dates of sowing (Table 49).

Evaluation of quinoa germplasm at RRS Bharuch

A pot experiment was continued during the *rabi* season of 2021-22 at the ICAR-Central Soil Salinity Research Institute (CSSRI), Regional Research Station (RRS), Bharuch, Gujarat to evaluate the performance of different germplasm under saline water irrigation in Vertisols. The experiment was planned in CRD with 20 germplasms of quinoa and 4 levels of irrigation water i.e. Irrigation with normal water (I_1): Irrigation water of 10 dS/m (I_2), 20dS/m (I_3) and 30dS/m (I_4) salinity with three replications. Results of the pot experiment

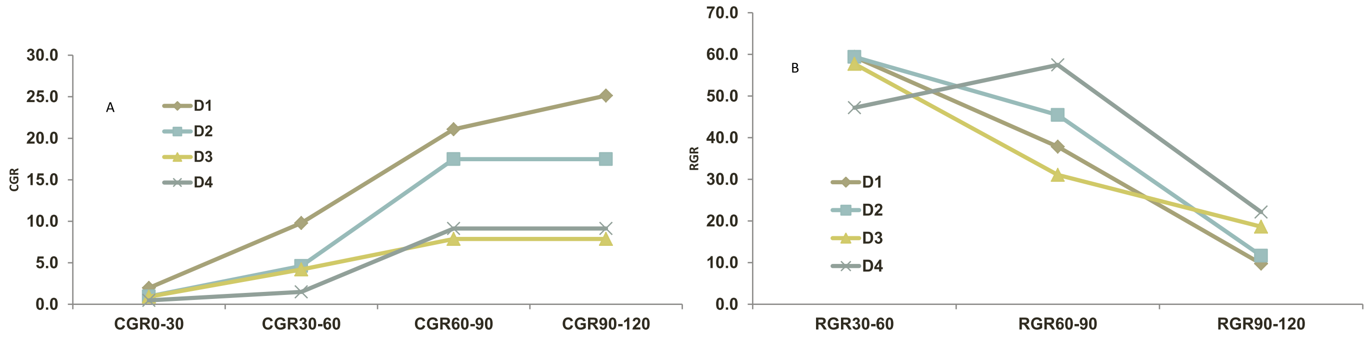


Fig 29. Effect of sowing time on CGR (g/day) and RGR (mg/g/day) of quinoa

Table 49. Effect of different date of sowing on growth and yield of quinoa

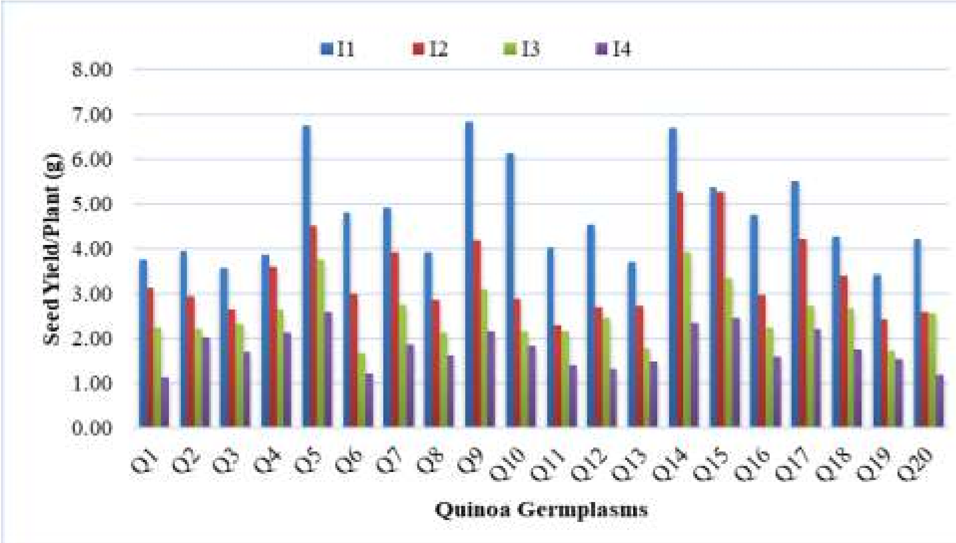
Date of sowing	Plant height 90 DAS	DMA (g/plant) 120 DAS	SPAD 120 DAS	NDVI 120 DAS	No. of branches 60 DAS	Length of main panicle(cm)	Grain yield (q/ha)	Stover Yield (q/ha)	HI	Test weight
15th Oct	121.2a	41.6a	36.7b	0.61a	36.7a	16.1a	34.4a	35.0	50.0a	3.6a
30th Oct	115.7a	27.8ab	39.2b	0.54ab	25.3b	13.3b	21.7b	33.9	39.5b	2.8b
15th Nov	98.8b	20.3b	43.0ab	0.43b	18.7c	8.1c	10.2c	32.2	24.4c	2.6bc
30th Nov	97.b	19.2b	55.1a	0.54ab	16.2c	7.2c	8.8c	29.4	23.1c	2.1c

revealed that highest plant height at 30 DAS was observed in germplasm Q5 (EC896207), Q20 (EC896099), Q9 (EC896218) and Q8 (EC896209). Highest plant height at 60 DAS observed in germplasms Q5 (EC896207), Q9 (EC896218) and at 90 DAS in Q5 (EC896207) and Q7 (EC896231). Branches per plant at harvest were counted and were found maximum in germplasm Q1 (EC507739), Q3 (EC507740) and Q14 (EC896074). Main panicle length was measured at the time of harvest and it was found highest in germplasm Q5 (EC896207), Q7 (EC896231), Q8 (EC896209), Q9 (EC896218). Under best available water irrigation, highest seed yield/plant was obtained in the germplasm Q9 (EC896218) followed by Q5 (EC896207, Q14 (EC896074) and Q10 (EC896213). Irrigation with 10 EC saline water reduced the yield of all germplasms significantly and germplasm Q15 (EC896208) gave the highest seed yield followed by Q14 (EC896074) and Q5 (EC896207). Germplasm Q14 (EC896074) gave significantly highest seed yield followed by Q5 (EC896207) and Q15 (EC896208) under irrigation with 20 EC saline water. At the highest level of saline water irrigation (30 EC) germplasm Q5 (EC896207) gave highest seed yield followed by Q15 (EC896208) and Q14 (EC896074) and Q17 (EC896075) (Fig. 30).

Screening Quinoa germplasm in coastal saline soil

A pot experiment was conducted during the *rabi* season of 2021-22 at the ICAR-CSSRI, RRS, Canning town, West Bengal. Thirty quinoa germplasm were planted in completely randomized design with three replications. Four treatments of saline water Irrigation with normal water (I1): Irrigation water of 10 dS/m (I2), 20 dS/m (I3) and 30 dS/m (I4) salinity with three replications. The seeds of these thirty lines were sown on 04.01.2021. Observations were taken on days to anthesis (DTA), days to maturity (DTM), plant height (PH), main panicle length (MPL), number of branches (NB) and biomass (BM). All the growth, yield parameters and yield showed a significant decrease as the levels of salinity increased in all the germplasm. At control the grain yield performance of best 5 five

Fig 30. Seed yield/plant (g) of 20 quinoa germplasms under different salinity levels



germplasms was in the order of EC896074 (3.88g/plant), EC896114 (3.57 g/plant), EC896078 (3.53 g/plant), IC411824 (3.52 g/plant) and EC896071 (3.39 g/plant). While at highest level of salinity, the best performer germplasms in terms of grain yield were EC896208 (3.59 g/plant), EC896086 (3.14 g/plant), EC896078 (2.97 g/plant), EC507740 (2.95 g/plant) and (EC896262 (2.92 g/plant).

Alternate Land Use

Improving the productivity of senile ber orchards through top working (Rajkumar)

The rejuvenation of old and senile orchard of ber was initiated during 2020 through top working. Beheading of trees was done during May 2020. Approximately ten buddings per tree were done in July-August on the newly emerged branches by using scion buds of improved cultivars like 'Thai apple ber', 'Tikdi', 'Gola' and 'Umran'. However, survival was approximately 70 per cent buds per tree. Various fruit quality parameters like fruit weight (g), fruit length (mm), fruit diameter (mm), fruit volume (mm^3), pulp & stone weight (g) were recorded as shown in table 50. The maximum fruit weight was recorded in cultivar 'Thai apple ber' (39.45g) followed by 'Gola' (16.30 g) and 'Umran' (14.7g); respectively. Similarly, the maximum fruit length was recorded in cultivar 'Thai apple ber' (47.68 mm), followed by 'Umran' (38.84 mm) and 'Tikadi' (33.60 mm); respectively. Similarly, the maximum fruit diameter was recorded in cultivar 'Thai apple ber' (39.36 mm), followed by 'Gola'(29.16 mm) and 'Umran' (26.21 mm); respectively. The maximum fruit volume was recorded in cultivar 'Thai apple ber' (39.33 mm^3), followed by 'Umran' (17.67 mm^3) and 'Gola' (15.33 mm^3); respectively. The highest pulp weight was recorded in cultivar 'Thai apple ber' (37.26 g) followed by 'Gola' (15.55 g) and 'Umran' (12.49 g); respectively. However, maximum stone weight (2.23 g) was found maximum in cultivar 'Umran' followed by 'Thai Apple' (2.19 g) and '*Z. Rotundifolia*' (0.77 g); respectively.

The physiological parameters like relative water content (%), leaf area (cm^2), leaf length (cm), leaf width (cm), Chl 'a' (g/mg FW), Chl 'b'(g/mg FW) and Total Chl (g/mg FW) recorded in various genotypes of ber (table 51). Parameters like relative water content (%), Chl 'a' (g/mg FW) and Chl 'b' (g/mg FW) differ non-significantly. Whereas, maximum leaf area (37.50 cm^2) was recorded in cultivars 'Thai Apple' followed by 'Umran' (26.77 cm^2) and 'Gola' (22.43 cm^2), respectively. Leaf length varied from (4.53 cm) in *Z. Rotundifolia* to (12.32 cm) in 'Thai Apple'. Similarly, leaf width varied from (2.80 cm) in *Z. Rotundifolia* to (5.19 cm) in 'Thai Apple'. Whereas, Total Chl varied from (2.55 g/mg FW) in Gola to (3.76

Table 50. Fruit quality parameters of different ber cultivars

Cultivars	Fruit Wt (g)	Fruit Length (mm)	Fruit Dia (mm)	Fruit Volume (mm^3)	Pulp Weight (g)	Stone wt (g)
Thai Apple	39.45a	47.68a	39.36a	39.33a	37.26a	2.19a
Z. Rotundifolia	3.04c	16.77d	18.07c	1.67d	2.27c	0.77b
Tikadi	5.99bc	33.60c	17.63c	7.67cd	5.24bc	0.75b
Gola	16.30b	32.45c	29.16b	15.33bc	15.55b	0.75b
Umran	14.72b	38.84b	26.21b	17.67b	12.49bc	2.23a
LSD at 5%	11.51	4.76	2.98	8.34	11.39	0.49

Table 51. Physiological parameters in different ber cultivars

Cultivars	RWC (%)	Leaf area (cm^2)	Leaf length (cm)	Leaf width (cm)	Chl 'a' (g/mg FW)	Chl 'b' (g/mg FW)	Total Chl (g/mg FW)
Thai Apple	64.20	37.50a	12.32a	5.19a	1.63c	2.13a	3.76a
Z. Rotundifolia	61.68	8.51d	4.53d	2.80d	1.72a	1.05bc	2.77bc
Tikadi	75.38	16.25c	8.17c	3.26cd	1.72a	0.99bc	2.71bc
Gola	71.65	22.43b	10.16b	3.84bc	1.65bc	0.91c	2.55c
Umran	65.87	26.77b	10.62b	4.21b	1.68ab	1.41b	3.09b
LSD at 5%	NS	5.81	0.92	0.89	NS	NS	0.628

g/mg FW) in 'Thai Apple'. On the basis of fruit quality parameters cv. 'Thai apple' found superior to other cultivars of ber. However, on the basis of physiological parameters cv. 'Gola' showed significant superiority over other ber cultivars.

Exploration and characterization of sapota cultivars for salt tolerance (Rajkumar, Ashwani Kumar and Raj Kumar)

Fruits of seventeen cultivars of sapota were collected & sown for evaluation. Various fruit parameters like fruit length (mm), breadth (mm), weight (gm) and TSS (^{0}B) were recorded from collected sapota fruits and are presented in table 52. Maximum fruit breadth (61.50 mm) was recorded in CSRS-10 (PKM 1) while it was found minimum (41.37) in CSRS-12 (PKM 3). Fruit length was recorded maximum 71.27 mm in CSRS-10 (PKM 1) while it was found minimum (44.59 mm) in CSRS-6 (PNP 4). Maximum fruit weight (123 g) was recorded in CSRS-10 (PKM 1) while it was found minimum (51.18 g) in CSRS-1 (AM). Fruit moisture content was found maximum 73.59 % recorded in CSRS-3 (PNP 1) followed by 73.53 % in CSRS-10 (PKM 1) while it was found minimum (69.90 %) in CSRS-9 (AS). Maximum TSS (^{0}Brix) was 26.5 ^{0}Brix recorded in CSRS-5 (PNP 3) while it was found minimum (18.0 ^{0}Brix) in CSRS-13 (CO-1). While, fruit parameters like fruit length (mm), breadth (mm) and weight (gm) differed significantly. Fruit moisture content (%) and TSS (^{0}Brix) had no significant variation.

In another experiment, twelve cultivars were transplanted in pots and treated with different residual sodium carbonate irrigation water (RSC_{iw}) treatments for evaluation of sodicity tolerance in different sapota cultivars. The treatments comprising utilization of different RSC_{iw} irrigation water as well as various sapota cultivars showed significant variations in vegetative growth parameters like plant height (cm), plant spread (cm) and NS (cm) in different cultivars of sapota. Whereas, treatment and genotypes differ non significantly for all the vegetative parameters as mentioned in table 53. The maximum plant height (104.08 cm), plant diameter (12.01 mm), EW (56.89 cm, NS (56.50 cm) and plant spread (56.63 cm) was reported under control. While, the minimum plant height

Table 52. Variation of various fruit parameters in different cultivars of sapota

Genotypes	Fruit Breadth (mm)	Fruit Length (mm)	Fruit Weight (g)	Fruit Moisture content (%)	TSS (^{0}Brix)
CSRS-1 (AM)	44.40bc	46.16f	51.18d	70.59	24.93
CSRS-2 (JS)	52.10abc	47.79ef	80.79bcd	72.93	19.70
CSRS-3 (PNP 1)	55.33abc	58.91bcd	95.97ab	73.59	23.03
CSRS-4 (PNP 2)	48.91abc	64.48abc	90.73abc	71.58	24.13
CSRS-5 (PNP 3)	48.37abc	52.75def	71.67bcd	71.57	26.50
CSRS-6 (PNP 4)	44.56abc	44.59f	54.83cd	70.19	21.10
CSRS-7 (PNP 5)	48.56abc	55.11cdef	72.85bcd	71.54	26.07
CSRS-8 (PNP 6)	45.93abc	51.11def	64.52bcd	70.59	25.80
CSRS-9 (AS)	49.86abc	47.48ef	68.22bcd	69.90	18.67
CSRS-10 (PKM 1)	61.50a	71.27a	123.00a	73.53	25.07
CSRS-11 (PKM-2)	49.07abc	50.27def	64.47bcd	72.72	25.55
CSRS-12 (PKM-3)	41.37c	58.87bcd	54.74cd	70.83	25.27
CSRS-13 (CO-1)	47.20abc	57.97bcde	76.48bcd	74.06	18.00
CSRS-14 (CO-2)	50.84abc	57.82bcde	80.96bcd	72.05	23.37
CSRS15(Jhumkiya)	49.60abc	67.03ab	91.26abc	70.79	23.00
CSRS-16 (Kalipatti)	60.17ab	44.60f	73.64bcd	73.48	26.33
LSD@ 5%	16.981	10.913	36.7	NS	NS

Table 53. Effects of RSCiw on vegetative growth parameters in different cultivars of sapota

Factors	Plant Ht (cm)	Plant Dia (mm)	EW(cm)	NS(cm)	Plant Spread (cm)
Sodicity treatments					
Control	104.08a	12.01a	56.89a	56.50a	56.63 a
RSC~2.5 meq/l	68.58b	10.16b	41.28b	41.50b	42.74b
RSC~5 meq/l	38.36c	6.83c	28.33c	29.78c	29.97c
CD @ 5% (T)	8.13	1.03	6.76	6.91	6.29
Genotypes					
PKM 3 (CSRS-12)	76.11bc	10.70abc	48.22abc	42.89abc	45.56abc
PKM 2 (CSRS-11)	108.11b	15.18a	67.22a	65.22a	66.22a
PKM 1 (CSRS-10)	86.22ab	13.87ab	59.11ab	60.89ab	60.00 ab
Reyan (CSRS-17)	58.00c	15.99a	26.78c	31.22c	29.00c
Jhumkiya(CSRS-15)	60.56bc	10.84ab	33.67c	40.78bc	37.22c
CO-1 (CSRS-13)	60.56bc	11.81ab	41.56bc	42.22abc	41.89bc
PNP 6 (CSRS-8)	53.67c	11.39ab	34.22c	33.56c	33.89c
PNP 5 (CSRS-7)	67.11bc	9.04b	32.11cde	32.89c	37.50 bc
PNP 4 (CSRS-6)	57.22c	12.28ab	36.89bc	36.56c	36.72c
PNP 3 (CSRS-5)	66.22bc	10.65ab	43.89bc	39.78bc	41.83bc
PNP 2 (CSRS-4)	75.67bc	11.42ab	36.67bc	38.67bc	46.44bc
JS (CSRS-2)	74.33bc	11.04ab	45.67abc	46.44abc	46.06abc
CD @ 5% (G)	16.27	2.07	13.53	13.82	12.59
CD @ 5% (TXG)	28.19	NS	23.44	NS	21.82

(38.36 cm), plant diameter (6.83 mm), EW (28.33 cm, NS (29.78 cm) and plant spread (29.97 cm) was found with use RSC irrigation water (~5 meq/l) treatment. Among different genotypes maximum plant height (108.11 cm) was recorded in PMK 2 (CSRS-11) followed by 86.22 cm in PKM 1 (CSRS-10). Whereas, maximum plant diameter (15.99 mm) was recorded in Reyan (CSRS-17) followed by (15.18 mm) in PKM 2 (CSRS-11). Similarly, the maximum plant spread (66.22 cm) was recorded in PKM 2 (CSRS-11) followed by (60.0 cm) in PKM 1 (CSRS-10). EW and NS was recorded highest in PKM 2 (CSRS-11) at 67.22 and 65.22 cm, respectively.

Saline water irrigation leads to variations in physiological parameters like Chlorophyll 'a' (mg/g FW), chlorophyll 'b' (mg/g FW), total chlorophyll (mg/g FW), proline (µg/g), Na^+ (%), K^+ (%) and K^+/Na^+ as shown in table 54. Whereas, effect of genotypes was significant for other physiological parameters except proline and K^+. While, interaction effect was non-significant. The maximum chlorophyll 'a' (1.52 mg/g FW), chlorophyll 'b' (0.81 mg/g FW), total chlorophyll (2.34 mg/g FW), K^+(1.16 %) and K/Na (3.68) were recorded under control treatment. While, highest proline (0.12 µg/g) and Na (0.61 %) under high saline water *i.e.,* EC_{iw}~12 dS m^{-1} treatment. However, minimum chlorophyll 'a' (0.8 mg/g FW), chlorophyll 'b' (0.44 mg/g FW), total chlorophyll (1.24 mg/g FW), K^+(0.84) and K/Na (1.72) were recorded under high saline water *i.e.,* EC_{iw}~12 dS m^{-1} treatment. Although, minimum proline (0.09 µg/g) and Na (0.34%) were recorded under control treatment. Among various genotypes of sapota, maximum chlorophyll 'a' (1.34 mg/g FW) was recorded in Jhumkiya (CSRS-15) followed by (1.27 mg/g FW) in CO-1 (CSRS-13) while it was minimum 0.93 in PKM 2 (CSRS-11). Similarly, maximum chlorophyll 'b' (0.79 mg/g FW) was recorded in Jhumkiya (CSRS-15) followed by (0.73 mg/g FW) in CO-1 (CSRS-13) while it was minimum 0.43 in PKM 2 (CSRS-11). Similarly, highest total chlorophyll (2.22 mg/g FW) was recorded in Jhumkiya (CSRS-15) followed by (2.0 mg/g FW) in CO-1 (CSRS-13) while it was minimum 1.35 in PKM 2 (CSRS-11). Proline didn't have any significant variation among the genotypes,

Table 54. Effects of saline irrigation water on physiological parameters in different cultivars of sapota

Factors	Chl 'a' (mg/g FW)	Chl 'b' (mg/g FW)	Total Chl (mg/g FW)	Proline (µg/g)	Na^+ (%)	K^+ (%)	K^+/Na^+ (%)
Salinity treatments							
Control	1.52a	0.81a	2.34a	0.09b	0.34b	1.16	3.68a
ECiw~4 dS m^{-1}	1.24b	0.65b	1.90b	0.10b	0.42ab	1.05	2.75b
ECiw~8 dS m^{-1}	1.00c	0.59b	1.59c	0.11a	0.54a	0.96	2.11b
ECiw~12 dS m^{-1}	0.80c	0.44b	1.24c	0.12a	0.61a	0.84	1.72b
CD @ 5% (T)	0.16	0.14	0.24	0.01	0.14	0.20	1.05
Genotypes							
PKM 2 (CSRS-11)	0.93b	0.43b	1.35b	0.10	0.50ab	1.03	2.49ab
Reyan (CSRS-17)	1.03b	0.55b	1.57b	0.11	0.35b	1.09	3.66a
Jhumkiya (CSRS-15)	1.34a	0.79a	2.22a	0.10	0.51a	0.95	2.15b
CO-1 (CSRS-13)	1.27a	0.73a	2.00a	0.10	0.55a	0.94	1.96b
CD @ 5% (G)	0.16	0.14	0.24	N.S.	0.14	N.S.	1.05
CD @ 5% (T × G)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

maximum proline (0.11 µg/g) was observed in Reyan (CSRS-17). Although, the maximum Na (0.55 %) was recorded in CO-1 (CSRS-13) followed by (0.51 %) in Jhumkiya (CSRS-15) while it was minimum 0.35 % in Reyan (CSRS-17). Whereas, maximum K (1.09 %) was recorded in Reyan (CSRS-17) and followed by (1.03%) in PKM 2 (CSRS-11) while it was minimum 0.94 % in CO-1 (CSRS-13). Similarly, the maximum K/Na (3.66) was recorded in Reyan (CSRS-17) followed by (2.49) in PKM 2 (CSRS-11) while it was minimum 1.96 in CO-1 (CSRS-13). Saline irrigation water treatments significantly reduced plant growth parameters Whereas, Cv CO-1 followed by PKM-2 showed better performance as compared to other cultivars using saline water irrigation. Thus, PKM-2 can be option for cultivation under both high RSC and saline irrigation water.

Assessing the genetic diversity and deciphering the molecular mechanism for salinity tolerance in Sandalwood (*Santalum album* L.). (Raj Kumar, SL Krishnamurthy, Rakesh Banyal and Ashwani Kumar)

This project was initiated during October 2021 with the aim to assess genetic diversity, identify germplasm, and understand molecular mechanism for salinity tolerance in the sandalwood**.** During current year, we collected 120 germplasm form different states of the country namely, Karnataka, Maharashtra, Gujarat, Chhattisgarh, Rajasthan, Haryana, Punjab, Orissa, Madhya Pradesh, Kerala and Tamil Nadu. We assessed the variability in seedling characteristics in 120 genotypes of sandalwood. The findings showed that the mean seedling height and collar diameter in different genotypes were ranged between 9.9–45.2 cm and 1.5-4.1 mm, respectively. The number of leaves and branches were ranged between 10.5-38.4 and 0.8-5.5, respectively. The shoot biomass, root biomass, and number of haustoria (Picture) were ranged between 1.8-7.5g, 1.2-3.3g and 6.1-53.4, respectively. The findings suggest existence of substantial variability for the various growth and morphological parameters in sandalwood genotypes. Further, we assessed the salinity tolerance of sandalwood to screen genotypes under saline conditions. The results showed high ($P<0.05$) variation for salinity tolerance ranging from 25% (*L. leucocephala*) to 59.8% (*D. sissoo*) was observed in the sandalwood (Figure 31). Under control conditions, the plant dry biomass ranged from 17.6 to 43.84 g, while under salinity stress, it ranged from 4.54 to 25.19g. An overall 41.2-75 % decline in plant biomass was observed under saline condition, compared to control. The results revealed that

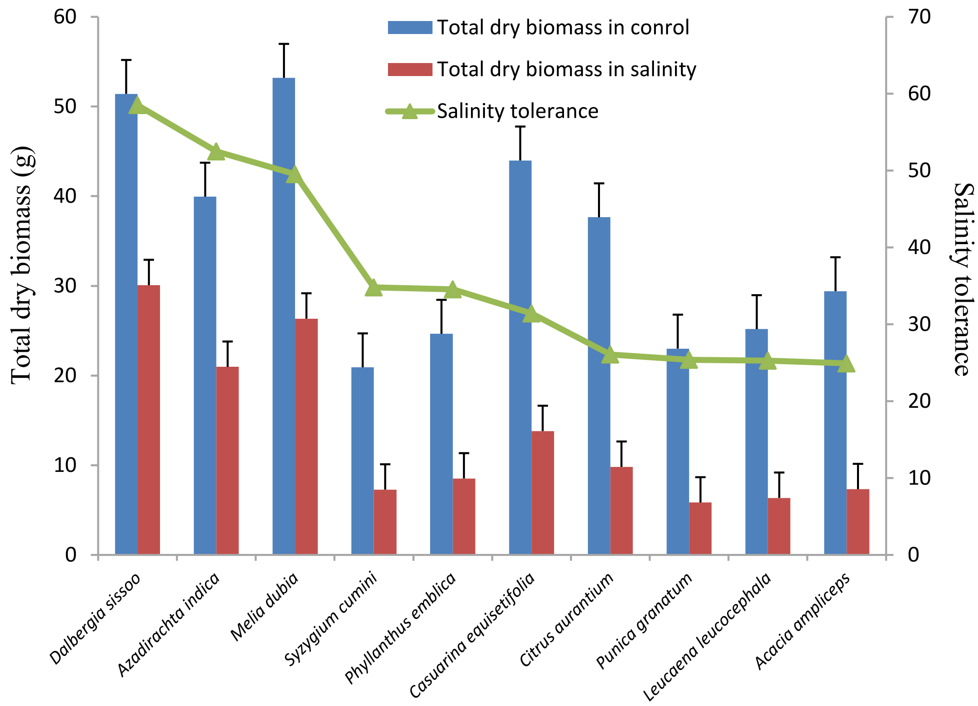


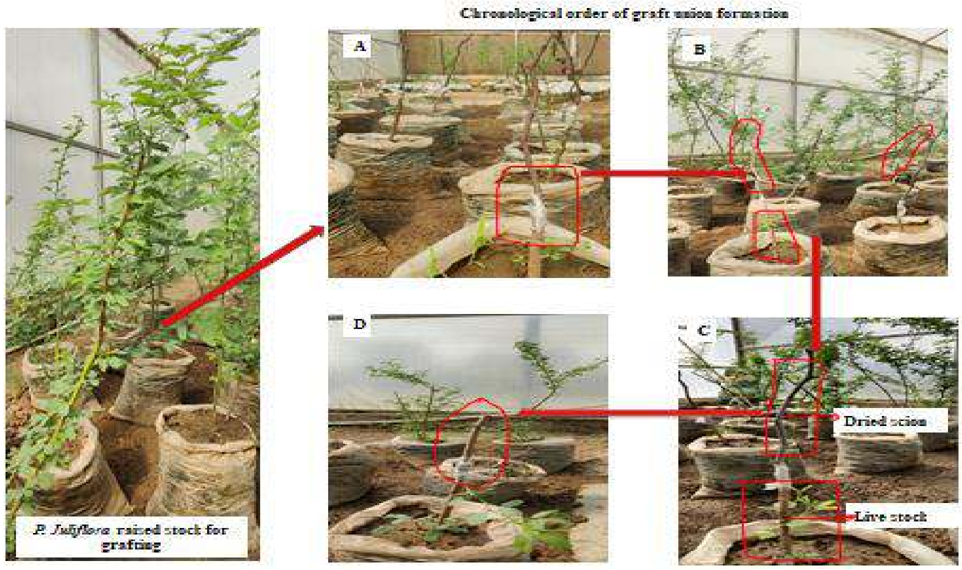
Fig 31. Plant dry biomass and salinity tolerance of Santalum album with 10 host plant species.

sandalwood grown with host species, such as, *Dalbergia sissoo*, *Azadirachta indica*, and *Melia dubia* exhibited greater tolerance to salinity via producing the higher biomass. Overall, sandalwood grown with *D. sissoo* produced highest ($P<0.05$) biomass under salinity stress and showed the highest tolerance (59.80%) to salinity stress. Our findings suggested that sandalwood growth varied with the host species both under control and saline conditions, and it exhibited a good growth potential under the moderate saline conditions.

Unravelling interspecific graft compatibility mechanisms to improve *Prosopis juliflora* (Rakesh Banyal, Anita Mann and Raj Kumar)

Improvement of trees and crops through various approaches especially conventional, physiological and molecular is the way to find the answer too many intractable problems. *Prosopis* performs exceptionally well in greening the worlds' dry zones especially saline and saline-alkaline (usar) soils, where no other vegetation exists. Plantation on these soils is the viable option to reclaim and combat the ever increasing demand of tree products because supply of wood products from existing forest areas couldn't match with the level of current demand. The earlier studies conducted on this aspect identified many woody species as highly and moderately tolerant. But, there is still need to have in-depth research to further improve the salt tolerant tree species in terms of output and usability. Interspecies grafting is possible in genus *Prosopis*. This approach can be adopted to convert invasive *Prosopis juliflora* plantations into resource with highly economical *P. cineraria* and *P. alba* (thorn less) species for better products and productivity. With this backdrop, the proposal to convert *Prosopis juliflora* from invasive to resource is being undertaken for Indian conditions to increase the productivity of the dry land saline areas by developing basic understanding of physiological and molecular mechanisms in establishing union in grafts.

Chronological order of graft union formation



During the first phase of the project, 750 saplings of *P. juliflora* raised through the local germplasm in quasi-controlled nursery conditions. In the month of July and December, 2022, grafting was done on the six months old *P. juliflora* seedlings with scions of *P. cineraria* and *P. alba*. But, graft union formation was not matured and the scion portion dried slowly and finally died in both the species. Although, some bud formation was seen in graft union of *P. juliflora* with *P. alba* but could not sustained for longer. Now, the efforts would be to explore the factors putting hindrance in union formation in the next phase of the project.

Development of *Prosopis* germplasm bank (Rakesh Banyal)

Prosopis genotypes planted in germplasm bank were evaluated during 2022-23 based on establishment and growth performance (Table 55 and Fig. 32). The survival percentage ranged from 16.7 to 87.5 percent with highest in $PG_{8\&9}$ and lowest in PG_7. Plant height was maximum (5.99 m) in PG_5 and minimum (4.16 m) in PG_1 genotype. PG_5 gave highest values of stem diameter (12.3 cm) and crown spread (29.6 m^2) compared to rest of the genotypes (Table 55). The overall performance rating ranking order of genotypes based on survival

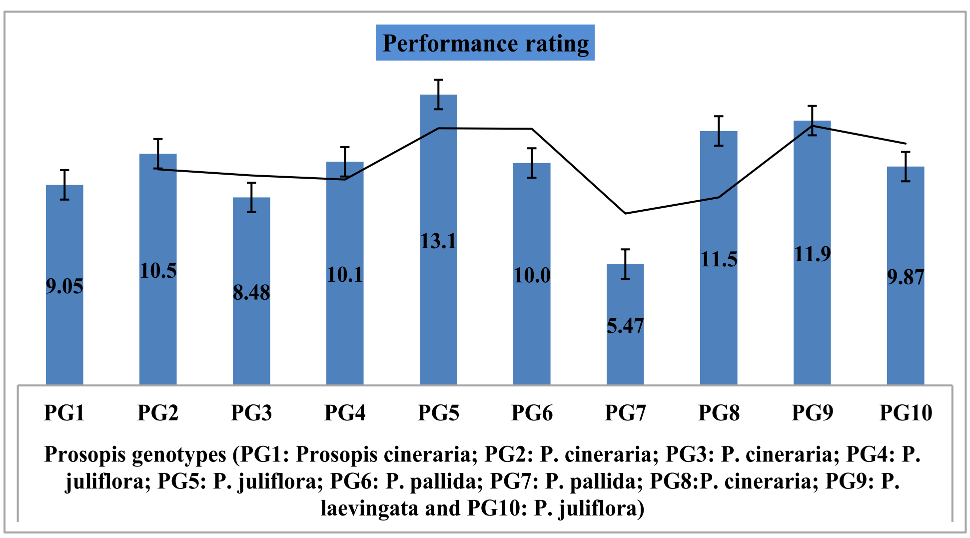


Fig 32. Performance rating of Prosopis genotypes during fifth year of out-planting in partially reclaimed sodic soils

Table 55. Survival and growth of Prosopis genotypes during 2021

Prosopis genotype*	Survival %	Plant height (m)	Stem dia. (cm)	Crown spread (m^2)
PG1	66.7 (+0.00)	4.16 (+0.12)	8.83 (+0.28)	3.67 (+0.50)
PG2	81.3 (+2.08)	4.29 (+0.06)	7.42 (+0.26)	3.70 (+0.80)
PG3	60.4 (+2.08)	4.27 (+0.22)	8.91 (+0.35)	4.98 (+1.30)
PG4	70.8 (+2.41)	5.23 (+0.28)	10.2 (+0.40)	7.42 (+1.65)
PG5	75.0 (+0.00)	5.99 (+0.25)	12.3 (+0.41)	29.6 (+17.2)
PG6	72.9 (+2.08)	5.00 (+0.20)	9.22 (+0.49)	4.94 (+0.80)
PG7	16.7 (+0.00)	6.09 (+0.35)	12.1 (+0.34)	11.6 (+2.40)
PG8	87.5 (+2.41)	4.88 (+0.25)	8.84 (+0.28)	4.68 (+0.90)
PG9	87.5 (+4.17)	5.37 (+0.21)	9.25 (+0.44)	7.72 (+1.30)
PG10	70.8 (+2.41)	4.92 (+0.23)	8.50 (+0.27)	6.03 (+0.60)

Values in parenthesis are SEm
*PG1: Prosopis cineraria; PG2: P. cineraria; PG3: P. cineraria; PG4: P. juliflora; PG5: P. juliflora; PG6: P. pallida;
PG7: P. pallida; PG8:P. cineraria; PG9: P. laevingata and PG10: P. juliflora

and growth traits was in the order of *P. juliflora* (PG_5)> *P. laevingata* (PG_9)> *P. cineraria* (PG_8)> *P. cineraria* (PG_2)> *P. juliflora* (PG_4)> *P. pallida* (PG_6)> *P. juliflora* (PG_{10})> *Prosopis cineraria* (PG_1)> *P. cineraria* (PG_3) in fifth year aged germplasm bank (Fig. 32).

Prosopis plantation

Reclamation and Management of Alkali Soils of Central and Eastern Gangetic Plains

Combating sub-soil sodicity constraints of central Indo-Gangetic plains of Uttar Pradesh for enhancing crop productivity (S.K. Jha, Arjun Singh, C.L. Verma and A.K. Singh)

The field experiment which was started in 2020 on partially reclaimed sodic soil of Shivri farm Lucknow for the management of sub surface sodicity and for boosting up the productivity of rice and wheat in such soils, continued. The experiment involved 12 treatments with three replications (Fig. 33).

The wheat and mustard which were sown in the rabi season was harvested and the treatment wise yields were recorded. The wheat yield was recorded maximum (34.2 q ha^{-1}) in the treatment T12 followed by T11 with a yield of 31.3 q ha^{-1}. On the other hand, the mustard yield was found maximum (15.69 q ha^{-1}) in the treatment T12 (Fig. 34).

After harvest of wheat and mustard, the saturated hydraulic conductivity (Ks) was also determined in order to assess the lateral movement of water. The Ks of soil is required for designing sub-surface horizontal drainage systems, irrigation systems, ground water abstraction structures and recharge systems. In this determination, inverse auger hole method was used assuming hemispherical bottom, using equation:

$$Ks = 1.15 r \tan\alpha$$

Where tan α = [log10 (ho+r/2)-log10(ht+r/2)]/(t-to) and Ks=saturated hydraulic conductivity; r= radius of auger hole; ho= water depth in auger hole at time t=0; ht= water depth in auger hole at time t. The augur hole upto 45 cm depth was made in the plot and was saturated with the water for two days and on third day again water was filled upto the brim of the hole. There after the water drop was recorded hourly. After recording the water drop, the vertical section of the augur hole was studied. It was found that the Ks value was very low i.e. varied from 0.89 cm h^{-1} to 1.46 cm d^{-1}.

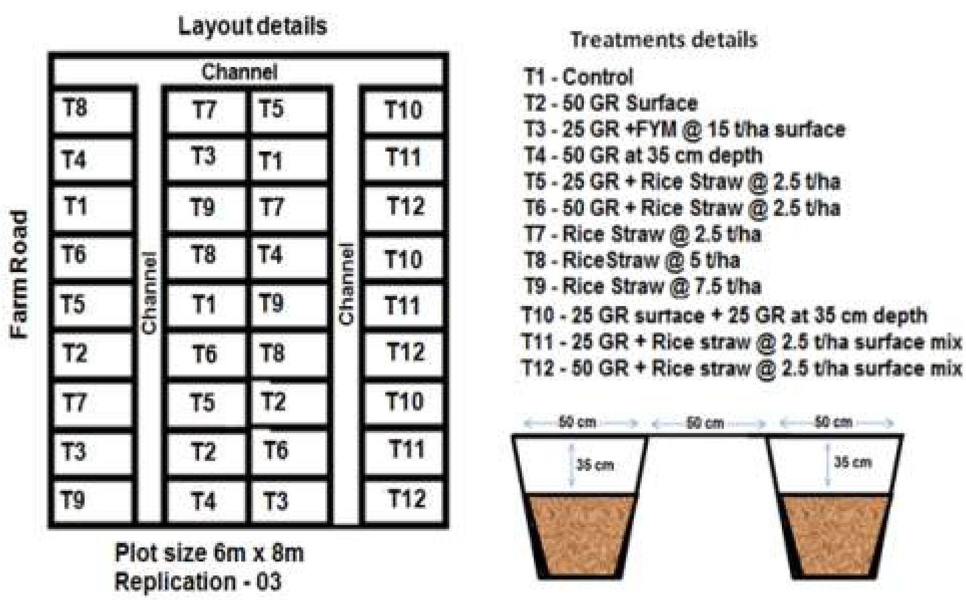


Fig 33. Layout and treatment design of the experiment

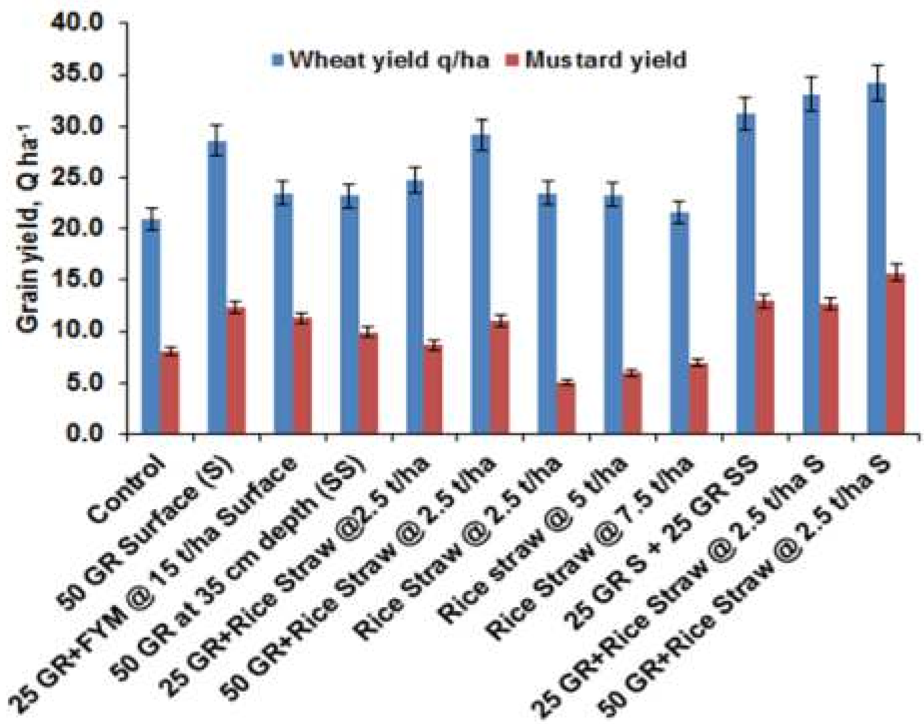


Fig 34. Grain yield of wheat and mustard

Table 56. Changes in soil pH in channel and without channel soils under various treatments

	Soil pH					
Treatments	**0-15 cm**		**15-30 cm**		**30-45 cm**	
	CH	**W.CH**	**CH**	**W.CH**	**CH**	**W.CH**
Control	9.06		9.5		9.65	
50 GR Surface	9.12		9.28		9.51	
25GR+FYM 15 t/ha S	9.13		9.42		9.58	
50 GR SS	8.75	9.18	9.28	9.31	9.5	9.47
25 GR SS+RS 2.5 t/ha SS	8.85	9.05	9.37	9.45	9.4	9.5
50 GR SS+RS 2.5 GR SS	8.91	8.93	9.22	9.36	9.2	9.3
RS 2.5 t/ha SS	8.92	9.23	9.41	9.57	9.5	9.61
RS 5 t/ha SS	8.99	9.13	9.17	9.42	9.5	9.57
RS 7.5 t/ha SS	9.06	9.18	9.31	9.48	9.4	9.54
25 GR S+25 GR SS	9.1		9.27		9.39	
25 GR S+2.5 t/ha S	8.98		9.09		9.33	
50 GR S+2.5 t/ha S	8.79		9.28		9.35	

In the kharif season, the rice was transplanted, which was harvested in the last week of October, 2022. The maximum rice yield (5.11 t ha^{-1}) was recorded in the treatment T12, which was statistically at par to T2 (4.95 t ha^{-1}).

The soil samples up to depth of 45 cm were collected from each plots taking both channel and without channel soils separately. The analysis of the soil revealed the pH reduction in the channel soil compared to without channel soil in all the depths (Table 56).

Microbially mediated paddy and wheat crop residue decomposition to enhance nutrient recycling and soil health management (Sanjay Arora, Atul K. Singh and Madhu Choudhary)

Out of 97 fungal isolates, 20 fungal isolates were having potential for the production of cellulolytic enzymes by the method of solid-state fermentation. A small fraction of substrate (paddy, wheat, and sugarcane trash) was air dried and cut into small pieces to a particle size of 2-3 mm to evaluate it as a substrate for production of cellulolytic enzymes. A total of 20 fungal cultures were maintained on potato dextrose agar (PDA) and stored at 4 °C. Four fungal isolates showed brown pigment production- a positive qualitative test for lignin degradation- on Tannic acid media which occurred due to oxidizing activity by the isolates on phenolic structured substrate.

Solid state fermentation (SSF)

For solid state fermentation experiment was conducted with 2.5 g of dried substrate in Reese's mineral medium in a flask. The media with substrate was inoculated with one week old fungal cultures and incubated at 28 ± 2 °C for 10 and 20 days under static condition. The crude enzyme was extracted from substrate wheat, paddy and sugarcane trash with sodium citrate buffer (50 mM, pH 4.8) at room temperature. The suspension was filtered and centrifuged for removal of solid particulate matter. The supernatant was used for enzyme assay.

Among 22 fungal isolates, maximum production of CMCase (6987.76 U/ml) was found from AF4A isolate followed by 6893.49 U/ml, 6778.57 U/ml, and 6666.09 U/ml from 25C, BFA and GP-1, respectively, after 10 days of incubation from paddy straw substrate. In case of wheat straw substrate maximum production was observed 6768.57 U/ml and 6699.56 U/ml by ETM and JJF strain, respectively. In the case of trash substrate highest production 6828.52 U/ml showed by AF4A strain after 10 days incubation. After 20 days of incubation again maximum production was obtained of CMCase (1704.71 U/ml) by AF4A followed by 1459.63 U/ml, and 1413.45 U/ml by the strain 25C and BFA respectively, after 10 days of incubation from paddy straw (Fig. 35).

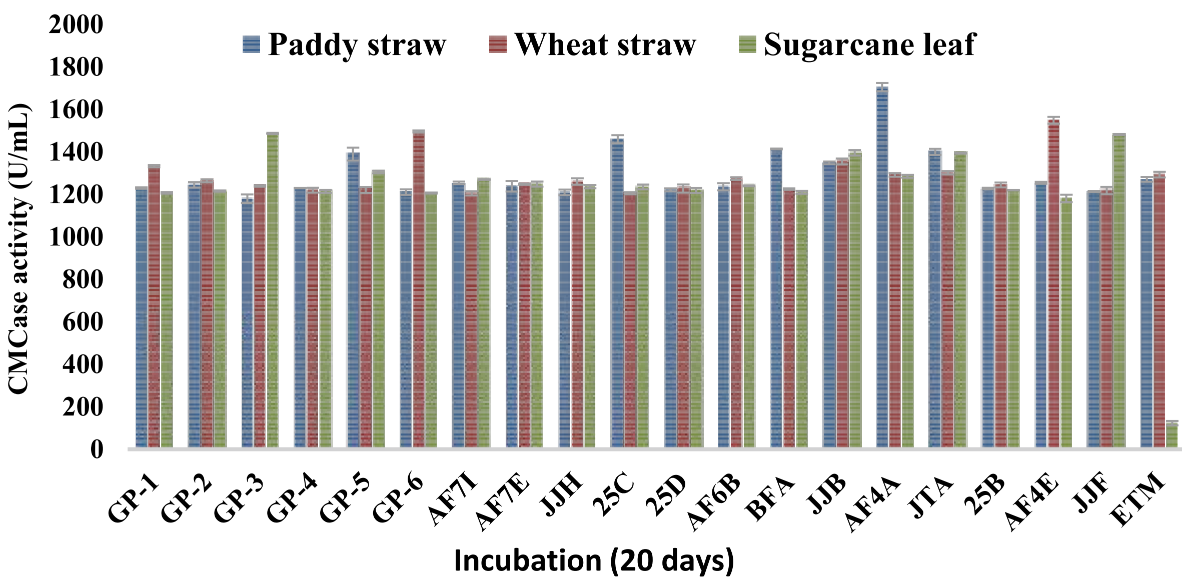


Fig 35. CMCase activity from three substrate by solid state fermentation, 20 days incubation at 28 ± 1 °C

The isolate, AF4A showed maximum activity of xylanase (1704.71 U/ml) from paddy straw, AF4E (1548.42 U/ml) from wheat straw and JJF (1491.38 U/ml) from trash substrate on 10 days of incubation. The results of maximum production of xylanase enzyme in the wheat straw substrate (9547.97 U/ml) by AF7E as compared to others substrate while least production in the trash substrate (1690.06 U/ml) by the GP-3 strain at 20 days of incubation. Maximum production of amylase activity (1195.54 U/ml) by the strain of GP-4 from paddy straw, followed by wheat straw 1246.13 U/ml by AF4E, and sugarcane trash 1015.56 U/ml by GP-2 after 10 days of incubation. After 20 days of incubation maximum production was observed in the trash substrate (6480.5 U/ml) by the strain JJF while lower production was observed in paddy straw substrate (487.4 U/ml) by the strain GP-1 on 20 days of incubation.

Dry weight loss examination of substrate

After enzyme extraction the all three residues (substrate) were dried in an oven at 40°C and noted the dry weight of substrate. The dry matter loss of the substrate varied from 22% to 44% of paddy straw and 10% to 34% of wheat straw and 14% to 34% of sugarcane trash.

Compatibility testing of fungal isolates

Compatibility test

Among 20 fungal isolates were tested for their compatibility on PDA agar plates and incubated at 28±1°C under static conditions for 3-5 days. Eighteen fungal isolates were selected as potential lignocellulolytic agents for in-vitro compatibility study based on their optimum growth rate to go for preparation of consortia formulation in standardized media/carrier. Out of eighteen AF4E, JJH and ETM are not compatible with GP-1 strain. Strain 25C is not compatible with AF4E & AF7E and AF7I is not compatible with 25D & GP-5 strain. ETM and BFA are not compatible with GP-2 strain and GP-3 strain is not compatible with all of eighteen isolates except AF7I, GP-1 and GP-2 strains.

In-situ decomposition of crop residues as influenced by fungal inoculation

In the field experiment on moderately sodic soil (pH 8.8; ESP 17.3), it was observed that consortia of lignocelluloytic fungal isolates inoculated to wheat and rice residues and incorporated to soil, influenced the grain and straw yield of succeeding rice and wheat crops. There was 31.71 per cent higher grain yield of paddy in treatment plot where wheat residue was incorporated with inoculation of fungal consortia compared to residue burning. Incorporating wheat residues into soil after urea spray resulted in 22.72 % increase in grain and straw yield of paddy over incorporation only (Table 57). Similarly, 28.5 per cent increase in wheat yield was observed when paddy crop residues were

Table 57. Effect of crop residue management on yield of rice-wheat (Kharif 2021 & Rabi 2021-22) in sodic soil

Treatments	Rice yield (q/ha)	Wheat yield (q/ha)
T1: Residue Burning	36.67	25.21
T2: Residue Retained	32.67	24.33
T3: Residue Incorporated	36.67	27.87
T4: Residue Incorporated+ Urea spray	45.00	28.47
T5: Residue Retained + CLDF (Consortia)	39.20	30.73
T6: Residue Incorporated+ CLDF (Consortia)	48.30	32.40
CD (5%)	4.2	2.6

Table 58. Effect of crop residue management on yield of rice-wheat (Kharif 2021 & Rabi 2021-22) in partially reclaimed soil

Treatments	Rice yield (q/ha)	Wheat yield (q/ha)
T1: Residue Burning	41.32	30.40
T2: Residue Incorporated+ Urea spray	44.39	32.33
T3: Residue Incorporated+ CLDF (Consortia)	53.17	34.73
T4: Residue Incorporated+ Halo-CRD (Consortia)	50.73	33.40
CD (5%)	5.1	1.8

Field experiment at Shivari experimental farm

inoculated with consortia of lignocelluloytic fungi and incorporated in soil compared to residue burning while 16.25 per cent increase in wheat yield was obtained when compared to the residue incorporated without inoculation. The results are indicative that the lignocelluloytic fungal isolates have potential for in-situ degradation of paddy and wheat crop residues and thus can be a viable option to combat residue burning issues in rice or sugarcane based cropping areas.

In another experiment in reclaimed soil, paddy residue incorporation with fungal consortia inoculation effect on wheat yield was compared with our earlier developed bacterial formulation Halo-CRD and it was observed that maximum wheat grain yield of 34.73 q/ha was in RI with fungal inoculation compared to 33.40q/ha with inoculation of bacterial formulation (Halo-CRD), although both showed statistically significant yield over residue burning (Table 58).

Spatial and temporal analysis of waterlogging and salt dynamics for crop planning in sharda sahayak canal command of Uttar Pradesh (R.H. Rizvi, Sanjay Arora and C.L. Verma)

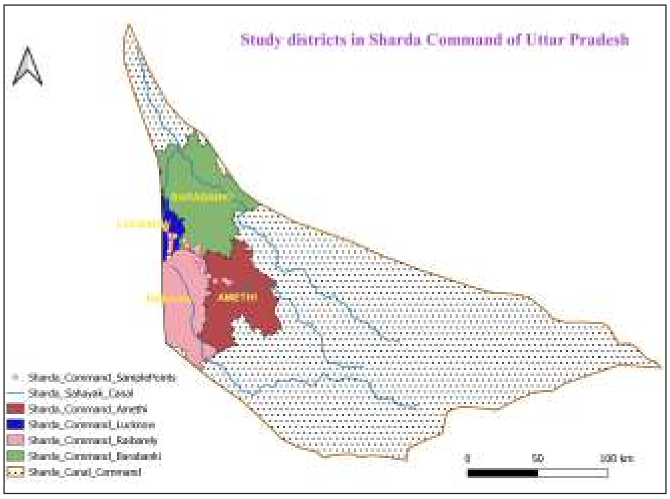
This project was initiated in March, 2022 with the aim of mapping waterlogged salt affected areas in Sharda Canal Command. This command comprises of 18 districts of Uttar Pradesh and has geographical area of 359864.38 km^2. Field survey was conducted in Sharda Canal Command of Amethi, Lucknow, Barabanki and Raibareli districts and total 43 soil sample with GPS points were collected. These samples were collected at two depths: 0-15 cm and 15-30 cm and were analysed in lab for parameters viz. pH, EC, OC, and saturation extract pH_e, EC_e, and Na. Basic maps showing canal command in study districts with soil samples were prepared in GIS platform (Fig. 36).

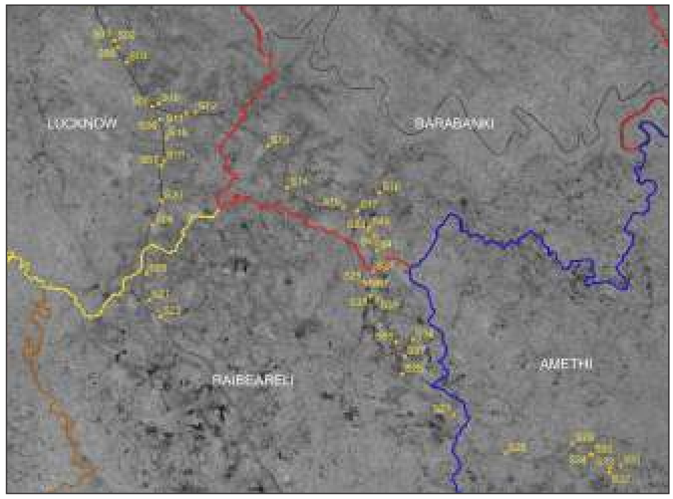
Soil parameters analysis

About 75% of soil samples (32 out of 43) at 0-15 cm depth have pH value more than 10.0 indicating that soils in Sharda Canal Command falls under severely sodic category. Soil EC ranged between 0.219 to 8.92 dS/m and soil OC ranged from 0.04 to 0.64%. pH_e was in the range of 7.73 to 10.69 and EC_e was in the range of 0.66 to 26.76 dS /m. Saturation extract Na was found as low as 1.578 meq/l and as high as 437.174 meq/l in these samples (Table 59A). Significantly high correlations were found between soil pH and pH_e (0.901). EC has very good correlations with pH_e, EC_e and Na (0.700, 0.813 & 0.893). Saturation extract Na has high correlations with pH_e and EC_e (0.754 and 0.878). Soil organic carbon (OC) content was found to have negatively correlated with all other soil parameters.

Spectral correlation analysis

Sentinel-2 MSI data for the study districts was downloaded from USGS Earth Explorer website for Nov. 2021 (post-monsoon) and May 2022 (pre-monsoon). These data were pre-processed and analysed using open source QGIS software (v 3.24.0). Salinity indices





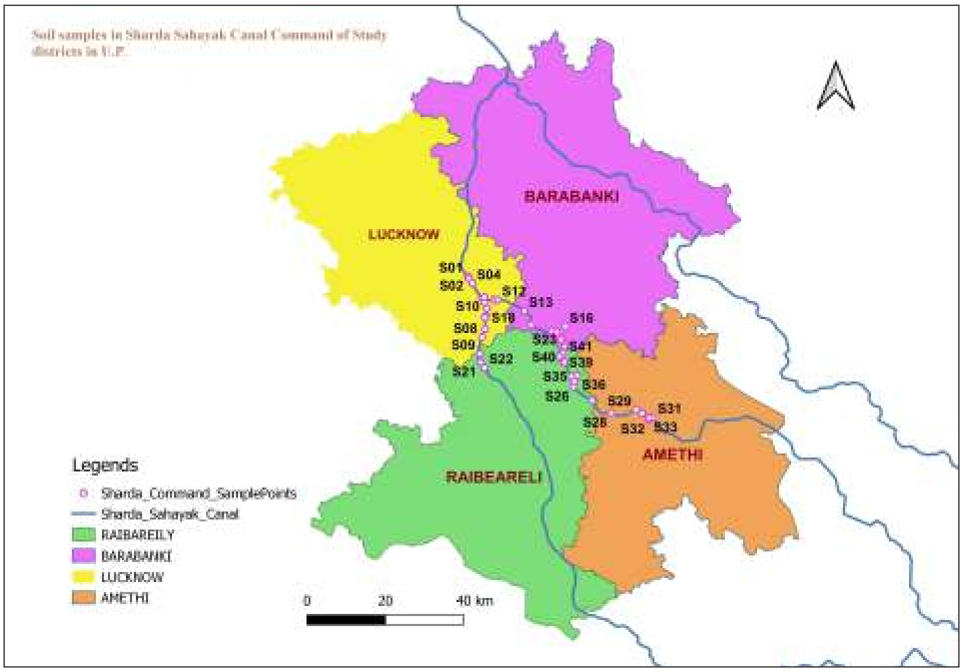


Fig 36. Maps showing soils samples collected from Sharda Canal Command

Table 59A. Effect of wheat residue management on yield of rice (Kharif 2021)

	pH	EC (dS/m)	OC (%)	pHe	ECe (dS/m)	Na (meq /l)
Minimum	7.810	0.219	0.039	7.730	0.659	1.578
Maximum	10.930	8.920	0.642	10.690	26.760	437.174
Mean	10.059	2.594	0.252	9.637	7.946	115.575
Std. Error	0.145	0.418	0.021	0.141	1.330	19.615
Std. dev	0.843	2.435	0.141	0.819	7.757	114.373

(SI1, SI2, SI3, SI4, SI5, SI6, BI and NDSI) were computed using green, red and NIR bands of sentinel-2 images. Correlation analysis was done among soil parameters and salinity indices (Table 59B). Soil pH has good correlation with salinity index-4 (0.363) whereas soil EC has good correlation with salinity index-3 (0.398). Both pH_e and Na found to have good correlations (0.446 & 0.384) with spectral reflectance in near-infra red (SR-NIR) band. EC_e is found to be poorly correlated with all the salinity indices as well as spectral reflectance in red (SR-R), and near-infra red (SR-NIR) bands. All the soil parameters are negatively correlated with salinity index-6 (SI6). NDSI has low correlations with soil parameters (pH, EC, pH_e, EC_e & Na).

Table 59B. Correlations between soil parameters and spectral indices

	SI1	SI2	SI3	SI4	SI5	SI6	BI	NDSI	SR_NIR	SR_R
pH	0.358	0.362	0.332	0.363	-0.319	-0.267	0.326	0.185	0.309	0.341
EC	0.365	0.367	0.398	0.369	-0.216	-0.259	0.393	0.063	0.385	0.345
pHe	0.395	0.389	0.425	0.390	-0.319	-0.298	0.432	0.071	0.446	0.368
ECe	0.147	0.150	0.174	0.149	-0.084	-0.127	0.180	-0.024	0.198	0.136
Na	0.289	0.308	0.362	0.310	-0.195	-0.230	0.368	-0.016	0.384	0.288
OC	-0.372	-0.384	-0.310	-0.382		0.286	-0.302	-0.231	-0.257	-0.357

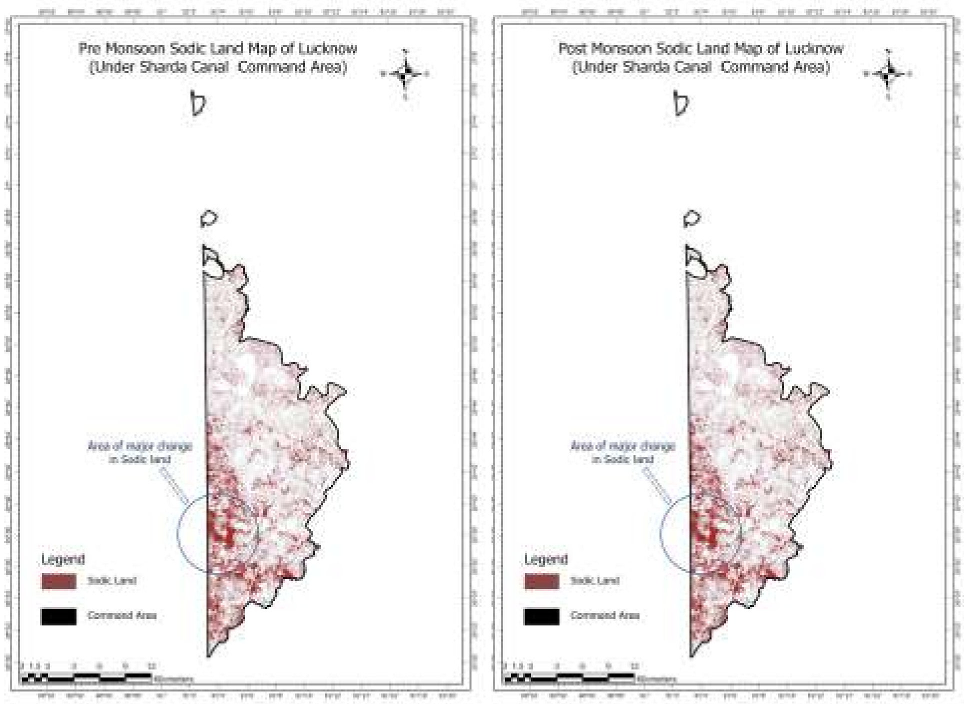


Fig 37. Sodic soils mapping in Canal Command of Lucknow district for pre- and post-monsoon

Mapping of salt affected area

Salt affected soils (sodic) in Canal Command of Lucknow district has been mapped using Sentinel-2 data for pre-monsoon (May, 2022) and post-monsoon (Nov. 2021) periods and with the help of GPS points collected for soil samples. Preliminary estimates suggest that area under sodic soils for pre- and post-monsoon periods come out to be 8681.51 and 6824.75 ha, respectively (Fig. 37). So, there was decline in sodic area in the post-monsoon period. This may be due to the leeching of salts below the surface after rainfall.

Evaluation of multiple auger planting technique for fruit crops in partially reclaimed sodic soil (Chhedi Lal Verma, A.K. Singh, T. Damodaran and S.K. Jha)

Sodic soils in Indo-Gangetic plains is generally having light to medium textured sandy loam in the surface and clay loam in lower depths with $CaCO_3$ concentration. This results in existence of hardpan of both indurated Kankar and clay with a thickness ranging from few centimetres to about 0.30 m at a depth of 0.5 to 1.0 m. Reclamation of surface soil using gypsum for cereal production is successful but does not support deep rooted crops or plantation tree. Auger hole and pit methods were tested for establishing fruit tree species by filling 5 and 10 kg of gypsum in each auger hole and 10 and 20 kg of gypsum in each pit. After seven years Ziziphus mauritiana, Syzygium cuminii, Psidium guajava, Emblica officinalis, and Carissa caranandus were the successful species. Similar results were also obtained at Shivri Research Farm, Lucknow. Growth of fruit trees was superior in pit method of planting. In sodic soils, presence of kankar or clay pan impedes water and air flows and root growth. Ber, guava, jamun, aonla and tamarind could be successfully grown in a degraded alkali land (pH 10.5) by planting in the gypsum treated auger holes of about 25 cm diameter and 160-180 cm deep. Ber, guava, jamun and karonda showed 100% survival planted in amended auger-holes (120 cm deep, 45 cm dia. at surface and 20 cm at base) in a sodic soil (pH_2 >10.0; ESP ~90.0) having ~40 cm thick precipitated $CaCO_3$ layer. A technique of multiple auger hole is hypothesized as a new technique for plantation in sodic soil. A large diameter hole (25 cm to 30 cm) in the middle and 5 to 7 small diameter (10 cm) around it filled with mixed soil with FYP, gypsum and sand treated with bio-formulation would perform in a better way for root spread, nutrient and water supply. The depth of hole should be such that it should break the kankar pan. Large number of auger holes would reduce the effective bulk density of the soil surrounding the large hole. Root penetration around the large bore hole in search of water and nutrients would lead to better plant growth. Nutrients and water could be supplemented through small diameter auger holes. A new tractor mounted multiple auger system was fabricated in the ICAR IISR Workshop Ber is a hardy fruit crop having good tolerance to sodicity and productivity potential but its fruit bearing time is about five years. Apple ber is improved variety of ber has good fruit bearing ability right after the plantation. In the present study the multiple auger hole technique would be tested for apple ber in sodic soils at Shivri Research Farm, Lucknow. The objectives were: 1. To design and fabricate multiple bore auger system for sodic soil planting, 2. To evaluate performance of annual fruit/ early fruit bearing plants, and 3. To evaluate changes in soil properties around the holes.

Treatments: 1. Depth of auger hole: 100 cm; 2. Number of multiple holes: 5; 3. Planting materials: Apple ber

Input mixture: 1. 33.3% volume of dugout soil + 33.3% sand + 33.3% FYM + 2 kg gypsum; 2. 33.3% volume of dugout soil + 33.3% sand + 33.3% FYM + 2 kg gypsum + microbial formulations

Development of tractor operated PTO driven multiple auger system

Tractor operated PTO driven multiple (three) auger system was developed for digging multiple three circular pits simultaneously. It was mounted type equipment rigidly attached to three point linkage. Multiple auger system (MAS) was designed to make deep (1.0 m) with large diameter auger (300 mm) in the centre whereas adjacent auger on both sides would make small diameter (150 mm) shallower holes (0.90 m). The developed MAS consisted of main frame, pit digging blades and power transmission units (photos). During pit digging operation auger blades cut the soil and flutes carry the cut soil out off pit for getting clean pit. Vertical and horizontal angles of the blade and speed of auger flutes are critical parameters for achieving the desired results. These parameters were optimized and pit digger was designed and developed. Details are presented below.

Main frame

A rigid framework was provided to support pit digging blades and power transmission units. The framework was made of MS square pipe and was properly strengthened by cross supports. The framework was mounted through 3-point linkage with the tractor.

First prototype of Multiple Auger System

Pit digging blade

The equipment was provided with three blades for digging three pits at a time. Each blade was like two augers having replaceable blades at the tip. Augers rotate in clockwise direction. Flutes of the auger blades were designed in such a way that caused least chocking. Performance of blades at three levels of vertical angle i.e. 0^0, 5^0 and 10^0, three levels of horizontal angle i.e. 0^0, 15^0, 30^0 and 45^0 for two types of shapes i.e. straight and curved edges was observed. Blades having 5^0 vertical angle, 30^0 horizontal angle and with curved edge performed the best. Designed blades had 5^0 vertical angle, 30^0 horizontal angle, curved sharpened edges and 370 mm flute pitch.

Power transmission

Rotary power from tractor PTO was transmitted to main gear box through UJ cross and flexible propeller shaft and from main gear box output shaft to pit digging blades. Main gear box consisted of a pair of heavy duty bevel gears. Main gear box was a bevel gear box with speed ratio of 1.8:1. The power from main gear box output shaft was transmitted to central pit digging blades directly and through V-belt pulleys to adjacent pit digging blades. The first prototype of MAS was fabricated in the workshop of Agricultural Engineering Division of IISR. All the moving parts were guarded to avoid any accident.

After augering three hole a place the direction of the system is rotated by right angle and five holes were made in two goes (photos). Several improvements in the parts were done after running the prototype in real field conditions in normal soil of ICAR-IISR fields. IISR scientists are working on development of power transmission system for multiple auger hole making system.

Auger holes made in a line should be at higher elevation in order to avoid entry of water in the holes to avoid waterlogging situations. To achieve it, a ditch line was created and outward slope was given for quick removal of rainfall induced rainfall. For collecting leachate from the hole bottom a transparent plastic tube should be inserted in the holes.

Holes made in sodic soil by multiple auger system

Leachate can be collected through the plastic tube. For taming roots of plants away from the main hole small diameter hole filled with treated soils and nutrients could be made in a desired pattern in future.

Filling of input mixture

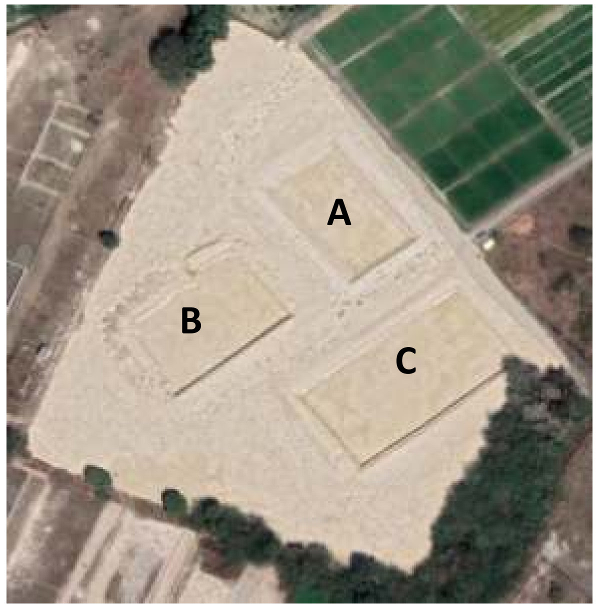
Input mixtures of 33.3% volume of dugout soil + 33.3% sand + 33.3% FYM + 2 kg gypsum with and without microbial formulations were filled in the auger holes after thorough mixing of all inputs manually. Nursery of apple ber (cloned plants) were procured from Malihabad nursery and planted during February 2022.

Development of integrated organic farming system model in partially reclaimed sodic soil of Uttar Pradesh for livelihood security (Arjun Singh, S. K. Jha, C. L. Verma, T. Damodaran, A. K. Singh and Sanjay Arora)

Reclaimed sodic soils have been referred to as virgin soil owing to very low agricultural activities on these lands. It was estimated that about 8 lakh ha land have been remediated for sodicity in Uttar Pradesh and holds a great conversion potential under organic agricultural system. Integrated farming systems being a holistic approach to diversify the agricultural income from various options, can be adopted in these areas for improving livelihood of the farmers. With this aim, under the project three Integrated organic Farming System models suited for small, marginal and large land holding farmers are being developed. Under these three fish ponds of sizes 1500 sq. mt, 2500 sq mt and 3000 were developed. Due to the digging activity sub-surface soils with high pH occupied the top soil levels and changed the soil physico-chemical characteristics of the IFS models. The ph values ranged from 10 to 10.09 for the area. In terms of nutrient content also OC level of only 0.22-0.35 % was obtained, whereas available nitrogen was 0.0048 % which was very low indicating low fertility of the soil (Table 60). In order to reclaim the soils marine gypsum was applied along with green manuring. Which was followed by rice crop

Table 60. Soil physico-chemical characteristics of IFS model site

Parameters	Values
Org. C	0.22-0.35 % (Low)
Avail N	0.0048 % (Low)
Avail P	11.85 ppm (Low)
Avail K	3.61 ppm (Low)
Avail Fe	8-11 ppm (Adequate)
Avail Zn	0.2 -0.6 ppm (Low)



Photos showing calcite deposition at the site subsurface level and the bird eye view of the IFS model

(variety CSR 46). Due to high pH and low fertility status of the soil the crop didn't obtained the yield potential. In order to sustain the IFS model fish farming was also initiated with 1000 fingerlings, the biomass increase among the fishes ranged from 822 to 900 gm from the initial weight of 450 to 540 gm after 2 months of laying. Other active infrastructural support was also initiated for upgrading farm mechanization as well as regional stations farmer training support.

Survey and Sampling of calcareous sodic soils of Bihar

Harnessing productivity potential of calcareous salt affected soils of Bihar through improved reclamation technologies (Sanjay Arora, A.K. Singh, Arjun Singh, S.P. Singh, S.S. Prasad and Arijit Barman)

In a survey in Muzaffarpur and Samastipur district of Bihar, soil samples were collected to assess the nature and extent of calcareous sodic soils. It was observed that free $CaCO_3$ content ranged from 12.7 to 28.3 per cent. The pH of surface soil ranged between 7.95 to 8.75 while in sub-surface it ranged between 8.06 to 8.57. Ammonium acetate extractable exchangeable Ca content ranged between 32 to 49 meq/l in surface and 32 to 49.5 meq/l in sub-surface soil layer.

Kinetics of $CaCO_3$ dissolution from calcareous sodic soils

In a batch kinetic study was conducted with calcareous sodic soils, the effect of native $CaCO_3$ dissolution in presence of organic amendments, it was re-affirmed that sulphinated pressmud amendment with soil incubated at 28±1°C helped in release of Ca+Mg due to dissolution of $CaCO_3$. It was higher is soils having higher content of free $CaCO_3$ and the effect was more pronounced in the presence of pressmud. It is indicative of native $CaCO_3$ dissolution that may help in self amelioration of soil sodicity. It was observed that it followed first order and elovcih kinetic model with highest R2 value both in presence and absence of sulphinated pressmud.

Effect of interventions on performance of salt tolerant variety grown on calcareous sodic soil

In order to ameliorate calcareous sodic soil with different interventions involving green

Table 61. Effect of GM, Manure, Pressmud and STV on rice growth and yield (average $CaCO_3$: 12.6%; pH_2: 8.3-9.1) total 12 sites

Interventions	**Plant height (cm)**		**Grain yield (t/ha)**		**Straw yield (t/ha)**	
	STV	**TV**	**STV**	**TV**	**STV**	**TV**
I0: No amendment/FP	106.5	98.2	2.54	2.18	3.61	3.77
I1: With GM (Dhaincha)	111.7	102.1	2.86	2.32	4.24	4.38
I2: With Cow Manure @ 10t/ha	114.2	104.5	3.04	2.54	5.47	4.85
I3: With Pressmud @ 5t/ha*	116.6	105.4	3.45	2.67	5.86	5.03
I4: With GM+ Cow Manure	116.5	106.2	3.67	2.95	6.08	5.22
I5: With GM+ M Enriched Cow Manure (Halo-Mix)	119.1	108.3	3.88	3.14	6.29	5.50
I6: With GM+ M Enriched Cow Manure+ ME Pressmud	119.5	112.4	4.12	3.68	6.73	5.68

Table 62. Effect of GM, Manure, Pressmud and STV on soil properties

Interventions	Soil pH_2	EC_2 (dS/m)	$CaCO_3$ (%)	Org C (%)	ESP	Ex Ca (meq/l)	Ex Na (ppm)
I0: No amendment/FP	9.12	1.79	12.2	0.36	39.4	152.5	111.0
I1: With GM (Dhaincha)	8.94	1.62	11.9	0.41	36.5	191.0	105.5
I2: With Cow Manure @ 10t/ha	8.78	1.55	10.5	0.39	35.6	222.5	99.2
I3: With Pressmud @ 5t/ha*	8.66	1.61	10.4	0.40	34.1	200.5	95.7
I4: With GM+ Cow Manure	8.74	1.18	10.1	0.41	33.4	243.6	93.4
I5: With GM+ M Enriched Cow Manure (Halo-Mix)	8.51	1.06	9.7	0.42	30.2	249.1	91.2
I6: With GM+ M Enriched Cow Manure+ ME Pressmud	8.39	0.94	9.4	0.42	28.6	256.5	84.5

manuring, use of cow manure and pressmud as soil amendment and cultivation of salt tolerant variety, on-farm trails were conducted at 12 sites in calcareous sodic soil sites. It was observed that salt tolerant rice variety (CSR46) performed better over the traditional variety. There was maximum increase in grain yield of salt tolerant variety to the tune of 52.7% and traditional variety to the extent of 44.0% with green manuring coupled with use of microbial enriched cow manure and pressmud as soil amendment over of no amendment (Table 61).

Soil pH got reduced and there was decrease in free $CaCO_3$ content with the introduction of green manuring with microbial enriched cow manure and pressmud indicating dissolution. Soil organic C content build-up was noticed to the extent of 0.06% in one crop season with adopted interventions over no amendment (Table 62). There was substantial increase in exchangeable Ca content and decrease in exchangeable Na content with different imposed amendments in calcareous sodic soils. Soil microbiological properties viz. bacterial and fungal population as well as dehydrogenase activity was also found to be maximum in soils amended with green manuring+ microbially enriched cow manure+ pressmud.

Isolation of calcium carbonate dissolving bacteria (CCDB) from calcareous sodic soils

An attempt was made to isolate and identify microorganisms with $CaCO_3$ dissolving activity from calcareous sodic soils of Bihar that may be beneficial in self-reclamation of sodic soils. 17 bacterial isolates were isolated by serial dilution method. The isolates were screened for their Gram reaction and determined the motility of the isolates. Additional tests were performed for the characterization of the isolates, which included determination of the oxidase and catalase and acid production. In order to determine the

Isolation of calcium carbonate dissolving bacteria (CCDB) from calcareous sodic soils

carbonates ($CaCO_3$ and $MgCO_3$) dissolution potential of bacterial isolates, the zone of clearance around the colonies in the specific media was considered as positive for carbonate dissolution capabilities. Five isolates showed potential for dissolution of carbonates based on clear zone formation.

Screening and evaluation of Wheat, Mustard and Rice genotypes for sodicity tolerance (Ravikiran KT)

Wheat

Station trial

Four station trials were conducted during Rabi 2021-22. In first experiment, a set of 225 entries from CIMMYT, Mexico was evaluated under sodicity (pH ~ 8.8) with checks KRL210, PBW343, HD2967, and PBW502 in augmented RCB design with five blocks in one 2.5m row. The best performing entries were 1176 (401 g/plot), 1180 (397 g/plot), 1118 (360 g/plot), 1088 (345 g/plot) and 1136 (337 g/plot). In a second experiment a set of 210 entries were assessed under pH ~9.1 in augmented RCB with 10 blocks in one row of 2m. The checks used were KRL210, HD3086, HD2009 and Kharchia 65. The entries found promising were KRS21149 (233 g/plot), KRS21022 (231 g/plot), KRS21176 (221 g/plot), KRS21143 (228 g/plot), and KRS21174 (207 g/plot). In third experiment, 25 advanced breeding lines were evaluated in RCBD with three replications under pH ~ 9.2 with a plot size of 2 sq m. The best performers of this experiment were KRL2014 (174 g/plot), KRL283 (158 g/plot), KRL2006 (155 g/plot), and KRL2020 (150 g/plot) (C.D. at 5% - 28.56). In the fourth experiment, 10 promising entries were evaluated in RCBD with three replications among which the top three entries were KRL2028 (129 g/plot), KRL210 (107 g/plot) and KRL2007 (107 g/plot) (C.D. at 5% - 20.92).

State varietal trials

Five entries KRL-386, KRL-377, KRL-370, KRL-423 and KRL-1803 received from Karnal were submitted and evaluated under U.P. state adaptive trial under sodic condition at two RATDS centres, Hardoi and Etawah during Rabi, 2021-22. Among these KRL-370 and KRL-386 were identified for release for the salt affected soils of Uttar Pradesh. Remaining entries were promoted to next year of testing.

Mustard

National trial

A set of 11 entries were evaluated under high sodicity (pH ~ 9.2) at Experimental research farm, Shivri, RRS, Lucknow in RCBD with three replications as a part of AICRP on Rapeseed-Mustard: Salinity/alkalinity trial (AVT-1)-2021-22 during Rabi, 2021-22. Data were recorded on grain yield and its contributing traits. Seed yield (kg ha^{-1}) ranged between 1111.1 and 1849.38 with a mean of 1419.75 (C.D.$_{.5\%}$ - 247.28). Highest seed yield was registered by CSCN 21-4 with a mean seed yield of 1849.38 kg/ha. In a second trial, a set of five entries were evaluated under three level fertility levels (100% RDF, 125% RDF, and 150% RDF) in split plot design with three replications. In general, all the entries showed superior seed yields in 150% RDF and the entry Ag-26 showed the highest grain yield across all the treatments.

State varietal trials

Under UP State Adaptive trial under sodic condition at two RATDS farms, Hardoi and Etawah, six entries (CS2007-165, CS2009-154, CS299-313, CS2009-335, CS 2005-143 and CS 2002-99) received from Karnal were tested during Rabi, 2021-22 and all these entries were promoted to next year of testing.

Mung

Sixteen Mungbean genotypes were evaluated as a part of Summer trail under AICRP on MULLaRP, 2022 under pH of 8.87±0.1. The seed yield varied between 179 kg ha^{-1} to 529.08 kg ha^{-1} with a mean of 385.57 kg ha^{-1}. The genotypes SAS-22-3 (529.08 kg ha^{-1}), SAS-22-14 (516.16 kg ha^{-1}), SAS-22-8 (495.20 kg ha^{-1}), SAS-22-2 (492.38 kg ha^{-1}) and SAS-22-1 (487.91 kg ha^{-1}) were best performing.

Rice

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

Advanced varietal trial – 2

AVT-2 comprised of 13 entries (5201 to 5213) including local check (CSR56) which were evaluated under high pH situation (~9.6) during Kharif, 2022 at experimental research farm, Shivri, RRS, Lucknow. The trial was laid out in RCBD with four replications. The plot size maintained was 3 m × 2 m with a line to line spacing of 20 cm and plant to plant spacing of 15 cm. Significant reduction was observed in plant biomass and grain yield among all the entries tested. The entries, 5205 and 5203 were found to be the most early and the entries, 5205 (3333 kg ha^{-1}), 5208 (3264 kg ha^{-1}), 5210 (3215 kg ha^{-1}), 5203 (2771 kg ha^{-1}) and 5202 (2604 kg ha^{-1}) were found to be promising in terms of grain yield (trial mean – 2509 kg ha^{-1}).

Advanced varietal trial – 1

AVT-1 comprised of 15 entries (5301 to 5315) including local check (CSR56) which were evaluated under high pH situation (~9.5) during Kharif, 2022 at experimental research farm, Shivri, RRS, Lucknow. The trial was laid out in RCBD with four replications. The plot size maintained was 3 m × 2 m with a line to line spacing of 20 cm and plant to plant spacing of 15 cm. Significant reduction was observed in plant biomass and grain yield among all the entries tested. The entries 5309 (3583 kg ha^{-1}), 5308 (3438 kg ha^{-1}), 5306 (3375 kg ha^{-1}), 5305 (3354 kg ha^{-1}), and 5302 (3313 kg ha^{-1}) to be promising in terms of grain yield (trial mean – 3103 kg ha^{-1}). Compared to local check (CSR56) all of them showed higher days to 50% flowering with lowest being 5312 (84 days) and highest being 5303 (117 days).

Initial varietal trial

IVT comprised of 24 entries (5401 to 5424) including local check (CSR56) which were evaluated under high pH situation (~9.4) during Kharif, 2022 at experimental research farm, Shivri, RRS, Lucknow. The trial was laid out in RCBD with four replications. The plot size maintained was 3 m × 2 m with a line to line spacing of 20 cm and plant to plant spacing of 15 cm. Significant reduction was observed in plant biomass and grain yield among all the entries tested. The entries, 5409 (3000 kg ha^{-1}), 5401 (2833 kg ha^{-1}), 5403 (2750 kg ha^{-1}), 5416 (2750 kg ha^{-1}) and 5421 (2583 kg ha^{-1}) were found to be promising in terms of grain yield (Trial mean – 2143 kg ha^{-1}).

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 farm, Lucknow during Kharif, 2022 with the aim to study the nutrient responsiveness and use potential of promising AVT-2 entries. The trial was conducted in split plot design with two fertilizer levels - 50% RDF and 100% RDF and eight genotypes and five checks including local check (CSR56) replicated thrice. The plot size adopted was 5 m × 1 m with a pH_2 of ~8.9. All the entries showed an increased grain yield with increase in the fertilizer from 50% to 100% RDF. However, among the entries tested, CSR 46 registered highest grain yield (3.4 t ha^{-1} under 50% RDF and 5.5 t ha^{-1} under 100% RDF) under both fertilizer level and among the test genotypes, IET 29356 and IET 29366 were found promising under 100% RDF whereas IET 29360 and IET 29365 were best under 50% RDF.

Seed production and distribution

During Rabi, 2021-22, 12.8 Q foundation seed of salt tolerant wheat variety KRL 210 and 4.7 Q foundation seed of salt tolerant mustard variety CS 60 was produced and distributed to the farmers. During Kharif, 2022, 3Q TL seed of CSR 36 and 25Q TL seed of CSR 46 have been produced. A total of 10 Q TL seed of KRL 283 and 1.5 Q seed of CS 60 was distributed to the farmers under SC-SP sub-plan.

Germplasm maintenance

A total of 80 released varieties of rice including those released from ICAR-CSSRI are being maintained at RRS, Lucknow. A total of 250 wheat advanced breeding lines and five released varieties of mustard is being multiplied and maintained.

Development of soil moisture sensor to automate solar PV based irrigation system for salt affected soils (Atul Kumar Singh, C. L. Verma, A. K. Bhardwaj, Anju K. Singh and V. K. Mishra)

Sensor based instrument do provides opportunity for real time estimation of soil water content but most of the commonly available instruments are sophisticated and mostly manageable at R&D level. At farm level, user-friendly soil moisture sensors are required, with less technicality and cost effective to facilitate application of adequate amount and timely application of irrigation water. Considering above the project aims to develop a soil moisture sensor, this further can be explored to engage the developed sensor in automation of irrigation systems In this endeavour, a prototype of soil moisture sensor has been developed which can indicate different soil moisture levels. The developed prototype is based on resistive concept. It indicates soil moisture status through four light indicators. The developed prototype is suitable to measure soil moisture in the range of 10 to 25 percent i.e below field capacity. The prediction pattern of soil moisture by the prototype during performance testing in field indicates R^2 value of 0.68. The field testing

Soil Moisture Sensor

Table 63. Scheme of light indication based on sensor value and soil moisture

Sl. No.	Sensor Value (mV)	LED lights	Decision
1	Less than 1300	BLUE	Ample moisture **Irrigation not required**
2.	1301-1600	GREEN	Adequate moisture **Irrigation not required**
3.	1601-1800	YELLOW	Low moisture **Irrigation required**
4.	Greater than 1801	RED	Very Low moisture **Immediate irrigation required**

result of prototype reflects that the sensing range of soil moisture content of developed soil moisture sensor has been enhanced and the sensor was able to read the variation in soil moisture content between 6 percent to 38 percent. The correlation between sensor value and soil moisture shows that second-degree polynomial relationship was found satisfactory. The R^2 value observed was 0.68. The prediction pattern shows better results when soil moisture content was in the range of 10 to 25 percent while when soil moisture content goes above 25 percent the fluctuation in observation was greater. Based on results it was observed that the developed prototype may be useful for decision making regarding when to irrigate during crops grown in rabi season. Whereas, incase of rice crop since the field is moreover under saturation hence the prototype may require further development. Considering this it was decided to finally make a product which provide indication about soil moisture content for scheduling irrigation in rabi crops (photo). Based on the results during the field test four ranges of moisture were fixed to develop a prototype which can be used at field level. The four ranges were fixed to indicate the status of soil moisture content and are presented in the table 63.

The above ranges are fixed keeping in view the level of soil moisture content at wilting point and field capacity which ranged between 12-14 percent for wilting point and 24-26 percent for field capacity of the soil where prototype was tested. Based on soil moisture depletion concept for scheduling irrigtaion and combining the physical observations in field during the test the ranges for indicating through different LED colour lights were fixed. The BLUE colour lights indicate ample moisture which falls when sensor reading is below 1300 mV which suggest irrigtaion is not required. The GREEN light indicate for adequate moisture when the sensor value was in the range of 1301 to 1600 mV and it suggests irrigation is not required. The YELLOW light indicated for low moisture which suggest for requirement of irrigtaion and the sensor values ranged between 1601 to 1800 mV. The fourth RED light reflects towards very low moisture which suggests for immediate irrigation and it glows when sensor value goes above 1801 mV.

Development of climate smart sodic village in Uttar Pradesh (Atul Kumar Singh, T. Damodaran, Sanjay Arora, C.L. Verma, Arjun Singh, Ravi Kiran, S.K. Jha, R.H. Rizvi and Ranjay Kumar Singh)

The situation of agriculture under sodic environment becomes complex due to several direct and indirect effects of climate change such as precipitation patterns, higher atmospheric temperatures, increase in frequency of droughts, floods and storms, greenhouse gas emissions. It has been realized that at farmers level the awareness to climatic problems in combination with existing problems. In this project attempt has been made to assess the existing practices in sodic agriculture and introduce suitable acceptable practices through demonstration and knowledge sharing at farmers field for greater awareness.

Two panchayat one each in Unnao and Hardoi were identified namely Shankarpur (Unnao) and Kasimabad-Bariyaa (Hardoi). Most of the lands under these panchayat are also under cultivation but due to high sodicity level part of the land results in poor agricultural productivity. Hence for project intervention we selected one hamlets in panchayat where sodicity level is highest. Before deciding the interventions preliminary information of the panchayat were gathered through discussions with farmers and by conducting PRA presented in table 64. About 55 farmers opted for different interventions covering 22 ha of area at Ullarapur and 83 farmers covering 38 ha area at Hannihya. This resulted in involvement of about 140 farmers covering 60 ha area under different interventions at Unnao and Hardoi sites. To facilitate interactions within the farmers several meets were organized at both the sites where farmers narrated about their experiences.

It is observed that farmers of focused villages having sodic land are generally taking Rice and Wheat as major crop. In case of fertilizer application mainly use of N and P is reported which in the range of 120-180 Kg/ha (N) and 30 to 90 Kg/ha (P) whereas none of the farmers reported use of K. This shows higher use of Nitrogen and deficient in P and K. The average paddy productivity was reported to be in the range of 2.5 to 3.0 t/ha whereas incase of wheat the productivity was in the range of 2 to 2.5 t/ha. Generally, farmers reported to practice 3 to 5 irrigations in paddy depending upon rainfall and the same in wheat was reported to be 2 to 4. As reported by the farmers generally hybrid or traditional paddy and wheat varieties is being used. In Hannihya village farmers never used gypsum for reclamation whereas incase of Ullarapur the farmers reported use of gypsum 15-20 years before. The farmers reported some of the major problem which they are facing in

Table 64. Profile of the identified panchayat

Item	Kasimabad-Bariyaa (Hardoi)	Shankarpur (Unnao)
Nos. of hamlets	8	2
Total population	3975	3700
Households	427	425
Total Agri land (ha)	172	550
Land affected by sodicity (ha)	63	160
Sodicity category	Normal to severe	Normal to severe
Number of farmers	366	375
Holding size	90-95% small and marginal	95% small and marginal
Source of irrigation	ground water	ground water & canal
Irrigation water rate (Rs./hr)	200-250	200-250
Use of gypsum earlier	no	yes
Major crops	paddy and wheat	paddy and wheat
Other crops	oilseed, pulses, vegetables, sugarcane, flowers, menta etc.	mustard
Use of salt tolerant varieties	no	no
Other key components of Agri system	cow, baffalo, goatary, poultry, fishery	cow, baffalo, goat

Table 65. Soil Characteristics of the samples collected from farmer's field

Soil Parameters	Ullarapur		Hannihya	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
EC (dS/m)	0.19 - 7.47	0.17 - 7.71	0.13 - 1.28	0.11 - 1.47
pH	7.1 - 10.0	7.5 - 10.0	7.0 - 9.1	7.46 - 10.1
ECe (dS/m)	0.57 - 18.05	0.51 - 18.46	0.50 - 2.80	0.42 - 1.55
pHe	7.8 - 9.4	7.28 - 8.94	7.6 - 9.12	8.28 - 9.17
OC (%)	0.26 - 0.45	0.12 - 0.22	0.21 – 0.49	0.12 - 0.21
Ca (meq/l)	1.0 - 15.5	0.5 - 2.5	1.0 - 6.0	0.5 - 2.0
Ca+Mg (meq/l)	1.0 - 20.5	1.0 - 4.5	1.5 - 6.0	1.0 -3.0
CO_3 (meq/l)	1.0 - 13.0	1.0 11.0	1.0 - 8.0	1.0 - 5.0
HCO_3 (meq/l)	0.0 - 11.5	2.0 - 7.5	1.0 - 8.0	1.0 - 5.0
Cl^- (meq/l)	2.5 – 65	2.5 - 57.0	2.5 - 10.0	2.5 - 6.0
Avail N (Kg/ha)	62.72 - 188.16	62.72 - 144.25	106.62 - 188.16	62.72 - 175.61
Na (ppm)	83.75 - 5707.00	77.95 - 5947.5	35.85 - 2327.5	38.3 - 3017.0
K (ppm)	59.5 - 221.75	61.75 - 165.5	62.75 - 233.0	61.75 - 165.0
Ca (meq/l)	5.5 - 23.5	4.5 - 20.0	10.5 - 19.5	10.5 - 20.5
Ca+Mg (meq/l)	2.0 15.5	2.0 - 15.0	5.5 - 18.5	3.5 - 17.0

agricultural perspective are: (I) timely sowing/planting of crops, (ii) timely availability of irrigation water, (iii) fall of groundwater level, (iv) excess rainfall during particular periods, (v) intermittent drought spells, (vi) erratic change in temperature, (vii) availability of quality agricultural inputs, (viii) rise of prices of agricultural inputs, (ix) lack of technical know how, (x) storage and marketing of farm produce, and (xi) production of crops not satisfactory. The soil samples of farmers field were taken from Ullarapur and Hannihya to understand the nature of soil before deciding any interventions. About 28 soil samples were collected from Ullarapur village of Unnao from different locations and similarly 14 soil samples were collected from different locations of village Hannihya of Hardoi during the month of April to June. The soil samples were analyzed for different parameters and the range (minimum to maximum) are depicted in table 65.

Based on information and discussions with farmers several interventions were planned to introduce at farmers field during the kharif 2022 that includes (a) Green manuring (Sowing of Dhaincha); (b) land laser leveling; (c) raising bund height, (d) salt tolerant crop varieties, (e) use of microbial bioformulations (Halo-Mix); (f) promoting use of crop residue decomposer (Halo-CRD); (g) promoting use of compost

The feedback from farmers were collected about impact of interventions introduced. The result were encouraging as farmers those adopted for green manuring they reported that they decreased the dose of Urea. In case of farmers those adopted Land Laser Levelling informed about uniform growth of crop, saving of water by 10-20 percent besides increase in yield. The farmers adopting raising of bund height reported that the 1-2 number of irrigations was reduced due to that there was saving of irrigation water. The farmers adopting the salt tolerant varieties reported yield between 3 to 4.5 t/ha which shows increasing trends with respect to the varieties they have been using earlier. The use of bioformulations resulted in better crop growth and farmers also reported that their crop yield increased, similar was also incase of farmers used compost.

Reclamation and Management of Salt Affected Vertisols

Assessment and mapping of salt affected soils of Gujarat using remote sensing and GIS (Anil R. Chinchmalatpure, Sagar Vibhute, Vineeth T.V., A.K. Mandal, M.J. Kaledhonkar and Arijit Barman)

In the present study, to characterize, assess and map salt affected soils of Gujarat state using remote sensing and GIS till date soil samples were collected from 1579 geo-reference points in different districts of Gujarat using auger upto 120 cm soil depth. Among the soil samples analysed for 0-15 cm depth, about 74.66% soil samples recorded EC_e less than or equal to 4 dS/m whereas, 25.34% soil samples showed ECe more than 4.0 dS/m. This analysis suggests that saline area is about 25% and normal area is about 75% (Fig. 38). The data showed the predominance of subsurface salinity. Data on soil pH_s

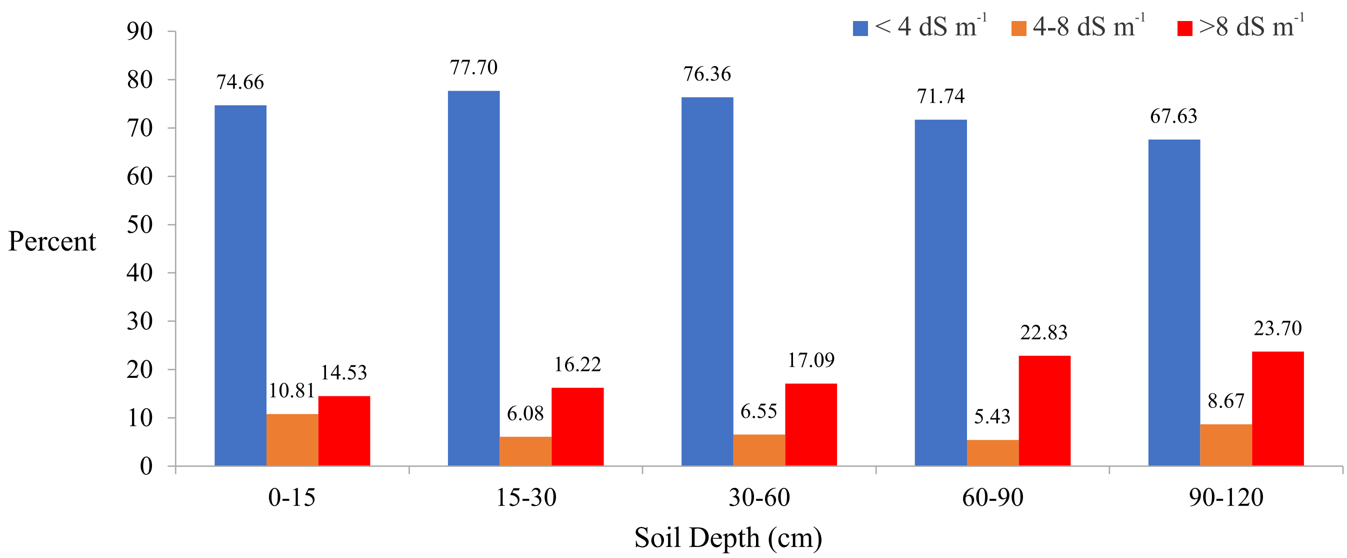


Fig 38. Percent representation of soil samples in different salinity classes

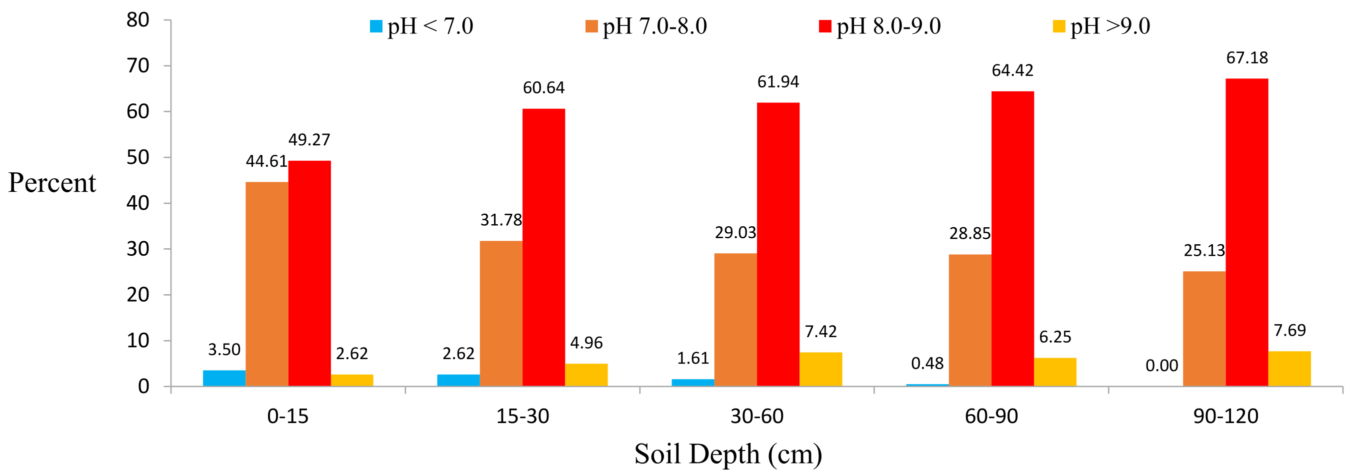


Fig 39. Percent representation of soil samples in different pH classes

Table 66. Physico-chemical properties of soil samples for different depths from geo-referenced sampled points

	EC_e (dS m^{-1})	pH_s	Ca^{++} (me l^{-1})	Mg^{++} (me l^{-1})	Na^{+} (me l^{-1})	K^{+} (me l^{-1})	CO_3^{--} (me l^{-1})	HCO_3^{-} (me l^{-1})	Cl^{-} (me l^{-1})	SO_4^{2-} (me l^{-1})
Soil Depth 0-15 cm (Number of Samples 693)										
Mean	13.78	7.17	15.93	27.95	176.13	2.16	1.40	1.51	141.69	7.16
Max	165.0	8.84	341.0	1080.0	4683.04	162.23	18.0	19.25	4200.0	86.62
Min	0.23	5.45	0.02	0.03	0.20	0.01	0.00	0.00	1.50	0.00
SD	27.95	0.49	34.78	74.39	522.57	11.32	1.70	1.80	349.03	10.38
Soil Depth 15-30 cm (Number of Samples 583)										
Mean	8.93	7.32	9.10	17.15	112.43	1.15	1.54	1.53	85.12	5.80
Max	115.0	9.06	311.0	585.0	4096.5	132.8	20.0	21.25	2550.0	98.08
Min	0.22	5.36	0.02	0.03	0.25	0.01	0.00	0.00	1.00	0.00
SD	18.33	0.52	20.83	43.50	350.21	6.26	2.02	1.95	218.53	9.10
Soil Depth 30-60 cm (Number of Samples 533)										
Mean	9.67	7.37	8.62	16.34	113.10	1.02	1.54	1.50	89.49	6.27
Max	106.0	9.25	145.0	315.0	3040.87	126.3	24.0	16.75	1725.0	87.50
Min	0.23	5.62	0.00	0.00	0.19	0.00	0.00	0.00	1.00	0.00
SD	18.36	0.52	16.58	35.25	304.35	5.82	2.29	2.05	199.99	9.40
Soil Depth 60-90 cm (Number of Samples 400)										
Mean	11.18	7.37	9.40	18.73	140.33	1.35	1.65	1.63	106.01	7.14
Max	121.0	9.18	91.00	290.0	3793.48	171.8	18.00	17.00	1850.0	96.71
Min	0.21	6.05	0.00	0.00	0.01	0.00	0.00	0.00	1.00	0.00
SD	19.98	0.63	16.32	40.30	397.01	8.87	2.33	2.11	225.73	10.03
Soil Depth 90-120 cm (Number of Samples 361)										
Mean	11.99	7.42	9.61	19.11	134.81	1.31	1.68	1.73	116.44	7.53
Max	101.0	9.25	90.5	295.0	2938.7	141.74	21.00	16.75	2075.00	90.27
Min	0.22	6.18	0.00	0.00	0.20	0.01	0.00	0.00	0.02	0.00
SD	20.32	0.53	16.34	37.40	316.04	7.75	2.35	2.18	242.47	10.46

analysis showed that large number of samples fall under 8.0 to 9.0 pH category and soil pH increased with depth (Fig. 39). The data on soluble cation and anions revealed that among cations the dominance of Na^+ followed by Mg^{2+}, Ca^{2+}, and K^+ and among anions Cl^- > SO_4^{2-} > CO_3^{2-}>HCO_3^-.

The electrical conductivity of saturation extract of surface soils (0-15 cm) ranged from 0.23 to 165.0 dS/m. The pH_s ranged from 5.45 to 9.26 (Table 66). The electrical conductivity of saturation extract of soils (15-30 cm depth) ranged from 0.22 to 115.0 dS/m. The pH_s ranged from 5.36 to 9.06. The electrical conductivity of saturation extract of soils (30-60 cm depth) ranged from 0.23 to 106.0 dS/m. The pH_s ranged from 5.62 to 9.25. The electrical conductivity of saturation extract of soils (60-90 cm depth) ranged from 0.21 to 121.0 dS/m. The pH_s ranged from 6.05 to 9.18. The electrical conductivity of saturation extract of soils (90-120 cm depth) ranged from 0.22 to 101.0 dS/m. The pH_s ranged from 6.18 to 9.25 with mean value of 7.42 Among the soluble ions, sodium is dominant among all cations and chloride is dominant among anions in all soil depths.

Impact of agricultural waste on the shrink-swell behavior, cracking dynamics and yield of crops in saline *Vertisol* of Gujarat (Anil R. Chinchmalatpure Sagar Vibhute and Monika Shukla)

Soil cracks are of critical importance in a variety of circumstances and also pose serious problems in crop production in Vertisols. The presence of 2:1 type expanding clays e.g. montmorillonite causes swelling and shrinking in Vertisols and responsible for development of cracks. These cracks are sometimes as deep as 50 cm and more. These cracks affects yield through poor crop growth due to hydrological problems as well as loss of nutrients and water to the deeper layers. An experiment was conducted in a randomized complete block design (RCBD) to study the effect of agricultural waste viz., rice straw, sugarcane bagasse, water hyacinth and chopped cotton stalk and their application as surface retention on the cracking behaviour of saline Vertisols of Gujarat in a pigeon pea and wheat cropping system. The treatments such as T1 = Fallow land + no waste, T2 = Crop + no waste, T3 = Crop + Rice straw (@5 t/ha), T4 = Crop + Rice Straw (@10 t/ha), T5 = Crop + Sugarcane bagasse (@5 t/ha), T6 = Crop + Sugarcane bagasse (@10 t/ha),

Table 67. Effect of crop residues on the physical properties (related to cracking pattern and behavior of Vertisols)

SN	Dry Bulk Density (Bdd)	Wet Bulk Density (Bdw)	Max. Water Holding Capacity (MWHC) (%)	COLE core {(BDd/BDw)^(1/3)-1}	Volumetric shrinkage (VS){(COLE core +1)^3-1
T1	1.40	1.68	21.15	0.0589	0.187
T2	1.38	1.66	21.85	0.0597	0.190
T3	1.36	1.56	24.84	0.0447	0.140
T4	1.27	1.51	26.48	0.0561	0.178
T5	1.31	1.58	22.89	0.0505	0.192
T6	1.26	1.49	24.88	0.0543	0.172
T7	1.25	1.47	24.23	0.0526	0.166
T8	1.23	1.45	24.86	0.0534	0.169
T9	1.36	1.58	22.65	0.0487	0.153
T10	1.37	1.55	22.76	0.0403	0.126
SEd+	0.02	0.03	1.60		

Table 68. Effect of crop residues on the dimensions of cracks formed in Vertisols

SN	Crack Length (L)(m)	Crack Width (W)(m) (weighted mean)	Crack Depth (D)(m) (weighted mean)	Surface area (m^2)(2.L.D.)	Crack Volume (m^3)(L.W.D)	Crack Area Density (%) (Area of cracks/ net area of plot; 12 m^2)
T1	3.793	0.0290	0.530	4.024	0.058	0.918
T2	3.703	0.0270	0.501	3.708	0.050	0.832
T3	3.550	0.0230	0.376	2.667	0.031	0.679
T4	3.680	0.0223	0.371	2.728	0.030	0.685
T5	3.486	0.0230	0.310	2.163	0.025	0.668
T6	3.470	0.0237	0.340	2.361	0.028	0.685
T7	3.520	0.0227	0.280	1.974	0.022	0.665
T8	3.463	0.0213	0.290	2.011	0.021	0.615
T9	3.606	0.0247	0.305	2.199	0.027	0.743
T10	3.490	0.0230	0.323	2.258	0.026	0.669
SEd±	NS	0.03	0.06			

T7 = Crop + Water hyacinth (@5 t/ha), T8 = Crop + Water hyacinth (@10 t/ha), T9 = Crop + Cotton stalk (@5 t/ha), and T10 = Crop + Cotton stalk (@10 t/ha) were imposed just before the sowing of the crop. The textural analysis of the soil of experimental site revealed the clayey in nature with clay content 60 to 70%. The results of the analysis of soil samples revealed that the ECe of soil (surface horizon) varied from 0.56 dS m^{-1} in T_4 (paddy straw @ 10t/ha) to 0.70 dS m^{-1} in T_1. Slight increase in organic carbon was observed with T_6 (0.71%) treatment followed by T5 (0.66%), T8 (0.67%) and T7 (0.63%) over T1 (0.45%) treatments.

Physical properties like bulk density, water holding capacity and COLE values were measured for soils under different treatments and it is observed that the dry and wet bulk density values were minimum under T8 treatment followed by T7, T6 and T4. Maximum water holding capacity of soil was obtained for soils under T4 treatment (Table 67). Crack dimensions like crack length, width, depth, surface area, crack volume and crack area density were measured. Minimum crack volume and crack area density was observed in T8 followed by T7, T5 and T6 (Table 68) reflecting ameliorative effect of crop residues in development of cracks. Crack area density (CAD) of the soil was initially 0.918% and after application of different crop wastes CAD values decreased. Minimum was observed under T8. Among all treatments Water hyacinth and sugarcane bagasse showed positive impact on cracking properties of Vertisols.

Pulpwood-based silvipastoral systems for saline *Vertisols* (Monika Shukla and Vineeth TV)

After initial screening of various pulpwood species, Eucalyptus and Acacia were transplanted in field during September 2019. Growth parameters of these 2.5 year old trees has been taken at the time of second year fodder sorghum sowing and average height of Eucalyptus was 10.40 m and Acacia mangium was 6.45 m. Diameter at breast height was also higher in Eucalyptus (20.40 cm) than in Acacia mangium (16.33 cm).

Intercropping experiment

Field studies at experimental farm, Samni of ICAR-CSSRI, RRS, Bharuch were conducted for intercropping of different fodder crops/grasses with two pulpwood species Acacia mangium and Eucalyptus to find out suitable silvi-pastoral system for saline Vertisols. Due to continued failure of establishment of Chloris gayana and Echinochloa crusgalli under tree plantation these grasses were replaced with Dichanthium annulatum (Marvel grass, Jinjva) and wild grass Sorghum halepense (Johnson grass) respectively. Sorghum halepense planting was done in the month of October 2021. Planting of Dichanthium annulatum was done in the month of December 2021. Establishment of both grasses was satisfactory.

Tree + Fodder Sorghum

Tree + Fodder sorghum intercropping

In the month of February 2022, fodder sorghum variety GFS 6 was sown between the rows of both tree species with spacing of 50 cm. Various growth and yield parameters of fodder sorghum were recorded to study their performance as intercrop under different tree species. Data revealed that overall performance of sorghum crop was better under the Eucalyptus as compared to Acacia mangium. Growth of crop was observed restricted under crop sown in border rows (1 m away from tree trunk). Due to short tree height of Acacia mangium which might interfered in the growth and yield of sorghum crop, this

Table 69. Growth and yield parameters of fodder sorghum intercropped with different tree species during summer

Tree		Plant Height (cm)	No. of Leaves /Plant	Stem Dia (cm)	Fresh Weight /Plant (g)	Fresh Weight Leaf/ plant (g)	Fresh Weight Shoot/ plant (g)	Dry Weight /Plant (g)	Dry Weight Leaf/ plant (g)	Dry Weight Shoot/ plant (g)	DMC (%)	GFY (t ha^{-1})	GIF Fodder (Rs/ha)
Acacia mangium	Border rows	79.20	4.27	0.43	25.73	5.99	19.75	8.87	2.82	6.05	34	3.75	13137
	Middle rows	85.13	4.53	0.56	35.47	9.37	26.10	14.51	4.47	10.05	41	4.97	17399
Eucalyptus camaldulensis	Border rows	87.60	4.33	0.59	31.67	9.25	22.42	13.46	4.62	8.84	43	4.90	17165
	Middle rows	96.07	4.60	0.68	40.07	10.51	29.56	18.52	4.99	13.53	46	5.32	18605
	SeM	3.09	0.14	0.04	1.35	0.45	1.18	1.37	0.40	1.05	4	0.31	
	CD	9.63	0.44	0.13	4.21	1.41	3.66	4.28	1.24	3.27	NS	0.97	

DMC: Dry Matter Content, GFY: Green Fodder Yield, GIF: Gross Income From

Table 70. Growth and yield parameters of Dichanthium annulatum intercropped with different tree species during summer

Tree		Plant Height (cm)	No. of Leaves /Plant	No. of Tillers	Fresh Weight /Plant (g)	Dry Weight /Plant (g)	DMC (%)	GFY (t ha^{-1})	GIF Fodder (Rs/ha)
Acacia mangium	Border rows	150.47	375.33	36.60	174.33	23.67	13.69	4.85	9,708
	Middle rows	158.53	470.60	48.07	218.67	30.33	13.85	6.77	13,539
Eucalyptus camaldulensis	Border rows	154.53	420.00	53.20	191.67	36.33	19.76	7.39	14,783
	Middle rows	161.93	541.20	55.40	236.40	47.33	20.04	8.00	15,999
	SeM	1.68	15.07	2.99	10.57	3.05	2.13	0.59	
	CD	5.22	46.92	9.31	32.89	9.50	NS	1.83	

DMC: Dry Matter Content, GFY: Green Fodder Yield, GIF: Gross Income From

impact was more pronounced as compared to Eucalyptus. Crops sown in the middle rows (crop rows starting at 1.5m away from tree trunk) under Eucalyptus gave better growth and yield parameters and green fodder yield t/ha. Poor performance of fodder sorghum was observed in the border row crop sown as intercrop with Acacia mangium and given lowest green fodder yield (3.75 t/ha). Highest sorghum green fodder yield (5.32 t/ha) and gross income from fodder (Rs. 18,605/- per ha) recorded from the middle row intercrop (crop rows starting at 1.5m away from tree trunk) with Eucalyptus followed by middle row intercrop with Acacia mangium (4.97 t/ha) (Table 69).

Tree + Dichanthium annulatum

Tree + *Dichanthium annulatum* intercropping

In the month of December 2021, rooted slips of Dichanthium annulatum was sown between the rows of both tree species with spacing of 50 cm x 50 cm. Data revealed that overall performance of grass was better under the Eucalyptus as compare to Acacia mangium. Growth of crop was observed restricted under crop sown in border rows (1 m away from tree trunk) (Table 70). Border impact was more visible in Acacia mangium due

Table 71. Growth and yield parameters of Sorghum halepense intercropped with different tree species during summer

Tree		Plant Height (cm)	No. of Leaves /Plant	No. of Tillers	Fresh Weight /Plant (g)	Dry Weight /Plant (g)	DMC (%)	GFY (t ha^{-1})	GAIF Fodder (Rs/ha)
Acacia mangium	Border rows	185.07	173.67	16.27	1.15	382.67	33.33	39.23	1,37,320
	Middle rows	223.00	205.73	17.73	1.26	423.33	33.57	47.01	1,64,540
Eucalyptus camaldulensis	Border rows	222.67	259.60	19.67	1.36	441.67	33.24	52.96	1,85,357
	Middle rows	248.80	290.93	22.20	1.60	536.67	34.02	59.28	2,07,477
	SeM	10.00	21.85	1.08	0.08	5.78	1.77	3.33	
	CD	31.13	68.00	3.37	0.25	17.99	NS	10.36	

DMC: Dry Matter Content, GFY: Green Fodder Yield, GAIF: Gross Addition Income From

to short tree height which might interfere in the growth and yield of grass. Grass sown in the middle rows (crop rows starting at 1.5 away from tree trunk) under Eucalyptus gave higher growth and yield parameters and green fodder yield (8.00 t/ha) and gross income from fodder (Rs. 15,999/ha).

Tree + Sorghum halepense

Tree + *Sorghum halepense* intercropping

Rooted slips of Sorghum halepense was sown in the month of October 2021, between the rows of both tree species with spacing of 50 cm x 50 cm. Performance of S. halepense was better under the Eucalyptus as compare to Acacia mangium in terms of growth and yield. Growth of crop was found restricted under crop sown in border rows (1 m away from tree trunk) under both trees. Border impact was more visible in Acacia mangium due to short tree height which might interfere in the growth and yield of grass. Grass sown in the middle rows (crop rows starting at 1.5 away from tree trunk) under Eucalyptus gave higher growth and yield parameters and green fodder yield (59.28 t/ha) and gross income from fodder (Rs. 2,07,477/- per ha) (Table 71).

Performance of Indian mustard (*Brassica juncea*) under saline *Vertisols* (Monika Shukla, Vineeth TV and Anil R. Chinchmalatpure)

Mustard is not cultivated in the Bara tract of Gujarat. Specially under saline Vertisols usually in rabi season, poor-quality groundwater is available for taking rabi crops. ICAR-CSSRI has developed six salt-tolerant varieties of Indian mustard, which may be introduced as a new crop under these areas for improving livelihood of the farmers. A suitable sowing date is very important aspect for good agronomic performance of any crop. Keeping these points in view, the present study has been conducted to find out suitable salt tolerant variety and the refinement of package of practices for mustard for saline Vertisols of Gujarat.

Rabi experiment 2021-22

From the previous year experience, it was observed that October month is not suitable for mustard sowing as germination and initial seedling growth was seriously affected by high temperature. So, this year first sowing of mustard started from 2nd November and

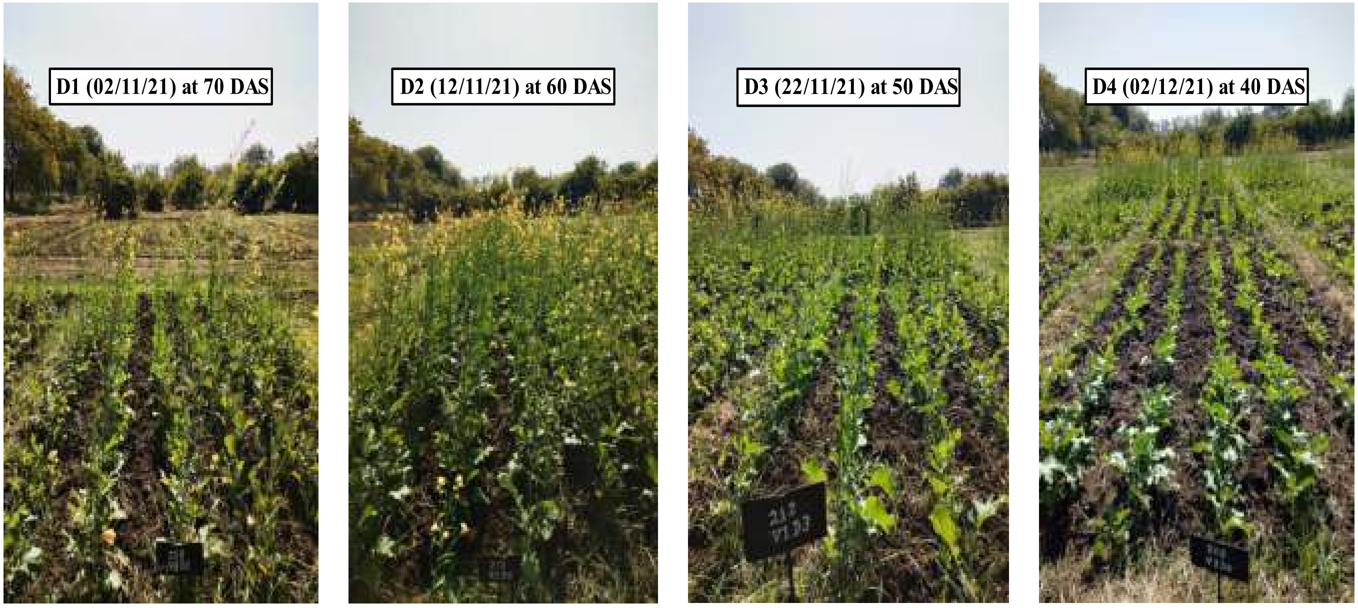
Table 72. Different growth parameters of mustard as affected by variety and date of sowing during 2021

Variety	PH (cm)		DW (g)		Plant Popu lation ($1m^2$)	No. of Primary Branches /Plant	No. of Secondary Branches /Plant	Days to 50% Flower ing	No. of Pods/ Plant	No.of Seeds/ Pod	Days to Physio logical Maturity	Seed Yield/ Plant (g)	Test weight (g)
	40 DAS	80 DAS	40 DAS	80 DAS									
Variety													
V1-CS 56	34.37	147.31	3.49	22.20	11.17	5.13	7.52	49.61	135.26	6.94	112	3.75	4.32
V2-CS 58	35.40	155.02	3.60	25.50	11.56	5.11	6.59	50.22	129.33	6.91	111	4.16	4.48
V3 CS-60	31.48	145.06	3.34	20.01	10.67	4.93	6.74	49.17	121.46	6.69	111	3.33	4.20
SeM	1.12	2.82	0.11	0.83	0.42	0.20	0.32	0.61	5.37	0.10	0.35	0.16	0.09
CD	3.22	8.12	0.32	2.39	NS	NS	NS	NS	NS	NS	NS	0.47	NS
Date of Sowing													
D1-02 Nov.	21.28	148.74	2.40	18.09	8.89	4.74	7.19	59.00	155.81	7.15	123	4.71	4.11
D2-12 Nov.	43.71	175.37	4.64	33.87	12.11	5.70	9.59	55.33	206.11	10.21	118	8.10	4.75
D3-22 Nov.	47.89	164.59	3.94	28.48	11.78	5.56	8.04	49.11	146.33	7.67	112	5.29	4.51
D4-02 Dec.	36.53	158.22	3.82	20.89	11.33	4.96	6.67	46.89	128.30	6.72	109	2.07	4.38
D5-12 Dec.	28.36	125.56	3.72	18.78	11.44	4.70	5.33	44.11	70.11	4.70	106	1.40	4.30
D6-22 Dec.	24.73	122.30	2.35	15.32	11.22	4.67	4.89	43.56	65.44	4.64	99	0.91	3.96
SeM	1.59	3.99	0.16	1.17	0.59	0.28	0.45	0.86	7.59	0.14	0.49	0.23	0.13
CD	4.56	11.48	0.45	3.37	1.70	0.81	1.29	2.48	21.82	0.40	1.42	0.66	0.38

PH: Plant Height, DW: Dry Weight/Plant

with 10 days interval sowings were done in 6 different dates upto 22nd December. Irrigation has been given at the critical stages and whenever needed to the crop with available saline groundwater (EC_{iw}- 6-7 dS m^{-1}). In all dates of sowing, crop established and data were recorded for various agro-morphological parameters of mustard (Table 72).

Data revealed that significantly highest plant height and dry weight per plant at 40 and 80 DAS was recorded with the variety CS 58 which was statistically at par with CS 56 except for dry weight per plant at 40. Plant population and days to 50% flowering was found statistically similar for all the varieties which means all varieties germinated well under saline Vertisols. Different date of sowing significantly affected various growth parameters of mustard. Data revealed that significantly highest plant height at 40 DAS and at 80 DAS was recorded with sowing on 22 November (D3) and 12 November (D2) sowing respectively. Dry weight per plant at 40 DAS and 80 DAS was observed maximum with the sowing on 12 November (D2). Plant height and dry weight per plant drastically reduced at later date of sowings i. e. at 12th and 22nd December (Table 72). Significantly highest plant population was recorded with sowing on 12 November (D2) which reflected good germination and establishment of crop on sowing at this date. Days to 50% flowering was strongly affected with date of sowing and with sowing on 02 November 2021 (D1) crop



Growth of crop at different dates of sowing

came to flowering at 59 days but this duration decreased with late sowing of mustard as crop came to flower at 55 days for 12 November (D2) sowing and lowest at 43 days for sowing on 22 December (D6). It was observed that most of the yield parameters were not affected with different variety.

Effect of date of sowing on yield parameters

Significantly highest values for yield parameters and seed yield were recorded with sowing of crop on 12 November (D2). Days to physiological maturity were highest (123 days) for 02 November (D1) sowing which reduced upto 99 days for 22 December (D6) sowing. Lowest values for all yield and yield parameters were recorded with late sowing on 22 December (D6). It was observed that duration of crop is reduced by 24 days with late sowing (02 December) as compared to sowing on 02 November that gave less time to growth of crop which further restricted assimilation of photosynthate and their partitioning in the seed.

Water management strategies for sustainable wheat production using saline groundwater in *Vertisol* (Sagar D. Vibhute, Vineeth T. V., Monika Shukla and Anil R. Chinchmalatpure)

Efficient water management is essential to reduce irrigation induced soil salinization problem arising due to application of poor quality water. In present study 3 irrigation methods viz. mini-sprinkler, drip and border irrigation along with KRL-210 salt tolerant wheat variety was evaluated for Vertisol of Gujarat. Irrigation water of 8 dS m^{-1} EC was applied during entire cropping season.

The results of 2021-22 rabi season (Table 73) revealed that the drip irrigation treatment has given superior grain yield. The grain yield in mini-sprinkler and border irrigation was at par with average grain yield of 2.7 t ha^{-1} whereas more than 20 % increase in grain yield was observed in drip irrigation. The significantly higher test weight showed superior grain quality under drip irrigated wheat. No significant sodium accumulation was observed in plant root and panicle for all treatments.

Table 73. Grain yield, crop parameters and ionic study of plant under different treatments

Treatment	Grain Yield(t ha^{-1})	Test Weight (g)	K/Na Ratio		
			Root	Shoot	Panicle
I_1 - Mini-sprinkler	2.75[b]	37.1[b]	1.00	2.85[b]	1.06
I_2 - Mini-sprinkler Deficit	2.63[b]	38.5[b]	1.00	2.92[b]	1.07
I_3 - Drip	3.37[a]	43.6[a]	1.02	4.80[a]	1.39
I_4 - Drip Deficit	3.29[a]	43.1[a]	1.00	5.05[a]	1.58
I_5 - Border	2.68[a]	39.2[a]	1.04	4.84[a]	1.30
I_6 - Surge Border	2.62[a]	38.9[a]	1.01	4.68[a]	1.32

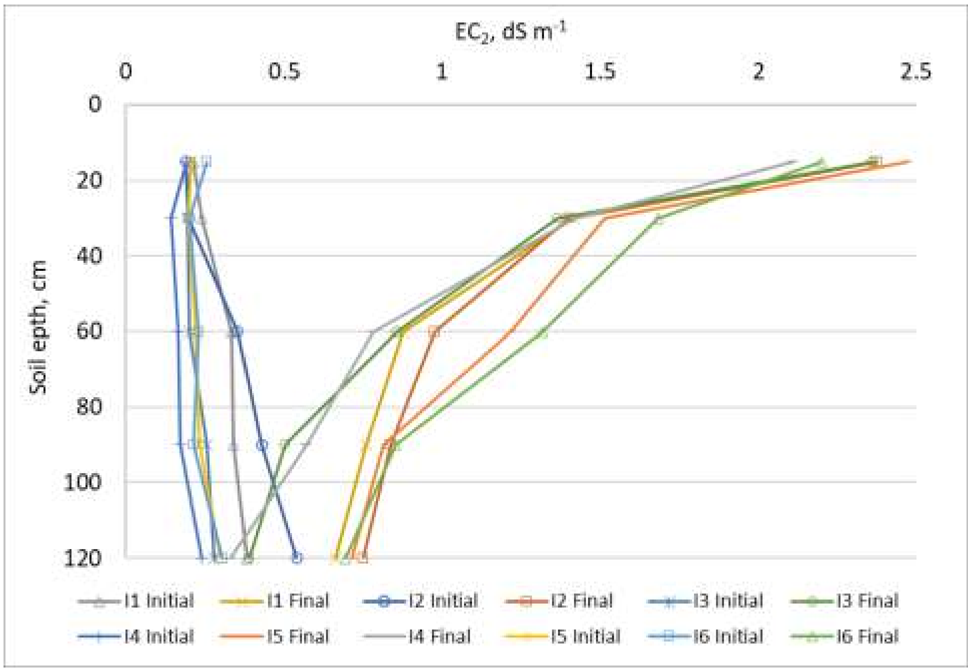


Fig 40. Seasonal salt accumulation under different treatments

Salt accumulation in crop root zone was also studied under different treatments and pre-season EC_2(Initial) and post harvesting EC_2 (Final) values are presented in figure 40. It was observed from the figure that the average EC_2 was increased by around 2 dS m^{-1} in all the treatments for surface layer. However, in case of drip irrigation, subsurface salt build up was lower as compared to border and mini sprinkler irrigation system. Moreover, EC_2 values under different treatments were again measured after the monsoon 2022 season to study the effect of monsoon rainfall on leaching of accumulated salts and it was found that the EC_2 value in all treatments has gone below 0.5 dS m^{-1}. This showed that the root zone salinity which was increased significantly after application of very high saline water of 8 dS m^{-1} was reduced drastically after monsoon season and may not have long-term effect of severe soil salinity build-up.

Development of *desi* cotton genotypes (*Gossypium herbaceum* and *G. arboreum*) for salt affected *Vertisols* (Vineeth TV, Lokeshkumar BM, Anil R. Chinchmalatpure and P.C. Sharma)

Cotton is a major cash crop classified as moderately tolerant to salt stress (threshold EC_e = 7.7 dS m^{-1}). This project was conceptualized for the development of salt tolerant Asiatic cotton genotypes for the salt affected Vertisols of Gujarat. To achieve the objective,

Table 74. Yield, yield attributes and leaf ionic assay of superior Gossypium herbaceum genotypes identified during the 2021-22 season on saline Vertisols

Genotype	Seed cotton yield (q/ha)	Yield advantage over LC & ZC (%)	Lint yield (q/ha)	GOT (%)	Boll weight (g/20 boll)	K/Na ratio
CSC-001	10.45	13.5	3.6	34.5	52	5.1
CSC-021	11.23	22	4.04	36	56	3.45
CSC-025	9.89	7.5	3.46	35	59	4.21
CSC-029	10	8.7	3.5	35	56	4.4
CSC-017	11.1	20.6	3.82	34.5	55	3.98
G Cot 23 (LC & ZC)	9.2	-	3.12	34	52	3.60

Data represents mean of three biological replicates; LC & ZC- Local and Zonal Check for yield

Table 75. Yield and leaf ion homeostasis of superior Gossypium arboreum genotypes on saline Vertisols

Genotype	Seed cotton yield (q/ha)	Yield advantage over LC (%)	Yield advantage over ZC (%)	K/Na ratio
AR-54	11.56	25	22.3	1.45
AR-81	10.98	18.9	16.1	1.25
AR-89	9	-	-	1.89
AR-90	9.67	4.7	2.3	1.45
LC (G Cot 19)	9.23	-	-	2.48
ZC (AKA 7)	9.45	-	-	1.67

Data represents mean of three biological replicates; LC & ZC- Local and Zonal Check for yield

following experiments were carried out and the breeding material was advanced during Kharif 2021. About 100 stabilized (F_8) G. arboreum and 90 stabilized (F_9) G. herbaceum lines were evaluated on salt affected field condition (EC_e of 5.64-9.67 dS m^{-1}) at experimental farm, Samni, Bharuch, Gujarat. The study identified 5 superior, high yielding and salt tolerant stabilized (F_9) Gossypium herbaceum genotypes. This was based on leaf ion homeostasis assay, seed cotton yield, lint yield, boll weight (g/20 boll) and ginning out turn (GOT) data as compared to Local and Zonal check variety (Table 74). CSC-001 and CSC-021 registered 13.5% and 22% higher yield over the local and zonal check variety for yield, G Cot 23, along with increased boll weight and leaf K/Na ratio.

The study also identified superior Gossypium arboreum genotypes based on seed cotton yield and leaf ion content on salt affected Vertisols (Table 75).

Ion homeostatic mechanism: Difference between the superior genotypes of two Asiatic cotton species evaluated

There was a conspicuous difference in the mechanism of ion homeostasis between the genotypes of Gossypium herbaceum and Gossypium arboreum as evident from the K/Na ratio of the leaf tissue subtending to the boll. From the three years data on ion content in the leaf subtending to the boll, it was clear that the herbaceum species showed ion exclusion behavior with much higher K/Na ratio. On the contrary, superior arboreum genotypes showed very low K/Na ratios in their leaf tissue, indicating a possible tissue tolerance mechanism prevalent in the species. Further confirmation on this aspect can be done via X-ray diffraction analysis to elucidate the sub cellular localization of ions in the leaf.

National trial: Br. 32b Initial Evaluation Trial (IET) of *Gossypium herbaceum*

The Br. 32b Initial Evaluation Trial (IET) of Gossypium herbaceum comprising of 9 entries including local (GN Cot 25) and zonal checks (G Cot 23) were evaluated across six locations including our Samni research farm [salt affected Vertisols (ECe 6.5 dS m^{-1})] in RBD with three replications. Only one entry (251) outperformed the local check under salinity stress and two entries (251 & 256) gave higher seed cotton yield than zonal check. Entry 251 showed the highest seed cotton yield (11.86 q ha^{-1}), followed by 256 (9.96 q ha^{-1}) and local check (9.17 q ha^{-1}).

Genetic enhancement of maize (*Zea mays* L.) for the development of high yielding and climate resilient hybrids (Vineeth TV; Collaborative project with ICAR IIMR Ludhiana)

Twenty five maize genotypes (inbred and wild genotypes) were evaluated in triplicates under varying levels of irrigation water salinity (0, 6 and 9 dS m^{-1}) on salt affected Vertisols. The objective was to identify salt tolerant lines along with key physiological traits related to enhanced salt tolerance. Among different genotypes, mean maximum cob yield across salinity levels was observed for IIMR 18 (2895 g) followed by IIMR 6 (2803 g), IIMR 19 (2505 g) and IIMR 1 (2235 g). Under moderate level of salinity stress (EC_{iw}–6 dS m^{-1}), IIMR 22 and IIMR 17 displayed higher reduction in cob yield (58 and 52%, respectively), whereas least reduction was noted in IIMR 12 and IIMR 6 (6 and 12%, respectively). It was also observed that at highest level of salinity (EC_{iw}–9 dS m^{-1}), higher decrease was noted in IIMR 22 (82%) and IIMR 12 (79%), whereas IIMR 6 and IIMR 18 showed the least decrease of less than 50%. Among different genotypes, mean maximum biomass across salinity levels was observed for IIMR 1 (5557 g) followed by IIMR 18 (5155 g), IIMR 14 (4412 g) and IIMR 8 (4238 g). Under moderate level of salinity stress (EC_{iw}–6 dS m^{-1}), IIMR 7 and IIMR 17 displayed higher reduction in biomass yield (50 and 47.4%, respectively), whereas least reduction was noted in IIMR 6 and IIMR 18 (16.7 and 18.6%, respectively). Moreover, under highest level of irrigation water salinity (EC_{iw}–9 dS m^{-1}), higher decrease in biomass was noted in IIMR 22 (79.4%) and IIMR 4 (76.2%), whereas IIMR 6 and IIMR 18 showed the least decrease of less than 50%.

Another important aspect of salinity stress is the ionic toxicity or accumulation of toxic ions. The present study dealt with salt dynamics of Na^+ and K^+ ions in maize upper leaves, lower leaves and root tissue, to fully understand the ion partitioning pattern under salinity stress. K^+/Na^+ ratio an important indicator of salinity stress decreased with increase in salinity, predominant decrease was noticed in the root tissue. Roots represented mean K^+/Na^+ of 5.17 under control condition which decreased to 1.76, 0.65 with progressive increase of salinity and genotypes displayed mean root K^+/Na^+ ratio of 1.94 to 3.88 across salinity levels, being highest in IIMR 6 (3.88) and lowest in IIMR 25 (1.94). Under control condition, mean lower leaf K^+/Na^+ was 5.05, which decreased by 2.5 and 6 folds under EC_{iw} 6 and 9 dS m^{-1}, respectively. Among genotypes, IIMR 14 had the highest lower leaf K^+/Na^+ of 4.28, while IIMR 6, IIMR 14 and IIMR 18 displayed higher $K^{+/}Na^+$ ratios (3.66, 4.28, 3.46, respectively) and least $K^{+/}Na^+$ of less than 2.0 in IIMR 25. It was interesting to note that upper leaf had higher $K^{+/}Na^+$ (2.4–7.01), being maximum in IIMR 18 and minimum in IIMR 17. Based on ion portioning, homeostasis and yield, seven high yielding salt tolerant genotypes have been identified (Table 76).

Table 76. Salt tolerant maize genotypes identified based on yield and ion homeostasis.

Genotype	Cob yield (g/plot)	Biomass yield (g/plot)	K/Na upper leaf	K/Na Lower leaf	K/Na ratio root
IIMR 18	2895	5155	7.01	3.46	3.43
IIMR 6	2803	4048	5.90	3.66	3.88
IIMR 19	2505	4786	5.33	3.06	2.82
IIMR 15	2421	3508	5.45	4.03	3.74
IIMR 1	2235	5557	3.18	2.40	2.85
IIMR 5	2106	4375	4.63	2.45	3.49
IIMR 8	2100	4238	4.85	2.85	3.13

25 genotypes of maize (Zea mays) including inbreds and wild genotypes were grown in the field for multiplication and maintenance of the rich germplasm and for future use in breeding programmes.

Reclamation and Management of Coastal Saline Soils

Effect of ameliorants on soil water functional relationships and salinity in an Inceptisol of coastal West Bengal (Shishir Raut, D. Burman, S.K. Sarangi and T.D. Lama)

A field experiment was conducted in an Inceptisol of Central Soil Salinity Research Institute, Canning Town research farm. The soil is clayey (16% sand, 30% silt and 54% clay). Four different ameliorants namely farm yard manure (F.Y.M.), poultry manure, Acacia leaf and tank silt were used. The design of the experiment was split plot with three replications where the ameliorants were put in the main plots and doses in the subplots. The doses were 2, 4, 6, 8, 10 and 12t / ha (T_1, T_2, T_3, T_4, T_5 and T_6, respectively) on the basis of moist weight. The ameliorants were added in the plots and well mixed at 0-15 cm soil layer before onset of monsoon (February-March, 2020). The field was left undisturbed for near two year so that the ameliorants were well decomposed. Soil samples were collected from 0-15 cm depth during May -June, 2022 and were analysed for different parameters. Rice cv. Lalminikit (WGL20471) was grown for winter season of 2021-22 to study the effect of salinity and ameliorants on growth of the crop.

Table 77. Effect of different ameliorants on soil bulk density and hydraulic conductivity

Ameliorants*	B.D. (Mg/ m^3)	H.C. (cm/h)
M1	1.28	5.0
M2	1.30	3.7
M3	1.30	4.5
M4	1.27	5.1
C.D. (p=0.05)	ns	ns

*M1 : F.Y.M., M2: green leaf manure, M3: tank silt and M4: Poultry manure

Soil bulk density and hydraulic conductivity

Soil bulk density was found higher for the control, 1.40 Mgm^{-3} soil than for all other amendment treatments were applied, averages of 1.29 (Table 77). Some differences in soil bulk density among amendment treatments were measured, for example, soil bulk density was higher for the green leaf manure treatment (1.30 Mgm^{-3}) than poultry manure treatment (1.27 Mgm^{-3}). There was a decrease in soil bulk density with the increase in amount of doses, 1.20 Mgm^{-3} for 12 t/ha amendments. Whereas, the value was 1.31 Mgm^{-3} for 2 t/ha amendment used. Changes in saturated hydraulic conductivity were also dependent on the treatment and doses (Table 77 and 78).

Table 78. Effect of different ameliorant doses on soil bulk density and hydraulic conductivity

Dose	B.D. (Mg/ m^3)	H.C. (cm/h)
T1 (2 t/ha)	1.31	1.0
T2 (4 t/ha)	1.30	2.0
T3 (6 t/ha)	1.30	3.0
T4 (8 t/ha)	1.27	4.2
T5 (10 t/ha)	1.25	5.0
T6 (12 t/ha)	1.20	5.5
C.D. (p=0.05)	0.13	1.20
Interaction ameliorant X dose	ns	s

ns : non-significant

The hydraulic conductivity values were little higher for F.Y.M. and poultry manure treatment (5.0-5.1 cmh^{-1}) than to green leaf manure and tank silt treatments (3.7-4.5 cmh^{-1}) for the soil. The saturated hydraulic conductivity was increased from 1.0 to 5.5 cmh^{-1} when the amount of doses increased from 2 to 12 t / ha. The use of different ameliorants did not bring about significant change in soil parameters like bulk density (B.D.) (avg. 1.29 Mgm^{-3}) and saturated hydraulic conductivity (H.C.) (4.6 cmh^{-1}) (Table 77). However, saturated HC for different plots treated with different doses of ameliorants differ significantly (C.D. $t_{0.05}$= 1.20 for the treated soil) (Table 78). The interaction effects of ameliorants and doses were also significant in bringing significant change in saturated hydraulic conductivity of soil.

Leaf area index and NDVI values were slightly higher in F.Y.M. and poultry manure treatments (3.5-3.6 and 0.42-0.45, respectively) which were higher than green leaf and tank silt treatments (3.2-3.3, 0.40-0.42, respectively). Similarly, rice grain and straw weights were higher for F.Y.M. and poultry manure treatments (3.4, 4.5 and 3.5, 4.7 t/ha, respectively) than other treatments (Table 79). With increment in treatment doses from 2t/ha to 12 t/ha, in general there was an increase in LAI (2.7-3.9), NDVI (0.31-0.48), grain weight (3.0-3.5 t/ha) and straw weight (4.0-4.8 t/ha) of rice (Table 79).

Table 79. Effect of different ameliorants and their doses on crop growth parameters, grain and straw yield

Ameliorants*	LAI	NDVI	Grain weight (t/ha)	Straw weight (t/ha)
M1	3.5	0.42	3.4	4.5
M2	3.2	0.40	3.2	4.2
M3	3.3	0.42	3.1	4.3
M4	3.6	0.45	3.5	4.7
CD (p=0.05)			ns	ns
Dose	**LAI**	**NDVI**	**Grain weight (t/ha)**	**Straw weight (t/ha)**
T1 (2 t/ha)	2.7	0.31	3.0	4.0
T2 (4 t/ha)	3.2	0.37	3.1	4.1
T3 (6 t/ha)	3.4	0.40	3.0	4.1
T4 (8 t/ha)	3.7	0.44	3.4	4.3
T5 (10 t/ha)	3.8	0.45	3.4	4.5
T6 (12 t/ha)	3.9	0.48	3.5	4.8
CD (p= 0.05)			0.15	0.20

*M_1: farm yard manure, M_2: green leaf manure, M_3: tank silt, M_4: poultry manure; LAI: leaf area index, NDVI: normalized difference vegetation index; T: treatment dose

Table 80. Percentage of soil pores in relation to ameliorant doses

Doses	Organic matter (%)	Macropore (%)	Micropore (%)	Total pore (%)
T1 (2 t/ha)	1.30	0.16	0.40	0.56
T2 (4 t/ha)	1.40	0.18	0.39	0.57
T3 (6 t/ha)	1.40	0.21	0.38	0.59
T4 (8 t/ha)	1.41	0.22	0.39	0.61
T5 (10 t/ha)	1.44	0.24	0.38	0.62
T6 (12 t/ha)	1.68	0.23	0.40	0.63
C.D. (p=0.05)	-	0.05	ns	ns

The soil amendment application increased soil porosity. Organic matter content was high for F.Y.M. and Poultry manure treatments (1.6 and 1.3 %, respectively than green leaf manure and tank silt treatments (1.1%). Total porosity varied from 0.56 to 0.62% in which macropores varied from 0.21-0.24%, but the difference was non-significant. With increase in ameliorant dose from 2 t/ha to 12 t/ha organic matter content of soil increased from 1.30-1.68% resulting in significant difference in macro pore spaces. The total pore spaces were also increased from 0.56-0.63 but the difference was non significant (Table 80). In general, with increase in ameliorant doses there was a decrease in EC values of soils.

Conjunctive use of poor quality water for zero-tillage potato under micro-irrigation system in coastal salt affected soil (K.K. Mahanta, S.K. Sarangi, D. Burman U.K. Mandal and T.D. Lama)


Sowing of potato seeds

After the monsoon recedes, the rainfall is erratic in coastal West Bengal and there is fresh water scarcity for agriculture. Potato can be cultivated with less water by utilizing residual soil moisture available during rice harvest and applying irrigation through efficient micro-irrigation systems.

An experiment was started at the institute farm of ICAR-CSSRI, RRS, Canning Town for zero tillage mulched potato under micro-irrigation and by conventional method with objectives; i.e to evaluate the water saving as well as performance of zero-tillage potato under micro-irrigation system and conventional practice, ii. To study the effect of fertigation and irrigation with water of different qualities through irrigation system and

The experimental plot

conventional method on crop productivity, iii.To devise irrigation scheduling for better cropping. The test crop is potato (var. Kufri Pokhraj).

Potato seeds which were of small size were planted as such, but bigger size seeds were cut into pieces according to size. The seed spacing was 20 cm in the lines parallel to the laterals. Farm yard manure (FYM) was put on the seeds and basal doze of fertilizer applied on it. The plots were covered with straw mulch. Recommended doses of fertilizers applied after 30, 45 and 60 days after sowing. Irrigation water of desired quality is prepared by mixing saline ground water or tidal river water with fresh water. Water salinity such as 1~2 dS/m and 5~6 dS/m are prepared and used in the experiment. Irrigation scheduling is done based on IW/CPE ratios 0.5 and 0.7. The laterals of the irrigation system were put on the straw mulch, so that it will be easy to take out the laterals after experimentation. The water was supplied through the drip system by a 0.5 HP electrical pump. Irrigation for conventional zero tillage potato was given through garden pipe by spraying on the crop.

Assessment of spatio-temporal variation of surface water quality in coastal area (D. Burman, T. D. Lama, U.K. Mandal, K. K. Mahanta and S. Mandal)

Drainage channel during rabi season in Sundarbans region

The research work was carried out under this project with the objectives to assess spatio-temporal variation of surface water quality of major river systems and drainage channels for agricultural uses and to analyze water resource use pattern for agricultural operation by the farmers in salt affected Ganges Delta in Sundarbans region of coastal West Bengal. Water samples from the rivers and drainage channels at different locations of Sundarbans regions were collected during *kharif*, *rabi* and summer seasons and different water quality parameters like EC_w, pH, Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-} and SO_4^{-} were analyzed.

The surface water quality parameters of river and drainage channels varied with locations, seasons and source. The salinity of water was lower during *kharif* season followed by *rabi* and summer seasons. The salinity of water was higher in the South and South-Eastern part of Sundarbans. The pH of the water is mostly in normal range. The spatio-temporal variation of quality of other parameters followed the similar trend of variation in salinity. The similar trend was observed during previous year. The Hooghly estuary receives freshwater flow through Bhagirathi-Hooghly rivers during the monsoon. All the other rivers have lost their upstream connections with the Ganges due to heavy siltation and solid waste disposal from the adjacent cities and towns. The water quality of Hooghly River was found suitable for irrigation during *rabi* and summer seasons.

In Sundarbans, many drainage channels are excavated to drain out excess water to the estuarine rivers through sluice gates placed at different locations in the channel. The harvested rain water in drainage channels during rainy season is used for cultivation of *rabi* crops by the farmers of the adjoining areas of drainage channels (Photo). However, this freshwater resource frequently becomes saline due to intrusion of saline water from the rivers especially during high tides. As a consequence, the farmers face difficulties for using such water for irrigation purpose. The water quality of the drainage channels was monitoring periodically during *rabi* and summer seasons to amaze its suitability for irrigating dry season crops. The salinity of water indicated that water is suitable for irrigation during *rabi* season (Fig. 41). However, the salinity of water of some of the drainage channels increased gradually after *rabi* season.

The house-hold survey was conducted in the different parts of Sundarbans region

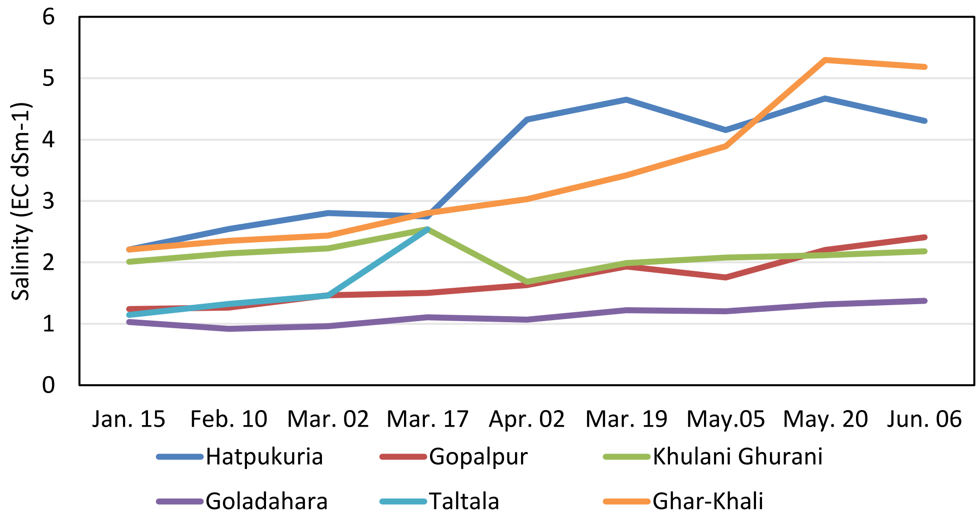


Fig 41. Changes in water salinity during rabi season in different drainage cannels

especially nearer to rivers and drainage channels to analyze the water resource use pattern by the farmers for agricultural activities. The cropping system is mainly rice based mono-cropping to triple cropping depending on the availability of fresh water for irrigation from different sources during post-monsoon period. The farmers nearer to Hooghly River and drainage channels use fresh water resources of Hooghly River and drainage channels for growing double or triple crops. The areas where good quality surface water is not available from river/ estuaries farmers depends of ground water or harvested rain water in the farm ponds for irrigating dry season crops. In this Ganges Delta the depth of suitable ground water for irrigation varies from >100 ft to 400 ft or even more. The farmers grow triple crops mostly in the areas where good quality ground water is available at shallow depth (>100 ft) and grow double crops where ground water is available at 250-400 ft depth. In most of the other areas in Sundarbans the fields remain fallow after *kharif* rice due to scarcity of fresh water for irrigation. The farmers use harvested rainwater in farm pond to grow *rabi* crops in a very limited areas in Ganged Delta of Sundarbans region.

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)

Considering the benefit of conservation tillage in rice-based cropping system a long-term field experiment has been carried out to evaluate the impact of conservation tillage on soil health, and carbon pools in coastal region of West Bengal. The design of experiment was split-split plot with cropping system rice-rice (RR) and rice-potato-mung bean (RPM) (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 and residue (R) and no residue (NR) under sub-sub plot treatments. Potato was grown under zero tillage with straw mulch and ridge-furrow system without mulching under RT and CT condition. The soil organic carbon content (SOC) and its different fractions in the soil was estimated through the modified Walkley and Black method using different concentration of H_2SO_4 (36N, 24N, 18N and 12N) and $K_2Cr_2O_7$ solution caused the production of different amount of heat of reaction. The results of soil physical, chemical and biological of properties after ten years of study is presented (Table 81 and 82). There was no difference in soil pH within the treatment. The ECe was more in RPM than RR, whereas residue plots has

Table 81. Soil properties after the harvest of rabi crop during May 2022

Treatments	pH	ECe (dS/m)	Available N Kg/ha	Available P Kg/ha	Available K Kg/ha	Bulk density Mg/m^3
Rice-Rice						
ZTR	7.39	1.91	388.2	12.34	545.9	1.41
ZTNR	7.76	2.18	402.1	8.67	460.9	1.58
RTR	7.55	2.31	338.8	13.71	546.4	1.43
RTNR	7.59	2.88	308.1	12.78	456.9	1.52
CTR	7.62	2.39	369.6	15.69	581.2	1.44
CTNR	7.53	3.05	246.4	12.93	518.6	1.54
Rice-potato-mung bean						
ZTR	7.59	4.67	422.5	11.41	551.5	1.31
ZTNR	7.33	5.37	436.9	10.57	529.8	1.44
RTR	7.41	4.43	368.2	15.2	554.9	1.34
RTNR	7.22	5.03	310.2	14.45	603.8	1.39
CTR	7.29	5.09	286.1	15.44	682.2	1.32
CTNR	7.37	5.64	272.2	12.22	715.2	1.43
LSD (p=0.05)						
Crop	NS	1.82	NS	NS	NS	0.09
Tillage	NS	NS	45.5	2.54	NS	NS
Residue	NS	0.49	22.24	2.34	NS	0.08
Interaction	NS	NS	NS	NS	NS	NS

*ZTR, Zero tillage with residue; ZTNR, Zero tillage with no residue; RTR, Reduced tillage with residue; RTNR, Reduced tillage with no residue; CTR, Conventional tillage with residue; CTNR, Conventional tillage with no residue

Table 82. Soil biological properties after rabi harvest during May 2022

Treatments	MBC (µg/g)	DHA (µg/g/h)	V labile C (%)	Labile C (%)	Less Labile C (%)	C (%)	Active pool (%)	Passive pool (%)
Rice-Rice								
ZTR	482.1	0.499	0.497	0.175	0.190	0.247	0.672	0.437
ZTNR	378.2	0.364	0.423	0.081	0.188	0.120	0.504	0.308
RTR	463.7	0.73	0.47	0.205	0.222	0.072	0.677	0.294
RTNR	346.2	0.386	0.41	0.111	0.226	0.064	0.522	0.290
CTR	435.2	0.533	0.37	0.195	0.245	0.140	0.566	0.386
CTNR	396.2	0.408	0.30	0.073	0.274	0.063	0.374	0.337
Rice-potato-mung bean								
ZTR	314.6	0.319	0.44	0.173	0.188	0.065	0.611	0.253
ZTNR	210.1	0.135	0.38	0.100	0.189	0.071	0.481	0.260
RTR	278.19	0.536	0.411	0.177	0.222	0.102	0.588	0.324
RTNR	223.4	0.209	0.301	0.184	0.245	0.060	0.485	0.305
CTR	280.1	0.455	0.341	0.124	0.305	0.101	0.465	0.407
CTNR	236.4	0.415	0.259	0.107	0.214	0.134	0.366	0.348
LSD (p=0.05)								
Crop	78.2	0.11	0.052	NS	NS	NS	0.049	NS
Tillage	NS	0.102	0.102	NS	NS	0.041	0.082	NS
Residue	64.2	0.13	0.051	0.052	NS	NS	0.092	NS
Interaction	NS	NS	0.064	NS	NS	NS	0.071	NS

*ZTR, Zero tillage with residue; ZTNR, Zero tillage with no residue; RTR, Reduced tillage with residue; RTNR, Reduced tillage with no residue; CTR, Conventional tillage with residue; CTNR, Conventional tillage with no residue

comparatively less soil salinity than non-residue plots. Permanganate oxidizable N was maximum in zero tillage with no residue plots may be because of less uptake of nitrogen by crops in those plots. Available P was also more in residue plots than no residue treatment. Bulk density was more in RR than RPM system and it was more in no residue plots. The cations and anions were more in RPM than RR system. The microbial biomass carbon and dehydrogenase activity was more in RR than RPM may be because of higher soil organic C in RR system (Table 82). Active pool has significant relationship with residue application and it was more in RR than RPM. There was no significant difference in passive pool of soil organic C. There was 7-8% yield reduction in case of zero tillage under rice cultivation but no yield reduction was there in case of zero tillage potato cultivation. Overall, the yield of potato was low because of heavy textured soils and yield was further less in case of ridge furrow system of cultivation.

Coastal salinity management and cropping system intensification through conservation agriculture (S.K. Sarangi, S. Raut, U.K. Mandal and K.K. Mahanta)

The project activity continued with *Kharif* rice during 2021, followed by potato, mustard and garlic during *Rabi* 2021-22 and Mung bean in Summer 2021-22. After the harvesting of the Kharif 2021 rice crop, the planting of subsequent Rabi crops (potato, mustard and garlic) was started from 10.11.2021 under zero tillage and mulching practice. The varieties for potato, mustard and garlic were Kufri Pukhraj, Garima and Yamuna Safed 2 respectively. Conventional planting (control) was delayed as there was heavy rain during 4-6 December 2021 due to the effect of cyclonic storm 'Jawad' and after that, it took three weeks for drying of wet soil for tillage operations and seed bed preparations and the planting were done on 27.12.2021. The experiment consists of three cropping systems viz. rice-mustard-green gram, rice-garlic-green gram and rice-potato-green gram. For mustard crop the treatments are conventional tillage (control), zero tillage (ZT) sowing with three spacings (20×10, 25×10 & 30×10 cm) and three mulch rates (2 t/ha, 4 t/ha and 6 t/ha). For garlic, the treatments are conventional tillage planting (control), ZT planting with three spacings (20x10, 25x10 & 30x10 cm) and three mulch rates (3 t/ha, 5 t/ha and 7 t/ha). Potato crop treatments are conventional ridge and furrow cultivation (control), ZT planting with three spacings (30x15, 45x15 & 60x15 cm) and three mulch rates (9 t/ha, 12 t/ha and 15 t/ha). There were three replications of each treatment.

For the conservation treatments rice straw was used as mulch in the *Rabi* crops and green gram stover left in the field for decomposition. In the conventional practice all the crop residues were removed from the system. Soil salinity (ECe) was observed in all the plots on monthly basis from December 2021. In control plots soil salinity varied from 2.70-4.05 dS/m during December 2021 to 11.82-15.08 dS/m during May 2022, whereas in paddystraw mulched plots soil salinity development was restricted and it was observed lowest with highest level of mulching. The soil salinity with 15 t/ha paddy straw mulching

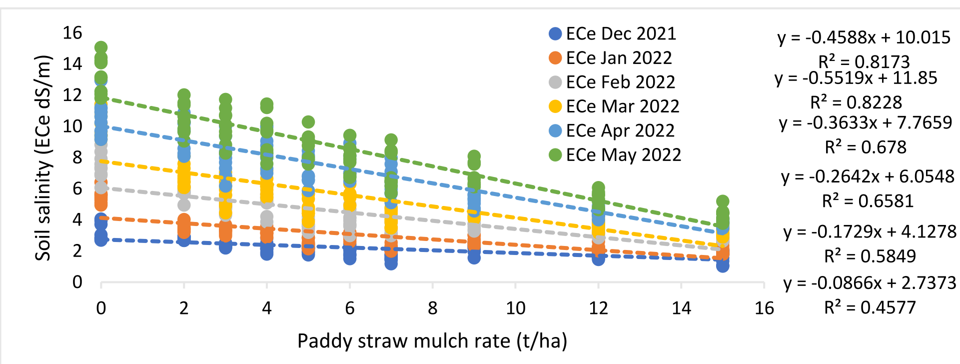


Fig 42. Effect of paddy straw mulching/residue retention on the soil salinity in subsequent rabi crops during December 2021 - May 2022

was in the range of 1.03-2.07 dS/m during December 2021 to 3.79-5.19 dS/m during May 2022. Soil salinity (ECe) had a negative correlation (r=-0.90) with amount (t/ha) of paddy straw mulching during *Rabi* 2021-22 season (Fig. 42). Significant effect of paddy straw mulching was observed on the weed biomass of the *Rabi* season crops. In control plots (without mulching-conventional tillage), the weed biomass was 1.89, 8.33 and 34.95 g/m^2 in mustard, potato and garlic crops respectively. With paddy straw mulching, the weed biomass reduced to 0.44, 3.30 and 12.00 g/m^2 in the respective crops.

The Green Seeker was observation was recorded at a height of 0.8-1.0 m above the crop canopy. In potato crop, lowest NDVI (0.24) was observed in conventional tillage crop without paddy straw mulching, whereas highest NDVI of 0.75 was recorded in the crop planted with 30×15 cm spacing with paddy straw mulching of 12 -15 t/ha. In mustard, lowest NDVI (0.41) was observed in broadcast sown crop under conventional tillage and without mulching. NDVI of mustard crop was more than 0.60 when the crop was sown with a mulch rate of 6 t/ha. In garlic, lowest NDVI of 0.18 was observed in conventional plating without PSM and highest NDVI (0.26-0.27) when the crop is planted with paddy straw mulching of 7 t/ha. The measure of chlorophyll in the rice plant leaves were measured by the handheld SPAD- 502Plus chlorophyll meter manufactured by Konica Minolta (https://www. konicaminolta.com/instruments/download/catalog/color/pdf/spad502plus_ catalog_ eng.pdf). The measurement was taken on fourth fully expanded leaf from the top and during the morning hours (7AM – 9 AM). For each sample, three observations were taken at base, mid and top of the leaf and the average was recorded.

In potato, the SPAD value was the lowest (34.6) for the conventional tillage crop planted without crop residue mulching. The higher SPAD value of > 55 was observed when the potato crop was planted with a row spacing of 30 -45 cm and with 12 -15 t/ha paddy straw mulching. In mustard crop, lowest SPAD value of 28.1 was observed in conventionally planted crop and highest value of 54.4, when the crop is planted at a spacing of 20×10 cm with 6 t/ha paddy straw mulching. Out of the three *Rabi* crops studied, higher SPAD values were observed in case of garlic, with lowest value of 55.1 in conventional tillage planted crop without crop residue mulching and the values are significantly higher (>70) under zero tillage planting with 5-7 t/ha paddy straw mulching.

Highest seed yield and net return in mustard crop was recorded due to zero tillage sowing and the effect of paddy straw mulching. Under the conventional tillage sowing the seed yield of mustard crop was the lowest (0.69 t/ha), which increased significantly to 1.59 t/ha when sown under zero tillage with a spacing of 25×10 cm & 6 t/ha PSM. The benefit cost ratio of mustard was more than 2.0 for all the conservation tillage treatments. Tuber yield and net return in potato crop was increased due to ZT planting and the effect of paddy straw mulching. The benefit cost ratio of potato cultivation was more than 1.5 for all the treatments involving zero tillage planting and paddy straw mulching. Bulb yield and net return in garlic crop was increased due to the effect of ZT planting and paddy straw mulching. The benefit cost ratio of potato cultivation was more than 1.5 for all the treatments involving zero tillage planting and paddy straw mulching except for the treatment ZT planting with 20×10cm spacing & 3 t/ha PSM. The green gram crop was grown after the harvest of potato/mustard and garlic.

The cropping system performance was evaluated in terms of rice equivalent yield (REY), cost of cultivation, gross return, net return and benefit cost ratio (Table 83). Highest REY of

Table 83. Rice equivalent yield and economics of rice-based cropping system in coastal saline region under different conventional and zero tillage and residue management during Rabi 2021-22

Rice based cropping systems	Rice Equivalent Yield (t/ha)	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	BCR
Crop/cropping system	**Conventional tillage -No mulching**				
Rice-fallow	4.94	55750	96225	40475	1.73
Rice-potato	16.10	206291	263625	48350	1.28
Rice-mustard	7.24	87215	130725	35091	1.50
Rice-garlic	15.11	207916	248775	51171	1.20
Rice-potato-green gram	17.78	232612	288825	48837	1.24
Rice-mustard-green gram	8.87	113536	155225	33285	1.37
Rice-garlic-green gram	15.86	234237	259975	40058	1.11
Cropping system	**Zero tillage+Paddy straw mulching**				
Rice-ZTPSM potato	25.84	198522	409675	136243	2.06
Rice-ZTPSM mustard	9.51	86585	164781	47524	1.90
Rice-ZTPSM garlic	23.42	206343	373175	149735	1.81
Rice-ZTPSM potato-ZT green gram	29.90	224720	470108	154830	2.09
Rice-ZTPSM mustard-ZT green gram	12.82	112140	214792	60533	1.92
Rice-ZTPSM garlic-ZT green gram	24.45	231898	388886	145922	1.68

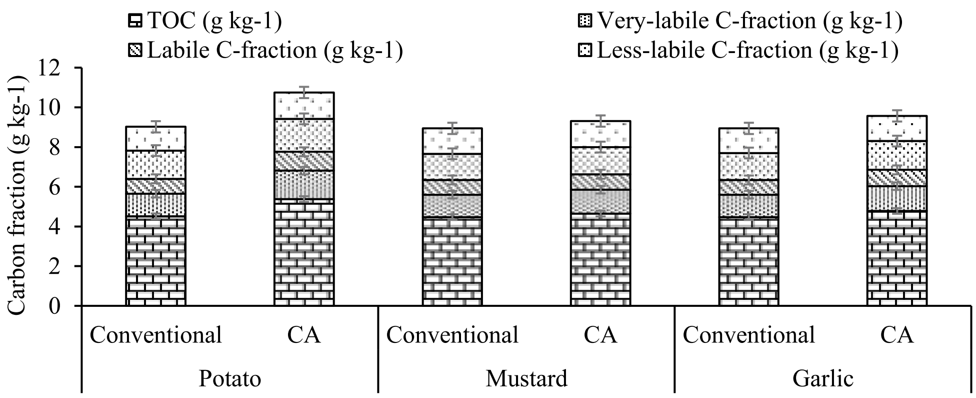


Fig 43. Effect of conventional and conservation agriculture (CA) practices on soil organic carbon status after two years

29.9 t/ha was observed in Rice-ZT potato-ZT green gram cropping system involving paddy straw mulching. Highest net return (Rs. 154830/ha) and BCR (2.09) was also observed in the above cropping system.

There was a significant effect of conservation agricultural practices (zero tillage planting, crop residue recycling and crop rotation) on soil organic carbon content. The total as well as labile soil organic carbon content increased significantly under conservation agricultural practices compared to conventional practices (Fig. 43).

Photo: AVT 2 -CSTVT experiment at ICAR-CSSRI, RRS, Canning Town during Kharif 2022

All India Co-ordinated Rice Improvement Project (AICRIP) - Coastal Saline Tolerant Variety Trial (S.K. Sarangi)

During the *Kharif* 2022, under nutrient management trial of AVT 2 – CSTVT, six entries were evaluated in split-plot design under mean soil salinity (ECe) of 5.02 dS/m. Main-plot treatments were 50 and 100% NPK. The entries in sub-plot were IET 27851, CSR 10, Improved White Ponny, CST 7-1, FL 478 and local check Canning 7. The seeds received from IIRR, Hyderabad was sown on the nursery on 27 June 2022. Seedlings were

Table 84. Performance of AVT 2 -CSTVT entries during Kharif 2022 at Canning Town

Main plot	Sub-plot: Cultivar	GY (t/ha)	SY (t/ha)	Days to FPF	Test wt (g)
F1: 50% NPK)	IET 27851	4.16	7.05	122	20.50
	CSR-10	4.32	5.63	115	27.37
	Improved White Ponny	5.41	6.73	121	17.40
	CST 7-1	5.81	6.76	116	29.93
	FL 478	2.07	2.74	89	
	LC (Canning 7)	3.48	4.41	96	
Mean	4.21	5.55	110	23.80	
F2: 100% NPK	IET 27851	5.04	7.90	122	22.60
	CSR-10	5.74	6.88	115	24.43
	Improved White Ponny	5.93	7.52	12018.27	
	CST 7-1	6.14	8.04	118	29.47
	FL 478	2.81	3.55	89	
	LC (Canning 7)	4.10	5.20	96	
Mean	4.96	6.52	110	23.69	

transplanted on 08 August 2022. Monitoring of the experiment was done by a team of scientist on 18 November 2022. Out of the six entries highest grain yield (5.98 t/ha) was produced by CST 7-1 followed by Improved White Ponny (5.67 t/ha). In all the entries, the grain and straw yields were higher under 100% NPK compared to 50% NPK (Table 84).

Coastal Salinity Tolerant Varietal Trial (CSTVT) (Nitish Ranjan Prakash and S.K. Sarangi)

Our center acts as voluntary centre in AICRP on rice. A total of 30 rice genotypes were evaluated under All India Co-ordinated Rice Improvement Project - Coastal Salinity Tolerant Varietal Trial - Initial Varietal Trial (AICRIP-CSTVT-IVT). It includes 26 entries along with Canning 7 as local check. Average yield of trial (1692.87 kg/ha) of the trials was very low as many entries were died because of heavy rainfall and water stagnation in field during August and September. Complete loss of many entries were observed due to submergence and salinity such as Entry 5610, 56212, 5626, 5630. Mean yield was highest in entry numbers 5601 and 5603 (3.9 t/ha). Ten lines were received under AICRP-CSTVT-AVT1&2 for evaluation including Canning 7 as local check. Average yield of trial (2254 kg/ha) was very low as many entries were died because of heavy rainfall and water stagnation in field in last of august and September. Severe yield loss of many entries were observed due to submergence and salinity in entries 5504, 5502, 5506, 5503. Mean yield was highest in entry numbers 5501 and 5507 (approx. 4.7 t/ha). Details of both the trials AICRIP-CSTVT-IVT and AICRIP-CSTVT-AVT1&2 are given in table 85.

Table 85. Details of Coastal Salinity Tolerant Varietal Trial (CSTVT) conducted

Particulars	IVT trials	AVT2-NIL(CS)
Number of Entries	30 (5601-5630)	4 (5501-5510)
Replication	4	4
Spacing	15 x 15 cm	15 x 15 cm
Local Checks	Canning 7	Canning 7
Date of Sowing	21.06.2022	20.06.2022
Date of Transplanting	12.08.2022	12.08.2022
Plot size	4.455 m2	4.455 m2

Mapping and characterization of salt affected soils in coastal West Bengal [T.D. Lama, D. Burman, U.K. Mandal, A.K. Mandal, S.K. Sarangi, S. Raut, K.K. Mahanta, K.D. Sah and S. Mukhopadhyay, (NBSS&LUP Regional Centre, Kolkata)]

Assessment and monitoring of the extent of salt-affected soil and the severity of soil salinity is necessary for developing strategies to improve agricultural production in the coastal areas. The present study was initiated to map the extent of and to develop an updated database of salt-affected soils in coastal West Bengal. Soil samples (346 sites) were collected along with their GPS locations from the four coastal districts of North 24 Parganas, South 24 Parganas, Howrah and East Midnapore in West Bengal. The samples were processed and analyzed for the determination of EC and pH in the saturation extracts. ECe of the surface soil (0-15 cm) ranged from 0.31 - 19.62, 0.05 - 22.32, 0.41 - 6.71 and 0.35 - 10.58 dS m^{-1}, respectively, in South 24 Pargans, North 24 Parganas, Howrah and East Midnapore districts. 40% of the surface soil samples in South 24 Parganas had EC_e below 2 dS m^{-1}, while it was 65, 48 and 51% in North 24 Parganas, Howrah and East Midnapore, respectively. The percent samples having EC_e of 2-4 dS m^{-1}, were 23, 9, 39 and 30% while the percent samples having EC_e above 4 dS m^{-1}, were 37, 26, 12 and 18%, respectively, in North 24 Parganas, Howrah and East Midnapore. In the 15-30 cm layer, the EC_e varied from 0.27 - 10.90, 0.21 - 7.83, 0.36 - 3.25 and 0.11 - 6.74 dS m^{-1}, respectively, in South 24 Pargans, North 24 Parganas, Howrah and East Midnapore. The percent samples (15-30 cm) having EC_e below 2 dS m^{-1} were 45, 72, 79 and 67%, respectively in in South 24 Pargans, North 24 Parganas, Howrah and East Midnapore. The corresponding percent samples having EC_e of 2-4 dS m^{-1} were 28, 8, 7 and 27%. Samples having EC_e above 4 dS m^{-1} was 27, 15 and 7% in South 24 Pargans, North 24 Parganas and East Midnapore only.

The pH_s in surface soil varied from 2.40 to 8.57 in the different districts. 45% of the surface soil samples in South 24 Parganas pH_s of 6.5-7.5, followed by 43, 39 and 21% in East

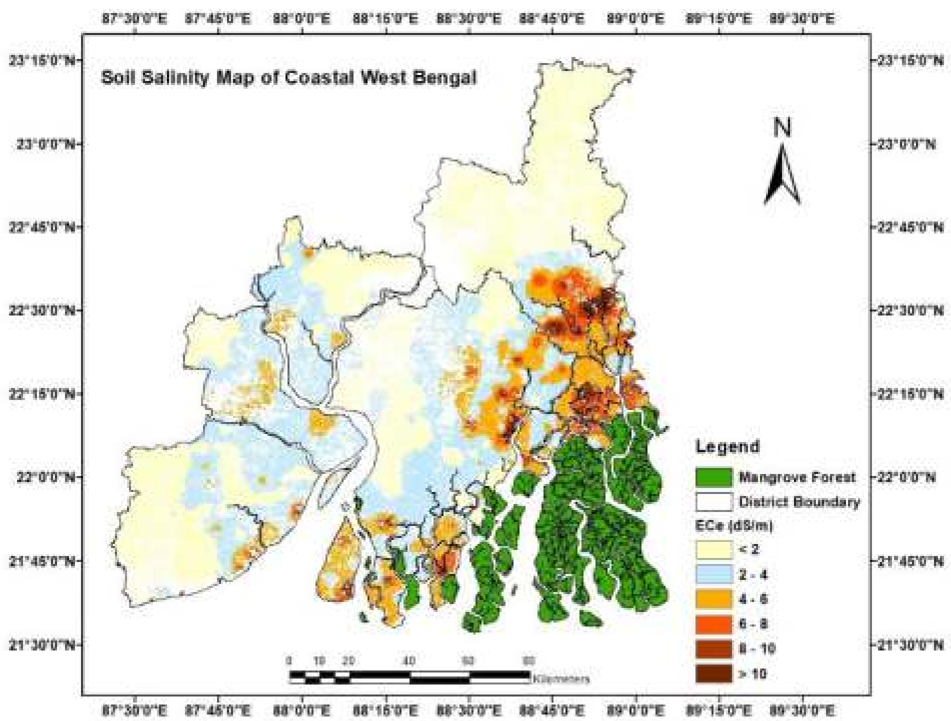


Fig 44. Surface soil salinity map of coastal West Bengal

Table 86. Extent of salt-affected soil in coastal West Bengal

Salt-affected area in coastal West Bengal (lakh ha)			
District	**Slightly saline**	**Saline**	**Total**
South 24 Pgs	1.42	1.24	2.66
North 24 Pgs	0.19	0.74	0.93
East Midnapore	1.07	0.22	1.29
Howrah	0.43	0.05	0.48
Total	3.11	2.26	5.37

Midnapore, North 24 Parganas and Howrah, respectively. The percent surface samples having pH_s in the range of 7.5-8.5 were 24, 44, 45 and 39% in South 24 Parganas, North 24 Parganas, Howrah and East Midnapore, respectively. In the pH_s range of 5.5-6.5, the percent surface samples were 23, 12, 15 and 9%, respectively, in these districts. A few samples had pH_s of 4.5-5.5 in South 24 Parganas, North 24 Parganas and East Midnapore. pH_s below 4.5 was observed in 3, 15, and 9% of the surface sample in South 24 Parganas, Howrah and East Midnapore disctricts suggesting the presence of acid sulphate soils. In the sub-surface samples (15-30 cm), 42, 36, 18 and 39% had pH_s of 6.5-7.5 and 44, 52, 52 and 46% had pH_s of 7.5 to 8.5 in South 24 Parganas, North 24 Parganas, Howrah and East Midnapore, respectively. The percent sub-surface samples having pH_s of 5.5-6.5 were 7, 7, 12, and 7% while for pH_s of 4.5-5.5 it was it was 4, 5, 3 and 1%, respectively in South 24 Parganas, North 24 Parganas, Howrah and East Midnapore. In the sub-surface layer, 3,15 and 7% samples had pH_s below 4.5 in the districts of South 24 Parganas, Howrah and East Midnapore. The spatial distribution maps of soil ECe and pH_s were generated using the Inverse Distance Weighting interpolation technique in the GIS environment. Based on the surface soil salinity map (Fig. 44), the total salt-affected soil in the coastal West Bengal was estimated at 5.37 lakh hectares with the maximum area of 2.66 lakh ha in the district of South 24 Parganas (Table 86).

Development of rice genotypes and germplasm maintenance (Nitish Ranjan Prakash, S. K. Sarangi and S.L. Krishnamurthy)

In year 2022-23, we have collected 650 rice genotypes from other institutes as exchange and gifts to broaden our germplasm base. A total of 393 rice landraces were also collected from local farmers, NGOs and SHGs. These germplasm were multiplied during Kharif 2022. In Rabi 2021-22, 93 genotypes were evaluated under high salinity conditions and salt tolerant genotypes such as Dudheswar, Parbati, Kakua etc. were identified. Similarly, 66 genotypes were also evaluated in under low salinity conditions. Genotypes performing low and high for different traits in low salinity plots in Rabi 2021-22 is given in table 87.

During Kharif-2022, 33 genotypes in Late group (>130 days to flowering; DTF), 57 in Medium (110-130 DTF), 40 in mid-Early (100-110 DTF) and 22 in Early (<100 DTF) were evaluated under lowland condition and 45 lines were evaluated under semi-deep condition (> 45 cm standing water for 1-2 months). These rice genotypes including released varieties, landraces and genetic stocks were evaluated in alpha lattice design with two replication under irrigated lowland situation. Spacing was kept at 20 x 20 cm within genotypes and 60 cm between genotypes in a 5m x 1m plot. The observations were recorded for days to 50% flowering (DTF), plant height (PH), number of tillers (NT), number of ear bearing tillers (EBT), grain yield (YLD) and straw yield (SY). Table 88 denotes genotypes which were performing better under all these five conditions for different traits.

Table 87. High and low genotypes under low salinity trials conducted in Rabi 2021-22.

Trait	Low	High
DTF	CSR 40, Nona Bokra, Verisal, IET4786	Gangajali, Jhumur
PH	Sujala, Kshitish (IET4094), IET4786	IR 77664-B-25-1-2-1-3-12-5-A., Parbati,
EBT	Verisal, Ajit, CSR 22	Mayna, Latika, Dudheswar
YLD	Gangajali, Kakua, CSR 40	CSRC(S)-50-2-1-2-B, CSRC(S)-53-1-B-1-B, IR 10206-29-2-1-1, IET 1444 (Rashi), CSR 35

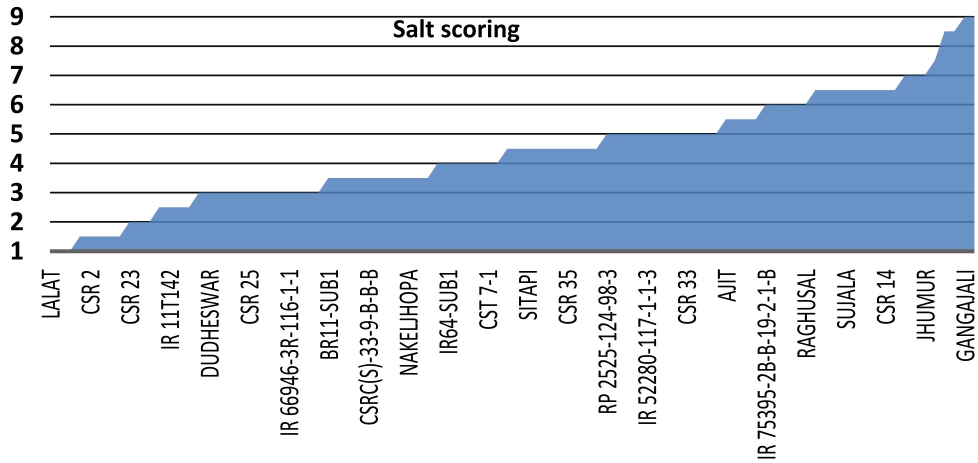


Fig 45. Salt Evaluation Score (SES) of 93 genotypes under high salinity plot in Rabi 2021-22

In Rabi 2022-23 a complete set of Early and Mid-early genotypes are being evaluated in randomized complete block design (RCBD) with two replication in low and high salinity plots. Preliminary yield trials (PYTs) of each with 9 advanced breeding lines respectively were conducted in Kharif 2022 under saline as well as semi-deep situations. Coastal salinity

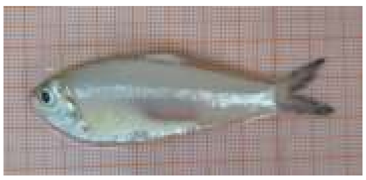
Table 88. High and low performing genotypes for under trials conducted in Kharif 2022.

Trial	Trait	Low	High
Late	DTF	Fulkhar, Gangajali, Medhi, Suakalma, Sumati	Bharatsal, Kalobora
	PH	Suakalma	Dadsal
	EBT	Dadsal	Sindurmukhi
	YLD	Suakalma	Dadsal, Vasamanik
Medium	DTF	BRRI Dhan 75	Pankaj
	PH	BRRI Dhan 75	Talmugur-1, Talmugur-2
	EBT	CST 7-1, CSR 31, Gobindobhog	Talmugur-1, CSR 39, Arjunsal
	YLD	Verisal	Manisha, Koushalya
Mid-Early	DTF	Mayna, Ciherang Sub1, IR 77664-B-25-1-2-1-3-12-5-A,Latika	Gayatri
	PH	CSR 26, Gayatri, Pusa44	CSR 4
	EBT	IR29, Lakkansal	Parbati, CSR 32
	YLD	Pusa44, Mayna	Neta, CSR 4
Early	DTF	Annada, IET4786, Bidhan 2	BRRI Dhan 47
	PH	IET4786	BRRI Dhan 55
	EBT	IR 66946-3R-149-1-1	Sujala
	YLD	Letasol	PUSA (NR) 580-6 IET 1444 (Rashi)
Semi-deep	DTF	Verisal	NC 678, Asfal
	PH	Jhulur, Murkimala, Bakrisal,	Manas Swarobor, SR26B
	EBT	Gangajali, Murkimala	Bombaimugi, Sindurmukhi
	YLD	Verisal, Gangajali, Medhi	SR26B, Nalini

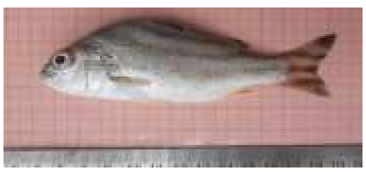
PYT was done to include our lines in AICRIP-CSTVT-IVT trials and semi-deep PYT was done to include our entries in AICRIP-Semi deep trials. Both these trials were conducted in two replications each with 5 m^2 plot area. In coastal salinity trials, checks were Bhutnath (National Check), Pokkali (Tolerant check), Pusa 44 (Susceptible check) and Canning 7 (Local Check). Similarly in semi deep PYT trials, Local Check – Amalmona, National Check – CR Dhan 510, and Regional Check – CR Dhan 506 were used.

In CSTVT-PYT, none of the genotypes performed better than national check Bhutnath. In semideep-PYT, lines such as CSRC(D)12-8-12 and CSRC(D)5-2-2-2 performed better than national check CR Dhan 506 and will be promoted to IVT this year Kharif season. Crossing of salt tolerant landraces and high yielding lines were obtained in Rabi-2021-22 and the seeds are now in F_2 stage. Cross attempted in Kharif 2022 are now available and will be sown in next Kharif 2023 for generation advancement.

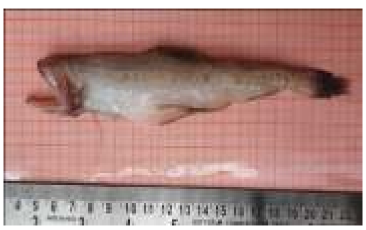
Assessment of Ichthyofaunal diversity, biology and stock assessment of selected species along the estuary of Sundarbans (Rinchen Nopu Bhutia and U.K. Mandal)



Esculosa thoracata



Terapon jarbua



Harpadon nehereus

Estuaries are the most productive habitat and a unique ecosystem. It provides suitable environment for the growth and survival of the fishes. It forms the cornerstone of the inland capture fisheries, supporting the diverse ichthyofauna in the region. But this ecosystem are facing constant threat from anthropogenic, environmental and climatic factors which ultimately questions the long-term sustainability of the resources unless these resources are managed through comprehensive management plans. Thus under this project during the year 2022, the sampling was conducted from different sampling sites starting from Canning towards the mouth of estuary along the Matla estuary, Sundarban. Total of 29 species of fishes has been identified from Matla estuary namely *Liza parsia, Tenualosa ilisha, Strongylura strongylura, Esculosa thoracata, Setipinna phasa, Bregmoceros macclandi, Coilia ramcarti, S. taty, Pampus argenteus, Lates calcarifer, Lutjanus johnii, Polynemus paradiseus, scatophagus argus, Johnius belangarii, Sillaginopsis panijus, Pampus chinensis, Terapon jarbua, Lepturocanthus savala, Mystus gulio. M. vittatus, Acanthopagrus berda, Otolithoides pama, T. toil, Corica soborna, Boleopthalmus boddarti, Plotossus canius, Eleutheronema tetradatylum, Lagocephalus lunaris, Gudusia chapra and Harpadon nehereus (photos)*. Fishes were composed of members of the order Clupeiformes, Scombriformes, Perciformes, Gobiiformes, Tetraodontiformes, Aulopiformes, Mugiliformes,Beloniformes and Gadiformes (Fig. 46). The maximum numbers of species belonged to the commercially important order perciformes followed by clupeiformes.

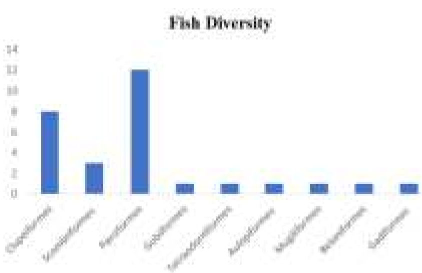


Fig 46. Order-wise species composition

NICRA: Climate change mitigation and adaptation strategies for salt affected soils with the objective of Management of sea water intrusion due to climate variability in coastal regions (UK Mandal, KK Mahanta and S Raut; PI: AK Bhardwaj, CSSRI, Karnal)

Characterizing soil salinity at the regional scale remains a difficult task despite decades of effort in soil mapping. Using satellite remote sensing, an effort has been made to identify the coastal salt-affected soils in India. The study made use of the Landsat-8 satellite's OLI (Operational Land Imager). These images were downloaded from the United States Geological Survey (USGS) Earth Explorer website. For multi-temporal studies, absolute radiometric calibration was done to minimize the impacts of changing atmospheric conditions, solar inclination, and sensor view angle. In the ERDAS software, images were

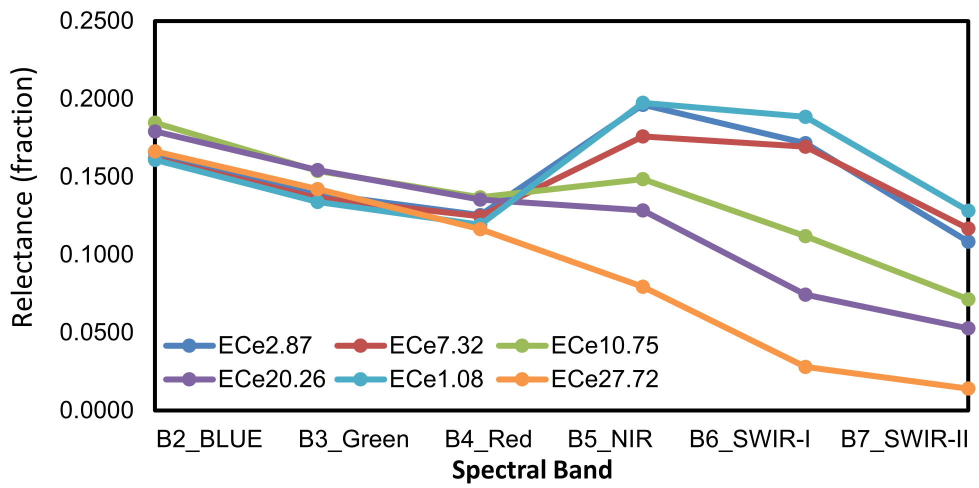


Fig 47. Reflectance curves of different salinity levels

Table 89. Spectral reflectance curves of different soil salinity level (measured as Electrical conductivity of salutation paste extract) for Landsat-8 OLI.

	Ece	EC (1:2)
B2_BLUE (0.452-0.512 um)	0.305	0.306
B3_G (0.533-0.590 um)	0.265	0.280
B4_R (0.636-0.673 um)	0.134	0.167
B5_NIR (0.85-0.88 um)	-0.455	-0.427
B6_SWIR-I (1.57-1.65 um)	-0.301	-0.260
B7_SWIR-II (2.11-2.29 um)	-0.235	-0.194

Table 90. Effect of nano-urea and conventional urea on NDVI, yield and fruit N content for okra cultivation

Treatments	NDVI	Yield (Kg/ha)	Fruit N content (% dry weight)
T1	0.817	8921.1	2.081
T2	0.873	15219.3	2.315
T3	0.853	13504.5	2.296
T4	0.823	9517.2	2.212
T5	0.817	9316.9	2.165
LSD (p =0.05)	0.033	1042.0	0.171

Table 91. Effect of nano-urea and conventional urea application on soil pH, EC, NO_3^- leachate and soil available nitrogen under okra cultivation

Treatments	Soil pH	Soil EC (dS/m)	No_3^- Leachate (mg/l)	Soil available N (kg/ha)
T1	6.38	0.54	0.678	77
T2	6.04	0.66	1.216	138.6
T3	6.51	0.64	0.847	123.2
T4	6.38	0.64	0.782	107.8
T5	6.15	0.48	0.742	92.4
LSD (p =0.05)	NS	NS	0.183	19.2

categorized using unsupervised classification, and Google Earth was used for ground truthing. The spectral band value for each sampling point was extracted and a correlation matrix was generated between EC_e and $EC_{1:2}$ versus the various Bands 2, 3, 4, 5, 6 and 7 of Landsat-8 OLI (Table 89). The B2 (blue), B3 (green), and B4 (Red) showed positive correlations with salinity, on the other hand, B5 (near infrared), B6 (shortwave infrared 1) and Band 7 (shortwave infrared 2) showed negative r values. The spectral response patterns for soils under different salinity levels are presented in Fig. 47. The soils having higher EC_e have been found to reflect more incident light energy in the visible spectrum (Bands 2, 3, 4) than soils having lower salinity level whereas it is reverse for Bands 5, 6 and 7 and helps in differentiating salt affected soils from normal soils and vegetation. Three indices Normalized Difference Vegetation Index (NDVI), Salinity Index (SI), and Canopy Response Salinity Index (CRSI) were used for identifying salt-affected regions. For testing the vegetation index with soil salinity, 192 georeferenced soil samples from Indian Sundarbans were collected. A relationship was developed between NDVI, SI, and square of CRSI (CRSISQR) with EC_e (electrical conductivity of saturation paste extract) and $EC_{1:2}$ (1:2; soil: water). For the coastal region, soils with a value of CRSISQR< 0.16 were considered to be influenced by salt since the relationship between EC_e and the square value of CRSI had a maximum r^2 (0.49). India has estimated 13.27 lakh ha of total salt-affected soil in all the coastal districts, and Gujarat (5.30 lakh ha), West Bengal (5.16 lakh ha), and Andhra Pradesh (1.49 lakh ha) were identified as the top three coastal salt-affected states.

A field experiment was conducted at ICAR-CSSRI, Regional Research Station, Canning Town to examine the efficacy of nano-urea for okra (*Abelmoschus esculentus*) cultivation. The treatments were T1 = no fertilizer; T2 = recommended fertilizer dose @ 90:45:45 kg/ha:: $N:P_2O_5:K_2O$; T3 = 1/3N urea, PK + 1/3N urea + 1/3 N nano-urea on equivalent basis (nano); T4 = 1/3N urea, PK + 1/3N nano + 1/3 N nano; T5 = 1/3N nano, PK + 1/3N nano + 1/3 N nano. Nitrogen was applied in three split doses whereas P and K was applied as basal. The plant vigour was recorded during 50 days after sowing using Trimble Green Seeker and T2 and T3 recorded significantly higher NDVI values and T1 recorded the lowest (Table 90). Maximum okra yield was recorded in T2 whereas 51.6%, 10.1%, 45.9% and 49.4% yield reductions were recorded in T1, T3, T4, and T5, respectively. Fruit nitrogen content was also maximum in T2 (2.31%). The nitrate content in leachate collected in porous cup was analyzed and it was maximum in T2 (1.22 mg/l) where recommended dose of nitrogen as urea was applied compared to nano urea treated plots (0.74-0.85 mg/l) (Table 91). Soil available N was also maximum in T2 treated plot (Table 91). N_2O flux was assessed using static chamber –gas chromatography and there was no increase N_2O flux immediately after the application of nano-urea. The flux was measured after three days of nitrogen application and the flux was maximum in urea applied field (T2). The field experiment showed that there was yield penalty in case of nano-urea application but it has environmental benefit in terms of minimum nitrate level in leachate than the conventional urea application and there is a need to look after the application doses for nano urea.

ACIAR funded project: Mitigating risk and scaling-out profitable cropping system intensification practices in the salt-affected coastal zones of the Ganges Delta
(Sukanta K. Sarangi, D. Burman, U.K. Mandal, K.K. Mahanta and S. Mandal)

Nine fodder crops viz. alfalfa, berseem, rice bean, guinea grass, Hybrid Napier Bajra (HNB), humidicola grass, oat, para grass and sorghum were evaluated for three dates of planting (D1:01 December 2021, D2:01 January 2022 and D3:01 February 2022). Date of planting had a significant impact on fodder yield. The average green fodder yield was 46.57, 35.51 and 20.81 t/ha for D1, D2 and D3 respectively. However, among the fodder crops, highest mean fodder yield was recorded for sorghum (72.45 t/ha) followed by HNB (57.39 t/ha), Oat (52.18 t/ha) and rice bean (33.24 t/ha).

This IFS system model was established in the field of Mrs. Reba rani Mandal and Mr. Pravash Mandal (Latitude N 22^{0}07'50.42" Longitude E 88^{0}46'31.21"). Total land of this farmer was 8000 m^2, out of which fodder cultivation was in 1000 m^2 area, homestead area including goat shed was 1500 m^2, cultivated land for rice was 5000 m^2 and fish pond including dyke was of 500 m^2 area. After harvest of rice, moong was cultivated in 4000 m^2 area. Fish pond was for irrigation and fish production for home consumption. Goat rearing (18 nos.) was the focus of this IFS, however other enterprises such as one dairy cattle, 16 numbers of poultry birds were combined in the homestead area apart from fish pond. Dairy milk yield was 3 litres/day for about 7 months. In five bigha of low land, rice was grown during the *Kharif* season and after that moong was grown in 3 bigha area. Few banana plants were grown near to the pond. From 18 numbers of goat and one dairy cattle about 1.2 tonnes of manure was produced in a year, which was used for improving the fertility of soils used for fodder production.

Integrated Rice-Fish-Fodder based Livestock Farming model was established in the field of Mr. Jayakrishna Patra (Latitude N 22^{0}08'17.51" Longitude E 88^{0}46'43.50"). The total farm area was 9133 m^2, out of which fodder cultivation in 500 m^2 area, fish pond with fruit crops in dykes and homestead area cover 1633 m^2 area, and rice cultivation during the Kharif season in 7000 m^2 area (out of which vegetables in 467 m^2 area during the *Rabi* season).

There is a great potential for growing vegetables in bags in waterlogged paddy fields during *Kharif* season in the salt affected coastal lands of the Ganges Delta. This technology was demonstrated in 22 farmers' fields in the Gosaba, Bali and Chandipur Islands of Sundarbans region of West Bengal. Climbing types of vegetables such as cucumber and bitter gourd were cultivated along with rice in the paddy fields. In the homestead farming system, crops such as spinach, turnip and beet root were cultivated by involving 31 numbers of farmers. Experiment on management of waterlogging during the *Rabi* season by field scale interventions revealed that rainfall (71.8 mm) in the month of February 2022, affected the performance of potato crop in the farmers' fields where drainage provision was not there. In the control plots (without drainage) the crop was affected and shown the symptoms of wilting. Due better drainage, the potato crop performance was better in the plots with surface furrows. The soil water content of surface soil (0-20 cm) from these fields were observed at 7, 14 and 21 days of waterlogging. The soil water content was less in the treatment with 0.5% slope and connected to the water harvesting structure (pond) with furrows (Fig. 48).

Potato tuber yield was significantly reduced due to the effect of waterlogging, when there is no provision of draining the excess rain water (Table 92). The land with slope and furrows had less soil water content after the waterlogging event. The advantage of having a water harvesting structure is the rain water harvesting of about 670 m^3 of water from an area of 1 ha. There was also less soil salinity development when the soil is well drained.

Study was conducted under the project to evaluate the halophytic crop Quinoa (*Chenopodium quinoa* Willd) for its suitability and acceptability in costal saline soils of West Bengal. The crop was grown in 8 farmers' fields with different level of salinity (ECe) ranging from 5.6 – 19.1 dS/m. Data on soil salinity and seed yield of quinoa crop were collected from 6 farmers' fields. Grain yield of quinoa varied from 1.29 t/ha in highly saline

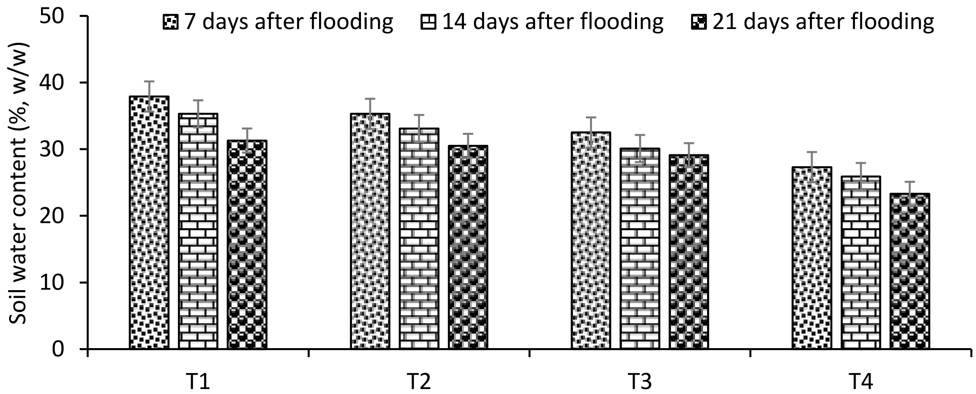


Fig 48. Effect of surface drainage on soil water content after the flooding event during Rabi 2021-22

[T1: Control (no drainage), T2: Plots with 0.5% slope, T3: Plots with 0.5% slope and provision of drainage by furrows; T4: Plots with 0.5% slope and provision of drainage by furrows, which are connected to the water harvesting structure (pond)]

Table 92. Effect of drainage on yield of potato and soil salinity during Rabi 2021-22

Treatments	Potato tuber yield (t/ha)	Rain water harvested (m3)	Soil salinity (ECe) dS/m
T1: Control (no drainage)	12.67c	0	5.58a
T2: Land with 0.5% slope	20.91b	0	4.92b
T3: T2 + furrows*	25.54a	0	4.12c
T4: T3 + water harvesting	28.49a	667.6	3.07d
SEm±	1.31	1.07	0.09
LSD (P=0.05)	4.05	3.29	0.27

*Furrows: 25 cm width and 15 cm depth at interval of 2 m

soil (ECe 19.1 dS/m) to 2.49 t/ha in saline soils with ECe of 5.6 dS/m. There was 48% yield reduction with increase in soil salinity from 5.6 to 19.1 dS/m. However, there is a potential for growing quinoa in the salt affected degraded coastal lands of the Ganges Delta. Experiment on low cost and water saving irrigation practices for horticultural crop such as bitter gourd was conducted involving pitcher irrigation, conventional check basin irrigation and different management practices of paddy straw mulching and water quality. In general, the soil salinity ($EC_{1:2}$) increased over time from 1.5 dS/m in January to 8.79 dS/m in May 2022. The soil salinity development was the least when pitcher is used for irrigation with best available irrigation water (BAW) with paddy straw mulching (PSM). Mean soil salinity for pitcher irrigation was 4.88 dS/m, whereas for check basin irrigation, the soil salinity increased to 5.71 dS/m. Irrigation with saline water (ECiw 5.82 dS/m) increased the mean seasonal soil salinity (EC1:2) to 6.43 dS/m, whereas soil salinity was less (4.16 dS/m) when non-saline (ECiw 1.27 dS/m) water was used for irrigation. Mulching with paddy straw also reduced the mean soil salinity build up during the *Rabi* season to 4.59 dS/m compared to no mulch treatment (6.00 dS/m). Highest yield and net return from bitter gourd crop were achieved under pitcher irrigation with BAW + PSM (Table 93). During the period the best cropping system intensification option i.e. rice-zero tillage planted and paddy straw mulched potato-green gram was out scaled in four clusters in Sundarbans (Gosaba, Bali, Chandiput and Canning). Zero tillage potato cultivation with paddy straw mulching was demonstrated in 61 farmers fields covering three islands (Bali, Chandipur and Gosaba) and Canning block of Sundarbans. The potato yield varied from 11.99 – 34.98 t/ha at Bali, 11.24 – 22.50 t/ha at Canning, 14.99 – 29.99 t/ha at Chandipur and 16.87 – 26.25 t/ha at Gosaba island. After harvest of ZT potato, green

Table 93. Effect of pitcher irrigation with saline water and paddy straw mulching on yield and economics of bitter gourd crop

Treatments	Yield (t/ha)	Cost of cultivation (/ha)	Gross return (/ha)	Net return (/ha)	BCR
Pitcher irrigation with SW*	3.85c	106250	115500	9250	1.09
Pitcher irrigation with SW + PSM	6.61b	110300	198240	87940	1.80
Pitcher irrigation with BAW**	6.95b	108500	208590	100090	1.92
Pitcher irrigation with BAW + PSM	9.07a	112100	272010	159910	2.43
Check basin irrigation with SW	2.14e	85300	64200	-21100	0.75
Check basin irrigation with SW + PSM	2.40e	81250	72000	-9250	0.89
Check basin irrigation with BAW	3.26d	87100	97800	10700	1.12
Check basin irrigation with BAW+ PSM	3.52c	83500	105480	21980	1.26

*SW: Saline water with ECiw 5.82 dS/m; **BAW: Best available water ECiw 1.27 dS/m

gram crop was grown under Rice-ZT potato-Green gram cropping pattern. Acid saline soil management through the application of lime was demonstrated and lime was provided to the farmers. Broccoli was found to be a very promising crop during the Phase I of the project was demonstrated in the farmers fields. The yield of broccoli varied from 12.00-31.87 t/ha. Broccoli crop has been a popular and profitable crop in the Gosaba island with BCR of 2.45-4.14. Sunflower crop was demonstrated in the Bali and Chandipur Islands. The yield of sunflower vaired from 0.85 – 1.28 t/ha and BCR was 1.48 – 1.78. Most preferred interventions reported by the farmers were, ZT potato with paddy straw mulching, application of lime for reclamation of acid sulphate soils and growing of new crops like broccoli, green gram, sunflower, quinoa and other vegetables.

DST funded project: Enhancing food and water security in degraded coastal soils through improved management of blue, green and gray water (U.K. Mandal, K.K. Mahanta, S. Mandal, T.D. Lama and D. Burman)

Exploration of ground water resources and its quality by geo-electrical methods is one of the inexpensive and in-situ methods and has been used for long time. The electrical resistivity method brings out the contrast between the water bearing formations against its surrounding strata and can provide precise information of the subsurface configuration of any area in a given hydrogeological set up. It can also delineate salt and fresh water boundary. The electrical resistivity method employs two kinds of surveys known as profiling i.e., lateral change and sounding (often referred to as Vertical Electrical sounding -VES). The depth wise true resistivity data are obtained from apparent resistivity data by computer programs. 15 vertical electrical soundings (VES) were carried out throughout the Basanti block to understand the overall geohydrological situation. The true resistivity values along with thicknesses of different layers are converted to delineate the resistivity vs depth map for entire Basanti block (Fig. 49). The low to moderate resistivity (< 1 ohm-m) of the formation particularly at a south eastern part suggested saline water in that region. A layer of fine sand and clay exists at a depth of 10-100 m below the ground level with a resistivity of > 20 ohm-m of variable thickness along with the previous clay layer forms the potential aquifer for groundwater in the study area particularly in North eastern part.

A low-cost biochar kiln was developed using locally available kerosene drum of 200 litre capacity .The kiln is about 60 cm diameter and 90 cm height with one square shaped hole of 16 x 16 cm cut at the kiln top for loading residues which can be closed by a metal lid with a handle. 25 holes of each 4 cm diameter were cut at the base of the cabinet to make

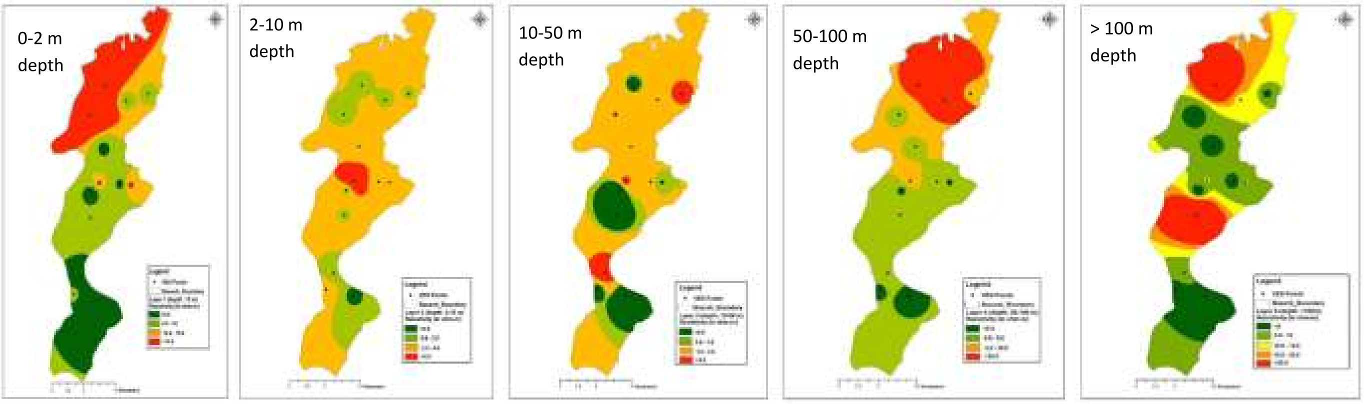


Fig 49. Depth wise resistivity value in Basanti block of Sundarbans

equidistance concentric circles at the bottom rim of the drum (photo). Prior to loading a bamboo pole was inserted through top hole and fixed to central bottom vent of the kiln to create a central vent through the packed residues. Then load the kiln with dried residue with gentle shaking and mount the kiln on raised stones to facilitate primary air flow through the bottom vents. Ignite it from the bottom for 3-4 min. Before ignition, the pole was carefully removed leaving a central vent through the loaded residues to ensure efficient flow of hot gases from bottom to top for continuous heat transfer through the residues. The target end stage of bio-carbonization was indicated by distinctive thin blue hot gases with puff of flame at the top hole of the kiln. At this stage, the kiln was ready to be sealed with mud to restrict the flow of air. The metal lid was placed over the top vent to block the upward movement of hot exhaust gases. Transfer the kiln to flat ground, seal with mud. Biochar samples in the kiln should be left for cooling for 3-4 h by heat loss though natural convection and radiation. After colling, the sealed mixture was removed thoroughly and the biochar was taken out and sieved. Here the residue from weeds, paddy straw, cotton stalk, water hyacinth and wood were used for biochar preparation.

Drum for biochar preparation

Locally available kerosene drum of 200 litre capacity was used for biochar kiln, length 90 cm and diameter 60 cm, 25 holes of each 4 cm diameter were cut at the base of the cabinet to make equidistance concentric circles at bottom rim

AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture

Amelioration of iron deficiency in direct seeded/aerobic rice grown on reclaimed sodic soil (B.L. Meena, R.K. Fagodiya, R.L. Meena, M.J. Kaledhonkar and P.C. Sharma)

In spite of high total iron in soils, its availability to crops is a major problem in many soils. The distribution of Fe in the soil fractions and the relationship between Fe associated with soil fractions and the plant-available Fe are therefore primarily affected by fertilization (in partially reclaimed sodic soils, which are not yet well understood. Keeping these facts in mind, a field experiment was conducted to address the iron deficiency of DSR with foliar (sprays of $FeSO_4.7H_2O$, Fe-EDTA, Fe-EDDHA and Fe-DTPA were done at 30, 45 and 60 days after sowing) and soil application (ferrous sulphate ($FeSO_4.7H_2O$) at the rate of 30, 40 and 50 kg ha^{-1}) of Fe sources under DSR (CSR-60) – wheat (KRL-210) cropping sequence. In this study, we measured the concentration of plant-available Fe in soils and the concentrations of Fe associated with different soil fractions (exchangeable fraction and fractions bound to carbonates, organic matter, oxides, and minerals) using a sequential extraction procedure. The relationships between plant-available Fe and the Fe fractions were analysed. The objectives of this study were to determine the effects of long-term cropping and fertilization on the distribution of Fe in the soil fractions and to examine the contribution of the Fe fractions to the available Fe.

The result showed that, among the soil application a treatment, 50 kg ha^{-1} was significantly increased the water soluble & exchangeable-Fe (0.49 mg kg^{-1}) and carbonated-Fe (5.89 mg kg^{-1}) concentration in soil solution as compare to control (Table 94). The values of carbonated-Fe was higher than exchangeable-Fe. It may be due to high $CaCO_3$ content in soil. The concentration of organic bound-Fe and oxide bound-Fe was significantly affected by soil application of Fe @ 30, 40 and 50 kg Fe ha^{-1}. It might be due to presence of organic carbon in surface soil. Foliar application did not significant effect on organic bound-Fe and oxide bound-Fe. Residual and total Fe was not significantly affect by source and method of Fe application. Residual Fe and total Fe were followed the similar trend under soil application of Fe. The maximum value of residual and total Fe was observed under the application of 50 kg Fe ha^{-1}.

Table 94. Distribution of Fe in different fractions in post-harvest soil of DSR as influenced by rate and methods of Fe application

Treatments	WS+Exch-Fe (mg kg^{-1})	Carb-Fe (mg kg^{-1})	OM-Fe (mg kg^{-1})	Oxide-Fe (mg kg^{-1})	Resi-Fe %	Total Fe %
T1: Control (no Fe application)	0.43	5.07	50.7	406	1.46	1.51
T2: 30 kg Fe ha^{-1} through $FeSO_4$	0.45	5.48	52.7	434	1.47	1.52
T3: 40 kg Fe ha^{-1} through $FeSO_4$	0.48	5.58	54.5	462	1.48	1.53
T4: 50 kg Fe ha^{-1} through $FeSO_4$	0.49	5.89	56.2	497	1.49	1.55
T5: Foliar sprays of 1.5% $FeSO_4.7H_2O$ (Thrice)	0.44	5.09	50.9	411	1.47	1.51
T6: Foliar sprays of 3% $FeSO_4.7H_2O$ (Thrice)	0.44	5.09	51.7	416	1.46	1.51
T7: Foliar sprays of 0.5% Fe-EDTA (Thrice)	0.44	5.02	51.2	411	1.47	1.52
T8: Foliar sprays of 0.2% Fe-EDDHA (Thrice)	0.45	5.01	51.8	415	1.47	1.52
T9: Foliar sprays of 0.5% Fe-DTPA(Thrice)	0.44	5.02	51.4	410	1.47	1.51
CD (p=0.05)	0.02	0.47	2.38	24.5	NS	NS

WS+Exch-Fe = Water soluble + Exchangeable; Carb-Fe= Carbonate Bound; Ox-Fe= Fe-Mn oxide bound; OM-Fe= Organically bound; RES-Fe= Residual

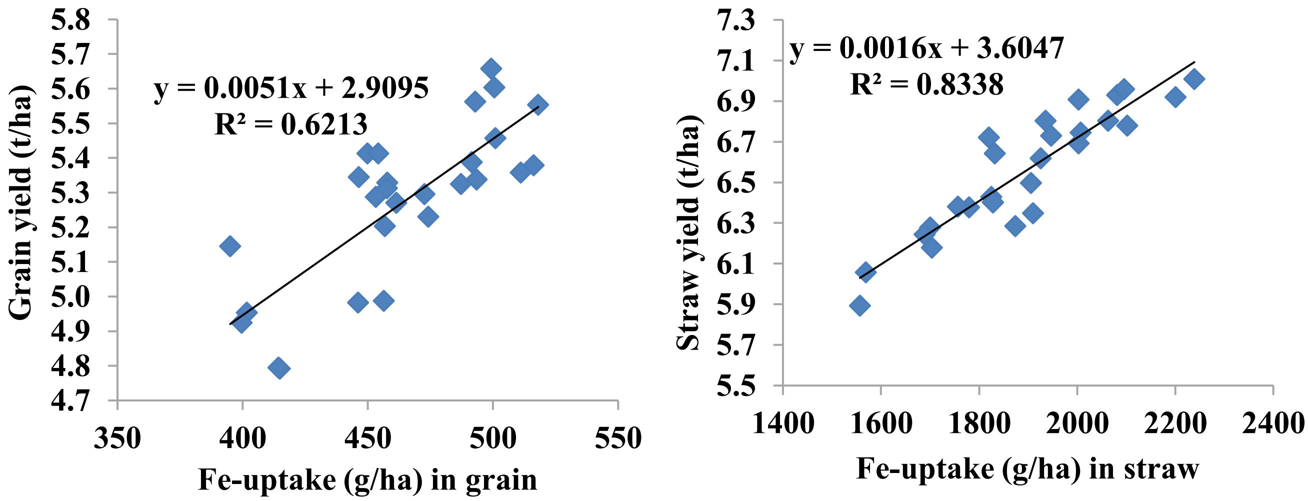


Fig 50. Relationship between yield of aerobic rice and Fe-uptake

Thus Fe fractions determine the availability of Fe to plants. The DTPA-Fe in soil significantly correlated with WS+ Ex-Fe, carbonated-Fe, OM-Fe and oxide-Fe in partially reclaimed soil. The iron availability in soil was enhanced by iron fertilization which increases the uptake of iron aerobic rice. The Fe-uptake was positively correlated with grain and straw yield. Grain yield (R^2 = 0.62) and straw yield (R^2 = 0.83) showed a linear relation with Fe-uptake (Fig. 50).

DST-PAU Project: North Indian Centre for Water Technology Research in Agriculture

Experiment 1: Development of technology for judicious use of saline groundwater in Agra district of Uttar Pradesh

In the Agra region, farmers use saline ground waters for crop production. The crop productivity is low due to saline water irrigation. The dilution of saline groundwater is possible through artificial groundwater recharge and same diluted groundwater can be used for crop production through drip to improve crop and water productivity. Therefore, a study was undertaken at Research Farm of RBS College, Agra, Uttar Pradesh for Tomato-Okra as well as Bajara- Mustard crop rotations. A tube well having recharge structure was constructed at research farm to dilute saline groundwater in aquifer itself. The experiment was planned with three irrigation water quality levels (saline groundwater, diluted saline groundwater due to recharge and stored rainwater) as main irrigation water quality treatments while irrigation water application (drip irrigation at 80% ET_c, drip irrigation at 100% ET_c and flood irrigation) and mulch (no much and mulch at 6 t ha^{-1}) as sub treatments.

Results revealed that tomato fruit yield significantly decreased in saline ground water (EC_{iw} 6 dS m^{-1}) without recharge as compared to saline ground water (diluted) from the well with rain water recharge and stored rain water (Table 95). Similar results were recorded during all the three years of experimentation. Treatment of stored rainwater gave the highest B: C ratio followed by saline ground with water recharge and saline groundwater alone. In case of irrigation method/schedule, yield at 80% ETc and 100% ETc with drip irrigation were significantly higher in comparison to yield under flood irrigation. The effect of crop residue at rate of 6 t ha^{-1} on tomato yield was found significant.

Table 95. The yield (t ha^{-1}) of Tomato and Mustard crops as influenced by different treatments during 2021-22

Tomato		**Mustard**	
Treatments	**Yield (t ha^{-1})**		**Yield (t ha^{-1})**
Source of water:			
S (Saline ground water (EC_{iw} 6 dS m^{-1}) without recharge)	12.14	S (Saline ground water (EC_{iw} 10 dS m^{-1}) without recharge)	1.71
SD (S ground Water (Diluted) from tube well with recharge)	16.58	SD (S ground Water (Diluted) from tube well with recharge)	2.06
SR (Stored rain water)	18.06	SR (Stored rain water)	2.17
		F (Surface flood irrigation (Recommended)	1.72
CD at 5%	3.37	CD at 5%	0.29
Method of irrigation:			
D80 (Drip irrigation at 80% of ETc)	15.42		
D100 (Drip irrigation at 100% of ETc)	17.10		
F (Surface flood irrigation) (Recommended)	14.27		
CD at 5%	0.92		
Mulch level:		**Mulch level:**	
M0 (No mulch)	14.15	M0 (No mulch)	1.82
M6 (Crop residue mulch (6t ha^{-1})	17.05	M6 (Crop residue mulch (6 t ha^{-1})	2.01
CD at 5%	1.90	CD at 5%	NS
Interactions		Interactions	
S x M	NS	S x M	NS
M x I	NS		
S x I	NS		
S x M x I	NS		

The yield of mustard was significantly affected due to irrigation water quality. The highest yield was recorded in stored rainwater while lowest was under saline water treatment. However, effect of mulch on yield was not significant.

Experiment 2: Development of technology for judicious use of sodic groundwater in Patiala district of Punjab

This experiment on direct seeded rice–wheat rotation along with drip irrigation was initiated on farmer's field at village Budhmor in Patiala district of Punjab. Soil samples (0-15 cm depth) collected from selected field were analyzed for soil chemical properties and soil fertility parameters. The texture of experimental field is silt loam and having alkaline with pH (1:2) value of 8.33 and EC (1:2) 0.57 dSm^{-1}; alkaline permanganate oxidizable nitrogen was 154.8 kg ha^{-1}, available phosphorus was 8.2 kg/ha, 1 N ammonium acetate exchangeable potassium was 200 kg ha^{-1} and organic carbon as 0.56%. The groundwater was source of irrigation and it was of sodic in nature with pH 8.02 indicating that the water was neutral to alkaline in nature. The EC of the soil sample was 0.71 dS m^{-1}. The concentration of Na^+, Ca^{2+} + Mg^{2+}, K^+, Cl^- and CO_3^- + HCO_3^- in groundwater sample were 6.15, 1.40, 0.11, 0.30 and 5.29 me L^{-1}, respectively. The cationic concentration followed the order: Na^+ > Mg^{2+} + Ca^{2+}> K^+. The sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were 5.21 (mmol $L^{-1})^{1/2}$ and 3.89 meL^{-1}. The RSC value exceeds 2.5 me L^{-1}, the water is considered harmful as soil texture is silt loam.

Table 96. Effect of irrigation and gypsum application on wheat grain yield (t ha^{-1})

Levels of Irrigation	Levels of gypsum application			
	G1: No Gypsum	**G2: 25% GR**	**G3: 50% GR**	**Mean**
I1: 80 % of ETc (Drip)	3.70	4.02	4.83	4.18
I2: 100% of ETc (Drip)	3.73	3.97	4.22	3.97
I3: Flood (Surface)	2.88	2.96	3.14	2.99
Mean	3.44	3.65	4.06	3.72
CD(p=0.05)	I=0.21	G=0.19	I×G=0.32	

Table 97. Rice yield (t ha^{-1}) under DSR as influenced by different treatments (2022)

Levels of Irrigation	Levels of gypsum application			
	G1: No Gypsum	**G2: 25% GR**	**G3: 50% GR**	**Mean**
I1: 150 % of ETc (Drip)	2.77	2.83	3.08	2.89
I2: 175 % of ETc (Drip)	2.88	2.85	2.92	2.88
I3: Flood (Surface)	2.69	2.79	2.81	2.76
Mean	2.78	2.82	2.93	2.85
CD(p=0.05)	I=NS	G=0.86	I×G=NS	

Rabi 2021-22

Details of 1st wheat (KRL-210) crop during rabi 2021-22 and 2nd rice (CSR-30) crop during kharif 2022 are provided in this section. The wheat crop was sown on 24 November 2021 and harvested on 11 April 2022.Rainfall during crop period was 16.39 mm. The results (Table 96) showed that wheat yield was influenced by gypsum application as well as irrigation method. However, effect of mulch on wheat yield was not found significant.

Kharif 2022

The DSR (Direct Seeded Rice)-wheat crop rotation was followed. It was sown on 10 June 2022 and harvested on 9 November 2022. The rainfall during Kharif period was 443.2 mm. The field being low lying the runoff of the area accumulated in the field. The infiltration rate of the field is very low and runoff water remained standing for longer period and effect of irrigation treatment was not significant. However, effect of gypsum of crop yield was significant (Table 97). Similar to irrigation, effect of mulch of crop yield was not significant.

Experiment 3: Projection of climate parameters in climate changing scenario, their impact on water balance in cropped soil and groundwater at spatial scale

Groundwater modeling for Kaithal district of Haryana

The rice-wheat crop rotation is followed in the state of Haryana and major portion of the rice-wheat areas are in Karnal, Panipat, Kaithal and Kurukshetra districts. Therefore these districts were selected for groundwater modeling study. The calibration and validation of the groundwater model was done for Karnal and Panipat district separately and results have been reported earlier. The groundwater modeling for Kaithal district was undertaken during the period of this report. The weather data for Kaithal district were collected from meteorological observatory at RRS,College of Agriculture, Kaul under CCSHAU, Hisar. The water table data for Kaithal district were available from 2013 to 2021 for 59 locations from Groundwater Cell of Haryana as well as website of CGWB. The canal supply data from HSMITC Report and Aquifer properties from website of India-WRIS. These data were used for calibration and validation of groundwater model for Kaithal. Thus CROP WAT Model was used to work water requirement of rice and wheat crops for 9 years period in the Kaithal. The CROPWAT model considered contribution of rainfall towards the irrigation in the form of effective rainfall and crop water requirement was adjusted as per contribution of rainfall. Therefore, irrigation water requirement worked by CROP WAT model was to be met from canal and groundwater supply. In case of groundwater irrigated areas, it was fully met by groundwater supply. In case canal irrigated areas, there was canal water supply but it was not sufficient to cover all irrigations of both crops by canal water supply. Under such situations, contribution of groundwater supply was worked out considering canal water supply contribution. As canal water supply to Kaithal district is limited and again it was in pockets. Therefore, contribution of canal water supply in canal irrigated areas was taken as 25% and contribution of groundwater was taken as 75%. The crop areas under different crops were important for working out the groundwater pumping. The rice-wheat crop rotation covered majority of agricultural areas in the district, hence groundwater pumping was worked out on the basis of irrigation water requirement of these two crops. The irrigation water use efficiency for groundwater irrigated areas was taken as 70 per cent while it was taken as 50% for canal irrigated areas. Thus groundwater pumping was estimated.

The contribution of rainfall towards groundwater recharge was taken as 15% of annual rainfall amount as per CGWB norms. On an average, the recharge to groundwater was taken as 80% of seepage from the main canals, 60% of seepage from distributaries and 40% of seepage from the minors. The main canal runs for more number of days than other canals, hence the higher level of contribution to the groundwater recharge. On the basis of hydraulic data collected for water courses and field measurement by HSMITC (1983b), values of seepage loss for the lined and unlined water courses were estimated as 3.0 m^3/sec/106 m^2 and 7.53 m^3/sec/106 m^2, respectively. The recharge to groundwater body was taken as 40% of seepage because watercourses run for lesser number of days. On the basis of these assumptions, on an average recharge to groundwater was worked out as 23730 ha-m. Also deep percolation losses of water due to seepage and other factors from irrigated fields, where application was through canal supply was seen as 30-40% of water delivered at farm gate. In case of tube well irrigation, this loss was reported as 25%. Year wise total recharge as result of rainfall recharge, canal seepage and deep percolation losses were worked out.

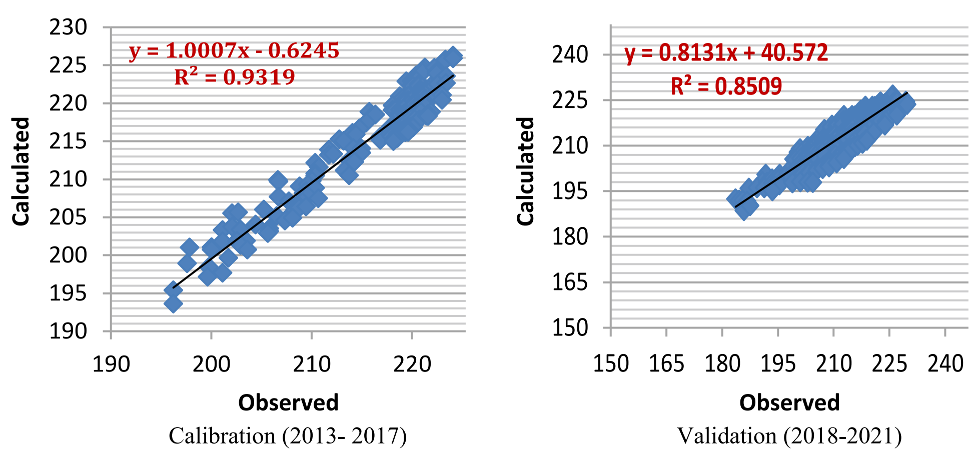


Fig 51. Comparison of observed and simulated hydraulic heads during calibration and validation groundwater model for Kaithal district

In case of active cells, cell wise elevation of bed rock and initial water table elevation were considered. Values of aquifer properties such as saturated Hydraulic conductivity (Kz=0.001 to 2.4 m/d, Kx&Ky = 0.1 to 24 m/d), Storage coefficient (110-5), Specific yield (0.15), Total porosity (0.25) and Effective porosity (0.14) were taken from CGWB. The pumping and recharge data were assigned to all active cells with time and there were 59 observation wells with latitude and longitude details. The historic data from these locations were used for calibration. The parameters used in calibration were further improved by PEST model and then those parameters were used for validation (Fig. 51).

Projects of AICRP on management salt affected soils & use of saline water in agriculture at centres

Survey and characterization of groundwater of Anantapur district for irrigation purpose (Bapatla)

The groundwater survey to know its quality was conducted during 2020-21 by collecting 492 samples from 63 mandals of Anantapur district of Andhra Pradesh. The pH value of samples varied from 6.7 to 8.4; EC ranged from 0.4 to 10.7 dS m^{-1}; SAR ranged from 0.43 to 36.34 and RSC ranged from nil to 15.4 (Table 98). Out of total samples, 66.26, 17.68, 1.42, 0.61, 5.69, 6.91 and 1.42% samples were good, marginally saline, saline, high SAR saline, marginally alkaline, alkali and high alkaline, respectively.

The earlier groundwater quality survey was conducted during 1990. The distribution of groundwater samples under different quality classes is given in Table 99. It indicated that samples under good quality category have been reduced from 88/3 to 66.26%. However, there were increases in samples under in marginally saline, saline, high SAR saline, marginally alkali, alkali and highly alkali classes. Major increase in samples of 8.18, 4.59 and 6.91% was observed in case of marginally saline, marginally alkali and alkali classes,

Table 98. Chemical properties of groundwater samples of Anantapur district

S.No.	Parameter	Range	S.No.	Parameter	Range
1	pH	6.7-8.4	7	Ca^{2+}(me L^{-1})	0.8-28.4
2	EC(dSm^{-1})	0.4-10.7	8	Mg^{2+}(me L^{-1})	0-43.2
3	CO_3^{2-} (me L^{-1})	-5.4-1.8	9	Na^{+}(me L^{-1})	0.73-70.1
4	HCO_3^{-} (me L^{-1})	0.88-15.4	10	K^{+}(me L^{-1})	0.001-51.76
5	Cl^{-}(me L^{-1})	0.4-59.6	11	RSC(me L^{-1})	-66.8-15.4
6	SO_4^{2-}(me L^{-1})	0.21-17.08	12	SAR	0.43-36.34

Table 99. Comparison of ground water quality of Anantapur district with previous survey

S.No.	Quality class	Percent samples		Number of samples	
		Previous (1990)	Present (2020-21)	Previous (1990)	Present (2020-21)
1	Good water	88.3	66.26	704	326
2	Marginally saline	9.5	17.68	75	87
3	Saline	1	1.42	8	7
4	High SAR Saline	0.1	0.61	1	3
5	Marginally alkali	1.1	5.69	9	28
6	Alkali	0	6.91	0	34
7	Highly alkali	0	1.42	0	7
	Total	100	100	797	492

respectively. Overall deterioration in groundwater quality might be due to over exploitation of groundwater and other anthropological reasons.

Survey and characterization of groundwater of Jodhpur district for irrigation purpose (Bikaner)

The data on ranges of chemical characteristics of groundwater samples from 89 villages of Bapini, Bawari, Jodhpur, Luni, Osian and Tinwari tehsils of Jodhpur district were taken. pH of the samples in Bapini, Bawari, Jodhpur, Luni, Osian and Tinwari tehsils varied from 7.49 to 8.41, 7.04 to 8.73, 7.06 to 8.50, 7.06 to 8.12, 7.54 to 8.25 and 7.23 to 8.10, whereas, EC ranged between 0.34 to 3.30, 0.36 to 9.77, 0.23 to 16.89, 4.68 to 41.10, 0.90 to 5.48 and 0.30 to 6.10 dS/m, respectively. The value of SAR of samples ranged between 2.52 to 8.72, 2.84 to 15.81, 2.20 to 21.40, 11.55 to 30.04, 4.68 to 11.48 and 2.84 to 12.51, whereas, soluble sodium percentage (SSP) of water samples varied from 60.75 to 66.97, 60.99 to 69.83, 57.19 to 69.75, 60.57 to 68.59, 61.47 to 68.77 and 58.38 to 69.29, respectively for Bapini, Bawari, Jodhpur, Luni, Osian and Tinwari tehsils of Jodhpur district. The Adj. SAR varied from 3.02 to 24.42, 3.40 to 56.90, 1.90 to 81.31, 35.80 to 132.16, 8.42 to 35.57 and 2.61 to 40.03 in Bapini, Bawari, Jodhpur, Luni, Osian and Tinwari tehsils of Jodhpur district, respectively. The RSC of these water samples ranged between Nil to 0.47, Nil to 3.85, Nil to 2.46, Nil to 7.07, Nil to 1.05 and Nil to 0.71 me/L in Bapini, Bawari, Jodhpur, Luni, Osian and Tinwari tehsils of Jodhpur district, respectively.

Categorization of water samples as per water quality standard (Gupta et al. 1994) is given in Table 100 and spatial distribution is given in Fig. 52. About 60 and 40% water samples in Bapini tehsil were found under good and marginally saline; 26.67,40 ,6.67, 23.33 and 3.33% water samples in Bawari tehsil lies under good, marginally saline, saline, high SAR saline and highly alkali; 28.13,18.75,50 and 3.12% water samples in Jodhpur tehsil lies under good, marginally saline, high SAR saline and highly alkali; 9.09, 86.36 and 4.55% water samples in Luni tehsil lies under saline, high SAR saline and highly alkali, 54.55, 39.39 and 6.06% water samples in Osian tehsil lies under good, marginally saline and high SAR saline and 66.67,26.67 and 6.66% water samples in Tinwari tehsil lies under good, marginally saline and high SAR saline.

Further, the concentration of fluoride in ground water samples ranged between 0.15 to 0.95, 0.16 to 8.30, 0.09 to 4.30, 0.15 to 20.00, 0.38 to 2.10 and 0.21 to 2.80 mg/L, whereas, Nitrate content of water samples varied from 21 to 597, 12 to 962, 6 to 806, 39 to 902, 6 to 470 and 9 to 1206 mg/L, respectively for Bapini, Bawari, Jodhpur, Luni, Osian and Tinvari tehsils of Jodhpur district.

Table 100. Distribution of different water quality categories in Jodhpur district

S.No.	Water quality categories	Percentage (%)					
		Tehsils					
		Bapini	Bawari	Jodhpur	Luni	Osian	Tinvari
1.	Good	60.00	26.67	28.13	-	54.55	66.67
2.	Marginally saline	40.00	40.00	18.75	-	39.39	26.67
3.	Saline	-	6.67	-	9.09	-	-
4.	High SAR saline	-	23.33	50.00	86.36	6.06	6.66
5.	Highly alkali	-	3.33	3.12	4.55	-	-

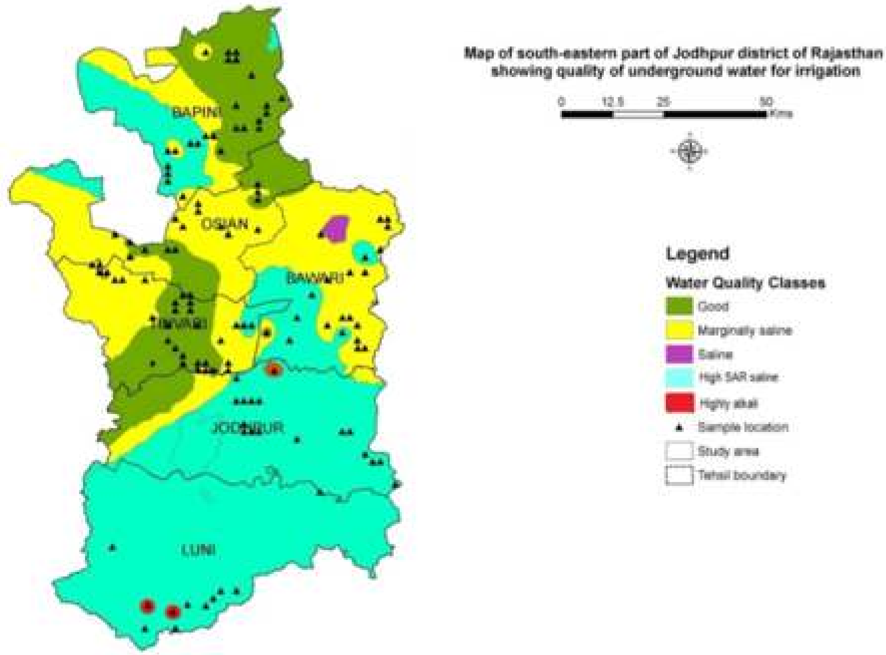


Fig 52. Groundwater quality of Jodhpur district, Rajasthan

Table 101. Range and mean of different water quality parameters for Hisar district

S.No.	Parameter	Range	Mean	S.No.	Parameter	Range	Mean
1	pH	6.35-9.48	7.73	7	Na^+ (me l^{-1})	1.50-108.20	29.57
2	EC (dSm^{-1})	0.20-14.90	4.30	8	K^+ (me l^{-1})	0.02-17.36	0.74
3	RSC (me l^{-1})	0.00-6.30	0.44	9	CO_3^{2-} (me l^{-1})	0.00-2.90	0.45
4	SAR (mmol $l^{-1})^{1/2}$	2.10-32.87	11.81	10	HCO_3^- (me l^{-1})	0.10-12.50	4.36
5	Ca^{2+} (me l^{-1})	0.08-12.50	2.87	11	Cl^- (me l^{-1})	1.60-132.00	25.27
6	Mg^{2+} (me l^{-1})	0.21-32.00	8.52	12	SO_4^{2-} (me l^{-1})	0.03-60.80	11.16

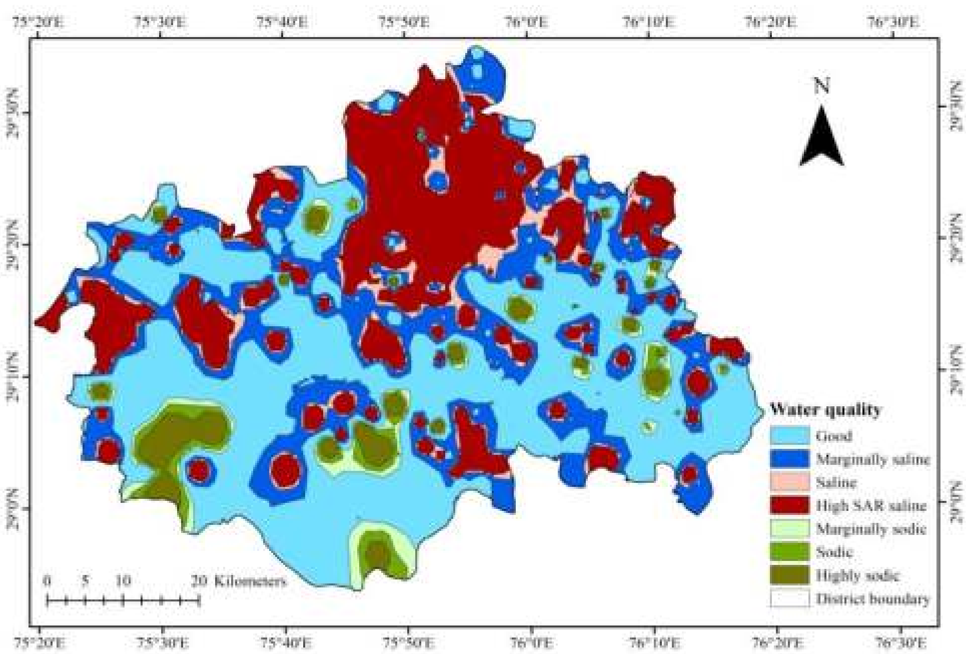


Fig 53. Groundwater quality map for Hisar district according to AICRP criteria

Survey and characterization of groundwater of Hisar district of Haryana for irrigation (Hisar)

Total 380 ground water samples from different blocks of Hisar district (40 from Agroha, 36 from Adampur, 57 from Barwala, 55 from Hansi-I, 29 from Hansi-II, 37 from Hisar-I, 32 from Hisar-II, 60 from Narnaund and 34 from Ukalana block) were collected for various chemical parameters, 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 of these blocks are given in table 101.

According to AICRP classification, it was found that overall in Hisar district, 26.3, 20.5, 5.5, 39.2, 1.1, 1.1 and 6.3 per cent samples were found in good, marginally saline, saline, high SAR saline, marginally alkali, alkali and highly alkali categories, respectively (Fig. 53). There was a little problem of alkalinity in groundwater of the district because marginally alkali and alkali categories were observed very scattered with small polygons.

Survey and characterization of groundwater quality of Pudukottai district of Tamil Nadu for irrigation purpose (Tiruchirappalli)

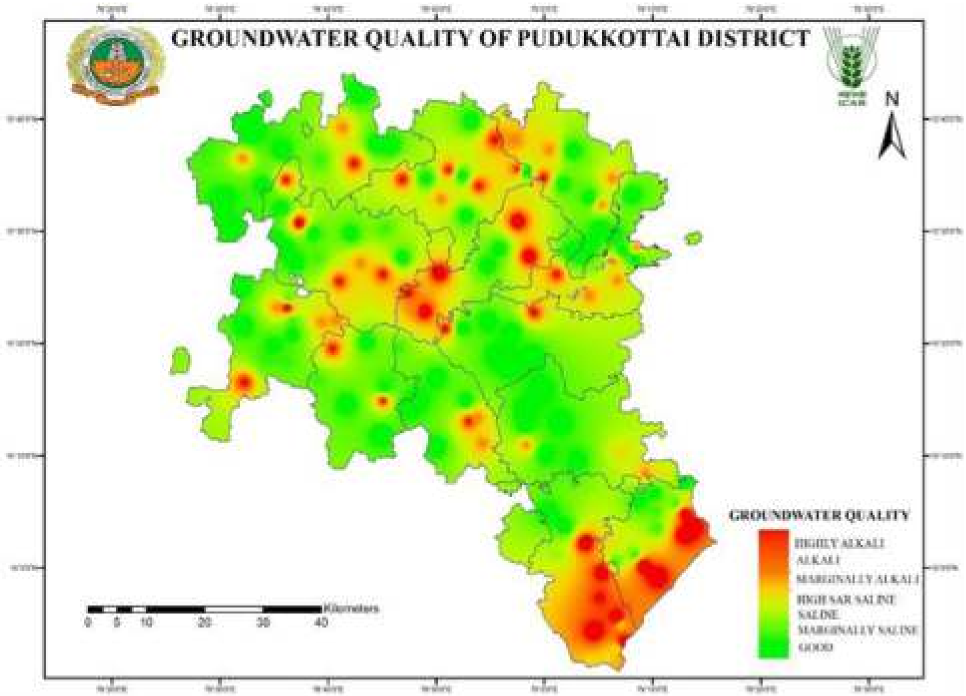
Pudukkottai district has an area of 4663 sq.km with a coast line of 42.8 km which includes 32 coastal villages and towns. Total 149 groundwater samples were collected based on grid survey during the month of March 2020 in the Pudukkottai district. The samples were analysed for pH, Electrical Conductivity (EC), cations viz., Ca^{2+}, Mg^{2+}, Na^+ and K^+ and anions viz., CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} by standard procedure. Mean concentrations of cations and anions are given in Table 102.

The EC, Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC) were used to determine distribution of different quality categories of groundwater in the district. Out of the total samples collected in Pudukkottai district 45% of samples were found as good quality and its remaining samples were found in different categories of water quality viz., Marginally saline (12%), Saline (1%), High-SAR saline (4%), Marginally alkali (14%), Alkali (14%) and High alkali (10%). Among the different blocks investigated, the highest

Table 102. Mean concentrations of cations and anions in different blocks of Pudukkottai

S. N.	Block name	Cations ($meqL^{-1}$)				Anions ($meqL^{-1}$)			
		Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}
1.	Viralimalai	4.54	5.43	9.44	0.58	3.28	6.25	9.10	0.61
2.	Annavasal	4.20	4.99	10.79	0.41	3.32	6.35	8.71	0.33
3.	Ponnamaravathi	4.73	6.82	12.60	1.84	3.90	6.78	12.20	0.61
4.	Avadaiyurkovil	4.84	10.30	53.88	3.35	2.69	5.72	57.76	1.32
5.	Manamelkudi	4.61	5.83	28.04	1.11	3.89	7.13	22.80	1.19
6.	Arantangi	4.49	3.35	16.60	0.45	2.39	4.59	13.85	0.33
7.	Thirumayam	3.39	7.01	12.46	0.36	2.78	7.95	13.10	0.44
8.	Arimalam	2.54	4.07	6.37	0.25	3.14	6.28	5.56	0.51
9.	Thiruvarankulam	3.35	3.25	6.64	0.96	2.76	5.65	5.75	0.34
10.	Pudukkottai	1.83	4.06	20.04	0.27	3.79	7.95	9.70	0.76
11.	Kunnandarkovil	2.09	3.15	5.63	0.21	3.09	5.55	4.69	0.24
12.	Gandarvakottai	2.15	2.68	4.01	0.19	2.00	4.45	4.44	0.19
13.	Karambakudi	2.68	3.16	4.46	0.37	2.20	4.70	4.80	0.19

Fig 54. Spatial distribution of different categories of groundwater quality in Pudukkottai district



percentage of samples with good quality were found in Thiruvarankulam (75%), Viralimalai (62.5%), Gandarvakottai (55%), Arantangi (55%), Arimalam (55%), Annavasal (50%) and Thirumayam (50%). The spatial distribution of groundwater quality categories of Pudukkottai district is provided in Fig. 54.

Survey and characterization of groundwater quality of Ferozepur district of Punjab for irrigation purpose (Bathinda)

The Ferozepur district is situated between 29°56'47" and 31°0'7" North latitudes and 72°52'4" and 75°01'11" East longitudes in southwest region of the Punjab state, India. The ranges of chemical constituents of groundwater were given in Table 103. The high pH of water was reported in Zira tehsil followed by Ferozepur and Guru Har Sahai. The electrical conductivity (EC) ranged between 1.0-8.7 dSm^{-1} with mean of 3.16 dSm^{-1}, 0.60-4.8 dSm^{-1} with mean of 1.93 dSm^{-1} and 0.28-4.50 dSm^{-1} with mean of 1.79 dSm^{-1} in Ferozepur, Guru Har Sahai and Ziraa tehsils, respectively. Ferozepur tehsil had highest RSC (3.57 meL^{-1})

Table 103. Range and average for different chemical constituents of ground water in Ferozepur district of Punjab

Name of Blocks →	Ferozepur		Guru Har Sahai		Zira	
Paremeters ↓	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**
pH	7.09-10-22	8.42	7.09-9.53	7.88	7.60-10.11	8.70
EC (dSm^{-1})	1.0-8.7	3.16	0.60-4.8	1.93	0.28-4.50	1.79
Ca^{+2} + Mg^{+2} (me L^{-1})	0.8.0-9.9	4.58	1.5-10.2	5.66	0.70-10.20	4.28
Cl^{-1} (me L^{-1})	0.80-19.0	5.86	1.0-16	2.98	0.80-15.60	3.71
CO_3^{-2} (me L^{-1})	0.0-1.0	0.54	0.0-0.3	0.17	0.0-0.90	0.25
HCO_3^- (me L^{-1})	2.0-11.6	7.02	1.2-13.6	6.43	1.0-9.0	4.27
RSC (me L^{-1})	0.0-8.0	3.57	0.0-12.0	2.69	0.0-4.60	1.97
SAR (m mol/l)	0.84-19.93	7.68	0.29-8.58	2.82	0.52-13.96	5.59
K (ppm)	7.5-157.0	39.09	10.4-25.8	15.97	0.15-91.60	24.71
Na (me L^{-1})	0.80-25.57	10.39	0.57-10.35	4.03	.87-21.43	7.48

Table 104. Distribution of different water quality categories in Ferozepur district of Punjab

Water quality category	Name of Tehsil						Ferozepur district	
	Ferozepur		Guru Har Sahai		Zira			
	Samples	%	Samples	%	Samples	%	Samples	%
A. Good	29	17.06	71	59.17	88	50.00	188	40.34
B. Saline								
I. Marginally Saline	15	8.82	20	16.67	23	13.07	58	12.45
II. Saline	29	17.06	3	2.50	9	5.11	41	8.80
III. High –SAR Saline	04	2.35	1	0.83	22	12.50	27	5.79
C. Alkaline Water								
I. Marginally alkaline	49	28.82	10	8.33	26	14.77	85	18.20
II. Alkaline	26	15.29	15	12.50	8	4.55	49	10.52
III. Highly alkaline	18	10.59	0	0	0	0	18	3.90
	170	100	120	100	176	100	466	100

followed by Guru Har Sahai (2.69 meL^{-1}) and Zera tehsil (1.97 meL^{-1}). Whereas, maximum Ca^{+2} $+Mg^{+2}$ was reported in Guru Har Sahai tehsil and minimum average value was recorded in Zira tehsil. Among the anions, chloride was dominant ion with values ranging from 0.80 to 19.0 meL^{-1} followed by bicarbonate (0.10-13.6 me L^{-1}) and carbonate (0.0 to 0.90 meL^{-1}).

Distribution of different water quality categories is given in table 104. The 40.3, 12.5, 8.8 and 5.79, 18.20, 10.52 and 3.90% samples were of good, marginally saline, saline and high SAR-saline, marginally alkaline, alkaline, highly alkaline categories in Ferozepur district. Maximum 59.17% samples with good quality irrigation water were reported in Guru Har Sahai tehsil followed by Zira (50.0%) and Ferozepur tehsil (17.0%).

Conjunctive use of alkali and canal water for Til (Sesamum indicum L.) – Lentil (Lens culinaris) cropping sequence (Agra)

An experiment was initiated at RBS College Agra to find out the suitable conjunctive use mode for til and lentil crop sequence. The yield responses of these crops to different conjunctive use modes were recorded for this purpose. Also changes in soil properties were observed. Treatments were i) all irrigations by canal water, ii) All by Alkali water, iii) One canal: One alkali, iv) One alkali: One canal and v) Mixing (1 Canal: 1 Alkali). The RSC of irrigation water was 8 meq/l. The design of the experiment was Randomized Block Design (RBD) with three replications. Plot size was 4m x 4m. The experiment started during 2020-21. The sowing was on Bed and furrow system in both crops. The first crop sown was Lentil in rabi season. The results obtained of Lentil crop have been described as follows.

The grain and Stover yield (2020-21) are also differed significantly amongst the different modes of canal and alkali irrigations water (Table 105). The higher grain and stover yield were recorded in canal irrigated treatment (6.01 q/ha and 23.04 q/ha) and lowest in all alkali water irrigated treatment (2.61 q/ha and 9.90 q/ha). During 2021-22, grain and stover yield differed significantly amongst the different mode of canal and alkali irrigations water. The higher grain and stover yield were recorded in canal irrigated treatment (6.3 q/ha and 23.00 q/ha) and lowest in all alkali water irrigated treatment (2.6 q/ha and 9.70 q/ha). The treatments One Canal: One Alkali and mixing (1:1) mode were found at par.

Table 105. Effect of different conjunctive use modes on yield of Lentil

Treatments	Grain yield ($q\ ha^{-1}$)	Stover yield ($q\ ha^{-1}$)	Grain yield ($q\ ha^{-1}$)	Stover yield ($q\ ha^{-1}$)	Mean Grain yield ($q\ ha^{-1}$)	Net profit ($Rs\ ha^{-1}$)	B:C ratio
	2020-21		2021-22				
All Canal Water	6.01	23.04	6.3	23.0	6.16	27,950	2.53
All alkali water	2.61	9.90	2.6	9.7	2.61	1,325	1.07
One Canal: One alkali	5.12	19.04	4.9	19.1	5.01	19,325	2.06
One Alkali: One Canal	4.1	15.58	4.0	15.5	4.05	12,125	1.66
Mixing (1:1)	5.2	20.50	5.1	20.4	5.15	20,375	2.12
CD at 5%	0.64	2.66	0.53	2.28	-	-	-

Table 106. Effect of alkali water irrigation to supplemental canal water irrigation on yield and yield attributing characters of Til (2021)

Treatments	Grain yield (q/ha)	Stover yield (q/ha)	Net profit (Rs/ha)	B:C ratio
All canal water	5.0	27.2	40,000	2.08
All alkali water	3.4	21.5	27,200	1.41
One Canal: One alkali	4.1	24.7	32,800	1.70
One Alkali: One Canal	4.0	24.6	32,000	1.66
Mixing (1:1)	4.2	26.8	33,600	1.74
CD at 5%	0.61	4.9	-	-

The initial soil ECe, pH and organic carbon is 2.3 (dS/m), 7.9 and 0.27%, respectively in surface layer (0-15cm). In case of lower depth (60-90cm) is ECe 1.5 (dS/m), pH7.9 and organic carbon 0.16 per cent. At harvest of 2021-22, the ECe, pH, SAR and ESP ranged at surface layer 2.8-3.6 dS/m, 7.9-8.2, 7.6-12.5 $(mmol/l)^{1/2}$ and 8.8-13.6 per cent. In general the ECe, pH, SAR and ESP at harvest of lentil crop are less in canal water as compared to alkali water alone and other modes of canal and alkali water.

The grain and stover yield of til differ significantly amongst the different mode of canal and alkali irrigations water (Table 106). The higher grain and stover yield were recorded in canal irrigated treatment (5.0 q/ha and 27.2 q/ha) and lowest in all alkali water irrigated treatment (3.4 q/ha and 21.5 q/ha).

In general the ECe, pH, SAR and ESP at harvest of lentil crop were less in canal water as compared to alkali water alone and other modes of canal and alkali water.

Enhancing water use efficiency in reclaimed waterlogged saline Vertisols by implementation of subsurface srainage aystem (Gangavathi)

The experiment consisted of i) Conventional drainage (CNV) during kharif season with continuous flooding (CF) method of irrigation (T1), ii) Conventional drainage (CNV) during kharif season with alternative wetting and drying (AWD) method of irrigation (T2), iii) T-1 + controlled SSD during fertilizer (CDF) application (for 12-15 days) only (T3) and iv) T-2 + controlled SSD during fertilizer application (for 12-15 days) (CDF) only (T4).

During the cropping season, observations were made on drain discharge (mm/day), drainage water salinity, salt output, and irrigation water applied in these systems. The mean soil salinity reduced slightly from initial (prior to imposition of treatment) to at crop harvest during kharif-2021 at all depths except 60-90 cm where slight increase was

Table 107. Nutrient loss (kg ha^{-1}) as influenced by different irrigation regime under conventional and controlled drainage system

S.No.	Treatments	Kharif-20	Kharif-21	Average
1.	CF	4.30	3.90	4.10
	CF-CDF	1.40	1.21	1.30
2.	AWD	3.80	3.05	3.42
	AWD-CDF	0.87	0.53	0.70

Table 108. Paddy grain yield (t ha^{-1}) as influenced by different irrigation regime under conventional and controlled drainage system

Season	Continuous Flooding (CF)	Alternative wetting and drying (AWD)
Initial (Kharif-2019)	5.80	5.04
Kharif-2020	6.15	5.46
Kharif-2021	6.70	5.75

observed under continuous method of irrigation. It also decreased under AWD method and overall soil salinity was within permissible limit (< 4 dS m^{-1}) in the effective crop root zone. The average drain discharge was higher (1.07 mm d^{-1}) under continuous flooding (CF) compared AWD (0.65 mm d^{-1}). Similarly, CF-CDF had higher drain discharge (0.44 mm d^{-1}) compared AWD-CDF (0.29 mm d^{-1}). The average drain water salinity over the season was generally higher during Kharif 2021 compared to Kharif 2020. However, unlike drain discharge, drainage water salinity was not much different among the four treatments which varied from 1.73 to 1.89 and 2.41 to 2.79 dS m^{-1} during Kharif 2020 and 2021 respectively. In accordance with drain discharge, the average total salt removed was higher under CF (1.58 t ha^{-1}) compared to AWD (1.07 t ha^{-1}) and CF-CDF (0.40 t ha^{-1}) compared to AWD-CDF (0.24 t ha^{-1}) respectively. The depth to water table was shallower by 5-6 cm under CF-CDF and AWD-CDF compared to CF and AWD respectively in both the seasons. The depth of irrigation was 147.5 vs. 129.5 cm and 154.1 vs. 132.4 cm under CF and AWD respectively during kharif 2020 and kharif 2021. This has led to saving of about 18.0 (12.2%) and 21.7 cm (14%) depth of irrigation water due AWD over CF during Kharif 2020 and Kharif 2021, respectively. The total loss of nitrogen was higher under CF and AWD compared to CF-CDF and AWD-CDF respectively in both the seasons (Table 107). It indicated the loss of nitrogen could be controlled by improving water management in drainage area.

Compared to initial (kharif 2019), the paddy grain yield increased by 6.0 and 15.5% under CF and the increase was 8 and 14% under AWD irrigation regime during kharif-20 and kharif-21 respectively (Table 108). However, though the differences in yield increase between CF and AWD was not much, generally grain yields were higher under CF compared to AWD The average paddy grain yield was higher by about 15% under CF compared to AWD.

Technology Assessed and Transferred

Performance assessment of subsurface drainage technology in saline vertisols of Maharashtra (Subhasis Mandal, Sagar D Vibhute, D.S. Bundela and Anil Kumar)

The study was undertaken to assess the socio-economic impact of sub-surface drainage (SSD) technology implemented for managing the waterlogged and saline soils in Maharashtra. Farmers' survey was conducted through personal interview of 35 farmers covering two villages (Shedshal and Kavtheswar) in Sangli district of Maharashtra. In addition, two Focused Group Discussion were also conducted with 4-5 farmers in each group for collecting the details relating to economic performance of the installed SSD system (before and after the installations) and understanding various technical and institutional constraints in out-scaling of SSD and, to find out the possible solutions thereof in the affected area. Also, an interaction meeting was conducted with key stakeholders, including state government officials, farmers and other implementing agencies. Average age of the farmers was 50 years and their on-average operating size of land holding was 5.94 acre. On an average 4.22 acre of their degraded land was restored by SSD installation. All these SSD system was installed by the farmers themselves with the financial support (in form of loan) from the sugarcane cooperative, which is actively promoting the SSD intervention in the study area. The SSD installations improved the soil quality mainly in terms of reducing pH and restored the degraded land (almost barren),

Table 109. Economics of cropping systems and financial viability of SSD systems in Sangli, Maharashtra

Particulars	**Shedshal village**			**Kavtheswar village**			**Average**		
	Sugarcane	**Soybean**	**System**	**Sugarcane**	**Soybean**	**System**	**Sugarcane**	**Soybean**	**System**
Economics of the cropping systems									
Seed cost	8000	4050	12050	8000	4000	12000	8000	4025	12025
Machine for land preparation	15000	8000	23000	10000	8000	18000	12500	8000	20500
Labour for sowing etc	16000	3000	19000	9000	2000	11000	12500	2500	15000
Fertiliser	25000	2000	27000	22000	3000	25000	23500	2500	26000
Pesticides	5000	6000	11000	5000	8000	13000	5000	7000	12000
Harvesting	0	5000	5000	0	3000	3000	0	4000	4000
Irrigation	8000	2500	10500	8000	3000	11000	8000	2750	10750
Total Cost	77000	30550	107550	62000	31000	93000	69500	30775	100275
Crop yields (3rd yr, t/acre)	45	12	57	45	12	57	45	12	57
Crop yields (1st yr, t/acre)	30	10	40	30	11	31	30	10.5	40.5
Gross return (3rd yr)	135000	72000	207000	131400	72000	203400	133200	72000	205200
Gross return (1st yr)	90000	60000	150000	87600	66000	153600	88800	63000	151800
Net return (3rd yr)	58000	41450	99450	69400	41000	110400	63700	41225	104925
Net return (1st yr)	13000	29450	42450	25600	35000	60600	19300	32225	51525
O/I ratio (3rd yr)	1.75	2.36	1.92	2.12	2.32	2.19	1.92	2.34	2.05
O/I ratio (1st yr)	1.17	1.96	1.39	1.41	2.13	1.65	1.28	2.05	1.51
Financial viability of SSD installations									
Initial investment (Rs/acre)								125200	
Internal Rate of Return (%)								28	
Net Present Value (Rs.)								173218	
Benefit Cost Ratio (Ratio)								1.32	
Payback period (Year)								3.46	

which is now suitable for cultivation. Average cost of SSD installation was calculated to be Rs. 1.25 - 1.65 lakh/acre (2022-23 prices), which was almost 25-50% higher as compared to 2017-18 year, indicating cost of inaction in restoration of land could be very high if the intervention is delayed. After installation of SSD, the sugarcane yields increased from 15-20 t/acre in 1st year to 45-60 t/acre in 4th year (Table 109). Similarly, soybean yield also increased from 1.0-1.1 t/acre in 1st year to 1.4 – 1.5 t/ha in 4th year after installation of SSD system. Economics of the cropping systems after restoration of land through SSD system indicated that on an average the sugarcane-soybean cropping systems can generate net return of Rs. 51525/acre in the first year which otherwise remained almost barren. Subsequently, the net return was increased to Rs. 104925/acre during 3rd year after the interventions. Financial viability of the SSD system was also examined by calculating the IRR, NPV, BCR and pay-back period, based on some assumption such as economic life (15 years), discount rate (12%) and cost-return would be changing in similar magnitude over the economic life (Table 109). The financial analysis indicated that such system is financially viable for long term investment in the affected area with favourable IRR (28%), NPV (Rs. 173218), BCR (1.2) and payback period (3.46 years). It also indicated that system can generate sufficient return to repay the loan amount for installation of SSD system. Based on the study, it is concluded that the SSD installation in the affected area is financially viable for long term investment. Successful model for implementation is gainful stakeholders' engagement including sugarcane cooperatives and central/state government departments and banking institutions. Bearing initial cost of SSD installation is challenging for farmers and need more support from government linking with ongoing reclamation of problem soil scheme or launching of separate schemes.

Technology for management of salt-affected soils in India – implications on farm income and food security (Subhasis Mandal and R.K. Singh)

Salt-affected soils are spread across 244 districts in the country and challenges agricultural performance and crop production. Agricultural performance and outcome indicators were identified to assess the agricultural situation in these districts having salt-affected soils in the country. These indicators were affecting the agricultural performance either positively or negatively. Positive indicators were**,** Income from agriculture (Rs/month, 2016-17), Cropping intensity (%, 2016-17), Irrigation intensity (%, 2016-17), Rice + wheat production in million tonnes (2016-17), Average yield of rice + wheat (t/ha, 2016-17), GDP from primary sector 2013 (Rs. million at 2004 constant prices), Agricultural workers number (2011 Census), Average farm size (ha, 2015-16) and Fertiliser use (NPK per ha of GCA, 2016-17). Negative indicators were % SAS area to NSA of district (2016-17), Poverty head count ratio (2021) and Area under fallow land (2017). District level information on identified indicators were collected, normalised and values were scaled in the range of 0-1. Value of positive indicators were scaled by using formula, value of the indicators (S_i) = (X_i – min. value) / (Max. value – min. value) and the negative indicators values were scaled by using the value of indicators (S_i) = (min. value - X_i) / (Max. value – min. value). After scaling, the values were distributed between 0 and 1, with best performing district as 1 and worst performing district as 0 (Figure 55). Finally, *Composite index for agricultural performance in salt-affected soil* was calculated by summing ΣS_i values, assuming equal weights. This Composite Index may serve as the baseline performance indicators in SAS districts. This will help to track the performance of the selected outcome indicators over the years in relation to SAS districts. Further, the index

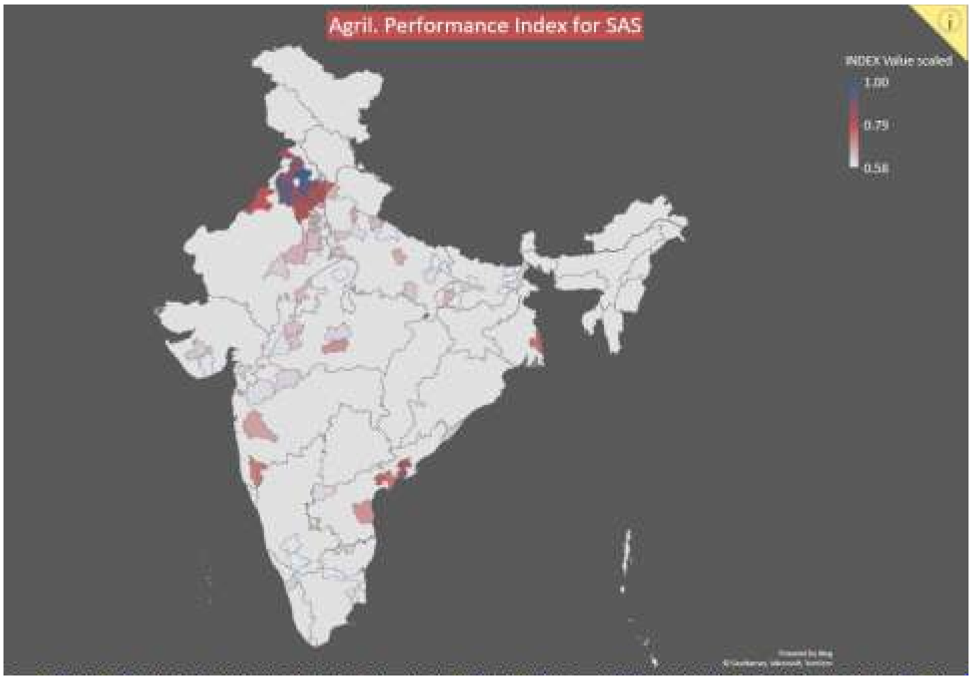


Fig 55. Composite index for agricultural performance in salt-affected soil in India

can be built upon with more indicators affecting the outcome of the SAS management in the country. This composite index would be helpful to assess the relative performance of SAS districts within states and across states w.r.t. the key indicators for future decision making and strategies.

Farmer Participatory Integrated Farming System Model for Improving Livelihood Security under Reclaimed Sodic Lands [Parvender Sheoran, S. Mandal, Awtar Singh, Rajkumar (Hort.), R.K. Fagodiya, P.R. Bhatnagar, R.N. Bhutia and J.K. Pundir (NDRI)]

Keeping in view of the existing cropping systems, the multi-enterprise integrated farming system (IFS) model was assessed as the potential alternate cropping system to be implemented in the farmers' fields in Haryana. Operational holding pattern in the state (Haryana) is dominated by marginal farmers (49%), followed by small (19%), semi-medium (17%), medium (12%) and large (3%) category of farmers. Average operational area of marginal farmers was 0.49 ha, 1.46 ha for small, 2.89 ha for semi-medium, 6.07 ha for medium and 19.04 ha for large categories of farmers. Overall, average farm size was 2.22 ha and the likely change in profitability analysis of the integrated farming system was assessed targeting this average area. Any change in the interventions will be compared with the profitability derived from the prevailing cropping systems. Prevailing cropping system, in terms of gross cropped area (average of 2008-2018) in the Haryana was dominated wheat (39%), rice (20%), cotton (9%), fodder (8%), rapeseed & mustard (8%), bajra (7%), pulses (2%), sugarcane (1%) and others (6%). The net returns from the existing cropping pattern across different farm sizes, including overall categories have been estimated, assuming the similar per cent share allocation by farmers irrespective of operational holdings. The estimated net returns on respective average operational area were ranging from Rs. 29959 for marginal categories of farmers to Rs. 1164117 for large categories of farmers in 2017-18 (Table 110). Overall, the net return from state's average size of operational area (2.22 ha) was estimated to be Rs. 135732 in a year (2017-18). It is rationally expected that any new/modified system (such as integrated farming system

Table 110: Estimated Net Return from Existing Cropping Pattern across Farm Sizes (2017-18)

Crops	Average NR (Rs/ha)	Marginal (0.49)	Small (1.46)	Semi-medium (2.89)	Medium (6.07)	Large (19.04)	All (2.22)
Fodder	15029	589	1754	3472	7293	22878	2667
Cotton	36326	1571	4681	9266	19461	61044	7117
Rapeseed &Mustard	56137	2215	6601	13065	27442	86079	10036
Sugarcane	218756	1585	4723	9348	19634	61588	7181
Pulses	57722	466	1387	2746	5769	18094	2110
Wheat	71751	13647	40662	80488	169052	530273	61828
Rice	80317	7766	23138	45801	96199	301751	35183
Bajra	37718	1402	4178	8271	17372	54492	6354
Others	25000	719	2141	4238	8901	27919	3255
All crops	-	29959	89265	176696	371123	1164117	135732

Note: Figures in parentheses are average farm size (ha) in each group

Table 111: Profitability of multi-enterprise Integrated Farming System Model at CSSRI, Karnal (2020-21)

Component	System	Area (ha)	Gross Return (Rs)	Expenditure (Rs.)	Profit / loss (Rs)
Grain crop	Rice-Wheat	0.40	89570	26860	62710
	Rice-Wheat-Moong	0.20	47182	15015	32167
	Maize-Wheat-Moong	0.40	75622	30185	45437
	Sub-total	212374 (16%)	72060 (8%)	140314 (32%)	
Horti/ Vegt. / Fodder	Horticulture	0.20	42050	8000	34050
	Vegetables	0.20	40300	19583	20717
	Fodder	0.40			
	Sub-total	82350 (7%)	27583 (3%)	54767 (13%)	
Subsidiary	Dairy	0.20	788902	620860	168042
	Fishery		176630	136700	39930
	Poultry		26880	9475	17405
	Mushroom		8740	3550	5190
	Fruits/Vegt. on dykes		9700	1580	8120
	Sub-total	1010852 (77%)	772165 (89%)	238687 (55%)	
All	Conventional RWS	2.00	447850	134300	313550
	Diversified Agriculture	1305576 (100 %)	871808 (100%)	433768 (100%)	

Note: Figures in parentheses shows % share of contributions by respective components

developed by ICAR-CSSRI) for changing the existing cropping systems would be compared with this level of profitability. The integrated farming system models as developed by ICAR-CSSRI comprised of crop-fish-livestock-subsidiary components and generated a net return of Rs. 433768 from similar area (2.0 ha) (Table 111), which was much higher as compared to the rice-wheat cropping system (Rs. 313550) or prevailing cropping systems (Rs. 135732) in the state.

Optimsation of net returns from integrated farming system model

Further, optimisation of the net return, subject to resource constraints in the IFS model was carried out by employing linear programming models (LPM). Net return optimization of income was assessed through LPM with the objective function of 'maximise net return', subject to various constraints. The model was specified as,

Maximise net return

$$Z = \sum_{j=1}^{n} CjXj \qquad \text{...... (1)}$$

Subject to constraints

$$\sum_{j=1}^{n} AijXij \leq Bi \quad \text{...... (2)}$$

$$Xij \geq 0 \quad \text{...... (3)}$$

(i = 1,2,3 …………., m resources)
(j = 1,2,3 …………., n activities)
Where,
Z = Total net return (income) to fixed factors
Cj = Net return per ha for jth activity
Xj = Level of jth activity
Aij = Amount of ith resources required for per ha of jth activity
Bi = Total available quantity of ith resources

Based on the existing enterprise taken in the model, the identified real activities were, Rice-wheat (X_1), Rice-wheat-moong (X_2), Maize-wheat-moong (X_3), Horticulture (X_4), Vegetables (X_5), Fodder (X_6), Dairy (X_7), Fishery (X_8) and Others/dykes (X_9). The production system was subjected to various constraints such as total land, capital, minimum/maximum area under each enterprises, however, availability of water was assumed to be not a constraint and also the labour was available as and when required. All the cost, return and input use data were taken from the records maintained for the system.

The analysis revealed that the re-allocation of resources can increase the net income to Rs. 457809 from 2.22 ha of land i.e., the average operational holding in Haryana (Table 112). This indicated that the profitability (Rs. 433768 from 2.0 ha) of the existing resource allocation was almost at par in the IFS model. Therefore, the integrated farming system model might be a profitable alternative diversified system other than the existing rice-wheat system. However, there are few issues needs to be address for promotion of such alternate farming system model in the target areas. These are, IFS model is profitable but capital and labour intensive, but the existing rice-wheat cropping system is easy to manage in terms of mechanization. The state like Haryana has level of farm mechanization over 70% in the farming activities where manual labour engagement is not quite favoured. There are many farmers in the state are operating the leased-in land

Table 112: Optimisation of net return from the Integrated Farming System Model at CSSRI, Karnal

Enterprise	Optimised area (ha)	% allocation	Net Return (optimised)	Average net return (Rs/ha)
Rice-wheat	0.40	18.0	62710	156775
Rice-wheat-moong	0.20	9.0	32167	160835
Maize-wheat-moong	0.40	18.0	45416	113539
Horticulture	0.40	18.9	71505	170250
Vegetables	0.20	9.0	20717	103585
Fodder	0.20	9.0	11514	57570
Dairy	0.20	9.0	168042	840210
Fishery	0.10	4.5	25000	250000
Others (dykes)	0.10	4.5	20738	207380
Total	**2.22**	**100**	**457809**	**-**

and such framers either cannot or not willing to (due uncertainty that he will get the land for longer period of time) modify lands to IFS model with high investment. The analysis indicated that maximum income (77%) in the IFS model comes from livestock and fishery component which often leads to trade-offs and specialization to few components rather than maintaining a large number of enterprises. A fishery with saline (poor quality) water is preferable by farmers but the same is not suitable for agriculture. Therefore, autonomous adoption of such high input intensive (fertiliser, labour and capital) IFS model is challenging, may be promoted by attracting private investment, viewing multi-functionality of agriculture (deriving value of the system beyond agriculture) as an opportunity.

Socio economic impact of long-term land reclamation measures at selected farms in Haryana (Suresh Kumar, Subhasis Mandal, Anil Kumar and R.K. Singh)

The present study was initiated with objectives of assessing the socio-economic and bio-physical changes in post-reclamation period in the selected farms of Haryana and, to identify the constraints in sustainable management of these reclaimed farms. Based on the secondary data, it can be stated that in Gudha farm (61.68 ha) the on average the rental value is Rs 1.14 lakh ha^{-1} (Fig. 56). Out of the 24 ha area reclaimed by the ICAR-CSSRI, Karnal, at present around 21.13 ha is under cultivation, generating revenue of Rs 27.03 lakh with an overage rental value of Rs 1.28 lakh ha^{-1}. Economic performance of the Gudhha farm vis-à-vis other farms in its vicinity (termed as non-Gudhha area, which was taken as benchmark for comparison) was assessed using crop productivity and net return over cost (variable cost + family labour + rent paid). The results showed that average yield of paddy was 3923 and 4011 kg ha^{-1}, for wheat the same was 3780 and 4240 kg ha^{-1}, for Gudhha and non-Gudhha area, respectively. Further, the net return for rice was Rs 45960 and Rs 41456 ha^{-1}, and for wheat it was Rs 34477 and Rs 36353 ha^{-1} for Gudhha and Non-Gudhha area, respectively.

Therefore, it can be stated that the reclaimed farm is performing almost at par with other areas. During the discussion with key stakeholders and *panchayat* members, it was found that in last 10 years gypsum had not been applied. Key measures taken by the *panchayat* to sustain the farm were: (a) land levelling at the interval of 3-4 years; (b) frequent deepening of tube-wells to mitigate the negative effects of declining of groundwater table at farm as well as in its vicinity, and (c) regular repair and maintenance of irrigation channels. Group discussion also revealed that farm is facing a host of management issues,

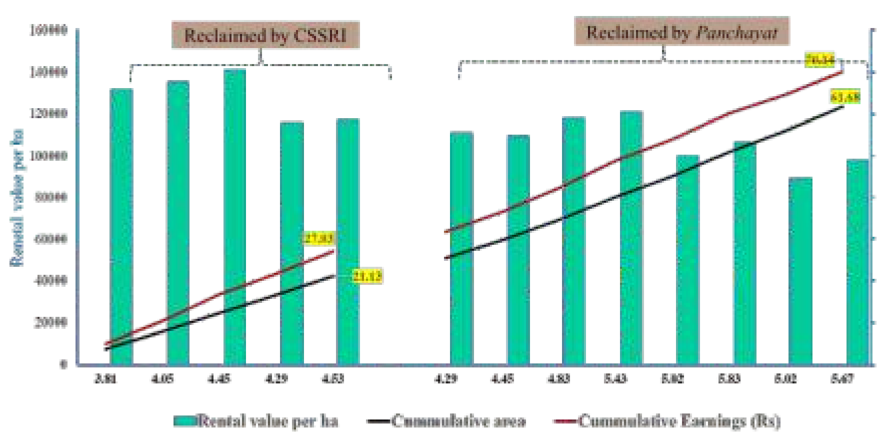


Fig 56. Revenue generation through land leasing at Gudhha farm

which may have implications for future sustainability. Among these key issues were: (a) declining groundwater table at alarming rate (1.4 to 2 feet per year); (b) imbalance/ indiscriminate use of fertilisers since SHC (soil health cards) were not provided for the *panchayat*/common lands; (c) almost no application of the FYM, this because of the fact that leasee farmers do have any short-term gain/incentive of applying FYM as the contract to cultivate the allocated plots mostly last in a year. On the other side, the panchayat was also found to be reluctant to supply the FYM because of limited availability of fund at its disposal; and (d) prevalence of mono-cropping (rice-wheat system) as once the land is leased-out, the leasee farmers prefer to choose the most profitable cropping system to maximise their revenue with little concerned for soil health management.

Empowering farmers through selective interventions in salt affected agroecosystems of Ghaghar Plains (Farmer FIRST) (Parvender, R.K. Singh, Satyendra Kumar, Arvind Kumar, Subhasis Mandal, Arijit Burman, Kailash Prajapat, Dar Jaffer Yusuf and K. Punnusamy)

Management of high RSC water irrigated sodic soils using Pressmud

Farmer's Field Photos

Pressmud is an economically viable alternative amendment for reviving the productivity of sodic soils. A study was conducted to investigate the effect of using Pressmud at 10 tonnes per hectare on the yield and economic returns of rice and wheat crops. The study was conducted through 17 demonstrations, and the parameters measured include soil pH, RSC_{iw}, grain yield, gross returns of rice-whet system (RWS), benefit-cost ratio, additional cost, additional returns, incremental income, and incremental input-output ratio (Table 113). The study found that the application of Pressmud at 10 t/ha resulted in a 14.5% increase in the yield of rice, and a 14.7% increase in the yield of wheat. The mean yield of rice in the control group was 3,855 kg/ha, whereas it was 4,412 kg/ha in the treatment group. Similarly, the mean yield of wheat in the control group was 3,421 kg/ha, whereas it was 3,924 kg/ha in the treatment group. The gross returns of RWS, which is the revenue obtained from selling the crops, was Rs. 1,60,672/ha in the control group, whereas, it was Rs 1,84,143/ha in the treatment group. The benefit-cost ratio, which measures the economic feasibility of the intervention, was 2.52 in the control group, and

Table 113. Effect of pressmud application on soil properties, crop yield and economic returns in high RSC water irrigated sodic soils for wheat and rice crop.

Parameters	Control	Pressmud @ 10 t/ha
No. of demonstrations (N)	17	
Soil pH	8.84 (8.35-9.00)	
RSCiw (me/l)	5.11 (3.5-6.5)	
Grain yield (kg/ha)		
Rice	3,855	4,412 (+14.5%)
Wheat	3,421	3,924 (+14.7%)
Gross Returns_RWS (Rs/ha)	1,60,672	1,84,143
Benefit:Cost ratio	2.52	2.61
Additional cost (Rs/ha)	6,730	
Additional returns (Rs/ha)	23,471	
Incremental income (Rs/ha)	16,741	
Incremental input-output ratio	3.49	

Table 114. Effect of source of N applied on rice and wheat yield and monetary returns

Parameters	Wheat 2020-21				Rice 2021	
	Sonepat (n=20)		Kaithal (n=2)		Kaithal(n=27)	
	33% N replacement through Nano-N (IP)	RDN through urea (FP)	33% N replacement through Nano-N (IP)	RDN through urea (FP)	33% N replacement through Nano-N (IP)	RDN through urea (FP)
Grain yield (kg /ha)	3382 (2.73%)	3292	4571(1.94%)	4484	4845(2.08%)	4746
Net returns (Rs. /ha)	40109	38800	63193	61827	77935	75999
Additional returns (Rs. /ha)	1785		1728		2313	
Incremental input-output ratio	3.75		4.77		6.12	

Note: Figures in parentheses indicate the per cent increase in grain yield over the farmers' practice.

2.61 in the treatment group. This indicates that the use of Pressmud provides a higher return on investment than the control group.

Enhancing nitrogen use efficiency using Nano–N in rice and wheat grown under salt affected soils

Sodic soils generally require additional fertilizer N because of inherently low N, dispersed and dissolved organic matter, higher volatilization losses, restricted microbial activity and N mineralization. Therefore, farmers tend to apply higher N to compensate the sodicity hazards and get higher yields. The survey data conducted in FFP adopted villages revealed that mostly farmers' apply 20-25% extra N as against the general recommendations for attaining higher yields under stress conditions. To demonstrate the optimal N use and enhance NUE in sodic soils, a total of 27 on-farm trials were conducted during the *Kharif* 2021 in rice (CSR 30, PB 1121, PB 1509 and PR type varieties) and 22 on-farm trials in wheat (KRL 210, HD 2967) during *Rabi* 2020-21 using Nano-N (IFFCO product) in comparison with farmers' practice using urea (Table 114). Basal N and first split of N was top-dressed as usual through conventional urea, though second split of N was replaced with Nano-N on equivalent basis.

Foliar spray of N through Nano-N in rice resulted in 2.1% higher yields as against the farmers' practice using conventional source (urea). Supplementation of N through Nano-N not only reduced fertilizer cost, but also resulted in additional income of Rs. 2313 /ha through yield enhancement. Similarly in wheat, foliar application of N through Nano-N resulted in 1.9% (Kaithal) to 2.7% (Sonepat) higher yields with additional income of Rs. 1728-1785 /ha as against the farmers' practice.

Economic impact assessment of technologies for management of salt-affected soils in India (under ICAR-NIAP Network project on Ecosystem, Agribusiness and Institutions, *Component 1: Impact assessment of agricultural technologies*) (Subhasis Mandal, Suresh Kumar and Anil Kumar)

ICAR-CSSRI, Karnal has developed five cultivars of salt-tolerant Indian Mustard (*Brassica juncea*); CS 52, CS 54, CS 56, CS 58 and CS 60 during 1997-2018. These varieties can tolerate sodicity up to pH_2 ~9.4 and salinity up to 12 dS/m. The grain yield in normal soils ranges from 1.8 to 2.8 t/ha and in salt affected soils, 1.5 to 2.9 t/ha. These varieties have been recommended for growing in salt-affected areas (domain) in India. Strategically, these salt-tolerant mustard varieties (STMVs) were developed to improve the level of salt-tolerance and yield over the preceding varieties, implying that CS 60 is the best among all others. To assess the impact of the STMVs, four varieties, namely, CS 54, CS 56, CS 58 and CS 60 were considered for estimating the prevailing adoption rate of STMVs during 2022-23. Reasons for selecting these varieties were, (a) availability of the seeds to farmers as the seeds of these varieties are being produced by Central and State departments/agencies for distribution purposes; (2) On-going Front Line Demonstrations (FLDs) trails at various locations to demonstrate their performances over the other varieties in salt affected soils; (3) Presumably prevalence of dissemination of their seeds from farmer-to-farmer based on their experiences, particularly under salt-stressed conditions; and (4) Earlier varieties with time are less performing and receives less priority for seed production demand; (5) Subsequent released varieties have higher preferences for seed production and dissemination owing to their yield and other associated multiple stressed tolerance advantages (*e.g.*, better performance of CS-60 in frost affected areas) over earlier ones. To obtain the demand for salt-tolerant seed production, distribution and subsequently adoption by farmers over a period of time (2005-2021), all these four varieties were taken into consideration for assessing the economic impact of salt-tolerant mustard varieties in India.

At present, the estimated domain area for salt-tolerant mustard varieties is around 5.63 million ha (m ha) spreading over major seven mustard growing states, Uttar Pradesh, Rajasthan, Madhya Pradesh, Gujarat, West Bengal, Punjab and Haryana. ICAR-CSSRI regularly receives indents for breeder seed production from Ministry of Agriculture and Farmers Welfare, Govt. of India and accordingly supplies the salt tolerant seeds. Breeder seeds are multiplied by various states agricultural department or private seed companies and then supplied to the framers. ICAR-CSSRI also produces some quantity of certified seeds and supplies to farmers directly from the Institute as per farmers' demand. The area under salt tolerant mustard varieties were estimated by using available information on breeder seed demand as received during 2005-2021. Conversion of breeder to

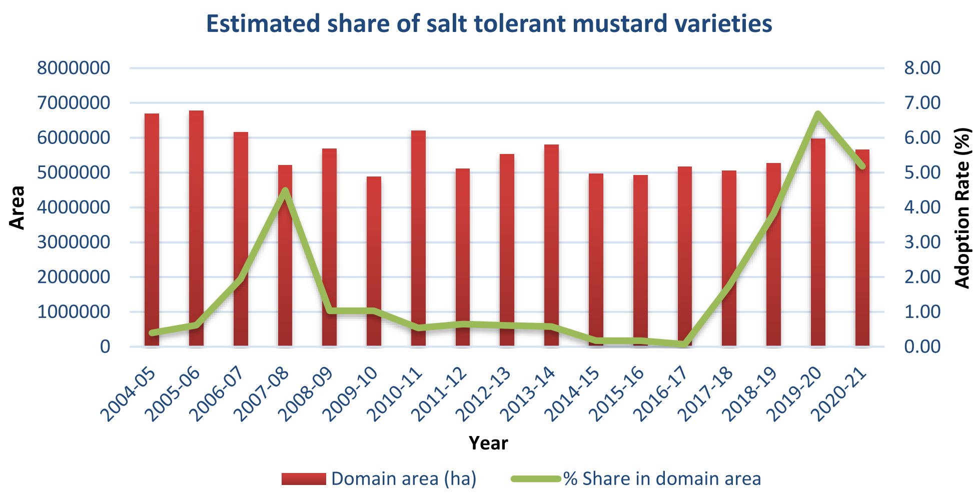


Fig 57. Estimated share of salt tolerant mustard varieties in India

Table 115. Estimated value of economic surplus due to salt-tolerant mustard varieties in India

Economic surplus	Value (Rs. Crores)	
	2005-2022	2005-2030
Consumers' surplus	175	2010
Producers' surplus	390	4472
Total economic surplus	565	6482

foundation (1:100) and further from foundation to certified seed (1:100) were computed by following the standard norms applicable for mustard crop. The area under salt tolerant mustard varieties were estimated by using available information on breeder seed demand as received from MoA&FW via ICAR, New Delhi during 2005-2021. The value of output was estimated by multiplying estimated production of mustard with minimum support price (MSP) of the corresponding years. The estimated value of output of mustard was accounted to be Rs. 5689 crores during 2005-2021.

Performance of salt tolerant mustard varieties of CSSRI (e.g., CS 60) in the salt-affected soil domain area was assessed through comparative economics of other popular mustard varieties (e.g., 45S46 of Pioneer) grown by farmers. The management practices of both the varieties were similar but the costs of cultivation of other varieties (here hybrid variety of 45S46 from Pioneer) was 8% higher than the STMVs mainly due to higher cost of seed (Rs. 150 and 900 per kg for CS 60 and 45S46, respectively). The profitability of the mustard in terms of net return was relatively higher (16%) for hybrid variety as compared to STMVs due to higher yield (15%). The loss of yield due to salt stress are somewhat compensated by the higher yield obtained from the hybrid mustard varieties, therefore, farmers often rely on these varieties despite knowing (or sometime unknowingly) that their land are affected by salt stress. It was also noted that most of the farmers were not well aware of salt stress situation, unless their land was severely affected and crop losses were very high (e.g., more than 25-30%). The STMVs performed very well during multiple stress condition including sodicity (pH above 8.5), very low temperature and also aphid infestation. During such stress the STMVs outperformed (sometime crop failed when non-STMVs were grown) the other (hybrid) mustard varieties and farmers were willing to adopt in larger scale. Based on the seed demand for salt-tolerant varieties, the estimated present (2022) adoption rate was 5.18% (Fig. 57), which was expected be as high as 15% by 2030 in response to increasing area under slat-affected soils as well as exogenous growth in area under mustard. The estimated yield advantage is 10.51% over the other prevailing varieties under salt-stress conditions, however, the cost of cultivation (Rs per ha) is slightly higher to the extent of 5.45% for the new variety adoption. The value of base year production (Q_0) and price (P_0) are 6991 (000' tonnes, TE-2005-06) and Rs. 1715 per quintal (MSP for year 2005), respectively. The estimated value of the consumer and producer surplus is Rs. 175 crores and Rs. 390 crores, respectively, up to 2022. The same was expected to be Rs. 2010 crores and Rs. 4472 crores, respectively by 2030, when the adoption rate approaches to the maximum (15%). The estimated value of total economic surplus was Rs. 565 crores and Rs. 6482 crores, respectively, during 2005-2022 and 2005-2030, respectively (Table 115).

Technology commercialized by RRS Lucknow

Halo-PSB Commercialization

A liquid microbial formulation of halophilic phosphate solubilizing bacteria "Halo-PSB" has been commercialized with M/s Parashar Agrotech Bio Pvt Ltd., Varanasi for mass scale production. The technology has been licensed to the firm through M/s Agrinnovate India Ltd, New Delhi on January 27, 2022 and the technology was formally transferred to the firm on April 13, 2022. This bio-formulation is effective in enhancing phosphorus availability and bio-remediation of salt affected soils. This has been found to enhance crop yields to the extent of 7.4 to 21 per cent under variable soil sodicity for rice, wheat, mustard, vegetables and fodder crops. The product is being produced for sale through Institute and till date it has been adopted by farmers covering an area of 4575 acres.

Inauguration of Infrastructure

On 3oth April, 2022, Dr. Trilochan Mohapatra, DG, ICAR and Secretary, DARE inaugurated the Agriculture Technology Information Centre at ICAR-CSSRI, Karnal.

Inauguration of Agriculture Technology Information Centre by Dr. Trilochan Mohapatra, DG ICAR & Secretary DARE

Farmers Training Hostel Inauguration

On November 11, 2022, Dr. S.K. Chaudhari, DDG (NRM), ICAR, New Delhi inaugurated the Farmers Training Hostel at CSSRI, RRS, Lucknow campus. Also, a bioformulation production unit developed under RKVY funded project was formally inaugurated by the Chief Guest in presence of Director Dr P.C. Sharma, former Director Dr. D.K. Sharma and staff of RRS, Lucknow. "Amrit Sarovar" developed at Shivri Farm under RKVY funded project was also formally inaugurated by the Chief Guest Dr. S.K. Chaudhari in presence of Dr. Vivek Kumar Singh, Director Agriculture, UP.

MISCELLANEOUS

Training and Capacity Building

Sr.	Name	Subject	Duration	Organiser
1.	Dr. Monika Shukla	Online training on 'Recent Development in Agroforestry Dimensions for Managing Salt Affected Ecologies'	22 February -03 March, 2022	ICAR-CSSRI, Karnal
2.	Sagar D. Vibhute	Online training programme on Advances in Web and Mobile Application Development	02-06 August, 2022	ICAR-NAARM, Hyderabad

Deputation of Scientists Abroad

Sr.	Name	Subject	Duration	Organiser
1.	Dr. Kailash Prajapat	New agricultural innovation programme on "Achieving Food Security Using Smart Farming Solutions" - Study Visit	13-19 September, 2022	GIMI, Nahalal, Israel
2.	Dr. U.K. Mandal	Attended the fourth Tropag International Agriculture Conference	31 October - 2 November, 2022	Brisbane, Australia

Awards and Recognitions

- Dr. P.C. Sharma, Director, ICAR-CSSRI was presented with prestigious Rafi Ahmed Kidwai Award for outstanding research in agricultural sciences today at 94th ICAR Foundation Day Celebration at A P Shinde Symposium Hall, NASC, PUSA, New Delhi.
- Dr. Parvender Sheoran, Principal Scientist, ICAR-CSSRI was presented with Swami Sahajanand Saraswati Outstanding Extension Scientist Award 2021 today at 94th ICAR Foundation Day Celebration at A P Shinde Symposium Hall, NASC, PUSA, New Delhi.
- Dr. P.C. Sharma was conferred Fellow of the National Academy of Agricultural Sciences, New Delhi.
- Dr. H. S. Jat was conferred Fellow of the National Academy of Agricultural Sciences, New Delhi.
- Dr. Satyendar Kumar was conferred Fellow of Indian Society of Agricultural Engineers, New Delhi.
- Dr. Satyendra Kumar received ICAR-CSSRI Excellence Award -2021.
- Dr. Raj Mukhopadhya was awarded "Fulbright-Nehru Postdoctoral Research Fellowship" for the year 2022-2023 at Carnegie Mellon University, Pittsburgh, USA funded by United States-India Educational Foundation, New Delhi.
- Dr. Raj Mukhopadhyaya received Young Scientist award (2022) from Clay mineral Society of India, New Delhi.
- Dr. Sanjay Arora was elected as Vice-Chair, IUSS Commission 3.6 Salt Affected Soils (2022-26)
- Dr. Sanjay Arora was nominated as Member of FAO-International Network of Salt Affected Soils (INSAS).
- Dr. R.H. Rizvi received Dr K.G. Tejwani award for Excellence in Agroforestry Research and Development in year 2022 by Indian Society of Agroforestry, Jhansi.
- Dr. Arjun Singh was awarded DST International Research Experience Fellowship for 6 months at Australia
- Dr. Bhaskar Narjary received best oral presentation Award in 6th National seminar of Indian Society of Soil Salinity and Water Quality, 2022.
- Best Poster Award for the work entitled "Morphological, ion homeostasis and physiological responses of Asiatic cotton genotypes on salt affected Vertisols" authored by Vineeth TV, Prasad, I., Chinchmalatpure, Anil R., Lokeshkumar, BM., Kumar, S., Ravikiran, KT and Sharma, P.C. at the 6th National conference of ISSSWQ during October 11-13 2022 at Tiruchirappalli, Tamil Nadu, India.
- Dr. A K Bhardwaj received best presentation award for paper entitled "Sustainable nutrient management strategies for rice wheat systems in Indo Gangetic Plain" (ORAL) in 1st International Symposium on "Cereals for Food Security and Climate Resilience" jointly organized by the Society for Advancement of Wheat and Barley Research (SAWBAR) and ICAR-Indian Institute of Wheat and Barley Research, Karnal during January 18-20, 2022, Karnal, India.
- Dr. A K Bhardwaj received best poster presentation award for the research paper on, "Nitrogen management options with nano urea and their growth and yield responses in rice-wheat cropping" (Manu Rani, Ajay Kumar Bhardwaj, Vishal Goyal, Parvender Sheoran,

Ashwani Kumar and Rakesh Mehra) in the 3rd international Web Conference on natural Resource Management for Global Food Security and Sustainable Development Goals" held on 2nd and 3rd December, 2022.

- Dr. Madhu Choudhary received Best Poster Award on "Soil biology and climate smart agriculture (CSA) practices under major agri-food systems of IGP" by Maize Technologists Association of India- New Delhi during National Conference on "Maize for Resource Sustainability, Industrial Growth and Farmers' Prosperity" from February 23-25, 2022 at Rajasthan College of Agriculture (RCA), Udaipur, Rajasthan
- Dr. A K Bhardwaj received best poster presentation award for the research paper on, "Effect of Salinity and Host Species on the Growth Pattern and Physiological Processes of Sandalwood (Santalum album L.) (Kamlesh Verma, Raj Kumar, Ashwani Kumar, RC Verma and AK Bhardwaj) in the 6th Natiional Conference held during October 11-13, 2022 at Anbil Dharmalingam Agricultural College & Research Institute, TNAU, Tiruchirappalli (T.N), India.
- Dr. H.S. Jat received Best Poster Award by Maize Technologists Association of India- New Delhi during National Conference on "Maize for Resource Sustainability, Industrial Growth and Farmers' Prosperity" from February 23-25, 2022 at Rajasthan College of Agriculture (RCA), Udaipur, Rajasthan
- Best paper award 3rd Prize was received for Poster presentation by Rajkumar, Ashwani Kumar & Anshuman Singh in the ISPP North Zonal Seminar-2022 on the topic "Genotypic variance against salinity tolerance among various Jamun (Syzygium cumini L. Skeels) genotypes" on 25th June, 2022 organized by Indian Society for Plant Physiology (North Zone) at ICAR-Sugarcane Breeding Institute, Regional Center Karnal, Haryana
- Dr. Raj Kumar Thakur received Best Oral presentation award during 3rd International Web Conference on Natural Resource Management for Global Food Security and Sustainable Development Goals held during December 2-3, 2022.
- Dr. Uttam Kumar Mandal received Best Oral Presentation Award - Paper presented on "Climate resilient technologies for management of natural resources" of the National Symposium on Self-Reliant Coastal Agriculture held at ICAR-CCARI, Goa, during 11-13, May, 2022
- Dr. Subhasis Mandal was Invited Speaker and presented paper on "Technologies for Management of Salt-Affected Soils in India: Contributions to National Food Security and Policy Implications" during ISSSWQ National Conference on Salinity Management for Land Degradation Neutrality and Livelihood Security under Changing Climate at ADAC&RI, Tiruchirappalli during 11-13th October 2022
- Dr. Subhasis Mandal was Invited Speaker for presentation of concept and action needed on "Incentives and Investment Opportunities and Challenges across Sectors and Regions" during two-day dialogue on 'Food Systems for India', by ICAR-National Institute of Agricultural Economics and Policy Research (NIAP), New Delhi
- Dr. Suresh Kumar received Young Agricultural Economist Award (2022) conferred by Agricultural Economics Research Association (India), New Delhi.
- Dr. Suresh Kumar received Best paper published for the year 2021 - Indian Journal of Soil Conservation published by Indian Association of Soil and Water Conservationists (IASWC), ICAR-IISWC, Dehradun, Uttarakhand. The award was given during the National Conference on "Landscape Management for Preventing Flood and Reservoir Sedimentation" (LMPFRS-2022) 22-24 September, 2022 / BAU at Ranchi (Jharkhand).

- Dr. Suresh Kumar received Best oral presentation Award - 6th National Salinity Conference on Salinity Management for Land Degradation Neutrality and Livelihood Security under Changing Climate at ADAC&RI, Tiruchirappalli (Tamil Nadu), 11-13 October 2022.
- Dr. Monika Shukla received Best Poster Award for the paper on "Performance of fodder intercropping with pulpwood species on saline Vertisols of Gujarat" In: 6th National Conference on 'Salinity Management for Land Degradation neutrality and Livelihood Security under Changing Climate' organized by Indian Society of Soil Salinity and Water Quality, Karnal at ADAC&RI, Tiruchirappalli (T.N.) India from 11–13 October 2022.
- Dr. Vineeth TV received Best Poster Award for the paper on "Morphological, ion homeostasis and physiological responses of Asiatic cotton genotypes on salt affected Vertisols" In: 6th National conference on salinity management for land degradation neutrality and livelihood security under changing climate" organized by Indian Society of Soil Salinity and Water Quality, Karnal at ADAC&RI, Tiruchirappalli (T.N.) India from 11–13 October 2022.

Linkages and Collaborations

International Collaboration

- Advanced Cultures on Rice for Shallow and Deep Water Situations with IRRI, Philippines
- Strategic Research Platform on Climate Smart Agriculture "Developing and defining climate smart agricultural practices portfolios in South Asia". ICAR-CCAFS
- Development of Sustainable Resources Management Systems in the water-vulnerable areas of India with JIRCAS Japan
- Studies on N-(n-butyl) Thiophosphoric Triamide (NBPT) as a Urease Inhibitor for Improving Nitrogen Use Efficiency in major cropping systems in India. CIMMYT, Mexico
- Cropping System Intensification in the Salt Affected Coastal Zones of Bangladesh and West Bengal, India with CSIRO and Murdoch University, Australia
- Bangladesh Agricultural Research Institute, Bangladesh Rice Research Institute and Khulna University.
- Cropping Systems Modeling to Promote Food Security and the Sustainable Use of Water Resources in South Asia with SAARC Agriculture Centre (SAC)
- CV Raman Fellow visiting scientist from Soil and Water Department, Faculty of Agriculture, Cairo University, Egypt
- Development of Crop and Nutrient Management Practices in Rice with IRRI, Philippines
- In the area of Wastewater Remediation with Singapore National University, Singapore
- International Collaborative Programme on Testing Rice Germplasm for Coastal Salinity (IRSSTN) with IRRI, Philippines
- Marker Assisted Breeding of Abiotic Stress Tolerant Rice Varieties with Major QTL for Drought, Submergence and Salt Tolerance (DBT, India and IRRI, Philippines)
- International Water Management Institute (IWMI), Colombo, Sri Lanka
- Research Institute of Theoretical & Applied Physical Chemistry (INIFTA), La Plata, Argentina (funded by UNESCO-TWAS-CONICETS).
- Sustainable Management of Wastewater through Forestry with University of Melbourne, Board of Meteorology Australia
- WAYAMBA University, Sri Lanka

National Collaborations

- 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
- All India Coordinated Cotton Improvement Project, Coimbatore
- AMAAS-Application of Micro-organism in Agriculture and Allied Sectors (Funded by

ICAR, New Delhi)

- Hindon Roots Sensing HIROS River Rejuvenation through Scalable Water- and Solute Balance Modelling and Informed Farmers' Actions. DST-NWO Hindon
- Enhancing nutrient use efficiency using nano-fertilizer in rice-wheat cropping system under salt stress with IFFCO, Chandigarh
- Anand Agricultural University, Anand
- ATAPI Seva Foundation, NGO Jambusar
- Banasthali Vidyapeeth, Banasthali, Rajasthan
- BBAU, Lucknow
- Bidhan Chandra KrishiVisvaVidyalaya, Kalyani (West Bengal)
- CCSHAU, Hisar, Haryana for Academic and collaborative research
- Coastal Salinity Tolerant Varietal Trial (CSTVT) and National Salinity and Alkalinity Screening Nursery (NSASN) with IIRR, Hyderabad
- College of Agriculture, Bharuch
- Cotton Research Station, Bharuch
- Cotton Research Station, Surat
- Department of Agriculture Govt. of Haryana
- Department of Agriculture, Government of West Bengal
- Department of Agriculture, Uttar Pradesh
- Department of Science and Technology, Govt. of India, New Delhi.
- Department of Soil Conservation, Government of West Bengal
- Indian Institute of Technology, Kanpur, India,
- FodazioneL'Alberodella Vita (FADV), Kolkata, West Bengal
- GB Pant Polytechnic College, Lucknow
- Gujarat Narmada Valley Fertilizer Company Ltd., Bharuch
- Haryana State Forest Department
- ICAR Indian Institute of Wheat and Barley Research, Karnal
- ICAR-Central Institute of Cotton Research, Nagpur
- ICAR-Central Institute of Fisheries Education, Mumbai
- ICAR-Central Institute of Freshwater Aquaculture, Rahara, Kolkata
- ICAR-Central Research Institute for Jute and Allied Fibres (CRIJAF), Barrackpore
- ICAR-CIFE, Mumbai
- ICAR-CISH, Lucknow
- ICAR-IISR, Lucknow
- ICAR-Indian Institute of Water Management, Bhubaneswar
- ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Kolkata Centre
- ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur

- ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan
- ICAR-NBFGR, Lucknow
- ICAR-NCIPM, New Delhi
- Indian National Academy of Engineering (INAE), Gurugram for joint Research proposal on Climate Change Impact on Water Resources and Agriculture: Mitigation and Adaptations for National Water and Food Security
- Inter-institutional collaboration with IISS Bhopal for standradising the conservation agriculture practices in rice-wheat cropping system on salt affected soils.
- Jaipur National University, Jaipur, Rajasthan
- Junagadh Agricultural University, Junagadh
- Kerala Agricultural University, Trivendrum
- KrishiVikas Kendra, Chaswad, Bharuch
- KrishiVikas Kendra, Dediapada, Narmada
- KrishiVikas Kendra, Surat, Dist. Surat
- KVK Dhoura, Unnao, Kaushambi, Pratapgarh, Sitapur, Auraiya and Bhadohi
- Linkage developed with Reliance Industries Ltd. for collaborative research on developing the alternate strategies for reclamation of sodic soils.
- Maharashtra Hybrid Seeds Co Pvt Ltd. (MAHYCO)
- Monsanto India Limited
- Multi-locational Evaluation of Bread Wheat Germplasm (NBPGR, New Delhi)
- NABARD, Mumbai & Chandigarh for Reclamation of Saline and Alkaline Soils in Haryana and Punjab
- Navsari Agricultural University, Navsari
- NCP, IGBP, IIRS, NRSA, Department of Space, Dehradun, Uttrakhand
- PRASARI, West Bengal
- Punjabi University, Patiala, Punjab
- 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
- Regional Remote Sensing Centre (East), ISRO, Kolkata
- Remote Sensing Application Centre, Lucknow Uttar Pradesh
- Rex Polyextrusion Pvt Ltd, Sangli, Maharashtra for outscaling of SSD technology in heavy soils
- Astal Poly Technik, Limited, Ahmedabad, Gujarat
- ROCL Jaipur Rajsthan and Horticulture Department, Govt. of J&K for salt tolerance evaluation of vaialble olive germplasm.
- SardarVallahbhai Patel University of Agriculture & Technology, Meerut (UP)
- SHIATS, Allahabad (U.P.)

- Strategies for Sustainable Management of Degraded Coastal Land and Water for Enhancing Livelihood Security of Farming Communities with RAKVK, West Bengal, CIBA, Chennai, CARI, Port Blair and BCKV, West Bengal
- Subham Seeds, Hyderabad (Maize)
- Tagore Society for Rural Development (TSRD), West Bengal
- Technical Guidance and Monitoring and Evaluation of Large-Scale Subsurface Drainage Projects in Haryana (Haryana Operational Pilot Project, Department of Agriculture, Haryana)
- U.P. Council of Agricultural Research (UPCAR), Lucknow
- U.P. Council of Science and Technology, Lucknow
- Uttar Pradesh Bhumi Sudhar Nigam, Lucknow
- VIKAS-NGO, Ahmedabad
- NTPC Ltd, New Delhi
- FAGMIL, Jodhpur (Rajasthan)
- Water Conservation Department, Directorate of Irrigation Research & Development (DIRD) and Department of Agriculture, Pune for promotion of SSD technology for reclamation of waterlogged and saline soils in Maharashtra.
- Water Technology Centre, TNAU, Coimbatore
- World Wide Fund (WWF)
- YSR Horticultural University

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मधु चौधरी, सुरेष कुमार ककरालिया, मनोज कुमार गोरा, तनुजा पुनियां, मनीष ककरालिया, योगेष कुमार, कजोड मल चौधरी, दीपक कुमार बिजारनियां, राज मुखोपाध्याय, रंजय कुमार सिंह, राजेन्द्र कुमार यादव, हनुमान सहाय जाट, प्रबोध चन्द्र शर्माए (2022). जलवायु स्मार्ट खेती की तकनीकियां किसानों के व्यवहारिक उपयोग हेतु सुझाव, भाकृअनुप-सीएसएसआरआई करनाल हिंदी बुलेटिन.

Participation in Conference/Seminar/Symposia/Workshop

Name	Title	Organizer/Place	Period
Monika Shukla	Online lecture on "Land Shaping Technologies for Managing Coastal Saline Soils"	ICAR-CSSRI, Karnal	19 February, 2022
H.S. Jat	Delivered a lecture on 'Precision nutrient and water management in maize systems for environmental stewardship' during National conference on 'Maize for Resource Sustainability, Industrial Growth and Farmers' Prosperity'	Rajasthan College of Agriculture (RCA), Udaipur, Rajasthan	23-25 February, 2022
Monika Shukla	Webinar on "Smart Agriculture" and "Budget Implementations"	IARI, New Delhi	24 February, 2022
RK Fagodiya	International Conference on Integrated Approaches in Science & Technology for Sustainable Future (IASTSF-2022)	J. C. Bose US&T, YMCA, Faridabad	28 February - 01 March, 2022
R.N. Bhutia	1st Indian Fisheries Outlook 2022: Priming Indian Fisheries in Attaining Sustainable Development Goals	ICAR-CIFRI, Barrackpore	22-24 March, 2022
Vineeth T. V.	Annual general meeting/workshop (AGM) of All India Coordinated Research project (AICCIP) on cotton (virtual mode)	Online	06-08 April, 2022
A.K. Singh and	National Webinar on Sustainable Interventions Towards Resource	ANRCM, Lucknow	22-23 April,
Sanjay Arora	Conservation and Natural farming	Online	2022
Vineeth T. V.	Annual group meeting of All India Coordinated Research project (AICRP) on Groundnut	Online	25-26 April, 2022
Ravikiran KT	Annual group meeting of All India Coordinated Rice Improvement project (AICRP)	Online	25-27 April, 2022
N.R. Prakash	International Symposium on "Advances in Plant Biotechnology and Nutritional Security" (APBNS-2022)	ICAR-NIPB, New Delhi	28-30 April, 2022
Uttam Kumar Mandal and D. Burman	Participated through virtual mode the National Symposium on Self-Reliant Coastal Agriculture (Online)	ICAR- Central Coastal Agricultural Research Institute, Goa	11-13 May, 2022
MJ Kaledhonkar	National Symposium on Indian Agriculture after Independence	ICAR, New Delhi	24 May, 2022
Sanjay Arora	participated in Biennial National conference of KVKs on "Sustainable Agricultural Production System"	Dr. YSPUH&F, Solan, HP	01-02 June, 2022
T.D. Lama	International Conference on Current Issues in Agricultural, Environmental and Biological Sciences for Sustainable Development (CIAEBSSD-2022)	Kalimpong Science Centre, Kalimpong, West Bengal	11-13 June, 2022
Rajkumar	Delivered a lecture on the topic 'Production technology of fruit crops' in the training "Establishment of orchard and its layout	HTI, Uchani Karnal	21 June, 2022
Awtar Singh and BL Meena	ISPP North Zonal Seminar-2022 On "Inter-Disciplinary Research Strategies for Climate Resilient Agriculture"	ICAR-Sugarcane Breeding Institute, Regional Centre,	25 June, 2022 Karnal
MJ Kaledhonkar	Annual Workshop of AICRP on Irrigation Water Management by (as ICAR nominated expert - Online)	ICAR-IIWM, Bhubaneswar, Odisha	19-22 July, 2022
Kailash Prajapat and RK Fagodiya	International conference on "Harnessing Indian Agriculture for Indigenous and Global Prosperity"	NAAS Complex, New Delhi	22-23 July, 2022
Awtar Singh	The Global Symposium on Soils for Nutrition - "Soils, where food begins"	Online	26-29 July, 2022
Sanjay Arora	International Conference on Salt-affected Soils (Online)	Ministry of Agricultural and Rural Affairs of China and the Global Soil Partnership of FAO	07-08 September, 2022
Sanjay Arora	29th Annual Zonal Workshop of KVKs	SVPUAT, Meerut	10-12 September, 2022
MJ Kaledhonkar	Brainstorming Session on Researchable Issues in Soil Science and Agricultural Chemistry	TNAU, Coimbatore	19 September, 2022
Suresh Kumar	Landscape Management for Preventing Flood and Reservoir Sedimentation (LMPFRS-2022)	BAU, Ranchi (Jharkhand)	22-24 September, 2022
MJ Kaledhonkar	Biennial Workshop of ICAR-AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture	ICAR-CSSRI, Karnal and TNAU, Coimbatore	10-11 October, 2022

All ICAR-CSSRI Scientists	6th National Conference on "Salinity Management for Land Degradation Neutrality and Livelihood Security under Changing Climate"	ISSSWQ/ ADAC&RI, Tiruchirappalli (TN)	11-13 October, 2022
Madhu Choudhary	Oral presentation on 'Climate smart agriculture for sustainable soil microflora' at International Conference on "Biotechnology for Better Tomorrow, ICBBT-2022"	Microbiologists Society India	29-30 October, 2022
Uttam Kumar Mandal	Attended the fourth TropAg International Agriculture Conference	ACIAR, Australia	31 October - 02 November 2022
Madhu Choudhary	Invited lecture "Climate smart farming and their effects on microbial properties under major agri-food systems of Indo-Gangetic Plains" in 7th International Conference of Indian Network for Soil Contamination Research (INSCR) on "Modulating the Environment with Microbes"	Indian Network for Soil Contamination Research & PhiXgen Pvt. Ltd, Gurugram	7-11 November, 2022
Subhasis Mandal and Parvender Sheoran	Two-day policy dialogue on 'Food Systems for India' at India Habitat Center, New Delhi	Bharat Krishak Samaj and ICAR-NIAP, New Delhi	15-16 November, 2022
A.R. Chinchmalatpure, S. Raut and T.D. Lama	86th Annual Convention of Indian Society of Soil Science and National Seminar on Development in Soil Science 2022	Mahatma Phule Krishi Vidyapeeth, Rahuri	15-18 November, 2022
A.K. Bhardwaj, A.K. Singh and Sanjay Arora	3rd International Web-Conference on Natural Resource Management for Global Food Security and Sustainable Development Goals	ANRCM, Lucknow and UAHS, Shivamogga	02-03 December, 2022
Suresh Kumar	System of Crop Intensification (ICSCI 2022) for Climate-Smart Livelihood and Nutritional Security	SARR, Hyderabad	12-14 December, 2022
R.N. Bhutia	International Conference on Responsible aquaculture and Sustainable Fisheries Interact –RASHI 2022"	College of Fisheries, CAU, Tripura	13-16 December, 2022
Suresh Kumar	Institutional Changes for Inclusive and Sustainable Agricultural Development by AERA India	SKUASTJ, Chatha Campus, J&K.	21-23 December, 2022

List of On-going Research Projects

Institute Funded Projects

Priority area - Data Base on Salt Affected Soils & Poor Quality Waters

1. NRMACSSRISIL201800100954. Mapping and characterization of salt affected soils in Uttar Pradesh using remote sensing and GIS. (A.K. Mandal, Arijit Barman, R.K. Fagodiya, Raj Mukhopadhyay, R.K. Yadav, Sanjay Arora, S.K. Jha, HR Rizvi, M.J. Kaledhonkar and P.C. Sharma)

Priority Area - Reclamation and Management of Alkali Soils

2. NRMACSSRISIL201800200955. Amelioration of iron deficiency in direct seeded/aerobic rice in reclaimed sodic soils. (Babu Lal Meena, Ram Kishor Fagodiya, R.L. Meena, M.J. Kaledhonkar and P.C. Sharma)
3. NRMACSSRISIL201801700969. Developing of soil quality indices for sodic soil under different reclamation strategies (Nirmalendu Basak, Arvind Kumar Rai, Parul Sundha, R.L. Meena, R.K. Yadav and P.C. Sharma)
4. NRMACSSRISIL201802200974. Rice-wheat system performances and dynamics of salt and water under contrasting tillage, residue and irrigation management practices. (H.S. Jat, Madhu Choudhary, Satyendra Kumar and P.C. Sharma)
5. NRMACSSRISIL201900100979. Impact assessment of salt tolerant wheat variety KRL 210 in salt affected regions. (Anil Kumar, S. Mandal, Kailash Prajapat, and Arvind Kumar)
6. NRMACSSRISIL201900800986. Technology for management of salt-affected soils in India-Implication on farm income and food security (Subhasis Mandal R.K. Singh)
7. NRMACSSRISIL202001301004. Low budget natural farming for sustainable crop production. (P.C. Sharma (PI);CSSRI-Raj Mukhopadhyay (CC-PI), RK Fagodiya, Awtar Singh, H.S. Jat;RRS, Lucknow: Arjun Singh (CC-PI), S.K. Jha; RRS Bharuch: Anil R. Chinchmalatpure (CC-PI), Monika Shulkla, Vineeth T.V., Sagar D Vibhute; RRS Canning Town: D. Burman (CC-PI), U.K. Mandal, S.K. Sarangi and T.D. Lama)
8. NRMACSSRISIL202100101022. Effect of residue management on soil microbial activities under salt affected soils in rice-wheat system. (Madhu Choudhary, H.S. Jat, Rakesh Kumar, Sanjay Arora and R.K. Yadav)
9. NRMACSSRISIL202100201023. Effect of reclamation techniques on CaCO3 dissolution and its implications on soils carbon dynamics in a calcareous sodic soil. (Ashim Datta, R.K. Yadav,P.C. Sharma and S. Mehetre)
10. NRMACSSRISIL202100901030. Farmer participatory integrated farming system model for improving livelihood security under reclaimed sodic land. (Parvender, S. Mandal, Awtar Singh, Rajkumar (Hort.), R.K. Fagodiya, P.R. Bhatnagar, R.N. Bhutia and J.K. Pundir (NDRI)
11. NRMACSSRISIL202200801055. Effect of rice straw retention, incorporation and residue decomposition on productivity, profitability, soil health and environment

under RW system. (Awtar Singh, Raj Mukhopadhyay, R. K. Fagodiya) NRMACSSRISIL202200801055. Effect of rice straw retention, incorporation and residue decomposition on productivity, profitability, soil health and environment under RW system. (Awtar Singh, Raj Mukhopadhyay, R. K. Fagodiya)

12. NRMACSSRISIL202102001041. Development of e-Extension models to reach the unreached for soil salinity knowledge management in India. (Anil Kumar, Subhasis Mandal and Kailash Prajapat).

13. NRMACSSRISIL202102201043. Development of reclamation materials with high gypsum equivalent for productive utilization of alkali soil and water. (Arvind Kumar Rai, Nirmalendu Basak, Parul Sundha, R.K Yadav and P.C. Sharma)

Priority Area - Drainage Investigations and Performance Studies

14. NRMACSSRISIL201900200980. Performance assessment of sub surface drainage technology in saline vertisols of Maharashtra (Subhasis Mandal, Anil Kumar, Sagar D Vibhute and D.S. Bundela)

15. NRMACSSRISIL202000100992. Long-term impact of sub surface drainage on clay mineralogical transformation, physio-chemical properties and hyper spectral signatures if saline soils under Inceptisol and Vertisol. (Raj Mukhopadhyay, Bhaskar Narjary, Arijit Barman and D.S. Bundela)

Priority Area - Management of Marginal Quality Waters

16. NRMACSSRISIL201900300981.Conjunctive water use strategies with conservation tillage and mulching for improving productivity of saline soils under high SAR saline water irrigation-(Arvind Kumar Rai, Nirmalendu Basak, Bhaskar Narjary and Gajender)

17. NRMACSSRISIL202000200993. Effect of saline environment and plastic mulch on vegetable crops under naturally ventilated polyhouse conditions. (RL Meena and Bhaskar Narjary)

18. NRMACSSRISIL202002301014.Changes in seed quality development of rice-wheat irrigated with residual alkalinity water.(Gajender, R.K. Yadav, Anita Mann, Nirmalendu Basak, and Vanita Pandey (IIWBR))

19. NRMACSSRISIL202102301044. Feasibility of salt harvesting from high salinity lands using polythene lined pond and enhanced evaporation techniques. (P.R. Bhatnagar and Bhaskar Narjary)

Priority Area - Crop Improvement for Salinity, Alkalinity and Waterlogging Stresses

20. NRMACSSRISIL202001501006. Exploring the conventional and molecular breeding approaches to develop salt tolerant high yielding Indian Mustard (Brassica juncea L.) genotypes. (Jogendra Singh, P.C. Sharma, Vijayata Singh and Ravi Kiran KT)

21. NRMACSSRISIL202001701008. Genetic approaches to improve wheat (Triticum aestivum L.) germplasm for salt tolerance. (Neeraj Kulshershtha, Arvind Kumar, P.C. Sharma, Ashwani Kumar, Vineeth TV and Ravi Kiran KT)

22. NRMACSSRISIL202001801009. Genetic improvement of rice genotypes for salt

tolerance using conventional and molecular breeding methods. (Krishnamurthy SL, Lokeshkumar BM, P.C. Sharma, H.S. Jat, Vineeth TV, Ravi Kiran KT and Dr. Devenna)

23. NRMACSSRISIL202002101012. Genetic improvement of Lentil (Lens culinaris Medikus) for salt tolerance using conventional and molecular breeding approaches. (Vijayata Singh and Ravi Kiran KT)

24. NRMACSSRISIL202002401015. Exploring production potential of Quinoa (chenopodium quinoa) under saline Agro-ecosystems of India. (Kailash Prajapat, SK Sanwal, Monika Shukla, Vineeth TV, Nitish Rnjan Prakash and Ravi Kiran KT)

25. NRMACSSRISIL202101801039. Physiological and molecular dissection of root system architecture (RSA) in wheat under salt stress. (Anita Mann, Arvind Kumar, Ashwani Kumar and Neeraj Kulshreshtha)

Priority Area - Agroforestry in Salt Affected Soils

26. NRMACSSRISIL202001101002 NRMACSSRISIL202001101002. Improving the productivity of senile ber orchards through top working. (Rajkumar)

27. NRMACSSRISIL202001201003. Exploration and characterization of spota cultivars for salt tolerance.(Rajkumar, Ashwani Kumar and Raj Kumar (Agroforestry))

28. NRMACSSRISIL202101901040. Assessing the genetic diversity and deciphering the molecular mechanism for salinity tolerance in Sandalwood (Santalum album L.). (Raj Kumar (Forestry), Krishnamurthy S. L., Rakesh Banyal and Ashwani Kumar)

Priority Area - Reclamation and Management of Coastal Saline Soils

29. 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)

30. NRMACSSRICIL201900600984. Mapping and characterization of salt affected soils in coastal West Bengal- (T.D. Lama, D. Burman, U.K. Mandal, A.K. Mandal, S.K. Sarangi, S. Raut, K.K. Mahanta, and S. Mukhopadhyay and S.K. Reza (NBSS&LUP regional centre Kolkata)

31. NRMACSSRISIL201900700985. Assessment of spatio-temporal variation of surface water quality in the salt affected Ganges delta of coastal West Bengal for agricultural uses (D. Burman, T.D. Lama, U.K. Mandal, K.K. Mahanta and S. Mandal)

32. NRMACSSRISIL202001401005. Coastal salinity management and cropping system intensification through conservation agriculture. (S.K. Sarangi, S. Raut, U.K. Mandal and K.K. Mahanta)

33. NRMACSSRISIL202001901010. Effect of ameliorants on soil water functional relationships and salinity in an inceptisol of Coastal West Bengal. (S. Raut, D. Burman, S.K. Sarangi and T.D. Lama)

34. NRMACSSRISIL202101201033. Development of better rice genotypes with tolerance to coastal salinity. (Nitish Ranjan Prakash, S.K. Sarangi and Krishnamurthy S.L.)

35. NRMACSSRISIL202101301034. Assessment of Ichthyofaunal diversity, biology and

stock assessment of selected species along the estuary of Sundarbans. (R.N. Bhutia and U.K. Mandal)

36. NRMACSSRISIL202200501052. Conjunctive use of poor quality water for Zero-tillage Potato under micro-irrigation system in coastal salt affected soil. (K. K. Mahanta, S.K. Sarangi, D. Burman, U.K.Mandal and T.D. Lama)

Priority Area - Reclamation and Management of Coastal Saline Soils

34. 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)

35. NRMACSSRISIL201801100964. Evaluation of pressurized irrigation system for rabi rice in coastal salt affected soils. (K.K. Mahanta, S.K. Sarangi, U.K. Mandal, D. Burman and S. Mandal)

36. NRMACSSRICIL201900600984. Mapping and characterization of salt affected soils in coastal West Bengal- (T.D. Lama, D. Burman, U.K. Mandal, A.K. Mandal, S.K. Sarangi, S. Raut, K.K. Mahanta, and S. Mukhopadhyay, (NBSS&LUP regional centre Kolkata)

37. NRMACSSRISIL201900700985. Assessment of spatio-temporal variation of surface water quality in the salt affected Ganges delta of coastal West Bengal for agricultural uses (D. Burman, T.D. Lama, U.K. Mandal, K.K. Mahanta and S. Mandal)

38. NRMACSSRISIL202001401005. Coastal salinity management and cropping system intensification through conservation agriculture. (SK Sarangi, S. Raut, UK Mandal and KK Mahanta)

39. NRMACSSRISİL202001901010. Effect of ameliorants on soil water functional relationships and salinity in an inceptisol of Coastal West Bengal. (S Raut, D. Burman, S.K. Sarangi and T.D. Lama)

40. NRMACSSRISIL202101201033. Development of better rice genotypes with tolerance to coastal salinity. (Nitish Ranjan Prakash, SK Sarangi and Krishnamurthy S.L.)

41. NRMACSSRISIL202101301034. Assessment of Ichthyofaunal diversity, biology and stock assessment of selected species along the estuary of Sundarbans. (R.N. Bhutia and U.K. Mandal)

Priority Area - Reclamation and Management of Salt Affected Vertisols

37. NRMACSSRISIL201800600959. Pulpwood-based silvipastoral systems for saline Vertisols. (Monika Shukla and Vineeth TV)

38. NRMACSSRISIL201800700960. Assessment and mapping of salt affected soils of Gujarat using remote sensing and GIS. (Anil R. Chinchmalatpure, Sagar Vibhute D. and Vineeth TV, A.K. Mandal, M.J. Kaledhonkar, Arijit Barman)

39. NRMACSSRISIL201800800961. Development of Desi cotton genotypes (G. herbaceum and G. arboreum) for salt affected Vertisols. (Vineeth TV, Lokeshkumar B.M., Anil R. Chinchmalatpure and P.C. Sharma)

40. NRMACSSRISIL202002201013.Performance of Indian mustard (Brassica juncea)

under saline Vertisols. (Monika Shukla, Vineeth TV and Anil R. Chinchmalatpure)

41. NRMACSSRISIL202101001031. Impact of agricultural waste on the shrink–swell behavior, cracking dynamics and yield of crops in saline Vertisols. (Anil R Chinchmalatpure, Sagar Vibhute, D. and Monika Shukla).

42. NRMACSSRISIL202101101032.Water management strategies for sustainable wheat production using saline groundwater in Vertisol. (Sagar D. Vibhute, Vineeth T.V., Monika Shukla and Anil R. Chinchmalatpure)

Priority Area - Reclamation and Management of Alkali Soils of Central and Eastern Gangetic Plains

43. NRMACSSRICIL202101501036. Harnessing productivity potential of calcareous salt affected soils of Bihar through improved reclamation technologies.(Sanjay Arora, AK Sngh, Arjun Singh, Ariji Barman, SP Singh (RAU) and SS Prasad (CoA, Dholi))

44. NRMACSSRISIL202200201049. Development of Climate Smart Sodic Village in Uttar Pradesh. (Atul Kumar Singh, T. Damodaran, Sanjay Arora, R H Rizvi, S. K. Jha, C. L. Verma, Arjun Singh, Ravi Kiran, Ranjay K. Singh)

45. NRMACSSRISIL202200301050. Spatial and temporal analysis of waterlogging and salt dynamics for crop planning in Sharda Sahayak Canal Command of Uttar Pradesh (Raza H. Rizvi, Sanjay Arora and CL Verma)

Foreign Funded Projects

1. NRMACSSRISOL201601500913. Strategic Research Platform on Climate Smart Agriculture "Developing and defining climate smart agricultural practices portfolios in South Asia". (P.C. Sharma, H.S. Jat, Raj Mukhopadhyay and Madhu Chaudhary) ICAR-CCAFS

2. NRMACSSRICOP201602200920 (Phase-II). Mitigating risk and scaling out profitable cropping system intensification practices in the salt affected coastal zones of the Ganges delta. (S. K. Sarangi, D. Burman, U. K. Mandal, K.K. Mahanta and Subhasis Mandal)- ACIAR.

3. NRMACSSRISOL201801300965. Development of sustainable resource management systems in water vulnerable regions of India. (Team Leader; P.C. Sharma, Dr. R.K. Yadav (PI), D.S. Bundela, Satyendra Kumar, Bhaskar Narjary, Gajender, A.K. Rai and S. Mandal) Funded by ICAR-JIRCAS, Japan

4. NRMACSSRICOL201702500949. Development of High Zinc rice varieties.(Krishnamurthy S.L. and P.C. Sharma)-IRRI

5. NRMACSSRICOL202000400995. Trait discovery-Rainfed Ecosystem. (Team Leader: Dr. P.C. Sharma) Krishnamurthy S.L., Lokeshkumar B.M.) Funded by IRRI, Philippines

6. NRMACSSRICOL202000500996. Rice grain quality and nutritional quality: Low arsenic rice, Bioactives in rice and Low GI rice. (Team Leader: Dr. P.C. Sharma) Krishnamurthy S.L., S.K. Sarangi, Lokeshkumar B.M.) Funded by IRRI, Philippines

7. NRMACSSRICOL202000600997. Climate Smart Management Practices. Sub Project 2.1 and 2.4 ((Team Leader: Dr. P.C. Sharma) H.S. Jat, Krishnamurthy S.L., Ravi

Kiran KT, S.K. Sarangi, Lokeshkumar B.M.) Funded by IRRI, Philippines

8. NRMACSSRICOL202000700998. Climate Smart Management Practices. Sub Project 2.4 (Team Leader: Dr. P.C. Sharma) H.S. Jat, Krishnamurthy S.L., S.K. Sarangi, Lokeshkumar B.M.) Funded by IRRI, Philippines

9. NRMACSSRISOL202100601027. Studies on N-(n-butyl) Thiophosphoric Triamide (NBPT) as a Urease Inhibitor for Improving Nitrogen Use Efficiency in major cropping systems in India. (Dr. PC Sharma (Team leader), Dr. HS Jat (CCPI, Karnal and Coordinator of four Subproject, Madhu Choudhary and Raj Mukhopadhyay) CIMMYT.

Externally Funded Projects

1. Intellectual property management transfer/commercialization of agricultural technologies renamed as NAIF. (H.S. Jat and Krishnamurthy SL) ICAR

2. 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): S.K. Sanwal, P.C. Sharma, (Mustard: component 4): Jogendra Singh, P.C. Sharma and Vijayata Singh)] – ICAR, New Delhi

3. NRMACSSRISOL201502200898. CRP on Conservation Agriculture 'Productive utilization of salt affected soils through conservation agriculture". (R.K. Fagodiya, Arvind Kumar Rai, Parvender and Priyanka Chandra)-ICAR

4. 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

5. NRMACSSRICOL201702300947. 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

6. NRMACSSRICOL201702400948. CRP on Agro-Biodiversity—Component 2 - Evaluation of rice germplasm accessions against biotic/abiotic stresses. (Krishnamurthy S.L. and P.C. Sharma)-ICAR

7. NRMACSSRICOL201702600950. HOPP Project "Technical guidance on monitoring & evaluation of large scale SSD projects in Haryana"{Team Leader: PC Sharma, D.S. Bundela (PI) Team A: Satyendra Kumar, Arijit Barman and Kailash Prajapat and Team B: R.L. Meena, Bhaskar Narjary, R.K. Fagodiya, Raj Mukhopadhyay, PR Bhatnagar)

8. NRMACSSRISOL201801200964. From QTL to Variety: Genomics assisted introgression and field evaluation of rice varieties with genes/QTLs for yield under drought, flood and salt stress. (Krishnamurthy S.L. and P.C. Sharma)

9. NRMACSSRICOL201900500983. North Indian Centre for Water Technology Research in Agriculture (Team leader: P.C. Sharma, M.J. Kaledhonkar (PI), B.L. Meena, Satyendra Kumar, Parvender Sheoran, Bhaskar Narjary, R.K Fagodiya, Awtar Singh, R.B. Singh and S.K. Chauhan (AICRP Agra Centre) ICAR

10. NRMACSSRICOP201901200990. Development of high density linkage map and tagging salinity tolerance in lentil using genotyping-by-sequencing approach for improving salt tolerance. (Vijayata Singh (CC-PI) and S.K. Sanwal (Co-PI), DBT funded

11. NRMACSSRISOL201901300991. Methodology for rapid detection, characterization and 3-D representation and risk zone identification of hot spots soil salinity in Rohtak district, Haryana using electromagnetic induction and remote sensing techniques.(Bhaskar Narjary, Arijit Barman, Raj Mukhopadhyay and D. S. Bundela) SERB-DST funded

12. NRMACSSRICOL202000901000. Assignment for study and development of practices for application of FGD Gypsum for sodic soil reclamation and it's effect on environment. (Parul Sundha, Nirmalendu Basak, A.K. Rai, Raj Mukhopadhyay, R.K. Yadav, and P.C. Sharma) NTPC

13. NRMACSSRICOL202001001001. Pilot Project on Reclamation of Saline and Alkaline soils in Haryana and Punjab.(Team Leader P.C. Sharma) Alkaline Soil Reclamation: R.K. Yadav (PI), A.K. Mondal, Ashim Datta, Naresh Arora. Training: Anil Kumar, Kailash Prajapat) (NABARD)

14. NRMACSSRICOL202002001011. Germplasm characterization and trait discovery in wheat using genomics approaches and its integration for improving climate resilience, productivity and nutritional quality. Sub Project 3: Evaluation of wheat germplasm for abiotic stresses (Component -6) (Arvind Kumar and Neeraj Kulshershtha) DBT Funded

15. NRMACSSRICOL202002101012. Leveraging genetic resources for accelerated genetic improvement of linseed using comprehensive genomics and phenotyping approaches. Sub project: Evaluation of linseed germplasm for major abiotic stresses (Drought and salt stress) (Component -4) (S.K. Sanwal and Jogindra Singh) DBT Funded

16. NRMACSSRISOL202002501016. Combating sub-soil sodicity constraints of central indo-gangetic plains of Uttar Pradesh for enhancing crop productivity" (S.K. Jha, C.L. Verma and Atul Kumar Singh) UPCAR Funded

17. NRMACSSRISOL202002601017. Microbial mediated paddy and wheat crop residue decomposition to enhance soil nutrient recycling and soil health management (Sanjay Arora, Y.P. Singh, Atul Kumar Singh and Madhu Choudhary) UPCAR Funded

18. NRMACSSRISOL202100301024. Development of technologies for sustainable use of sodic groundwater: Enhancing agricultural livelihood. (Nirmalendu Basak, Arvind Kumar Rai, Parul Sundha, Satyendra Kumar, Ranjay Kumar Singh, R.K. Yadav and P.C. Sharma) DST

19. NRMACSSRISOL202100401025. Assessment and use of soil health as a tool for doubling farmers' income, sustainable production and resource conservation in salt-affected soils of Haryana. (Nirmalendu Basak, Co-PIs: Suresh Gahlawat (DoA, Govt. of Haryana), Arvind Kumar Rai, Kailash Prajapat, Raj Mukhopadhyay, Gajender Yadav, Arijit Burman, Parul Sundha, Ranjay Kumar Singh, R.K. Yadav and

P.C. Sharma) RKVY

20. NRMACSSRISOL202100501026. Sensitizing farmers to the benefits of converting waste in to wealth through climate smart agriculture practices (CSAPs) in rice-wheat system of Haryana. (H.S. Jat, Madhu Choudhary, Raj Mukhopadhyay, R.K. Singh, R.K. Yadav, P.C. Sharma) RKVY

21. NRMACSSRISOL202100701028. Characterization of Chickpea germplasm resource to accelerate genomics-assisted crop improvement. (PC Sharma and Jogendra Singh) DBT

22. NRMACSSRISOL202100801029. Introgression of blight and blast resistance genes in salt tolerant basmati CSR30 rice variety through marker assisted backcross breeding (MABB). (Krishnamurthy, S.L., P.C. Sharma and Lokeshkumar B.M.,) SERB DST

23. NRMACSSRISOL202101401035. Enhancing food and water security in degraded coastal soils through improved management of blue, green and grey water.(U.K. Mandal, K.K. Mahanta, T.D. Lama, S. Mandal, D. Burman) DST

24. NRMACSSRISOL202101601037. Development of integrated organic farming system in partially reclaimed sodic soil of Uttar Pradesh for livelihood security. (Arjun Singh, S.K. Jha, C.L., Verma, T. Damodaran, A.K. Singh and Sanjay Arora) RKVY

25. NRMACSSRICOL202101701038. Management of Fusarium wilt in NER Banana using ICAR-FUSICONT technology. (T. Damodaran,) DBT

26. NRMACSSRICOL202102101042. Enhancing farmer's livelihood through identified interventions in waterlogged saline agroecosystems of Haryana. (Parvender Sheoran, Ranjay K Singh, Satyendra Kumar, Kailash Prajapat, Arvind Kumar, Arijit Barman, Subhasis Mandal, Ashwani Kumar, Bhaskar Narjary, Sohanvir Sing and K Ponnusamy (NDRI). FARMER FIRST, ICAR

27. NRMACSSRICOP202102501046. Hindon Roots Sensing HIROS River Rejuvenation through Scalable Water- and Solute Balance Modelling and Informed Farmers' Actions. (Team leader: P.C. Sharma, H.S. Jat, D.S. Bundela) DST-NWO Hindon

28. NRMACSSRISOI202102601047.Deciphering molecular mechanism of salinity tolerance at reproductive stage in rice landrace - Bhatada Rashi 1 (Krishnamurthy, S.L., Lokeshkumar B.M. and P.C. Sharma) LBS

29. NRMACSSRISOL202200101048.Development of Arbusular Fungi (AMF) based plant biostimulant to enhance productivity of salt affected soils. (Priyanka Chandra, Arvind Kumar Rai, Nirmalendu Basak, Parul Sundha, Kailash Prajapat and R.K Yadav) DST-SERB funded.

30. NRMACSSRICOP202200401051.Economics impact assessment of technologies for management of salt-affected soils in India. ICAR-NIAP Network Project on production systems, Agribusiness and Institutions (Component-I Impact assessment of agricultural technologies) (Subhasis Mandal, Suresh Kumar, Anil Kumar)

31. NRMACSSRISOL202200701054. Sensitizing farmers on organic farming of basmati rice in Haryana and establishment of rice quality laboratory and gene bank at

CSSRI Karnal. (S. L. Krishnamurthy, B. M. Lokeshkumar, P. C. Sharma) RKVY

Collaborative

1. NRMACSSRISL202102401045. Novel genetic approaches for development of climate smart rice varieties. (Krishnamurthy, S. L. (Co-PI) Collaboration with IIRR, Hyderabad

Consultancy

1. Consultancy: Subsurface drainage for heavy soils of Maharashtra, Karnataka, Gujarat, AP & Telangana (Team Leader: PC Sharma, DS Bundela (PI), Anil R. Chinchmalatpure, Sagar D Vibhute and Subhasis Mandal)

Contract Research

1. Enhancing nutrient use efficiency using nano-fertilizer in rice-wheat cropping system under salt stress. (Ashwani Kumar, Parvender Sheoran, Anita Mann and Ajay Bhardwaj) funded by IFFCO

INSTITUTE ACTIVITIES

Institute Management Committee Meeting

The 46th Institute Management Committee meeting was held on 4th March, 2022 at ICAR-CSSRI, Karnal in dual mode (online and physical) and was attended by all the head of divisions of the Institute and the following IMC Members.

1.	Dr. P. C. Sharma, Director, ICAR-CSSRI, Karnal.	Chairman
2.	ADG (Soil and Water Mgt.), NRM Div., ICAR, New Delhi	Member
3.	Sh. S.S. Josan, Representative of Director (Agriculture), GoP	Member
4.	Dr. Naseeb Singh, CCSHAU, Hisar	Member
5.	Dr. Sewa Ram, ICAR-IIWBR, Karnal	Member
6.	Dr. Pratap Bhattacharya, ICAR-NRRI, Cuttack	Member
7.	Dr. J. Rane, ICAR-NIASM, Baramati	Member
8.	Dr. N. Ravishankar, ICAR-IIFSR, Modipuram	Member
9.	Sh. Hemchand Kaushik, Nominee of the President, ICAR	Member
10.	Sh. Mehar Chand Gahlot, Nominee of the President, ICAR	Member
11.	Sh. N.K. Arora, Deputy Director (Finance), ICAR-NAHEP, New Delhi	Member
12.	Sh. Brahm Parkash, AO, ICAR-CSSRI, Karnal	Member Sec.

IMC meeting in progress

The Meeting started with the confirmation of the proceedings of the last meeting held on 9th March, 2021. Subsequently, the research achievements of different Divisions, Regional Research Stations and Project Coordinating Unit were discussed. This was followed by discussion on other activities carried out during by the Institute. These included activities by the Institute Rajbhasha Committee, different trainings and programs organized during the period, the issues related to staff position, Institute budget and expenditure, sale of farm produce, publications, linkages, collaborations and the activities related to '*Swachh Bharat Abhiyaan*' and '*Mera Gaon Mera Gaurav*' programme.

Workshop, Seminar, Training, Foundation Day and Kisan Mela organised

Glimpse of Kisan Mela in UP

Kisan Mela organized at RRS Lucknow jointly with Agriculture Department, U.P.

A three days Kisan Mela cum Exhibition was organized at CSSRI, RRS Lucknow jointly with Agriculture Department, U.P. on "Khet ki Chunotiya evam Samadhan" during January 7-9, 2022. The Mela was inaugurated by Shri Kaushal Kishore ji, Minister of State for Housing and Urban Affairs, Government of India.

Kharif Kisan Mela - Karnal 2022

The Kharif Kisan Mela was organised on March 15, 2022 in collaboration with Department of Agriculture and Farmers' Welfare, Govt. of Haryana at playground of the institute. Sh. Sanjeev Kumar Verma, Divisional Commissioner of Karnal Division graced the occasion as chief guest. In his address to the participating farmers, he emphasized on the role of integrated and traditional farming practices in providing resilience production and diversity of products. He also appraised about the farmers' welfare schemes announced by the state government and called upon to get maximum benefit out of them. Guest of Honour, Dr. Gurbachan Singh, Chairman GSFERD, Karnal told that adoption of multienterprise based integrated farming system model can increase income by 3-4 times and this also lowers the risks under small land holding farming situation. He urged that there is need to work together by different stakeholders and farmers for betterment of farming community. Dr. Aditya Pratap Dabas, Deputy Director Agriculture, Karnal emphasized on different crop residue management technologies and urged the farmers to manage crop residues in the field for better soil health and protecting the environment. P.C. Sharma, Director, ICAR-CSSRI, Karnal, in his welcome address, presented an overview of improved salt tolerant varieties, salinity management and

S.K. Verma addressing the farmers

resource conservation technologies developed by the institute. The Kisan Mela was attended by about 1800 farmers, stakeholders and school children. To showcase the latest technologies to the participating farmers about 50 exhibition stalls were put by the ICAR institutes situated at Karnal, various private firms and progressive farmers. Farmers were also distributed seeds of salt tolerant varieties of rice crop. Lectures on improved agro-techniques for salt affected soil and poor quality irrigation delivered by the subject matter specialist of the institute and invited speakers of other institutes. A general knowledge quiz on agriculture related aspects was also conducted in the Mela and 26 progressive farmers were felicitated in the Mela.

54th Foundation Day

CSSRI celebrated its 54th Foundation Day on 3rd March 2022. Chief Guest, Prof. B.R. Kamboj, Vice Chancellor, Chaudhary Charan Singh Haryana Agricultural University, Hisar, inaugurated the function. The chief guest in his address talked about the important role that CSSRI has played in the reclamation of salt affected soils throughout the country, the technologies that this Institute has given to the farmers and the overall impact that it posses towards increasing the GDP of India. He also discussed about the collaborations that HAU and CSSRI are doing in terms of research and PhD Scholars. Earlier, Dr. P.C. Sharma, Director told about the various technologies developed by the institute, describing in detail the achievements of the institute. On this occasion, the chief guest released two research bulletins and distributed the Annual Awards of CSSRI. Dr. V.K. Kharche was awarded with the ICAR-CSSRI Excellence Award in Soil Salinity for the year 2020. Sh. B.M. Meena was awarded with best employee award in technical category for the year 2021. Smt. Pragnya K Parekh was awarded with best employee award in administration category for the year 2021.

Dr. B.R. Kamboj delivering the foundation day lecture


Dr. V.K. Kharche being awarded by Chief Guest and Director

Mini STL kit based soil & water testing training

Training on "Mini STL kit based Soil and Water Testing" sponsored by State Department of Agriculture and Farmers' Welfare, Govt. of Haryana was organized by ICAR-CSSRI, Karnal. The training was provided to 19 Assistant/Associate Professors from different Govt. Colleges of Haryana State during 05-07 July 2022 and to 36 GSSS Science teachers from different Govt. Schools of Haryana State during 12-14 July 2022. In these training programmes, major aspects of soil and water testing viz., Scope and importance of soil and water testing in India, Salinity and its impact on nutrients and water availability, Orientation to mini STL kit and other instruments used for soil and water testing were covered. Practical's on Preparation and Processing of Soil/Water Samples for analysis, Preparation of solution/reagent for mini STL kit, Estimation of EC, pH, Carbon, Phosphorus, Potassium, Micronutrients, Sulphur, Calcium and Magnesium of soil using mini STL kit were trained. Pre- and post-training evaluation of all trainees was also carried out which showed that the percentage increase in knowledge from pre training evaluation test to post training evaluation test was found to be 27.00% for Assistant/Associate Professors and 32.7 % for GSSS Science teachers.

Swachhata Abhiyan programme

ICAR-Central Soil Salinity Research Institute, Karnal organized Swachhata Abhiyan programme during16-31 December, 2022. In the closing ceremony of the programme, Sh.Yogender Rana, District President BJP, Karnal graced the occasion as the Chief Guest and Sh. Sanjay Bathala, representative Hon'ble Chief Minister, Government of Haryana as the Guest of Honour. Sh. Yogender Rana, in his address, emphasized the role of peoples' participation and their individual duties for keeping the nation clean, and also underlined the progress and achievements made in clean India campaign through various programmes implemented by the Government of India. On this occasion, Sh. Sanjay Bathala shared his vision and valuable experience of last 8 years being a part of Swachh Bharat Mission. Further, he laid emphasis on positive and favourable change soccurred in the attitude of people vis-à-vis cleanliness, which he considered as a great step forward to achieve the objectives of clean India. Further, he called for taking cleanliness as fundamental duty of every citizen as this would help fulfilling the

ICAR-CSSRI Employees during Swachhta Pakhwada 2022 Event aspirations of India. Dr P.C. Sharma, Director, ICAR-CCSRI, Karnal highlighted the various activities and programmes conducted during 16-31, December, 2022 as part of Swachhata Abhiyan programme at the Institute and in its vicinity including that in the 50 villages adopted by the Institute. He pointed out that in programmes conducted by the Institute, farmers including children and women were sensitized about the multiple aspects of cleanliness using various technologies.

Kisan Diwas Celebration

The Institute organized Kisan Diwas on 23rd December, 2022 at village Dabri of Karnal district to honour the farmers having extra-ordinary achievements in the farming sector. In this programme, Dr. S.K. Chaudhari, DDG (NRM), ICAR was the Chief Guest and Dr A. Velmurugan, ADG (SWM), ICAR was the Guest of Honor. Addressing the gathering of around 200 farmers, Dr. S.K. Chaudhari apprised them about different government s chemes for the benefits of the farmers and the steps to take advantage of them. He emphasised the need for enhancing the soil fertility by adopting conservation agriculture including the proper management of crop residues in the rice-wheat cropping system. On this occasion, Dr. A. Velmurugan shared his experiences with the farmers adopting traditional practices for sustainable agriculture in Andaman and Nicobar Islands and elsewhere which could be replicated by the farmers of Haryana State. Earlier, Dr P.C. Sharma, Director of the Institute apprised the gathering about the technologies developed by the Institute for management of salt-affected soils and poor-quality water for irrigation. He informed that the Institute has developed 23 salt-tolerant crops varieties of rice, wheat, mustard and chickpea, which are playing important role in increasing the income of the farmers having slat-affected soils. On this occasion, some of the progressive farmers and farm women of self-help groups also shared their experiences in achieving success in farm related endeavours.

Glimpse of Kisan Diwas Celebration

Kharif Kisan Goshthi and Quality Seed distribution Programme

On 27th May, 2022 a farmers-scientist interface meeting-cum-Kisan Goshthi was organized at village Kathura (Sonipat) under CSSRI led Farmer FIRST Project. About 70 participating farmers were given seed of improved paddy varieties (PB 1121, PB 1718, PB 1509, PB 1692, CSR 56 and CSR 60). CSSRI Scientists discussed about the characteristics of the improved rice varieties and shared the tips to get higher yields by following recommended management practices. He stressed upon the need of using good quality seed for raising healthy and disease-free nursery for better crop establishment and higher yields. Farmers should apply balanced fertilizers including micro nutrients based on Soil Health Card curtailing unnecessary investments on applying only NPK fertilizers. Farmers were apprised about controlling the Foot Rot and Bakanae disease in paddy. Farmers were informed that this is a seed-borne disease and can be controlled only with the proper seed treatment. There is no chemical control after its occurrence and the plants need to be uprooted and destroyed properly to control its further spread. For seed treatment, the farmers should treat the paddy seed with ready-mix of carbendazim + mancozeb @ 3 g/kg of seed. In case of Iron deficiency, ferrous sulphate @ 0.5% solution should be sprayed and repeat the same after 7 days, if necessary. Proper care should be taken while uprooting the nursery seedlings by irrigating the nursery field a day before transplanting and N application should be stopped 5-7 days before uprooting.

Kharif Kisan Goshti on balanced fertilization and distribution of biofertilizers

ICAR-Central Soil Salinity Research Institute, Karnal organized Kharif Kisan Goshti at village Kathura, Sonipat under Farmer First Project (FFP) on July 29, 2022. A total of 50 farmers from the adopted village participated in the programme. There is problem of waterlogged saline soils having shallow marginal saline to highly saline groundwater in the village. At the outset Dr. Parvender Sheoran briefed about importance of balanced fertilization in crops to achieve the higher yield. Azotobacter, P.S.B, Zinc and Sagarika were distributed to the farmers. Control measures for the pest and disease management were also suggested in paddy.

Kisan Goshti and input distribution programme

Scenes from Kisan Goshthi

ICAR-CSSRI, Karnal organized Kisan Goshti and input distribution programme at village Kathura, Sonipat under Farmer First Project on August 8. A total of 80 farmers from the adopted village participated in the programme. Dr. Parvender Sheoran informed the farmers about pest and disease management in paddy and suggested them not to go for the application of banned insecticides and use only recommended insecticides at recommended rates for the control of insects. It is expected to help in maintaining the quality of produce and also reduces the cost of input. Dr. Sohavir Singh informed the farmers about the importance of green fodder and balanced nutrition in the life of animals. Dr. Singh said that Napier grass is perennial grass and provide green produce during the off-season too when there is shortage of green fodder. It is a rich source of the protein and crude fiber which contains about 18-20% protein and 35% crude fiber. The grass can be grown successfully in problematic soil by cuttings. In addition to this Dr. Singh informed the farmers about the diseases of animals mainly occurred during the monsoon season and also suggested them the preventive measures. Dr. Singh also alerted farmers on the deadly disease of animals (Lumpy skin diseases) mainly in cows. Deworming tablets, Napier grass cuttings, mineral mixture were distributed to the farmers.

Awareness Gram Sabha under Vigilance Awareness Week

Dr. Anil in talk with the villagers

ICAR-Central Soil Salinity Research Institute, Karnal observed the Vigilance Awareness Week during 31st October to 6th November, 2022. In this regard, a three month campaign on six different preventive vigilance measures was to be carried out as per the guidelines of CVC and the Council. As part of the campaign, out-reach activities for public were carrie d out by the Institute in order to sensitise the rural people on theme "Corruption free India for a developed Nation". The Institute conducted Awareness Gram Sabha in Dabri panchayat of Karnal district on 24th November, 2022 in the presence of 50 villagers to disseminate the information regarding the menace of corruption and the different measures that public can undertake to redress it. In this programme, awareness was created about the need to remain vigilant in the matter of their development so that transparent and effective governance could be ensured. The campaign also apprised the villagers about the various options available for them to lodge complaints for redressal of their grievances.

Parthenium awareness week

Dr. Sheoren addressing the students

ICAR-Central Soil Salinity Research Institute, Karnal organized parthenium awareness week at Govt. Senior Secondary School, Kathura, Sonepat under Farmers FIRST project (FFP) on August 23, 2022 in which about 200 students of class 11th and 12thand 25 school teachers participated. Dr. Parvender Sheoran (PI) FFP sensitized the students about the origin, spread, identification and hazard of parthenium. In addition to this, he explained integrated management approach for parthenium by various means such as mechanical and manual methods, cultural management, chemical management, biological method, and also the use of parthenium as compost etc. One battery operated spray pump with 2 litres of glyphosate was handed over to the Principal, Govt. Girls Sr. Sec. School, Kathura, Sonepat for the chemical control of parthenium in the school premises. Dr. Kailash Prajapat and Dr. R. K. Fagodiya (Co-PIs) FFP informed the students about importance of agricultural sciences, role of different agricultural institution and job opportunities in agricultural sciences. Students showed their huge interest in the agriculture stream. Dr. Sheoran and his team members promise the students to guide them for preparing the competitive exams for agricultural sciences for their higher education.

8th International Yoga Day Celebrations

Employees doing Yoga

On the 21st of June, the employees of ICAR-CSSRI and its regional station in Bharuch celebrated the 8th International Yoga Day. This day is celebrated worldwide to highlight the importance of yoga in maintaining a healthy mind and body. The employees performed various yoga asanas, from simple breathing exercises such as Pranayama to the more advanced asanas such as Vrikshasana. The employees enthusiastically participated in the celebration. The employees also engaged in discussions about the benefits of yoga and how it can help reduce stress, anxiety and other physical ailments. The employees also shared their personal experiences of how yoga has helped them in their daily lives. The celebration of International Yoga Day was not only limited to the employees but was also open for their family members. The children of the employees also participated in performing basic yoga asanas which was a joy to watch. The celebration of International Yoga Day by the employees was a testament to the importance of yoga in our daily lives. The day ended with a pledge by the employees to continue practicing yoga and to spread awareness about the benefits of yoga to others.

List of Scientific, Technical and Administrative Personnel

Parbodh Chander Sharma, Ph.D., Director

Division of Soil and Crop Management

R.K. Yadav, Ph.D., Head (A)

A.K. Mandal, Ph.D.

A.K. Rai, Ph.D.

H.S. Jat, Ph.D.

A.K. Bhardwaj, Ph.D.

Rakesh Banyal, Ph.D.

Gajender Yadav, Ph.D.

Madhu Choudhary, Ph. D.

Nirmalendu Basak, Ph.D.

Ashim Dutta, Ph.D.

Parul Sundha, Ph.D.

Raj Kumar, (Agroforestry) Ph.D.

Rajkumar, (Horticulture) Ph.D.

R.L. Meena, Ph.D.

Arijit Burman, Ph.D. (16.09.22)[a]

Awtar Singh, Ph.D

Priyanka Chandra, Ph.D.

Manish Kumar, M.Sc (study leave)

Raj Mukhopadhyay, Ph.D.

Technical Officers

Naresh Kumar, Ph. D.

Dilbag Singh

Division of Crop Improvement

Neeraj Kulshereshtha, Ph.D., Head (A)

S.K. Sanwal, Ph.D.

Anita Mann, Ph.D.

S.L. Krishna Murthy, Ph.D

Joginder Singh, Ph.D.

Ashwani Kumar, Ph.D

Arvind Kumar, Ph.D.

Avni, Ph.D. (02.12.22)[b]

Vijayata Singh, Ph.D.

Lokesh Kumar B.M.

Division of Irrigation and Drainage Engineering

D.S. Bundela, Ph.D., Head

P.R.Bhatnagar

Satyender Kumar, Ph.D.

Bhaskar Nurjury, Ph.D.

R.K. Fagodiya, Ph.D.

Pathan Aslam Latif, M.Tech. (study leave)

Jaffer Yousuf Dar, M.Sc.

Technical Officers

Dharam Pal Kansia, M.Lib.

Division of Social Science Research

Anil Kumar, Ph.D. Head (A)

Subhasis Mandal, Ph.D.

R.K. Singh, Ph.D.

Parvender Sheoran, Ph. D.

Suresh Kumar, Ph.D. (18.04.22)[b]

Kailash Prajapat, Ph.D.

Bhagya Vijayan

AICRP (Saline Water)

M.J. Kaledhonkar, Ph.D., P.C.

Babu Lal Meena, Ph.D.

Regional Research Station, Canning Town

D. Burman, Ph. D., Head (A)

U.K. Mandal, Ph.D.

S.K. Sarangi, Ph. D.

T.D. Lama, Ph.D.

Shishir Raut, Ph. D.

K.K. Mahanta, Ph. D.

Nitish Ranjan Prakash, Ph. D.

Rinchen Nopu Bhutia, M.Sc.

Technical officers

Sivaji Roy, M.Sc

S. Mandal, B.Sc.

Regional Research Station, Bharuch

Anil R. Chinchmalatpure, Ph.D., Head

Sharwan Kumar, Ph.D

Monika Shukla, Ph.D.

David Cames D., M.Sc. (study leave)

Vibuti Sagar, M.Tech.

Bisweshwar Gorain, M.Sc.

Vineeth TV, M.Sc.

Technical Officer

Akshay Kumar

Regional Research Station, Lucknow

T. Damodaran, Ph.D., Head (A)

Chhedi Lal Verma, Ph.D.

Atul Kumar Singh, Ph.D.

Sanjay Arora, Ph.D.

S.K. Jha, Ph.D.

Arjun Singh, Ph.D.

Ravi Kiran, Ph.D.

R.H. Rizvi, Ph.D.

Technical Officer

C.S. Singh, Ph.D.

Hari Mohan Verma, M.Tech.

Administrative and Supporting Section

Administration

Abhishek Rana, CAO

Sunil Kumar, SFAO

Tarun Kumar, AAO

Sultan Singh, AAO

Dinesh Gugnani, PS (31.08.22)[c]

Santra Devi, PS

Rita Ahuja, PS

Sunita Malhotra, PS

Shashi Pal, PS

RTI Cell

Parvender Sheoran, Ph.D., CPIO

N.K. Vaid, M.Tech., APIO

Transparency Officer

Dr. A.K. Rai

Priortizing, Monitoring and Evaluation (PME) and Institute Technology Management Unit (ITMU)

H.S. Jat, Ph.D

Technical Officer

Vinod Kumar, M.A.

Public Relation Officer

Anil Kumar Sharma, M.A. (30.09.22)[c]

Farm Section

Ganesh Patel, STO

Library

Meena Luthra, M. Lib.

Medical Unit

Chanchal Rani

Geeta Rani

Estate Section

N.K. Vaid, M.Tech. OIC (Estate Civil)

Kulbir Singh, Diploma

* Superscripts a, b, c and d refer to date of relieving, joining, superannuation and date of death, respectively.

ICAR-CSSRI Staff Position

Statement showing the total number of employees and the number of Scheduled Castes (SC)/Scheduled Tribes (ST) as on 31.12.2022.

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		76	76	5	6.58	4	5.27
Lowest rung of Class-1		7	7	2	28.58	1	14.29
Class-II		37	37	6	16.22	4	10.82
Class-III		73	73	5	6.9	3	4.11
Class-IV (excluding sweepers)		-	-	-	-	-	-
Class-IV (only sweepers)		-	-	-	-	-	-
Total		193	193	18	9.33	12	6.22

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 31.12.2020.

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 2022

Main Institute, Karnal

During the year 2022, a total rainfall of 1328 mm was recorded at Agro-met Observatory, Karnal as compared to the mean annual rainfall of 746.8 mm (for the last 50 years). The year was an excessive rainfall year (178% of the long-term mean annual rainfall) whereas the year 2021 was also an excessive rainfall year (177%). The maximum monthly rainfall of 472.0 mm was recorded during July. During the monsoon season, the highest rainstorm of 191.6 mm was recorded on 29thJuly and the second highest of 153.2 mm on 24th September. During January and February, there was a good amount of rainfall of 93.1 and 29.9 mm which substantially reduced the irrigation demand of wheat and other Rabi crops, met either from canal water or groundwater tube wells or both. There was no winter rainfall (March) as compared to 4.0 mm the last year winter rainfall. Poor rainfall resulted in high irrigation demands for different Rabi crops during March leading to bumper Rabi crop production. There were 63 rainy days as compared to 60 days during the last year.

The minimum and maximum air temperatures, 3.1 0C and 43.7 °C were recorded on 1st January and 6th June, respectively. The air relative humidity was the lowest (11%) on 7th April while the highest (100%) was recorded on several occasions during the year. The highest soil temperatures at 5 and 10 cm depth were 53.4 0C and 46.5°C on 5th June. The lowest values at same depths were recorded as 4.5 0C, 5.5 0C, and 11 °C on 3rd January (5, 10 and 20 cm depth). The total open pan evaporation during the year was 1333.0 mm, which was almost same to the current annual rainfall. The lowest evaporation of 0.1 mm was recorded on 12th January and the highest of 14.2 mm was on 14th June. The average sunshine hours per day were 4.8. The highest and lowest vapour pressure values were 29.7 and 6.4 mm on 2nd August and 1st January, respectively. The average wind speed was 1.9 km per hour. The monthly weather parameters recorded at Agro-meteorological Observatory, ICAR-CSSRI, Karnal (Haryana) for the year 2022 are presented in Table 105.

Weather Report 2022 Bharuch

Agro-meteorological observations (Table I) recorded at Regional Cotton Research Station, NAU, Bharuch during the year 2022 revealed that this region received normal rainfall of 806.3 mm spread over 51 days. Season's highest rainfall 472.1 mm was received during July followed by 135.8 mm, 104.7 mm, 58.0 mm and 35.7 mm in the month of September and August, October and June 2022, respectively. Maximum air temperature ranged from 27.7oC (January) to 39.3 oC (April) and minimum air temperature varied from 14.0 oC (January) to 27.9 oC (May). Pan evaporation varied from 2.6 mm day-1 to 8.8 mm day-1 during the year. The average bright sunshine hours varied from 1.5 to 9.0 hr/day. Mean relative humidity ranged from 40.2 to 84.8 per cent the year. The average wind speed varied from 0.2 kmph to 11.5 kmph during the year.

Weather Report 2022 Canning Town

The onset of southwest monsoon took place on 10th June, 2022 in this region. The rainfall was normal during 2022 and the total annual rainfall of 1568.6 mm recorded by the meteorological unit of this Centre. Though the onset of monsoon was normal it was weak during June and June rainfall was even less than the evaporation demand of this month. In July rainfall was also quite less and because of that sowing of rice as well as transplanting was delayed in this year. August recorded the maximum rainfall of 491.8 mm. There were three extreme events of rainfall on 11.08.22, 24.08.22 and 13.9.22 when more than 100 mm rainfall recorded in a day. This year during January and February also recorded 86.8 mm rainfall which helped in rabi season crop. The minimum temperature reached its lowest value of 10.4oC on 30.01.22 while the highest maximum temperature of 38.8oC was recorded on 25.4.22. 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 105.

Table 103: Mean monthly weather parameters for the year 2022 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	
				I	II	I	II	I	II	I	II				
Jan.	15.3	8.1	-	9.3	14.7	9.2	13.0	8.8	10.3	98	83	20.8/31	10.0/13	13.8/08	3.1/01
Feb.	21.1	8.1	-	9.1	20.7	8.8	15.4	8.5	10.0	97	56	24.2/23	14.1/01	14.4/27	5.0/06
Mar.	30.7	14.8	-	16.6	30.4	15.7	21.1	13.1	13.3	91	41	38.4/01	23.5/02	21/18	8.0/01
Apr.	39.6	19.6	-	23.7	39.0	17.8	20.9	11.8	7.5	54.0	15	42.7/30	34.2/22	24.0/30	14.8/02
May	37.4	24.5	-	27.1	36.3	22.9	25.1	18.4	17.1	69	39	42.8/01	27.2/24	27.5/01	19.3/05
Jun.	38.4	25.6	-	28.5	37.3	24.1	25.8	20.0	18.0	70.2	42.4	43.7/06	27.0/19	29.4/14	21.0/22
Jul.	33.3	26.8	-	28.2	31.8	27.2	28.2	26.4	26.5	92.4	75.8	36.8/05	27.2/01	29.7/07	24.0/01
Aug.	33.1	26.1	-	27.6	31.7	32.3	26.7	25.8	27.3	92.9	75.5	35.6/11	29.2/08	27.6/09	24.0/15
Sept.	32.4	24.4	-	25.7	31.3	25.2	27.1	23.8	24.4	96.1	72.3	35.4/10	24.6/24	27.3/10	22.3/24
Oct.	31.0	18.4	-	19.8	30.2	19.2	22.5	16.5	15.8	93.6	50.2	34.6/05	27.2/11	23.6/01	14.0/25
Nov.	27.4	12.3	-	13.5	26.5	12.9	18.8	11.0	11.7	92.6	44.5	30.7/01	25.4/26	18.3/06	8.4/24
Dec.	20.8	7.9	-	9.0	19.9	8.8	15.4	8.4	10.6	97.1	62.1	25.6/01	09.7/26	10.2/11	5.0/24
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	**30.04**	**18.05**	-	**19.8**	**29.1**	**18.6**	**21.6**	**16.04**	**16.04**	**86.9**	**54.7**	-	-	-	-

Month	Soil Temperature, °C (Depth-wise)						Rainfall*			Evaporation		Sunshine (hr/day)	
	5 cm		10 cm		20 cm								
	I	II	I	II	I	II	Monthly (mm)	No of rainy days	Heavy/ date	mm/ day	mm/ month		
Jan.	9.3	17.5	9.5	14.9	11.7	13.2	93.1	09	26.0/23	0.8	24.2	2.0	1.6
Feb.	9.0	24.3	9.4	20.1	12.6	15.8	29.9	03	15.2/04	1.8	50.5	6.1	2.3
Mar.	16.4	38.6	17.1	32.8	20.8	26.4	0.0	0	-	3.7	114.7	8.0	1.3
Apr.	23.5	47.2	24.4	41.4	28.5	34.5	0.0	0	-	7.6	226.7	7.8	1.7
May	27.6	45.4	28.0	40.9	30.4	35.3	111.0	04	37.8/23	7.1	206.9	7.0	5.0
Jun.	29.3	46.5	29.9	42.0	32.1	35.8	52.8	03	39.0/22	7.9	228.1	7.8	3.4
Jul.	28.6	37.9	28.7	35.4	29.3	31.5	472.0	12	191.6/29	4.6	125.4	4.9	3.1
Aug.	27.6	36.2	27.6	34.7	29.3	32.7	108.4	09	23.6/10	3.9	119.4	7.2	2.3
Sept.	27.2	38.7	27.3	35.6	28.5	31.0	441.6	09	153.2/24	3.1	58.4	5.8	1.2
Oct.	20.5	32.0	20.7	29.0	22.8	26.2	18.0	03	14.2/12	2.9	89.1	6.7	0.9
Nov.	14.1	28.7	14.8	25.5	16.9	21.4	0.0	00	-	1.8	52.5	4.8	0.4
Dec.	9.4	23.9	10.1	19.8	13.0	16.2	1.2	01	1.2/30	1.2	37.1	4.8	0.5
Total	-	-	-	-	-	-	**1328.0**	**53**	-	-	**1333.0**	**72.9**	**23.7**
Average	**20.2**	**34.7**	**20.6**	**31.0**	**22.9**	**26.6**	**110.6**	**4.41**	-	**3.9**	**111.0**	**6.0**	**1.9**

Table 104. Monthly average agro-meteorological parameters at Bharuch during 2022

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	27.7	14.0	0	0	67.4	10.9	14.9	5.5	7.2	4.4
February	31.8	14.3	0	0	50.1	11.0	9.5	3.9	8.7	5.4
March	37.2	20.4	0	0	42.6	13.9	11.8	5.0	7.6	8.8
April	39.3	22.9	0	0	40.7	17.5	12.2	6.1	9.0	8.5
May	38.8	27.9	0	0	59.9	25.2	21.7	11.5	9.0	8.8
June	37.0	27.1	35.7	4	63.3	23.5	22.3	10.4	7.9	7.1
July	29.7	25.6	472.1	23	84.8	24.0	24.1	8.1	1.5	2.6
August	30.7	25.5	104.7	12	78.1	23.7	23.5	0.2	3.3	3.6
September	32.8	25.6	135.8	10	72.9	23.9	22.3	4.5	4.6	4.4
October	33.1	23.7	58.0	2	60.7	20.1	19.9	3.5	7.0	5.6
November	33.6	18.0	0	0	40.2	12.8	9.6	3.4	8.7	4.9
December	31.7	14.4	0	0	56.4	12.8	17.2	4.8	7.9	4.4
Total			**806.3**	**51.0**						
Average	**33.6**	**21.6**			**59.7**	**18.3**	**17.4**	**5.6**	**6.9**	**5.7**

Table 105. Mean monthly weather parameters at Canning Town (Latitude 22°15' N, longitude 88°40' E, altitude (AMSL) 3.0 m) during the year-2022

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	23.64	14.39	19.01	83.94	59.71	15	3	0.97	2.64	6.04
Feb	27.1	15.99	21.54	83.43	50.25	71.8	2	1.21	3.29	6.7
Mar	33.45	21.85	27.65	78.26	54.77	0	0	1.89	5.16	7.55
Apr	35.06	26.61	31.02	86.17	72.79	0	0	2.53	11.26	6.98
May	35.12	25.7	30.41	76.77	67.68	241.8	12	4.89	7.89	5.81
Jun	34.24	26.73	30.49	80.23	70.97	112.8	10	3.1	9.73	2.72
Jul	33.4	26.73	30.07	85.23	81.16	159.4	16	2.03	7.68	5.34
Aug	32.81	26.63	29.72	86.65	79.43	491.8	18	2.19	7.09	4.19
Sep	32.94	26.89	29.92	86.27	79.67	362.4	13	3.5	5.77	5.69
Oct	32.03	24.27	28.15	88.94	77.26	113.6	8	2.68	3.72	6.54
Nov	29.81	18.7	24.25	79.63	56.77	0	0	2.11	2.17	8.21
Dec	27.01	15.18	21.1	77.61	49.81	0	0	1.61	2.2	6.04
Total						**1568.6**	**82**			
Mean	**31.38**	**22.47**	**26.94**	**82.76**	**66.69**			**2.39**	**5.72**	**5.98**

2022

ICAR-Central Soil Salinity Research Institute

Karnal, Haryana- 132001